REPORT OF REVIEW ELEVATE INFRASTRUCTURE MECHANICALLY STABILIZED EARTH (MSE) WITH PRECAST CONCRETE FACING PANELS AND INEXTENSIBLE SOIL REINFORCEMENTS

October 2025

HIGHWAY INNOVATIONS, DEVELOPMENTS, ENHANCEMENTS AND ADVANCEMENTS (IDEA)

The Elevate Infrastructure MSE Precast Concrete Facing and Inextensible Reinforcement Retaining Wall System has been evaluated in accordance with the IDEA protocol. Key information regarding this system is presented in this section of this final report of review. Important details of the system's components, design, construction and quality control measures are presented in the attached final submittal. Design parameters defined within the submittal are summarized in the table located on page 5 of this IDEA report.

Applicant Information

Elevate Infrastructure
Attn: Matt Byron Austin
2495 Bungalow Rd
Morris, IL 60450
Ph: 636.346.9245
www.ElevateInfrastructure.com

Review Summary

Following its initial review of Elevate Infrastructure Concrete Facing and Inextensible Reinforcement Retaining Wall System submittal, the review team provided the applicant with a series of comments, and requests for clarification and additional analysis. The applicant has been thorough in its responses and the review team finds that there are no outstanding issues that should be brought to the attention of transportation agencies. Rather, agencies are encouraged to rely upon the Elevate Infrastructure Precast Concrete Facing and Inextensible Reinforcement Retaining Wall System submittal (appended) for projects where the Elevate Infrastructure Retaining Wall System is proposed.

Submittal Checklist

The checklist used from the IDEA protocol for this evaluation is C4 – Initial Technical Evaluation Checklist for Concrete Panel Paired with Inextensible Reinforcement. This is the first evaluation of the Elevate Infrastructure Precast Concrete Facing and Inextensible Reinforcement Retaining Wall System by either the IDEA, or the predecessor HITEC, evaluation programs.

Confidential Information

The applicant has the option to omit information from the version of its submittal that is attached to the final report if it believes that such information is confidential. In such instances, the applicant will notify the review team. However, for the Elevate Infrastructure Precast Concrete Facing and Inextensible Reinforcement Retaining Wall System, no information has been designated by the applicant as confidential.

System Description

Components
The major components of the Elevate Infrastructure MSE Panel Wall System are precast concrete facing panels, inextensible steel soil reinforcements, and select granular backfill. Other standard components include a concrete leveling pad, high-density polyethylene or rubber bearing pads, shims, panel joint geotextile, adhesive, tie-strips and bolt sets for connecting soil reinforcement to panel tie strip connections. The precast concrete facing that has a minimum thickness of 6 inches. Standard precast panel shapes are rectangular 5' x 5' or 5' x 10'. The soil reinforcing consists of either Elevate Wave Strip or Elevate Ladder Strip steel reinforcement connected to the facing, for any specific wall only one reinforcement type (i.e., Ladder Strip or Wave Strip) is used. The connector is embedded into the panel, has dual steel plates protruding from the back of the panel, and facilitates a double-shear type bolted connection to the discrete steel soil reinforcement strip or ladder.

System History
In 2023 Elevate combined their extensive precast and engineering experience with proven MSE wall technology to provide the Elevate MSE Panel Wall System with inextensible soil reinforcement.

System Properties
The following properties are reported by the applicant for the Elevate Infrastructure Precast Concrete Facing and Inextensible Reinforcement Retaining Wall System.

Soil Reinforcement
The Elevate MSE Panel System offers two types of inextensible soil reinforcement: the Elevate Ladder Strip and the Elevate Wave Strip. Both are designed to interface with the precast panel via a single-point connection using a dual plate connector, but they differ in geometry, material form, and structural behavior.

The Elevate Ladder Strip is a welded wire mat reinforcement consisting of W11 longitudinal wires spaced at 2 inches on center, with 4-inch wide W11 transverse wires welded every 12 inches, conforming to ASTM A1064. This mat is welded to a steel connector tab with a bolt hole to mechanically connect to the panel.

The Elevate Wave Strip is a cold-formed, solid 2-inch wide strip made from ASTM A1011 Grade 65 steel. The strip is formed into a continuous oscillating wave profile, which increases its bearing area and interaction with the backfill.

Both reinforcement types are engineered to meet MSE wall performance criteria. The choice between Ladder and Wave Strip reinforcement depends on factors such as site conditions, backfill type, wall height, and contractor preference.

Soil Reinforcement-Facing Panel Connection Capacity
Both wave strip and ladder reinforcement are connected to the facing with a double shear type connection using a single bolt to a tie strip protruding from the back face of the panel. The tie strip consists of two parallel plates, with aligned 9/16-inch holes. The reinforcement is provided with a 9/16-inch diameter hole on one end and fits in between the two plates of the tie strip. The bolt is ½-

inch in diameter. The tie strip and bolt are protected from corrosion through the application of a zinc coating, applied by hot-dip galvanizing in conformance with ASTM A123.

Soil Reinforcement Design Tensile Strength
The design tensile strength of the Wave Strip and Ladder Strip are controlled by the tensile strength of the reinforcement. The Wave Strip soil reinforcement has tensile strengths of F_u = 80 ksi and F_y = 65 ksi. The Ladder Strip soil reinforcement has tensile strengths of F_u = 75 ksi and F_y = 65 ksi. The connection between the reinforcement and facing panel has been designed to have a higher tensile resistance then the soil reinforcement.

Pullout Design Parameters

Testing has indicated that the Wave Strip and Ladder Strip exhibit significantly higher F* values than the defaults listed in AASHTO. Independent pullout testing was conducted by SGI Testing Services, LLC, in Norcross, GA. The tests assessed the pullout behavior of both Wave and Ladder Strip reinforcements using representative backfill types. Testing of the Ladder Strip was performed on strips with W11 transverse and cross wires.

For the Wave Strip, a friction factor (F*) of 4.6 was observed near the top of the structure for fine-grained fill, decreasing linearly to 2.3 at 20 feet depth. For granular fills, higher F* values up to 6.0 were recorded, with a similar tapering pattern. The test demonstrated that the alpha value is equal to 1.0 for the Wave Strip. Elevate recommends using the fine-grain material pullout resistance in design with F* value equal to 3.50 at the top and decreasing linearly to 1.50 at a depth of 20 feet and below the ground surface.

Similarly, for the Ladder Strip, a friction factor (F*) of 5.1 was observed near the top of the structure for fine- grained fill, decreasing linearly to 2.5 at 20 feet depth. For granular fills, higher F* values up to 6.8 were recorded, with a similar tapering pattern. The test demonstrated that the alpha value is equal to 1.0 for the Ladder Strip. Elevate recommends using the fine-grain material pullout resistance in design with F* value equal to 4.00 at the top and decreasing linearly to 1.50 at a depth of 20 feet and below.

Retaining Wall Design
The design methodology for an Elevate Infrastructure MSE wall considers both the external and internal stability of the structure. Internal stability is determined using the Coherent Gravity Method (CGM). The CGM is provided in Section 2.1.2 of the attached final submittal and in detail in both FHWA-HIF-24-002 "Design and Construction of Mechanically Stabilized Earth (MSE) Walls" and AASHTO LRFD 9th Edition (2020).

The design examples in this submittal were performed using both MSEW+ and proprietary software developed by Elevate Infrastructure. The scope of this review did not provide for a comprehensive evaluation of the Elevate Infrastructure software. However, the applicant states that the design of the Elevate Infrastructure MSE Precast Concrete Facing and Inextensible Reinforcement Retaining Wall System is consistent with current AASHTO specifications. This assertion is supported by the results of the analyses of example problems in the submittal, performed with both the proprietary software and the computer program MSEW+.

Agencies may check designs with commercial programs, using the design properties listed in the table attached to this review report.

System Innovations
Elevate Infrastructure claims that their system provides the following innovations:

The Elevate MSE System introduces a significant innovation in design methodology through its integration with a proprietary software tool—Elevate Wall Designer—developed in collaboration with CTiSoftware. While the physical materials used in the system—such as precast concrete panels, Wave Strips, and Ladder Strips—are based on well-established, non-proprietary technologies, the way in which the system is engineered represents a distinct advancement in design workflow and quality control.

The innovation lies in the comprehensive, column-by-column design approach that the software enables. Unlike traditional design tools and spreadsheets—which allow for the design of multiple sections but do not provide an elevation-based layout—the Elevate Wall Designer allows the user to model the entire wall elevation and dynamically assign loading conditions and geometry across each column. This capability ensures a fully- integrated design that reflects real-world wall configurations, obstructions, and variable surcharge conditions with exceptional accuracy. Once wall geometry and site-specific loading inputs are defined, the software performs complete LRFD checks across the entire wall.

Reviewer Comments
Following its initial review of the Elevate Infrastructure MSE Precast Concrete Facing and Inextensible Reinforcement Retaining Wall System submittal, the review team provided the applicant with 34 comments and requests for clarification. The applicant has been thorough in its responses and the review team finds that there are no outstanding issues that should be brought to the attention of the transportation agencies. Rather, the agencies are encouraged to rely upon the final Elevate Infrastructure MSE Precast Concrete Facing and Inextensible Reinforcement Retaining Wall System submittal for projects where the Elevate System is proposed.

Closing

An update technical evaluation should be performed for the Elevate Infrastructure MSE Precast Concrete Facing and Inextensible Reinforcement Retaining Wall System in five years (i.e., September 2030) or upon notice that a significant modification of the system has been made. For details regarding update technical evaluations and other guidance for the use of technical evaluations by transportation agencies, go to https://www.geoinstitute.org/special-projects/idea.

Summary Table MSEW+ Input Parameters for Elevate Infrastructure Precast Concrete Facing and Inextensible Reinforcement Retaining Wall System

Reinforcement	Design Life	F_y (ksi)	b (in)	t (in)	α	f*		Factored Tensile Resistance (kips)[1]
						Overburden Pressure up to 2,500 psf	Overburden Pressure 2500 psf	
Wave Strip	75	65	2.00	0.156	1.00	3.5	tan φ[3]	9.80
Wave Strip	100	65	2.00	0.156	1.00	3.5	tan φ[3]	7.51
			Dia. (in)					
Ladder Strip W11	75	65	0.374	na	1.00	4.0	tan φ[3]	7.77
Ladder Strip	100	65	0.374	na	1.00	4.0	tan φ[3]	6.67/6.50[2]

[1] The factored tensile resistance considers metal loss over the design life due to corrosion. [2] The factor tensile resistance for 100 yr design life is 6.67 kips. The factored connection tensile resistance for 100 yr design life for the Ladder Strip is 6.50 kips and controls for this case. [3] The ELEVATE test results for overburden pressure greater 2500psf indicate a F* Recommended Design value of 1.5, but for consistency with other evaluations IDEA recommends using the AASHTO default value of tan φ.

Guidelines for the Applicant to use this checklist:

1. Provide your submittal in Adobe portable document format (i.e. PDF).

2. Organize the submittal based on the numbered outline shown in the checklist below. Use the numbered outline for a table of contents (TOC). Provide the response for each item in your report. Create *links* between the items in the TOC and the items in the report and appendices.

3. If reports, drawings or calculations are requested for a section, provide them in the appendix tabbed for that section. For example, design calculations are required for Item 2.3.1. They should be included in Appendix 2.3.1.

4. Mark the checklist at each item to indicate "yes" you have included the relevant information. If you must check "no", please provide a brief explanation if appropriate.

Section 1: ERS Components

1.1	Facing Unit		
	Yes	No	Item
1.1.1	☐	☒	Does the wall system contain what you consider to be an innovation that is related to the facing unit? If yes, please describe the innovation briefly. As items below apply to the innovation, please describe the innovation in further detail.
1.1.2	☒	☐	List each type of facing unit.
1.1.3	☒	☐	Provide specifications for each facing unit.
1.1.4	☒	☐	Provide standard dimensions, tolerances and typical steel reinforcement schedule (if any is used) for each type of unit (e.g. standard, crest, corner, base, etc.) in plan and section drawings.
1.1.5	☒	☐	Provide the target 28-day minimum compressive strength.
1.1.6	☒	☐	Provide the target percent air range.
1.1.7	☒	☐	Producers will change mix design to accommodate state requirements.
1.1.8	☐	☒	Describe with text any unit shear, alignment or bearing devices. Provide specifications and detail drawings.
1.1.9	☒	☐	Describe with text any filter which is used to prevent migration of fill soil through wall face. Provide specifications.
1.1.10	☒	☐	Describe with text the aesthetic facing options that are available. Provide photos, drawings and brochures as appropriate.
1.1.11	☒	☐	Describe any limits on the facing units that are created by curved wall sections and corners.

1.2	Inextensible Reinforcement		
	Yes	No	Item

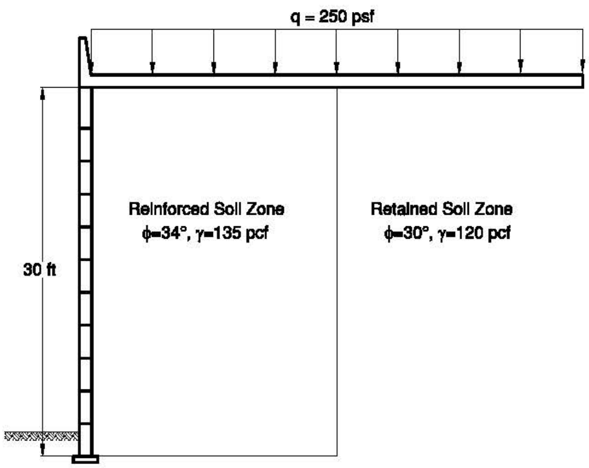
1.2.1	☒	☐	Does the wall system contain what you consider to be an innovation that is related to the reinforcement? If yes, please describe the innovation briefly. As items below apply to the innovation, please describe the innovation in further detail.
1.2.2	☒	☐	List each reinforcement type that is to be used with the facing system.
1.2.3	☒	☐	For each type provide physical property specifications. Address ultimate and yield strengths as well as welds if they are applicable.
1.2.4	☒	☐	For each reinforcement type describe corrosion protection measures. If coatings or galvanization are used, provide minimum thickness for 75-year design life (based on the electrochemical requirements listed in AASHTO).
1.2.5	☒	☐	For each reinforcement type provide sacrificial steel thickness for 75 and 100-year design life.
1.2.6	☒	☐	For each reinforcement type provide the results of any corrosion tests that have been performed.
1.2.7	☒	☐	For each reinforcement type provide detail drawings that show dimensional tolerances.
1.2.8	☒	☐	Describe with text and drawing details how the reinforcement connects to facing units.
1.2.9	☒	☐	List each connection device that is used to connect the facing unit and reinforcement.
1.2.10	☒	☐	For each connection device provide physical property specifications. Address ultimate and yield strengths as well as welds if they are applicable.
1.2.11	☒	☐	For each connection device describe corrosion protection measures and provide specifications. If coatings or galvanization are used, provide minimum thickness for 75-year design life (based on the electrochemical requirements listed in AASHTO).
1.2.12	☒	☐	For each connection device provide sacrificial steel thickness for 75 and 100 year design life.
1.2.13	☒	☐	For each connection device provide the results of any corrosion tests that have been performed.
1.2.14	☒	☐	For each connection device provide detail drawings that show dimensional tolerances.
1.2.15	☒	☐	List facing unit-reinforcement connection strength tests performed, provide test results and strength envelopes the Applicant recommends for design.
1.2.16	☒	☐	List reinforcement pullout (ASTM D6706) tests performed and provide results. Provide test soil properties, corresponding pullout friction factors (F*) and scale effect correction factors (α) Applicant recommends for design (it is recognized that for inextensible reinforcement the value of α may be 1.0). Discuss how test results support these recommendations based on Appendix B at FHWA-NHI-10-025. If no tests have been performed, list the default values that should be used based on FHWA-NHI-10-024/025

1.2.17	☐	☒	List soil-reinforcement interface shear (ASTM D5321) tests performed and provide results. List interface friction angle (□) Applicant recommends for design. Discuss how test results support these recommendations. If no tests have been performed, list the default values that should be used based on FHWA-NHI-10-024/025.

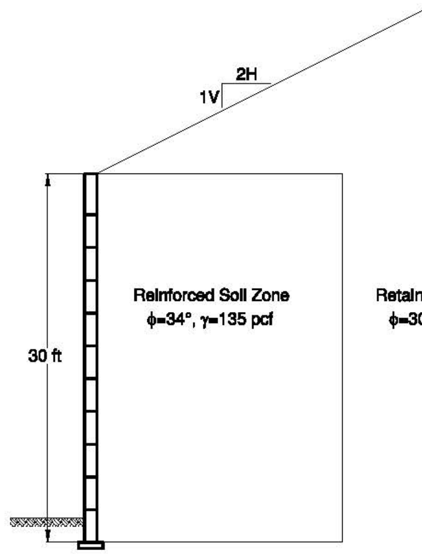
1.3	Other Components		
	Yes	No	Item
1.3.1	☐	☒	Does the wall system contain what you consider to be an innovation that is related to a wall component? If yes, please describe the innovation briefly. As items below apply to the innovation, please describe the innovation in further detail.
1.3.2	☒	☐	Reinforced Soil - Provide the standard Atterberg Limits range, grain-sized distribution range, minimum effective internal angle of friction and limiting electrochemical properties. Are these soil parameters consistent with current AASHTO requirements?
1.3.3	☒	☐	Drainage - Describe with text any internal and external drainage measures that are inherent in the wall system. That is, they are not optional measures such as blanket and chimney drains or drainage swales, but are built-into wall components.
1.3.4	☒	☐	Coping – Describe with text standard coping that may be used with the wall system, not including the previously described cap units. Provide typical dimensions, and plan and section view drawings. – Pat…our convo abt optimizing for weight & dimensions…?
1.3.5	☒	☐	Traffic Barriers – describe with text traffic barriers (i.e. moment slab, post and beam or other) that may be used with the system and any limitations that may apply. Provide typical plan and section view drawings.
1.3.6	☒	☐	Slip Joints – describe with text how slip joints are made to accommodate potential differential settlement. Provide typical plan and elevation view drawings.

Section 2: ERS Design

2.1	Design Methodology		
	Yes	No	Item
2.1.1	☒	☐	Does the wall system contain what you consider to be an innovation that is related to the design methodology? If yes, please describe the innovation briefly. As items below apply to the innovation, please describe the innovation in further detail.
2.1.2	☒	☐	Describe the design methodology thoroughly, and provide references to supporting literature as appropriate.
2.1.3	☒	☐	Describe how and provide typical plan and section detail drawings of the facing and reinforcement to handle vertical and horizontal obstructions in the reinforced zone.



Problem 1
Design Life 75 Years



Problem 2
Design Life 75 Years

2.2	Design Example		
	Yes	No	Item
2.2.1	☒	☐	Problems 1 and 2—provide complete calculations for both problems using MSEW. If the design is performed with software that is not commercially available or is proprietary, please provide sample calculations with references to support the analysis.

Section 3: Construction

3.1	Construction Procedures		
	Yes	No	Item
3.1.1	☐	☒	Does the wall system contain what you consider to be an innovation that is related to the construction procedures? If yes, please describe the innovation briefly. As items below apply to the innovation, please describe the innovation in further detail.
3.1.2	☒	☐	Provide the construction manual for the wall system and at a minimum they should include the following items.
3.1.3	☒	☐	Describe any limitations of facing unit installation at inside and outside curved sections of the wall and at corners as well as any modifications that are required to be made to the facing unit. – Use MP answers/details from 1.1.11
3.1.4	☒	☐	Describe procedures to install earth reinforcement at curved sections of the wall and at corners. Specifically address any measures that are to be taken at intersection or overlapping panels of reinforcement.
3.1.5	☒	☐	Describe measures that are required to maintain the design vertical and horizontal alignment of the wall face.
3.1.6	☒	☐	Describe the procedures to install soil in the reinforced soil zone.
3.1.7	☒	☐	Describe measures that are required to prevent erosion behind and in front of the wall during construction.

3.1.8	☒	☐	Describe experience or other special qualifications that are required of the wall construction contractor.
3.1.9	☒	☐	Describe the procedures to install soil in the reinforced soil zone.

Section 4: Quality Control

4.1	Manufacturing		
	Yes	No	Item
4.1.1	☒	☐	Describe the quality control measures that are required for the manufacturing of facing units. You may do this by providing a manufacturing QC manual.
4.1.2	☒	☐	Describe the quality control measures that are required for the manufacturing of earth reinforcement components. You may do this by providing a manufacturing QC manual.
4.1.3	☒	☐	Describe the quality control measures that are required for the manufacturing of any shear, alignment, bearing or connection devices. You may do this by providing a manufacturing QC manual.

4.2	Construction		
	Yes	No	Item
4.2.1	☒	☐	Describe the quality control measures that are required during construction of the wall system. If these measures are described in the system's construction manual then state that they are so included and refer the reviewer to the appropriate section of the submittal.

5: Performance

5.1	Performance History		
	Yes	No	Item
5.1.1	☒	☐	Provide a description of the system's development and usage history. Then describe the following:
5.1.2	☒	☐	The oldest three structures.
5.1.3	☒	☐	The tallest three structures.
5.1.4	☒	☐	Provide a list of private- and public sector users who have approved the use of the system. Also provide the contact information for a person at the user agency who may be contacted regarding the wall system's performance.

6: Other

6.0	Other Information		
6.1	☒	☐	In this section, please include anything you think will better help a reviewer understand your ERS that has not been adequately address in the previous questions.

Elevate MSE Panel Wall IDEA Submittal

Section 1 – ERS Components

Section 5 – Performance

Section 6 – Other

ERS Components

1.1 FACING UNIT

1.1.1 Facing Unit Innovations

Elevate does not claim to have any facing unit innovations.

1.1.2 Facing Unit Types

The Elevate Infrastructure MSE Panel Wall System contains 3 distinct facing elements:

1. Precast Concrete Panel – Standard 5' x 10' x 6" or 5' x 5' x 6" MSE panel
2. Corner Unit
3. Slip Joint

1.1.3 Facing Specifications

Facing unit specifications are located in Appendix A 1.1.3

1.1.4 Facing Unit Dimensions, Tolerances, & Typical Sections

Facing unit details are located in Appendix A 1.1.4

1.1.5 28-Day Minimum Compressive Strength

The materials, manufacturing, storage, handling and erection of concrete panels shall conform to the requirements of AASHTO LRFD Bridge Design Specifications, with including: Portland cement concrete used in panels shall conform to Class A (AE) with a minimum compressive strength at 28 days of 4,000 psi.

1.1.6 Target Percent Air Range

Air content tests will be performed in accordance with AASHTO T152 or AASHTO T196. Air content samples will be taken at the beginning of each day's production and at the same time the compressive samples are taken. As shown in the table below, typical air content range for panels poured in accordance with AASHTO Class A (AE) is to be 6% +/- 1.5%.

1.1.7 Producer Mix Design

Precast concrete mix designs are specified by the Project Owner and will vary between jurisdictions. Typical designs conform to AASHTO Class A or A(AE).

AASHTO LRFD Bridge Construction Specifications, Table 8.2.2-1

Concrete Class	Min. Cement Content	Max. Water / Cementitious Material Ratio	Air Content Range	Size of Course Aggregate Per AASHTO M43	Size Number per AASHTO M43	28 days Compressive Strength
	lb /yd^3	lb per lb	%	Nominal Size		Psi
A	611	0.49	-	1.0 in. to No. 4	57	4,000
A(AE)	611	0.45	6 +/- 1.5	1.0 in. to No. 4	57	4,000

1.1.8 Shear, Alignment, or Bearing Devices

Shear between precast facing elements is not considered in the design. Typically, this requirement is for small, drycast segmental block facing units. Bearing pads are required in the horizontal joint between precast concrete MSE panels to accommodate differential movements, distribute loads evenly, and prevent concrete-to-concrete contact, which could lead to spalling or localized stress concentrations. They help maintain proper panel alignment, absorb minor deflections, and improve the overall durability and performance of the wall system.

Typical bearing pad placement for a wall column < 20' tall

The bearing pads are made from preformed EPDM rubber pads conforming to ASTM D-2000 M2AA 807 with a durometer of 80 +/- 5. Bearing pad details & calculations are located in Appendix A1.1.8.

1.1.9 Panel Joint Filter Fabric

Geotextile fabric is used to cover the joints at the rear-face of the precast panels to prevent soil from migrating out of the backfill zone. Rolls of fabric are provided in widths to meet the contract specifications. Fabric to be centered on panel joint. Fabric shall conform to AASHTO Guide Specifications for Highway Construction, separation fabric, unless otherwise specified. AASHTOM M288 covers the standards for both woven & nonwoven geotextile requirements. The fabric is typically 6oz and comes in strips that are 12" or 18" wide. Detail located in Appendix A1.1.9.

1.1.10 Aesthetic Facing Options

Precast concrete facing panels offer a wide range of aesthetic options. Casting directly onto the steel form will provide a plain smooth finish; while installing a urethane formliner will allow for a wide array of patterns and textures. More traditional finishes include stone, brick, and rustication. Custom designs can also be incorporated. See Appendix A1.1.10 for examples.

1.1.11 Curved Wall Sections & Corners

For walls founded on curves, panels are dimensioned as a series of chords to approximate the desired alignment. While no additional modifications are required, the installing contractor may opt to construct a wider leveling pad to facilitate panel placement and alignment. Proper attention should be given to the installation of soil reinforcement elements to maintain structural integrity. Panel length and joint configuration are determined by the curve's radius, with tighter curves necessitating shorter panel lengths. Standard 5' x 10' panels can accommodate a minimum radius of 100', while standard 5' x 5' panels can achieve a minimum radius of 50' without modification.

Precast corner elements are utilized for external corners and 90°-internal corners. For angles less than 70°, the MSE wall design will incorporate a bin wall configuration in accordance with FHWA-NHI-10-024. In acute corner conditions, adjacent panels may require additional connection using flat plate steel in conjunction with Elevate's standard inextensible soil reinforcement system to ensure structural stability.

Curved wall details are located in Appendix A1.1.11

1.2 INEXTENSIBLE REINFORCEMENT

The Elevate MSE Panel System offers two types of inextensible soil reinforcement: the Elevate Ladder Strip and the Elevate Wave Strip. Both are designed to interface with the precast panel via a single-point connection using a dual plate connector, but they differ in geometry, material form, and structural behavior. Each wall is engineered and manufactured with a single soil-reinforcement-type. While it is sometimes feasible to optimize the design with multiple strip-types, Elevate only supplies a single type of soil reinforcement per retaining wall.

The Elevate Ladder Strip is a welded wire mat reinforcement consisting of W11 longitudinal wires spaced at 2 inches on center, with 4-inch wide W11 transverse wires welded every 12 inches, conforming to ASTM A1064. This mat is welded to a steel connector tab with a bolt hole to mechanically connect to the panel. Ladder Strips are ideal for straightforward applications, offering predictable pullout performance and ease of handling in the field. Their open geometry promotes interaction with coarse backfill materials and facilitates effective compaction.

The Elevate Wave Strip is a cold-formed, solid 2-inch wide strip made from ASTM A1011 Grade 65 steel. The strip is formed into a continuous oscillating wave profile, which increases its bearing area and interaction with the backfill. The corrugated geometry of the Wave Strip increases its contact area with the surrounding soil, which enhances pullout resistance in granular backfill. Its solid steel construction and compact profile make it well-suited for applications with space constraints or where tight reinforcement placement is required.

Both systems are engineered to meet MSE wall performance criteria. The choice between Ladder and Wave Strips depends on factors such as site conditions, backfill type, wall height, and contractor preference.

1.2.1 Inextensible Soil Reinforcement Innovations

Elevate does not claim to have any inextensible soil reinforcement innovations.

1.2.2 Inextensible Soil Reinforcement

Elevate Infrastructure MSE Panel Walls feature two distinct soil reinforcement elements.

1. Elevate Ladder Strip – Two longitudinal W11 wires @ 2" o.c. welded to a connector tab with 4" wide W11 transverse wires welded every 12" along the reinforcement length.

2. Elevate Wave Strip – A 2" (typ.) wide steel strip configured into a wave formation.

Details for each reinforcement type are located in Appendix A1.2.2.

1.2.3 Inextensible Soil Reinforcement Property Specifications

Elevate Ladder Strips are manufactured in accordance with ASTM A1064—Standard Specification for Steel Wire & Welded Wire Reinforcement, Plain, and Deformed, for Concrete—or ASTM A706—Standard Specification for Deformed & Plain Low-Alloy Steel Bars for Concrete Reinforcement. ASTM A1064 steel to have a minimum tensile strength of 75ksi and a minimum yield strength of 65ksi. Deformed steel wire shall have a minimum yield strength of 70ksi (tensile 80ksi). A 7-gauge 1.5" x 5.5" bar is welded to the end of the wire configuration to allow for a mechanical connection to the panel. The bar connector is manufactured per ASTM A1011 HSLAS Grade 55 Class 2 with a minimum tensile strength of 65ksi and a minimum yield of 55ksi. Alternatively, Ladder Strips can be manufactured per ASTM A706 in which case steel to have a minimum tensile strength equal to 80ksi and a minimum yield strength of 60ksi.

Elevate Wave Strips are 2" wide (typ.) steel strips manufactured per ASTM A1011 Grade 65 steel and cold-formed into a repeating wave configuration.

Both soil reinforcement types use a single-point connection to the precast MSE panel through a Dual Plate Connector, which is embedded in the panel and extends from the rear face. Connector to be manufactured per ASTM A1011 (AASHTO M270) Grade 50 with a minimum tensile capacity of 65ksi and a minimum yield capacity of 50ksi. Unit to be hot dip galvanized after final configuration.

1.2.4 Corrosion Protection

Elevate inextensible soil reinforcement elements are hot-dip galvanized per ASTM A123 (AASHTO M111) after they are welded or formed into their final configuration. Minimum zinc thickness to be 2 oz/ft^2 or 3.4 mils.

1.2.5 Corrosion Protection Sacrificial Steel Thickness

Sacrificial steel thickness is evaluated following AASHTO Article 11.10.6.4.2a-1, which defines the reduction in thickness over time based on exposure and expected service life. Our Wave Strip and Ladder Strip follow the same degradation model and design assumptions, with strength reduction applied per AASHTO for both galvanized and carbon steel loss over a 75- or 100-year design life.

Ec = En + Es

where: Ec = thickness of metal reinforcement at end of service life as shown in AASHTO Figure 11.10.6.4.1-1 (mil)

En = nominal thickness of steel reinforcement at construction (mil)

Es = sacrificial thickness of metal expected to be lost by uniform corrosion during service life of structure (mil)

Ec will vary for a service life of 75 years or 100 years. For structural design of the Ladder Strip, the sacrificial thicknesses are determined for all exposed surfaces. Structural design, and therefore corrosion, is applied to the longitudinal wires only. For the structural design of the Wave Strip, the sacrificial thickness is determined for the top and bottom surfaces. The following metal loss rates are used in the determination of the sacrificial thickness and are consistent with AASHTO.

- Loss of galvanizing equal to 0.58 mil/yr for the first two years and 0.16 mil/yr for each subsequent year.
- Loss of carbon steel equal to 0.47 mil/yr after the depletion of the zinc.

The galvanizing is applied by the method of hot-dip in conformance with ASTM A123. The galvanized coating is required to be applied at a minimum of 2 oz./ft^2 or 3.4 mils in thickness. The sacrificial thickness of metal expected to be lost at the end of the 75-year service life is equal to 0.056 inches and at the end of 100-year service life the sacrificial thickness of metal expected to be lost is equal to 0.079 inches. Based on the AASHTO requirements and removing the sacrificial thickness of the metal from the W11 wires, at end of the service life, for the Ladder Strip the allowable design strength is equal to 7.77 kips for a 75-year service life and 6.50 kips for a 100-year service life. For the Wave Strip, the allowable design strength is equal to 9.80 kips for a 75-year service life and 7.51 kips for a 100-year service life. Calculations for a 75-year and 100-year design life can be found in Appendix 1.2.5.

1.2.6 Corrosion Testing

Elevate inextensible soil reinforcements & life-span calculations comply with AASHTO LRFD Bridge Specifications. No corrosion testing has been conducted.

1.2.7 Soil Reinforcement Dimensional Tolerances

Elevate Ladder Strip tolerances are as follows:

- Transverse & longitudinal wire lengths: +/- 1/2”
- Transverse & longitudinal wire spacing: +/- 1/2”
- Bar connector dimensions: +/- 1/8”
- Wire thickness: 0.004” per ASTM A1064

Elevate Wave Strip tolerances are as follows:

- Stee gauge: +/- 0.008”
- Width: +/- 0.01”

- Length: +/- 0.01”
- Camber: 0.01” per 5’
- Wave length: +/- 0.1” over 10”
- Wave period: + 0.01”

Detailed drawings are located in Appendix A1.2.7.

1.2.8 Soil Reinforcement Connection Detail

Both the Ladder Strip and Wave Strip utilize a single-point mechanical connection to the precast facing unit through a dual-plate connector extending from the rear face of the panel. This dual-shear & single-point allows the soil reinforcement to pivot around obstructions in the reinforced backfill like piles, sewers, utility lines, etc. while providing an extremely reliable means of internal stability.
The dual plate connector has been widely used in the MSE-industry to provide a reliable connection for single-point & strip-style reinforcements. Connectors are embedded in the precast panel, protruding from the rear-face and provide a connection point for the Elevate inextensible soil reinforcement.
Connection details are located in Appendix A1.2.8.

1.2.9 Soil Reinforcement Connection Device

The Dual Plate Connector Details are located in Appendix A1.2.9

1.2.10 Soil Reinforcement Property Specifications

Elevate Infrastructure’s Ladder Strip Soil Reinforcement abides by ASTM 1064 and consists of a welded wire grid joined to a flat bar creating an inextensible soil reinforcement with high pullout capacity. The soil reinforcement is mechanically connected to the panel by way of a ½” galvanized F3125 Gade A325 bolt.
Ladder Strip Soil Reinforcement Specifications are located in Appendix A1.2.10L

The Elevate Wave Strip is an inextensible strip-style soil reinforcement manufactured from 2” wide slit-coils of Grade 65 steel. Wave strips are manufactured from processed coil and cold formed into the required shape and dimensions. Their physical and mechanical properties shall conform to ASTM A1011, Grade 65 or equal. Galvanization shall conform to the minimum requirements of ASTM A123 (AASHTO M111).
Wave Strip Soil Reinforcement Specifications are located in Appendix A1.2.10W

1.2.11 Corrosion Protection Measures

Elevate inextensible soil reinforcement strips are to be hot-dip galvanized per ASTM A123 (AASHTO M111). Units are to be galvanized after final configuration.

1.2.12 Sacrificial Steel Thickness

Both the Wave Strip and Ladder Strip are connected to the facing with a double shear connection using a single bolt to an embedded connector protruding from the back face of the panel. The embedded connector is designed for steel tensile capacity for the net steel area, concrete pullout (PCI Design Handbook, 7th Edition, Section 6.5.4), bolt strength (AASHTO 6.13.2.7-2 and 6.13.2.9) to resist the maximum tensile loads calculated in the reinforcement strip. In addition, the embedded connector has been independently evaluated by connection strength testing. Calculations for a 75-year and 100-year design life can be found in Appendix 1.2.

1.2.13 Corrosion Tests

Elevate inextensible soil reinforcements & life-span calculations comply with AASHTO LRFD Bridge Specifications. No corrosion testing has been conducted.

1.2.14 Connection Device Dimensional Tolerances

Dimensional Tolerances are located in Appendix A1.2.9

1.2.15 Soil Reinforcement Connector Testing

The Elevate MSE Wall System utilizes the same single point dual plate connector that has decades of proven success. Testing data performed on the dual plate connector embedded in a precast panel are located in Appendix A.2.15.

1.2.16 Soil Reinforcement Pullout Testing

Inextensible soil reinforcement testing for both strip-types was performed by an independent testing facility in conformance with ASTM D6706 “Measuring Geosynthetic Pullout Resistance in Soil" with modifications.

Testing has indicated that the Wave Strip and Ladder Strip exhibit significantly higher F* values than the defaults listed in AASHTO. Independent pullout testing was conducted by SGI Testing Services, LLC, in Norcross, GA. The tests assessed the pullout behavior of both Wave and Ladder Strip reinforcements using representative backfill types. Testing of the Ladder Strip was performed on strips with W11 transverse and cross wires.

The Elevate steel strips were tested for pullout in 3 distinct materials to represent a wide range of fill parameters—sand, graded aggregate base, and AASHTO #57 stone. Material gradations, direct shear results, and compaction-moisture for each fill-type are outlined in Appendices A1.2.16L & A1.2.16W.

The Ladder Strip behaves in much the same way as ribbed steel strips due to the narrow spacing of the longitudinal wires and spacing of the transverse bars (AASHTO C11.10.6.3.2). Therefore, both the Wave Strip and the Ladder Strip are treated as ribbed strips when determining the default pullout friction factor, F* per AASHTO Figure 11.10.6.3.2-2.

For the Wave Strip, a friction factor (F*) of 4.6 was observed near the top of the structure for fine-grained fill, decreasing linearly to 2.3 at 20 feet depth. For granular fills, higher F* values up to 6.0 were recorded, with a similar tapering pattern. The test demonstrated that the alpha value is equal to 1.0 for the Wave Strip. Elevate recommends using the fine-grain material pullout resistance in design with F* value equal to 3.50 at the top and decreasing linearly to 1.50 at a depth of 20 feet and below as shown in Appendices 1.2.16L & W.

Similarly, for the Ladder Strip, a friction factor (F*) of 5.1 was observed near the top of the structure for fine-grained fill, decreasing linearly to 2.5 at 20 feet depth. For granular fills, higher F* values up to 6.8 were recorded, with a similar tapering pattern. The test demonstrated that the alpha value is equal to 1.0 for the Ladder Strip. Elevate recommends using the fine-grain material pullout resistance in design with F* value equal to 4.00 at the top and decreasing linearly to 1.50 at a depth of 20 feet and below as shown in Appendices 1.2.16L & W.

Elevate Ladder Strip Soil Reinforcement testing is located in Appendix A1.2.16L

Elevate Wave Strip Soil Reinforcement testing is located in Appendix A1.2.16W

1.2.17 Soil Reinforcement Interface Shear Tests

Not applicable for Elevate Panel MSE Wall System

1.3 OTHER COMPONENTS

1.3.1 Wall System Innovations

Elevate MSE Panel Wall Systems are derived from experience in engineering & construction, and as such, no innovations are claimed.

1.3.2 Reinforced Soil Parameters

Soil properties for the select granular backfill used in the reinforced zone typically follow AASHTO guidelines. In general; the gradation, weight, electrochemical properties, and friction angle should promote a durable, cohesive, free-draining mass.

More specifically, the Atterberg Limits for the reinforced backfill should fall within an acceptable range to provide adequate shear strength and minimize potential for excessive plasticity or moisture retention. Typically, the liquid limit (LL) should not exceed 30, and the plasticity index (PI) should remain below 6 to ensure good drainage and reduce long-term settlement risks.

Backfill material shall be reasonably free from organic or otherwise deleterious materials and shall conform to the gradation limits as determined by AASHTO T27 and be obtained from natural sources.

The granular material shall also have a high effective internal friction angle. Unless governed by the Owner, the friction angle for reinforced select granular backfill shall be no less than 34 degrees as determined by the standard Direct Shear Test per ASHTO T236. Testing shall be conducted on samples compacted to 95 percent of AASHTO T99, Methods C or D, with oversize corrections applied per Note 7, at optimum moisture content. Structural material where at least 80 percent of particles exceed 3/4 inch in size is exempt from testing.

The material shall be largely free of shale or other weak, low-durability particles. Additionally, it must demonstrate a magnesium sulfate soundness loss of no more than 30 percent after four cycles.

Regarding the electrochemical requirements, the backfill shall meet the following criteria:

Electrochemical Parameters	Testing Methods
Resistivity > 3,000 ohm centimeters	AASHTO T288-91
pH 5 - 10	AASHTO T289-91
Chlorides < 100 parts per million	AASHTO T291-91
Sulfates < 200 parts per million	AASHTO T290-91

All cited requirements are in conformance with AASHTO guidelines.

1.3.3 Drainage

The exact specifications for the MSE wall drainage system is specified by the Owner. Segmental panel design has inherent drainage in the 3/4" gaps surrounding every panel as well as a free-draining reinforced mass.

Typical drainage for MSE walls include a 6" corrugated perforated pipe surrounded by free draining material wrapped in a separation fabric. Based on each site's grading and site plans, the installing contractor is responsible for daylighting the 6" pipe in accordance with the contract plans & specifications.

1.3.4 Precast Coping

Elevate's standard precast coping unit is 2' tall x 10' wide. A 9" throat is used to accommodate a 6" thick panel with up to 3" of aesthetic relief.

Precast coping unit details are located in Appendix A1.3.4

1.3.5 Precast Traffic Barrier

Precast traffic barriers can offer accelerated construction, especially on top of long runs of straight & level MSE wall. Specifications and dimensions vary between jurisdictions, however they typically consist of a precast F-Shaped barrier on top of a U-shaped precast coping. Epoxy-coated rebar protrudes from the rear coping leg to tie into the CIP moment slab.

Detail for a typical precast barrier-coping element is located in Appendix A1.3.5A

Alternatively, the precast coping can be cast with protruding rebar from the top in the F-shape to assist with slip forming or casting barriers in the field. These units are known as "Half Copings".

Detail for Half Copings are located in Appendix A1.3.5B

1.3.6 SLIP JOINTS

In wall areas that are more prone to differential settlement, slip joints are used to create a more sustainable, flexible retaining wall. They can also be used to facilitate wall geometry. Typical slip joint applications include construction stage lines, dissimilar foundation material, kink points, and radius formation.

Slip joint details are located in Appendix A1.3.6

ERS Design

2.1 DESIGN METHODOLOGY

2.1.1 Design Innovation

The Elevate MSE System introduces a significant innovation in design methodology through its integration with a proprietary software tool—Elevate Wall Designer—developed in collaboration with CTiSoftware. While the physical materials used in the system—such as precast concrete panels, Wave Strips, and Ladder Strips—are based on well-established, non-proprietary technologies, the way in which the system is engineered represents a distinct advancement in design workflow and quality control.

The innovation lies in the comprehensive, column-by-column design approach that the software enables. Unlike traditional design tools and spreadsheets—which allow for the design of multiple sections but do not provide an elevation-based layout—the Elevate Wall Designer allows the user to model the entire wall elevation and dynamically assign loading conditions and geometry across each column. This capability ensures a fully-integrated design that reflects real-world wall configurations, obstructions, and variable surcharge conditions with exceptional accuracy.

Once wall geometry and site-specific loading inputs are defined, the software performs complete LRFD checks across the entire wall, generating:

- Design calculations for every column
- Drawing sets with system-specific layout and labeling
- A full bill of materials (BOM) tailored for production and procurement
- Exports to global stability software for further analysis, if needed.

The tool not only accelerates the engineering process, but also reduces errors associated with manual data transfer between independent drafting, calculation, and specification systems. By consolidating all design outputs into a single platform, the software streamlines coordination between engineering, drafting, and production—leading to significant time savings and improved accuracy on real-world projects. To date, the Elevate Wall Designer has been used in the design of hundreds of MSE walls, affirming its reliability and efficiency.

While Elevate Wall Designer is currently used internally by Elevate and our affiliated engineering team, the system allows export into industry-standard software (e.g., Vespa3) to facilitate third-party review and verification, making it both innovative and adaptable.

2.1.2 Design Methodology

The Elevate Wall Designer design methodology shall conform to the required edition and year of the AASHTO LRFD Bridge Specification. Complete descriptions of the design methods conforms with the 2020 AASHTO LRFD Bridge Specification, 9th Edition are provided in Appendix 2.2.1. The design that is submitted in this report follows the Coherent Gravity design method. Other methods, such as the simplified method, can be used with the Elevate system. Below is a description of the design methodology.

Internal Stability

Internal stability of the Elevate MSE System is evaluated using the Coherent Gravity Method described in AASHTO 11.10.6.2.1d with resistance factors as specified in AASHTO 11.5.7*.

- <u>Assumed Failure Surface</u>: The failure surface for inextensible soil reinforcement is bilinear per AASHTO Figure 11.10.6.2.1d-1. It is a function of the back slope at the top of the structure and intersects the ground surface at the location of the mechanical height.

- Distribution of Horizontal Stress: The load in the reinforcement shall be determined at two critical locations: the zone of maximum stress and the connection with the wall face. Potential for reinforcement rupture and pullout are evaluated at the zone of maximum stress, which is assumed to be located at the boundary between the active zone and the resistant zone. Potential for reinforcement rupture are also evaluated at the connection of the reinforcement to the wall facing. For the Coherent Gravity Method, the reinforced wall mass is treated as a rigid body. Vertical stress shall be calculated at each reinforcement level using an equivalent uniform pressure that accounts for load eccentricity caused by the lateral earth pressure acting at the back of the reinforced soil mass above the reinforcement level being considered. This base pressure shall be applied over an effective width of reinforced wall mass as shown in AASHTO Figure 11.10.6.2.1d-2.

* In welded wire soil reinforcement systems, configurations that utilize a grid composed of multiple longitudinal wires connected to the panel face via a wire loop and pin typically warrant a reduced resistance factor. This reduction accounts for the potential of non-uniform stress distribution among the longitudinal wires, particularly in systems that use wide mesh formats with four or more longitudinal elements. In those designs, load transfer at the connection is assumed to concentrate disproportionately on interior wires, analogous to a multi-span beam subjected to uniform loading with simple supports. While this analogy is conservative, it disregards the significant restraint provided by the compacted soil backfill—effectively acting as a beam on an elastic foundation, which would distribute loads more evenly. Historically, early welded wire systems with broader meshes were penalized for this assumed behavior by assigning lower allowable stresses (e.g., 0.48 Fy), corresponding to a reduced resistance factor. By contrast, the Elevate Ladder Strip avoids this problem by design. It consists of only two longitudinal wires spaced at 2 inches, directly connected to the concrete panel via a single-point bolted connector. This narrow configuration ensures that both longitudinal wires share the applied load equally, eliminating the concern of internal force imbalance common in wider mesh systems with longer spans between longitudinal elements (e.g., 6", 8", or 9" spacings). Due to its simplified and efficient load path, the Elevate Ladder Strip conforms to the design intent and analytical framework of AASHTO Section 11.5.7 and C11.10.6.3.2, and thus it is appropriate to apply a resistance factor of 0.75 for connection strength.

External Stability
For external stability calculations of the Elevate MSE Wall System, the load factors are taken from AASHTO Tables 3.4.1-1 and 3.4.1-2. The resistance factors are taken from AASHTO Table 11.5.6-1.

- Sliding: Sliding is evaluated per AASHTO 11.10.5.3. For the sliding calculation, the beneficial contribution of the live load to resisting forces and moments is neglected. The calculation for sliding resistance at the base of the MSE structure is performed for three load conditions (maximum, minimum, and critical check). The critical check uses the most severe force effect and is a combination of maximum and minimum values. For sliding, the most severe force effect occurs when the resisting force is a minimum value and the driving force is a maximum value. Sliding resistance is a strength limit state check and therefore service limit state calculations are not considered. The minimum friction angle between the foundation soil and the reinforced soil is used for the sliding analysis.

- Eccentricity: Eccentricity (overturning) is evaluated per AASHTO 11.10.5.5. For the eccentricity calculation, the beneficial contribution of live load to resisting forces and moments is neglected. The calculations for limiting eccentricity at the base of the MSE structure are performed for three load combinations. The critical check uses the most severe force effect and is a combination of maximum and minimum values. For limiting eccentricity, the most severe force effect occurs when the resisting moment is a minimum value and the overturning moment is a maximum value. Note that limiting eccentricity is a strength limit state check and therefore service limit state calculations are not performed. The MSE structures are typically founded on soil and therefore the eccentricity shall be located within the middle 2/3 of the base of the wall in conformance with AASHTO 11.6.3.3.

- Bearing Capacity (overall and local): For bearing resistance calculations, the effect of live load over the soil reinforcing is included. In LRFD, the applied pressure is compared with the factored bearing resistance when computed for strength limit state and for settlement analysis it is compared to the service limit state bearing resistance. The Strength I Maximum load combination results in the extreme force effect in terms of maximum bearing stress and therefore governs the bearing resistance mode of failure. The Service I load combination is evaluated to compute the bearing stress for any settlement analysis. The foundation design and bearing resistance shall be the responsibility of the owner's geotechnical engineer.
- Global Stability: Global stability (including deep seated rotation) should be evaluated per AASHTO 11.10.5.6 and is typically the responsibility of the owner's geotechnical engineer in publicly-funded developments.

Settlement: MSE structures are very flexible. This flexibility enables the entire structure to accommodate significant total and differential settlement without any damage to the facing itself. Total and differential settlement shall be calculated by the owner's geotechnical engineer and provided to the wall designer. The Elevate system utilizes a ¾" joint width and can tolerate differential settlement of up to 1/200 with its 5'x10' panel system or up to 1/100 with its 5'x5' panel system per AASHTO C11.10.4.1.

2.1.3 Obstructions in Reinforced Fill

Elevate MSE walls utilize a single-point mechanical connection that allows the soil reinforcement to pivot horizontally to avoid obstructions in the backfill including drainage inlets, light poles, guardrails, fence posts, sewers, utilities, etc. The strip-style reinforcements can also bend vertically as required for lateral sewers or abutments.

Occasionally a new connector location must be manufactured in the field. Typically, a horizontal skew of up to 15° is allowed for horizontal obstructions. If the conditions in the field will not permit for a $\leq$ 15° skew, an additional connector can be fabricated in the field by sandwiching 2 angle irons measuring 3" x 4" x 3/8" with 9/16" Ø bolt holes. The new connector device should align with the horizontal plane of the dual plate connector that is to be replaced. The angle irons are mounted to the back of the panel with HILTI KWIK Bolts, and a 2" long ASTM F3125 Grade A325 bolt is used to connect the soil reinforcement device.

HILTI Kwik Bolts are specified to be hot dip galvanized per ASTM A123. While the manufacturer does not explicitly state a design service life for their bolts, the anchor bolts are specified to follow the same galvanized finish as the soil reinforcement elements (ASTM A123).

If larger obstructions are encountered and skewing of the strips is not feasible, larger angle irons measuring 5" x 3" x 1/4" x 10' are mounted to the back of the panel and are fastened to the panel via HILTI KWIK Bolts and dual plate connectors. If those obstructions are located more than 3 rows down from the top of the wall a 7" x 4" x 3/8" x 10' angle is used in its place. Reinforcement strips that are unable to be skewed around the obstruction are relocated along the angle iron outside of the obstruction. Where the relocated strips are attached along the 10' wide angle iron, a 3" x 4" angle iron is mounted below the larger angle iron to create a new strip connector. 9/16" Ø bolt holes are drilled in the angle irons, so a 2" long 1/2" Ø ASTM A449 bolt can be used to secure the relocated strip to the field-fabricated connector.

Soil reinforcement obstruction details are located in Appendix A2.1.3.

2.2.1 Example MSE Wall Design Scenarios

Two example design cases are included in the appendix:

Problem 1:

- Level surcharge

- H = 30-ft
- 75-year design life
- Reinforcing Strip = Wave Strip

Problem 2:

- 2H:1V infinite slope
- H = 30-ft
- 75-year design life
- Reinforcing Strip = Wave Strip

Each design example in the Appendix includes a detailed glossary and AASHTO/FHWA reference specifications of the AASHTO Coherent Gravity design procedure. The calculations are validated using the Elevate proprietary design software Elevate Wall Designer and the commercially available software program MSEW+. While MSEW+ performs Coherent Gravity calculations according to AASHTO 2017-2020, it is important to note the following differences between MSEW+ and Elevate Wall Designer:

- For slope surcharges, MSEW+ uses the unit weight of select fill for the material on slope. The Elevate program allows the user to specify the unit weight of the material on the slope above the reinforced zone, and it is our stance that this should match the retained fill properties to align with typical construction practices. Normally, this is not a big difference, but it does result in some variance between the two calculation methods.
- The inflection point for K and F* = 19.7-ft (6m) in MSEW+, whereas Elevate uses an inflection point of 20-ft per AASHTO.
- There are often minor differences between MSEW+ and Elevate in the calculated loads and resistances in the upper 2 layers of reinforcement and bottom layer of reinforcement. MSEW+ uses an average horizontal pressure at each level of soil reinforcing that is based on the program's definition. Elevate does not use the average horizontal pressure to calculate the maximum tensile force. Elevate uses the actual location of the soil reinforcing and the actual tributary area. The tributary area that each soil reinforcing element must resist is defined as the mid-point distance between each soil reinforcing. These minor differences are typically inconsequential but may result in an additional reinforcement on the top and bottom layers

The solutions for Problems 1 & 2 are located in Appendix A2.2.1

Construction

3.1 CONSTRUCTION PROCEDURES

3.1.1 Construction Innovation

The construction of MSE panel walls has become widespread across the United States, with standardized practices adopted by all major USDOT agencies. Elevate does not claim to introduce new innovations in MSE panel wall construction.

3.1.2 Construction Manual

The construction manual for Elevate MSE Panel Walls is located in Appendix A3.1.2

3.1.3 Panel Wall Curvature

Where there are curves and corners, the wall can be installed according to the design, however alternative backfill compaction means & methods may be required in locations with a tight inside radius or corner. Smaller compaction equipment may be needed, or it may be beneficial to use open-graded crushed stone backfill in these areas or for the entire structure. A crushed stone will require minimal compaction effort compared to a sandy or more well graded backfill. Alternatively, lightweight flowable fill may also be feasible.

Panels can be placed on curves of varying radius by placing them in a series of cords. The size of the radius will also dictate the length of the panel and the required panel joint configuration. The tighter the radius the smaller the panel length will be. The minimum radius (without bevels) for 5'x10' panels is 100-ft and for 5'x5' panels is 50-ft. Further, a tighter radius may require that the panel joints be cast with special edge treatments, e.g., beveled.

Corner panels are used for both inside and outside corners. The Elevate corner unit is adjustable. If the corner angle is less than 70-degrees, the MSE structure may be required to be designed as a bin wall as specified in FHWA-NHI-10-024 for the extent of the wall where the full length of the reinforcement cannot be installed without encountering the opposite wall face.

These corner and curve solutions allow Elevate panels to be used in a wide range of geometries without requiring significant customization.

Please refer to Step 3 Panel Installation in the construction manual for more detailed information.

3.1.4 Soil Reinforcement Installation at Curves & Corners

The installation procedure for Elevate Strips in curved wall sections and at corners follows the same fundamental approach as in straight wall segments. Soil reinforcement strips are to be placed perpendicular to the wall face and securely fastened to the dual-plate connector using a ½-inch galvanized nut and bolt, ensuring full engagement and proper load transfer. In curved sections, the chorded panel layout may result in variations in strip spacing within the reinforced fill zone. While this can lead to localized areas where adjacent steel strips overlap, direct contact between strips without intervening reinforced fill is permissible.

3.1.5 Vertical & Horizontal Panel Alignment

Refer to 'Step 3 Panel Installation' as well as 'Quality Assurance – Wall Alignment' in the included construction manual in Appendix A3.1.2.

3.1.6 Installation of Reinforced Backfill

Refer to 'Step 4 Soil Reinforcement & Backfill' and 'Step 5 Continued Backfill & Panel Placement' in the included construction manual in Appendix A3.1.2.

3.1.7 Erosion Prevention

At the end of daily construction activities, the grade above the MSE wall should be sloped away from the wall to prevent water from pooling or flowing directly over the edge, which could lead to erosion or undermining of the backfill. A smooth, compacted surface should be maintained to minimize water infiltration, and, if necessary, shallow drainage channels or berms can be created to direct runoff away from the wall face. In areas prone to heavy rainfall, temporary erosion control measures such as straw wattles, silt fences, or plastic sheeting may be installed to further protect the backfill and prevent washout. Furthermore, the front face of the wall should be brought up to grade as quickly as possible to prevent erosion beneath the panels and/or leveling pad.

3.1.8 Contractor Qualifications for Constructing MSE Walls

It is the responsibility of the Owner to ensure that the contractors performing work on site are qualified for the activities which they are performing. Before construction activities begin, Elevate coordinates with the wall-installer and reviews the construction manual as well as any a-typical details contained in the approved Elevate shop drawings to ensure quality and communication.

While Elevate does not impose any strict objective prequalification requirements for constructing an Elevate MSE Panel Wall System, it is preferred that the on-site managing personnel have experience with, at a minimum, modular block-style retaining wall construction; as the principles of proper leveling, alignment, and reinforcement are similar. They should be familiar with the use of soil reinforcement materials and understand how backfill placement affects the overall stability of the structure. Additionally, a strong working knowledge of proper drainage techniques is important to help mitigate water buildup behind or in front of the wall, which could lead to long-term stability issues.

In addition to working retaining wall knowledge, the contractor should have general grading experience to ensure proper site preparation and prevent potential erosion around the structure. Proper compaction of backfill materials, as well as attention to drainage flow paths, plays a key role in maintaining the integrity of the wall. Surveying for alignment and elevation control is also essential, as accurate placement of the panels and reinforcement elements is critical for both the structural performance and the final appearance of the wall.

It is the contractor's responsibility to follow the project plans and specifications while adhering to industry best practices for MSE wall installation. Coordination with engineers, inspectors, and other stakeholders may be necessary to address site-specific challenges and ensure compliance with project requirements. Proper planning, execution, and quality control measures are all key elements for constructing a successful and long-lasting Elevate MSE Wall.

3.1.9 Reinforced Soil Installation

Information and details regarding the installation of fill in the reinforced zone is located in "Step 4: Soil Reinforcement & Backfill" section of the Elevate MSE Panel Wall Construction Manual in Appendix A3.1.2.

Quality Control

4.1 MANUFACTURING

4.1.1 PRECAST PANEL FACING UNIT QAQC

Information & details regarding the manufacturing of Elevate MSE Panels is located in Appendix A4.1.1 in addition to Appendix A1.1.3.

4.1.2 ELEVATE STEEL STRIP QAQC

Information & details regarding the manufacturing of Elevate MSE Steel Strips is located in Appendices A4.1.2, A1.2.10L, and A.2.10W.

4.1.3 SHEAR, ALIGNMENT, BEARING, OR CONNECTION DEVICES

Bearing pads typically measuring ¾" are used to separate panels along the horizontal joints. Details for the Elevate bearing pads is located in Appendix A1.1.8. Elevate MSE panels do not include male-female pin connections.

4.2 CONSTRUCTION

4.2.1 QUALITY CONTROL MEASURES FOR MSE PANEL WALL CONSTRUCTION

Details regarding construction quality are located in Appendices A4.2.1 & A3.1.2.

Performance

5.1 PERFORMANCE HISTORY

5.1.1 Development and Usage History

Mechanically Stabilized Earth retaining wall structures have been utilized in heavy civil infrastructure for over 50 years in The United States. Since the first wall constructed in the United States in 1971, private companies have pioneered technology to promote more sound/efficient designs while Departments of Transportation have independently developed standards & specifications to maximize safety and encourage competition. While the engineering & manufacturing of MSE wall systems requires a very specific set of skills, the widespread adaptation of mechanically stabilized structures across the country has led to a common thread of standards & specifications.

Today, MSE walls are regularly used for grade separation applications including bridges, slope stabilization, roadway superelevations, erosion control, and dam operations. When specified by Departments of Transportation, MSE walls are designed & constructed as a collaboration between the private and the public sector.

Elevate Infrastructure has partnered with Transportation Owners & contractors since 2014 to supply high quality retaining walls including precast counterfort walls, post & panel walls, “big block” walls, and temporary wire walls for heavy highway & railway projects across the country. With headquarters in Morris, Illinois; all of these initial non-MSE wall projects were constructed in the Chicago-land area for The Illinois DOT, The Illinois State Toll Highway Authority (ISTHA), The Chicago DOT, The Cook County DOT, as well as other similar local agencies.

In 2023 Elevate combined their extensive precast & engineering experience with proven, off-patent MSE wall technology to provide a true alternative to the consolidated MSE wall industry by delivering a desperately-needed level of customer service, quality, & cost-effective MSE solutions to the heavy civil industry. At first, MSE walls were supplied locally to the Chicago market as a proof of concept; and gradually services were expanded to the greater Midwest area including Wisconsin, Missouri, Iowa, Nebraska, South Dakota, and Kansas. Today, Elevate is poised

5.1.2 Oldest Three Structures

The first three walls supplied by Elevate Infrastructure were:

1. **Illinois State Toll Highway Authority Contract I-21-4832**

This project features a single MSE panel wall with standard 5’ x 10’ precast panels and Ladder Strip Soil Reinforcements. Wall TS25.79R, NB is a 2,735’ long wall with an average height of 7’ tall that supports the northbound lanes of Highway I-294 running through Chicago, Illinois. Most of the wall was constructed with a single full-height panel. The wall was designed to accommodate 13 large drainage structures in the reinforced backfill zone, as well as a cast-in-place moment slab with a 6’ tall parapet including a mounted noise wall. The wall features a cut-stone formliner finish and was constructed in August of 2023. The structure is still standing proudly in Cook County, Illinois.

2. **Wisconsin DOT IH 41 Airport Freeway**

The Wisconsin DOT specified two U-shaped abutment walls to support the reconstruction of Loomis Road over IH43/41 in Milwaukee County. Elevate engineered and manufactured both of these structures in 2023 with the Elevate Ladder Strip Soil Reinforcements. The tallest section of wall is nearly 30' tall, and the longest soil reinforcement strips are 25' long, and the single row of piles in the backfill was the only obstruction. The wall was constructed with typical Wisconsin-sand backfill, so optimal moisture and compaction played a critical role in ensuring quality construction.

3. **Illinois DOT Dauberman Road US-30 Bridge**

Illinois DOT Contract 61H95 featured 4 abutment walls supporting the construction of Dauberman Road over US 30 as well as a BNSF rail line in Kane County, IL. All 4 walls were constructed from the fall of 2023 through the spring of 2024 with Elevate Ladder Strip Soil Reinforcements. The tallest individual structure is the south abutment wall super-elevating Dauberman Road over the BNSF rail line. The bridge embankment sits on top of a 32' tall panel wall structure, and the abutments were constructed with soil reinforcement strips extending from the backwall of the abutment. This project also serves as a great example of why MSE walls should not be specified with a smooth finish unless they are going to be painted/stained after completion.

5.1.3 Tallest Three Structures

Currently, the tallest three structures constructed by Elevate Infrastructure as of this writing are:

1. **Illinois DOT Dauberman Road US-30 Bridge** (see #3 above for project description)
2. **Wisconsin DOT IH 41 Capital Drive Bridge** (see #2 above for project description)
3. **Missouri DOT Melville Road Bridge**

MoDOT Job No. J8S3156 is a new bridge being constructed over Highway 44 in Springfield, Missouri. Each abutment wall runs about 210 lineal feet and stand 23' tall with no corners or kinks. Both walls feature 8' tall abutments on top of the reinforced backfill, and they were built in the summer of 2025 with Elevate Wave Strip Soil Reinforcements. The installed MSE panel wall area for both walls is 6,205 square feet.

5.1.4 Approved Jurisdictions

The list of approved agencies and contacts are located in Appendix A5.1.4.

Other

6.1 OTHER INFORMATION

We support the world of heavy civil retaining wall construction by leveraging decades of experience & engineering innovation. Over the years, we've developed practical tools—including in-house design software—that help us work smarter, move faster, and provide a high quality product. Our approach allows us to deliver reliable, efficient, and cost-effective MSE wall solutions that meet the demands of modern infrastructure.

For more than a decade, Elevate Infrastructure, LLC has been engineering & manufacturing retaining walls across a range of systems—including Precast Counterfort walls, Post & Panel walls, and modular precast walls. Today, under new leadership, Elevate's Mechanically Stabilized Earth Walls have quickly begun to play an essential role in rebuilding United States infrastructure.

Elevate Infrastructure is built on innovation and made in America.

Elevate MSE Panel Wall IDEA Submittal – Appendix Table of Contents

Section 1 – ERS Components

Section 2 – ERS Design

Section 3 – Construction

Section 4 – Quality Control

Section 5 – Performance

Appendix A1.1.3

APPENDIX A1.1.3 – FACING UNIT SPECIFICATIONS

CASTING

The materials, manufacturing, storage, handling and erection of concrete panels shall conform to the requirements of AASHTO Standard Specifications for Highway Bridges, with the following exception: Portland cement concrete used in panels shall conform to Class A (AE) with a minimum compressive strength at 28 days of 4,000 psi.

All panels shall be cast face down in smooth, flat, steel forms. Panel anchors and inserts shall be placed in a template at the back of the panel in order to ensure proper location. Galvanized anchors and inserts shall not be allowed to contact black steel panel reinforcing. Concrete shall be placed without interruption. Unless a self-consolidating concrete mix is used, concrete shall be vibrated using a form vibrator or hand vibrator. Clear form oil shall be used.

The rear-face of each panel shall be screed smooth to eliminate open aggregate pockets & surface distortions in excess over 0.5".

PANEL REINFORCEMENT

Welded wire panel reinforcement shall be in accordance with ASTM A1064 & ASTM A185. Bar reinforcements shall be in accordance with ASTM A706. Reinforcement clearance from rear-face of panel to be 2" or as specified by the governing Standards & Specifications. All structural members shall be in accordance with ASTM A510. Refer to Elevate Infrastructure shop drawings for specific reinforcement schedules.

TESTING & INSPECTION

Acceptability of all panels shall be on the basis of compressibility tests and visual inspection. Precast units shall be considered acceptable regardless of curing time when compressive strength meets or exceeds the 28-day compressive strength benchmark.

Acceptance of concrete panels with respect to compressive strength will be determined on the basis of production lots. A production lot is defined as a group of panels that will be represented by a single compressive strength sample and will consist of either 40 panels or a single's day production, whichever is less. During the production of the concrete panels, the manufacturer will randomly sample the concrete in accordance with AASHTO T141. A single compressive strength sample, consisting of four cylinders, will be randomly selected for every production lot.

Compression test shall be prepared in accordance with AASHTO T23, and testing shall be conducted in accordance with AASHTO T22.

For the initial strength test results, if the compressive strength is in excess of 4,000 psi, then these test results will be utilized as the compressive strength test results for that production lot, and the 28-day requirement will be waived for the lot in question.

Acceptance of a production lot will be made if the compressive strength test result is greater than or equal to 4,000 psi. If the compressive strength is less than 4,000 psi the acceptance of the production lot will be based on meeting the following criteria in its entirety:

- 90% of the compressive strength test results for the overall production shall exceed 4,000 psi
- The average of any six consecutive compressive strength test results exceed 4,000 psi.

Air content tests will be performed in accordance with AASHTO T152 or AASHTO T196. Air content samples will be taken at the beginning of each day's production and at the same time the compressive samples are taken.

The slump test will be performed in accordance with AASHTO T119. The slump will be determined at the beginning of each day's production and at the same time the compressive samples are taken.

MARKING

The date of production, the production lot number, and the name of the manufacturer shall be clearly inscribed on the rear-face of the panel unless instructed otherwise by Elevate Infrastructure or the governing-DOT.

MIX DESIGN

The precaster's concrete mix design shall be approved by the Owner/DOT for use in casting concrete MSE panels.

ACCEPTANCE

The acceptance of concrete units for compressive strength compliance will be conducted on a per-production-lot basis. Each production lot will be represented by a single compressive strength sample and shall not exceed 40 panels or one day's production, whichever is lesser.

REJECTION

The rejection of concrete units for non-compressive strength compliance may be due to:

- *Molding*: defects that indicate imperfect molding
- *Texture*: defects indicating honeycombed or excessive open texture in concrete.
- *Color*: strong color variation on the front face of the panel beyond the normal contrast from release agents & curing compounds.
- *Physical Appearance*: defects in physical characteristics including severely cracked, broken, or chipped panels. Panels shall be free of chips and cracks when viewed from a distance of 20 feet under diffused lighting.

Minor chips and cracks incidental to the standard operating procedures for manufacturing & shipping precast materials are not grounds for rejection.

HANDLING, STORAGE, & SHIPMENT

The panels shall be fully supported until the concrete reaches a minimum compressive strength of 1,500 psi. The panels may be shipped after reaching a minimum compressive strength of 3,000 psi. All panels shall be handled, stored and shipped in such a manner as to eliminate the dangers of chipping, discoloration, cracks, fractures, and excessive bending stresses. Panels in storage shall be supported on firm blocking to protect the panel connection devices and the exposed exterior finish. Blocking or dunnage to be aligned vertically throughout the stack (Figure 1) to prevent cracking & deformations. Reference the "Quality Assurance & Quality Control Manual for Precast Concrete Panels in MSE Walls" from Elevate Infrastructure for specific procedural guidelines & recommendations.

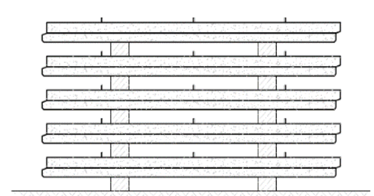


FIGURE 1

Tolerances

All panels to be manufactured for the following tolerances:

- *Dimensions*: panel dimensions shall be within 3/16" of dimensions as noted on the plans
- *Squareness*: Difference of the two verticals not to exceed ½".
- *Smoothness*: smooth panel surface finish shall be free of defects that exceed 1/4" in 5'. If the Owner has more stringent tolerances, those shall be followed for production. Variance in textured panel surface finishes will vary by the total and average reliefs of the applied formliner.

Specification Standards List—American Society for Testing & Materials (ASTM):

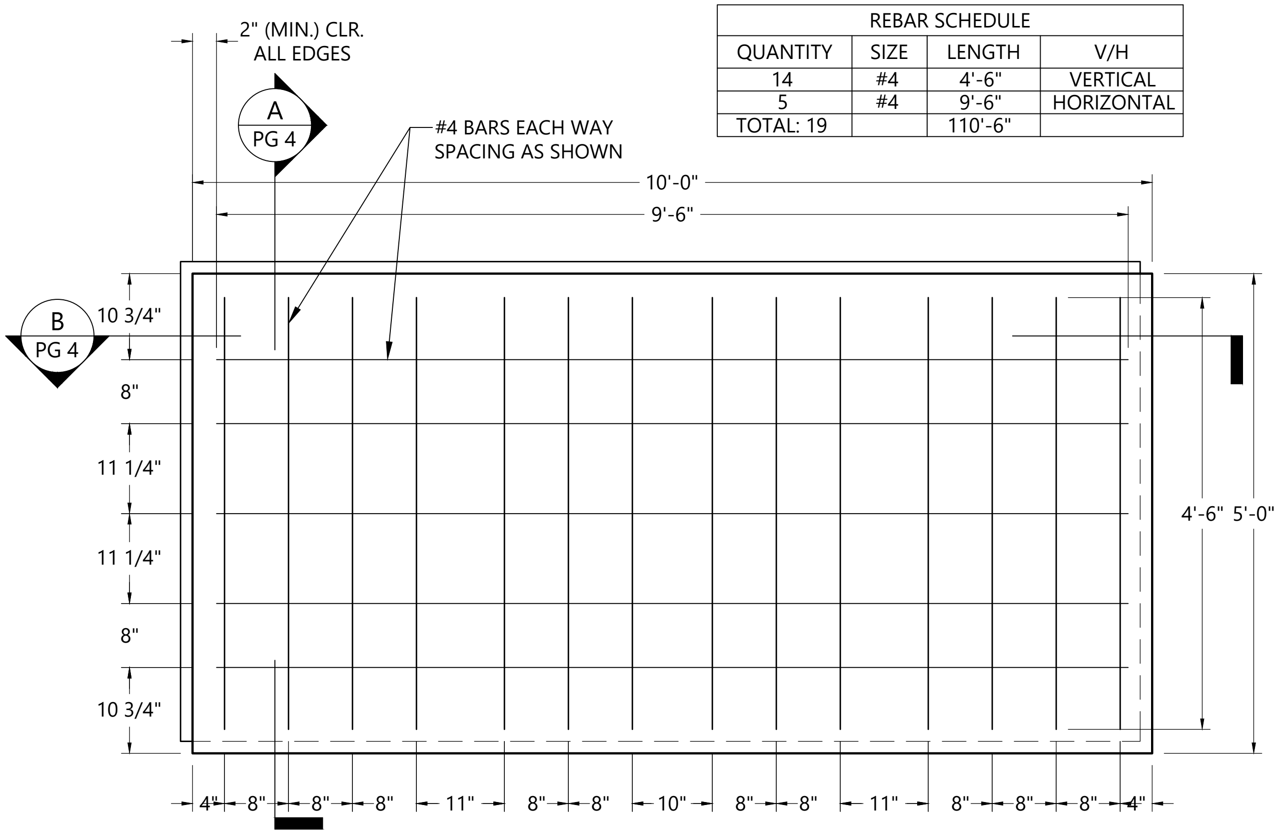
A36 – Standard Specification for Carbon Structural Steel
A82 – Standard Specification for Steel Wire, Plain, for Concrete Reinforcement
A123 – Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
A325 – Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105ksi Minimum Tensile Strength
A510 – Standard Specification for General Requirements for Wire Rods and Coarse Round Wire, Carbon Steel
A1064 – Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete
A615 – Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
A780 – Standard Specification for the Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
A884 – Standard Specification for Epoxy-Coated Steel Wire and Welded Wire Reinforcement
C150 – Standard Specification for Portland Cement

Quality Testing Standards—American Association of State Highway & Transportation Officials (AASHTO)

M85 – Standard Specification for Portland Cement
T22 – Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens
T23 – Standard Method of Test for Making and Curing Concrete Test Specimens in the Field
T141 – Standard Method of Test for Sampling Freshly Mixed Concrete
T24 – Standard Method of Test for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
T152 – Standard Method of Test for Air Content of Freshly Mixed Concrete by the Pressure Method.
T196 – Standard Method of Test for Air Content of Freshly Mixed Concrete by the Volumetric Method
T119 – Standard Method of Test for Slump of Hydraulic Cement Concrete

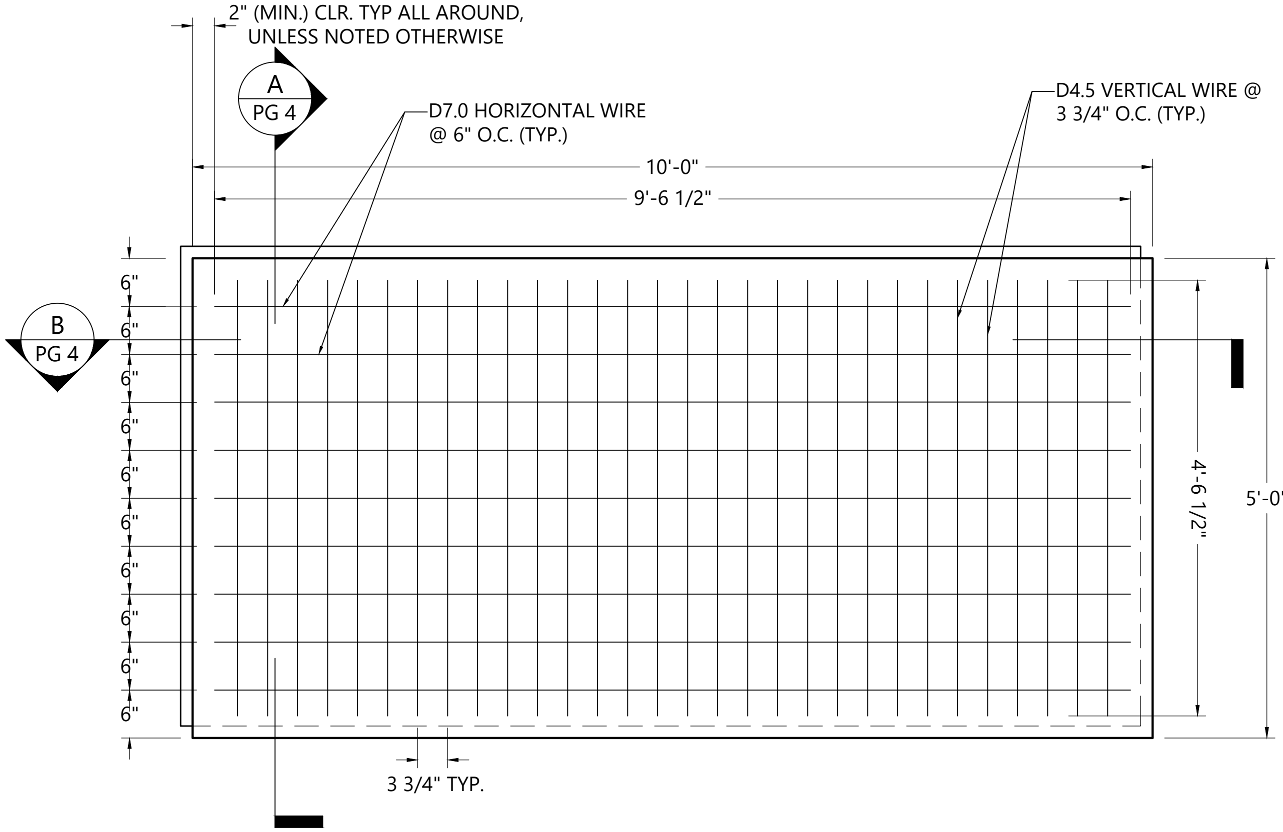
Appendix A1.1.4

REBAR SCHEDULE			
QUANTITY	SIZE	LENGTH	V/H
14	#4	4'-6"	VERTICAL
5	#4	9'-6"	HORIZONTAL
TOTAL: 19		110'-6"	



5x10 PANEL REINFORCING ELEVATION (REBAR)

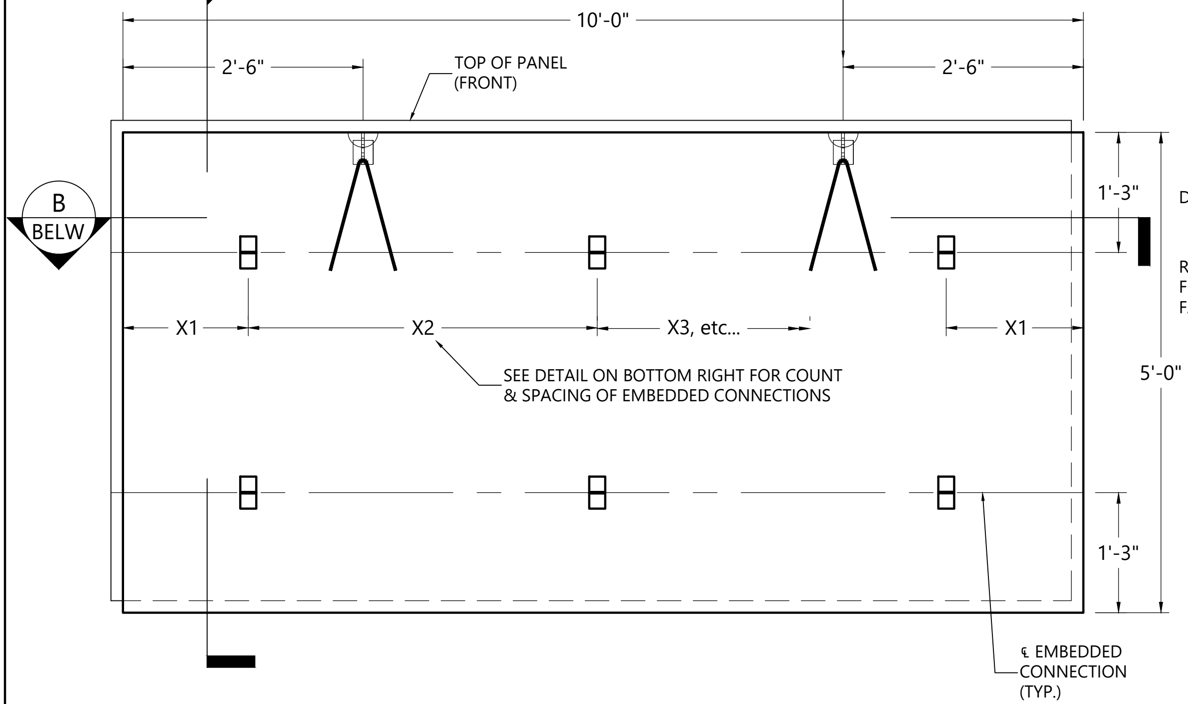
FROM SOIL OR CASTING FACE



5x10 PANEL REINFORCING ELEVATION (WWF)

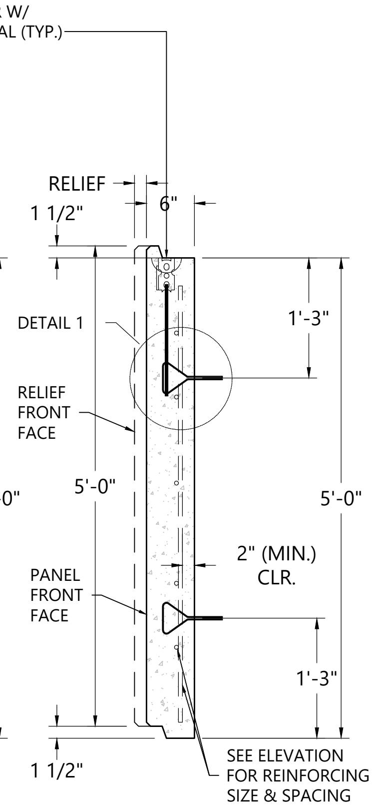
FROM SOIL OR CASTING FACE

ELEVATE INFRASTRUCTURE	DRAWING TITLE: PRECAST PANEL REINFORCEMENT	DRAWN BY: UM
	PREPARED FOR:	DATE:
	PROJECT:	DWG:



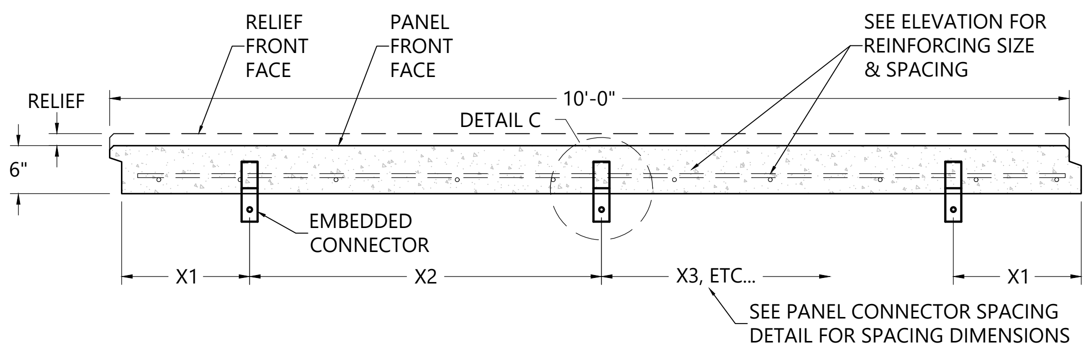
5x10 PRECAST PANEL ELEVATION

FROM SOIL OR CASTING FACE



SECTION A-A

NO SCALE



SECTION 'B'

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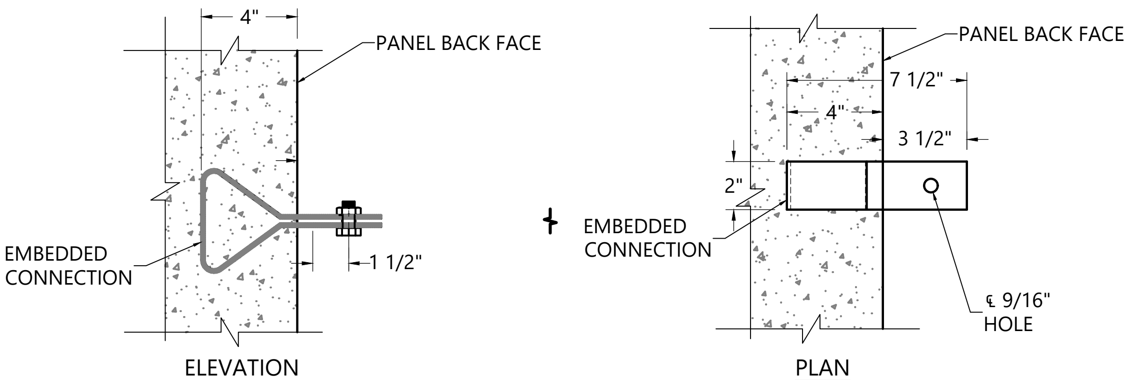


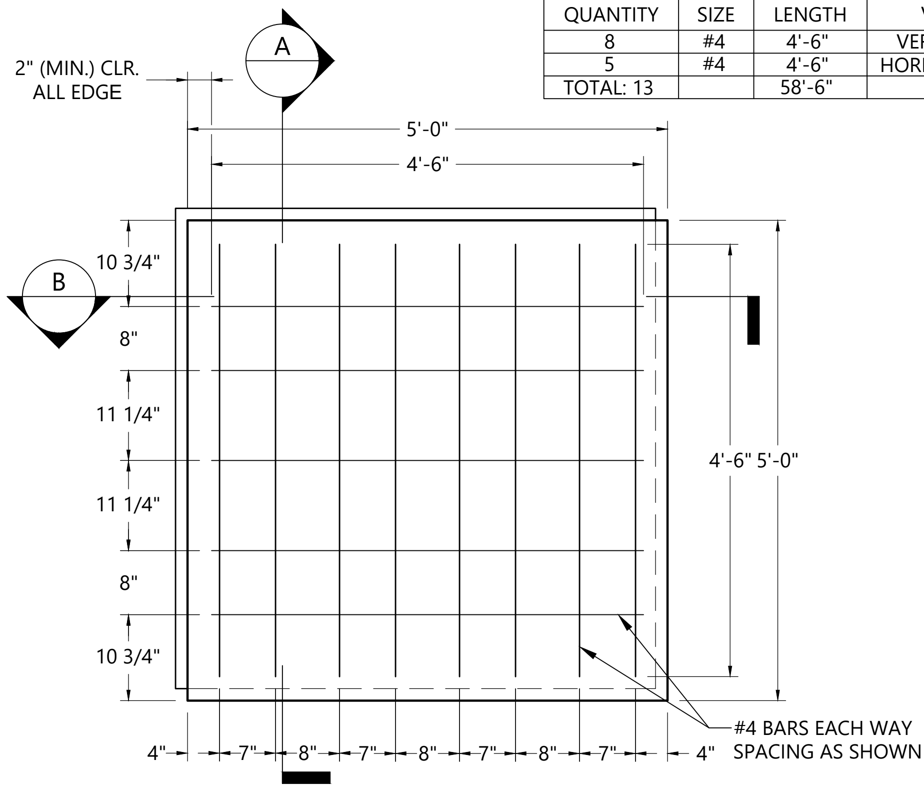
DETAIL 'C'

NO SCALE

ELEVATE
INFRASTRUCTURE

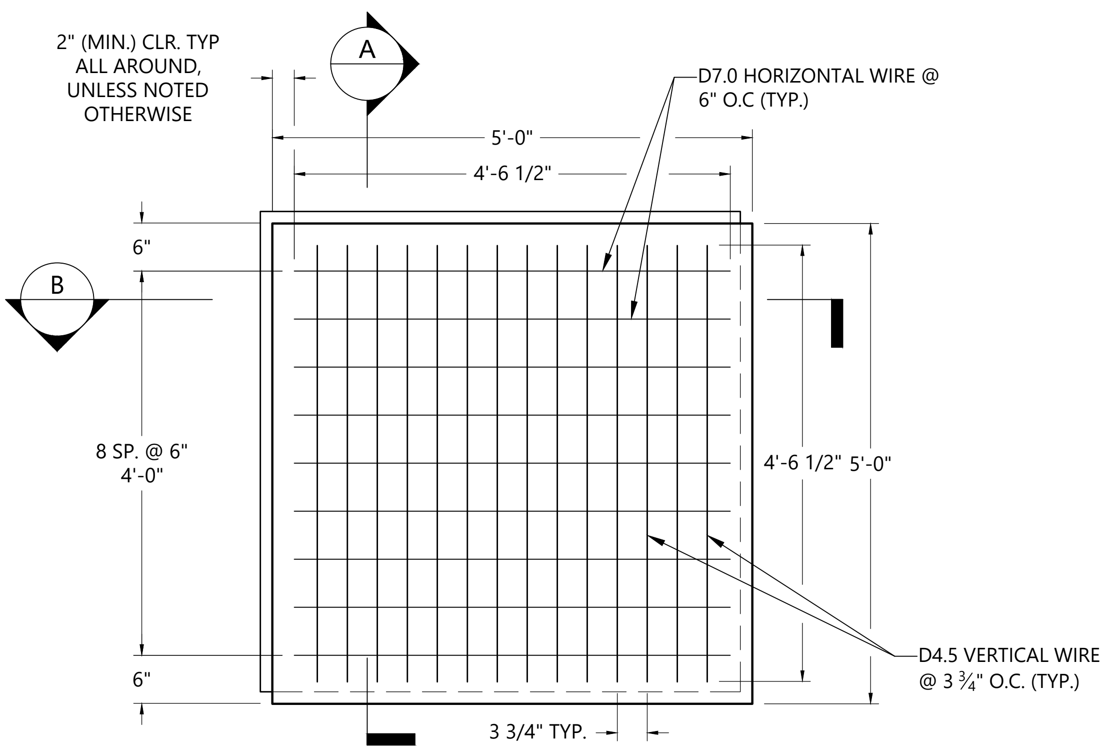
DRAWING TITLE: PANEL DETAILS		DRAWN BY: UM
PREPARED FOR:		DATE:
PROJECT:		DWG:

REBAR SCHEDULE			
QUANTITY	SIZE	LENGTH	V/H
8	#4	4'-6"	VERTICAL
5	#4	4'-6"	HORIZONTAL
TOTAL: 13		58'-6"	



5x5A PANEL REINFORCING ELEVATION (REBAR)

FROM SOIL OR CASTING FACE



5x5A PANEL REINFORCING ELEVATION (WWF)

FROM SOIL OR CASTING FACE

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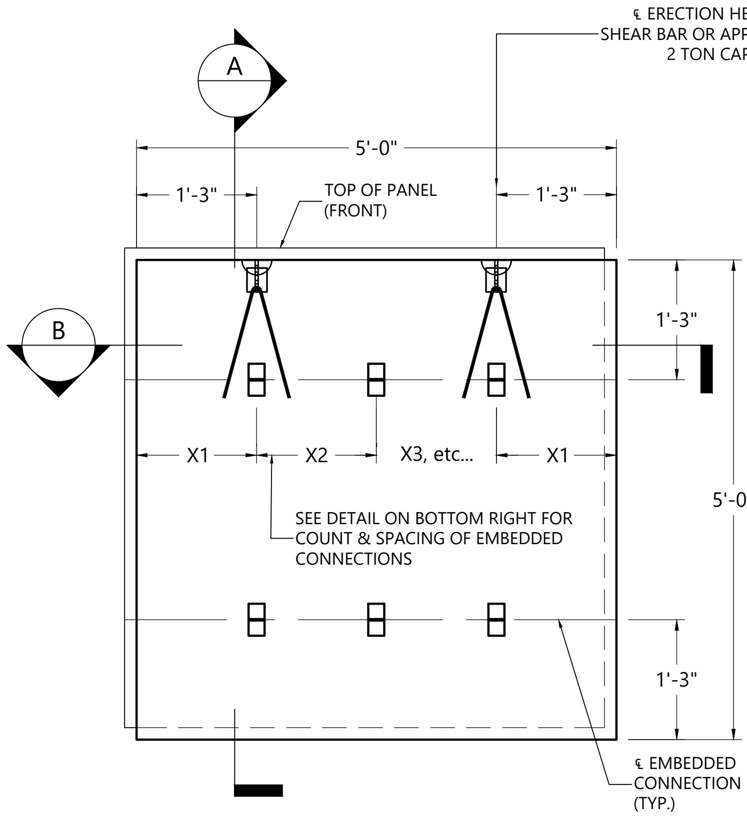
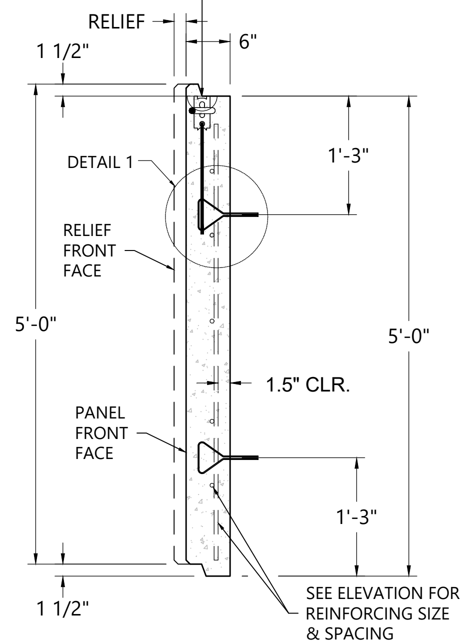
	PREPARED FOR:	DATE:
	PROJECT:	DWG:



5x5A PRECAST PANEL ELEVATION

FROM SOIL OR CASTING FACE



SECTION 'A'

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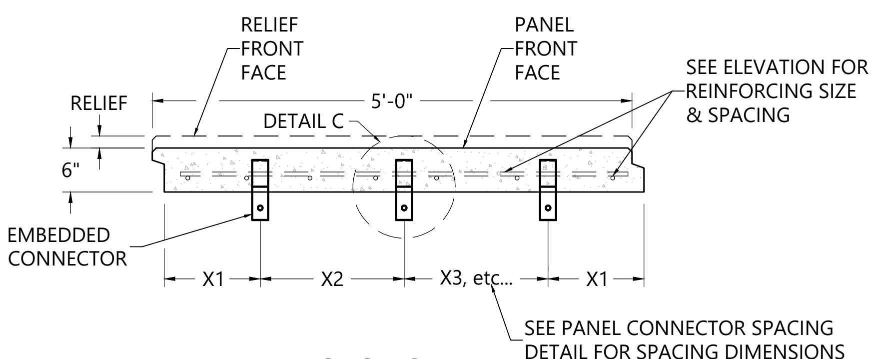

SECTION 'B'

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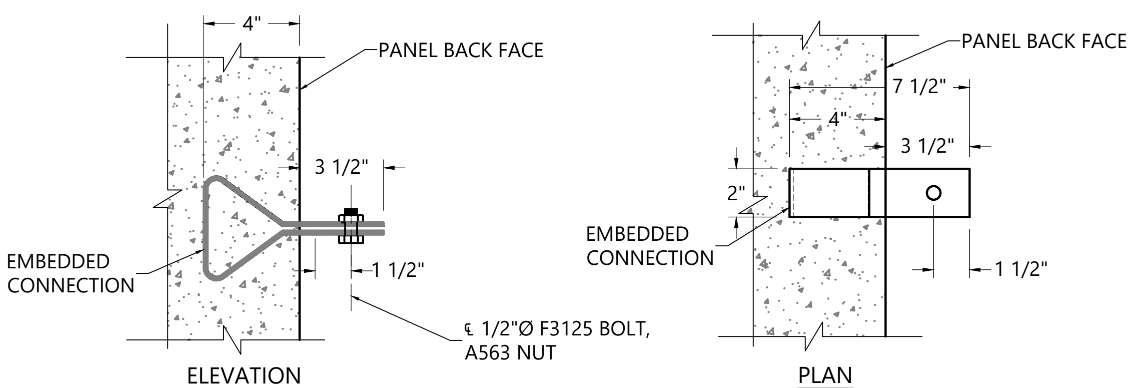
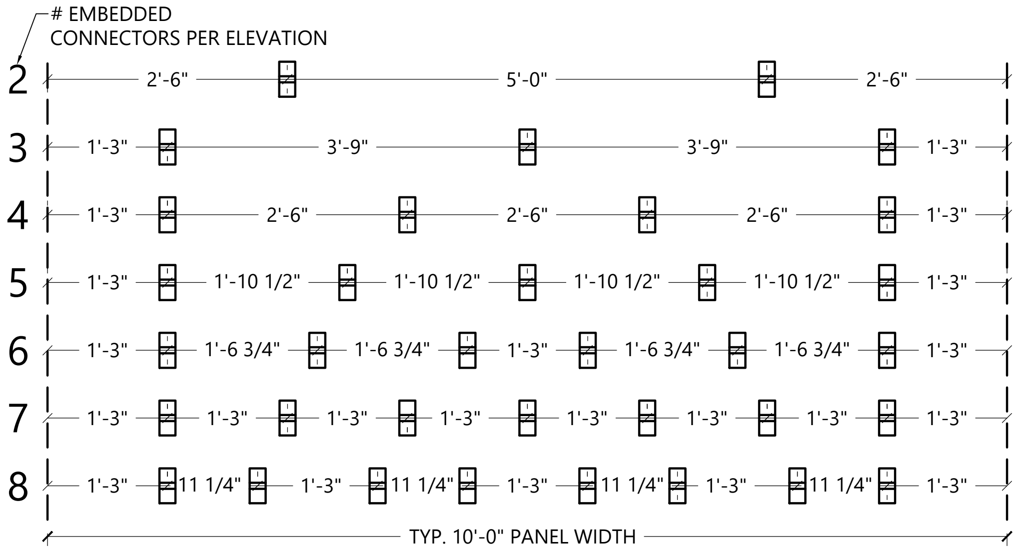


DETAIL 'C'

NO SCALE

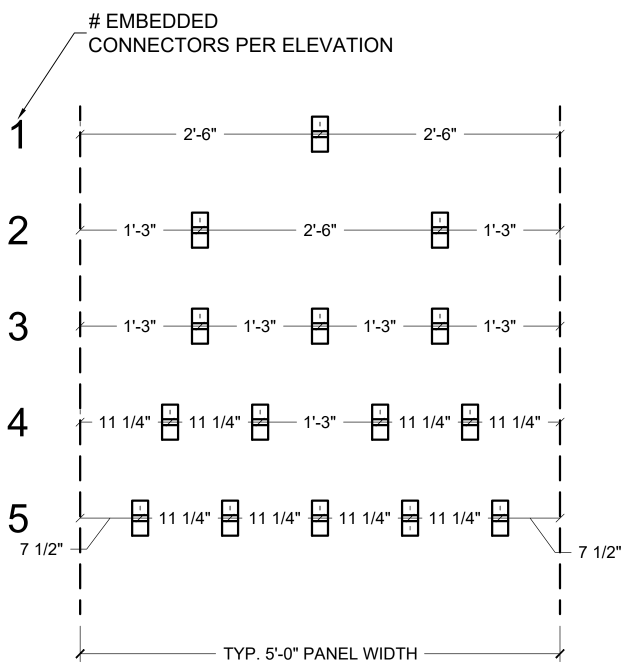
ELEVATE INFRASTRUCTURE	DRAWING TITLE: 5X5 PANEL DETAILS	DRAWN BY: UM
	PREPARED FOR:	DATE:
	PROJECT:	DWG:



NOTE:
1. NUMBER OF EMBEDDED CONNECTORS PER ELEVATION IS SPECIFIED ON WALL ELEVATIONS.
2. AT CONFLICTS MOVE CONNECTOR A MAXIMUM 1"

5x10 PANEL - CONNECTOR HORIZONTAL SPACING

NO SCALE

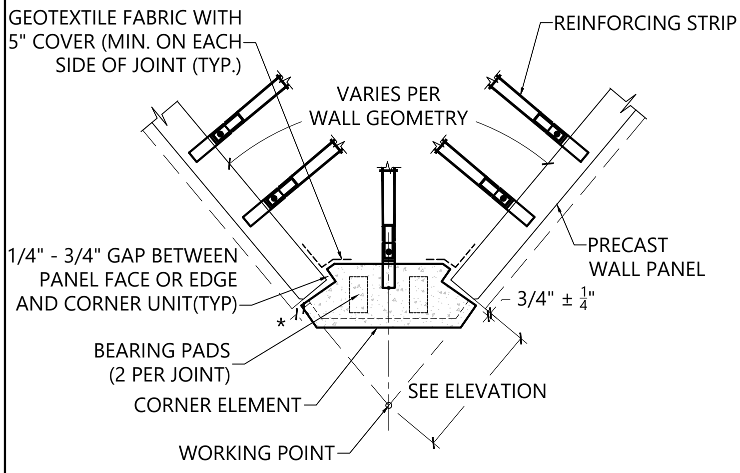


NOTE:
1. NUMBER OF EMBEDDED CONNECTORS PER ELEVATION IS SPECIFIED ON WALL ELEVATIONS.
2. AT CONFLICTS MOVE CONNECTOR A MAXIMUM 1"

5x5A PANEL - CONNECTOR HORIZONTAL SPACING

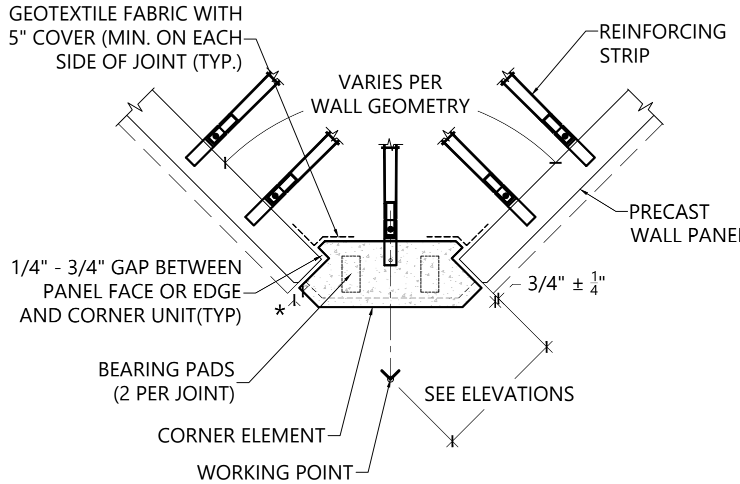
NO SCALE

ELEVATE INFRASTRUCTURE	DRAWING TITLE: PANEL CONNECTOR SPACING	DRAWN BY: UM
	PREPARED FOR:	DATE:
	PROJECT:	DWG:



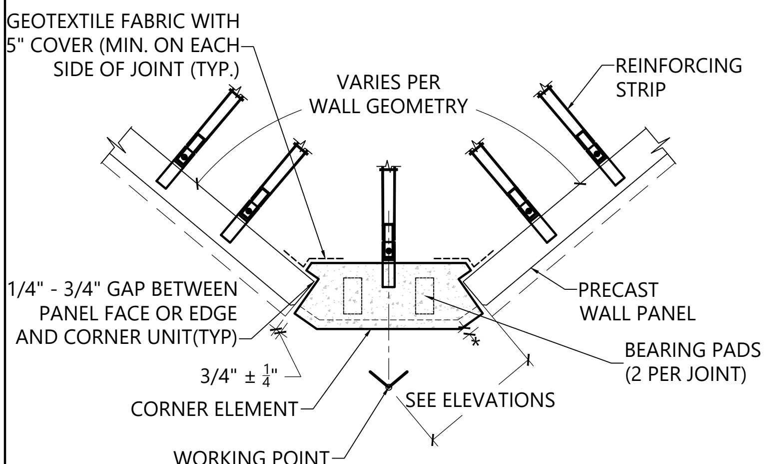
70° CORNER ELEMENT DETAIL

NO SCALE



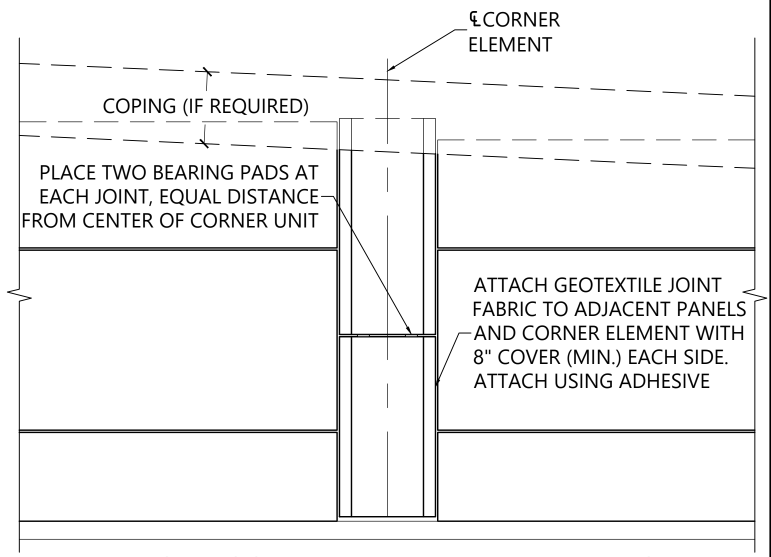
90° CORNER ELEMENT DETAIL

NO SCALE



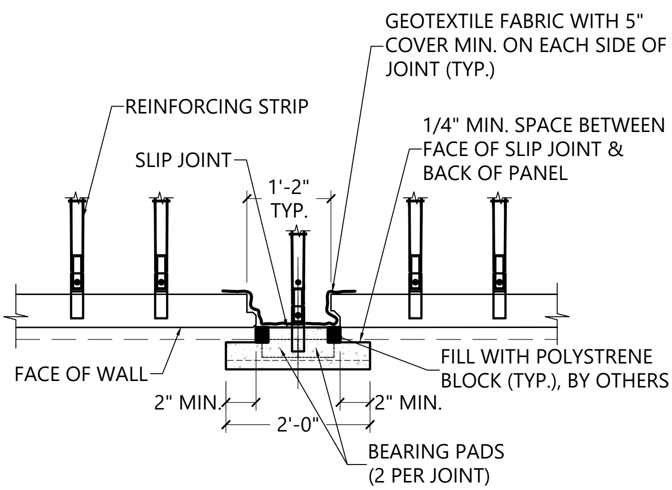
110° CORNER ELEMENT DETAIL

NO SCALE



TYPICAL CORNER ELEMENT ELEVATION

NO SCALE



SLIP JOINT DETAIL

NO SCALE

ELEVATE INFRASTRUCTURE		
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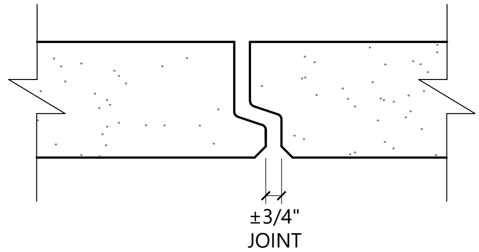
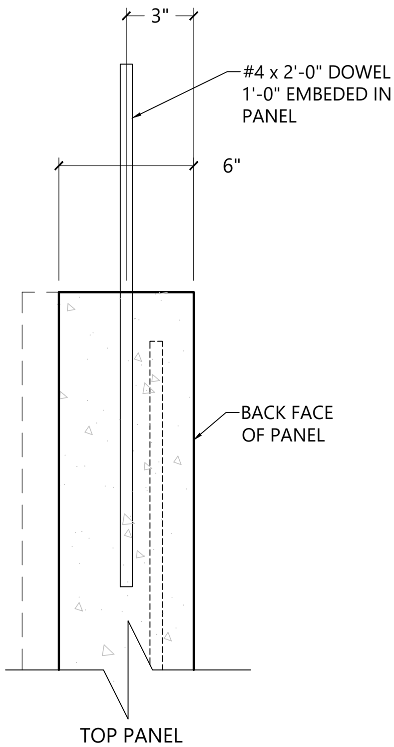
	PREPARED FOR:	DATE:
	PROJECT:	DWG: 24



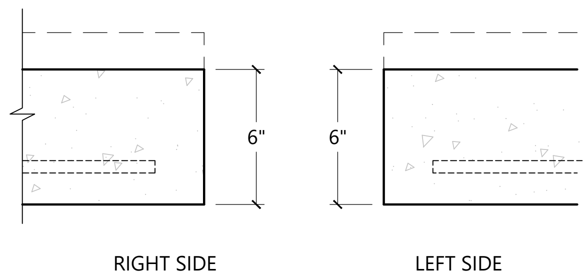
VERTICAL JOINT DETAIL

N.T.S.



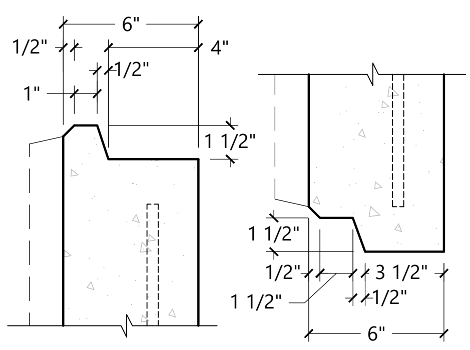
NOTE:
SEE SPECIAL PANELS FOR
TOP DOWEL LOCATIONS.

TOP PANEL DOWEL DETAIL



NOTE:
SEE SPECIAL PANELS FOR LOCATION
OF FLAT SIDE.

PANEL W/O SHIP LAP
PLAN VIEW



PANEL TOP & BOTTOM
SECTION DETAIL

ELEVATE INFRASTRUCTURE	DRAWING TITLE: PANEL EDGE DETAILS	DRAWN BY: UM
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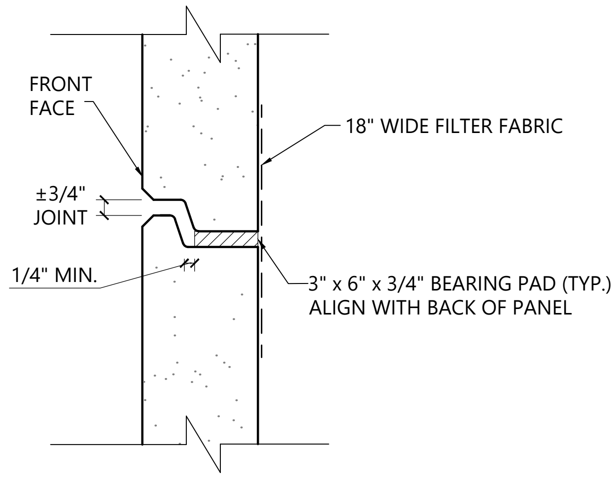
	PROJECT:	DWG:

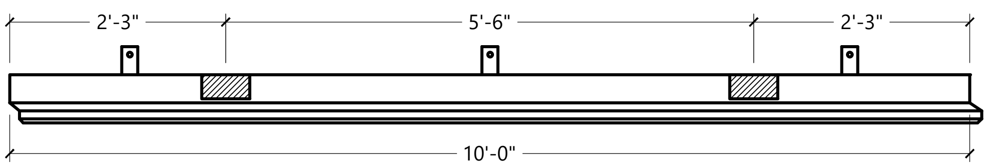
Appendix A1.1.8

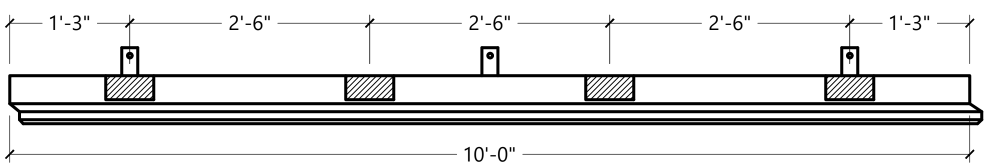


TYPICAL BEARING PAD DETAIL

N.T.S.

NUMBER OF BEARING PADS PER JOINT	
TOTAL WALL HEIGHT (# PANELS ABOVE JOINT)	NUMBER OF BEARING PADS REQUIRED PER JOINT
≤25' (≤4)	2
25'-45' (5-9)	4
>45' (10 OR MORE)	8





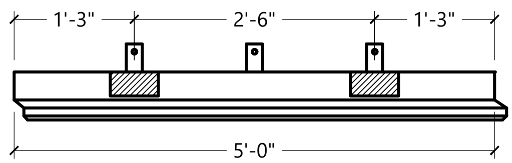
NOTE:
1. WHERE WALL HEIGHT TRANSITION TO A HEIGHT THAT EXCEEDS 45 FEET 8 BEARING PADS PER PANEL SHALL BE USED AND SHALL BE PLACED SIDE BY SIDE.
2. WALL HEIGHT IS MEASURED FROM TOP OF LEVELING PAD TO TOP OF PANEL.
3. BEARING PAD IS 80 DUROMETER 3/4"x 3"x 6"

BEARING PAD PLACEMENT ON 5'x10' PANEL

NO SCALE

ELEVATE
INFRASTRUCTURE

DRAWING TITLE:	BEARING PAD DETAILS	DRAWN BY: UM
PREPARED FOR:		DATE:
PROJECT:		DWG:



NOTE:
1. WHERE WALL HEIGHT TRANSITION TO A HEIGHT THAT EXCEEDS 45 FEET, 4 BEARING PADS PER PANEL SHALL BE USED AND SHALL BE PLACED SIDE BY SIDE.
2. WALL HEIGHT IS MEASURED FROM TOP OF LEVELING PAD TO TOP OF PANEL.
3. BEARING PAD IS 80 DUROMETER 3/4"x 3"x 6"

BEARING PAD PLACEMENT ON 5x5A PANEL

NO SCALE

ELEVATE INFRASTRUCTURE	DRAWING TITLE: BEARING PAD DETAILS	DRAWN BY: UM
	PREPARED FOR:	DATE:
	PROJECT:	DWG:

Project Number:	N/A
Project Name:	IDEA Submittal
Description	Bearing Pads
Date:	8/28/2025

ELEVATE RETAINING WALLS

BEARING PAD DESIGN

Bearing Pad Design Parameters

Bearing Pad Specifications:	ASTM D2000, 2AA, Durometer 80 +-5		
Panel Height =	5	ft	
Panel Width =	10	ft	
Panel Thickness =	6	in	
(1) Average Weight for a 10' Wide Panel =	3800	lbs/panel	
(2) Area of one pad =	18	in^2	
(3) Thickness of one pad =	0.75	inches	
(4) Vertical Loading Factor =	2		(FHWA NHI-132042 Sect. 3.6.1.2)

Stress at 0.125" compression

(5) Compressive Stress per testing (16.8% vert. strain) =	957	psi	
0.75 in * (1-0.168) = 0.624 in > 0.5 inches	OK		(FHWA NHI-132042 Sect. 3.6.1.2)

(6) Ultimate Load per Pad under maximum compression = (5) x (2) = 17226 lbs

(7) Allowable Load per Pad under maximum compression = (6)/(4)= 8613 lbs

Determine Maximum Wall Height Supported by pads (5'x10' Panels)

(8) No. of Pads per Panel Joint	(9) Allowable Load = (8)x(7)	(10) Allowable # Panels = (9)/(1)	Total Height Allowed Above Joint (ft)	Wall Height from top of Leveling Pad (ft)
2	17226	4.53	22.7	25.2
4	34452	9.07	45.3	47.8
6	51678	13.60	68.0	70.5

REX-HIDE INDUSTRIES, INC.

P.O. Box 4726
Tyler, Texas 75712-4726
Phone: 903-593-7387
Fax: 903-592-0122

Custom Rubber Extrusion Division

Product Certification

Customer: **FASTENAL COMPANY**

Part Number: **¾" Bearing Pad**
¾" x 3" x 6"

Rex-Hide Part No.: 73148087
Order No.: 157552
Compound: 148

Quantity: 2400 Pcs
Date Cured: 6 / 6 / 23
Date Shipped: 6 / 12 / 23

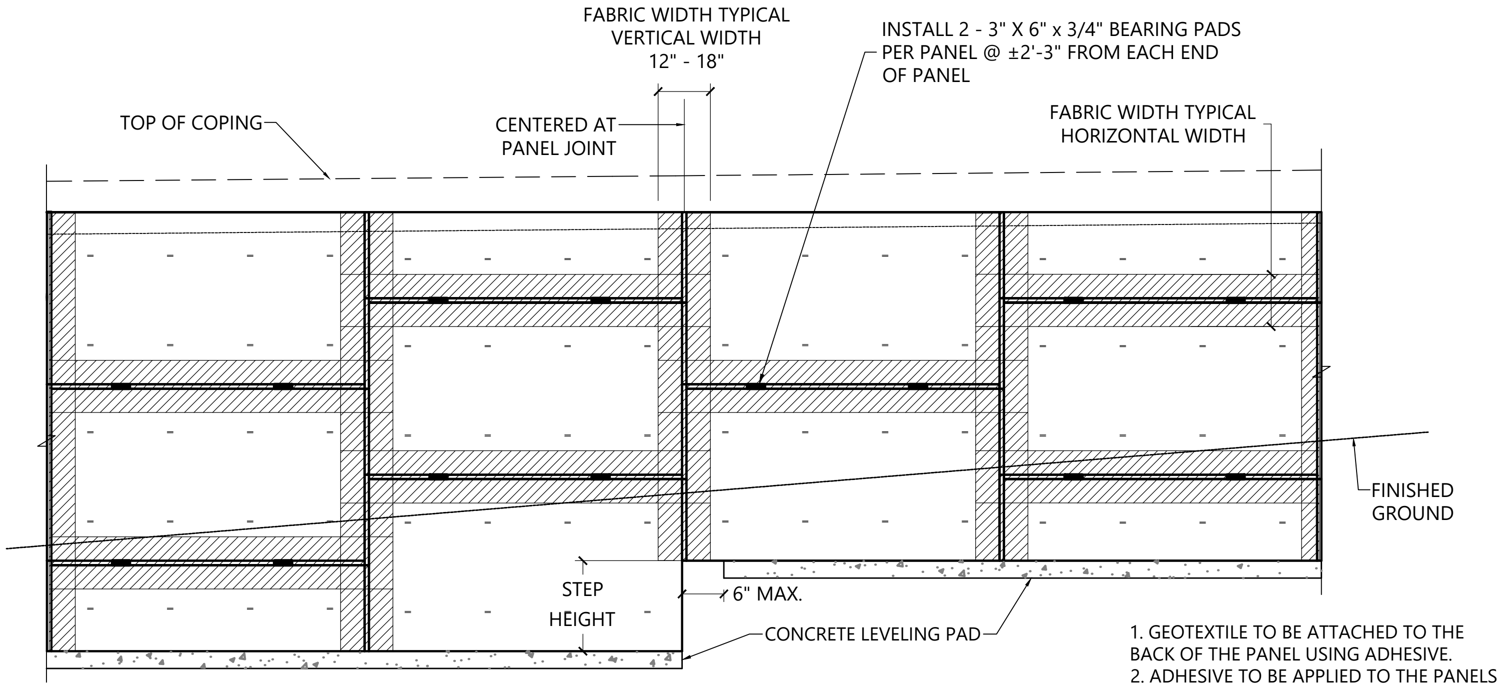
Material Specification: ASTM D2000: M2AA807, A13, B33, C12, F17

Requirements	Limits	Results
Originals		
Tensile (MPa) min	7 [1,015psi]	1413
Elongation (%) min	100	437
Durometer	75 – 85	83
Compression Set (ASTM D395) 22 hrs @ 70 °C, solid (%) max:	50	**21**
Heat Age (70 hrs @ 70 °C)		
Tensile change (%) max:	± 30	**+ 7**
Elongation Change (%) max:	- 50	**- 7**
Durometer Change:	± 15	**+ 3**
Ozone Resistance (ASTM D1171) Quality retention rating, Min. %:	85	**85**
Low Temp Brittleness: (ASTM D2137) Method A, 9.3.2 non-brittle after 3 min @ -40 °C	Pass	**Pass**

THIS PRODUCT MANUFACTURED IN TYLER, TEXAS, U.S.A.

Quality Assurance

Appendix A1.1.9



1. GEOTEXTILE TO BE ATTACHED TO THE BACK OF THE PANEL USING ADHESIVE.
2. ADHESIVE TO BE APPLIED TO THE PANELS ONLY.
3. FABRIC SHALL OVERLAP A MINIMUM OF 4". QUANTITIES SUPPLIED ARE BASED ON A 4" OVERLAP.

TYPICAL FILTER CLOTH, BEARING PAD, AND LEVELING PAD STEP DETAIL

NO SCALE

ELEVATE INFRASTRUCTURE

DRAWING TITLE: FABRIC & LEVELING PAD DETAILS	DRAWN BY: UM
PREPARED FOR:	DATE:
PROJECT:	DWG:

Appendix A1.1.10

APPENDIX A1.1.10 – AESTHETIC FACING OPTIONS

BRICK PATTERN

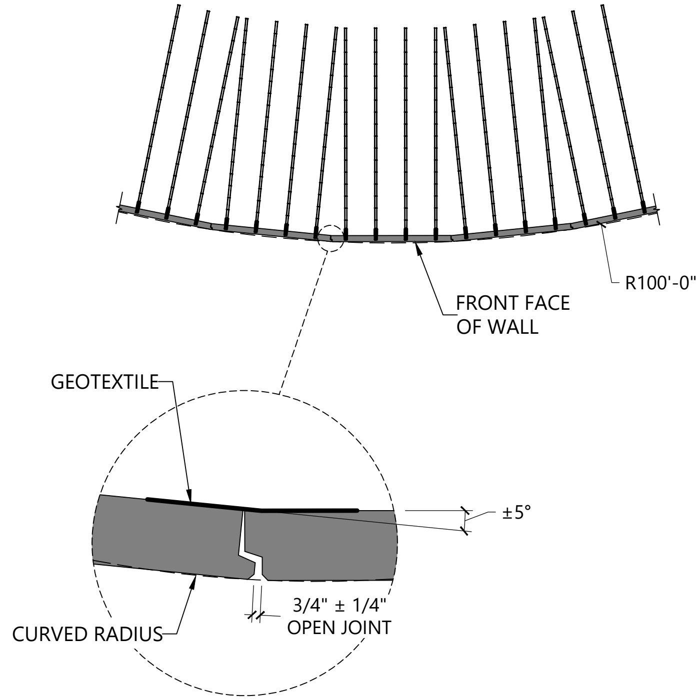
RUSTICATION PATTERN

SMOOTH PATTERN

Stone Pattern

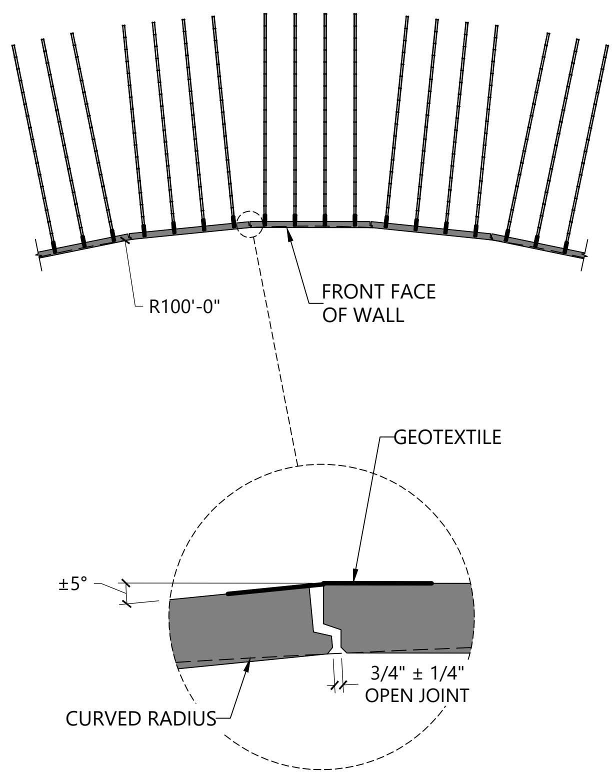
Custom Designs

Appendix A1.1.11



CONVEX CURVE DETAIL (5X10A)

NO SCALE

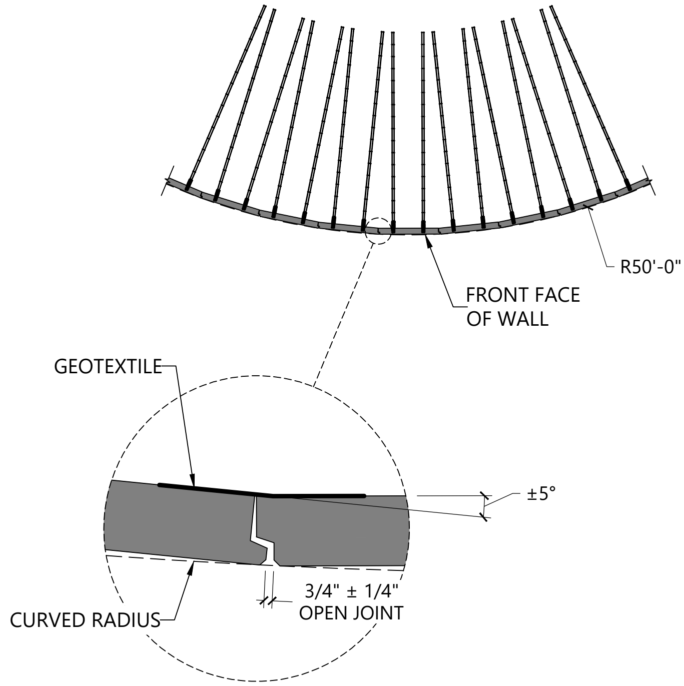


CONCAVE CURVE DETAIL (5X10A)

NO SCALE

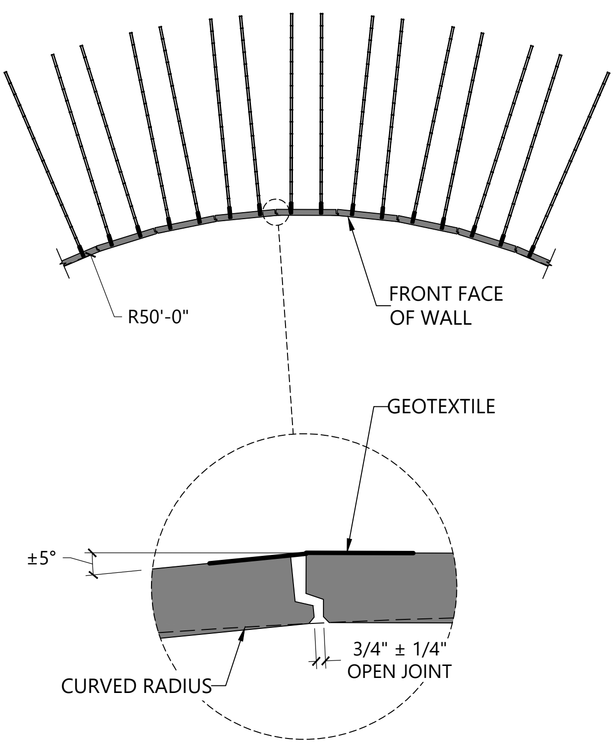
ELEVATE INFRASTRUCTURE

DRAWING TITLE: CONCAVE AND CONVEX CURVE		DRAWN BY: UM
PREPARED FOR: IDEA SUBMITTAL		DATE:
PROJECT:		DWG:



CONVEX CURVE DETAIL

NO SCALE



CONCAVE CURVE DETAIL (5X5A)

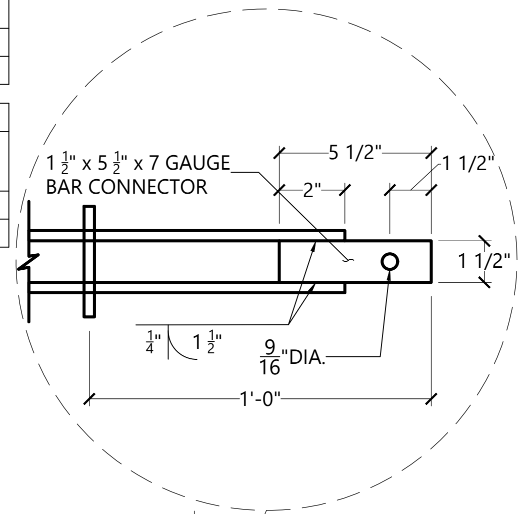
NO SCALE

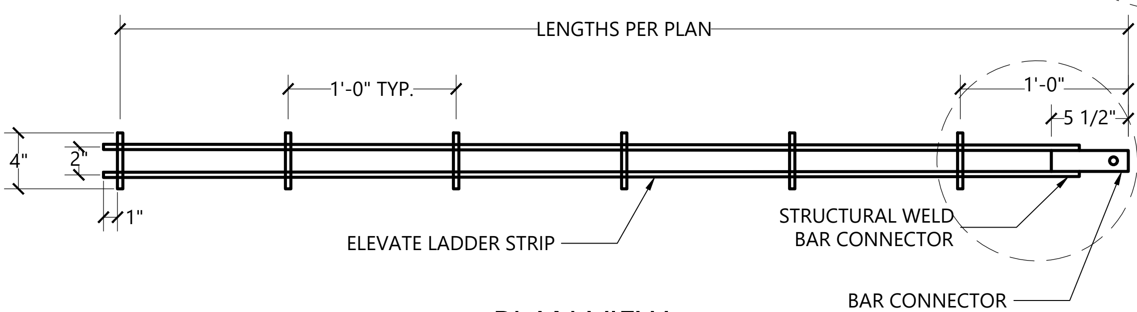
ELEVATE INFRASTRUCTURE	DRAWING TITLE: CONCAVE AND CONVEX CURVE	DRAWN BY: UM
	PREPARED FOR: IDEA SUBMITTAL	DATE:
	PROJECT:	DWG:

Appendix A1.1.2

SAMPLE ELEVATE LADDER STRIP REINFORCING SCHEDULE - ASTM A706 SPEC.						
TYPE	LONGITUDINAL BAR SIZE	TRANSVERSE BAR SIZE	LONGITUDINAL BAR SPACING	TRANSVERSE BAR SPACING	TRANSVERSE BAR WIDTH	NUMBER OF LONGITUDINAL BARS
2 - #3	#3 REBAR	#3 REBAR	2"	1'-0"	4"	2
2 - #4	#4 REBAR	#4 REBAR	2"	1'-0"	4"	2

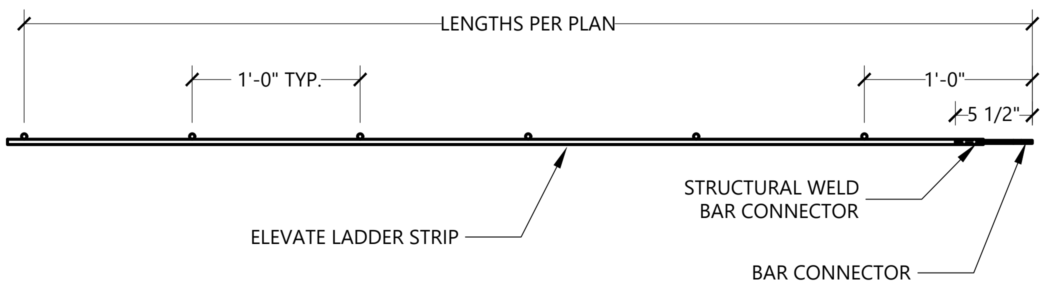
SAMPLE ELEVATE LADDER STRIP REINFORCING SCHEDULE - ASTM A1064 SPEC.						
TYPE	LONGITUDINAL BAR SIZE	TRANSVERSE BAR SIZE	LONGITUDINAL BAR SPACING	TRANSVERSE BAR SPACING	TRANSVERSE BAR WIDTH	NUMBER OF LONGITUDINAL BARS
2 -W11	W11	W11	2"	1'-0"	4"	2
2 - W16	W16	W16	2"	1'-0"	4"	2





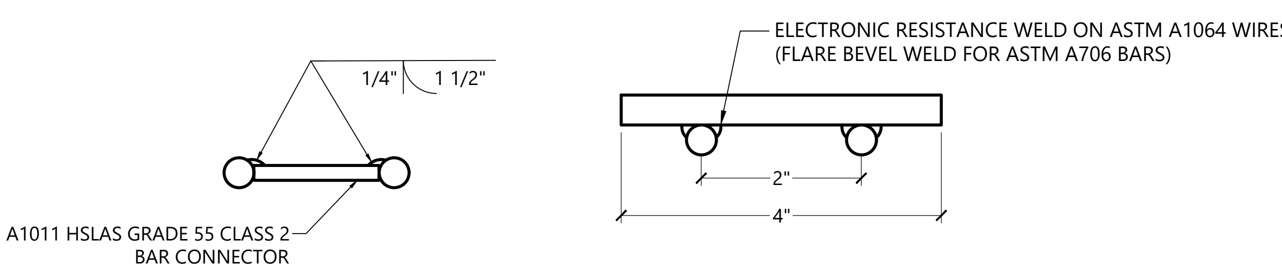
PLAN VIEW

NO SCALE



SECTION VIEW

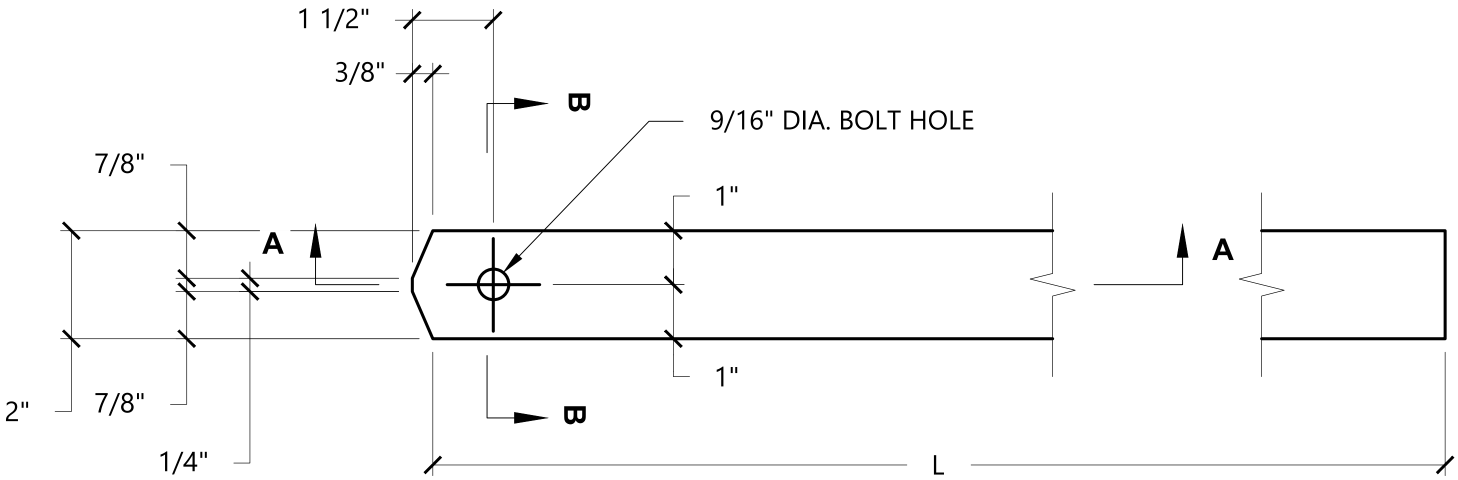
NO SCALE



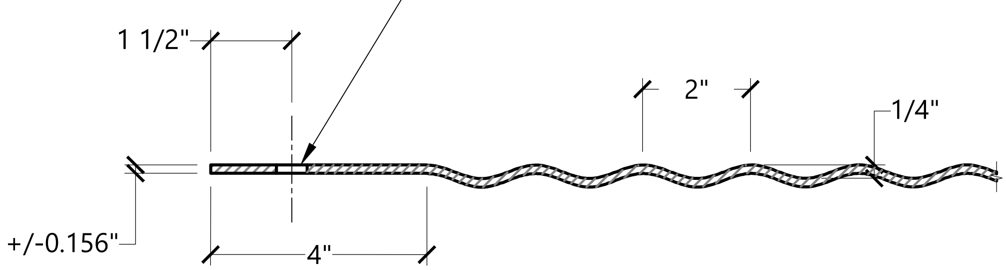
ELEVATE LADDER STRIP WELD DETAILS

NO SCALE

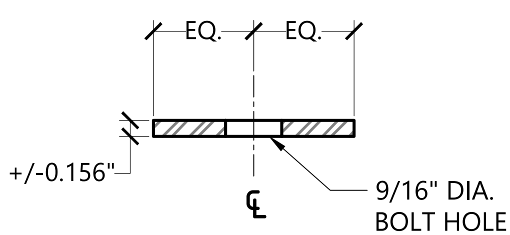
ELEVATE INFRASTRUCTURE	DRAWING TITLE: ELEVATE LADDER STRIP	DRAWN BY: UM
	PREPARED FOR:	DATE:
	PROJECT:	DWG:



PLAN VIEW



SECTION A-A



SECTION B-B

ELEVATE INFRASTRUCTURE		
	DRAWING TITLE: ELEVATE WAVE STRIP	DRAWN BY: UM
	PREPARED FOR:	DATE:
	PROJECT:	DWG:

Appendix A1.2.5

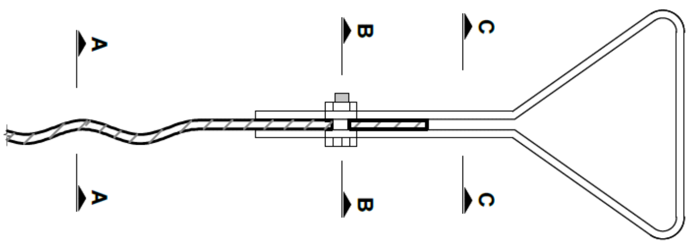
Project Number:	N/A	
Project Name:	Elevate IDEA Submittal	
Description	Connection Calculations - 100 year	
Date:	8/29/2025	

ELEVATE RETAINING WALLS

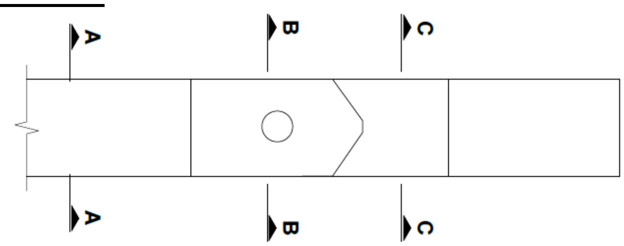
Design Life 100 years

Corrosion method: AASHTO (AASHTO assumes resistivity >3000 ohm-cm and 5<pH<10)

STRIP DESIGN SUMMARY



ELEVATION



PLAN

Strip Properties

Strip Size	Wave Strip	
Strip Thickness	0.156	in (uncoated)
Strip Width	2	
Coating	Galvanized	
Coating thickness	3.4	mils
Fy	65	ksi
Fu	80	ksi
Hole Diameter	0.5625	in

Material	Duration (yrs)	Loss Rate (mils/yr)
Zinc	2	0.58
Zinc, Subsequent	14	0.16
Carbon Steel	59	0.47
Carbon Steel (75-100yr)	25	0.47

Sacrificial Thickness, Es = 0.04288 in

Determine Long Term Strip Capacity

Longitudinal Elements	Strip Coated Thickness (in)	2Es (in)	Net Thickness (in)	Net Area , in^2"	Allowable % Stresses	Yield Strength, Ys ksi	Factor, ϕ (Table 11.5.7.1)	Strip Capacity, kips.
Wave Strip (Section A-A)	0.163	0.0858	0.077	0.154	100%	65	0.75	7.51
At Hole (Section B-B)	0.163	0.0000	0.156	0.224	100%	80	0.75	13.46

Project Number:	N/A	
Project Name:	Elevate IDEA Submittal	
Description	Connection Calculations - 100 year	
Date:	8/29/2025	

ELEVATE
RETAINING WALLS

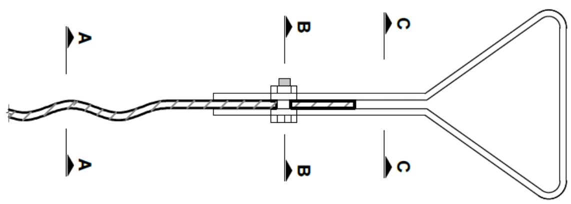
EMBEDDED CONNECTOR DESIGN SUMMARY

Embedded Connector Properties

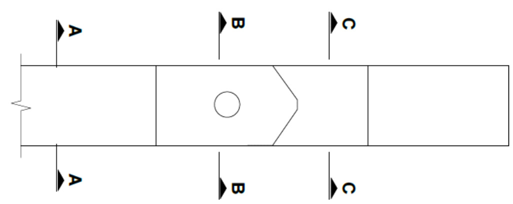
Connector Width	2	in
Connector Thickness	0.1345	in (one side)
Hole Diameter	0.5625	in
Number of Plates	2	
Connector Coating	Galvanized	
Coating Thickness	3.4	mils
Fy	50	ksi
Fu	60	ksi

Material	Duration (yrs)	Loss Rate (mils/yr)
Zinc	2	0.58
Zinc, Subsequent	14	0.16
Carbon Steel	59	0.47
Carbon Steel (75-100yr)	25	0.47

Sacrificial Thickness, Es = 0.04288 in



ELEVATION



PLAN

Determine Long Term Embedded Connector Capacity

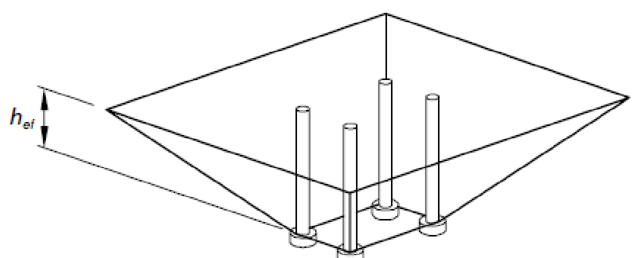
Connector Section	Coated Thickness (in)	Es, in	Net Thk., in	Net Area, in^2	Allowable % Stresses	Yield Strength, Ys ksi	Factor, ϕ (Table 11.5.7.1)	Connector Capacity, kips.
Net Area (Sec. B-B)*	0.138	0.0429	0.095	0.137	100%	60	0.75	12.29
Gross Area (Sec. C-C)	0.138	0.0858	0.052	0.104	100%	50	0.75	7.82

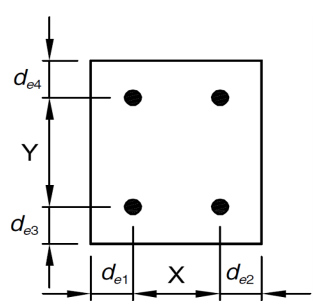
*Corrode only on exposed sides.

Pullout Resistance of Embedded Connector

Per PCI Design Handbook, 7th Edition, Section 6.5.4

f'c =	4000	psi
λ (lightweight concrete) =	1	
ϕ =	0.7	
h_{ef} =	3.5	in
$C_{bs} = 3.33\lambda\sqrt{f'_c/h_{ef}}$ =	112.57	(Eq. 6-4)
C_{crb} (assume cracked) =	0.8	
X =	2	in
Y =	4	in





When edge distance <1.5h_{ef} :

d_{e1} =	5.25	in
d_{e2} =	5.25	in
d_{e3} =	5.25	in
d_{e4} =	5.25	in

$\Psi_{ed,N} = 0.7 + 0.3d_{e,min}/1.5h_{ef}$ (Eq. 6-5)

$\Psi_{ed,N}$ = 1.00

$\phi N_{cb} = \phi C_{bs}(d_{e1}+X+d_{e2})(d_{e3}+Y+d_{e4})(\Psi_{ed,N})C_{crb}$ = **11426** lbs (Fig. 6.5.2, Case 6)

Project Number:	N/A
Project Name:	Elevate IDEA Submittal
Description	Connection Calculations - 100 year
Date:	8/29/2025

ELEVATE RETAINING WALLS

BOLT ASSEMBLY DESIGN SUMMARY

Bolt Shear Strength

Bolt Designation F3125 High Strength Bolts (Galvanized)

Net Nominal Bolt Diameter, Db = 0.500 in

Min Tensile Strength of Bolt, Fub = 120 ksi (AASHTO 2007 6.4.3)

Cross Sectional Area Ab = 0.196 in^2

Number of Shear Planes Ns = **2**

Nominal Shear Resistance, Rn

Rn = 0.45 x Ab x Fub x Ns

(AASHTO 2020 6.13.2.7-2)

Rn = 21.21 kips

Factored Shear Resistance of Bolt, Rr (ϕxRn)

	Resistance Factor ϕs *	LRFD Load	Rr	
Static	**0.8**	Strength I	16.96	kips
Static+Seismic	**1**	Extreme Event I	21.21	kips
Static+Traffic Impact	**1**	Extreme Event II	21.21	kips

*AASHTO 2020 6.5.4.2 and 6.5.5

Bolt Hole Bearing (on Embedded Connector)

Nominal Bolt Diameter Dbc = 0.500 in

Plate Thickness at end of Service Life tc = 0.095 in (for 1 plate)

Plate Tensile Strength Fu = 60 ksi

Nominal Bearing Resistance at Bolt Hole, Rn

Rn = 2.4 x Dbc x 2tc x Fu

(AASHTO 2020 6.13.2.9)

Rn = 13.68 kips

Factored Bearing Resistance of Embedded Connector at Bolt Hole, Rr (ϕxRn)

	Resistance Factor ϕs *	LRFD Load	Rr	
Static	**0.8**	Strength I	10.95	kips
Static+Seismic	**1**	Extreme Event I	13.68	kips
Static+Traffic Impact	**1**	Extreme Event II	13.68	kips

*AASHTO 2020 6.5.4.2 and 6.5.5

Bolt Hole Bearing on Wave Strip

Nominal Bolt Diameter Dbc = 0.500 in

Plate Thickness at end of Service Life Ec = 0.156 in

Plate Tensile Strength Fu = 80 ksi

Nominal Bearing Resistance at Bolt Hole, Rn

Rn = 2.4 x Dbc x tc x Fu

(AASHTO 2020 6.13.2.9)

Rn = 14.98 kips

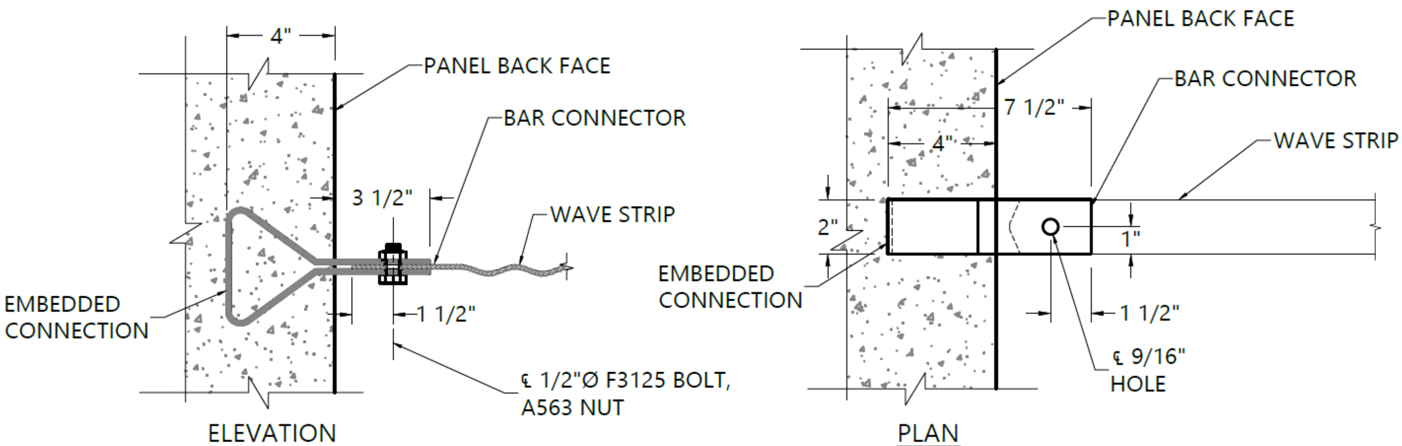
Factored Bearing Resistance of Wave Strip at Bolt Hole, Rr (ϕxRn)

	Resistance Factor ϕbb *	LRFD Load	Rr	
Static	**0.8**	Strength I	11.98	kips
Static+Seismic	**1**	Extreme Event I	14.98	kips
Static+Traffic Impact	**1**	Extreme Event II	14.98	kips

*AASHTO 2020 6.5.4.2 and 6.5.5

Project Number:	N/A
Project Name:	Elevate IDEA Submittal
Description	Connection Calculations - 100 year
Date:	8/29/2025

ELEVATE RETAINING WALLS



DETAIL AT CONNECTOR

NO SCALE

Summary of Calculated Factored Resistances

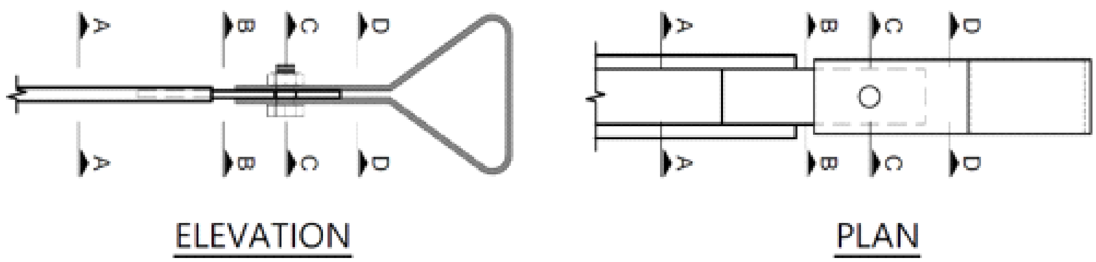
Tensile Resistance of Strips	**7.51**	kips	CONTROLS
Tensile Resistance of Net Area of Wave Strip at Bolt	**13.46**	kips	
Tensile Resistance of Net Section of Embedded Connector	**12.29**	kips	
Tensile Resistance of Gross Section of Embedded Connector	**7.82**	kips	
Pullout Resistance of Embedded Connector	**11.43**	kips	
Bolt Shear Resistance	**16.96**	kips	
Bolt Hole Bearing Resistance on Embedded Connector	**10.95**	kips	
Bolt Hole Bearing Resistance on Wave Strip	**11.98**	kips	

Project Number:	N/A	
Project Name:	Elevate IDEA Submittal	ELEVATE RETAINING WALLS
Description	Connection Calculations - 100 year	
Date:	8/29/2025	

Design Life 100 years

Corrosion method: AASHTO (AASHTO assumes resistivity >3000 ohm-cm and 5<pH<10)

STRIP DESIGN SUMMARY



Wire Properties

Wire Size	W11
Wire Diameter	0.374 in (uncoated)
Number of Wires	2
Coating	Galvanized
Coating thickness	3.4 mils
Fy	65 ksi
Fu	75 ksi

Material	Duration (yrs)	Loss Rate (mils/yr)
Zinc	2	0.58
Zinc, Subsequent	14	0.16
Carbon Steel	59	0.47
Carbon Steel (75-100yr)	25	0.47

Sacrificial Thickness, Es = 0.04288 in

Determine Long Term Strip Capacity

Longitudinal Elements	Bar Coated Diameter (in)	2Es (in)	Net Dia. (in)	Net Area 2 bars, in^2"	Allowable % Stresses	Yield Strength, Ys ksi	Factor, ϕ (Table 11.5.7.1)	Strip Capacity, kips.
W11 (Section A-A)	0.381	0.0858	0.295	0.137	100%	65	0.75	6.67

Bar Connector Properties

Plate Width	1.57 in
Plate Thickness	0.1793 in (uncoated)
Hole Diameter	0.5625 in
Plate Coating:	Galvanized
Coating thickness	3.4 mils
Fy	55 ksi
Fu	65 ksi

Material	Duration (yrs)	Loss Rate (mils/yr)
Zinc	2	0.58
Zinc, Subsequent	14	0.16
Carbon Steel	59	0.47
Carbon Steel (75-100yr)	25	0.47

Sacrificial Thickness, Es = 0.04288 in

Determine Long Term Plate Capacity

Bar Connector Section	Coated Thickness (in)	2Es, in	Net Thk., in	Net Area, in^2	Allowable % Stresses	Yield Strength, Ys ksi	Factor, ϕ (Table 11.5.7.1)	Strip Capacity, kips.
Net Area (Sect. B-B)	0.186	0.0858	0.100	0.158	100%	55	0.75	6.50
Gross Area (Sect. C-C)	0.186	0.0000	0.179	0.181	100%	65	0.75	8.81

Project Number:	N/A	
Project Name:	Elevate IDEA Submittal	
Description	Connection Calculations - 100 year	
Date:	8/29/2025	

ELEVATE RETAINING WALLS

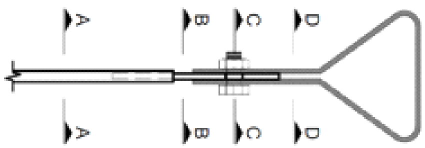
EMBEDDED CONNECTOR DESIGN SUMMARY

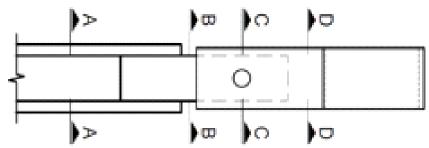
Embedded Connector Properties

Connector Width	2	in
Connector Thickness	0.1345	in (one side)
Hole Diameter	0.5625	in
Number of Plates	2	
Connector Coating	Galvanized	
Coating Thickness	3.4	mils
Fy	50	ksi
Fu	60	ksi

Material	Duration (yrs)	Loss Rate (mils/yr)
Zinc	2	0.58
Zinc, Subsequent	14	0.16
Carbon Steel	59	0.47
Carbon Steel (75-100yr)	25	0.47

Sacrificial Thickness, Es = 0.04288 in





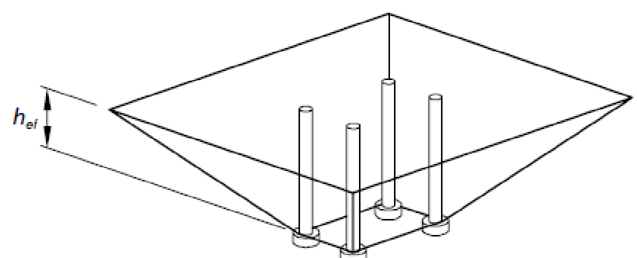
Determine Long Term Embedded Connector Capacity

Connector Section	Coated Thickness (in)	Es, in	Net Thk., in	Net Area, in^2	Allowable % Stresses	Yield Strength, Ys ksi	Factor, ϕ (Table 11.5.7.1)	Connector Capacity, kips.
Net Area (Sec. C-C)*	0.138	0.0429	0.095	0.137	100%	60	0.75	12.29
Gross Area (Sec. D-D)	0.138	0.0858	0.052	0.104	100%	50	0.75	7.82

*Corrode only on exposed sides.

Pullout Resistance of Embedded Connector

Per PCI Design Handbook, 7th Edition, Section 6.5.4



$f'c =$ 4000 psi

λ (lightweight concrete) = 1

$\phi =$ 0.7

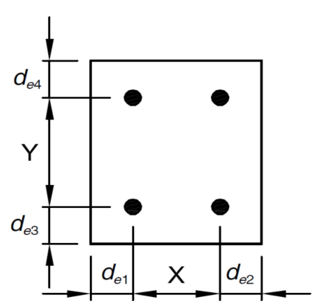
$h_{ef} =$ 3.5 in

$C_{bs} = 3.33\lambda\sqrt{(f'_c/h_{ef})} =$ 112.57 (Eq. 6-4)

C_{crb} (assume cracked) = 0.8

X = 2 in

Y = 4 in



When edge distance <1.5h_{ef} :

$d_{e1} =$ 5.25 in

$d_{e2} =$ 5.25 in

$d_{e3} =$ 5.25 in

$d_{e4} =$ 5.25 in

$\Psi_{ed,N} = 0.7 + 0.3d_{e,min}/1.5h_{ef}$ (Eq. 6-5)

$\Psi_{ed,N} =$ 1.00

$\phi N_{cb} = \phi C_{bs}(d_{e1}+X+d_{e2})(d_{e3}+Y+d_{e4})(\Psi_{ed,N})C_{crb} =$ **11426** lbs (Fig. 6.5.2, Case 6)

Project Number:	N/A
Project Name:	Elevate IDEA Submittal
Description	Connection Calculations - 100 year
Date:	8/29/2025

ELEVATE RETAINING WALLS

BOLT ASSEMBLY DESIGN SUMMARY

Bolt Shear Strength

Bolt Designation: F3125 High Strength Bolts (Galvanized)

Net Nominal Bolt Diameter,	Db =	0.500	in
Min Tensile Strength of Bolt,	Fub =	120	ksi (AASHTO 2007 6.4.3)
Cross Sectional Area	Ab =	0.196	in^2
Number of Shear Planes	Ns =	2	

Nominal Shear Resistance, Rn

Rn = 0.45 x Ab x Fub x Ns

(AASHTO 2020 6.13.2.7-2)

Rn = 21.21 kips

Factored Shear Resistance of Bolt, Rr (ϕxRn)

	Resistance Factor ϕs *	LRFD Load	Rr	
Static	0.8	Strength I	16.96	kips
Static+Seismic	1	Extreme Event I	21.21	kips
Static+Traffic Impact	1	Extreme Event II	21.21	kips

*AASHTO 2020 6.5.4.2 and 6.5.5

Bolt Hole Bearing (on Embedded Connector)

Nominal Bolt Diameter	Dbc =	0.500	in
Plate Thickness at end of Service Life	tc =	0.095	in (for 1 plate)
Plate Tensile Strength	Fu =	60	ksi

Nominal Bearing Resistance at Bolt Hole, Rn

Rn = 2.4 x Dbc x 2tc x Fu

(AASHTO 2020 6.13.2.9)

Rn = 13.68 kips

Factored Bearing Resistance of Embedded Connector at Bolt Hole, Rr (ϕxRn)

	Resistance Factor ϕs *	LRFD Load	Rr	
Static	0.8	Strength I	10.95	kips
Static+Seismic	1	Extreme Event I	13.68	kips
Static+Traffic Impact	1	Extreme Event II	13.68	kips

*AASHTO 2020 6.5.4.2 and 6.5.5

Bolt Hole Bearing on Bar Connector

Nominal Bolt Diameter	Dbc =	0.500	in
Plate Thickness at end of Service Life	Ec =	0.179	in
Plate Tensile Strength	Fu =	75	ksi

Nominal Bearing Resistance at Bolt Hole, Rn

Rn = 2.4 x Dbc x tc x Fu

(AASHTO 2020 6.13.2.9)

Rn = 16.14 kips

Factored Bearing Resistance of Bar Connector at Bolt Hole, Rr (ϕxRn)

	Resistance Factor ϕbb *	LRFD Load	Rr	
Static	0.8	Strength I	12.91	kips
Static+Seismic	1	Extreme Event I	16.14	kips
Static+Traffic Impact	1	Extreme Event II	16.14	kips

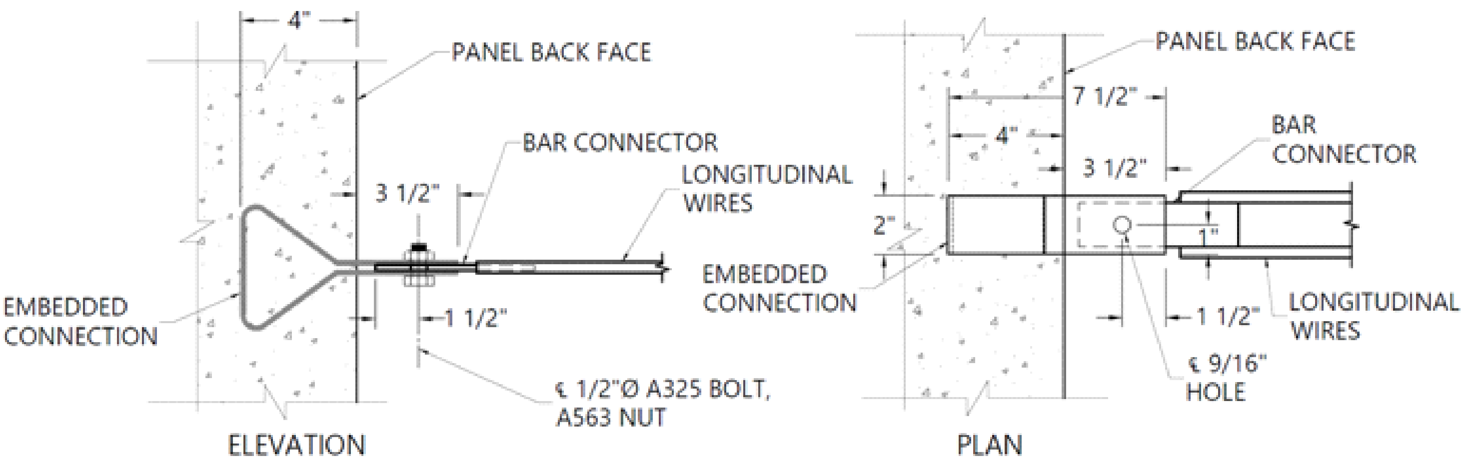
*AASHTO 2020 6.5.4.2 and 6.5.5

Project Number:	N/A	
Project Name:	Elevate IDEA Submittal	
Description	Connection Calculations - 100 year	
Date:	8/29/2025	

ELEVATE RETAINING WALLS

WELD CONNECTION CHECK

Weld Type = flare bevel groove			ϕ_v =	1.0		
Weld Length, L =	1.5	in	Fy =	55	ksi	
Weld Size, E =	0.25	in	Rr = min	$2*0.6\phi_{e2}F_{exx}*A*\sqrt{2}/2$		(AASHTO 6.13.3.2.3b)
Area, A = E*L =	0.375	in^2		$2*0.58\phi_v F_y*A$		(AASHTO 6.13.5.3-1)
ϕ_{e2} =	0.8		Rr =	17.82	kips (Static)	
Fexx =	70	ksi	Rr =	22.27	kips (Extreme I & II)	



DETAIL AT CONNECTOR
NO SCALE

Summary of Calculated Factored Resistances

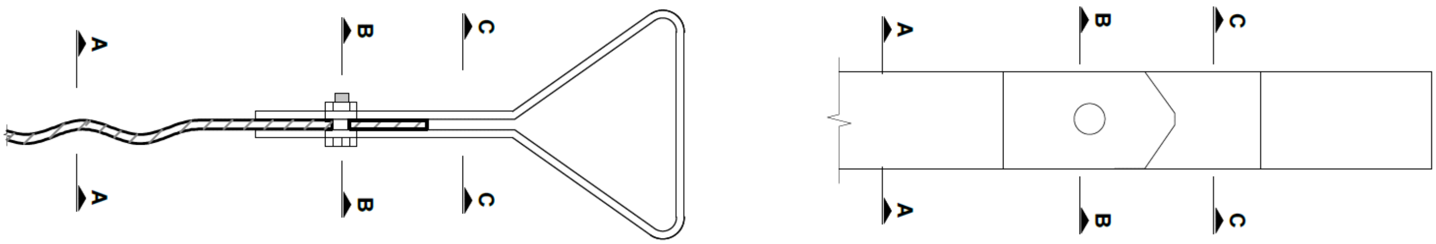
Tensile Resistance of Wires	**6.67**	kips	
Tensile Resistance of Net Area of Bar Connector	**6.50**	kips	CONTROLS
Tensile Resistance of Gross Area of Bar Connector	**8.81**	kips	
Tensile Resistance of Net Section of Embedded Connector	**12.29**	kips	
Tensile Resistance of Gross Section of Embedded Connector	**7.82**	kips	
Pullout Resistance of Embedded Connector	**11.43**	kips	
Bolt Shear Resistance	**16.96**	kips	
Bolt Hole Bearing Resistance on Embedded Connector	**10.95**	kips	
Bolt Hole Bearing Resistance on Bar Connector	**12.91**	kips	
Weld Between Bar Connector and Wires	**17.82**	kips	

Project Number:	N/A
Project Name:	Elevate IDEA Submittal
Description	Connection Calculations - 75 year
Date:	8/29/2025

ELEVATE RETAINING WALLS

Design Life 75 years
Corrosion method: AASHTO (AASHTO assumes resistivity >3000 ohm-cm and 5<pH<10)

STRIP DESIGN SUMMARY



Strip Properties

Strip Size	Wave Strip	
Strip Thickness	0.156	in (uncoated)
Strip Width	2	
Coating	Galvanized	
Coating thickness	3.4	mils
Fy	65	ksi
Fu	80	ksi
Hole Diameter	0.5625	in

Material	Duration (yrs)	Loss Rate (mils/yr)
Zinc	2	0.58
Zinc, Subsequent	14	0.16
Carbon Steel	59	0.47
Carbon Steel (75-100yr)	0	0.47

Sacrificial Thickness, Es = 0.03113 in

Determine Long Term Strip Capacity

Longitudinal Elements	Strip Coated Thickness (in)	2Es (in)	Net Thickness (in)	Net Area , in^2"	Allowable % Stresses	Yield Strength, Ys ksi	Factor, ϕ (Table 11.5.7.1)	Strip Capacity, kips.
Wave Strip (Section A-A)	0.163	0.0623	0.101	0.201	100%	65	0.75	9.80
At Hole (Section B-B)	0.163	0.0000	0.156	0.224	100%	80	0.75	13.46

Project Number:	N/A
Project Name:	Elevate IDEA Submittal
Description	Connection Calculations - 75 year
Date:	8/29/2025

ELEVATE RETAINING WALLS

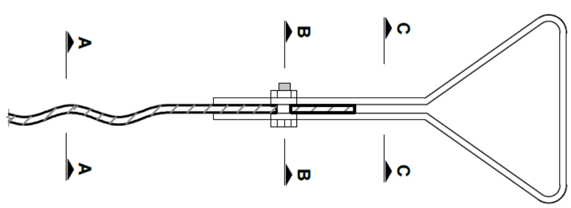
EMBEDDED CONNECTOR DESIGN SUMMARY

Embedded Connector Properties

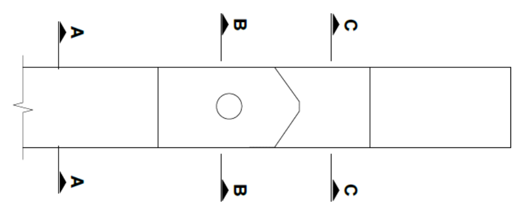
Connector Width	2	in
Connector Thickness	0.1345	in (one side)
Hole Diameter	0.5625	in
Number of Plates	2	
Connector Coating	Galvanized	
Coating Thickness	3.4	mils
Fy	50	ksi
Fu	60	ksi

Material	Duration (yrs)	Loss Rate (mils/yr)
Zinc	2	0.58
Zinc, Subsequent	14	0.16
Carbon Steel	59	0.47
Carbon Steel (75-100yr)	0	0.47

Sacrificial Thickness, Es = 0.03113 in



ELEVATION



PLAN

Determine Long Term Embedded Connector Capacity

Connector Section	Coated Thickness (in)	Es, in	Net Thk., in	Net Area, in^2	Allowable % Stresses	Yield Strength, Ys ksi	Factor, ϕ (Table 11.5.7.1)	Connector Capacity, kips.
Net Area (Sec. B-B)*	0.138	0.0311	0.107	0.153	100%	60	0.75	13.81
Gross Area (Sec. C-C)	0.138	0.0623	0.076	0.151	100%	50	0.75	11.35

*Corrode only on exposed sides.

Pullout Resistance of Embedded Connector

Per PCI Design Handbook, 7th Edition, Section 6.5.4

$f'c$ = 4000 psi

λ (lightweight concrete) = 1

ϕ = 0.7

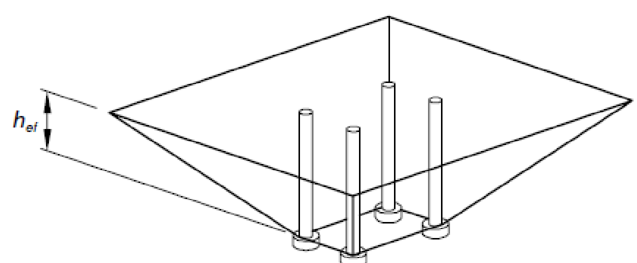
h_{ef} = 3.5 in

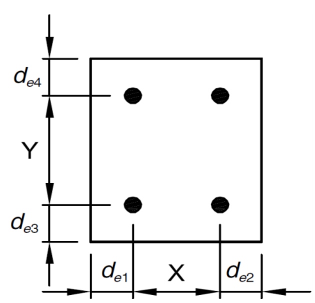
$C_{bs} = 3.33\lambda\sqrt{(f'_c/h_{ef})}$ = 112.57 (Eq. 6-4)

C_{crb} (assume cracked) = 0.8

X = 2 in

Y = 4 in





When edge distance <1.5h_{ef} :

d_{e1} = 5.25 in

d_{e2} = 5.25 in

d_{e3} = 5.25 in

d_{e4} = 5.25 in

$\Psi_{ed,N} = 0.7 + 0.3d_{e,min}/1.5h_{ef}$ (Eq. 6-5)

$\Psi_{ed,N}$ = 1.00

$\phi N_{cb} = \phi C_{bs}(d_{e1}+X+d_{e2})(d_{e3}+Y+d_{e4})(\Psi_{ed,N})C_{crb}$ = **11426** lbs (Fig. 6.5.2, Case 6)

Project Number:	N/A
Project Name:	Elevate IDEA Submittal
Description	Connection Calculations - 75 year
Date:	8/29/2025

ELEVATE RETAINING WALLS

BOLT ASSEMBLY DESIGN SUMMARY

Bolt Shear Strength

Bolt Designation: F3125 High Strength Bolts (Galvanized)

Net Nominal Bolt Diameter, Db = 0.500 in

Min Tensile Strength of Bolt, Fub = 120 ksi (AASHTO 2007 6.4.3)

Cross Sectional Area Ab = 0.196 in^2

Number of Shear Planes Ns = **2**

Nominal Shear Resistance, Rn

Rn = 0.45 x Ab x Fub x Ns

(AASHTO 2020 6.13.2.7-2)

Rn = 21.21 kips

Factored Shear Resistance of Bolt, Rr (ϕxRn)

	Resistance Factor ϕs *	LRFD Load	Rr	
Static	**0.8**	Strength I	16.96	kips
Static+Seismic	**1**	Extreme Event I	21.21	kips
Static+Traffic Impact	**1**	Extreme Event II	21.21	kips

*AASHTO 2020 6.5.4.2 and 6.5.5

Bolt Hole Bearing (on Embedded Connector)

Nominal Bolt Diameter Dbc = 0.500 in

Plate Thickness at end of Service Life tc = 0.107 in (for 1 plate)

Plate Tensile Strength Fu = 60 ksi

Nominal Bearing Resistance at Bolt Hole, Rn

Rn = 2.4 x Dbc x 2tc x Fu

(AASHTO 2020 6.13.2.9)

Rn = 15.37 kips

Factored Bearing Resistance of Embedded Connector at Bolt Hole, Rr (ϕxRn)

	Resistance Factor ϕs *	LRFD Load	Rr	
Static	**0.8**	Strength I	12.30	kips
Static+Seismic	**1**	Extreme Event I	15.37	kips
Static+Traffic Impact	**1**	Extreme Event II	15.37	kips

*AASHTO 2020 6.5.4.2 and 6.5.5

Bolt Hole Bearing on Wave Strip

Nominal Bolt Diameter Dbc = 0.500 in

Plate Thickness at end of Service Life Ec = 0.156 in

Plate Tensile Strength Fu = 80 ksi

Nominal Bearing Resistance at Bolt Hole, Rn

Rn = 2.4 x Dbc x tc x Fu

(AASHTO 2020 6.13.2.9)

Rn = 14.98 kips

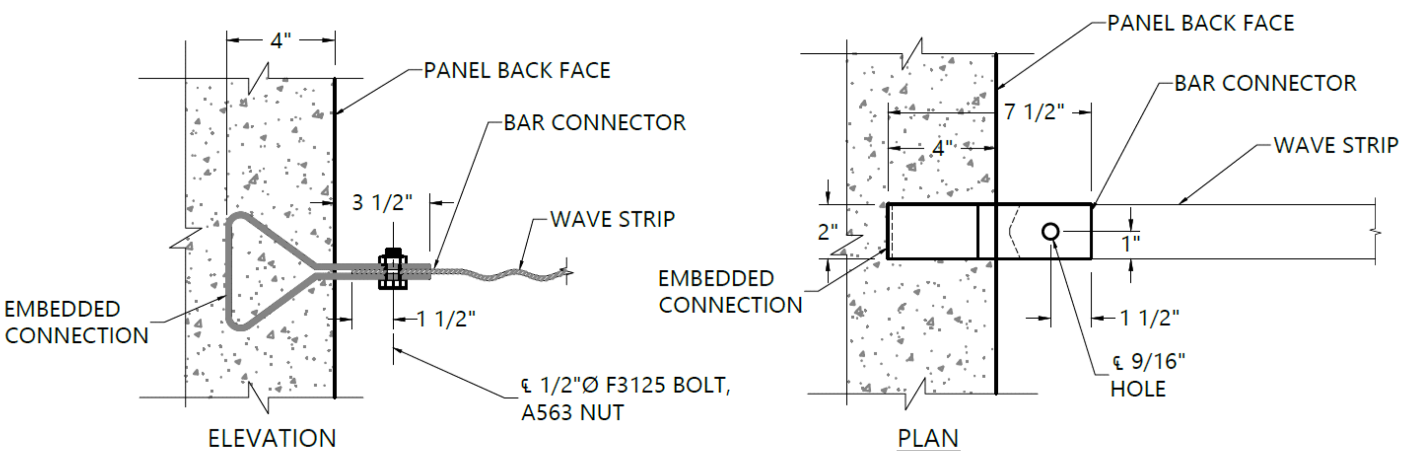
Factored Bearing Resistance of Wave Strip at Bolt Hole, Rr (ϕxRn)

	Resistance Factor ϕbb *	LRFD Load	Rr	
Static	**0.8**	Strength I	11.98	kips
Static+Seismic	**1**	Extreme Event I	14.98	kips
Static+Traffic Impact	**1**	Extreme Event II	14.98	kips

*AASHTO 2020 6.5.4.2 and 6.5.5

Project Number:	N/A
Project Name:	Elevate IDEA Submittal
Description	Connection Calculations - 75 year
Date:	8/29/2025

ELEVATE RETAINING WALLS



DETAIL AT CONNECTOR
NO SCALE

Summary of Calculated Factored Resistances

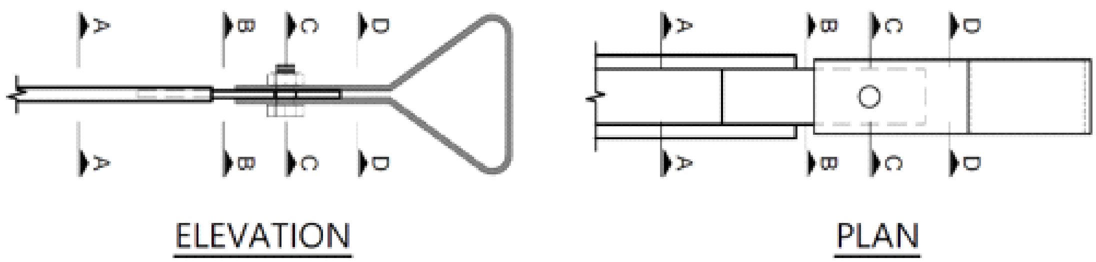
Tensile Resistance of Strips	**9.80**	kips	CONTROLS
Tensile Resistance of Net Area of Wave Strip at Bolt	**13.46**	kips	
Tensile Resistance of Net Section of Embedded Connector	**13.81**	kips	
Tensile Resistance of Gross Section of Embedded Connector	**11.35**	kips	
Pullout Resistance of Embedded Connector	**11.43**	kips	
Bolt Shear Resistance	**16.96**	kips	
Bolt Hole Bearing Resistance on Embedded Connector	**12.30**	kips	
Bolt Hole Bearing Resistance on Wave Strip	**11.98**	kips	

Project Number:	N/A	ELEVATE RETAINING WALLS
Project Name:	Elevate IDEA Submittal	
Description	Connection Calculations - 75 year	
Date:	8/29/2025	

Design Life 75 years

Corrosion method: AASHTO (AASHTO assumes resistivity >3000 ohm-cm and 5<pH<10)

STRIP DESIGN SUMMARY



Wire Properties

Wire Size	W11
Wire Diameter	0.374 in (uncoated)
Number of Wires	2
Coating	Galvanized
Coating thickness	3.4 mils
Fy	65 ksi
Fu	75 ksi

Material	Duration (yrs)	Loss Rate (mils/yr)
Zinc	2	0.58
Zinc, Subsequent	14	0.16
Carbon Steel	59	0.47
Carbon Steel (75-100yr)	0	0.47
Sacrificial Thickness, Es =		0.03113 in

Determine Long Term Strip Capacity

Longitudinal Elements	Bar Coated Diameter (in)	2Es (in)	Net Dia. (in)	Net Area 2 bars, in^2"	Allowable % Stresses	Yield Strength, Ys ksi	Factor, ϕ (Table 11.5.7.1)	Strip Capacity, kips.
W11 (Section A-A)	0.381	0.0623	0.319	0.159	100%	65	0.75	7.77

Bar Connector Properties

Plate Width	1.57 in
Plate Thickness	0.1793 in (uncoated)
Hole Diameter	0.5625 in
Plate Coating:	Galvanized
Coating thickness	3.4 mils
Fy	55 ksi
Fu	65 ksi

Material	Duration (yrs)	Loss Rate (mils/yr)
Zinc	2	0.58
Zinc, Subsequent	14	0.16
Carbon Steel	59	0.47
Carbon Steel (75-100yr)	0	0.47
Sacrificial Thickness, Es =		0.03113 in

Determine Long Term Plate Capacity

Bar Connector Section	Coated Thickness (in)	2Es, in	Net Thk., in	Net Area, in^2	Allowable % Stresses	Yield Strength, Ys ksi	Factor, ϕ (Table 11.5.7.1)	Strip Capacity, kips.
Net Area (Sect. B-B)	0.186	0.0623	0.124	0.194	100%	55	0.75	8.02
Gross Area (Sect. C-C)	0.186	0.0000	0.179	0.181	100%	65	0.75	8.81

Project Number:	N/A	
Project Name:	Elevate IDEA Submittal	
Description	Connection Calculations - 75 year	
Date:	8/29/2025	

ELEVATE RETAINING WALLS

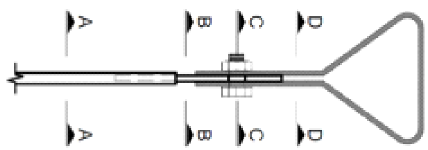
EMBEDDED CONNECTOR DESIGN SUMMARY

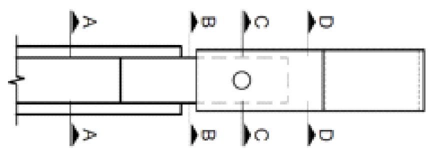
Embedded Connector Properties

Connector Width	2	in
Connector Thickness	0.1345	in (one side)
Hole Diameter	0.5625	in
Number of Plates	2	
Connector Coating	Galvanized	
Coating Thickness	3.4	mils
Fy	50	ksi
Fu	60	ksi

Material	Duration (yrs)	Loss Rate (mils/yr)
Zinc	2	0.58
Zinc, Subsequent	14	0.16
Carbon Steel	59	0.47
Carbon Steel (75-100yr)	0	0.47

Sacrificial Thickness, Es = 0.03113 in





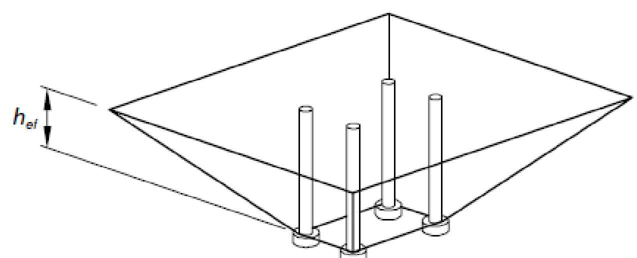
Determine Long Term Embedded Connector Capacity

Connector Section	Coated Thickness (in)	Es, in	Net Thk., in	Net Area, in^2	Allowable % Stresses	Yield Strength, Ys ksi	Factor, ϕ (Table 11.5.7.1)	Connector Capacity, kips.
Net Area (Sec. C-C)*	0.138	0.0311	0.107	0.153	100%	60	0.75	13.81
Gross Area (Sec. D-D)	0.138	0.0623	0.076	0.151	100%	50	0.75	11.35

*Corrode only on exposed sides.

Pullout Resistance of Embedded Connector

Per PCI Design Handbook, 7th Edition, Section 6.5.4



$f'c$ = 4000 psi

λ (lightweight concrete) = 1

ϕ = 0.7

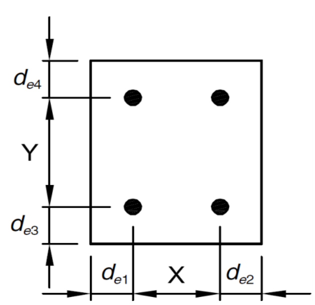
h_{ef} = 3.5 in

$C_{bs} = 3.33\lambda\sqrt{(f'_c/h_{ef})}$ = 112.57 (Eq. 6-4)

C_{crb} (assume cracked) = 0.8

X = 2 in

Y = 4 in



When edge distance <1.5h_{ef} :

d_{e1} = 5.25 in

d_{e2} = 5.25 in

d_{e3} = 5.25 in

d_{e4} = 5.25 in

$\Psi_{ed,N} = 0.7 + 0.3d_{e,min}/1.5h_{ef}$ (Eq. 6-5)

$\Psi_{ed,N}$ = 1.00

$\phi N_{cb} = \phi C_{bs}(d_{e1}+X+d_{e2})(d_{e3}+Y+d_{e4})(\Psi_{ed,N})C_{crb}$ = **11426** lbs (Fig. 6.5.2, Case 6)

Project Number:	N/A
Project Name:	Elevate IDEA Submittal
Description	Connection Calculations - 75 year
Date:	8/29/2025

ELEVATE RETAINING WALLS

BOLT ASSEMBLY DESIGN SUMMARY

Bolt Shear Strength

Bolt Designation F3125 High Strength Bolts (Galvanized)

Net Nominal Bolt Diameter, Db = 0.500 in

Min Tensile Strength of Bolt, Fub = 120 ksi (AASHTO 2007 6.4.3)

Cross Sectional Area Ab = 0.196 in^2

Number of Shear Planes Ns = **2**

Nominal Shear Resistance, Rn

Rn = 0.45 x Ab x Fub x Ns

(AASHTO 2020 6.13.2.7-2)

Rn = 21.21 kips

Factored Shear Resistance of Bolt, Rr (ϕxRn)

	Resistance Factor ϕs *	LRFD Load	Rr	
Static	**0.8**	Strength I	16.96	kips
Static+Seismic	**1**	Extreme Event I	21.21	kips
Static+Traffic Impact	**1**	Extreme Event II	21.21	kips

*AASHTO 2020 6.5.4.2 and 6.5.5

Bolt Hole Bearing (on Embedded Connector)

Nominal Bolt Diameter Dbc = 0.500 in

Plate Thickness at end of Service Life tc = 0.107 in (for 1 plate)

Plate Tensile Strength Fu = 60 ksi

Nominal Bearing Resistance at Bolt Hole, Rn

Rn = 2.4 x Dbc x 2tc x Fu

(AASHTO 2020 6.13.2.9)

Rn = 15.37 kips

Factored Bearing Resistance of Embedded Connector at Bolt Hole, Rr (ϕxRn)

	Resistance Factor ϕs *	LRFD Load	Rr	
Static	**0.8**	Strength I	12.30	kips
Static+Seismic	**1**	Extreme Event I	15.37	kips
Static+Traffic Impact	**1**	Extreme Event II	15.37	kips

*AASHTO 2020 6.5.4.2 and 6.5.5

Bolt Hole Bearing on Bar Connector

Nominal Bolt Diameter Dbc = 0.500 in

Plate Thickness at end of Service Life Ec = 0.179 in

Plate Tensile Strength Fu = 75 ksi

Nominal Bearing Resistance at Bolt Hole, Rn

Rn = 2.4 x Dbc x tc x Fu

(AASHTO 2020 6.13.2.9)

Rn = 16.14 kips

Factored Bearing Resistance of Bar Connector at Bolt Hole, Rr (ϕxRn)

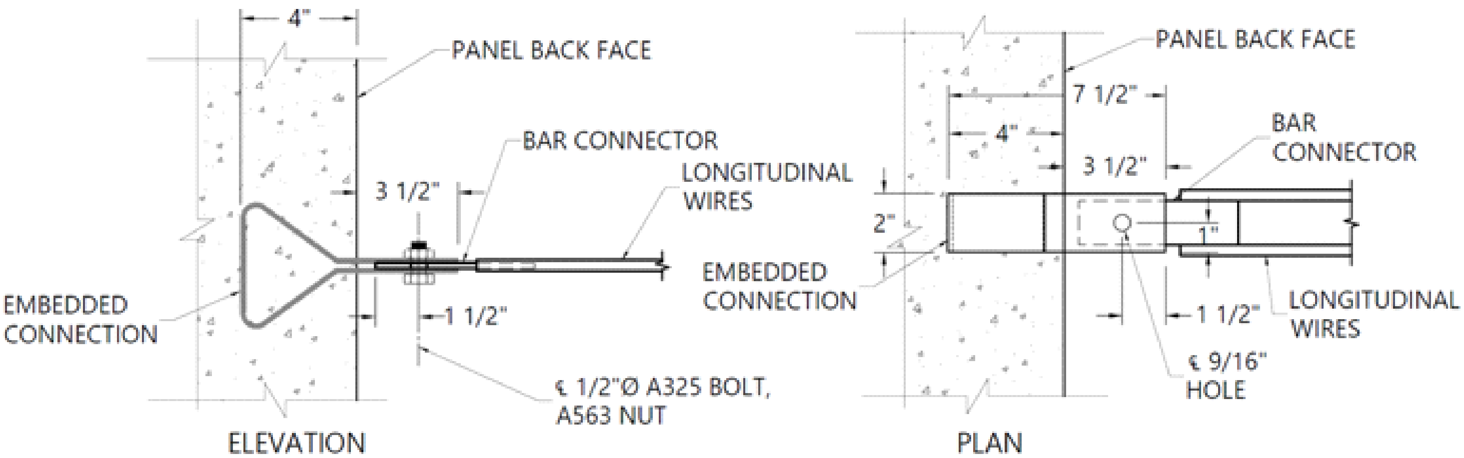
	Resistance Factor ϕbb *	LRFD Load	Rr	
Static	**0.8**	Strength I	12.91	kips
Static+Seismic	**1**	Extreme Event I	16.14	kips
Static+Traffic Impact	**1**	Extreme Event II	16.14	kips

*AASHTO 2020 6.5.4.2 and 6.5.5

Project Number:	N/A	ELEVATE RETAINING WALLS
Project Name:	Elevate IDEA Submittal	
Description	Connection Calculations - 75 year	
Date:	8/29/2025	

WELD CONNECTION CHECK

Weld Type = flare bevel groove			ϕ_v =	1.0	
Weld Length, L =	1.5	in	Fy =	55	ksi
Weld Size, E =	0.25	in	Rr = min	$2*0.6\phi_{e2}F_{exx}*A*\sqrt{2}/2$	(AASHTO 6.13.3.2.3b)
Area, A = E*L =	0.375	in^2		$2*0.58\phi_v F_y*A$	(AASHTO 6.13.5.3-1)
ϕ_{e2} =	0.8		Rr =	17.82	kips (Static)
Fexx =	70	ksi	Rr =	22.27	kips (Extreme I & II)



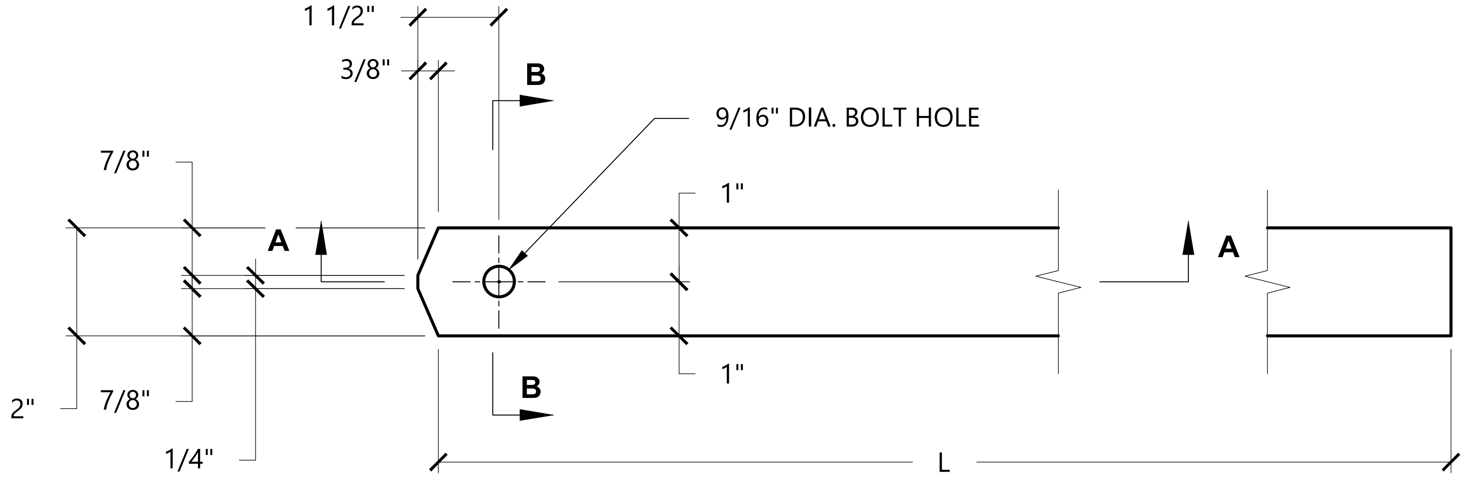
DETAIL AT CONNECTOR

NO SCALE

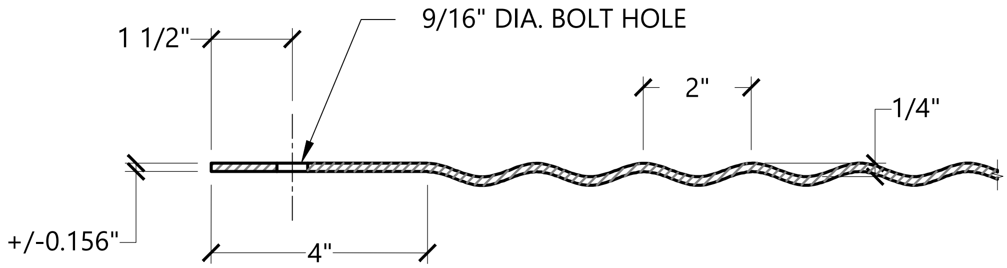
Summary of Calculated Factored Resistances

Tensile Resistance of Wires	**7.77**	kips	CONTROLS
Tensile Resistance of Net Area of Bar Connector	**8.02**	kips	
Tensile Resistance of Gross Area of Bar Connector	**8.81**	kips	
Tensile Resistance of Net Section of Embedded Connector	**13.81**	kips	
Tensile Resistance of Gross Section of Embedded Connector	**11.35**	kips	
Pullout Resistance of Embedded Connector	**11.43**	kips	
Bolt Shear Resistance	**16.96**	kips	
Bolt Hole Bearing Resistance on Embedded Connector	**12.30**	kips	
Bolt Hole Bearing Resistance on Bar Connector	**12.91**	kips	
Weld Between Bar Connector and Wires	**17.82**	kips	

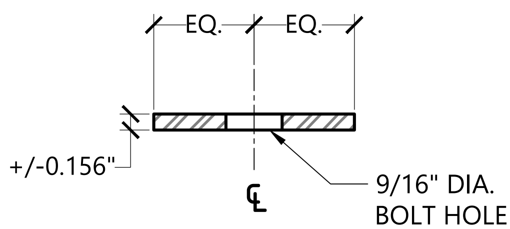
Appendix A1.2.7



PLAN VIEW



SECTION A-A



SECTION B-B

	DIMENSIONS/DETAILS	SPECS // FINISH
ELEVATE WAVE STRIP	0.156" X 2" STEEL STRIP	ASTM 1011, GRADE 65
	HOT DIP GALVANIZED	ASTM A123 (AASHTO M111 EQUIVALENT)

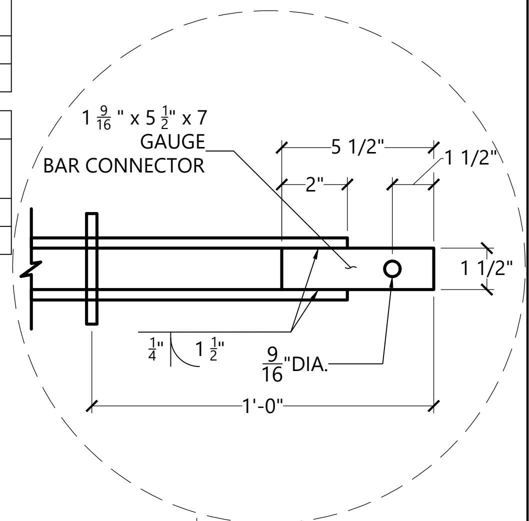
ELEVATE WAVE STRIP DETAIL

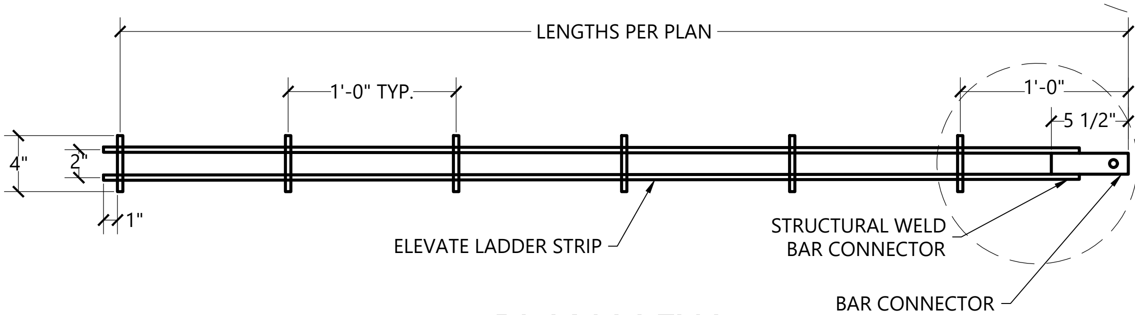
NO SCALE

ELEVATE INFRASTRUCTURE	DRAWING TITLE: ELEVATE WAVE STRIP	DRAWN BY: UM
	PREPARED FOR: IDEA SUBMITTAL	DATE:
	PROJECT:	DWG:

SAMPLE ELEVATE LADDER STRIP REINFORCING SCHEDULE - ASTM A706 SPEC.						
TYPE	LONGITUDINAL BAR SIZE	TRANSVERSE BAR SIZE	LONGITUDINAL BAR SPACING	TRANSVERSE BAR SPACING	TRANSVERSE BAR WIDTH	NUMBER OF LONGITUDINAL BARS
2 - #3	#3 REBAR	#3 REBAR	2"	1'-0"	4"	2
2 - #4	#4 REBAR	#4 REBAR	2"	1'-0"	4"	2

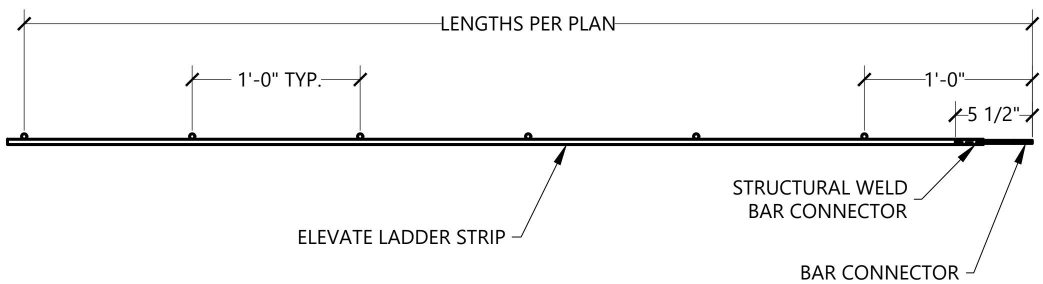
SAMPLE ELEVATE LADDER STRIP REINFORCING SCHEDULE - ASTM A1064 SPEC.						
TYPE	LONGITUDINAL BAR SIZE	TRANSVERSE BAR SIZE	LONGITUDINAL BAR SPACING	TRANSVERSE BAR SPACING	TRANSVERSE BAR WIDTH	NUMBER OF LONGITUDINAL BARS
2 -W11	W11	W11	2"	1'-0"	4"	2
2 - W16	W16	W16	2"	1'-0"	4"	2





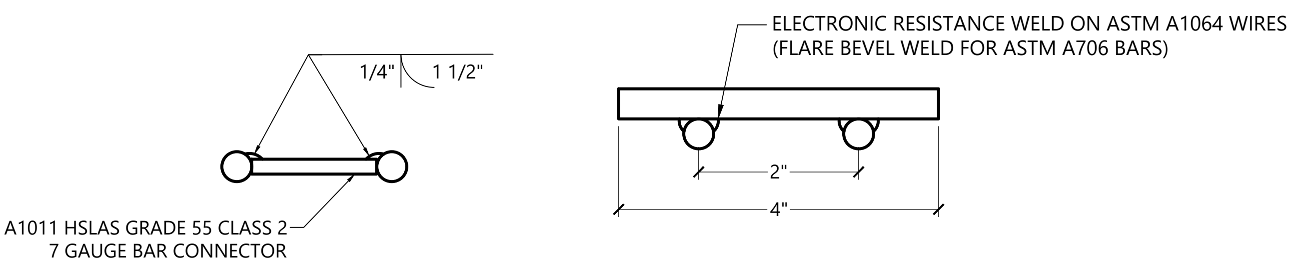
PLAN VIEW

NO SCALE



SECTION VIEW

NO SCALE

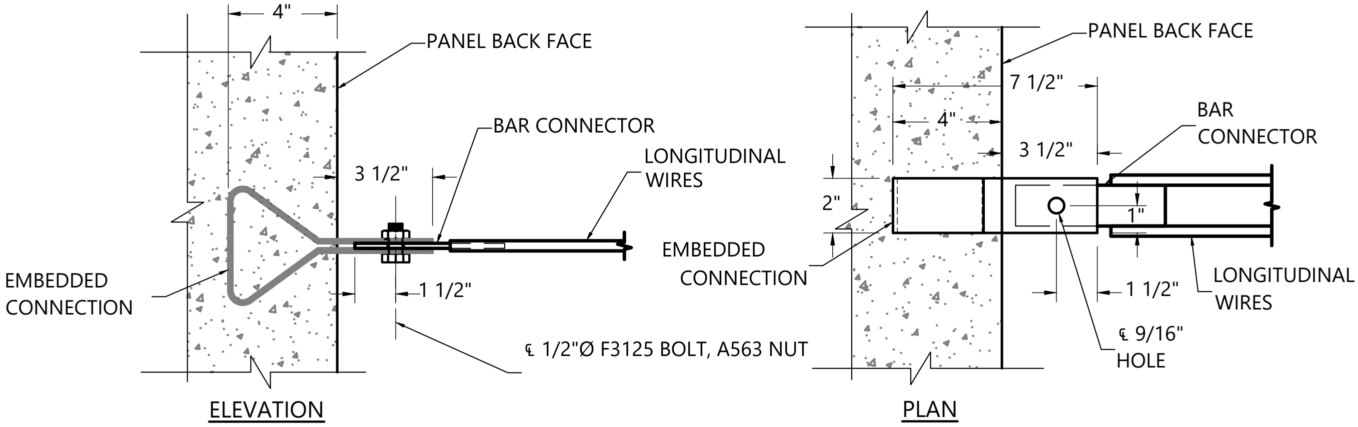


ELEVATE LADDER STRIP WELD DETAILS

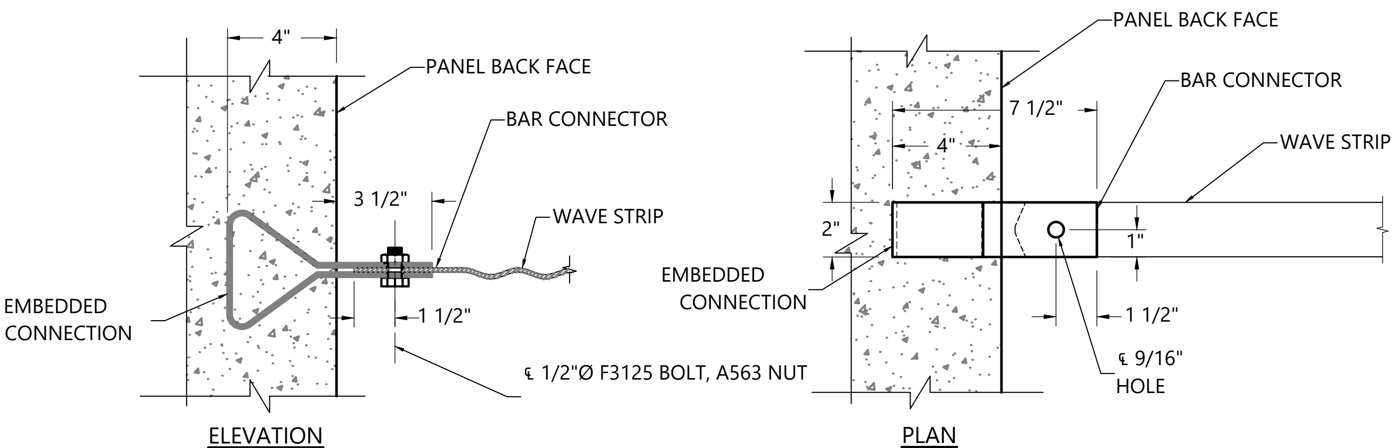
NO SCALE

ELEVATE INFRASTRUCTURE		
	DRAWING TITLE: ELEVATE LADDER STRIP	DRAWN BY: UM
	PREPARED FOR: IDEA SUBMITTAL	DATE:
	PROJECT:	DWG:

Appendix A1.2.8



LADDER STRIP MECHANICAL CONNECTION DETAIL



WAVE STRIP MECHANICAL CONNECTION DETAIL

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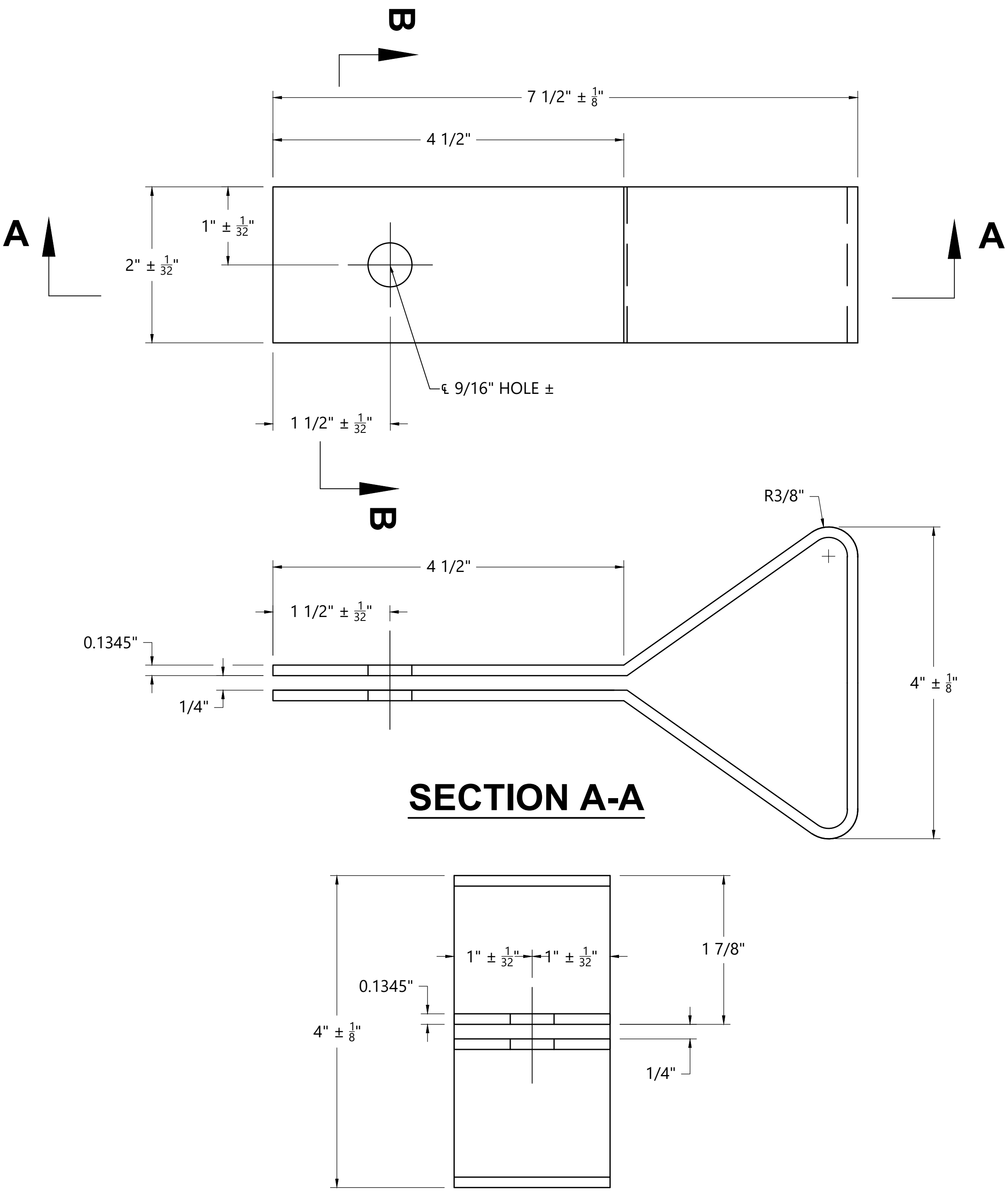
	PREPARED FOR:	DATE:
	PROJECT:	DWG:

Appendix A1.2.9

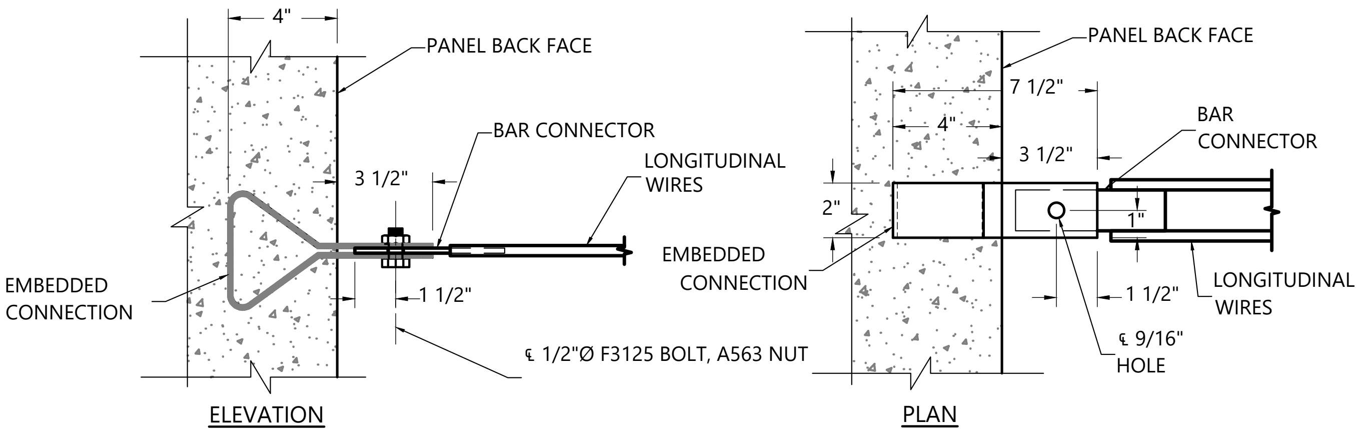


SECTION A-A

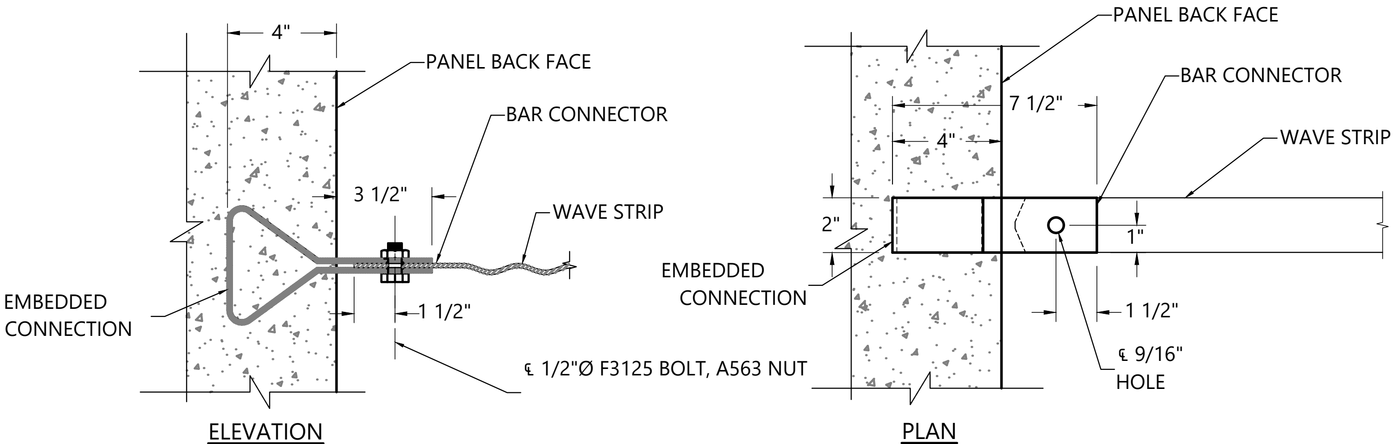
SECTION B-B

NOTES:
- EMBEDDED CONNECTOR TO BE 10 GAUGE, 50 KSI STEEL (ASTM A1011 HSLAS GRADE 50 CLASS 2).
- HOLE DIAMETER IS 9/16" ±1/64". TO BE HOT DIP GALVANIZED AFTER FABRICATION.
- OVERALL DIMENSION TOLERANCES SHALL BE AS SHOWN. THICKNESS TOLERANCE SHALL BE +/- 0.001".
-GALVANIZE WITH A MINIMUM OF 2 OZ./SF OR 3.4 MILS. IN THICKNESS, APPLIED IN CONFORMANCE TO AASHTO M 111M (ASTM 123).

ELEVATE INFRASTRUCTURE	DRAWING TITLE: CONNECTOR DETAILS	DRAWN BY: UM
	PREPARED FOR:	DATE:
	PROJECT:	DWG:



LADDER STRIP MECHANICAL CONNECTION DETAIL



WAVE STRIP MECHANICAL CONNECTION DETAIL

ELEVATE INFRASTRUCTURE

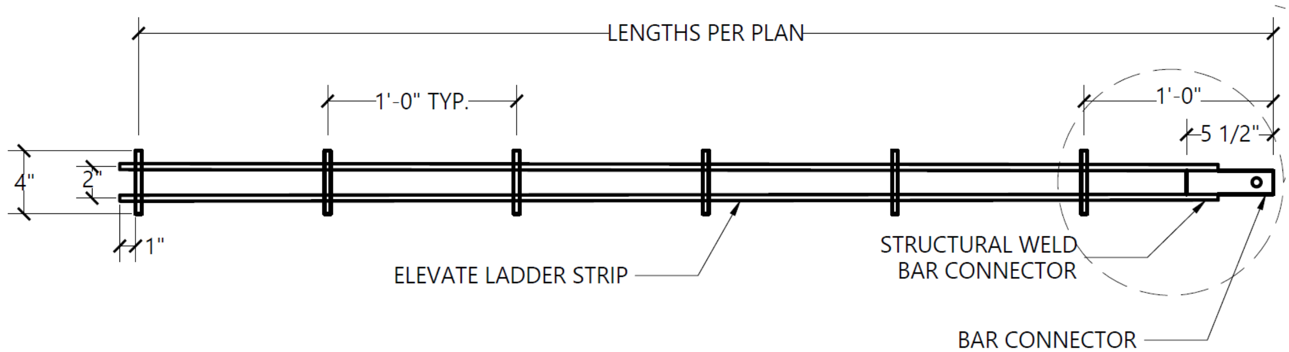
DRAWING TITLE: MECHANICAL CONNECTION	DRAWN BY: UM
PREPARED FOR:	DATE:
PROJECT:	DWG:

Appendix A1.2.10L

APPENDIX A1.2.10L ELEVATE LADDER STRIP SOIL REINFORCEMENT SPECIFICATIONS

Steel Soil Reinforcements – Material Production Standards (1064)

Abiding by the ASTM 1064 specification, Elevate Infrastructure's Ladder Strip Soil Reinforcement consists of a welded wire grid joined to a flat bar creating an inextensible soil reinforcement with high pullout capacity. The soil reinforcement is mechanically connected to the panel by way of a ½" galvanized A325 bolt which allows the soil reinforcement to pivot around obstructions in the reinforced backfill as necessary.



Welded Wire Steel Soil Reinforcement Material Parameters & Specifications

All smooth and deformed welded wire mesh shall be fabricated in conformance to ASTM A1064. Plain or smooth steel wire shall have a minimum yield strength of 65ksi (tensile 75ksi). Deformed steel wire shall have a minimum yield strength of 70ksi (tensile 80ksi). The bar connector is to be manufactured per ASTM A1011 HSLAS Grade 55 Class 2. When specified by the contract, all welded wire steel soil reinforcement materials to be manufactured in The United States of America from 100% domestically sourced steel. No foreign steel or billets to be used in the manufacturing process.

Individual soil reinforcement grids can be manufactured independently or derived from a larger welded wire sheet. If soil reinforcements are manufactured as part of a sheet with a wider overall width before being parsed into their final configuration, care must be taken to ensure individual soil reinforcements are in conformance with the tolerance dimensions specified herein.

Welded wire soil reinforcements to be hot dip galvanized per ASTM A123 (AASHTO M111) after being welded into their final configuration.

Storage, Handling, & Delivery

Welded wire steel soil reinforcements shall be shipped and stored in bundles. Each bundle is to be tagged and marked to note the provided lengths, gauges, and quantities. Bundles are separated by dunnage. Confirmation of quantities to be verified by Contractor on site.

Soil reinforcement bundles are delivered to the project site on flatbed trucks. Elevate Infrastructure recommends offloading bundles using a forklift or heavy duty construction slings. For soil reinforcements longer than 20', Elevate recommends a spreader bar to prevent excessive deflection in the welded wire units. Soil reinforcements shall not be stored directly on the ground, but rather shall be stored on dunnage to prevent surface deterioration and/or distortion. The Contractor is ultimately responsible for proper storage & handling of the soil reinforcements.

Field Adjustments

Occasionally field conditions will require slight variations in the welded wire reinforcements. Coated welded wire reinforcing shall not be field cut, unless expressly permitted by Elevate Infrastructure. If cutting of the welded wire reinforcement is deemed an appropriate adjustment, hydraulic-powered or friction cutting tools are to be used to minimize coating damage (flame cutters are not allowed). Uncoated, exposed steel shall be repaired in accordance with ASTM A780 and shall be applied to achieve a dry film equal to or exceeding that designated in the contract documents. All touch-ups shall be fully cured prior to placing in the reinforced backfill.

Definitions

Definitions and details are referenced from the "Concrete Reinforcing Steel Institute Manual of Standard Practice" and the "Wire Reinforcement Institute Manual of Standard Practice":

Welded Wire Reinforcement (WWR) — Material composed of cold-worked steel wire, fabricated into sheets by the process of electric resistance welding.

Wire Size — Diameters are referenced in terms of "W" and "D". The "W" represents plain or smooth wire and the "D" represents deformed wire. The proceeding number is the cross-sectional area of a given wire multiplied by 100.

Ex: W11 has a nominal diameter of .374". The nominal area (in^2) = 0.110.

Wire Spacing — Distance between parallel lines shall be measured from centerline-to-centerline.

Sheet Width — The manufactured welded wire sheet measured from centerline-to-centerline of the outermost longitudinal wires. This dimension does not include overhangs.

Sheet Length — The manufactured welded wire sheet measured from tip-to-tip of the longitudinal wires. This dimension includes overhangs.

Side Overhang — The extension of the transverse wires beyond centerline of the outside longitudinal wires. This dimension is omitted in standard sheet dimensions.

Overall Width — The manufactured welded wire sheet measured from tip-to-tip of the transverse wires. This dimension includes overhangs. Overall Width = Sheet Width + Side Overhang.

End Overhang — The extension of the longitudinal wires beyond the centerline of the first & last transverse wires. This dimension is included in the sheet length dimension.

Steel Soil Welded Wire Reinforcement Tolerances

Sheet Width — permissible variation shall not exceed +/- 0.5" center-to-center distance between outside longitudinal wires.

Overall Width — permissible variation shall not exceed +/- 1" of the overall width.

Sheet Length — overall length may vary by +/- 1" or 1%; whichever is greater.

Side Overhang — permissible variation shall not exceed +/- 0.5".

Transverse Spacing – permissible variation shall not exceed +/- 1" center-to-center distance between individual transverse bars or the first transverse bars leading edge of the RET BAR connector.

Deformed Wire Weight — deformed wire weight shall be within +/- 6% of a comparable smooth wire weight of the same parameters (cross-sectional area).

Plain Wire Diameter — permissible variation in diameter of smooth/plain/"W" wire per ASTM 1064

- +/- 0.004" for wire size W5 – W12
- +/- 0.006" for wire size W12.1 – W20

Specification Standards List—American Society for Testing & Materials (ASTM)

A36 – Standard Specification for Carbon Structural Steel

A123 – Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

A780 – Standard Specification for the Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

A1064 – Standard Specification for Carbon-Steel Wire and Welded Wire Reinforcement, Plain and Deformed, for Concrete

A1011 – Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability

(QA/QC Manual on Following Page)

ELEVATE LADDER STRIP– QUALITY ASSURANCE/QUALITY CONTROL

This manual is intended as an instruction guide to the Steel Processing Company responsible for manufacturing the welded wire soil reinforcements for Elevate Infrastructure. While Elevate provides guidance, it is the ultimate responsibility of the Steel Processing Company to meet the requirements and schedule of the project that is agreed to prior to production. This manual references—and should be used in conjunction with the "Steel Soil Reinforcements—Material Production Standards." It is imperative that the Steel Processing Company review each project's specifications. Project requirements may differ from the Elevate Infrastructure standard specifications. If the Steel Processing Company, inspector, owner, or owner's representative has any questions concerning this manual or the drawings and specifications provided by Elevate Infrastructure for a particular project please contact the proper Elevate representative.

SHOP DRAWING & PURCHASE ORDER VERIFICATION

Elevate Infrastructure is to provide the Steel Processing Company with a complete bill of materials for each project. The purchase order and bill of materials will include the following:

- ASTM designation
- Tensile Requirements
- Width
- Length
- Gauge
- Quantity

The Steel Processing Company and Elevate will agree on the scheduled delivery date to the project jobsite, and it will be the responsibility of the Steel Processing Company to reach this deadline.

STEEL CERTIFICATION, GRADE, WELDING, & PURCHASING

The standard ASTM designation for the Elevate Infrastructure's welded wire soil reinforcement is ASTM A1064. Wire to have minimum tensile strength 75ksi & minimum yield strength 65ksi.

After the welded wire reinforcement is fabricated a 1.5" x 5.5" flat bar connector is to be welded to the leading end of the wire configuration. The weld is to be a minimum of 1.5" in length. The thickness of the bar is to be 7 gauge (0.1875"). The bar connector is to be manufactured per ASTM A1011 HSLAS Grade 55 Class 2. Welding the flat bar connector to the wire can be either robotically or manually welded per American Welding Society D1.4 Standards.

Unless otherwise noted in the plans, all steel is to be sourced and manufactured in the United States of America. No foreign steel or billets to be used in the manufacturing of any coils or wire. Proof of "Buy America" compliance is to be provided with every production run.

WELDED WIRE SOIL REINFORCEMENT MANUFACTURING

The steel soil reinforcement gauges may vary based on retaining wall design parameters, however the standard configuration uses W11 longitudinal & transverse bars. The Steel Processing Company will be responsible for manufacturing the proper quantities and lengths for each reinforcement type.

The final configuration of the welded wire soil reinforcements shall conform to the approved shop drawing dimensions, gauges, and lengths as stipulated in the contract documents. Elevate Infrastructure will provide the Steel Processing Company with a detailed breakdown of the types & lengths to be manufactured for each project as well as a list of required certifications.

Individual soil reinforcement grids can be manufactured independently or derived from a larger welded wire sheet. If soil reinforcements are manufactured as part of a sheet with a wider overall width before being parsed into their final configuration, care must be taken to ensure individual soil reinforcements are in conformance with the tolerance dimensions as specified by Elevate Infrastructure.

HANDLING & DELIVERY

The Steel Processing Company will deliver the welded wire reinforcements to the galvanizer bundled and tagged according to type & length. The soil reinforcements are to be rotated on their side (perpendicular to the plane of installation) and bound with industrial plastic strapping to simplify material handling. Dunnage is to be used in conjunction with the strapping to provide support while loading & unloading the material.

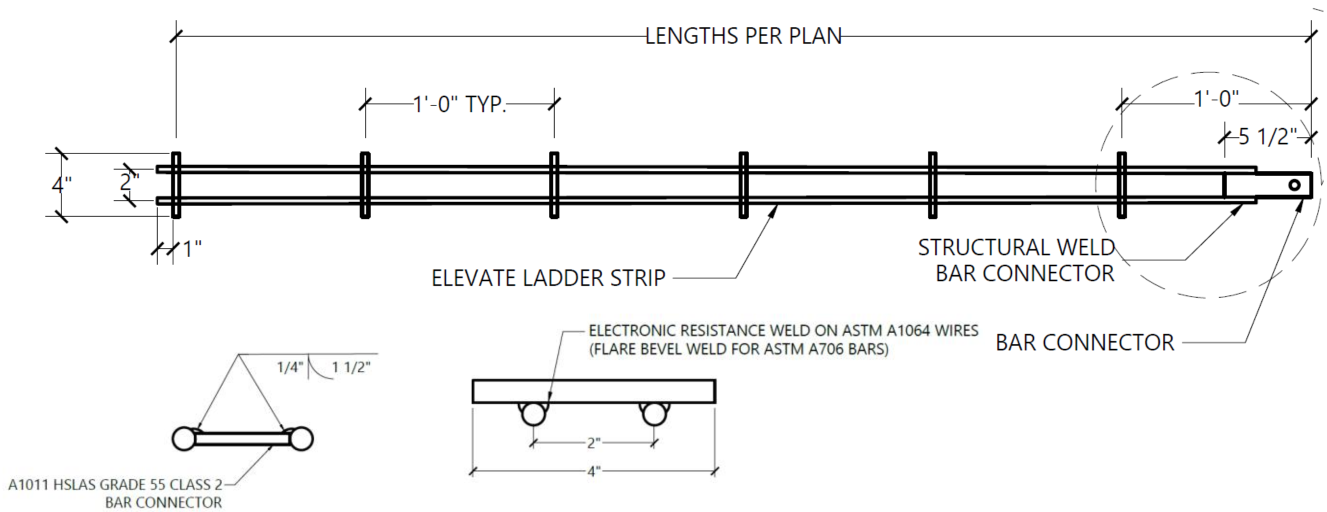
Elevate Infrastructure recommends using heavy duty construction slings to handle the bundles of soil reinforcements. If forklifts are used to handle the bundles, care must be taken to avoid damaging the overhangs.

Once bound, each bundle is to be tagged with a heavy-duty label identifying the quantity, length, and type of soil reinforcements in each bundle. The galvanizer will use an identical set of tags to reconcile quantities and identify the bundles to the Contractor on site.

Soil reinforcements to be hot dip galvanized per ASTM A123 / AASHTO M111. Once the zinc has dried, soil reinforcements are to be bundled & bound with industrial plastic strapping and wooden dunnage in the same rigid manner as described above. Each bundle will be tagged with heavy duty labels identifying the quantity, length, wall identification/number, and type of soil reinforcements contained in each bundle.

APPENDIX A1.2.10L ELEVATE LADDER STRIP SOIL REINFORCEMENT SPECIFICATIONS

Elevate's steel soil reinforcement per ASTM A706 is a grid of configured rebar welded to a flat end plate to create an inextensible soil reinforcement with high pullout capacity. The soil reinforcement is mechanically connected to the precast panel by way of a ½" galvanized A325 bolt which allows the soil reinforcement to pivot around obstructions in the reinforced backfill as necessary. In lieu of automated resistance welding machinery, the steel soil reinforcements per A706 are to be manufactured with preconfigured jigs operated by certified welders & scrutinized by certified weld-inspectors.



Steel Soil Reinforcement Material Parameters & Specifications

All smooth and deformed bar shall be fabricated in conformance to ASTM A706. Plain or smooth steel bar shall be Grade 60 with a minimum yield strength of 60ksi and a minimum tensile strength of 80ksi. The bar connector is to be manufactured per ASTM A1011 HSLAS Grade 55 Class 2. When specified by the contract, all steel soil reinforcement materials to be manufactured in The United States of America from 100% domestically sourced steel. No foreign steel or billets to be used in the manufacturing process.

Steel bars and the connector tab are to be welded to their final configuration per Elevate Infrastructure's specifications and per the American Welding Society Standards as described in AWS D1.4 Structural Welding Code—Steel Reinforcing Bars.

Steel soil reinforcements to be hot dip galvanized per ASTM A123 (AASHTO M111) after being welded into their final configuration.

Storage, Handling, & Delivery

After the steel soil reinforcements are welded into their final configuration, they shall be shipped and stored in bundles. Each bundle is to be tagged and marked to note the provided lengths, gauges, and quantities. Bundles are separated by dunnage. Confirmation of quantities to be verified by Contractor on site.

Soil reinforcement bundles are delivered to the project site on flatbed trucks. Elevate recommends offloading bundles using a forklift or heavy duty construction slings. For soil reinforcements in excess of 20', a spreader bar is recommended to prevent excessive deflection in the soil reinforcement units. Soil reinforcements shall not be stored directly on the ground, but rather shall be stored on dunnage to prevent surface deterioration and/or distortion. The Contractor is ultimately responsible for proper storage & handling of the soil reinforcements.

Field Adjustments

Occasionally field conditions will require slight variations in the prefabricated steel soil reinforcements. Coated reinforcements shall not be field cut, unless expressly permitted by Elevate Infrastructure. If cutting of the reinforcement is deemed an appropriate adjustment, hydraulic-powered or friction cutting tools are to be used to minimize coating damage (flame cutters are not allowed). Uncoated, exposed steel shall be repaired in accordance with ASTM A780, and a dry film equal to or exceeding that designated in the contract documents shall be applied to achieve design life requirements. All touch-up shall be fully cured prior to placing in the reinforced backfill.

Definitions

The American Welding Society D1.4 Structural Welding Code was used in conjunction with the stated ASTM's & AASHTO codes for the following definitions & clarifications.

Bar — Rolled flange steel sections having a maximum dimension of the cross section less than 3 inches (ASTM A6)

Bar Size — Diameters are based on the number of eighths of an inch included in the nominal diameter of the bars. Ex: a bar designation of #3 would have a nominal diameter of 0.375" (3 ÷ 8 = 0.375").

Grade — Per ASTM A706 bars are of two minimum yield strength levels; namely grade 60 & Grade 80.

Spacing — Distance between parallel lines shall be measured from centerline-to-centerline.

Side Overhang — The extension of the transverse bars beyond centerline of the outside longitudinal bars.

Overall Width — The manufactured soil reinforcement measured from tip-to-tip of the transverse wires. This dimension includes overhangs. Overall Width = Sheet Width + Side Overhang.

End Overhang — The extension of the longitudinal bars beyond the centerline of the first & last transverse wires.

Steel Soil Reinforcement – The manufactured soil reinforcement consisting of two longitudinal bars at a standard 2" spacing with transverse bars every 12".

Steel Soil Reinforcement Tolerances

Sheet Width — permissible variation shall not exceed +/- 0.5" center-to-center distance between outside longitudinal bars.

Longitudinal Bar Spacing — Permissible variation shall not exceed +/- 0.5" center-to-center distance between outside longitudinal bars.

Transverse Spacing – permissible variation shall not exceed +/- 1" center-to-center distance between individual transverse bars or the first transverse bars leading edge of the RET BAR connector.

Overall Width — Permissible variation of the transverse bar shall not exceed +/- 1" of the overall width.

Soil Reinforcement Length — Overall length of the longitudinal bars may vary by +/- 1" or 1%; whichever is greater.

Sheet Length — overall length may vary by +/- 1" or 1%; whichever is greater.

Side Overhang — permissible variation shall not exceed +/- 0.5".

SPECIFICATION STANDARDS LIST—AMERICAN SOCIETY FOR TESTING & MATERIALS (ASTM):

A6 – Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling

A36 – Standard Specification for Carbon Structural Steel

A123 – Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

A706 – Standard Specification for Deformed and Plain Low-Alloy Steel Bars for Concrete Reinforcement

A780 – Standard Specification for the Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings

A1011 – Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability

ELEVATE LADDER STRIP– QUALITY ASSURANCE/QUALITY CONTROL

In some scenarios, manufacturing the steel soil reinforcements according to the strict standards of ASTM A1064 may not be feasible. In those cases, ASTM A706—Standard Specification for Deformed & Plain Low-Alloy Steel Bars for Concrete Reinforcement—shall be followed.

This manual is intended as an instruction guide to the Steel Processing Company responsible for manufacturing the steel soil reinforcements per ASTM A706 for Elevate Infrastructure. While Elevate provides guidance, it is the ultimate responsibility of the Steel Processing Company to meet the requirements and schedule of the project that is agreed to prior to production. This manual references—and should be used in conjunction with—Elevate Infrastructure's "Steel Soil Reinforcements—Material Production Standards (706)". It is imperative that the Steel Processing Company review each project's specifications and shop drawings. Project requirements may differ from Elevate Infrastructure's standard specifications. If the Steel Processing Company, inspector, owner, or owner's representative has any questions concerning this manual or the drawings and specifications please contact Elevate Infrastructure directly.

SHOP DRAWING & PURCHASE ORDER VERIFICATION

Elevate Infrastructure is to provide the Steel Processing Company with a complete set of shop drawings and bill of materials for each project. The shop drawings and bill of materials will include the following:

- ASTM designation
- Tensile Requirements
- Width
- Length
- Gauge
- Quantity

The Steel Processing Company and Elevate will agree on the scheduled delivery date to the project jobsite and it will be the responsibility of the Steel Processing Company to reach this deadline.

STEEL CERTIFICATION, GRADE, WELDING & PURCHASING

The standard ASTM designation for Elevate Infrastructure's steel soil reinforcements is ASTM A706. Bars to be either smooth or deformed. Tensile requirements are Grade 60—minimum yield strength to be 60ksi and minimum tensile strength to be 80ksi.

A 7-gauge 1.5" x 5.5" flat bar connector is to be welded to the leading end of the bar configuration. The weld is to be a minimum of 1.5" in length. The bar connector is to be manufactured per ASTM A1011 HSLAS Grade 55 Class 2. All welding to be per Elevate Infrastructure's structural weld specifications and in accordance with the American Welding Society D1.4 Structural Welding Code [for] Steel Reinforcing Bars.

Unless otherwise noted in the plans, all steel is to be sourced and manufactured in the United States of America. No foreign steel or billets to be used in the manufacturing of any coils or bar. Proof of "Buy America" compliance is to be provided with every production run.

Soil Reinforcement Manufacturing

MSE wall soil reinforcements come in a range of bar sizes based on the retaining wall design parameters. The standard configuration consists of #3 longitudinal & transverse bars. The Steel Processing Company is ultimately responsible for manufacturing the proper quantities, lengths, and gauges for each reinforcement designation. Typical steel soil reinforcement production lines per ASTM A706 include a series of preconfigured jigs to ensure quality, efficiency, and speed.

The final configuration of the steel soil reinforcements shall conform to the approved shop drawing dimensions, gauges, and lengths as stipulated in the contract documents. Elevate Infrastructure will provide the Steel Processing Company with a detailed breakdown of the types & lengths to be manufactured for each project as well as a list of required certifications.

Quality Assurance/Control/Inspection Procedures

Required steel properties including tensile, size, and deformations are verified according to the mill certifications provided by the steel supplier. The Steel Processing Company is responsible for ensuring the structural weld specifications (types, lengths, strengths, etc.) are met or exceeded through visual inspections in conjunction with randomized mechanical weld tests per job lot.

Handling & Delivery

The Steel Processing Company will deliver the steel soil reinforcements to the galvanizer bundled and tagged according to size & length. In order to achieve rigidity, the soil reinforcements are to be rotated on their side (perpendicular to the plane of installation) and bound with industrial strapping. Dunnage is to be used in conjunction with the strapping to provide support while loading & unloading the material.

Elevate recommends using heavy duty construction slings to handle the bundles of soil reinforcements. If forklifts are used to handle the bundles, care must be taken to avoid damaging the overhangs.

Once bound, each bundle is to be tagged with a heavy-duty label identifying the quantity, length, and type of soil reinforcements in each bundle. An identical set of tags will be provided to the galvanizer.

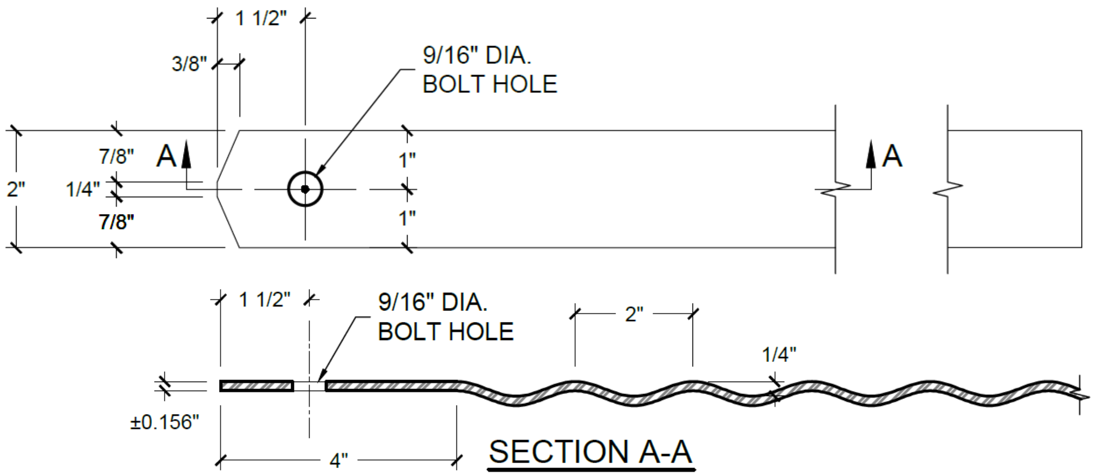
The galvanizer will use the duplicate set of tags to reconcile quantities and identify the bundles to the Contractor on site.

Soil reinforcements to be hot dip galvanized per ASTM A123 / AASHTO M111. Once the zinc has dried, soil reinforcements are to be bundled & bound with industrial plastic strapping and wooden dunnage in the same rigid manner as described above. Each bundle will be tagged with heavy duty labels identifying the quantity, length, and type of soil reinforcements contained in each bundle.

Appendix A1.2.10W

APPENDIX A1.2.10W ELEVATE WAVE STRIP SOIL REINFORCEMENT SPECIFICATIONS & QUALITY ASSURANCE/QUALITY CONTROL

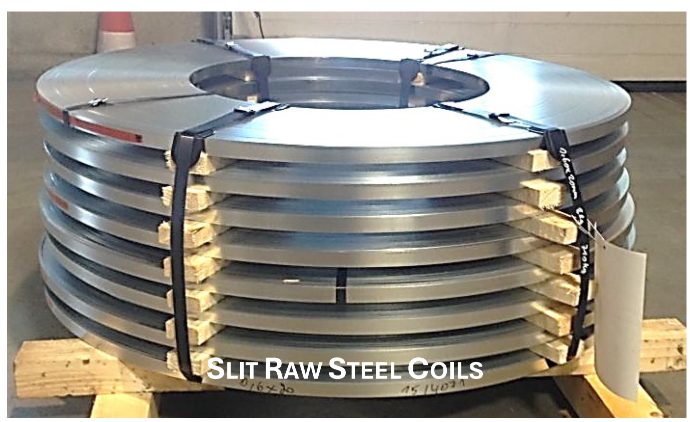
The Elevate WAVEstrip is an inextensible strip-style soil reinforcement manufactured from 2" wide slit-coils of Grade 65 steel. This manual is intended to serve as an instructional guide for the Owners reviewing the system as well as the steel fabricators & galvanizing facilities responsible for configuring and delivering the finished product.



Steel Soil Reinforcement Material Parameters & Specifications

Configured steel strips are manufactured from processed coil and cold formed into the required shape and dimensions. Their physical and mechanical properties shall conform to ASTM A1011, Grade 65 or equal. Galvanization shall conform to the minimum requirements of ASTM A123 (AASHTO M111).

Raw Coil Properties



Hot rolled coil meeting the specified designation shall be purchased at the given width listed on the shop drawings and bill of materials. Typical steel strip width shall be 2.0". All steel to be sourced domestically. The Steel Processing Company shall keep a copy of all certifications on file in their office as well as provide a copy to Elevate.

Each single coil, 2.0" in width, shall have an individual tag from the coil manufacturer listing the coil width, gauge, and length. It is the responsibility of the Steel Processing company to note the length of each individual coil in order to optimize the yield from each coil.

The gauge tolerance must be inspected when the coil is first received from the coil manufacturer. The Elevate WAVEstrip has a nominal thickness of 0.164 inches with a +/- tolerance of 0.008 inches. Minimum thickness to be 0.156 inches. For purchasing purposes, a standard 8-gauge material will meet the minimum requirements of the base configuration with a standard thickness of 0.164 inches and a minimum thickness of 0.156 inches (all steel calculations for wall design utilize a 0.156" thickness).

The length tolerance has a significant impact on project cost, and the configuration tolerance has a significant impact of soil reinforcement performance. While the manufacturing speed will vary depending on the processing equipment, all mandatory tolerance requirements are listed below:

Steel gauge: 0.164" nominal with 0.156" minimum
WAVEstrip Width: Plus/minus 0.01 inches
WAVEstrip Length: Plus/minus 0.01 inches
Hole: 0.563 inches (9/16") plus/minus 0.01 inches.
Camber: 0.01 inches in a length of 5 feet
Configuration Wave Length: Plus/minus 0.1 inches over 10 inches in length
Configuration Wave Period: Plus 0.01 inches

Sampling & Bundling

All tolerances listed above should be sampled at least once for every coil, whereas an average coil has an average length of 1,600 feet. This will result in an estimated sampling of 1% of the strips. Tolerance should be measured and recorded on a quality control checklist and submitted to Elevate Infrastructure.

After each strip is fully configured, they should be turned on their side edge and bundled in groups of +/- 10 strips. Each bundle is to be bound with at least two steel straps and blocking for transportation to the galvanizer.

Galvanizing

Galvanization shall according to ASTM A123 (AASHTO M111). Upon arrival at the galvanizing facility, steel strips should be removed from inbound truck and inspected to reconcile quantities and note any irregularities. Configured strips should be separated to ensure full zinc coverage. WAVEstrips shall be pickled in an acid bath as needed to provide a clean surface for zinc bonding. The proper zinc bath temperature should be established to meet ASTM A123 (AASHTO M111).

The kettle lead person should inspect the material prior to entering the kettle to insure proper pickling. The strips shall remain in the zinc bath until it reaches the temperature of the bath. Major uncoated areas will be cause for rejection. The galvanizing plant manager is responsible for all in-process and final inspections.

Once inspected, the WAVEstrips shall be again turned on their side surface to provide stiffness in each bundle for shipment and bound in groups not exceeding 5,000lbs each. Each bundle is to be tagged with the following information:

- Project name and location
- Strip length & quantity
- Steel coil and galvanizing ASTM designation
- Date of Galvanizing

Transportation

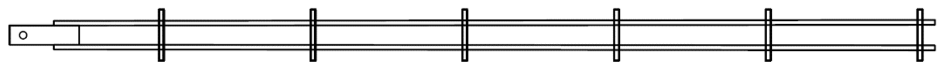
Loading the WAVEstrips for shipment will require padded straps, pallets, or racks. Care should be taken to minimize handling. Supports shall be adequate, firm, and placed evenly to prevent sagging. Bundles shall be loaded and secured to the truck bed such that the center of gravity of the load is as close as possible to the truck's center of gravity. Offloading will be the responsibility of the Contractor.

Specification Standards List – American Society for Testing & Materials (ASTM)
A1011 – Standard Specification for Steel, Sheet and Strip, Hot-rolled, Carbon, Structure, High Strength Low-Alloy and High-Strength Low-Alloy with Improved Formability

A123 – Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

Appendix A1.2.15

Independent Testing – Connector Pullout



Connector capacity testing was performed by CTL Group at Utility Concrete Products' production facility in Morris, IL on May 17th, 2022. Testing was performed to verify the capacity of the embedded connector that mechanically connects the Elevate Ladder Strip to the precast panel element.

Testing was performed on three separate connectors to a load of 10.5 kips in 1,750lb increments. No cracking or deflection was observed in any test. CTL Group's report, including instrument calibration, is included herein.

NOTE: Embedded connectors were placed per Elevate standard detail, and the concrete was poured using Utility Concrete Product's IDOT-approved mix design for 4,500psi concrete used for manufacturing precast concrete MSE wall panels. Results from these testing protocols are not incorporated into Elevate design calculations. Testing was performed for verification only.

RETAINING WALL ANCHOR CONNECTION LOAD TEST

by

Ulises Muro *

The test samples are double-plate connectors embedded in concrete panel walls designed to attach anchors and support the walls for a variety of applications such as the construction of highway ramps, retaining earth, or commercial walls.

The load was applied to 3 sets of double-plate connectors (See Fig. 1) equally spaced by approximately 3' on a precast concrete panel with dimensions 5'x10'. The anchors are designed to withstand a load of 7 kips. The tests were performed with a 1.5 safety factor resulting in a testing load of 10.5 kips.

Fig. 1 Double-plate Connector

* Associate II, CTLGroup, 5400 Old Orchard Road, Skokie, IL 60077

LOAD TEST

CTLGroup staff traveled to Utility Concrete Products in Morris, IL to perform the anchor connection load tests on May 17, 2022. The test apparatus consisted of a 3-legged steel stand, a calibrated load cell, a calibrated displacement sensor, a 20-ton hollow ram, a hydraulic pump, steel connector, steel bearing plates, and a threaded rod (See Fig. 2.)

Fig. 2 Test Setup

A seating load of 200 lbs. was applied, afterwards, the load was applied in increments of 1,750 lbs until a 10.5-kip load was reached. The load was held for 2 minutes after each increment. At 10.5 kips the load was held for 5 minutes to evaluate the reaction of the specimen.

Upon release of the load the specimens were visually inspected, no cracking on the concrete or deflection in the double plates on all three samples were observed. See Fig. 3, 4, and 5.

Fig. 3 Sample A Post Load

Fig. 4 Sample B Post Load

Fig. 5 Sample C Post Load

Conclusions

Three double plate anchors installed in the same way as the specimens on the precast sample were able to stand a load of 10.5 kips as no cracking on the concrete or deflection of double plate anchors was observed after testing.

APPENDIX

Calibration Files

Instrument Calibration Report

Corporate Office and Laboratory: 5400 Old Orchard Road, Skokie, IL 60077-1030

Calibration Report Number: 25-06-01-2021-4

Instrument Under Calibration	Signal Conditioner	N.I.S.T. Traceable Calibration References Utilized
Manufacturer: RDP **Model Number:** MD5/500AG **Serial Number:** 177507 **± Full Scale (in):** 0.5	**Manufacturer:** RDP **Model Number:** S7M12A **Serial Number:** 72043	**Displacement Reference** **Manufacturer:** Starrett **Model Number:** T462 **Serial Number:** CAL-01 **Calibration Due Date:** 1/13/2022 **Uncertainty (in):** 0.00003 **Calibration Report No:** CAL-01-PI-20210113

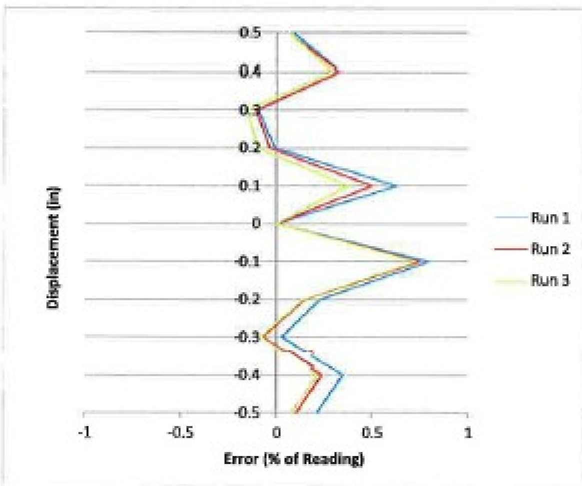
Readout Device	Calibration Information
Manufacturer: NI **Model Number:** 9215 **Serial Number:** 1332F08 **Channel:** 3 **Resolution (in):** 0.0001	**Temperature (°F):** 36.5 **Relative Humidity:** 75.2% **System Condition:** Good **Calibration Method:** Set The Disp. **Procedure Used:** WI25-CAL-DISP

Instruments Used

Manufacturer	Model Number	Serial Number	Calibration Date
Omega	HH314	80401789	8/21/2021

Displacement Calibration Data				Error			
				Relative Error		Fixed Error	
Reference (in)	Run 1 (in)	Run 2 (in)	Run 3 (in)	Max (%)	Repeatability (%)	Max (in)	Repeatability (in)
-0.5	-0.5011	-0.5005	-0.5004	0.22	0.14	-0.0011	0.0007
-0.4	-0.4014	-0.4010	-0.4009	0.35	0.13	-0.0014	0.0005
-0.3	-0.3001	-0.2998	-0.2998	-0.08	0.11	0.0002	0.0003
-0.2	-0.2005	-0.2003	-0.2003	0.23	0.09	-0.0005	0.0002
-0.1	-0.1008	-0.1008	-0.1007	0.80	0.07	-0.0008	0.0001
0.0	0.0000	0.0000	0.0000	0.00	0.00	0.0000	0.0000
0.1	0.1006	0.1005	0.1004	0.63	0.25	0.0006	0.0003
0.2	0.2000	0.1999	0.1998	-0.10	0.09	-0.0002	0.0002
0.3	0.2997	0.2997	0.2995	-0.16	0.08	-0.0005	0.0002
0.4	0.4013	0.4013	0.4012	0.33	0.04	0.0013	0.0002
0.5	0.5004	0.5003	0.5003	0.09	0.03	0.0004	0.0001

Relative error at zero is expressed as percent of full scale



Calibration Results

As Found: In Tolerance

As Left: In Tolerance

Expanded Uncertainty (in): 0.00073

Relative Error

Max (%): 0.80

Repeatability (%): 0.25

Fixed Error

Max (in): 0.0014

Repeatability (in): 0.0005

DAQ Settings

Signal Input Range: -1 to 1

Scaling Coefficients

a_0: 0.00000E+00

a_1: 5.04947E-02

a_2: 4.69615E-05

a_3: 1.91237E-06

a_4: -3.50534E-07

a_5: 0.00000E+00

This calibration has been performed using procedures described by the manufacturer, CTLGroup, or both. Results of this calibration apply only to the items described herein. Certificates of calibration for standards used are on file. This report may not be reproduced in any format unless the reproduction is a complete and true copy of the original. Calibrations are performed with standards whose values and measurements are traceable to the National Institute of Standards and Technology.

Calibration Date: 8/1/2021

Calibration Due Date: 8/30/2022

Performed By: Muro **Signature:** [signature] **Date:** 9/13/2021

Checked By: Loeppert **Signature:** [signature] **Date:** 9/28/21

Approved By: **Signature:** [signature] Digitally signed by Benjamin Trujillo ... Date: 2021.10.02 **Date:** 10/02/2021

Page 1 of 1

Instrument Calibration Report

Corporate Office and Laboratory: 5400 Old Orchard Road, Skokie, IL 60077-1030

Calibration Report Number: 25-07-06-2021-1

Instrument Under Calibration

Manufacturer: Sensotec
Model Number: 41/0573-02
Serial Number: 663490
Full Scale (klbf): -20

Signal Conditioner

Manufacturer: NI
Model Number: 9237
Serial Number: 16BE3FC

N.I.S.T. Traceable Calibration References Utilized

	Load Cell	Read Out
Manufacturer	Interface	Interface
Model Number	1620AJH-25K	9840-200-1
Serial Number	1156803	20136
Calibration Due Date	11/10/2021	4/22/2022
Uncertainty (klbf)	0.00078	0.000867972
Class A Range (klbf)	0.31046	
Calibration Report No	1156803-20201110	20136-21

Readout Device

Manufacturer: NI
Model Number: 9237
Serial Number: 16BE3FC
Channel: 0
Resolution (klbf): 0.001

Calibration Information

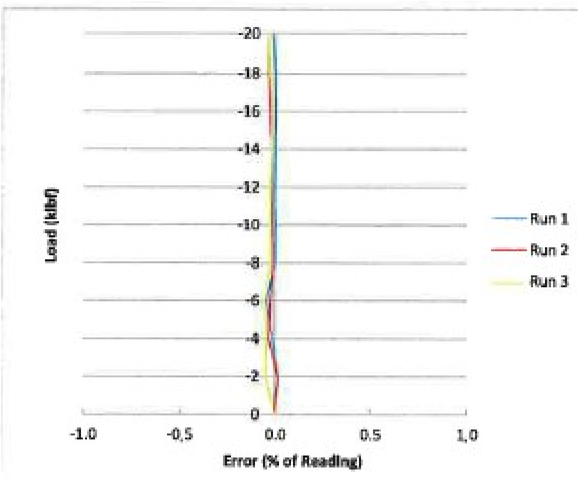
Temperature (°F): 74
Relative Humidity: 44.4%
System Condition: Good
Calibration Method: Set The Force
Procedure Used: WI25-CAL-LOAD

MTE Utilized

Manufacturer	Model Number	Serial Number	Calibration Due Date
Omega	HH314	80401789	8/21/2021

Compression Calibration Data				Error			
				Relative Error		Fixed Error	
Reference (klbf)	Run 1 (klbf)	Run 2 (klbf)	Run 3 (klbf)	Max (%)	Repeatability (%)	Max (klbf)	Repeatability (klbf)
0.00	0.000	0.000	0.000	0.00	0.00	0.000	0.000
-2.00	-2.000	-2.000	-1.999	-0.05	0.07	0.001	0.001
-4.00	-3.999	-3.999	-3.998	-0.05	0.03	0.002	0.001
-6.00	-5.997	-5.999	-5.997	-0.06	0.03	0.003	0.002
-8.00	-8.000	-7.999	-7.998	-0.03	0.02	0.002	0.002
-10.00	-10.000	-9.999	-9.997	-0.03	0.03	0.003	0.003
-12.00	-11.999	-11.997	-11.997	-0.03	0.02	0.003	0.003
-14.00	-14.000	-13.997	-13.997	-0.02	0.02	0.003	0.003
-16.00	-16.000	-15.996	-15.997	-0.02	0.02	0.004	0.004
-18.00	-18.000	-17.994	-17.995	-0.03	0.03	0.006	0.005
-20.00	-19.997	-19.992	-19.992	-0.04	0.02	0.008	0.005
0.00	-0.003	0.001	0.000	0.01	0.02	-0.003	0.003

Relative error at zero is expressed as percent of full scale



Calibration Results

As Found: In Tolerance
As Left: In Tolerance
Expanded Uncertainty (klbf): 0.006

Relative Error

Max (%): 0.06
Repeatability (%): 0.07
Return to Zero (%): 0.01

Fixed Error

Max (klbf): 0.008
Repeatability (klbf): 0.005
Return to Zero:(klbf) 0.003

Shunt Calibration

Shunt Value (Ω)	Reading (V)
43.4k	-2.019
Pins:	2,7

Scaling Coefficients

a_0: 0.00000E+00
a_1: 6.66765E+00
a_2: 6.85691E-03
a_3: 0.00000E+00
a_4: 0.00000E+00
a_5: 0.00000E+00

Signal Conditioner Settings

Scaled Units: kip
Max Signal Input: 0
Min Signal Input: -20
Bridge Type: Full
Vex Source: Internal
Vex Value (V): 2.5
Bridge Resis. (Ω): 350

This calibration has been performed using procedures described by the manufacturer, CTLGroup, or both. Results of this calibration apply only to the items described herein. Certificates of calibration for standards used are on file. This report may not be reproduced in any format unless the reproduction is a complete and true copy of the original. Calibrations are performed with standards whose values and measurements are traceable to the National Institute of Standards and Technology.

Calibration Date: 7/6/2021
Calibration Due Date: 7/31/2022

Performed By: Muro **Signature:** ______ **Date:** 8/18/21

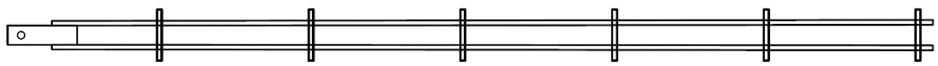
Checked By: Loeppert **Signature:** ______ **Date:** 9/28/21

Quality: **Signature:** ______ **Date:** 10/02/2021

Page 1 of 1

Appendix A1.2.16L

Independent Testing – Elevate Ladder Strip Pullout



Pullout testing was performed on the Elevate Ladder Strip soil reinforcements in accordance with ASTM D 6706 “Measuring Geosynthetic Pullout Resistance in Soil” with modifications. All tests & analyses were performed by SGI Testing Services, LLC at their certified testing facility in Norcross, GA. The final report was delivered to Elevate Infrastructure, LLC on July 5th, 2022. That report is included herein.

Testing was performed to derive the friction factor (F*) used in designing the Elevate MSE Panel Wall System. Test results are plotted against the conservative AASTHO default values to obtain a confidence interval for use during wall design.

The Elevate Ladder Strip was tested for pullout in 3 distinct materials which are intended to represent a wide range of fill parameters. The recommended F* design values use lower bound friction factor values. The friction factor is equal to 4.0 at the top of grade and decreases linearly to 1.5 at a depth of 20 feet.

Prepared for:

Elevate Infrastructure, LLC
2495 Bungalow Road
Morris, IL 60450

FINAL REPORT

PULLOUT TESTING ELEVATE LADDER STRIP WELDED STEEL BAR MAT IN SAND, SANDY GRAVEL, AND AASHTO #57 STONE

Prepared by:

SGI TESTING SERVICES, LLC

4405 International Blvd., Suite B-117
Norcross, GA 30093

Project Number SGI22040

4 July 2022

CAVEAT

The reported results apply only to the materials and test conditions used in the laboratory testing program. The results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analysis unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. This testing report is submitted for the exclusive use of the client to whom it is addressed.

1. INTRODUCTION

SGI Testing Services, LLC (SGI) conducted a laboratory testing program to determine the pullout resistance of Elevate Ladder Strip welded steel bar mat in three granular soils (i.e., sand, sandy gravel, and AASHTO #57 stone). The sample preparation procedures and testing conditions used in the testing program were specified by Mr. Matt Austin of Elevate Infrastructure, LLC. All of the pullout tests were conducted at SGI located in Norcross, Georgia.

2. TEST MATERIALS

Two types of materials were used in this testing program. Descriptions of these materials are given below:

- *Reinforcement Material:* Elevate Ladder Strip welded steel bar mat consisting of 4 inch wide W11 transverse steel bars at 12 inch spacing welded to two W11 (3/8 inch) longitudinal steel bars at 2 inch spacing; and

- *Soil Material*: Sand, graded aggregate base (GAB) material (i.e., sandy gravel), and AASHTO #57 stone manufactured by crushing granite rock by Vulcan Materials Company – Norcross Quarry. Particle size analysis, standard Proctor compaction, and direct shear tests were conducted on the three soils, and the test results are presented in Appendix A.

Elevate Ladder Strip welded steel bar mats were provided by Elevate Infrastructure, LLC. Bulk samples of the three soils were obtained from Vulcan Materials Company.

3. PULLOUT TEST EQUIPMENT

The pullout testing device used in this testing program had plan dimensions of 2 ft by 5 ft (0.6 m by 1.5 m) and an overall depth of 12 inch (300 mm). Normal (vertical) stresses were applied to the testing specimen through dead weight (steel plates) for low normal stress testing or air cylinders for high normal stress testing, and pullout (horizontal) loads were applied to the test specimen through two hydraulic cylinders. The schematic diagrams of the pullout testing device are shown in Figures 1 and 2.

4. TEST METHOD AND PROCEDURES

The pullout tests were performed in accordance with the ASTM D 6706, "*Measuring Geosynthetic Pullout Resistance in Soil*" with modifications. For each pullout test, the test specimen was set up in accordance with the following procedures and tested under the specific conditions as described below:

- The soil was placed in the lower half of the pullout box and compacted by hand tamping to form a 6-inch (150-mm) thick layer. The soil was compacted to approximately 95% of the maximum dry unit weight;
- For each pullout test, a bar mat was placed on top of the compacted soil as shown in Figures 3, 4, and 5. The front end of the bar mat was connected to the pullout loading harness;
- A "tell-tale" bar gage was connected to the rear end of the bar mat. Displacements at the rear end of the bar mat were measured by a linear variable differential transformer (LVDT);
- The soil was placed in the upper half of the pullout box and compacted by hand tamping to form a 6-inch (150-mm) thick layer. The soil was compacted to approximately 95% of the maximum dry unit weight;
- A load cell was then attached to the pullout loading harness to measure the pullout load of the bar mat at the specimen clamp. An LVDT was fixed to the specimen clamp to measure the pullout displacement at the specimen clamp.
- A specific normal stress was then applied to the test specimen through dead weight (steel plates) for low normal stress testing or air cylinders for high normal stress testing; and
- After application of the normal stress, the bar mat was subjected to pullout loading by displacing the bar mat specimen at a constant displacement rate of 0.04 inch/min (1 mm/min) as measured at the specimen clamp. The bar mat specimen was pulled until the pullout failure occurred.

Completed pullout test setups are shown in Figure 6 (normal stress applied by using dead weight) and Figure 7 (normal stress applied by using air cylinders).

5. PULLOUT TEST RESULTS

Three series of pullout tests were performed in this testing program. For each test series, the test conditions and test results are presented on a summary page in Appendix B. The summary page includes:

- Pullout force versus displacement figure;
- Pullout resistance versus normal stress figure; and
- A table that summarizes test conditions, maximum pullout resistance, bearing capacity factor (N_q), coefficient of apparent friction (F*), and failure mode.

The maximum pullout resistance (P_{max}) was directly measured from the pullout test and reported as a force in the unit of lbs. The bearing capacity factor (N_q), defined as the ratio of horizontal (bearing) stress to normal stress (σ_h / σ_n), was calculated using the equation as follows:

$$N_q = \frac{P_{\max}}{n L_t d_t \sigma_n} \qquad (1)$$

where:

P_{max}	=	maximum pullout resistance (load);
n	=	number of transverse bars embedded in soil;
L_t	=	length of the transverse bar (i.e., bar mat width);
d_t	=	diameter of the transverse bar (i.e., bar mat width); and
σ_n	=	total normal stress applied to the bar mat specimen.

It should be noted that the horizontal (bearing) stress is acting the transverse bar when the bar mat is pulled in the longitudinal direction from within soil.

The coefficient of apparent friction (F^*) was calculated using the equation as follows:

$$F^* = \frac{P_{\max}}{2L_e W \sigma_n} \quad (2)$$

where:

F^*	=	coefficient of apparent friction;
P_{max}	=	maximum pullout resistance;
L_e	=	initial embedded length of the bar mat;
W	=	initial width of the bar mat defined as the center to center distance between two longitudinal bars; and
σ_n	=	total normal stress applied to the bar mat specimen.

For each pullout test, the Elevate Ladder Strip welded steel bar mat was pulled until the pullout or tensile failure occurred. The bar mat was considered to be in the pullout failure mode when the tell-tale gage attached to the rear end of the bar mat specimen displaced at least 0.5 in. (13 mm) at the completion of the test and pullout load decreased or remained constant with increasing pullout displacement. The rupture failure mode of the mat occurred at the connection hole of the connection plate as shown in Figure 8.

6. CLOSURE

SGI appreciates the opportunity to provide laboratory testing services to Elevate Infrastructure, LLC. Should you have any questions regarding this report, or if you require additional information, please do not hesitate to contact the undersigned.

Sincerely,

Zehong Yuan, Ph.D., P.E.
Laboratory Manager

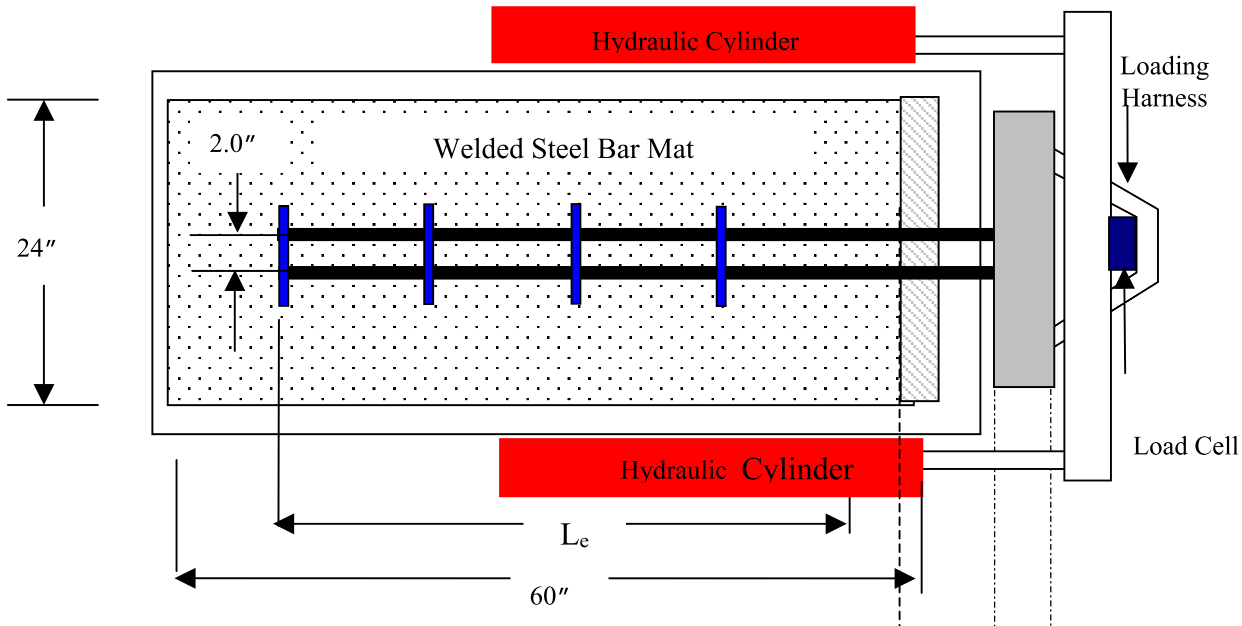


Figure 1. Plan view of pullout test setup (Note: not to scale).

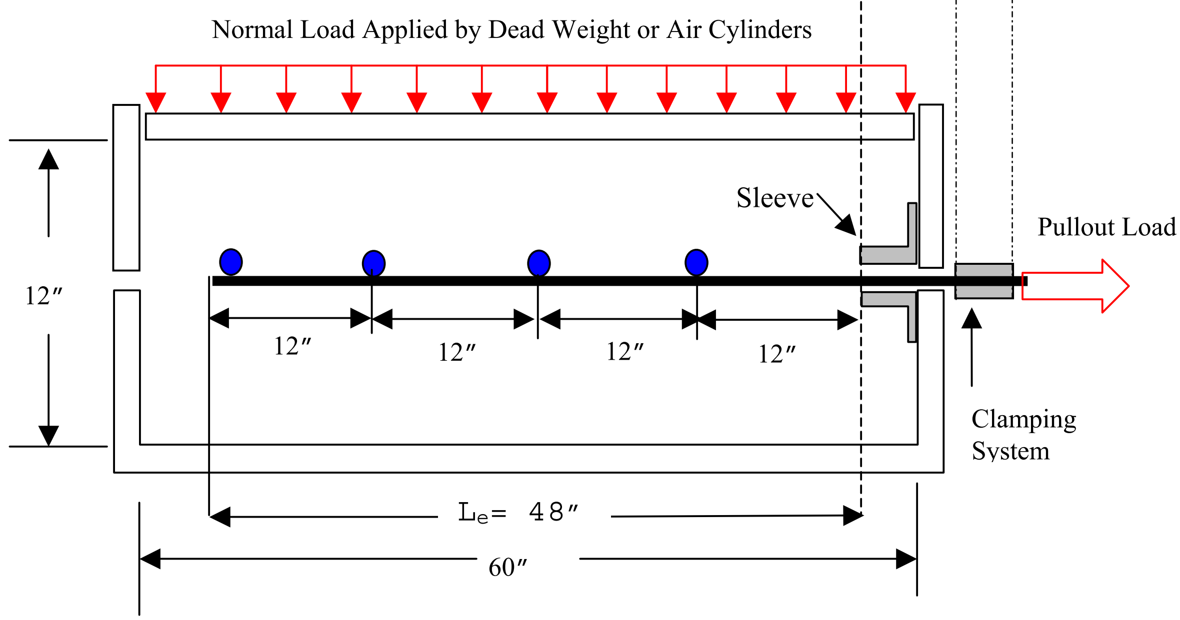


Figure 2. Cross-section of pullout test setup (Note: not to scale).

Figure 3. Elevate Ladder Strip placed on compacted sand.

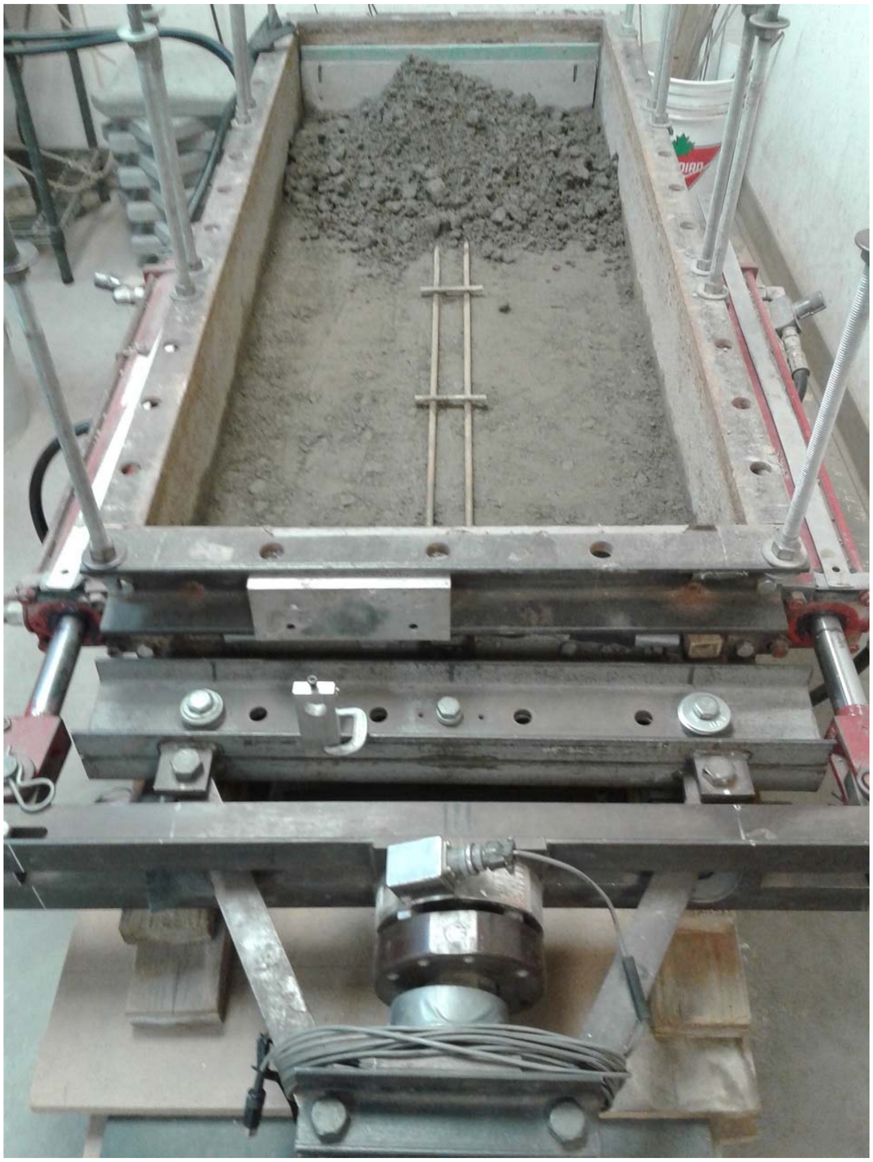


Figure 4. Elevate Ladder Strip placed on compacted GAB material.

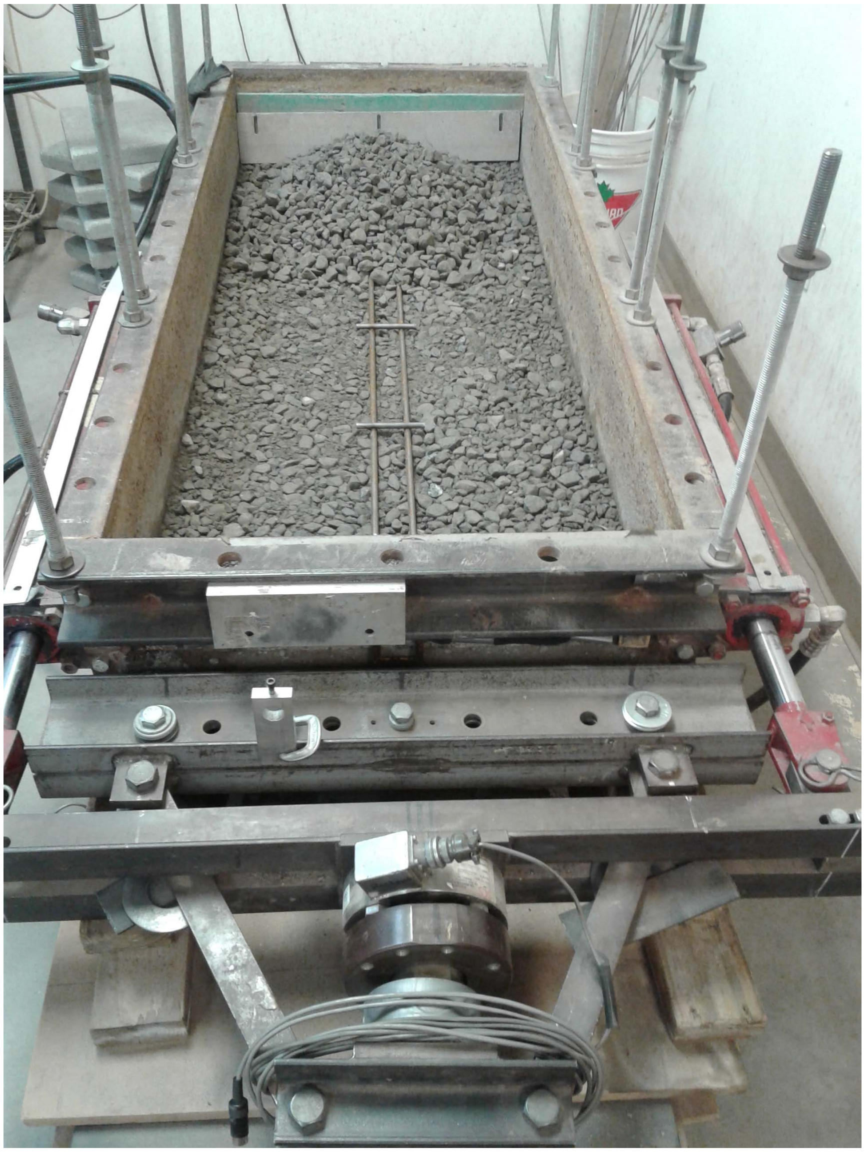


Figure 5. Elevate Ladder Strip placed on compacted AASHTO #57 stone.

Figure 6. A complete pullout test setup (200 psf normal stress by dead weight).

Figure 7. A complete pullout test setup (normal stress by using air cylinders).

Figure 8. Failure mode: rupture (i.e., tensile failure) of the 1.5 inch wide x 0.18 inch thick connection plate at the connection hole occurred in Tests #2F, 2G, and 3E, 3F, and 3G.

APPENDIX A

SUMMARY OF SOIL TEST RESULTS

SGI Testing Services, LLC

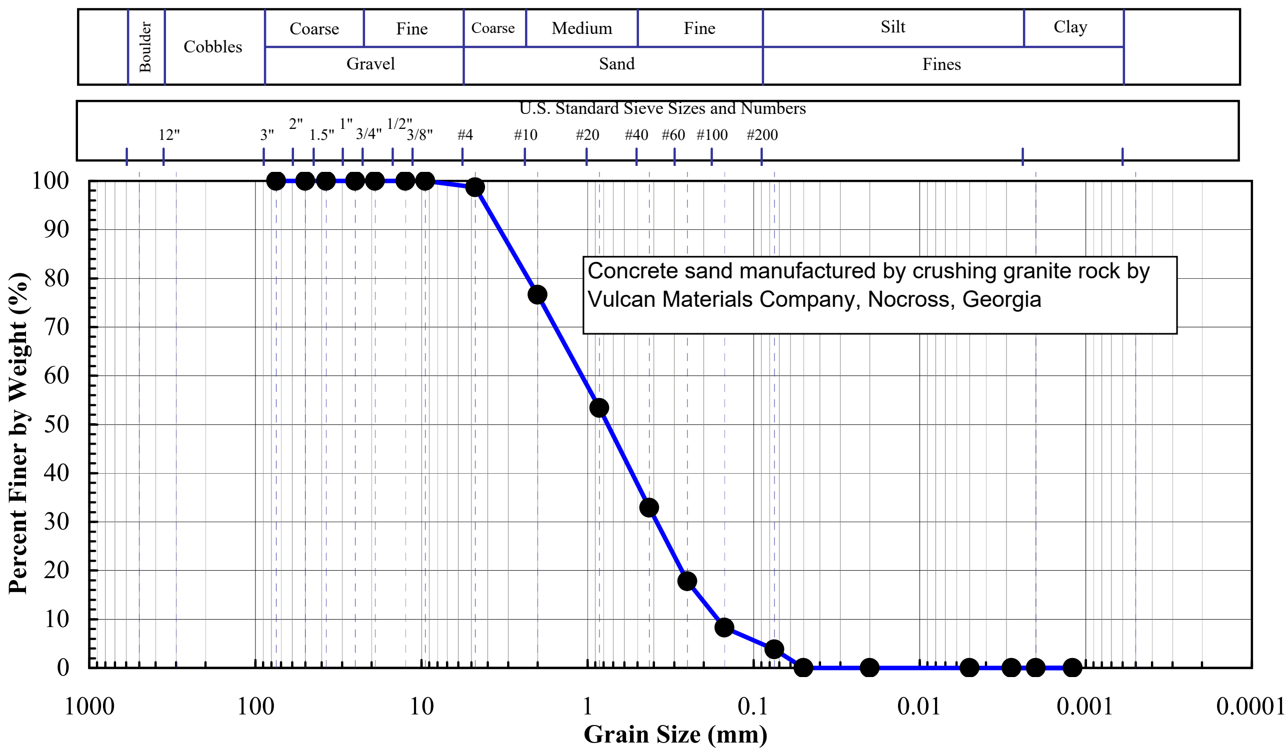
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931 8222 Fax: (770) 931 8240

Project Name:	Pullout
Project No:	SGI22040
Client Sample ID:	Concrete Sand
Lab Sample No:	SGISP

ASTM D 421, D 422, D 4318

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits, Classification

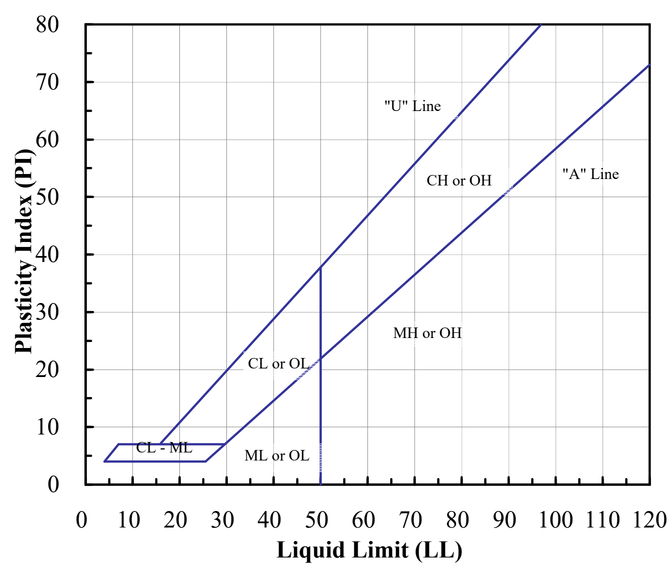


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
1/2"	12.5	100.0
3/8"	9.5	100.0
#4	4.75	98.7
#10	2.00	76.6
#20	0.850	53.4
#40	0.425	32.9
#60	0.250	17.8
#100	0.150	8.3
#200	0.075	3.8

Hydrometer Particle Diameter (mm)	% Finer
0.0500	
0.0200	
0.0050	
0.0020	
0.0012	

Gravel (%):	1.3
Sand (%):	94.9
Fines (%):	3.8
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	6.6
Coeff. Curv. (Cc):	0.83



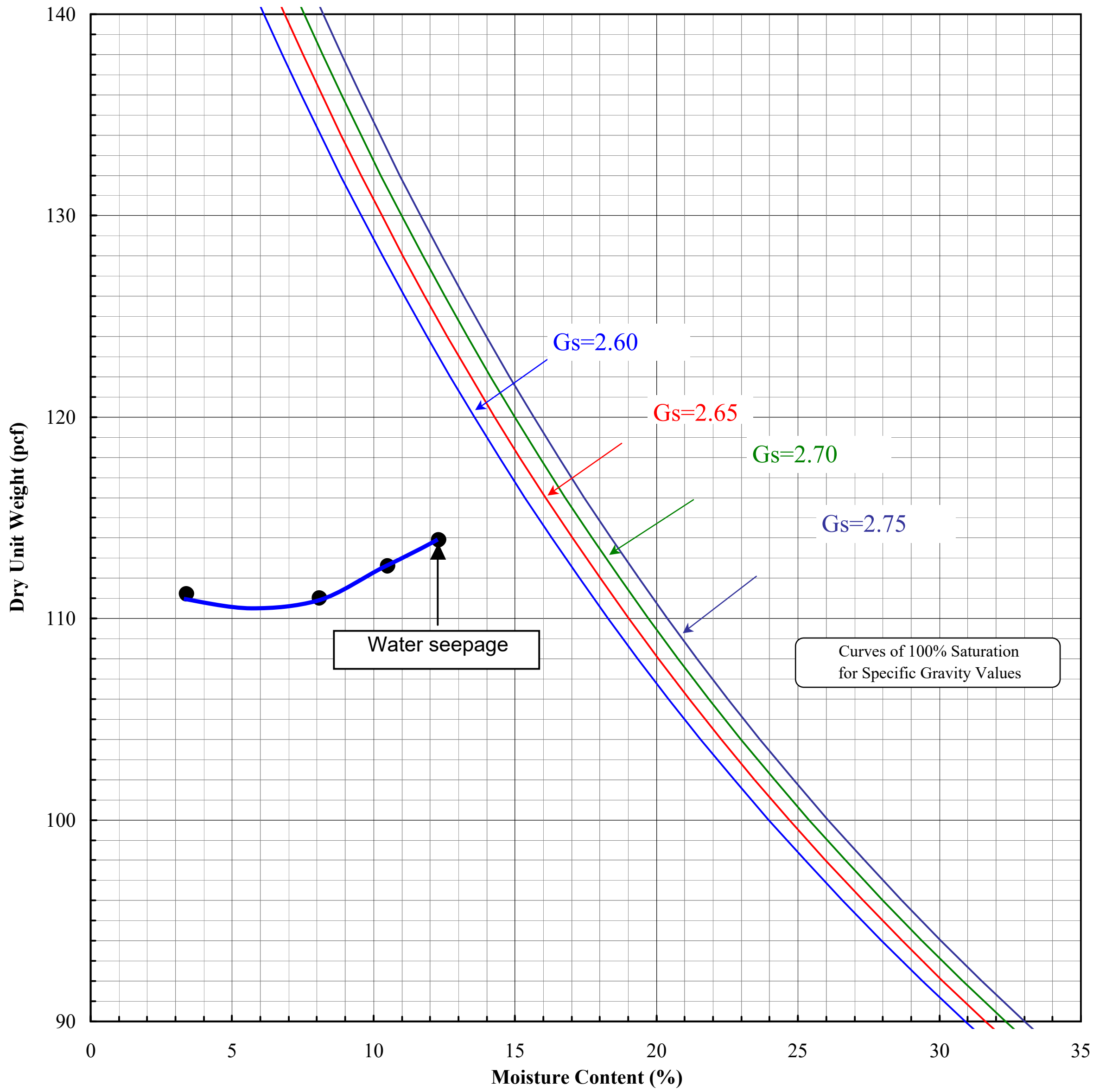
Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (%)	PL (%)	PI (-)	Engineering Classification
Concrete Sand	SGISP	-	3.8				SP (Poorly-Graded Sand)

Note(s):

SGI Testing Services, LLC
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931 8222 Fax: (770) 931 8240

Project Name: Pullout
Project No: SGI22040
Client Sample ID: Concrete Sand
Lab Sample No: SGISP

COMPACTION MOISTURE-DENSITY RELATIONSHIP (ASTM D 698 - Method A)

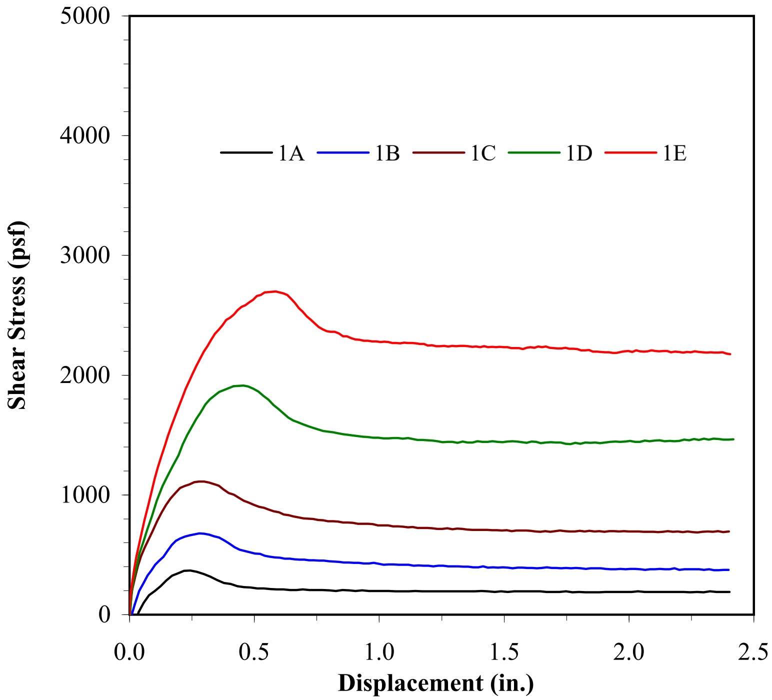


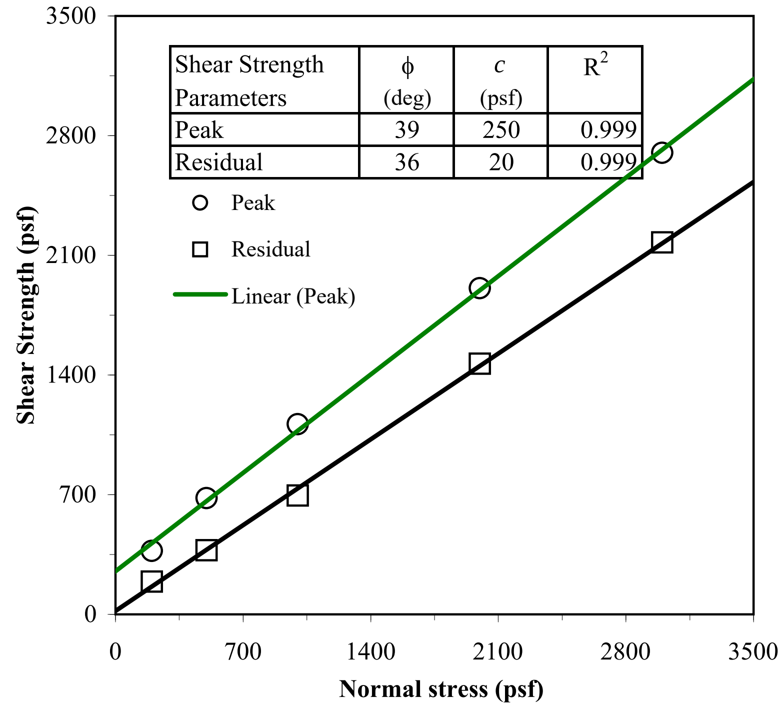
Client Sample ID.	SGI Sample ID NO.	Compaction Data		Maximum Dry Unit Weight and Optimum Moisture Content			
				Measured		Corrected	
		ω_i (%)	γ_d (pcf)	ω_{om} (%)	γ_{dmax} (pcf)	ω_{om} (%)	γ_{dmax} (pcf)
Concrete Sand	SGISP	3.4	111.2	12.0	114.0		
		8.1	111.0				
		10.5	112.6				
		12.3	113.9				

% Retained on #4 Sieve: 4.1
% Retained on #3/8" Sieve:
% Retained on 3/4" Sieve:
% Retained on 2.0" Sieve:

SGI TESTING SERVICES, LLC
DIRECT SHEAR TESTING (ASTM D 3080)

Internal shear strength of sand compacted to approximately 95% of maximum standard Proctor dry density at approximately 9% moisture content
(γ_{dmax} = 114 pcf, OMC = 12%)





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Initial γ_d (pcf)	Initial ω_i (%)	Initial ω_f (%)	After γ_d (pcf)	After ω_i (%)	After ω_f (%)	Shear Strength τ_P (psf)	Shear Strength τ_R (psf)	Failure Mode
1A	12 x 12	200	0.04	-	-	200	1.0	108.4	8.9					370	191	(1)
1B	12 x 12	500	0.04	-	-	500	1.0	107.9	9.4					680	375	(1)
1C	12 x 12	1000	0.04	-	-	1000	1.0	108.1	9.2					1112	695	(1)
1D	12 x 12	2000	0.04	-	-	2000	1.0	108.4	8.9					1908	1465	(1)
1E	12 x 12	3000	0.04	-	-	3000	1.0	108.6	8.7					2698	2175	(1)

NOTES:
(1) Sliding (i.e., shear failure) was forced to occur along the shear plane between the upper and lower shear box.
(2) The reported total-stress parameters of friction angle and cohesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The residual shear strength was calculated using the shear force measured at the end of the test.

SGI TESTING SERVICES, LLC

DATE OF REPORT:	6/30/2022
FIGURE NO.	A-3
PROJECT NO.	SGI22040
DOCUMENT NO.	
FILE NO.	

SGI Testing Services, LLC

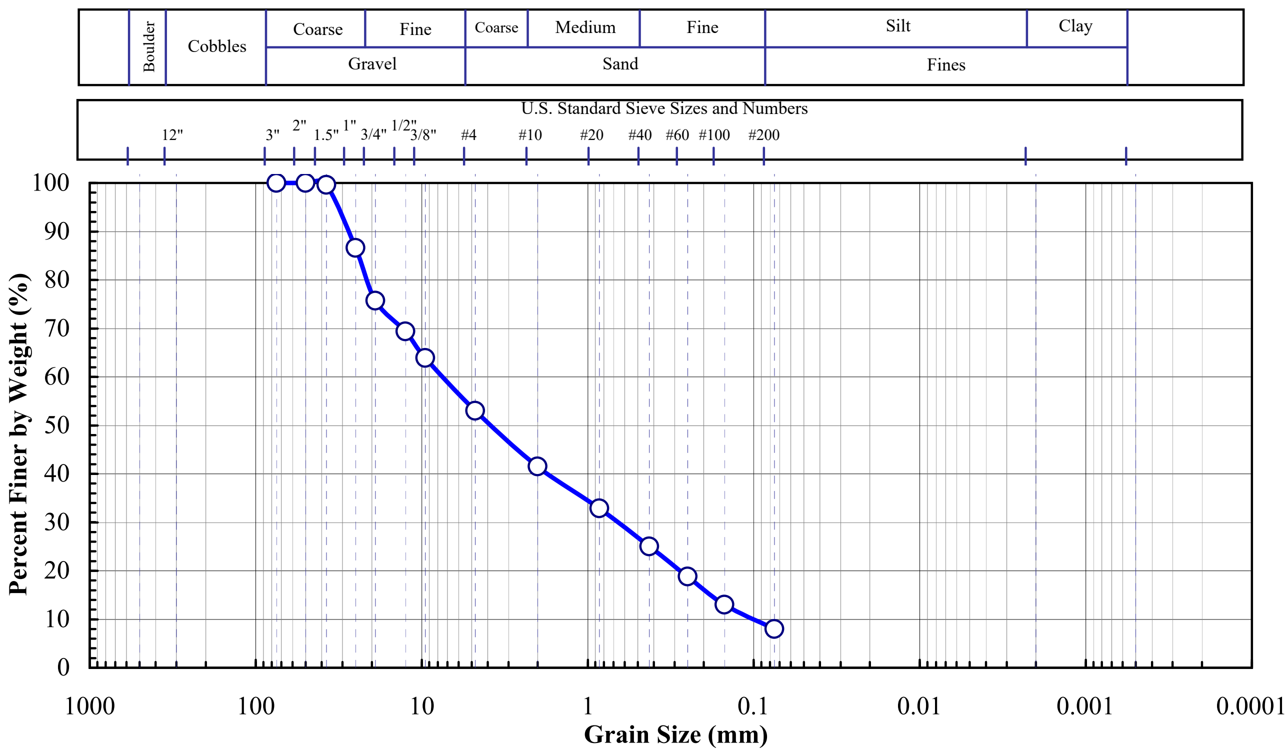
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931 8222 Fax: (770) 931 8240

Project Name:	Pullout
Project No:	SGI22040
Client Sample ID:	GAB Material
Lab Sample No:	SGIGAB

ASTM D 421, D 422, D 4318

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits, Classification

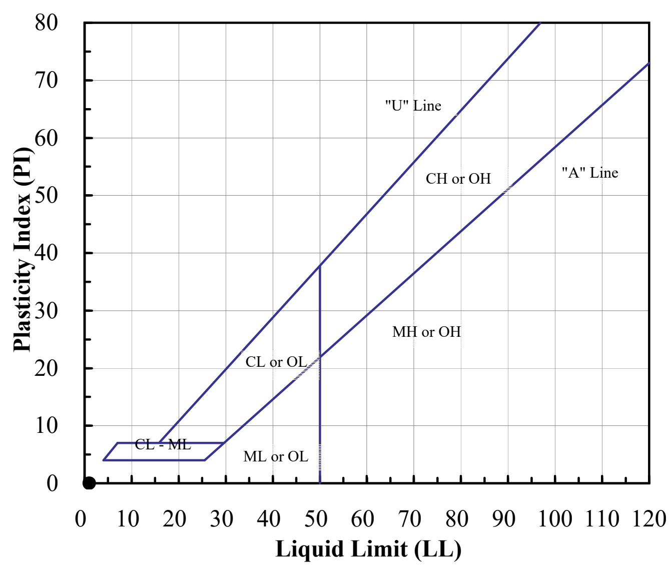


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	99.6
1"	25	86.6
3/4"	19	75.7
1/2"	12.5	69.4
3/8"	9.5	63.9
#4	4.75	53.0
#10	2.00	41.5
#20	0.850	32.9
#40	0.425	25.0
#60	0.250	18.8
#100	0.150	13.0
#200	0.075	8.0

Hydrometer Particle Diameter (mm)	% Finer
0.0288	
0.0184	
0.0109	
0.0079	
0.0012	

Gravel (%):	47.0
Sand (%):	45.0
Fines (%):	8.0
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	74.9
Coeff. Curv. (Cc):	0.59



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (%)	PL (%)	PI (-)	Engineering Classification
GAB Material	SGIGAB	-	8.0	-	-	-	GP-GM

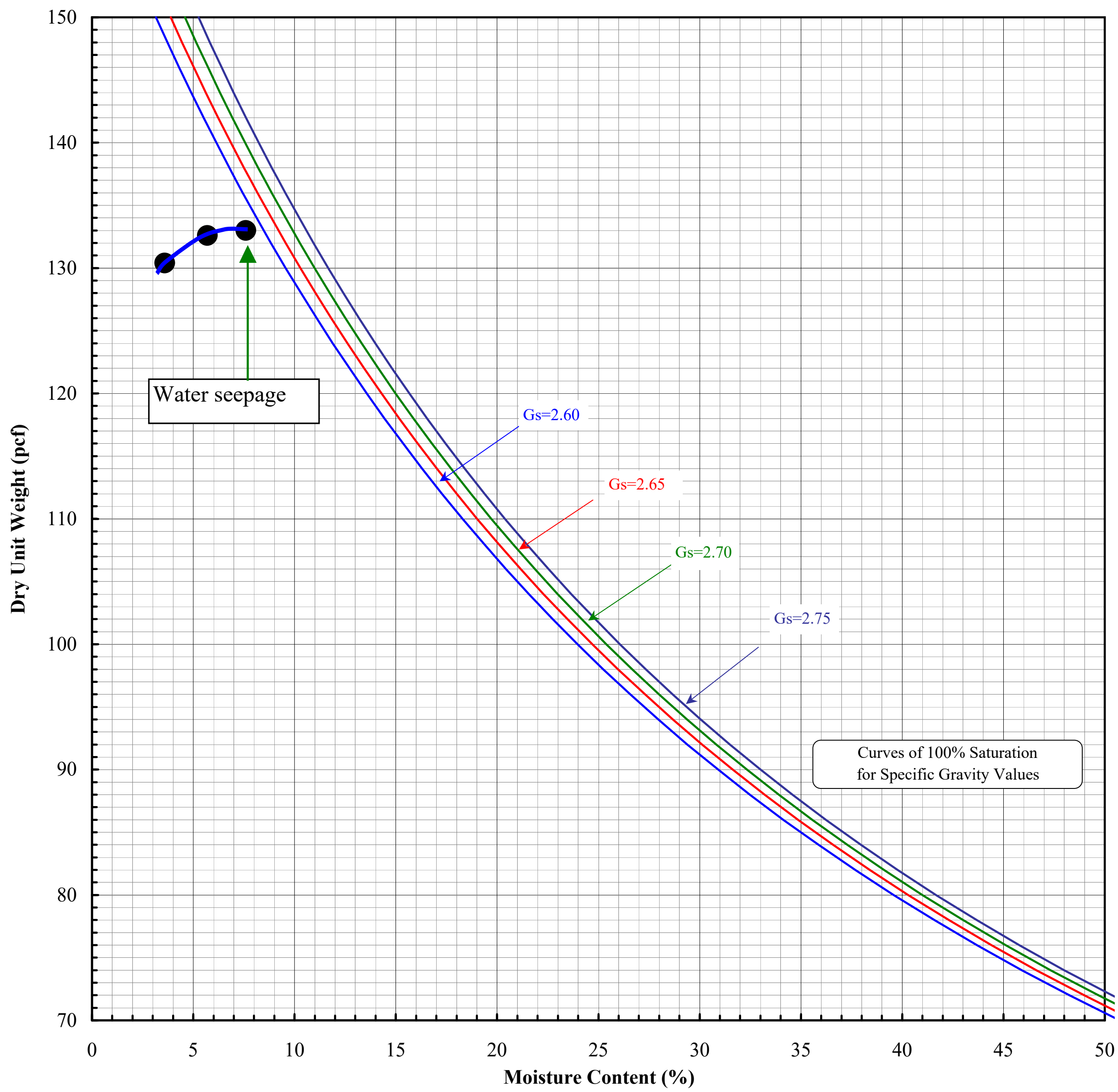
Note(s):

SGI Testing Services, LLC

4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931 8222 Fax: (770) 931 8240

Project Name:	Pullout
Project No:	SGI22040
Client Sample ID:	GAB Material
Lab Sample No:	SGIGAB

ASTM D698 **COMPACTION MOISTURE-DENSITY RELATIONSHIP** **Standard - Method C**



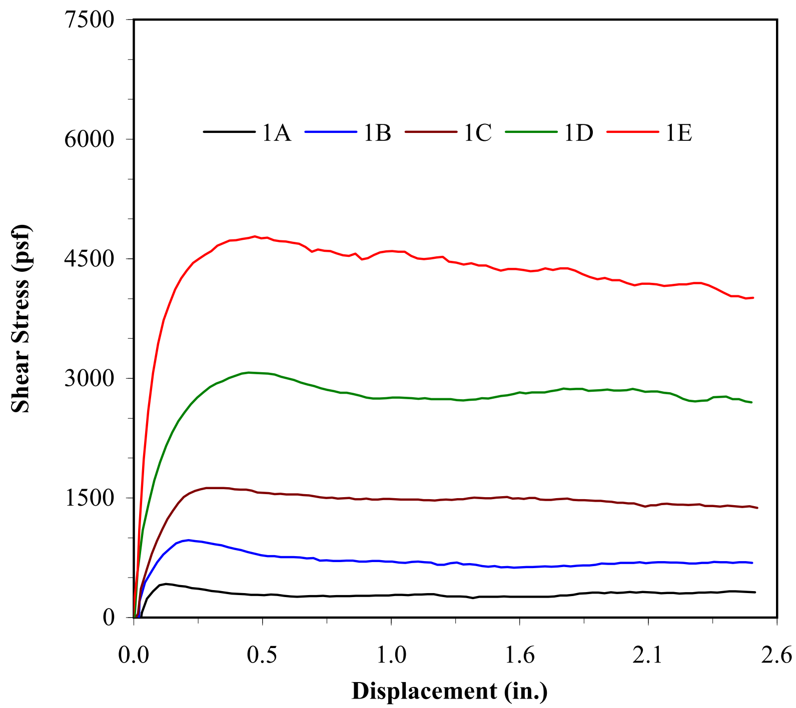
Client Sample ID.	SGI Sample ID NO.	Compaction Data		Maximum Dry Unit Weight and Optimum Moisture Content			
				Measured		Corrected	
		ω_i (%)	γ_d (pcf)	ω_{om} (%)	γ_{dmax} (pcf)	ω_{om} (%)	γ_{dmax} (pcf)
GAB Material	SGIGAB	3.6	130.4	7.6	133.0	6.0	139.1
		5.7	132.6				
		7.6	133.0				

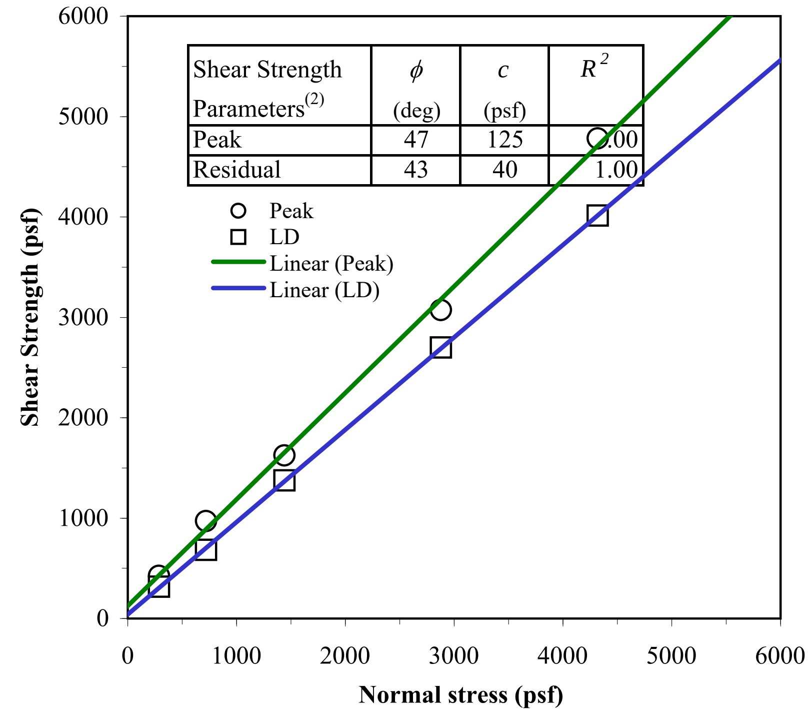
% Retained on #4 Sieve:	47.0
% Retained on #3/8" Sieve:	36.1
% Retained on 3/4" Sieve:	24.3
% Retained on 2.0" Sieve:	

SGI TESTING SERVICES, LLC

DIRECT SHEAR TESTING (ASTM D 3080)

Internal shear strength of GAB material compacted to approximately 95% of max standard Proctor dry density
(γ_{dmax} = 139.1 pcf, OMC = 6.2%, ASTM D 698)





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation						Soil Compaction			Shear Strength		Failure Mode
						Step 1		Step 2		Step 3							
				(psf)	(hour)	(psf)	(hour)	(psf)	(hour)	(psf)	(hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	τ_P (psf)	τ_R (psf)	
1A	12 x 12	288	0.04	-	-	288	1.0	-	-	-	-	132.2	3.9		423	317	(1)
1B	12 x 12	720	0.04	-	-	720	1.0	-	-	-	-	132.0	4.0		970	684	
1C	12 x 12	1440	0.04	-	-	1440	1.0	-	-	-	-	130.9	4.9		1623	1375	
1D	12 x 12	2880	0.04	-	-	2880	1.0	-	-	-	-	131.7	4.3		3071	2700	
1E	12 x 12	4320	0.04	-	-	4320	1.0	-	-	-	-	131.4	4.5		4782	4012	

NOTES:
(1) Shear failure was forced to occur internally through the soil specimen at the predetermined plane between the upper and lower shear box during each test.
(2) The reported total-stress parameters of friction angle and cohesion were determined from a best-fit line drawn through the test data. The residual shear strength was calculated using the shear force measured at the end of the test.

DATE REPORTED:	6/30/2022
FIGURE NO.	A-6
PROJECT NO.	SGI22040
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

GAB.DS.2021.xls

SGI Testing Services, LLC

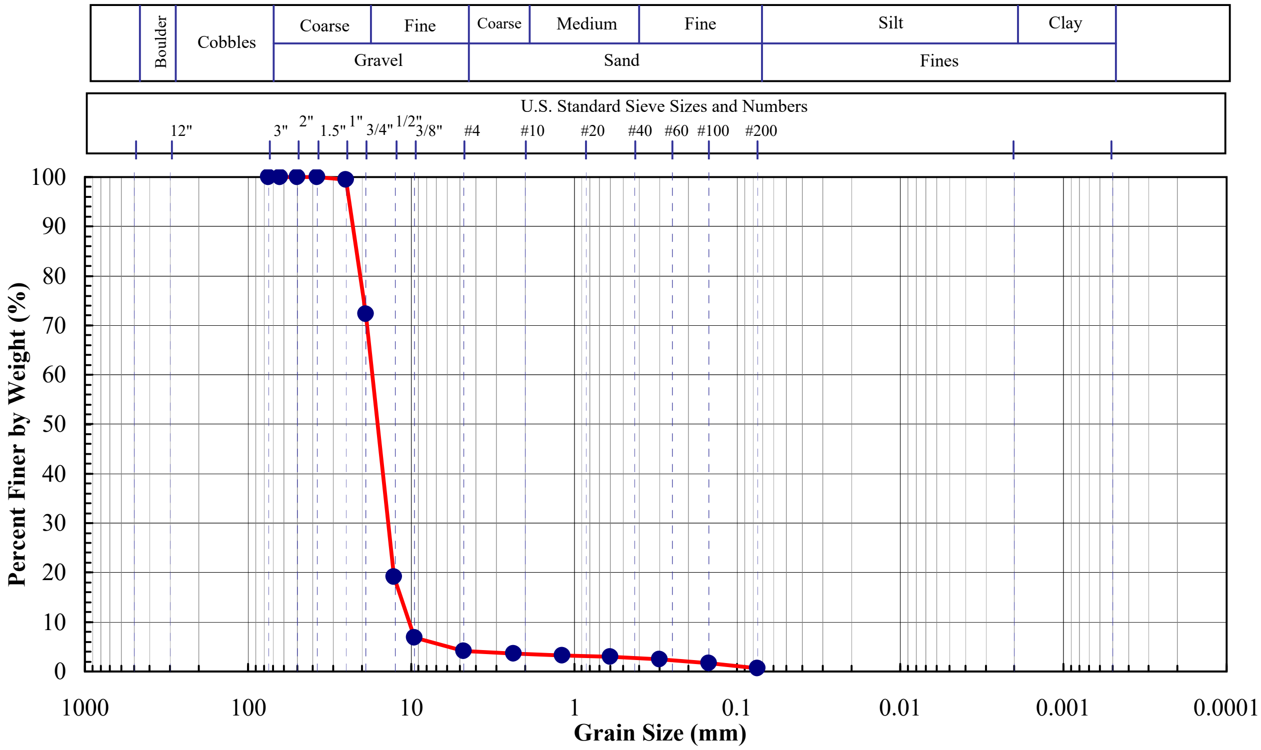
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931-8222 Fax: (770) 931-8240

Project Name:	Pullout
Project No:	SGI22040
Client Sample ID:	AASHTO #57 Stone
Lab Sample No:	SGIGP

ASTM D 2216, D 1140, D 422, C 136, D 4318, D 2487

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits, Classification

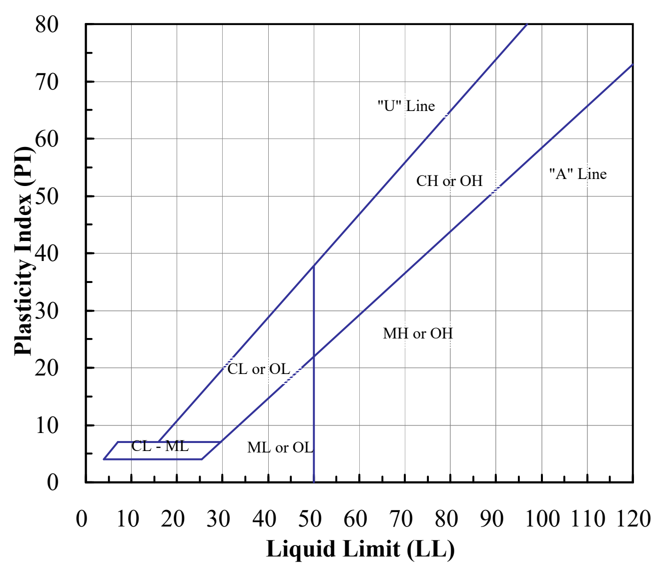


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	99.5
3/4"	19	72.3
1/2"	12.5	19.2
3/8"	9.5	6.8
#4	4.75	4.1
#8	2.36	3.6
#16	1.180	3.2
#30	0.600	3.0
#50	0.300	2.5
#100	0.150	1.7
#200	0.075	0.7

Hydrometer Particle Diameter (mm)	% Finer
0.0340	
0.0220	
0.0064	
0.0032	
0.0013	

Gravel (%):	95.9
Sand (%):	3.4
Fines (%):	0.7
Silt (%):	
Clay (%):	

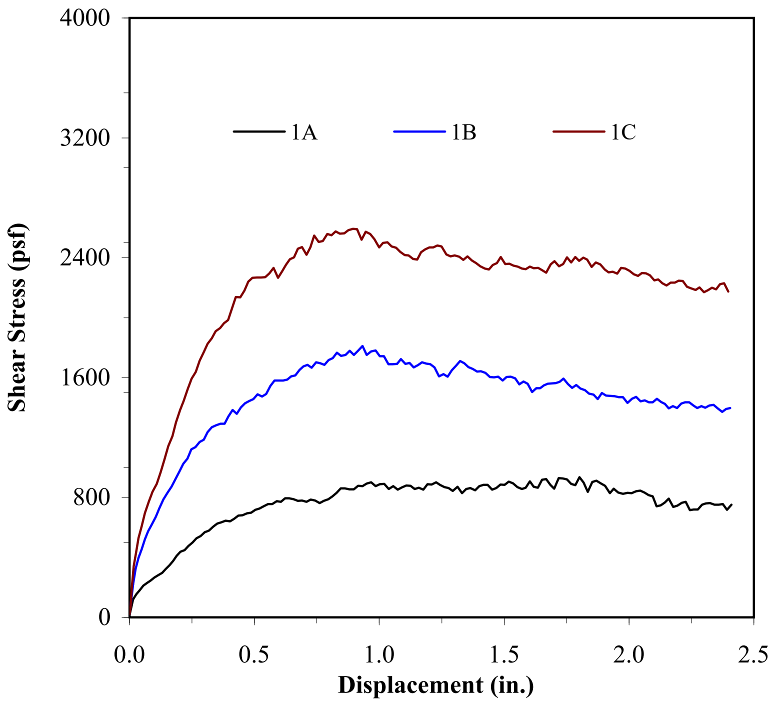
Coeff. Unif. (Cu):	1.7
Coeff. Curv. (Cc):	1.1

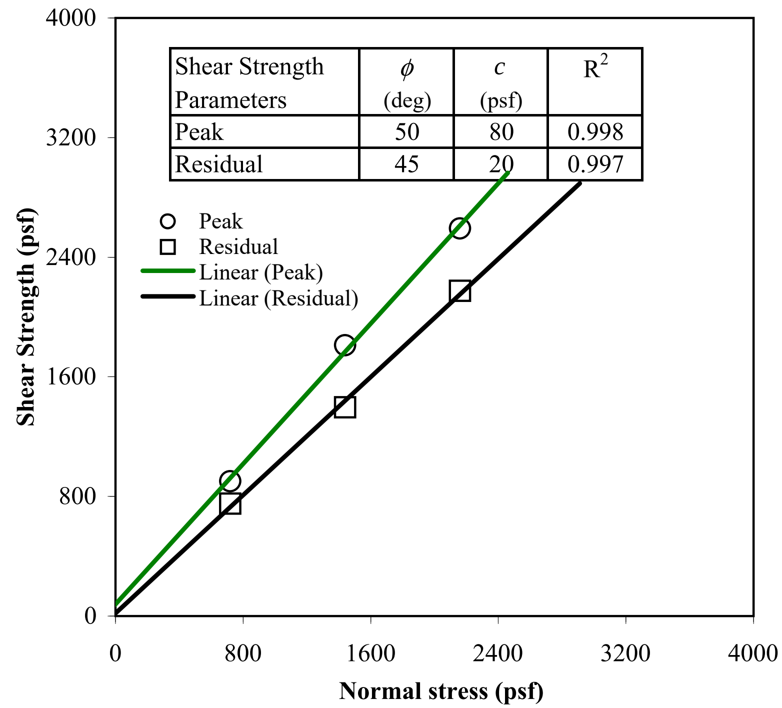


Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (%)	PL (%)	PI (-)	Engineering Classification
AASHTO #57 Stone	SGIGP		0.7				GP

SGI TESTING SERVICES, LLC
DIRECT SHEAR TESTING (ASTM D 3080)

Test Series No. 1: AASHTO No. 57 stone (gravel) compacted to approximately 95% max density under dry condition
(γ_{max} = 102.2 pcf, target dry unit weight γ_d = 97.1 pcf)





Test No.	Shear Box Size (in x in)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Gravel			Gravel			Shear Strength		Failure Mode
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	γ_d (pcf)	ω_i (%)	ω_f (%)	τ_P (psf)	τ_R (psf)	
1A	12 x 12	720	0.04	-	-	720	0.5	97.0	0.1					902	752	(1)
1B	12 x 12	1440	0.04	-	-	1440	0.5							1810	1396	(1)
1C	12 x 12	2160	0.04	-	-	2160	0.5							2592	2175	(1)

NOTES:
(1) Sliding (i.e., shear failure) was forced to occur along the shear plane between the upper and lower shear box.
(2) The reported total-stress parameters of friction angle and cohesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The residual shear strength was calculated using the shear force measured at the end of the test.

DATE OF REPORT:	6/30/2022
FIGURE NO.	A-8
PROJECT NO.	SGI22040
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

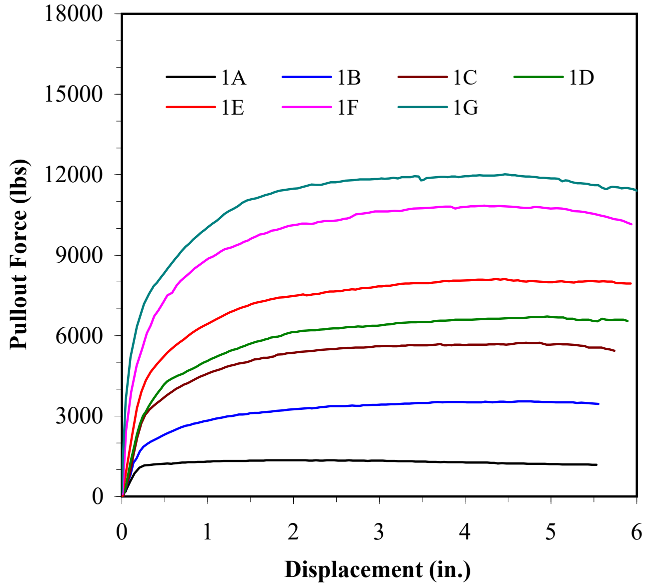
S21042-01.ds.xls

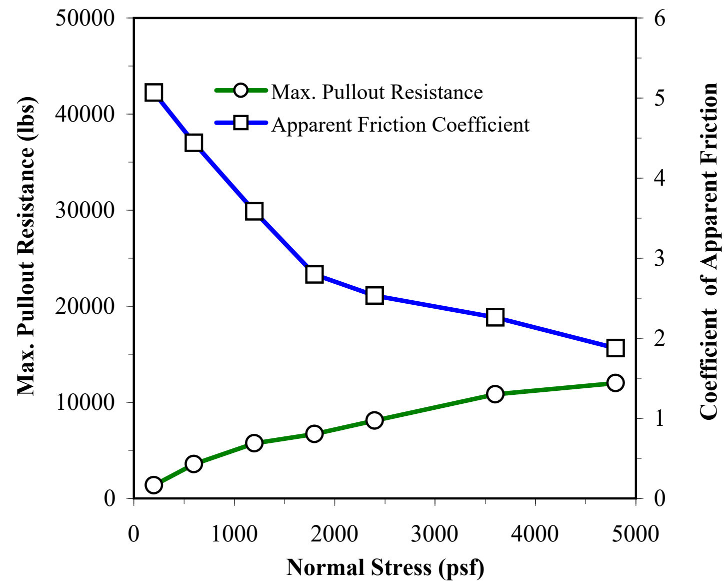
APPENDIX B

SUMMARY OF PULLOUT TEST RESULTS

ELEVATE INFRASTRUCTURE, LLC
STEEL GRID PULLOUT TESTING (ASTM D 6706)

TEST SERIES NO. 1: Elevate Ladder Strip welded steel bar mat (transverse bar diameter d_t = 3/8", length (L_t) = 4", and spacing = 12") within sand compacted to approximately 95% of max standard Proctor dry density at optimum moisture content (γ_{dmax} = 114 pcf, OMC = 12 %)





Test No.	Test Specimen Width[1] W (in.)	Embedment Length L (in.)	Normal Stress σ_n (psf)	Pullout Rate (in/min)	Depth from Back Fill Surface[4] z (ft)	Pullout Resistance 1/5" $P_{0.2''}$ (lbs)	1/2" $P_{0.5''}$ (lbs)	3/4" $P_{0.75''}$ (lbs)	Max P_{max} (lbs)	Bearing Stress Factor[2] $N_q = \frac{P_{max}}{nL_t d_t \sigma_n}$ (-)	Coefficient of Apparent Friction $F^* = \frac{P_{max}}{2WL\sigma_n}$ (-)	Failure Mode[3] (-)
1A	2.0	48.0	200	0.04	1.6	1062	1221	1270	1351	162.1	5.07	Pullout
1B	2.0	48.0	600	0.04	4.9	1611	2312	2639	3552	142.1	4.44	Pullout
1C	2.0	48.0	1200	0.04	9.9	2440	3715	4206	5733	114.7	3.58	Pullout
1D	2.0	48.0	1800	0.04	14.8	2582	4198	4649	6707	89.4	2.79	Pullout
1E	2.0	48.0	2400	0.04	19.8	3571	5261	5935	8106	81.1	2.53	Pullout
1F	2.0	48.0	3600	0.04	29.7	5161	7331	8224	10840	72.3	2.26	Pullout
1G	2.0	48.0	4800	0.04	39.6	6586	8362	9334	12010	60.1	1.88	Pullout

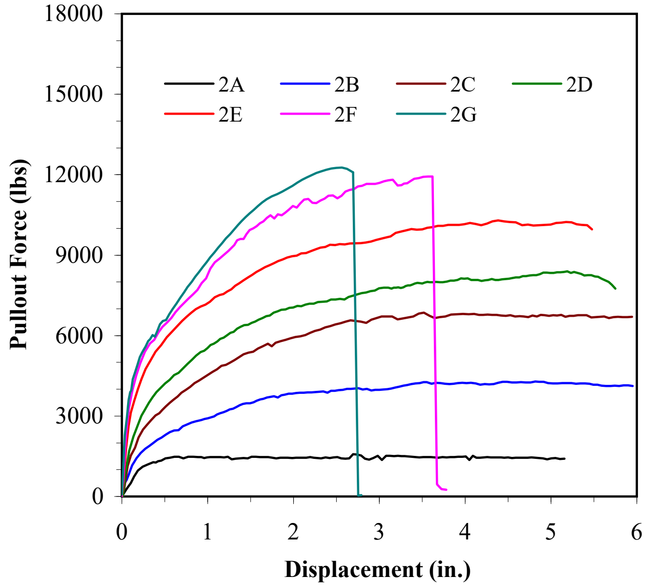
NOTE:
(1) Test Specimen Width: the center-to-center distance between the two longitudinal bars.
(2) n: number of transverse bars embedded in soil (n = 4 for each test); L_t = transverse bar length (4"); and d_t = transverse bar diameter (3/8").
(3) Pullout failure indicated by a minimum displacement of 0.5" measured at the rear end of the steel grid at the completion of the test.
(4) Depth from backfill surface: normal stress (psf) divided by as-placed (moist) soil unit weight.

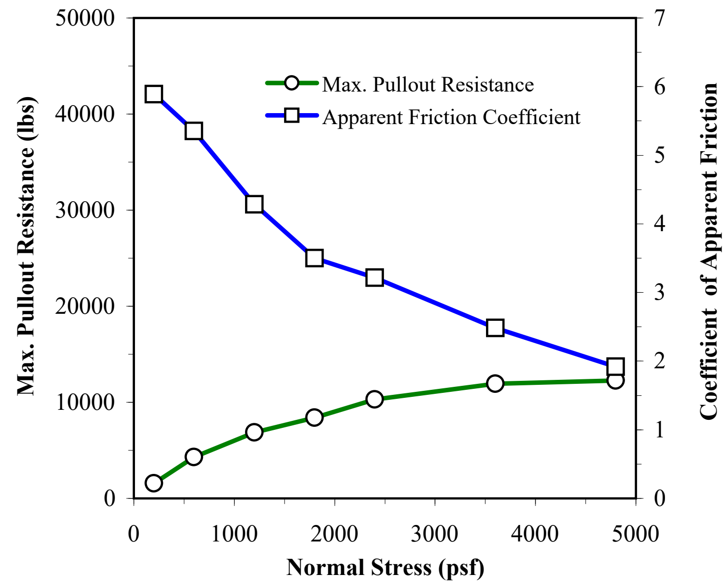
SGI TESTING SERVICES, LLC

DATE REPORTED:	6/30/2022
FIGURE NO.	1
PROJECT NO.	SG22040
DOCUMENT NO.	
FILE NO.	

ELEVATE INFRASTRUCTURE, LLC
STEEL GRID PULLOUT TESTING (ASTM D 6706)

TEST SERIES NO. 2: Elevate Ladder Strip welded steel bar mat (transverse bar diameter d_t = 3/8", length (L_t) = 4", and spacing = 12") within GAB material compacted to approximately 95% of max standard Proctor dry density at optimum moisture content (γ_{dmax} = 139 pcf, OMC = 6%)





Test No.	Test Specimen Width[(1)] W (in.)	Embedment Length L (in.)	Normal Stress σ_n (psf)	Pullout Rate (in/min)	Depth from Back Fill Surface[(4)] z (ft)	Pullout Resistance 1/5" $P_{0.2"}$ (lbs)	1/2" $P_{0.5"}$ (lbs)	3/4" $P_{0.75"}$ (lbs)	Max P_{max} (lbs)	Bearing Stress Factor[(2)] $N_q = \frac{P_{max}}{nL_t d_t \sigma_n}$ (-)	Coefficient of Apparent Friction $F^* = \frac{P_{max}}{2WL\sigma_n}$ (-)	Failure Mode[(3)] (-)
2A	2.0	48.0	200	0.04	1.4	1006	1412	1461	1571	188.5	5.89	Pullout
2B	2.0	48.0	600	0.04	4.3	1538	2276	2675	4284	171.4	5.36	Pullout
2C	2.0	48.0	1200	0.04	8.6	2235	3325	3989	6853	137.1	4.28	Pullout
2D	2.0	48.0	1800	0.04	12.9	2792	4206	4904	8400	112.0	3.50	Pullout
2E	2.0	48.0	2400	0.04	17.1	4125	5838	6692	10292	102.9	3.22	Pullout
2F	2.0	48.0	3600	0.04	25.7	4831	6408	7297	11928	79.5	2.48	Rupture
2G	2.0	48.0	4800	0.04	34.3	5104	6569	7733	12264	61.3	1.92	Rupture

NOTE:
(1) Test Specimen Width: the center-to-center distance between the two longitudinal bars.
(2) n: number of transverse bars embedded in soil (n = 4 for each test); L_t = transverse bar length (4"); and d_t = transverse bar diameter (3/8").
(3) Pullout failure indicated by a minimum displacement of 0.5" measured at the rear end of the steel grid at the completion of the test.
(4) Depth from backfill surface: normal stress (psf) divided by as-placed (moist) soil unit weight.

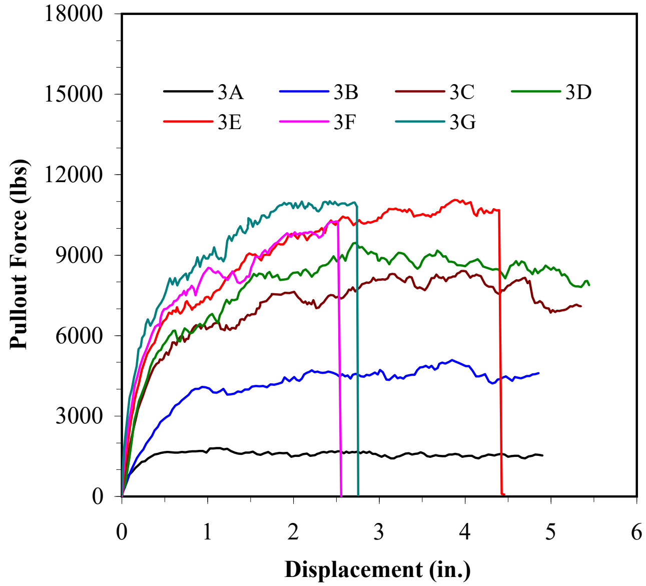
SGI TESTING SERVICES, LLC

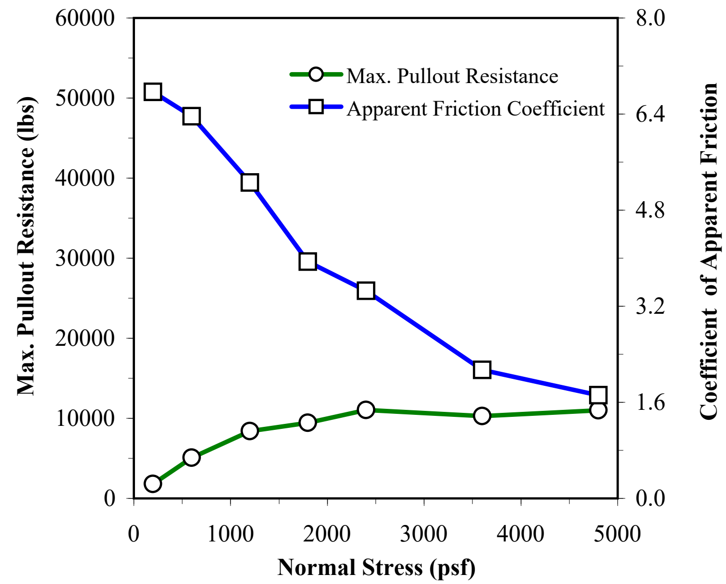
DATE REPORTED:	6/30/2022
FIGURE NO.	2
PROJECT NO.	SG22040
DOCUMENT NO.	
FILE NO.	

P22040-02.pullout.xls

ELEVATE INFRASTRUCTURE, LLC
STEEL GRID PULLOUT TESTING (ASTM D 6706)

TEST SERIES NO. 3: Elevate Ladder Strip welded steel bar mat (transverse bar diameter d_t = 3/8", length (L_t) = 4", and spacing = 12") within AASHTO #57 stone nominally compacted to approximately 98 pcf unit weight under dry conditions





Test No.	Test Specimen Width[1] W (in.)	Embedment Length L (in.)	Normal Stress σ_n (psf)	Pullout Rate (in/min)	Depth from Back Fill Surface[4] z (ft)	Pullout Resistance 1/5" $P_{0.2''}$ (lbs)	1/2" $P_{0.5''}$ (lbs)	3/4" $P_{0.75''}$ (lbs)	Max P_{max} (lbs)	Bearing Stress Factor[2] $N_q = \frac{P_{max}}{nL_t d_t \sigma_n}$ (-)	Coefficient of Apparent Friction $F^* = \frac{P_{max}}{2WL\sigma_n}$ (-)	Failure Mode[3] (-)
3A	2.0	48.0	200	0.04	2.0	1192	1649	1657	1805	216.6	6.77	Pullout
3B	2.0	48.0	600	0.04	6.1	1551	2914	3722	5092	203.7	6.37	Pullout
3C	2.0	48.0	1200	0.04	12.2	3365	5269	5874	8414	168.3	5.26	Pullout
3D	2.0	48.0	1800	0.04	18.4	3568	5719	6219	9454	126.1	3.94	Pullout
3E	2.0	48.0	2400	0.04	24.5	4244	6577	7263	11057	110.6	3.46	Rupture
3F	2.0	48.0	3600	0.04	36.7	4716	6991	7525	10261	68.4	2.14	Rupture
3G	2.0	48.0	4800	0.04	49.0	5510	7530	8255	11008	55.0	1.72	Rupture

NOTE:
(1) Test Specimen Width: the center-to-center distance between the two longitudinal bars.
(2) n: number of transverse bars embedded in soil (n = 4 for each test); L_t = transverse bar length (4"); and d_t = transverse bar diameter (3/8").
(3) Pullout failure indicated by a minimum displacement of 0.5" measured at the rear end of the steel grid at the completion of the test.
(4) Depth from backfill surface: normal stress (psf) divided by as-placed (moist) soil unit weight.

DATE REPORTED:	6/30/2022
FIGURE NO.	3
PROJECT NO.	SG22040
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

P22040-03.pullout.xls

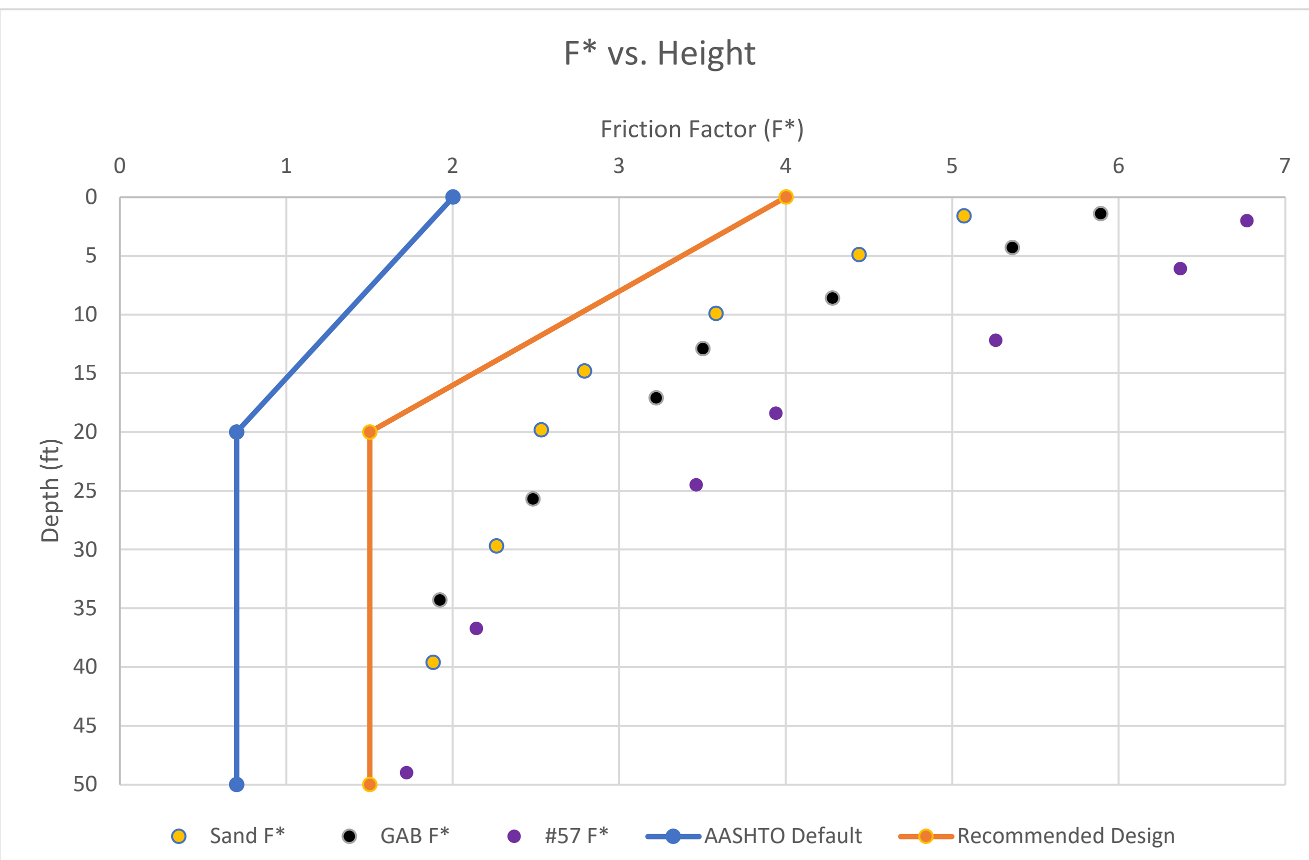
Ladder Strip

The pullout resistance factors (F*) from the test results presented in the report by SGI Testing Services, LLC Appendix B Figures 1-3 are plotted below. The recommended design F* was developed to be applicable for the most common backfills used in the reinforced zone on DOT projects. The AASHTO Default F*, i.e. the recommended value in the absence of testing, is plotted in blue for reference.

Normal	Sand		GAB		#57 Stone	
Stress (psf)	Depth (ft)	F*	Depth (ft)	F*	Depth (ft)	F*
200	1.6	5.1	1.4	5.9	2	6.8
600	4.9	4.4	4.3	5.4	6.1	6.4
1200	9.9	3.6	8.6	4.3	12.2	5.3
1800	14.8	2.8	12.9	3.5	18.4	3.9
2400	19.8	2.5	17.1	3.2	24.5	3.5
3600	29.7	2.3	25.7	2.5	36.7	2.1
4800	39.6	1.9	34.3	1.9	49	1.7

Recommended F* for Elevate Ladder Strip:
@ 0' depth: 4
@ 20' depth: 1.5

AASHTO Default F* for Elevate Ladder Strip:
@ 0' depth: 2
@ 20' depth: 0.67



Appendix A1.2.16W

Prepared for:

Elevate Infrastructure, LLC
2495 Bungalow Road
Morris, IL 60450

FINAL REPORT

PULLOUT TESTING
2.0 INCH WIDE WAVE STRIP
IN SAND, SANDY GRAVEL, AND
AASHTO #57 STONE

Prepared by:

SGI TESTING SERVICES, LLC

4405 International Blvd., Suite B-117
Norcross, GA 30093

Project Number SGI25019

21 April 2025

CAVEAT

The reported results apply only to the materials and test conditions used in the laboratory testing program. The results do not necessarily apply to other materials or test conditions. The test results should not be used in engineering analysis unless the test conditions model the anticipated field conditions. The testing was performed in accordance with general engineering testing standards and requirements. This testing report is submitted for the exclusive use of the client to whom it is addressed.

1. INTRODUCTION

SGI Testing Services, LLC (SGI) conducted a laboratory testing program to determine the pullout resistance of the Wave Strip in three granular soils (i.e., sand, sandy gravel, and AASHTO #57 stone). The sample preparation procedures and testing conditions used in the testing program were specified by Mr. Matt Austin of Elevate Infrastructure, LLC. All of the pullout tests were conducted at SGI located in Norcross, Georgia.

2. TEST MATERIALS

Two types of materials were used in this testing program. Descriptions of these materials are given below:

- *Reinforcement Material:* 2.0 inch wide by 0.157 inch thick Wave Strip steel strip with a wavelength of 50 mm (2 inch) and a wave height of 10 mm (0.4 inch) as shown in Figures 1 and 2.

- *Soil Material*: Sand, graded aggregate base (GAB) material (i.e., sandy gravel), and AASHTO #57 stone manufactured by crushing granite rock by Vulcan Materials Company – Norcross Quarry. Particle size analysis, standard Proctor compaction for sand and GAB material and relative density for AASHTO #57 stone, and direct shear tests were conducted on the three soils, and the test results are presented in Appendix A.

Wave Strip steel strip samples were provided by Elevate Infrastructure, LLC. Bulk samples of the three soils were obtained by SGI from Vulcan Materials Company.

3. PULLOUT TEST EQUIPMENT

The pullout testing device used in this testing program had plan dimensions of 0.6 m by 1.5 m (2 ft by 5 ft) and an overall depth of 300 mm (12 in.). Normal (vertical) stresses were applied to the testing specimen by using dead weights for low normal stress or air cylinders for high normal stress, and pullout (horizontal) loads were applied to the test specimen through two hydraulic cylinders. The schematic diagrams of the pullout testing device are shown in Figures 1 and 2.

4. TEST METHOD AND PROCEDURES

The pullout tests were performed in accordance with the ASTM D 6706, "*Measuring Geosynthetic Pullout Resistance in Soil*" with modifications. For each pullout test, the test specimen was set up in accordance with the following procedures and tested under the specific conditions as described below:

- The soil was placed in the lower half of the pullout box and compacted by hand tamping to form a 150-mm (6-inch) thick layer. The soil was compacted to approximately 95% of maximum dry unit weight;

- For each pullout test the steel strip was placed on top of the compacted soil as shown in Figures 5, 6, and 7. The front end of the steel strip was connected to the pullout loading harness;

- Two "tell-tale" wires were connected to the front and rear end of the steel strip. Displacements at the front and rear end of the steel strip were monitored during testing using linear variable differential transformers (LVDTs);

- The soil was placed in the upper half of the pullout box and compacted by hand tamping to form a 150-mm (6-inch) thick layer. The soil was compacted to approximately 95% of maximum dry unit weight;

- A load cell was then attached to the pullout loading harness to measure the pullout load of the steel strip at the specimen clamp. An LVDT was fixed to the specimen clamp to measure the total pullout displacement at the specimen clamp. A complete pullout test setup is shown in Figure 4;

- A specific normal stress was then applied to the test specimen by using dead weights for low normal stress or air cylinders for high normal stress; and

- After application of the normal stress, the steel strip was subjected to pullout loading by displacing the steel strip at a constant displacement rate of 1 mm/min (0.04 in./min) as measured at the specimen clamp. The steel strip specimen was pulled until the pullout failure occurred.

Completed pullout test setups are shown in Figure 8 (normal stress applied by using dead weight) and Figure 9 (normal stress applied by using air cylinders).

5. PULLOUT TEST RESULTS

Three series of pullout tests were performed in this testing program. For each test series, the test conditions and test results are presented on a summary page in Appendix B. The summary page includes:

- Pullout force versus displacement graph;
- Pullout resistance versus normal stress graph; and
- A table that summarizes test conditions, pullout resistances at selected displacements, maximum pullout resistance, and coefficient of apparent friction at a displacement of 0.75 inch and at maximum pullout resistance.

The coefficient of apparent friction at 0.75 inch was calculated using the equation as follows:

$$F^* = \frac{P_{0.75"}}{2L_e W \sigma_n}$$

where:

$P_{0.75"}$	=	Pullout resistance at a displacement of 0.75 inch;
F^*	=	Coefficient of apparent friction at a displacement of 0.75 inch;
L_e	=	Initial embedded length of the strip;
W	=	Initial width of the strip, and
σ_n	=	Total normal stress applied to the strip.

The coefficient of apparent friction at maximum pullout resistance was calculated using the equation as follows:

$$F^*_{\max} = \frac{P_{\max}}{2 L_e W \sigma_n}$$

where:

P_{max}	=	Maximum pullout resistance;
F^*_{max}	=	Coefficient of apparent friction at P_{max};
L_e	=	Initial embedded length of the strip;
W	=	Initial width of the strip, and
σ_n	=	Total normal stress applied to the strip.

For each pullout test, the Wave Strip steel strip was pulled until the pullout failure occurred. The pullout failure was assumed when the tell-tale wire attached to the rear end of the Wave Strip steel strip specimen displaced at least 25 mm (1 in.) at the completion of testing.

6 CLOSURE

SGI appreciates the opportunity to provide laboratory testing services to Elevate Infrastructure, LLC. Should you have any questions regarding this report, or if you require additional information, please do not hesitate to contact the undersigned.

Sincerely,

Zehong Yuan, Ph.D., P.E.
Laboratory Manager

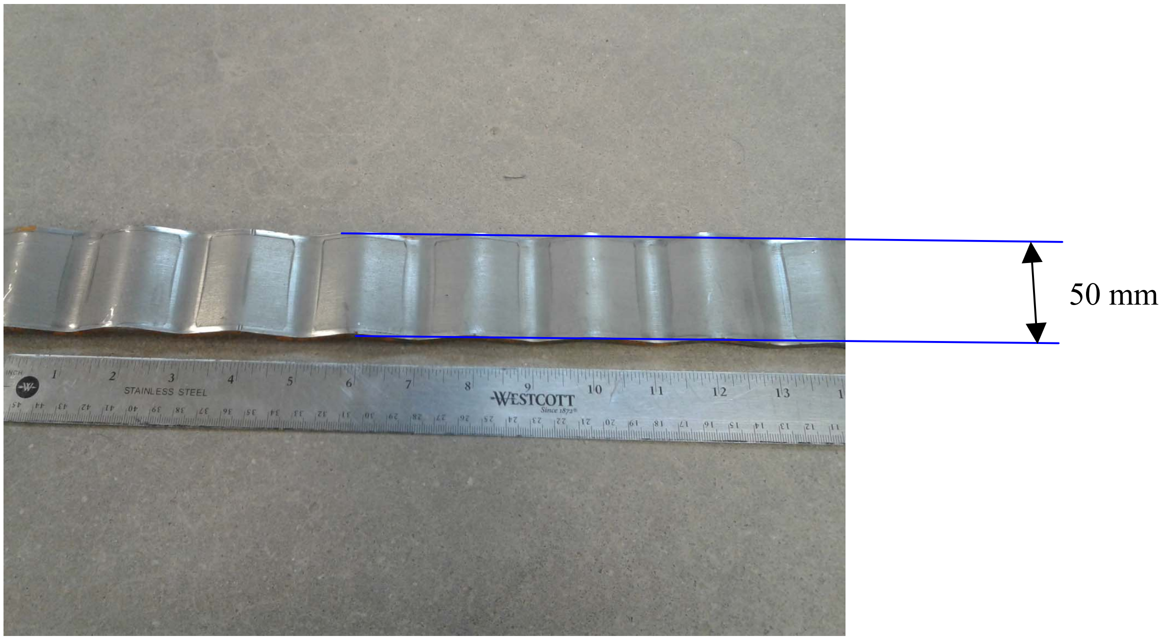


Figure 1. The Wave Strip steel strip with a 50 mm (2") wavelength.

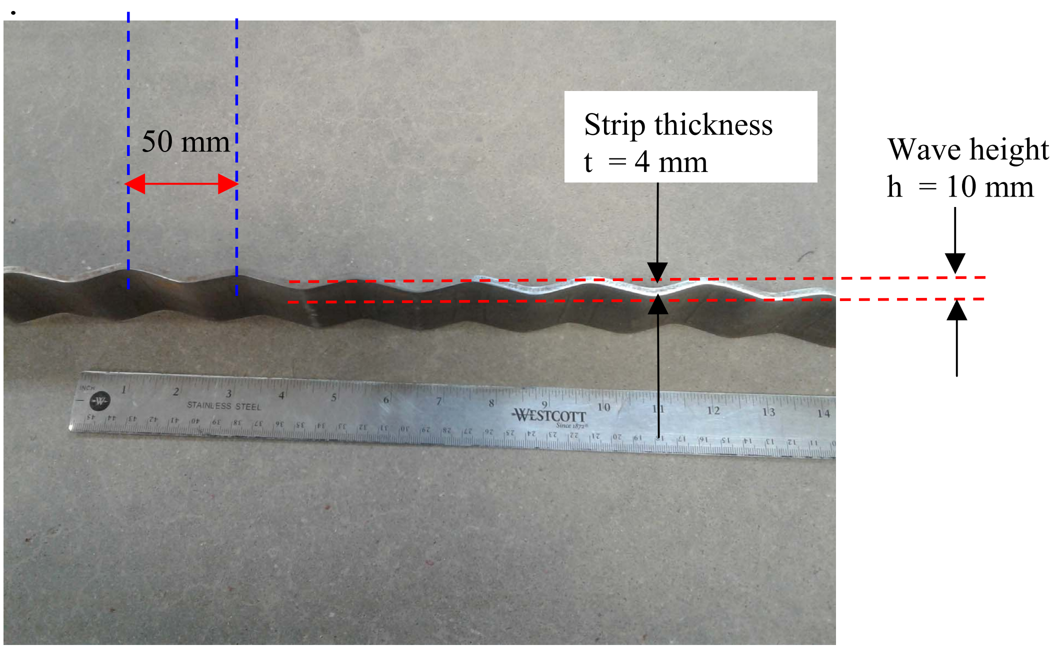


Figure 2. Wavelength (50 mm), wave height (10 mm) and thickness (4 mm) of the Wave Strip.

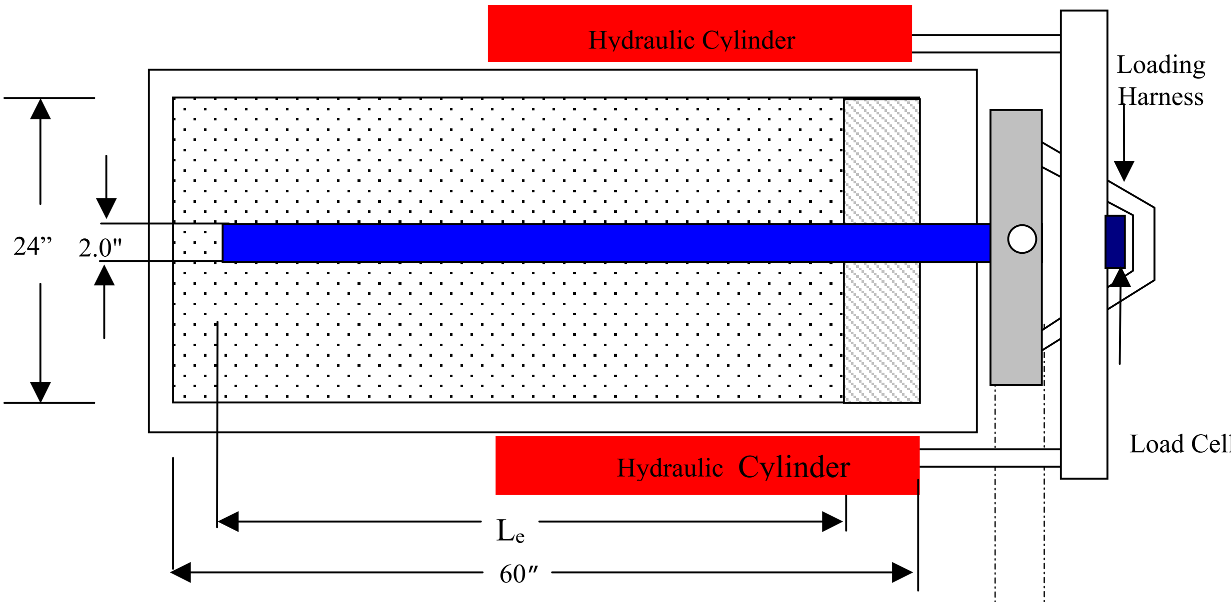


Figure 3. Plan view of pullout test setup (Note: not to scale).

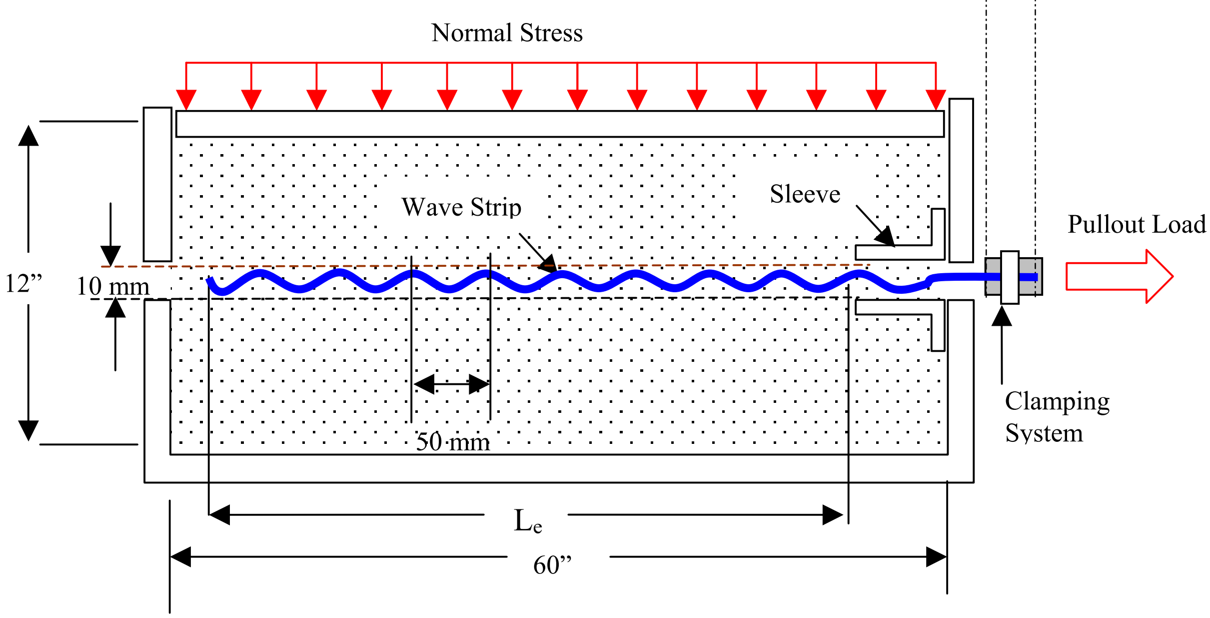


Figure 4. Cross-section of pullout test setup (Note: not to scale).

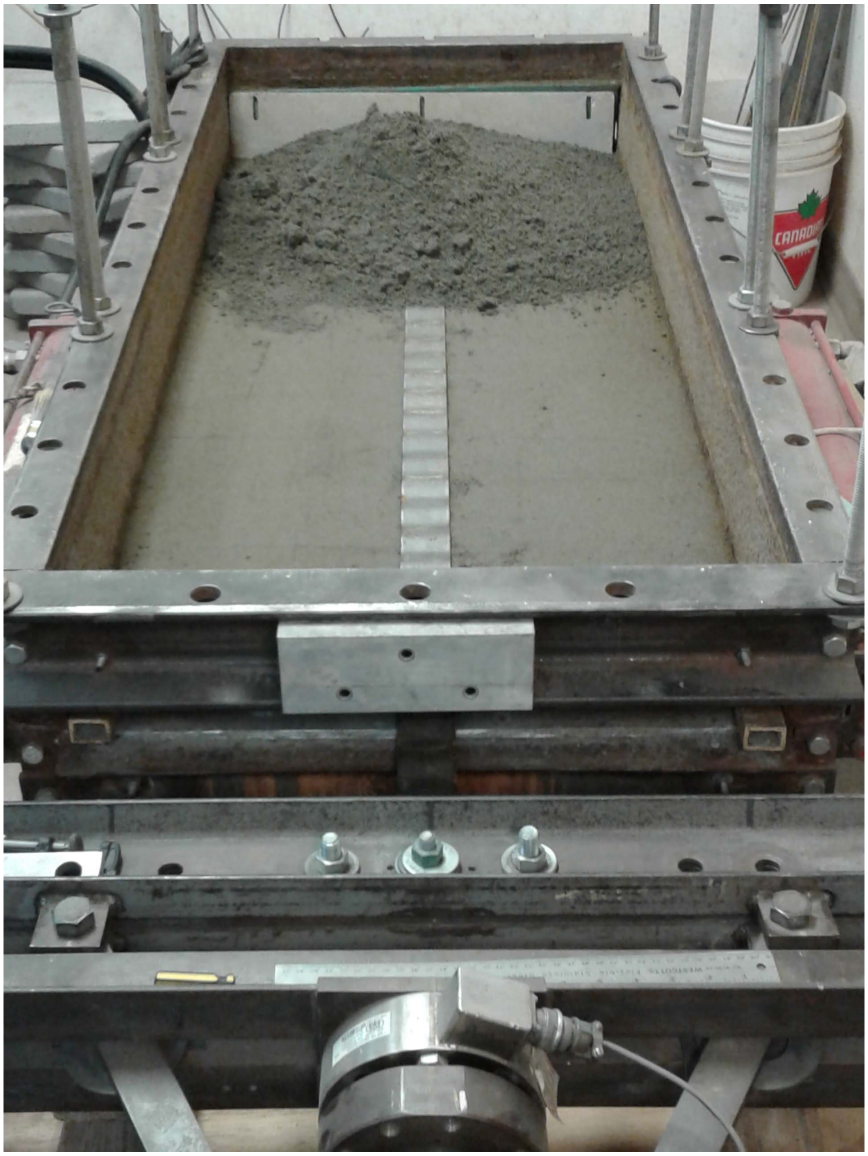


Figure 5. 2.0" wide Wave Strip placed on compacted sand.

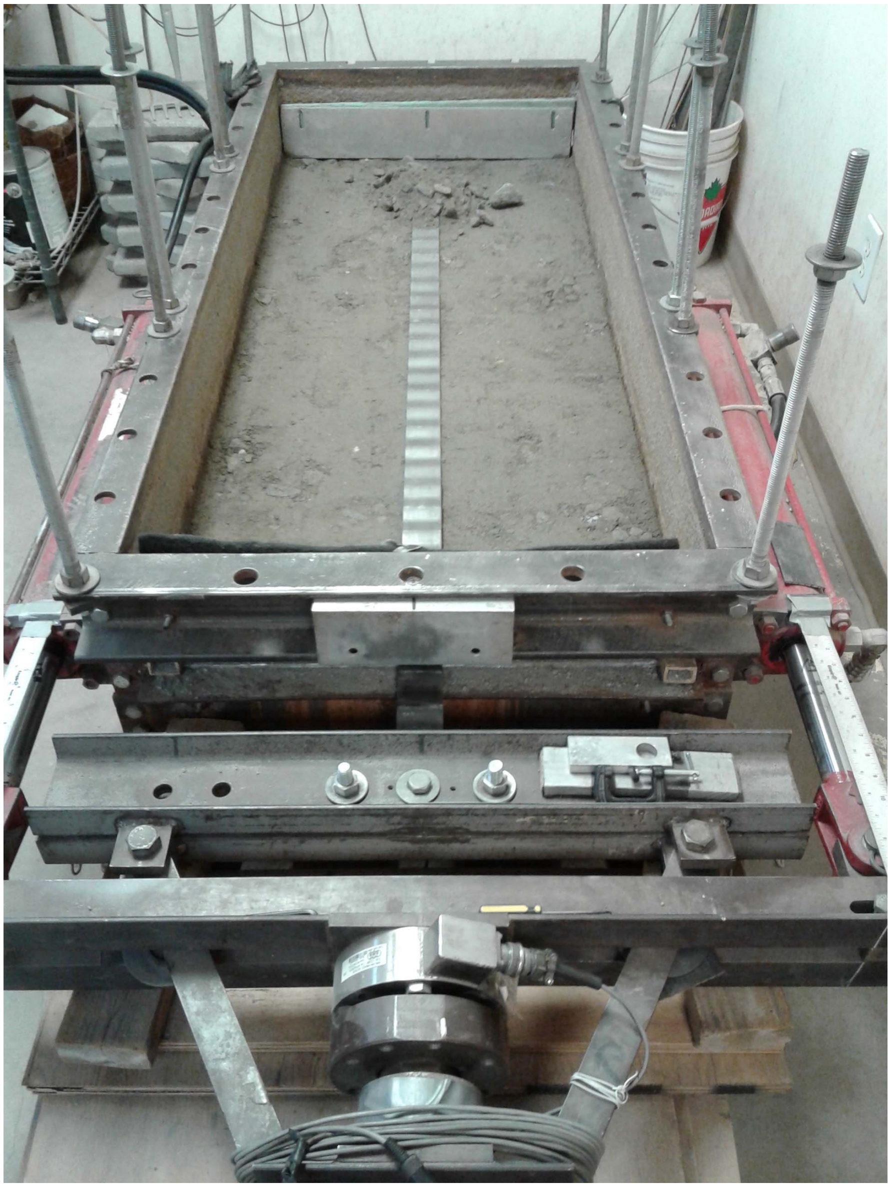


Figure 6. 2.0" wide Wave Strip placed on compacted sandy gravel (GAB material).

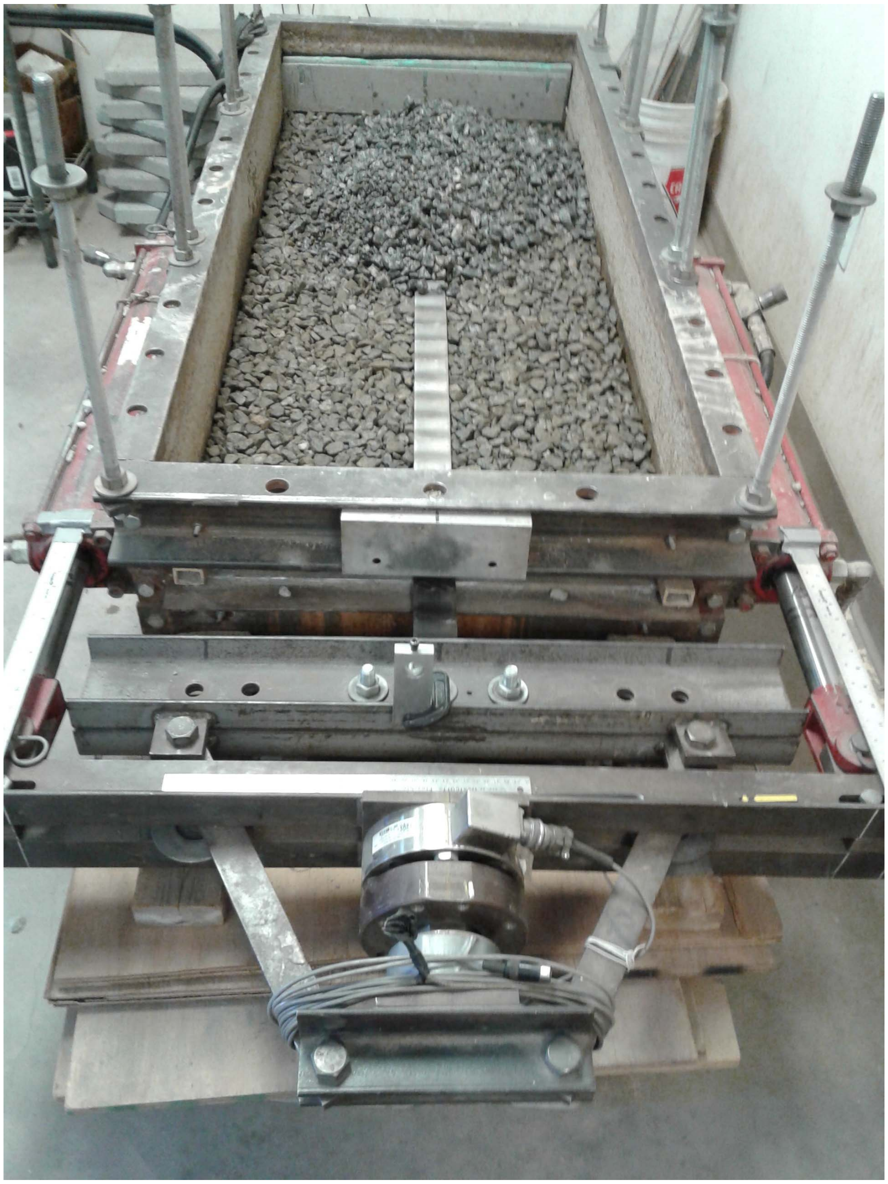


Figure 7. 2.0" wide Wave Strip placed on compacted AASHTO #578 stone.

Figure 8. A complete pullout test setup (200 psf normal stress by dead weight).

Figure 9. A complete pullout test setup (normal stress by using air cylinders).

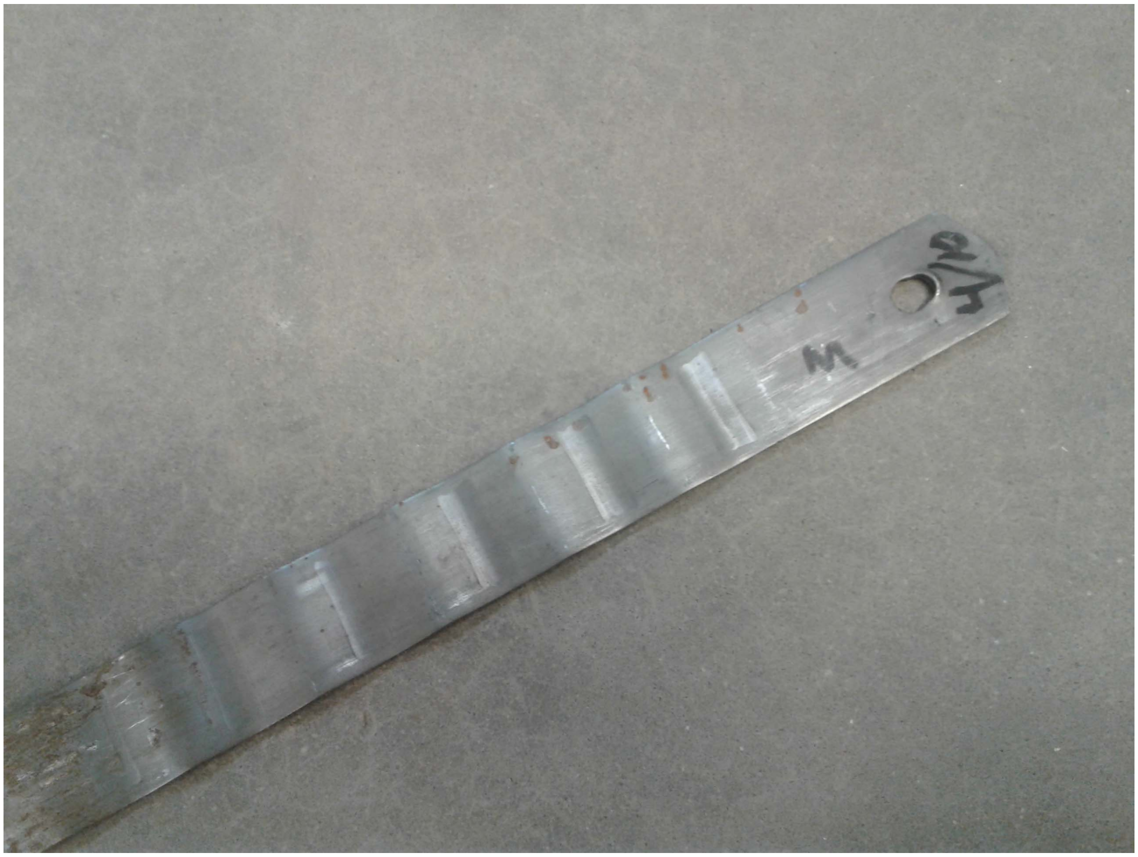


Figure 10. Failure mode: stretching of the Wave Strip connection hole observed at the completion of high pressure (4800 psf) test #3G in AASHTO #57 stone.

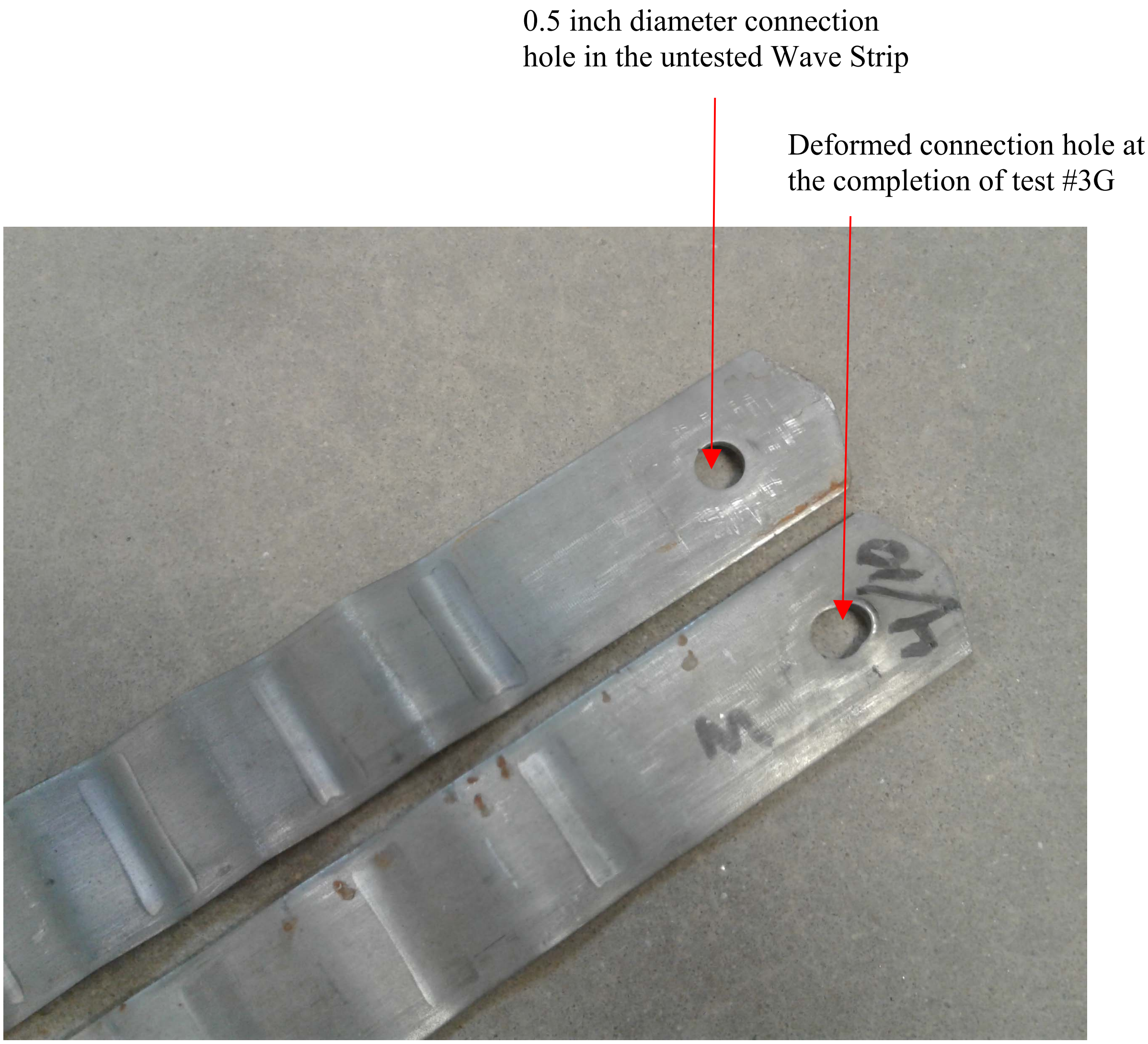


Figure 11. Failure mode: Deformed connection hole at the completion of high pressure (4800 psf) test #3G in AASHTO #57 stone.

APPENDIX A

SOIL TEST RESULTS

SGI Testing Services, LLC

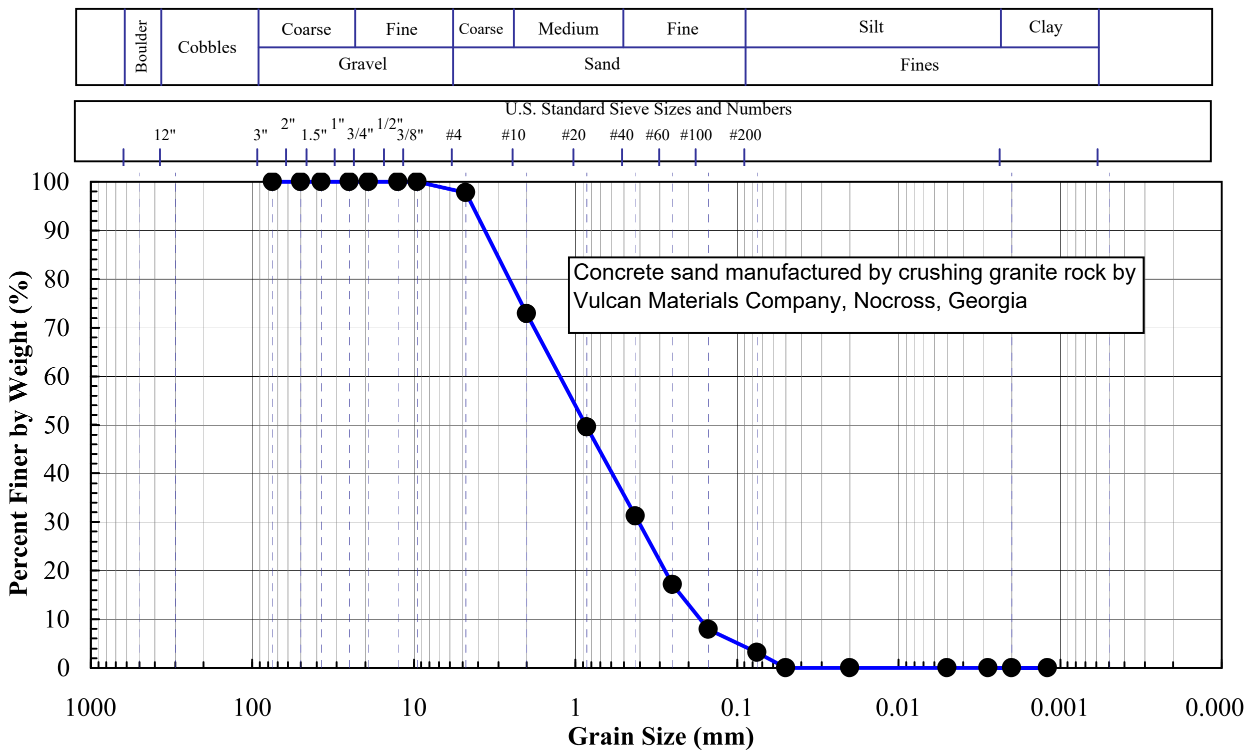
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931 8222 Fax: (770) 931 8240

Project Name:	Pullout
Project No:	SGI25019
Client Sample ID:	Sand
Lab Sample No:	SGISP2025

ASTM D 421, D 422, D 4318

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits, Classification

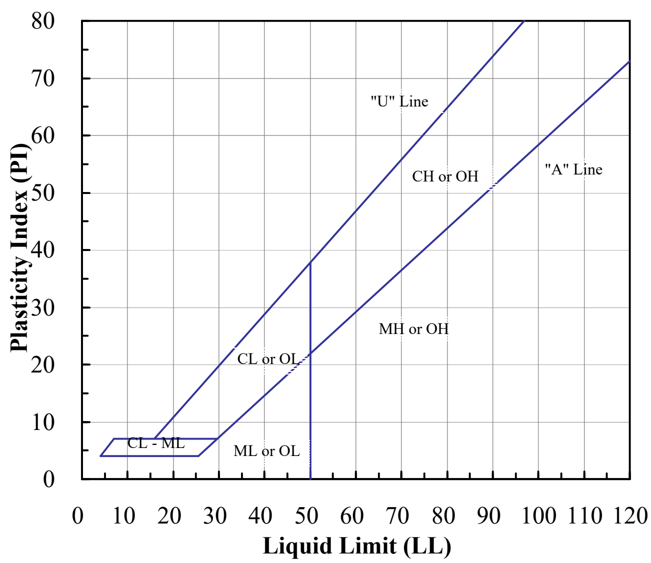


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	100.0
3/4"	19	100.0
1/2"	12.5	100.0
3/8"	9.5	100.0
#4	4.75	97.8
#10	2.00	72.8
#20	0.850	49.5
#40	0.425	31.2
#60	0.250	17.1
#100	0.150	7.9
#200	0.075	3.1

Hydrometer Particle Diameter (mm)	% Finer
0.0500	
0.0200	
0.0050	
0.0020	
0.0012	

Gravel (%):	2.2
Sand (%):	94.7
Fines (%):	3.1
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	7.4
Coeff. Curv. (Cc):	0.8



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (%)	PL (%)	PI (-)	Engineering Classification
Sand	SGISP2025	-	3.1				SP (Poorly-Graded Sand)

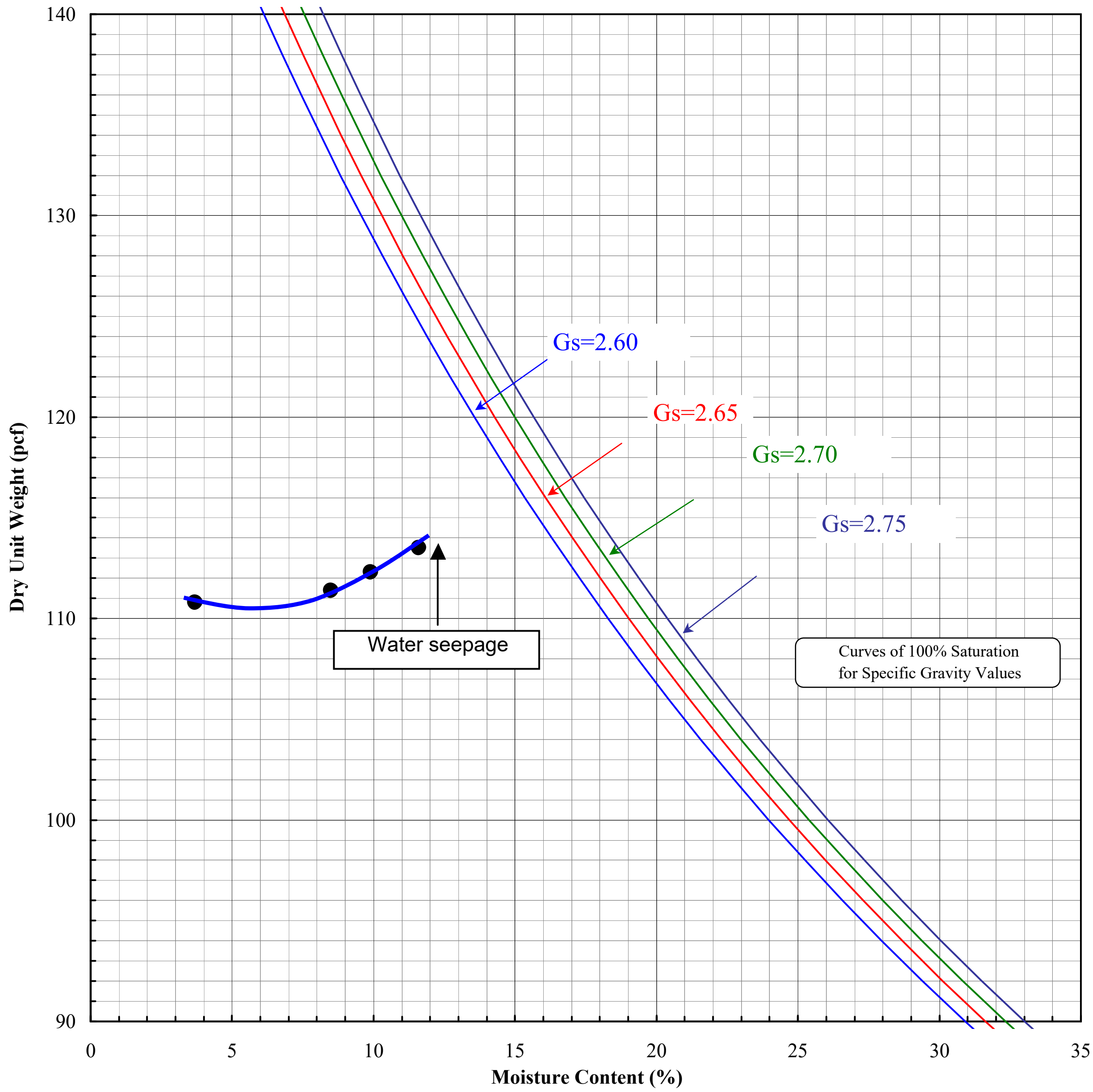
Note(s):

SGI Testing Services, LLC

4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931 8222 Fax: (770) 931 8240

Project Name:	Pullout
Project No:	SGI25019
Client Sample ID:	Sand
Lab Sample No:	SGISP2025

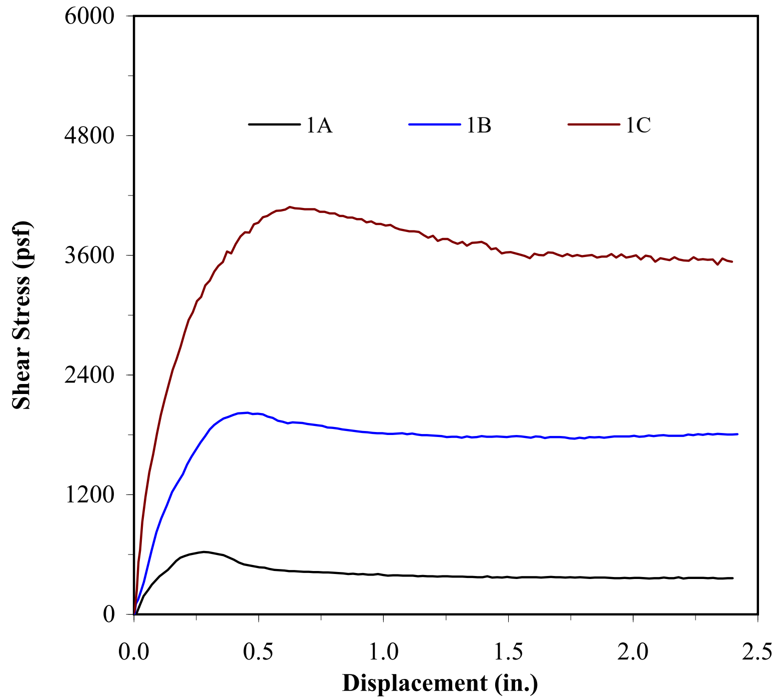
COMPACTION MOISTURE-DENSITY RELATIONSHIP (ASTM D 698 - Method A)

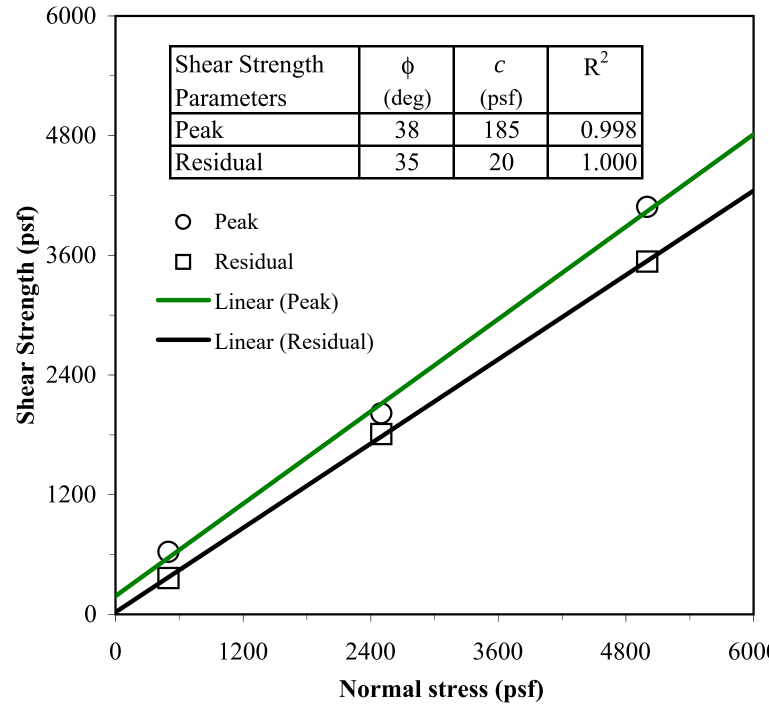


Client Sample ID.	SGI Sample ID NO.	Compaction Data		Maximum Dry Unit Weight and Optimum Moisture Content			
				Measured		Corrected	
		ω_i (%)	γ_d (pcf)	ω_{om} (%)	γ_{dmax} (pcf)	ω_{om} (%)	γ_{dmax} (pcf)
Sand	SGISP2025	3.7	110.8	11.6	113.5		
		8.5	111.4				
		9.9	112.3				
		11.6	113.5				

% Retained on #4 Sieve: 2.2
% Retained on #3/8" Sieve:
% Retained on 3/4" Sieve:
% Retained on 2.0" Sieve:

Internal shear strength of sand compacted to approximately 95% of maximum standard Proctor dry density at OMC
(γ_{dmax} = 113.5 pcf, OMC = 11.6%)





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Target Soil Compaction γ_d (pcf)	Target Soil Compaction ω_i (%)	Target Soil Compaction ω_f (%)	After γ_d (pcf)	After ω_i (%)	After ω_f (%)	Shear Strength τ_P (psf)	Shear Strength τ_R (psf)	Failure Mode
1A	12 x 12	500	0.04	-	-	500	1.0	107.8	11.6					625	362	(1)
1B	12 x 12	2500	0.04	-	-	2500	1.0							2015	1806	(1)
1C	12 x 12	5000	0.04	-	-	5000	1.0							4086	3535	(1)

NOTES:
(1) Sliding (i.e., shear failure) was forced to occur along the shear plane between the upper and lower shear box.
(2) The reported total-stress parameters of friction angle and cohesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The residual shear strength was calculated using the shear force measured at the end of the test.

DATE OF REPORT:	4/20/2025
FIGURE NO.	A-3
PROJECT NO.	SGI25019
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

SGI Testing Services, LLC

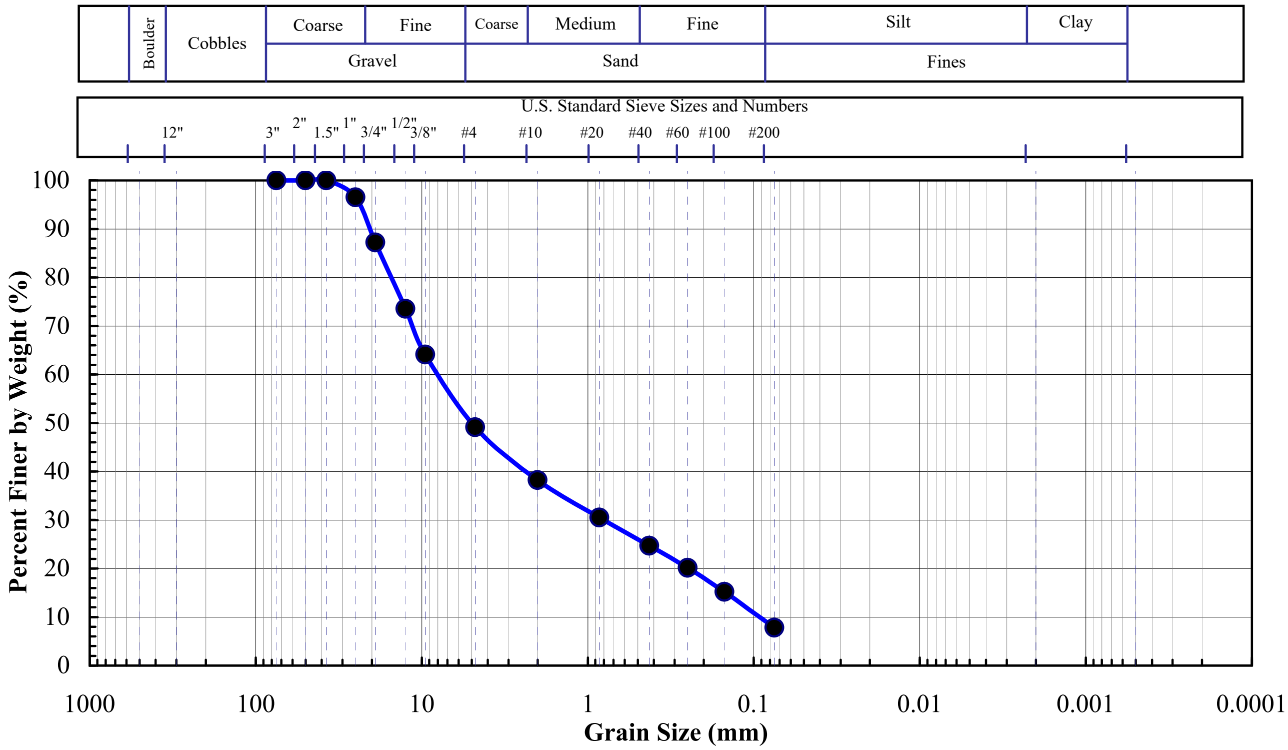
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931 8222 Fax: (770) 931 8240

Project Name:	Pullout
Project No:	SGI25019
Client Sample ID:	Sandy Gravel
Lab Sample No:	SGIGAB2025

ASTM D 421, D 422, D 4318

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits,

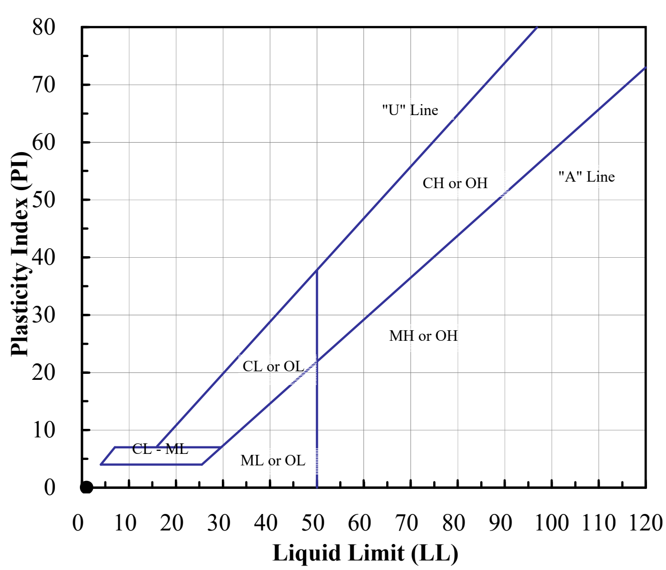


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	96.5
3/4"	19	87.2
1/2"	12.5	73.5
3/8"	9.5	64.1
#4	4.75	49.1
#10	2.00	38.2
#20	0.850	30.5
#40	0.425	24.7
#60	0.250	20.1
#100	0.150	15.2
#200	0.075	7.8

Hydrometer Particle Diameter (mm)	% Finer
0.0288	
0.0184	
0.0109	
0.0079	
0.0012	

Gravel (%):	50.9
Sand (%):	41.3
Fines (%):	7.8
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	85.3
Coeff. Curv. (Cc):	0.88



Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (%)	PL (%)	PI (-)	Engineering Classification
Sandy Gravel	SGIGAB2025	-	7.8	-	-	-	GP-GM

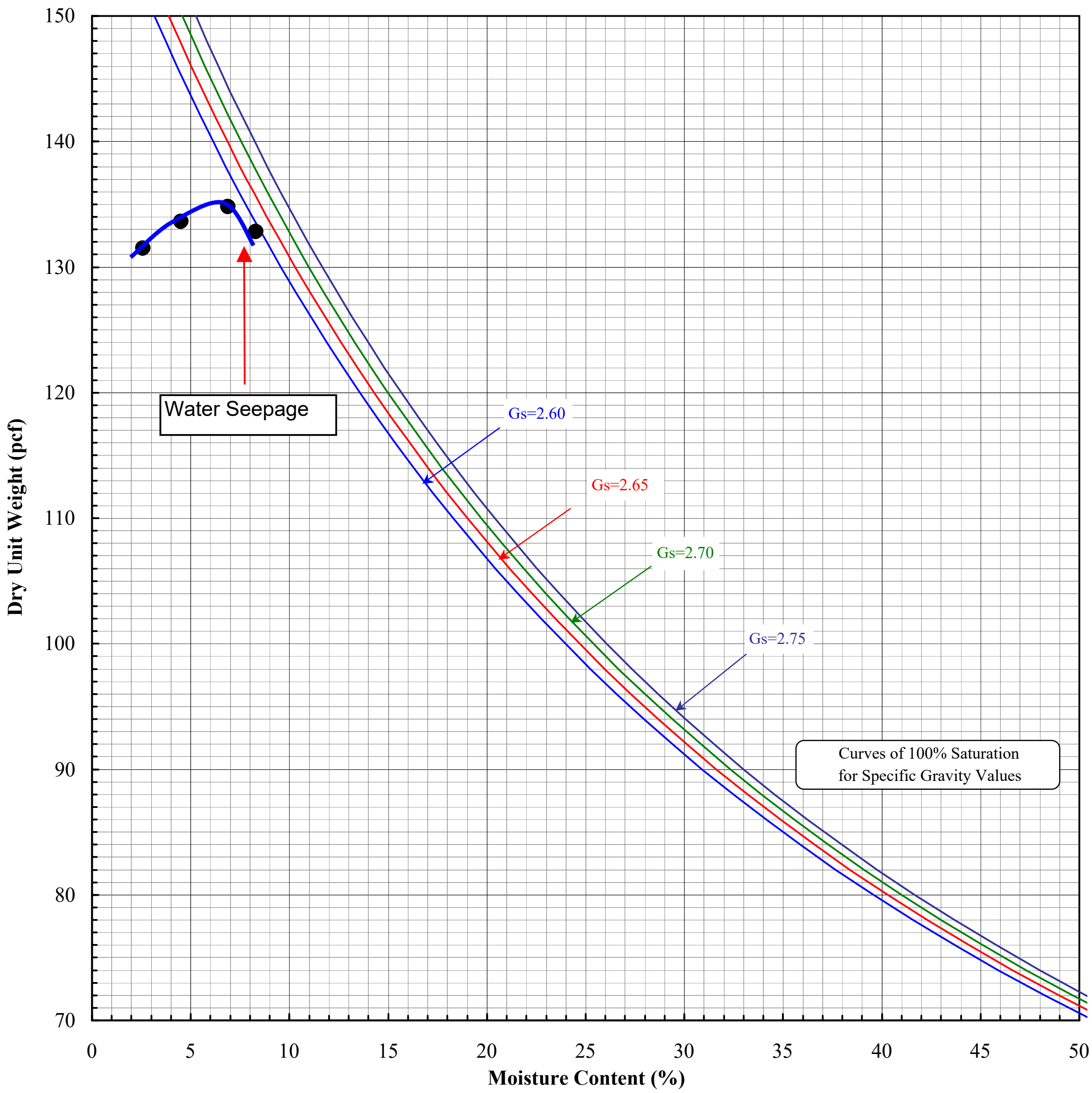
Note(s):

SGI Testing Services, LLC

4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931 8222 Fax: (770) 931 8240

Project Name:	Pullout
Project No:	SGI25019
Client Sample ID:	Sandy Gravel
Lab Sample No:	SGIGAB2025

ASTM D698 **COMPACTION MOISTURE-DENSITY RELATIONSHIP** **Standard - Method C**



Client Sample ID.	SGI Sample ID NO.	Compaction Data		Maximum Dry Unit Weight and Optimum Moisture Content			
				Measured		Corrected	
		ω_i (%)	γ_d (pcf)	ω_{om} (%)	γ_{dmax} (pcf)	ω_{om} (%)	γ_{dmax} (pcf)
Sandy Gravel	SGIGAB2025	2.6	131.5	7.0	135.0	6.4	138.5
		4.5	133.6				
		6.9	134.8				
		8.3	132.8				

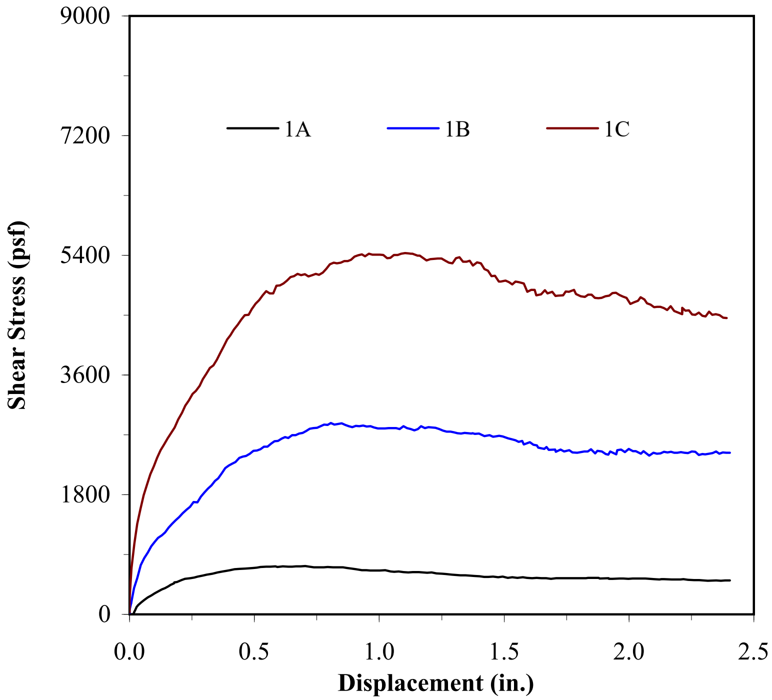
% Retained on #4 Sieve:
% Retained on #3/8" Sieve:
% Retained on 3/4" Sieve: 12.8
% Retained on 2.0" Sieve:

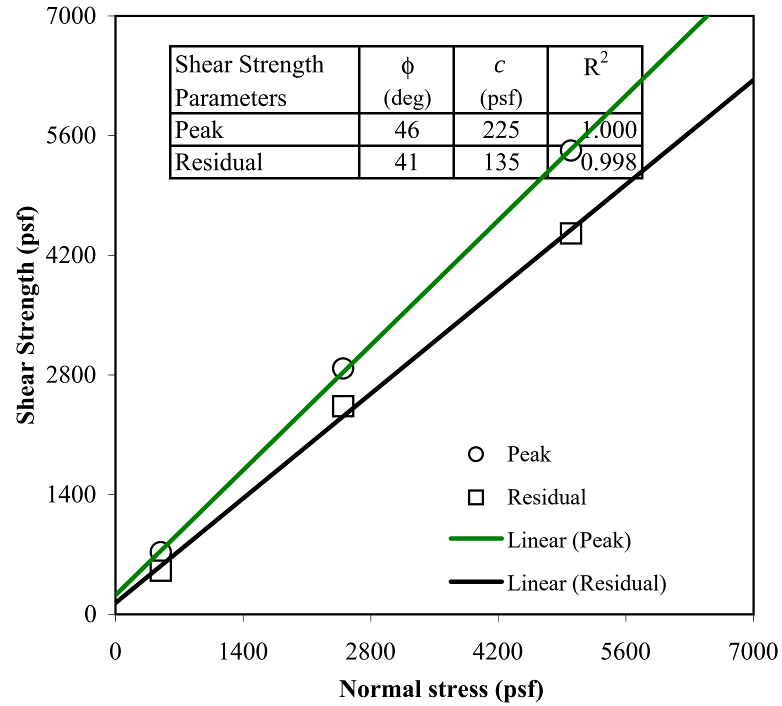
A-5

SGI.GAB.Compaction-2025.xls

ELEVATE INFRASTRUCTURE, LLC
DIRECT SHEAR TESTING (ASTM D 3080)

Internal shear strength of sandy gravel (graded aggregate base material) compacted to approximately 95% of maximum standard Proctor dry density at OMC (γ_{dmax} = 138.5 pcf, OMC = 6.4%)





Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking		Consolidation		Target Soil Compaction			After			Shear Strength		Failure Mode
				Stress (psf)	Time (hour)	Stress (psf)	Time (hour)	γ_d (pcf)	ω_i (%)	ω_f (%)	γ_d (pcf)	ω_i (%)	ω_f (%)	τ_P (psf)	τ_R (psf)	
1A	12 x 12	500	0.04	-	-	500	1.0							725	509	(1)
1B	12 x 12	2500	0.04	-	-	2500	1.0	131.6	6.4					2876	2432	(1)
1C	12 x 12	5000	0.04	-	-	5000	1.0							5425	4455	(1)

NOTES:
(1) Sliding (i.e., shear failure) was forced to occur along the shear plane between the upper and lower shear box.
(2) The reported total-stress parameters of friction angle and cohesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The residual shear strength was calculated using the shear force measured at the end of the test.

DATE OF REPORT:	4/20/2025
FIGURE NO.	A-6
PROJECT NO.	SGI25019
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

SGI.GAB.Shear-2025A.xls

SGI Testing Services, LLC

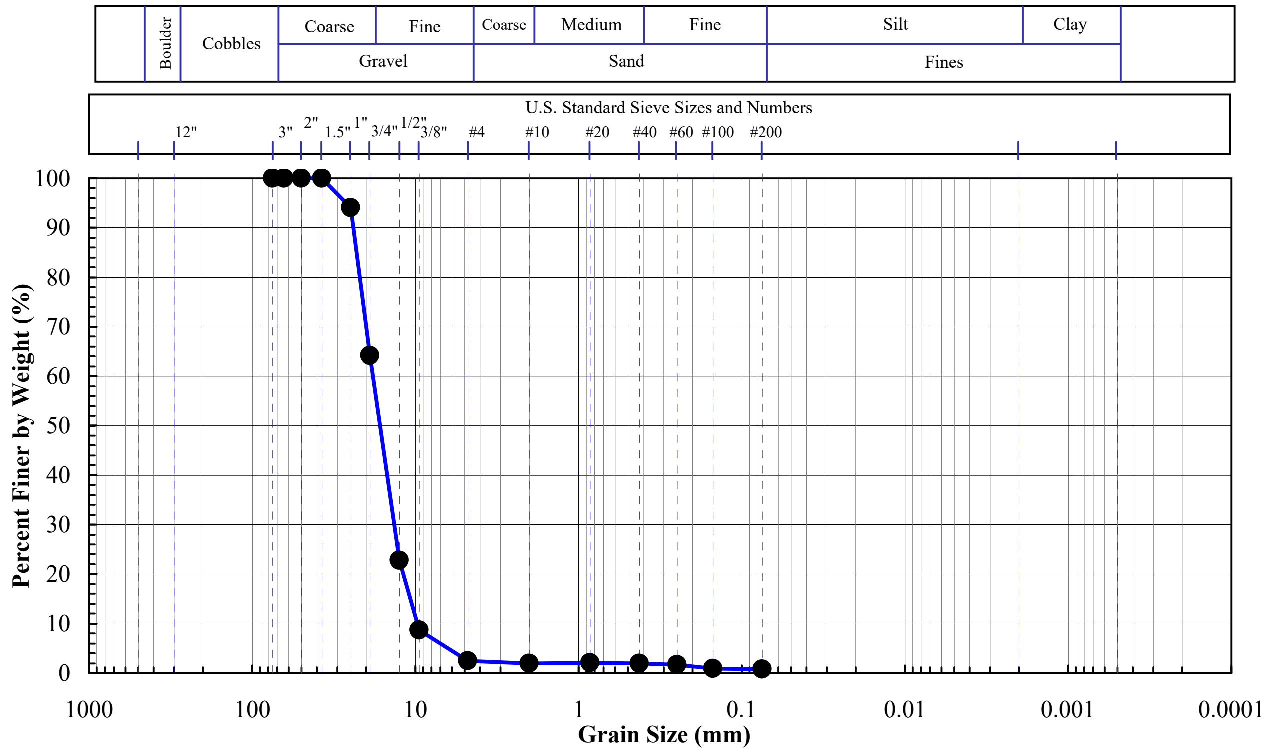
4405 International Blvd., Suite B-117, Norcross, GA 30093
Ph: (770) 931-8222 Fax: (770) 931-8240

Project Name:	Pullout
Project No:	SGI25019
Client Sample ID:	AASHTO #57 Stone
Lab Sample No:	SGIGP2025

ASTM D 421, D 422, D 4318

SOIL INDEX PROPERTIES

Moisture Content, Grain Size, Atterberg Limits,

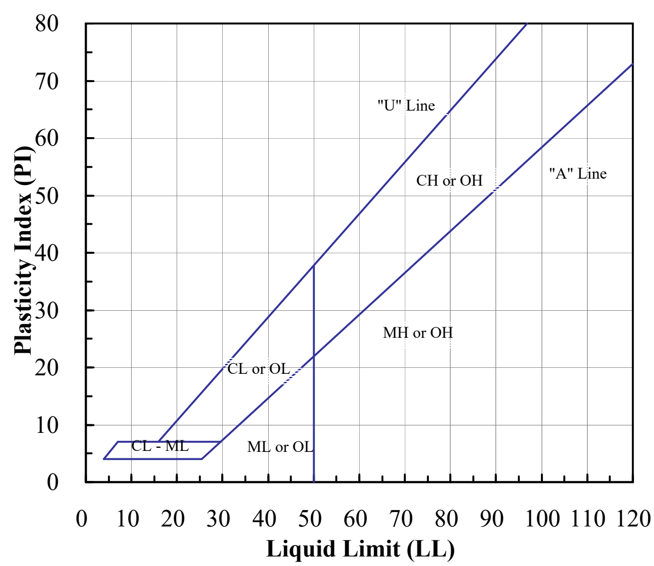


Sieve No.	Size (mm)	% Finer
3"	75	100.0
2"	50	100.0
1.5"	37.5	100.0
1"	25	94.0
3/4"	19	64.2
1/2"	12.5	22.8
3/8"	9.5	8.7
#4	4.75	2.5
#10	2.00	2.0
#20	0.850	2.1
#40	0.425	2.0
#60	0.250	1.7
#100	0.150	0.9
#200	0.075	0.8

Hydrometer Particle Diameter (mm)	% Finer
0.0340	
0.0220	
0.0064	
0.0032	
0.0013	

Gravel (%):	97.5
Sand (%):	1.7
Fines (%):	0.8
Silt (%):	
Clay (%):	

Coeff. Unif. (Cu):	1.9
Coeff. Curv. (Cc):	1.0



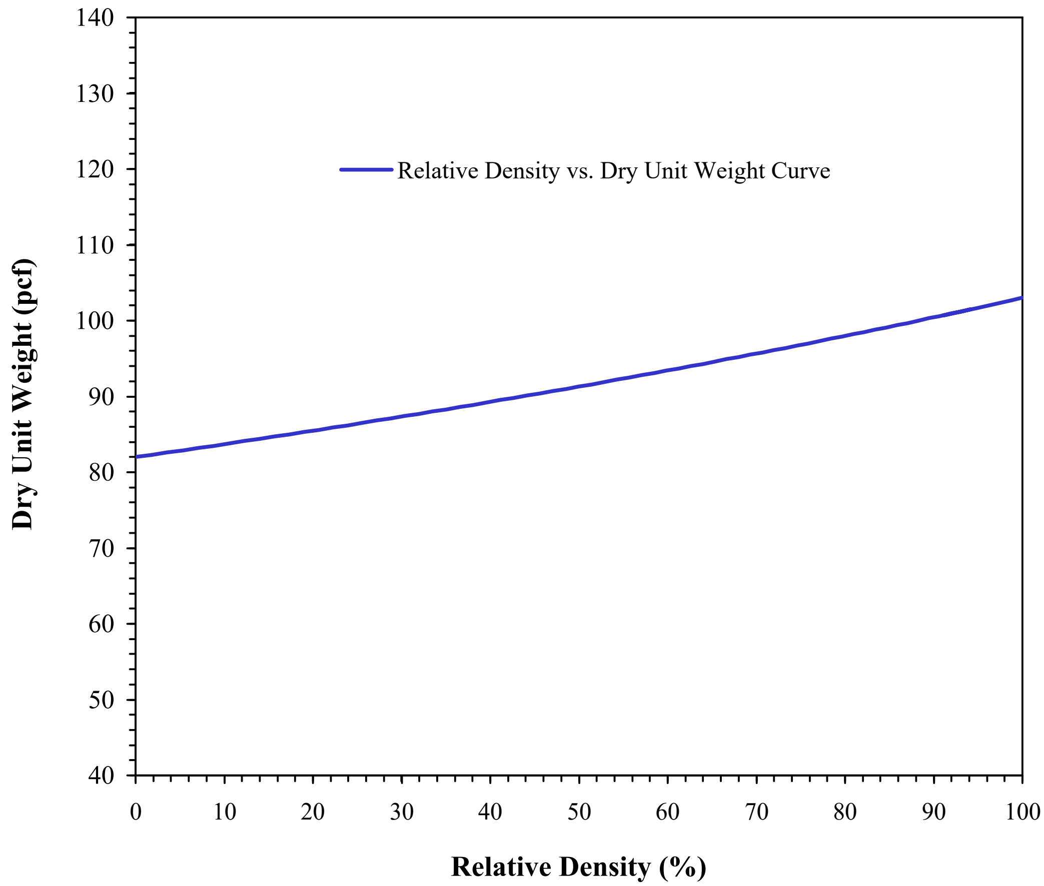
Client Sample ID.	Lab Sample No:	Moisture Content (%)	Fines Content < No. 200 (%)	Atterberg Limits LL (%)	PL (%)	PI (-)	Engineering Classification
AASHTO #57 Stone	SGIGP2025		0.8				GP (Poorly Graded Gravel)

ELEVATE INFRASTRUCTURE, LLC

RELATIVE DENSITY (ASTM D 4253/4254 - Dry Method)

AASHTO # 57 Stone

SGI Lab Sample ID: SGIGP2025



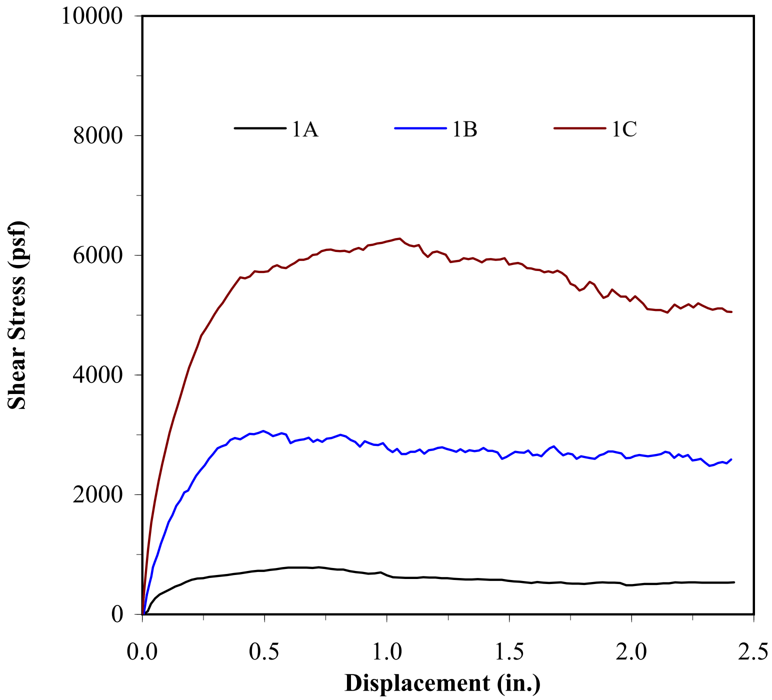
Target Property	Diameter of Mold (in.)	Height of Mold (in.)	Average Height of Sample (in.)	Volume of Sample (ft^3)	Dry Weight of Sample (g)	Dry Unit Weight (pcf)
Minimum Dry Unit Weight	5.99	7.70	7.70	0.126	4673	82.0
Maximum Dry Unit Weight	5.99	7.70	6.11	0.100	4660	103.0

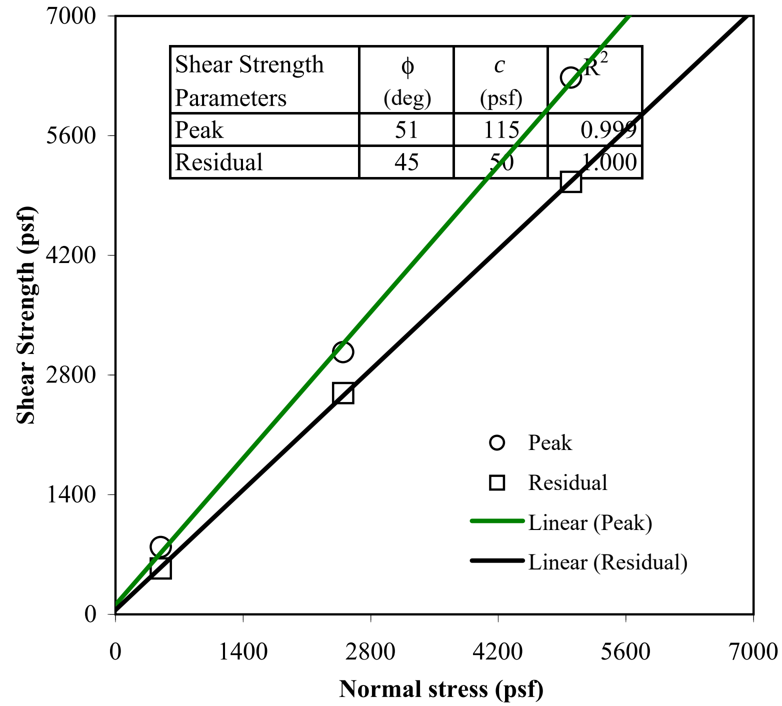
DATE REPORTED:	4/22/2025
FIGURE NO.	A-8
PROJECT NO.	SGI25019
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

ELEVATE INFRASTRUCTURE, LLC
DIRECT SHEAR TESTING (ASTM D 3080)

Internal shear strength of AASHTO #57 stone compacted to approximately 95% of maximum density under dry conditions
(γ_{dmax} = 103 pcf)





Shear Strength Parameters	ϕ (deg)	c (psf)	R^2
Peak	51	115	0.999
Residual	45	50	1.000

Test No.	Shear Box Size (in. x in.)	Normal Stress (psf)	Shear Rate (in./min)	Soaking Stress (psf)	Soaking Time (hour)	Consolidation Stress (psf)	Consolidation Time (hour)	Target Soil Compaction γ_d (pcf)	Target Soil Compaction ω_i (%)	Target Soil Compaction ω_f (%)	After γ_d (pcf)	After ω_i (%)	After ω_f (%)	Shear Strength τ_P (psf)	Shear Strength τ_R (psf)	Failure Mode
1A	12 x 12	500	0.04	-	-	500	1.0	97.9						786	537	(1)
1B	12 x 12	2500	0.04	-	-	2500	1.0							3065	2588	(1)
1C	12 x 12	5000	0.04	-	-	5000	1.0							6276	5056	(1)

NOTES:
(1) Sliding (i.e., shear failure) was forced to occur along the shear plane between the upper and lower shear box.
(2) The reported total-stress parameters of friction angle and cohesion were determined from a best-fit line drawn through the test data. Caution should be exercised in using these strength parameters for applications involving normal stresses outside the range of the stresses covered by the test series. The residual shear strength was calculated using the shear force measured at the end of the test.

SGI TESTING SERVICES, LLC

DATE OF REPORT:	4/20/2025
FIGURE NO.	A-9
PROJECT NO.	SGI25019
DOCUMENT NO.	
FILE NO.	

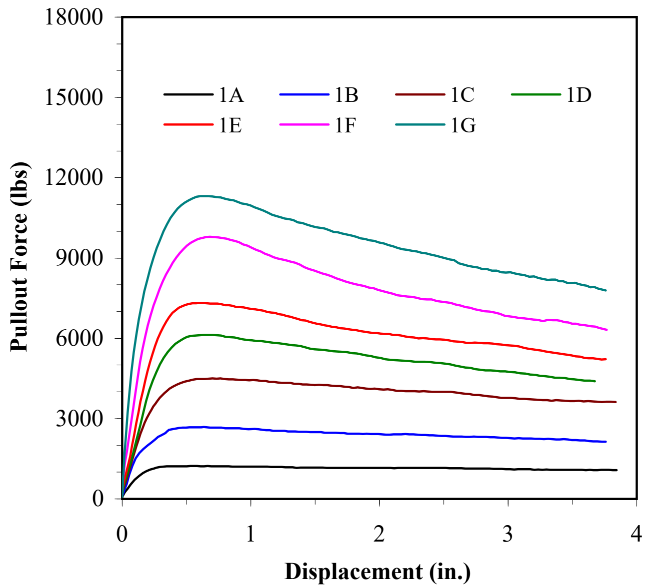
SGI.GP.Shear-2025.xls

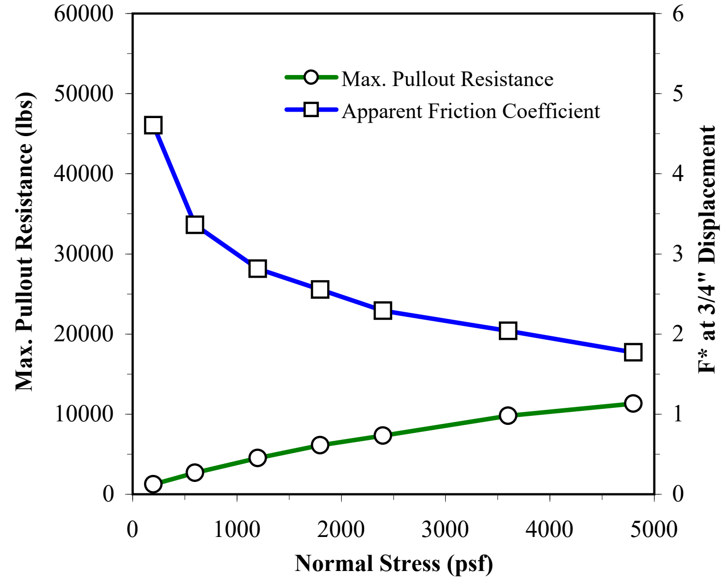
APPENDIX B

PULLOUT TEST RESULTS

ELEVATE INFRASTRUCTURE, LLC
STEEL STRIP PULLOUT TESTING (ASTM D 6706)

TEST SERIES NO. 1: 2-inch wide Wave Strip within sand compacted to approximately 95% of max standard Proctor dry density at optimum moisture content (γ_{dmax} = 113.5 pcf, OMC = 11.6 %)





Test No.	Test Specimen Width	Embedment Length	Normal Stress	Pullout Rate	Depth from Back Fill Surface	Pullout Resistance				Peak Coefficient of Apparent Friction	Coefficient of Apparent Friction at 3/4"	Failure Mode[3]
						1/5"	1/2"	3/4"	Max			
	W	L	σ_n		z	$P_{0.2''}$	$P_{0.5''}$	$P_{0.75''}$	P_{max}	$F^* = \frac{P_{max}}{2WL\sigma_n}$	$F^*_{0.75} = \frac{P_{0.75}}{2WL\sigma_n}$	
	(in.)	(in.)	(psf)	(in/min)	(ft)	(lbs)	(lbs)	(lbs)	(lbs)	(-)	(-)	(-)
1A	2.0	48.0	200	0.04	1.7	1060	1223	1228	1228	4.6	4.6	Pullout
1B	2.0	48.0	600	0.04	5.0	2003	2669	2690	2690	3.4	3.4	Pullout
1C	2.0	48.0	1200	0.04	10.0	3099	4399	4500	4500	2.8	2.8	Pullout
1D	2.0	48.0	1800	0.04	15.0	3871	6043	6130	6130	2.6	2.6	Pullout
1E	2.0	48.0	2400	0.04	19.9	4839	7263	7330	7330	2.3	2.3	Pullout
1F	2.0	48.0	3600	0.04	29.9	6486	9446	9790	9790	2.0	2.0	Pullout
1G	2.0	48.0	4800	0.04	39.9	8272	11109	11326	11326	1.8	1.8	Pullout

NOTE:

(1) $P_{0.75''} = P_{max}$ *if* P_{max} *occurred at a displacement < 0.75".*

(2) Failure Mode: pullout failure in each test as indicated by a minimum displacement of 1.0" measured at the tell-tale wire attached to the rear end of the steel strip.

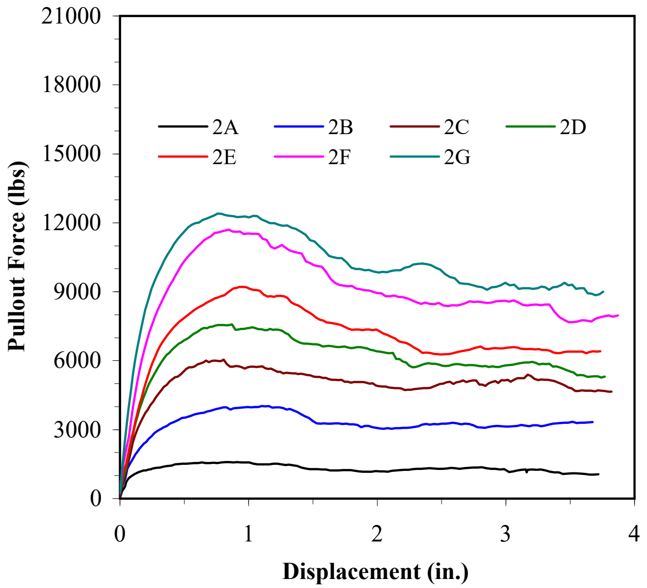
(3) Depth Z from backfill surface: normal stress (psf) divided by as-placed (moist) soil unit weight (pcf).

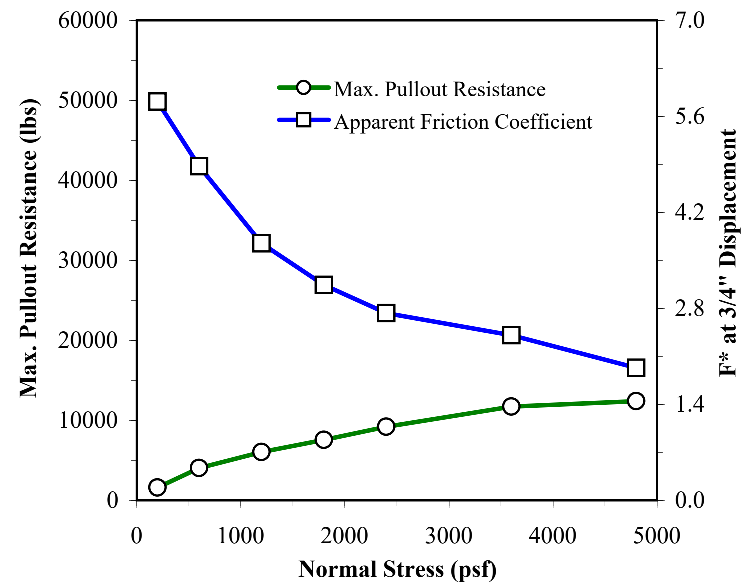
SGI TESTING SERVICES, LLC

DATE REPORTED:	4/21/2025
FIGURE NO.	1
PROJECT NO.	SG25019
DOCUMENT NO.	
FILE NO.	

ELEVATE INFRASTRUCTURE, LLC
STEEL STRIP PULLOUT TESTING (ASTM D 6706)

TEST SERIES NO. 2: 2-inch wide Wave Strip within sandy gravel (GAB material) compacted to approximately 95% of max standard Proctor dry density at optimum moisture content (γ_{dmax} = 138.5 pcf, OMC = 6.4 %)





Test No.	Test Specimen Width[1] W (in.)	Embedment Length L (in.)	Normal Stress σ_n (psf)	Pullout Rate (in/min)	Depth from Back Fill Surface z (ft)	Pullout Resistance 1/5" $P_{0.2"}$ (lbs)	1/2" $P_{0.5"}$ (lbs)	3/4" $P_{0.75"}$ (lbs)	Max P_{max} (lbs)	Peak Coefficient of Apparent Friction $F^* = \frac{P_{max}}{2WL\sigma_n}$ (-)	Coefficient of Apparent Friction at 3/4" $F^*_{0.75} = \frac{P_{0.75}}{2WL\sigma_n}$ (-)	Failure Mode[3] (-)
2A	2.0	48.0	200	0.04	1.4	1227	1522	1551	1600	6.0	5.8	Pullout
2B	2.0	48.0	600	0.04	4.3	2459	3519	3898	4030	5.0	4.9	Pullout
2C	2.0	48.0	1200	0.04	8.6	3747	5560	5997	6050	3.8	3.7	Pullout
2D	2.0	48.0	1800	0.04	12.9	4643	6893	7534	7580	3.2	3.1	Pullout
2E	2.0	48.0	2400	0.04	17.1	5029	7865	8729	9220	2.9	2.7	Pullout
2F	2.0	48.0	3600	0.04	25.7	6683	10333	11563	11710	2.4	2.4	Pullout
2G	2.0	48.0	4800	0.04	34.3	8267	11623	12372	12400	1.9	1.9	Pullout

NOTE:
(1) *$P_{0.75"}$ = P_{max} if P_{max} occurred at a displacement < 0.75".*
(2) Failure Mode: pullout failure in each test as indicated by a minimum displacement of 1.0" measured at the tell-tale wire attached to the rear end of the steel strip.
(3) Depth Z from backfill surface: normal stress (psf) divided by as-placed (moist) soil unit weight (pcf).

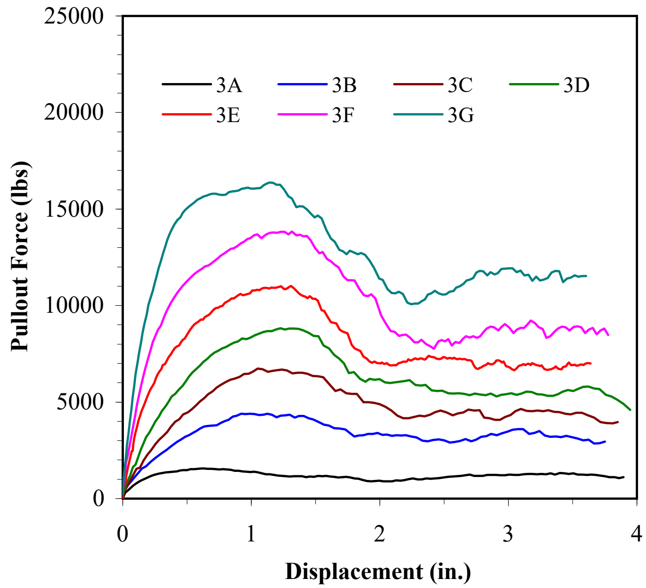
SGI TESTING SERVICES, LLC

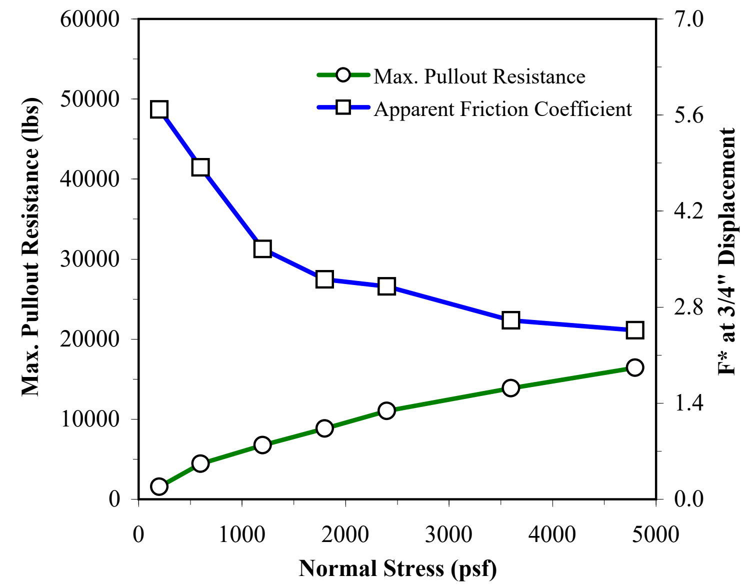
DATE REPORTED:	4/21/2025
FIGURE NO.	2
PROJECT NO.	SG25019
DOCUMENT NO.	
FILE NO.	

P25019-02.pullout.xls

ELEVATE INFRASTRUCTURE, LLC
STEEL STRIP PULLOUT TESTING (ASTM D 6706)

TEST SERIES NO. 3: 2-inch wide Wave Strip within AASHTO #57 stone compacted to approximately 95% of max dry density under dry conditions (γ_{dmax} = 103 pcf)





Test No.	Test Specimen Width(1) W (in.)	Embedment Length L (in.)	Normal Stress σ_n (psf)	Pullout Rate (in/min)	Depth from Back Fill Surface z (ft)	Pullout Resistance 1/5" $P_{0.2''}$ (lbs)	1/2" $P_{0.5''}$ (lbs)	3/4" $P_{0.75''}$ (lbs)	Max P_{max} (lbs)	Peak Coefficient of Apparent Friction $F^* = \frac{P_{max}}{2WL\sigma_n}$ (-)	Coefficient of Apparent Friction at 3/4" $F^*_{0.75} = \frac{P_{0.75}}{2WL\sigma_n}$ (-)	Failure Mode(3) (-)
3A	2.0	48.0	200	0.04	2.0	1117	1480	1515	1572	5.9	5.7	Pullout
3B	2.0	48.0	600	0.04	6.1	1803	3248	3870	4423	5.5	4.8	Pullout
3C	2.0	48.0	1200	0.04	12.3	2340	4448	5836	6752	4.2	3.6	Pullout
3D	2.0	48.0	1800	0.04	18.4	3350	6176	7688	8843	3.7	3.2	Pullout
3E	2.0	48.0	2400	0.04	24.5	5433	8487	9917	11023	3.4	3.1	Pullout
3F	2.0	48.0	3600	0.04	36.8	7316	11274	12512	13865	2.9	2.6	Pullout & hole stretching
3G	2.0	48.0	4800	0.04	49.1	10023	15040	15748	16440	2.6	2.5	

NOTE:
(1) *$P_{0.75''}$ = P_{max} if P_{max} occurred at a displacement < 0.75".*
(2) Failure Mode: pullout failure in each test as indicated by a minimum displacement of 1.0" measured at the tell-tale wire attached to the rear end of the steel strip.
(3) Depth Z from backfill surface: normal stress (psf) divided by as-placed (moist) soil unit weight (pcf).

DATE REPORTED:	4/21/2025
FIGURE NO.	3
PROJECT NO.	SG25019
DOCUMENT NO.	
FILE NO.	

SGI TESTING SERVICES, LLC

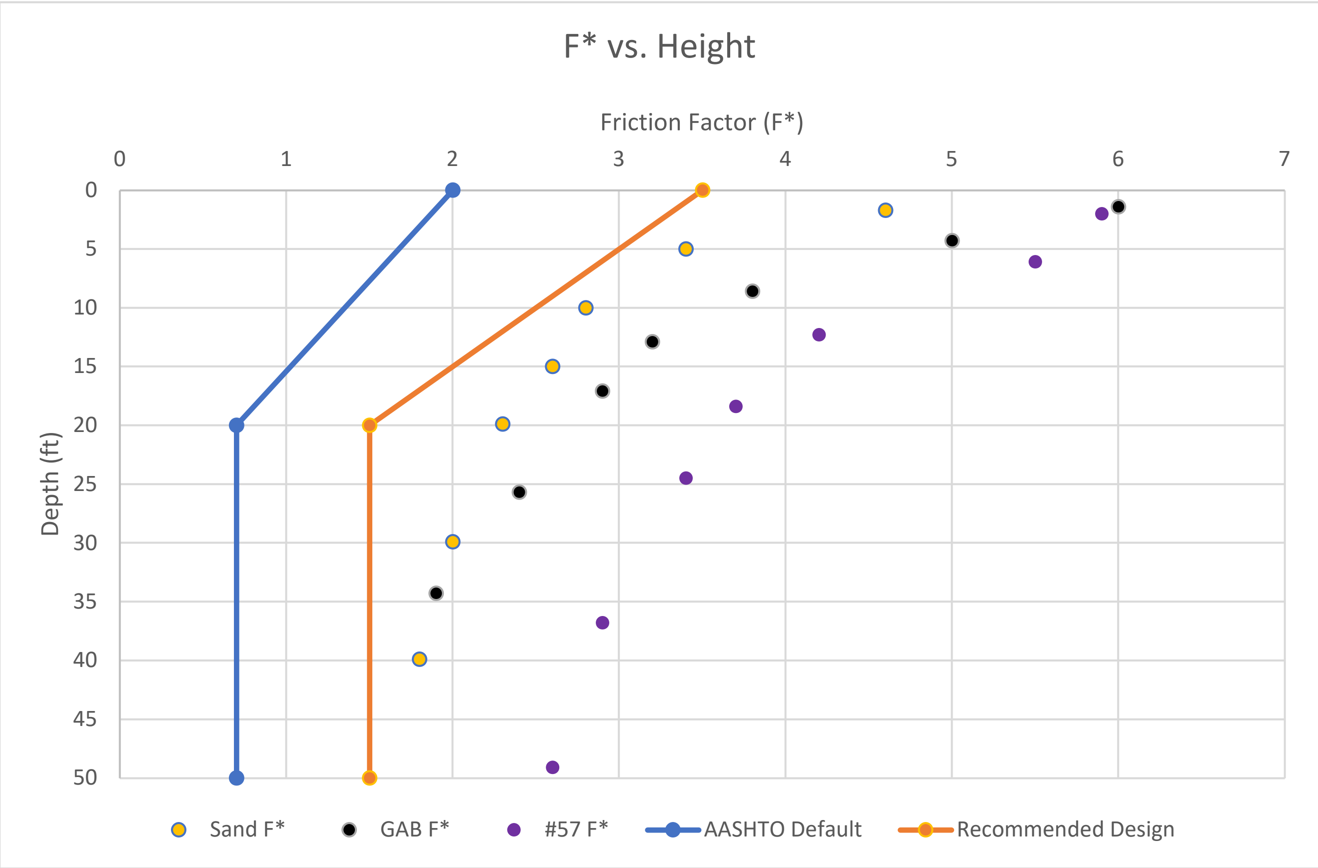
Wave Strip

The pullout resistance factors (F*) from the test results presented in the report by SGI Testing Services, LLC Appendix B Figures 1-3 are plotted below. The recommended design F* was developed to be applicable for the most common backfills used in the reinforced zone on DOT projects. The AASHTO Default F*, i.e. the recommended value in the absence of testing, is plotted in blue for reference.

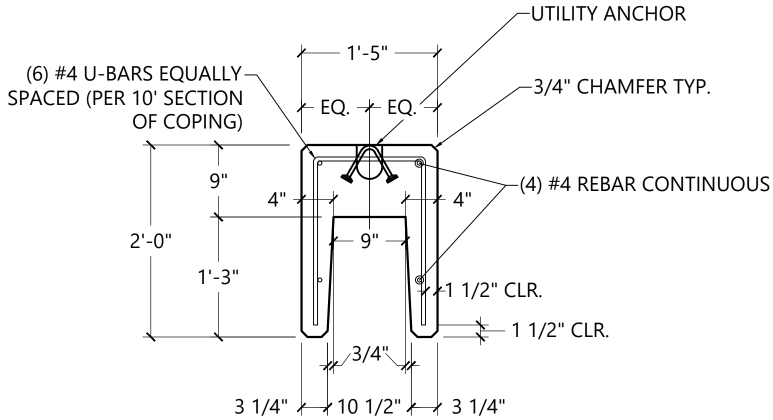
Normal	Sand		GAB		#57 Stone	
Stress (psf)	Depth (ft)	F*	Depth (ft)	F*	Depth (ft)	F*
200	1.7	4.6	1.4	6.0	2	5.9
600	5	3.4	4.3	5.0	6.1	5.5
1200	10	2.8	8.6	3.8	12.3	4.2
1800	15	2.6	12.9	3.2	18.4	3.7
2400	19.9	2.3	17.1	2.9	24.5	3.4
3600	29.9	2.0	25.7	2.4	36.8	2.9
4800	39.9	1.8	34.3	1.9	49.1	2.6

Recommended F* for Elevate Wave Strip:
@ 0' depth: 3.5
@ 20' depth: 1.5

AASHTO Default F* for Elevate Wave Strip:
@ 0' depth: 2
@ 20' depth: 0.67



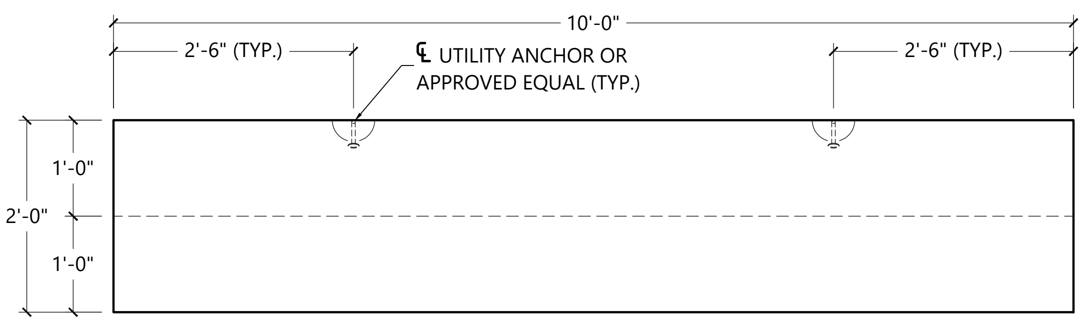
Appendix A1.3.4



PRECAST COPING SECTION DETAIL

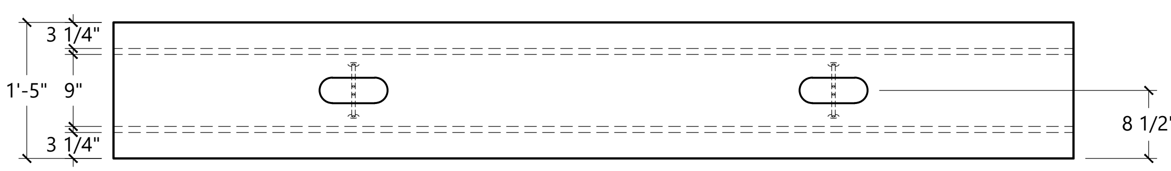
N.T.S.

NOTE:
1) CONCRETE = 4,000 PSI MIN.
2) STEEL = ASTM A706 GRADE 60, EPOXY COATED WHEN REQUIRED PER PROJECT OR WHEN PANEL REINFORCEMENT IS EPOXY COATED



PRECAST COPING ELEVATION

N.T.S.



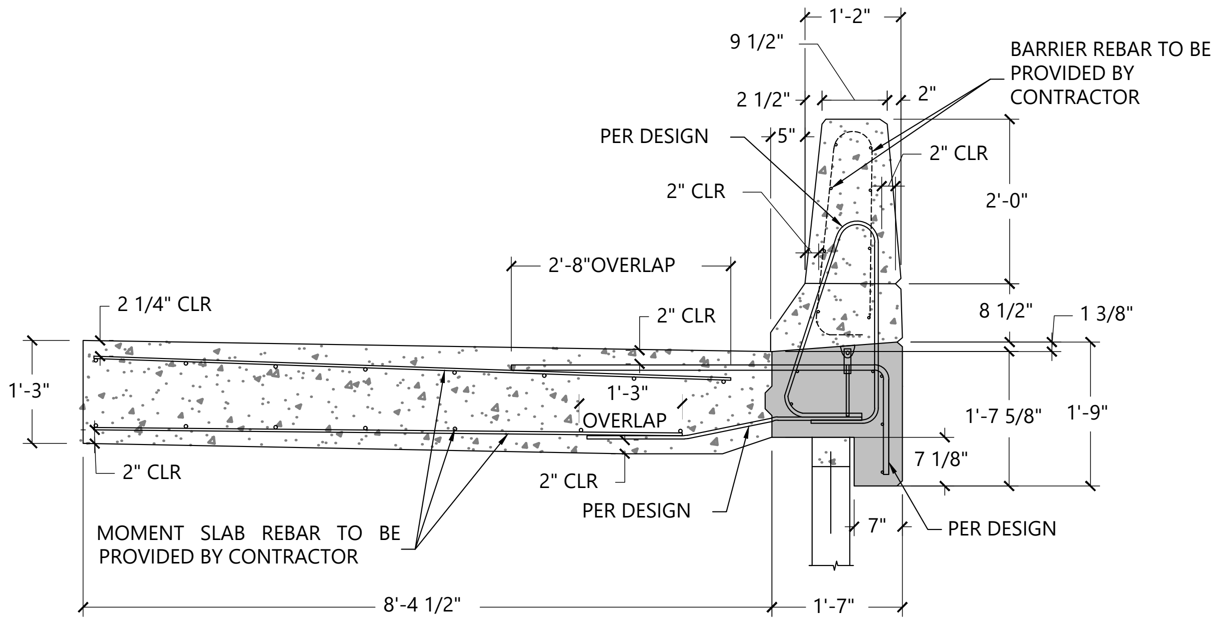
PRECAST COPING PLAN

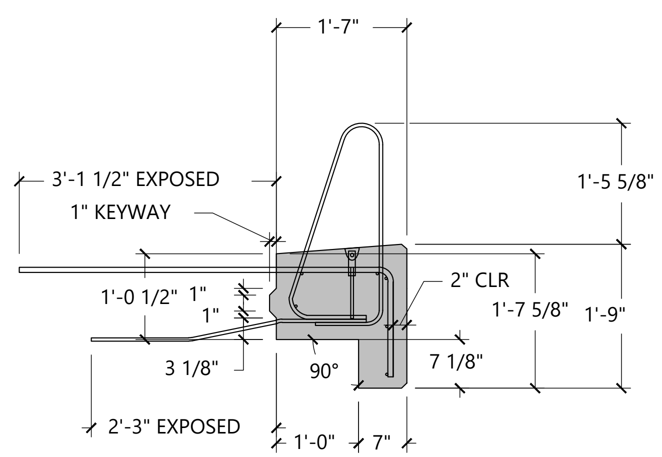
N.T.S.

ELEVATE INFRASTRUCTURE

DRAWING TITLE:	PRECAST COPING	DRAWN BY:	UM
PREPARED FOR:		DATE:	
PROJECT:		DWG:	18

Appendix A1.3.5A

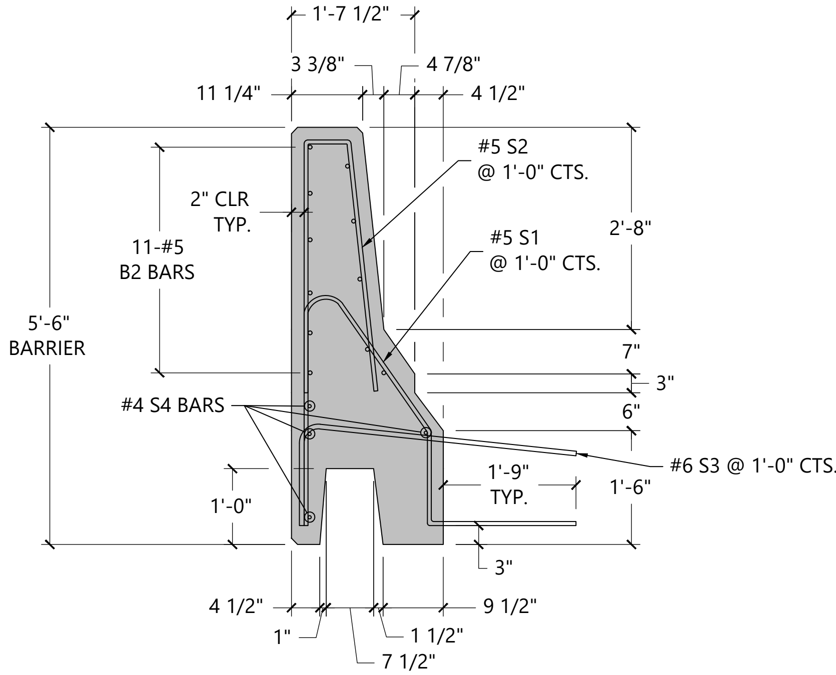




ELEVATE INFRASTRUCTURE

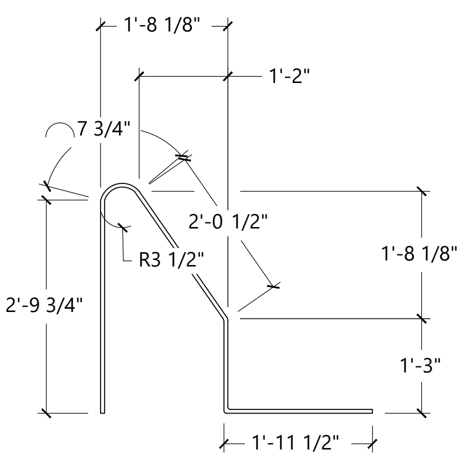
DRAWING TITLE:	PRECAST HALF COPING	DRAWN BY:	UM
PREPARED FOR:		DATE:	
PROJECT:		DWG:	

Appendix A1.3.5B

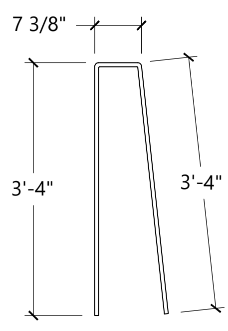


PRECAST BARRIER

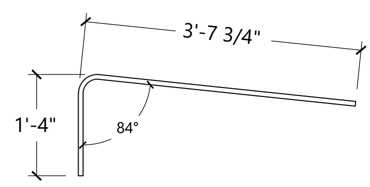
NO SCALE



S1 BAR



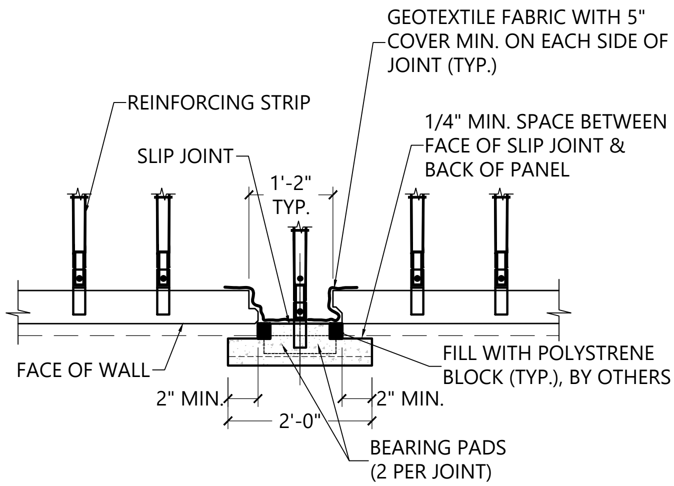
S2 BAR



S3 BAR

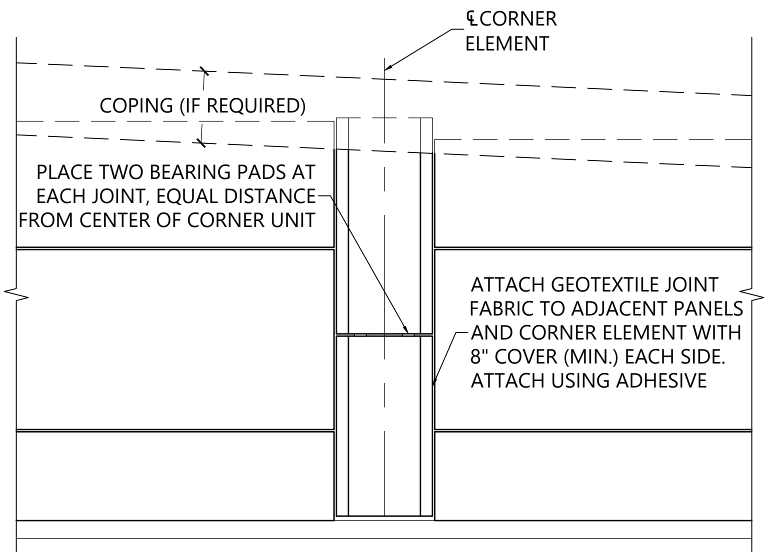
ELEVATE INFRASTRUCTURE	DRAWING TITLE: PRECAST BARRIER	DRAWN BY: UM
	PREPARED FOR:	DATE:
	PROJECT:	DWG:

Appendix A1.3.6



SLIP JOINT DETAIL

NO SCALE



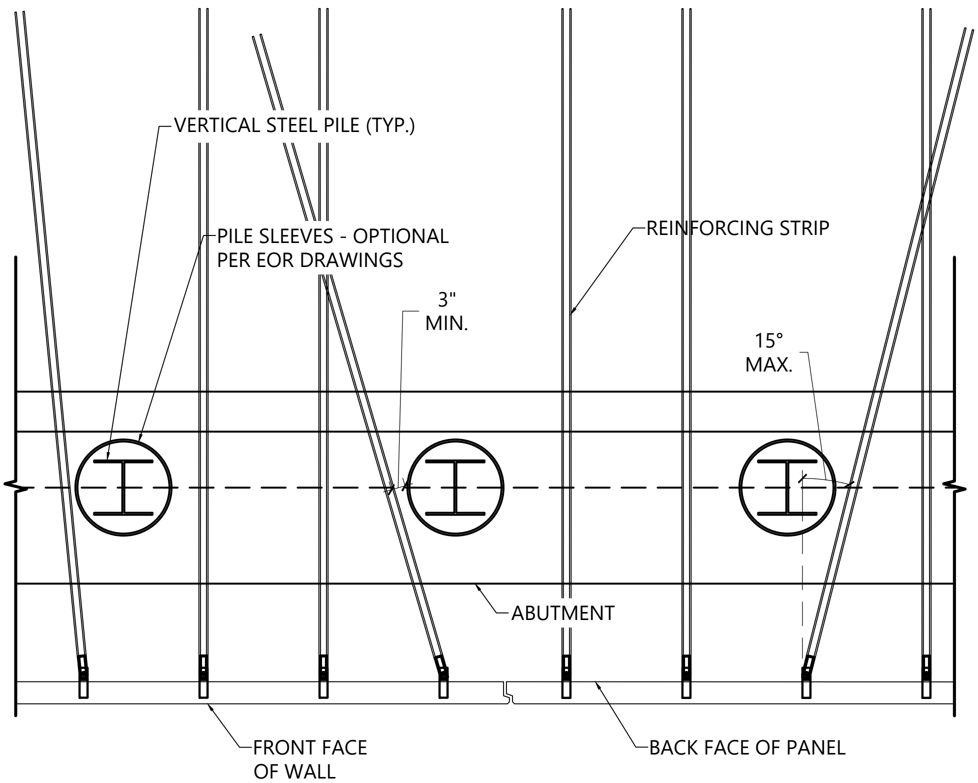
TYPICAL CORNER ELEMENT ELEVATION

NO SCALE

ELEVATE INFRASTRUCTURE	DRAWING TITLE: SLIP JOINT DETAILS	DRAWN BY: UM
	PREPARED FOR:	DATE:
	PROJECT:	DWG:

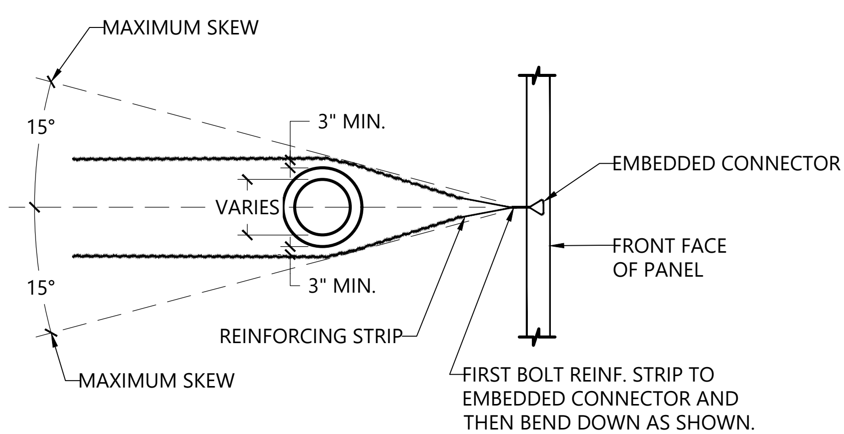
Appendix A2.1.3

NOTE:
IF SKEW IS GREATER THAN 15°
CONTACT AN ELEVATE
INFRASTRUCTURE REPRESENTATIVE



TYPICAL SKEWED REINFORCING STRIP AT ABUTMENT PILES

VERTICAL OBSTRUCTION - NO SCALE

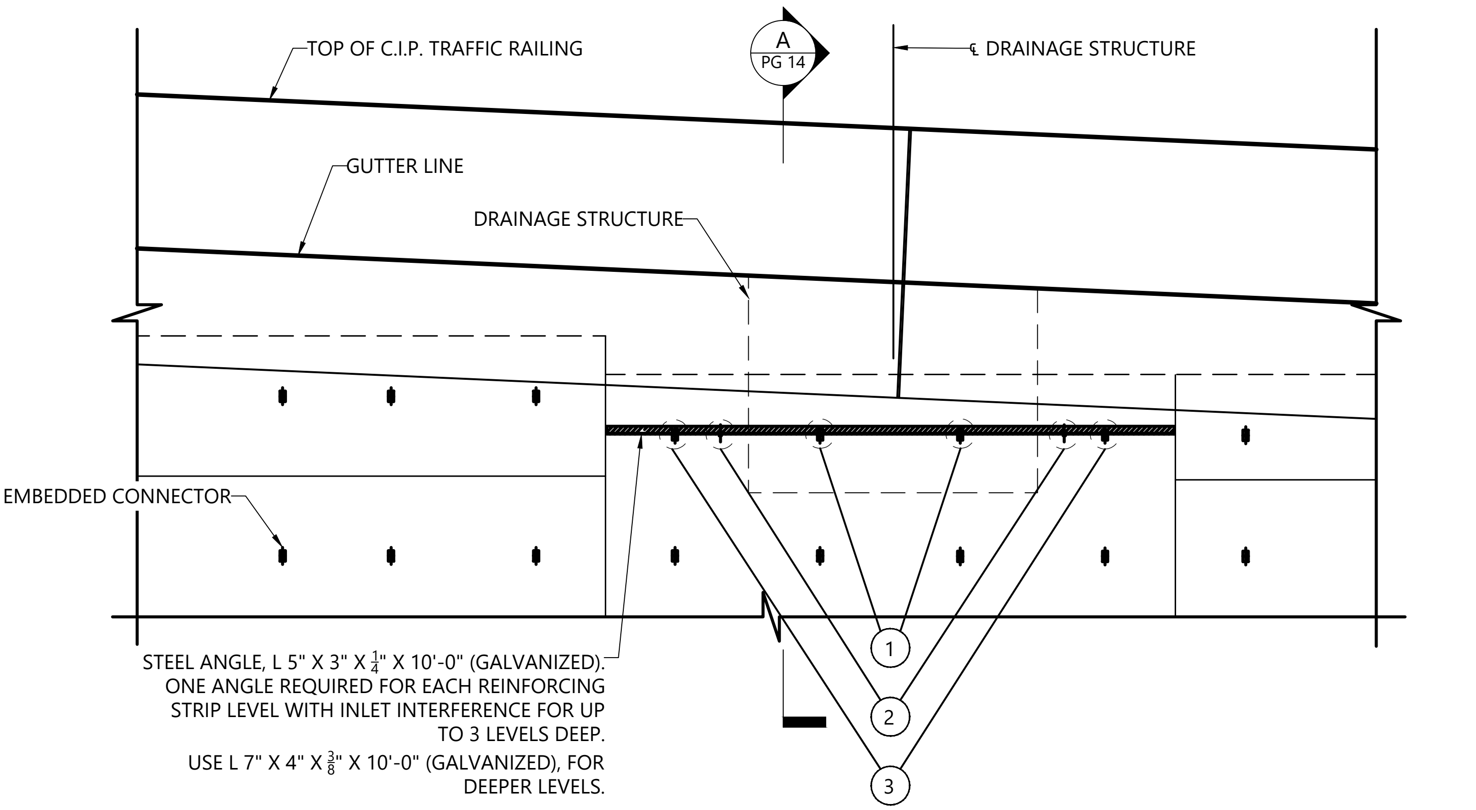


PIPE SHALL BE PLACED AT A DISTANCE FROM THE WALL WHICH WILL ALLOW FOR 15 DEGREE MAXIMUM.

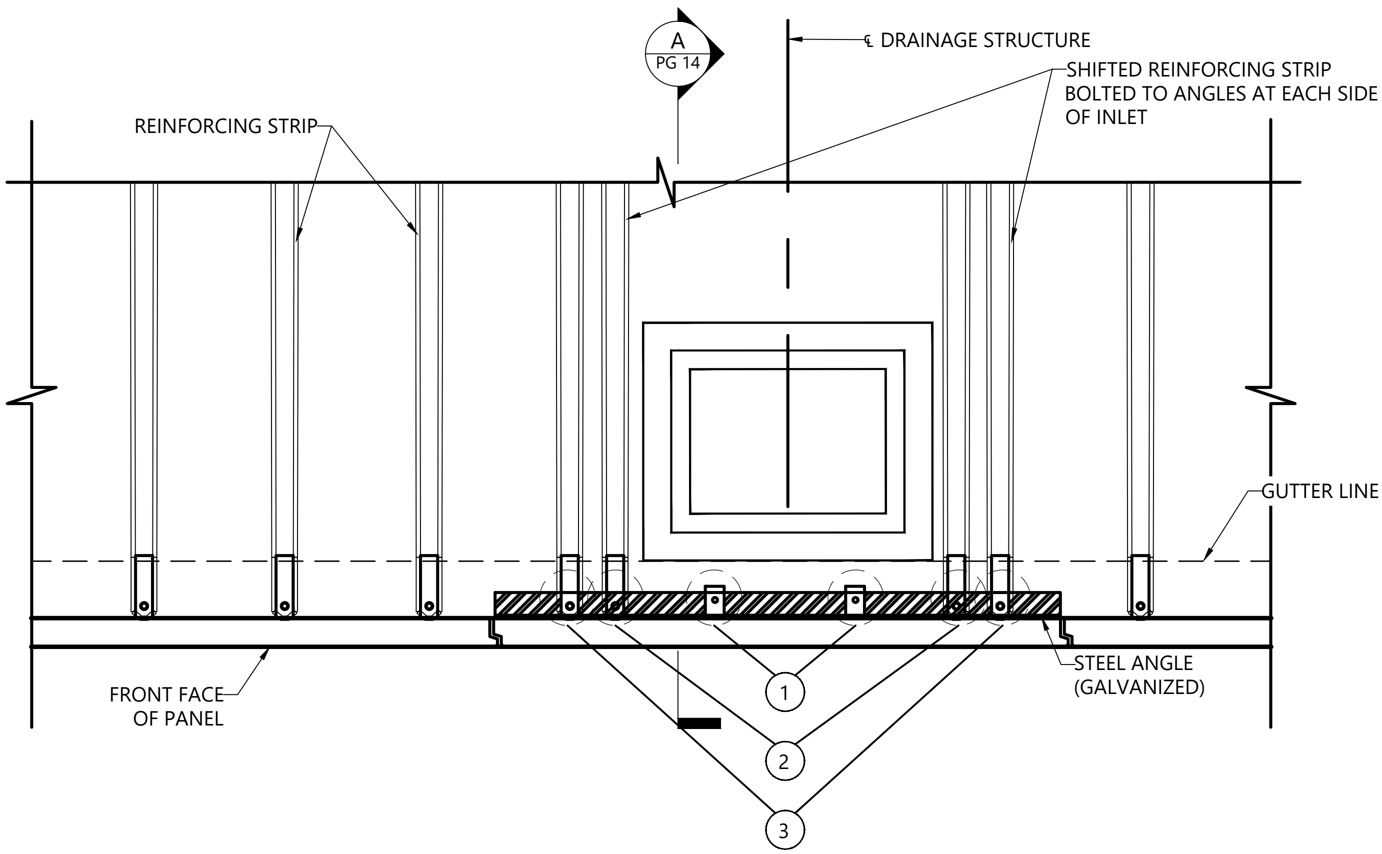
TYPICAL STRIP BENDING DETAIL

NO SCALE

ELEVATE INFRASTRUCTURE	DRAWING TITLE: STRIP SKEW DETAILS	DRAWN BY: UM
	PREPARED FOR:	DATE:
	PROJECT:	DWG:

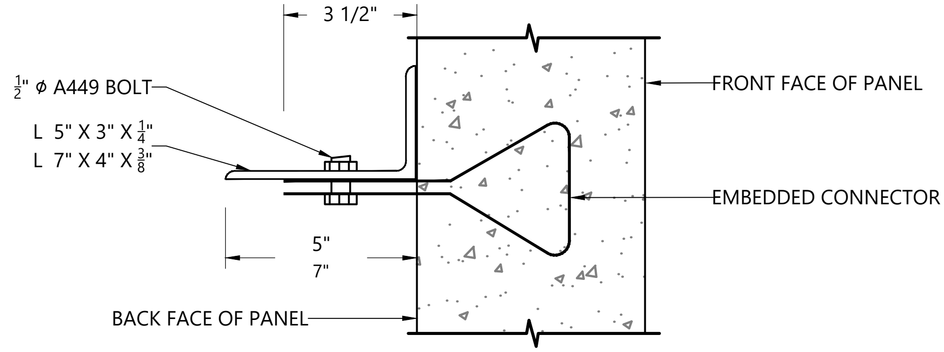


PARTIAL ELEVATION

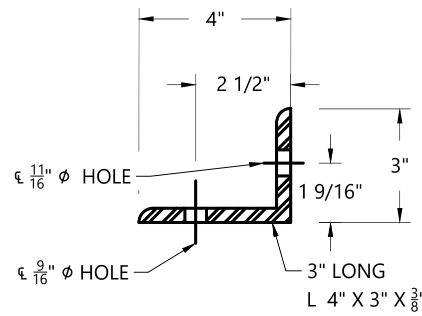


PARTIAL PLAN

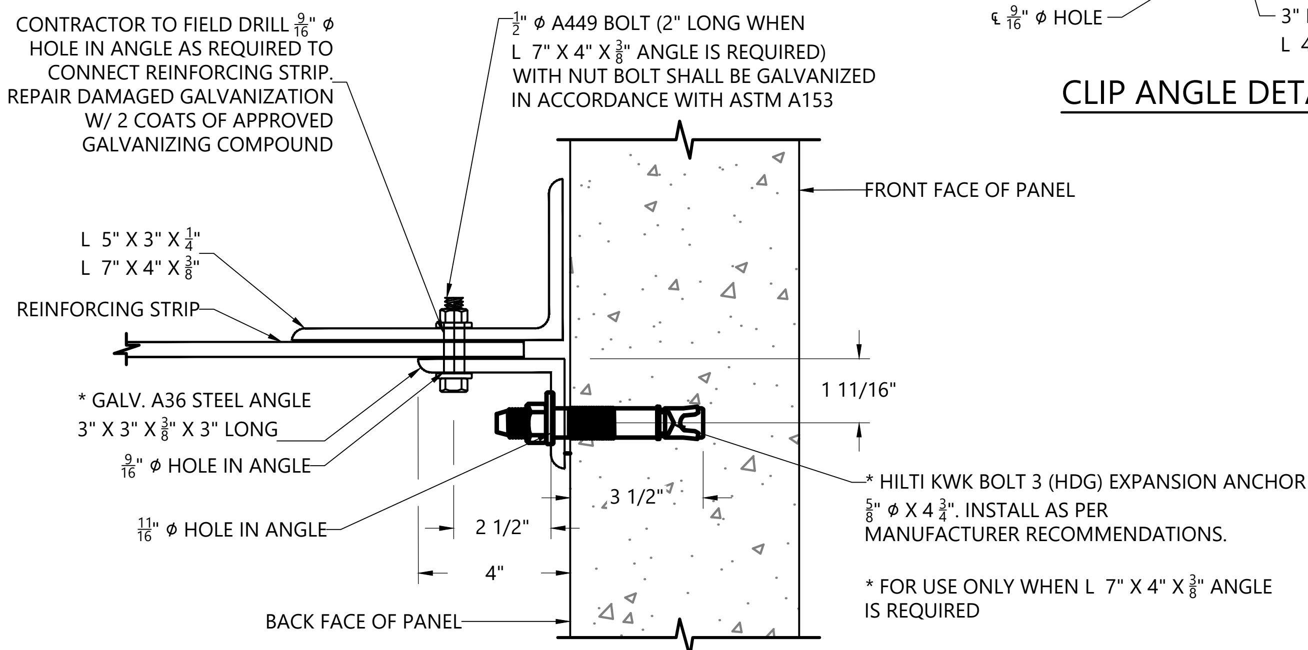
ELEVATE INFRASTRUCTURE		
	DRAWING TITLE: DRAINAGE OBSTRUCTION	DRAWN BY: UM
	PREPARED FOR:	DATE:
	PROJECT:	DWG:



① CONNECTION DETAIL
ANGLE BOLTED TO EMBEDDED CONNECTOR

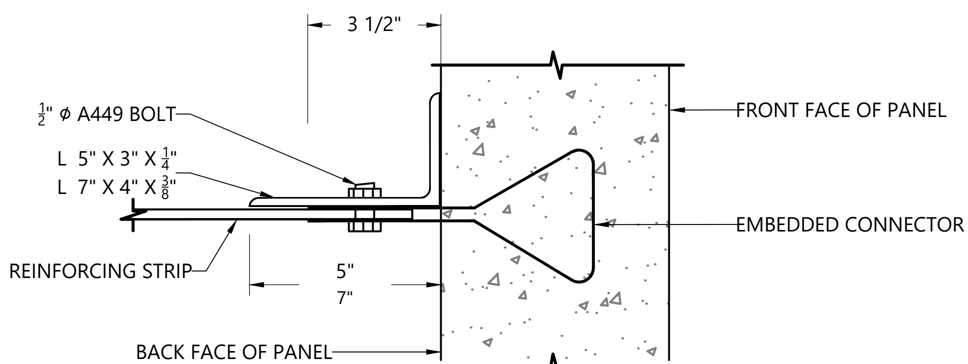


CLIP ANGLE DETAIL



② CONNECTION DETAIL
SHIFTED REINF. STRIP BOLTED TO ANGLE

1. 3 1/2" MIN. , 3 5/8" MAX NOMINAL EMBEDMENT
2. 3 7/8" MIN. , 4" MAX HOLE DEPTH

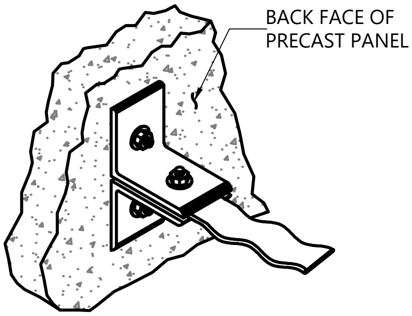


③ CONNECTION DETAIL
ANGLE BOLTED TO EMBEDDED CONNECTOR WITH REINF. STRIP

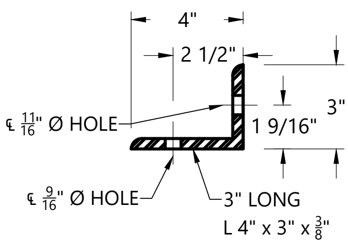
ELEVATE INFRASTRUCTURE

DRAWING TITLE: ANGLE DETAIL		DRAWN BY: UM
PREPARED FOR:		DATE:
PROJECT:		DWG:

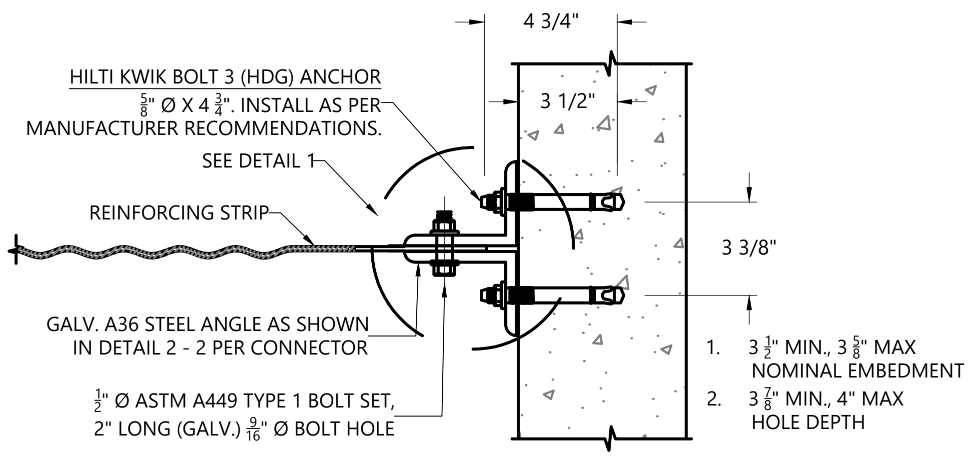
IN THE EVENT THAT A REINFORCING STRIP CANNOT BE SKEWED PER PLANS, THE STRIP MAY BE RELOCATED BY USING THE BELOW CONNECTION ASSEMBLY WITH PROPER DIRECTION FROM ELEVATE INFRASTRUCTURE. PANEL-SPECIFIC CONNECTION LOCATIONS SHALL BE COORDINATED WITH ELEVATE INFRASTRUCTURE ENGINEERING DEPARTMENT.



DETAIL 1



DETAIL 2



NOTE :
THE CONTRACTOR SHALL DRILL AND CLEAN HOLES REQUIRED FOR THE INSTALLATION OF THE ANCHORS AS PER THE MANUFACTURER'S RECOMMENDATIONS

ADDITIONAL CONNECTOR DETAIL

NO SCALE

ELEVATE INFRASTRUCTURE

DRAWING TITLE: ADDITIONAL CONNECTOR	DRAWN BY: UM
PREPARED FOR:	DATE:
PROJECT:	DWG:

Appendix A2.2.1

Problem 1

To the right of formulas and variables, in green you will see the AASHTO citation for where the variable or formula came from.

Key:

S- Section (left column of AASHTO)

F- Figure

T- Table

Eq- Equation

C – Commentary (right column of AASHTO)

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ELEVATE
RETAINING WALLS

Problem 1 – MSEW+ Verification

AASHTO 2017-2020
IDEA Calculations

MSEW+: Update # 2023.13

PROJECT IDENTIFICATION

Title:	IDEA Calculations
Project Number:	
Client:	Elevate Retaining Walls
Designer:	MHP
Station Number:	Problem 1

Description:

Example calculations

Company's information:

Name: DIY Retaining Wall
Street: 12400-3 Wake Union Church Rd, #232

Wake Forest, NC 27587

Telephone #:	919-374-0671
Fax #:	
E-Mail:	contact@diyretainingwall.com

File path and name: C:\Users\MattParrish\OneDrive - DIY Retaining Wall\DIY .....
.....\Problem 1 MSEW.BENp

Original date and time of creating this file: Tue Jun 24 07:27:04 2025

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

SOIL DATA

REINFORCED SOIL

Unit weight, γ	135.0 lb/ft ³
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft ³
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	120.0 lb/ft ³
Equivalent internal angle of friction, $\phi_{equiv.}$	30.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ²

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2973 (eq. 17 is utilized to calculate Ka for all batters)
(For external stability user specified δ = 20.00°)

BEARING CAPACITY

Bearing capacity is controlled by general shear.
Bearing capacity factors (calculated by MSEW): Nc = 30.14 $N\gamma$= 22.40

SEISMICITY

Not Applicable

FOR EXTERNAL STABILITY

Ka = 0.2973 In Coulomb equation for Ka, Omega was taken as ZERO and backslope inclined at angle I.

INPUT DATA: Metal strips
(Analysis)

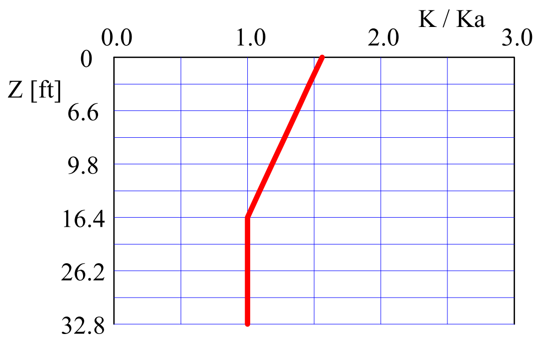
D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.0	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.202	N/A	N/A	N/A	N/A

Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	34.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	3.50	N/A	N/A	N/A	N/A
@ 19.7 ft or below	1.50	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth (Coherent Mass)

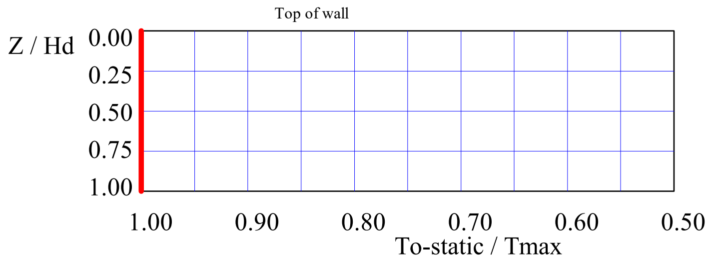
Z	K / Ka
0 ft	1.56
3.3 ft	1.47
6.6 ft	1.37
9.8 ft	1.28
13.1 ft	1.19
16.4 ft	1.09
19.7 ft	1.00



INPUT DATA: Facia and Connection (Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 0.50 ft. Horizontal distance to Center of Gravity of panel is 0.25 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ³

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



Connection strength, T-lot, is related to T-ult

D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	WAVE 2"	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	1.00	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 30.00 [ft] { Embedded depth is E = 2.00 ft, and height above top of finished bottom grade is H = 28.00 ft }

Soil in front of wall is Horizontal.

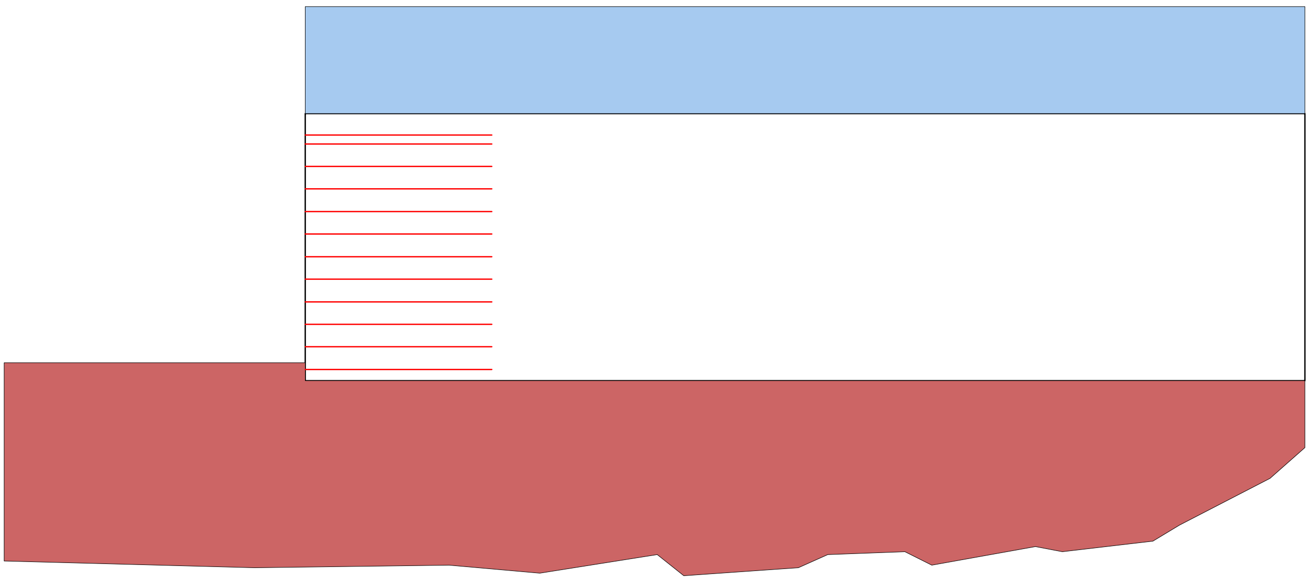
Batter, ω	0.0	[deg]
Backslope, β	0.0	[deg]
Backslope rise	0.0	[ft]

Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

U N I F O R M   S U R C H A R G E

Uniformly distributed dead load is 0.0 [lb/ft ²], and live load is 250.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

AASHTO 2017-2020 – Load and Resisting Factors

INTERNAL STABILITY

Load factor for vertical earth pressure, EV:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surcharge, LS: (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surcharge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	
Resistance factor for reinforcement tension	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement tension in connectors	ϕ	Static	Combined static/seismic
Metal Strips:		1.00	1.00
Resistance factor for Metal Strips pullout	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV		Static		Combined Static/Seismic
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH	$\gamma_{p\text{-}EH}$	1.50
Load factor for earthquake loads, EQ (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surcharge under seismic conditions:	$(\gamma_{p\text{-}LS})_{EQ}$	1.00
Load factor for dead load surcharge under seismic conditions:	$(\gamma_{p\text{-}ES})_{EQ}$	1.00

Resistance factor for shear resistance along common interfaces		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00
Resistance factor for bearing capacity of shallow foundation		Static	Combined Static/Seismic
	ϕ_b	0.65	0.90

ANALYSIS: CALCULATED FACTORS (Static conditions)

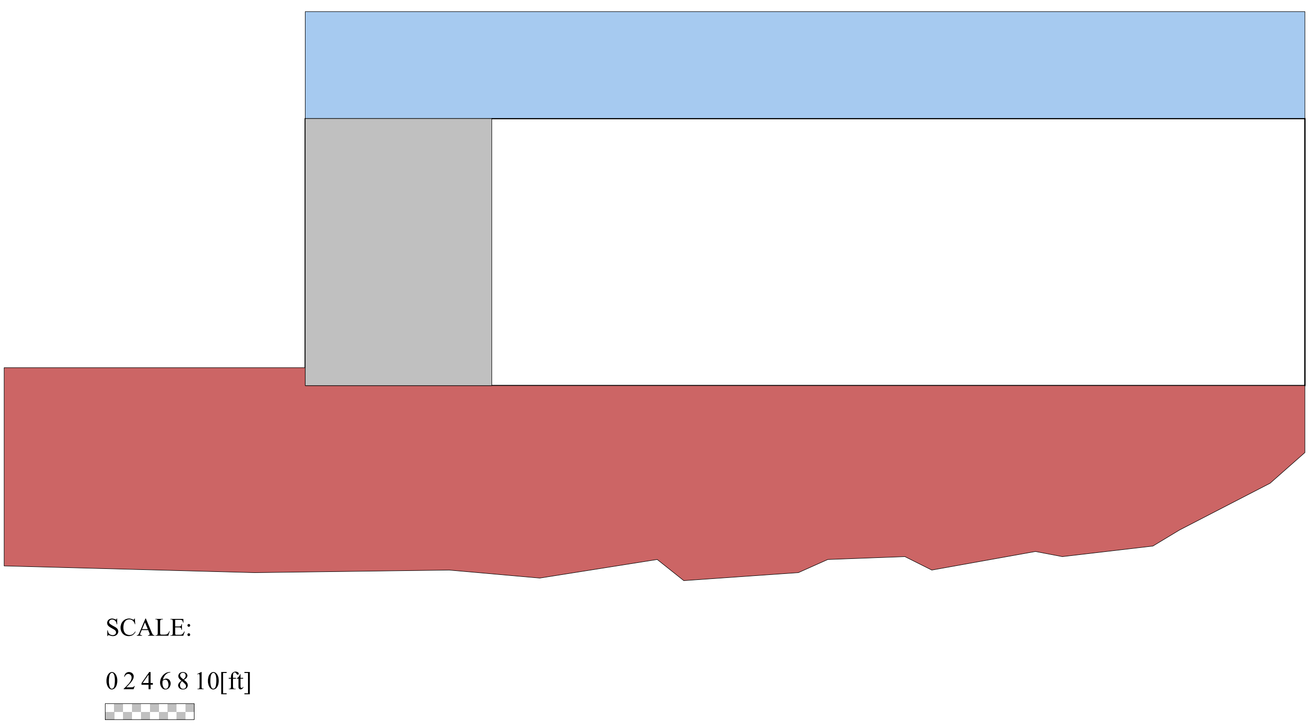
Bearing capacity, CDR = 2.19, factored bearing load = 7302 lb/ft².
Foundation Interface: Direct sliding, CDR = 2.077, Eccentricity, e/L = 0.0910, CDR-overturning = 3.89

METAL STRIP				CONNECTION						
#	Elevation [ft]	Length [ft]	Type #	CDR [connection break]	CDR Strength	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	1.27	21.00	1	1.58	1.58	1.184	4.252	2.509	0.0825	WAVE 2"
2	3.80	21.00	1	1.49	1.49	1.114	3.374	2.694	0.0667	WAVE 2"
3	6.33	21.00	1	1.68	1.68	1.257	3.162	2.911	0.0523	WAVE 2"
4	8.86	21.00	1	1.51	1.51	1.135	2.324	3.170	0.0393	WAVE 2"
5	11.39	21.00	1	1.68	1.68	1.259	2.200	3.486	0.0279	WAVE 2"
6	13.92	21.00	1	1.83	1.83	1.369	2.140	3.877	0.0179	WAVE 2"
7	16.45	21.00	1	1.53	1.53	1.145	1.627	4.376	0.0095	WAVE 2"
8	18.98	21.00	1	1.74	1.74	1.301	1.686	5.034	0.0026	WAVE 2"
9	21.51	21.00	1	2.03	2.03	1.526	1.687	5.942	-0.0026	WAVE 2"
10	24.04	21.00	1	2.52	2.52	1.890	1.610	7.273	-0.0061	WAVE 2"
11	26.57	21.00	1	4.99	4.99	3.745	1.999	9.418	-0.0080	WAVE 2"
12	27.57	21.00	1	3.48	3.48	2.613	1.020	10.676	-0.0082	WAVE 2"

BEARING CAPACITY for GIVEN LAYOUT – Using AASHTO 2017-2020 method

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-n	15982	N/A	[lb/ft ²]
Factored bearing load, σ_V	7302.1	N/A	[lb/ft ²]
Eccentricity, e	1.35	N/A	[ft]
Eccentricity, e/L	0.064	N/A	
CDR calculated	2.19	N/A	
Base length	21.00	N/A	[ft]

Unfactored applied bearing pressure = (Unfactored R) / [L - 2 * (Unfactored e)] =
Unfactored R = 96553.71 [lb/ft], L = 21.00, Unfactored e = 1.21 [ft], and Sigma = 5195.51 [lb/ft ²]



DIRECT SLIDING for GIVEN LAYOUT (for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 2.077

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	1.27	21.00	2.509	N/A	1	WAVE 2"
2	3.80	21.00	2.694	N/A	1	WAVE 2"
3	6.33	21.00	2.911	N/A	1	WAVE 2"
4	8.86	21.00	3.170	N/A	1	WAVE 2"
5	11.39	21.00	3.486	N/A	1	WAVE 2"
6	13.92	21.00	3.877	N/A	1	WAVE 2"
7	16.45	21.00	4.376	N/A	1	WAVE 2"
8	18.98	21.00	5.034	N/A	1	WAVE 2"
9	21.51	21.00	5.942	N/A	1	WAVE 2"
10	24.04	21.00	7.273	N/A	1	WAVE 2"
11	26.57	21.00	9.418	N/A	1	WAVE 2"
12	27.57	21.00	10.676	N/A	1	WAVE 2"

ECCENTRICITY for GIVEN LAYOUT (for Coherent Gravity Mass Method)

At interface with foundation: e/L static = 0.0910; Overturning: CDR-static = 3.89

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	1.27	21.00	0.0825	N/A	1	WAVE 2"
2	3.80	21.00	0.0667	N/A	1	WAVE 2"
3	6.33	21.00	0.0523	N/A	1	WAVE 2"
4	8.86	21.00	0.0393	N/A	1	WAVE 2"
5	11.39	21.00	0.0279	N/A	1	WAVE 2"
6	13.92	21.00	0.0179	N/A	1	WAVE 2"
7	16.45	21.00	0.0095	N/A	1	WAVE 2"
8	18.98	21.00	0.0026	N/A	1	WAVE 2"
9	21.51	21.00	-0.0026	N/A	1	WAVE 2"
10	24.04	21.00	-0.0061	N/A	1	WAVE 2"
11	26.57	21.00	-0.0080	N/A	1	WAVE 2"
12	27.57	21.00	-0.0082	N/A	1	WAVE 2"

RESULTS for STRENGTH [Note: Actual CDR = (Yield stress) / (Actual stress)] For Coherent Mass Method, Option B

Live Load included in calculating Tmax

#	Metal strip Elevation [ft]	Coverage ratio, Rc=b/Sh	Horizontal spacing, Sh [ft]	LTDS = Fy·Ac·Rc/b [lb/ft]	Tmax [lb/ft]	Tmd [lb/ft]	Specified minimum CDR Static	Actual calculated CDR Static	Specified minimum CDR seismic	Actual calculated CDR seismic
1	1.27	0.099	1.680	5852.9	4943.1	N/A	N/A	1.184	N/A	N/A
2	3.80	0.083	2.010	4892.0	4391.6	N/A	N/A	1.114	N/A	N/A
3	6.33	0.083	2.010	4892.0	3890.5	N/A	N/A	1.257	N/A	N/A
4	8.86	0.066	2.530	3886.5	3424.0	N/A	N/A	1.135	N/A	N/A
5	11.39	0.066	2.530	3886.5	3086.3	N/A	N/A	1.259	N/A	N/A
6	13.92	0.066	2.530	3886.5	2838.5	N/A	N/A	1.369	N/A	N/A
7	16.45	0.050	3.350	2935.2	2564.2	N/A	N/A	1.145	N/A	N/A
8	18.98	0.050	3.350	2935.2	2255.5	N/A	N/A	1.301	N/A	N/A
9	21.51	0.050	3.350	2935.2	1923.5	N/A	N/A	1.526	N/A	N/A
10	24.04	0.050	3.350	2935.2	1552.9	N/A	N/A	1.890	N/A	N/A
11	26.57	0.050	3.350	2935.2	783.8	N/A	N/A	3.745	N/A	N/A
12	27.57	0.050	3.350	2935.2	1123.4	N/A	N/A	2.613	N/A	N/A

RESULTS for PULLOUT

Live Load NOT included in calculating Tmax

NOTE: Live load is not included in calculating the overburden pressure used to assess pullout resistance.

#	Metal strip Elevation [ft]	Coverage Ratio Rc=b/Sh	Factored: Stat./Seis. Tmax [lb/ft]	Tmd [lb/ft]	Le (see NOTE)	La [ft]	Avail.Static Pullout, Pr [lb/ft]	Specified Static CDR	Actual Static CDR	Avail.Seism. Pullout, Pr [lb/ft]	Specified seismic CDR	Actual seismic CDR
1	1.27	0.099	4943.1	N/A	20.24	0.76	21018.2	N/A	4.252	N/A	N/A	N/A
2	3.80	0.083	4391.6	N/A	18.72	2.28	14817.8	N/A	3.374	N/A	N/A	N/A
3	6.33	0.083	3890.5	N/A	17.20	3.80	12300.4	N/A	3.162	N/A	N/A	N/A
4	8.86	0.066	3424.0	N/A	15.68	5.32	7956.8	N/A	2.324	N/A	N/A	N/A
5	11.39	0.066	3086.3	N/A	14.17	6.83	6791.0	N/A	2.200	N/A	N/A	N/A
6	13.92	0.066	2838.5	N/A	12.65	8.35	6075.5	N/A	2.140	N/A	N/A	N/A
7	16.45	0.050	2564.2	N/A	12.00	9.00	4170.7	N/A	1.627	N/A	N/A	N/A
8	18.98	0.050	2255.5	N/A	12.00	9.00	3802.6	N/A	1.686	N/A	N/A	N/A
9	21.51	0.050	1923.5	N/A	12.00	9.00	3245.9	N/A	1.687	N/A	N/A	N/A
10	24.04	0.050	1552.9	N/A	12.00	9.00	2500.7	N/A	1.610	N/A	N/A	N/A
11	26.57	0.050	783.8	N/A	12.00	9.00	1567.0	N/A	1.999	N/A	N/A	N/A
12	27.57	0.050	1123.4	N/A	12.00	9.00	1145.9	N/A	1.020	N/A	N/A	N/A

RESULTS for CONNECTION (static conditions)

Live Load included in calculating Tmax

#	Metal strip Elevation [ft]	Coverage ratio Rc=b/Sh	Horizontal spacing, Sh [ft]	Connection force, To [lb/ft]	Reduction factor for connection break, CRu	Long-term connection strength,Tac (break criterion) [lb/ft]	Metal strip long-term strength, [lb/ft]	CDR connection break Specified	CDR connection break Actual	CDR Metal strip strength Specified	CDR Metal strip strength Actual	Product name
1	1.27	0.099	1.680	4943	1.00	7804	7804	N/A	1.58	N/A	1.58	WAVE 2"
2	3.80	0.083	2.010	4392	1.00	6523	6523	N/A	1.49	N/A	1.49	WAVE 2"
3	6.33	0.083	2.010	3890	1.00	6523	6523	N/A	1.68	N/A	1.68	WAVE 2"
4	8.86	0.066	2.530	3424	1.00	5182	5182	N/A	1.51	N/A	1.51	WAVE 2"
5	11.39	0.066	2.530	3086	1.00	5182	5182	N/A	1.68	N/A	1.68	WAVE 2"
6	13.92	0.066	2.530	2839	1.00	5182	5182	N/A	1.83	N/A	1.83	WAVE 2"
7	16.45	0.050	3.350	2564	1.00	3914	3914	N/A	1.53	N/A	1.53	WAVE 2"
8	18.98	0.050	3.350	2255	1.00	3914	3914	N/A	1.74	N/A	1.74	WAVE 2"
9	21.51	0.050	3.350	1924	1.00	3914	3914	N/A	2.03	N/A	2.03	WAVE 2"
10	24.04	0.050	3.350	1553	1.00	3914	3914	N/A	2.52	N/A	2.52	WAVE 2"
11	26.57	0.050	3.350	784	1.00	3914	3914	N/A	4.99	N/A	4.99	WAVE 2"
12	27.57	0.050	3.350	1123	1.00	3914	3914	N/A	3.48	N/A	3.48	WAVE 2"

AASHTO 2017-2020
IDEA Calculations

MSEW+: Update # 2023.13

PROJECT IDENTIFICATION

Title:	IDEA Calculations
Project Number:	
Client:	Elevate Retaining Walls
Designer:	MHP
Station Number:	Problem 1 LL = 0 PSF

Description:

Example calculations

Company's information:

Name: DIY Retaining Wall
Street: 12400-3 Wake Union Church Rd, #232

Wake Forest, NC 27587
Telephone #: 919-374-0671
Fax #:
E-Mail: contact@diyretainingwall.com

File path and name: C:\Users\MattParrish\OneDrive - DIY Retaining Wall\DIY .....
.....\Problem 1 MSEW.BENp

Original date and time of creating this file: Tue Jun 24 07:27:04 2025

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

SOIL DATA

REINFORCED SOIL

Unit weight, γ	135.0 lb/ft ³
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft ³
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	120.0 lb/ft ³
Equivalent internal angle of friction, $\phi_{equiv.}$	30.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ²

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.2973 (eq. 17 is utilized to calculate Ka for all batters)
(For external stability user specified δ = 20.00°)

BEARING CAPACITY

Bearing capacity is controlled by general shear.
Bearing capacity factors (calculated by MSEW): Nc = 30.14 $N\gamma$= 22.40

SEISMICITY

Not Applicable

FOR EXTERNAL STABILITY

Ka = 0.2973 In Coulomb equation for Ka, Omega was taken as ZERO and backslope inclined at angle I.

INPUT DATA: Metal strips (Analysis)

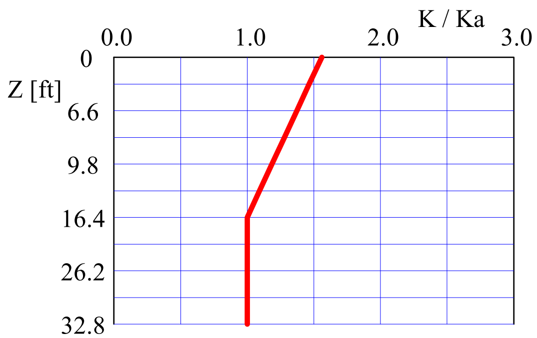
D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.0	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.202	N/A	N/A	N/A	N/A

Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	34.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	3.50	N/A	N/A	N/A	N/A
@ 19.7 ft or below	1.50	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth (Coherent Mass)

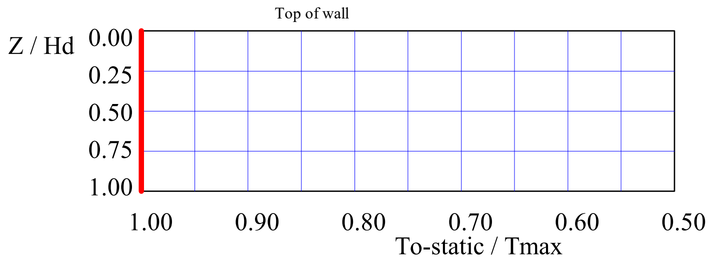
Z	K / Ka
0 ft	1.56
3.3 ft	1.47
6.6 ft	1.37
9.8 ft	1.28
13.1 ft	1.19
16.4 ft	1.09
19.7 ft	1.00



INPUT DATA: Facia and Connection (Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 0.50 ft. Horizontal distance to Center of Gravity of panel is 0.25 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ^{3}

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



Connection strength, T-lot, is related to T-ult

D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	WAVE 2"	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	1.00	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

Design height, Hd 30.00 [ft] { Embedded depth is E = 2.00 ft, and height above top of finished bottom grade is H = 28.00 ft }

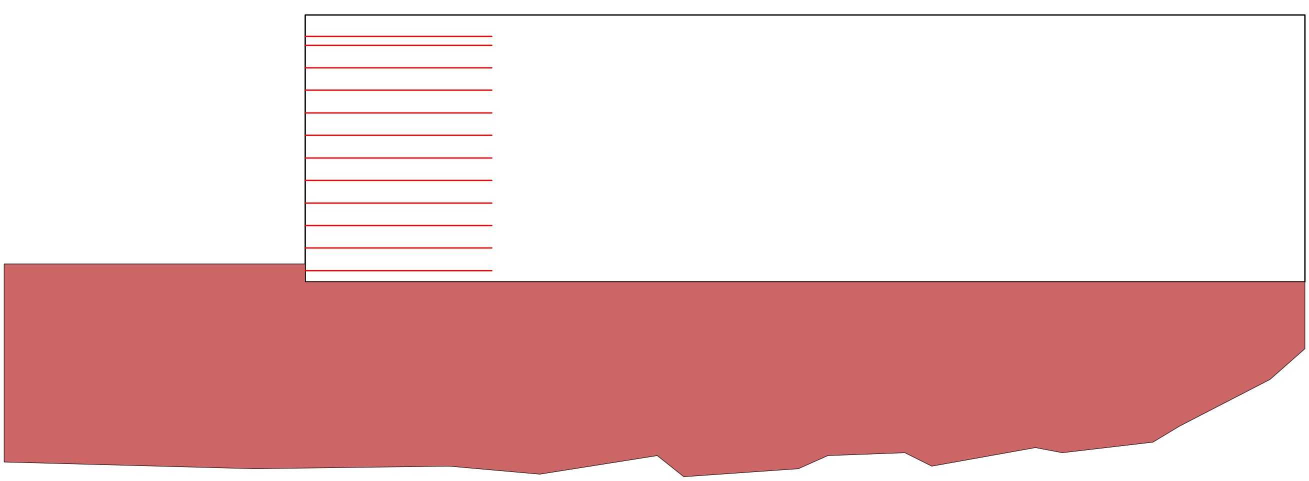
Soil in front of wall is Horizontal.

Batter, ω	0.0	[deg]	
Backslope, β	0.0	[deg]	
Backslope rise	0.0	[ft]	Broken back equivalent angle, I = 0.00° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E

Uniformly distributed dead load is 0.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

AASHTO 2017-2020 – Load and Resisting Factors

INTERNAL STABILITY

Load factor for vertical earth pressure, EV:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surcharge, LS: (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surcharge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	
Resistance factor for reinforcement tension	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement tension in connectors	ϕ	Static	Combined static/seismic
Metal Strips:		1.00	1.00
Resistance factor for Metal Strips pullout	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV		Static		Combined Static/Seismic
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH	$\gamma_{p\text{-}EH}$	1.50
Load factor for earthquake loads, EQ (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surcharge under seismic conditions:	$(\gamma_{p\text{-}LS})_{EQ}$	1.00
Load factor for dead load surcharge under seismic conditions:	$(\gamma_{p\text{-}ES})_{EQ}$	1.00

Resistance factor for shear resistance along common interfaces		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_{τ}	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_{τ}	1.00	1.00
Resistance factor for bearing capacity of shallow foundation		Static	Combined Static/Seismic
	ϕ_b	0.65	0.90

ANALYSIS: CALCULATED FACTORS (Static conditions)

Bearing capacity, CDR = 2.49, factored bearing load = 6571 lb/ft².

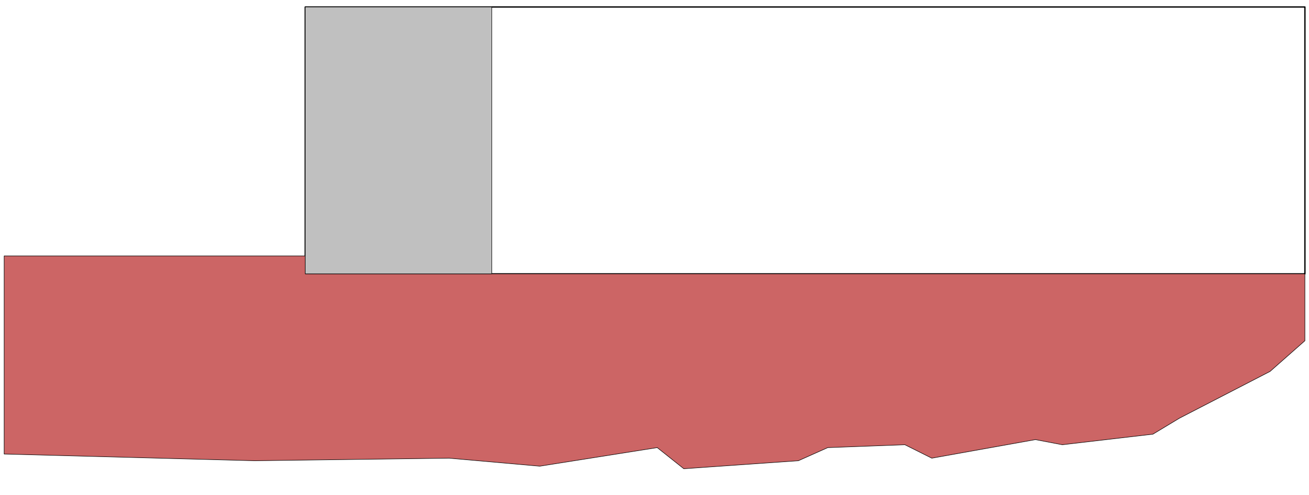
Foundation Interface: Direct sliding, CDR = 2.380, Eccentricity, e/L = 0.0714, CDR-overturning = 4.71

#	METAL STRIP Elevation [ft]	Length [ft]	Type #	CONNECTION CDR [connection break]	CDR Strength	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	1.27	21.00	1	1.76	1.76	1.318	4.734	2.893	0.0639	WAVE 2"
2	3.80	21.00	1	1.66	1.66	1.246	3.773	3.148	0.0501	WAVE 2"
3	6.33	21.00	1	1.89	1.89	1.415	3.558	3.458	0.0378	WAVE 2"
4	8.86	21.00	1	1.72	1.72	1.288	2.637	3.843	0.0270	WAVE 2"
5	11.39	21.00	1	1.93	1.93	1.445	2.525	4.332	0.0177	WAVE 2"
6	13.92	21.00	1	2.13	2.13	1.595	2.494	4.975	0.0099	WAVE 2"
7	16.45	21.00	1	1.82	1.82	1.363	1.937	5.858	0.0038	WAVE 2"
8	18.98	21.00	1	2.13	2.13	1.596	2.068	7.147	-0.0007	WAVE 2"
9	21.51	21.00	1	2.62	2.62	1.962	2.170	9.203	-0.0035	WAVE 2"
10	24.04	21.00	1	3.55	3.55	2.662	2.268	13.006	-0.0045	WAVE 2"
11	26.57	21.00	1	8.53	8.53	6.396	3.415	22.417	-0.0038	WAVE 2"
12	27.57	21.00	1	6.96	6.96	5.218	2.037	31.542	-0.0031	WAVE 2"

BEARING CAPACITY for GIVEN LAYOUT – Using AASHTO 2017-2020 method

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-n	16362	N/A	[lb/ft ²]
Factored bearing load, σ_V	6570.7	N/A	[lb/ft ²]
Eccentricity, e	1.14	N/A	[ft]
Eccentricity, e/L	0.054	N/A	
CDR calculated	2.49	N/A	
Base length	21.00	N/A	[ft]

Unfactored applied bearing pressure = (Unfactored R) / [L - 2 * (Unfactored e)] =
Unfactored R = 90541.06 [lb/ft], L = 21.00, Unfactored e = 1.03 [ft], and Sigma = 4780.16 [lb/ft ²]



SCALE:

0 2 4 6 8 10[ft]

DIRECT SLIDING for GIVEN LAYOUT (for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 2.380

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	1.27	21.00	2.893	N/A	1	WAVE 2"
2	3.80	21.00	3.148	N/A	1	WAVE 2"
3	6.33	21.00	3.458	N/A	1	WAVE 2"
4	8.86	21.00	3.843	N/A	1	WAVE 2"
5	11.39	21.00	4.332	N/A	1	WAVE 2"
6	13.92	21.00	4.975	N/A	1	WAVE 2"
7	16.45	21.00	5.858	N/A	1	WAVE 2"
8	18.98	21.00	7.147	N/A	1	WAVE 2"
9	21.51	21.00	9.203	N/A	1	WAVE 2"
10	24.04	21.00	13.006	N/A	1	WAVE 2"
11	26.57	21.00	22.417	N/A	1	WAVE 2"
12	27.57	21.00	31.542	N/A	1	WAVE 2"

ECCENTRICITY for GIVEN LAYOUT (for Coherent Gravity Mass Method)

At interface with foundation: e/L static = 0.0714; Overturning: CDR-static = 4.71

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	1.27	21.00	0.0639	N/A	1	WAVE 2"
2	3.80	21.00	0.0501	N/A	1	WAVE 2"
3	6.33	21.00	0.0378	N/A	1	WAVE 2"
4	8.86	21.00	0.0270	N/A	1	WAVE 2"
5	11.39	21.00	0.0177	N/A	1	WAVE 2"
6	13.92	21.00	0.0099	N/A	1	WAVE 2"
7	16.45	21.00	0.0038	N/A	1	WAVE 2"
8	18.98	21.00	-0.0007	N/A	1	WAVE 2"
9	21.51	21.00	-0.0035	N/A	1	WAVE 2"
10	24.04	21.00	-0.0045	N/A	1	WAVE 2"
11	26.57	21.00	-0.0038	N/A	1	WAVE 2"
12	27.57	21.00	-0.0031	N/A	1	WAVE 2"

RESULTS for STRENGTH [Note: Actual CDR = (Yield stress) / (Actual stress)] For Coherent Mass Method, Option B

Live Load included in calculating Tmax

#	Metal strip Elevation [ft]	Coverage ratio, Rc=b/Sh	Horizontal spacing, Sh [ft]	LTDS = Fy·Ac·Rc/b [lb/ft]	Tmax [lb/ft]	Tmd [lb/ft]	Specified minimum CDR Static	Actual calculated CDR Static	Specified minimum CDR seismic	Actual calculated CDR seismic
1	1.27	0.099	1.680	5852.9	4440.2	N/A	N/A	1.318	N/A	N/A
2	3.80	0.083	2.010	4892.0	3926.9	N/A	N/A	1.246	N/A	N/A
3	6.33	0.083	2.010	4892.0	3457.4	N/A	N/A	1.415	N/A	N/A
4	8.86	0.066	2.530	3886.5	3017.6	N/A	N/A	1.288	N/A	N/A
5	11.39	0.066	2.530	3886.5	2689.5	N/A	N/A	1.445	N/A	N/A
6	13.92	0.066	2.530	3886.5	2436.0	N/A	N/A	1.595	N/A	N/A
7	16.45	0.050	3.350	2935.2	2153.7	N/A	N/A	1.363	N/A	N/A
8	18.98	0.050	3.350	2935.2	1839.1	N/A	N/A	1.596	N/A	N/A
9	21.51	0.050	3.350	2935.2	1496.0	N/A	N/A	1.962	N/A	N/A
10	24.04	0.050	3.350	2935.2	1102.7	N/A	N/A	2.662	N/A	N/A
11	26.57	0.050	3.350	2935.2	458.9	N/A	N/A	6.396	N/A	N/A
12	27.57	0.050	3.350	2935.2	562.5	N/A	N/A	5.218	N/A	N/A

RESULTS for PULLOUT

Live Load NOT included in calculating Tmax

#	Metal strip Elevation [ft]	Coverage Ratio Rc=b/Sh	Factored: Stat./Seis. Tmax [lb/ft]	Tmd [lb/ft]	Le [ft]	La [ft]	Avail.Static Pullout, Pr [lb/ft]	Specified Static CDR	Actual Static CDR	Avail.Seism. Pullout, Pr [lb/ft]	Specified seismic CDR	Actual seismic CDR
1	1.27	0.099	4440.2	N/A	20.24	0.76	21018.2	N/A	4.734	N/A	N/A	N/A
2	3.80	0.083	3926.9	N/A	18.72	2.28	14817.8	N/A	3.773	N/A	N/A	N/A
3	6.33	0.083	3457.4	N/A	17.20	3.80	12300.4	N/A	3.558	N/A	N/A	N/A
4	8.86	0.066	3017.6	N/A	15.68	5.32	7956.8	N/A	2.637	N/A	N/A	N/A
5	11.39	0.066	2689.5	N/A	14.17	6.83	6791.0	N/A	2.525	N/A	N/A	N/A
6	13.92	0.066	2436.0	N/A	12.65	8.35	6075.5	N/A	2.494	N/A	N/A	N/A
7	16.45	0.050	2153.7	N/A	12.00	9.00	4170.7	N/A	1.937	N/A	N/A	N/A
8	18.98	0.050	1839.1	N/A	12.00	9.00	3802.6	N/A	2.068	N/A	N/A	N/A
9	21.51	0.050	1496.0	N/A	12.00	9.00	3245.9	N/A	2.170	N/A	N/A	N/A
10	24.04	0.050	1102.7	N/A	12.00	9.00	2500.7	N/A	2.268	N/A	N/A	N/A
11	26.57	0.050	458.9	N/A	12.00	9.00	1567.0	N/A	3.415	N/A	N/A	N/A
12	27.57	0.050	562.5	N/A	12.00	9.00	1145.9	N/A	2.037	N/A	N/A	N/A

RESULTS for CONNECTION (static conditions)

Live Load included in calculating Tmax

#	Metal strip Elevation [ft]	Coverage ratio Rc=b/Sh	Horizontal spacing, Sh [ft]	Connection force, To [lb/ft]	Reduction factor for connection break, CRu	Long-term connection strength,Tac (break criterion) [lb/ft]	Metal strip long-term strength, [lb/ft]	CDR connection break Specified	CDR connection break Actual	CDR Metal strip strength Specified	CDR Metal strip strength Actual	Product name
1	1.27	0.099	1.680	4440	1.00	7804	7804	N/A	1.76	N/A	1.76	WAVE 2"
2	3.80	0.083	2.010	3927	1.00	6523	6523	N/A	1.66	N/A	1.66	WAVE 2"
3	6.33	0.083	2.010	3457	1.00	6523	6523	N/A	1.89	N/A	1.89	WAVE 2"
4	8.86	0.066	2.530	3018	1.00	5182	5182	N/A	1.72	N/A	1.72	WAVE 2"
5	11.39	0.066	2.530	2690	1.00	5182	5182	N/A	1.93	N/A	1.93	WAVE 2"
6	13.92	0.066	2.530	2436	1.00	5182	5182	N/A	2.13	N/A	2.13	WAVE 2"
7	16.45	0.050	3.350	2154	1.00	3914	3914	N/A	1.82	N/A	1.82	WAVE 2"
8	18.98	0.050	3.350	1839	1.00	3914	3914	N/A	2.13	N/A	2.13	WAVE 2"
9	21.51	0.050	3.350	1496	1.00	3914	3914	N/A	2.62	N/A	2.62	WAVE 2"
10	24.04	0.050	3.350	1103	1.00	3914	3914	N/A	3.55	N/A	3.55	WAVE 2"
11	26.57	0.050	3.350	459	1.00	3914	3914	N/A	8.53	N/A	8.53	WAVE 2"
12	27.57	0.050	3.350	563	1.00	3914	3914	N/A	6.96	N/A	6.96	WAVE 2"

Problem 2

To the right of formulas and variables, in green you will see the AASHTO citation for where the variable or formula came from.

Key:

S- Section (left column of AASHTO)

F- Figure

T- Table

Eq- Equation

C – Commentary (right column of AASHTO)

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ELEVATE
RETAINING WALLS

Problem 2 – MSEW+ Verification

AASHTO 2017-2020
IDEA Calculations

MSEW+: Update # 2023.13

PROJECT IDENTIFICATION

Title: IDEA Calculations
Project Number:
Client: Elevate Retaining Walls
Designer: MHP
Station Number: Problem 2

Description:

Example calculations

Company's information:

Name: DIY Retaining Wall
Street: 12400-3 Wake Union Church Rd, #232

Wake Forest, NC 27587
Telephone #: 919-374-0671
Fax #:
E-Mail: contact@diyretainingwall.com

File path and name: C:\Users\MattParrish\OneDrive - DIY Retaining Wall\DIY .....
.....\Problem 2 MSEW.BENp

Original date and time of creating this file: Tue Jun 24 07:27:04 2025

PROGRAM MODE: ANALYSIS
of a SIMPLE STRUCTURE
using METAL STRIPS as reinforcing material.

SOIL DATA

REINFORCED SOIL

Unit weight, γ	135.0 lb/ft ³
Design value of internal angle of friction, ϕ	34.0 °

RETAINED SOIL

Unit weight, γ	120.0 lb/ft ³
Design value of internal angle of friction, ϕ	30.0 °

FOUNDATION SOIL (Considered as an equivalent uniform soil)

Equivalent unit weight, $\gamma_{equiv.}$	120.0 lb/ft ³
Equivalent internal angle of friction, $\phi_{equiv.}$	30.0 °
Equivalent cohesion, $c_{equiv.}$	0.0 lb/ft ²

Water table does not affect bearing capacity

LATERAL EARTH PRESSURE COEFFICIENTS

Ka (internal stability) = 0.2827 (if batter is less than 10°, Ka is calculated from eq. 15. Otherwise, eq. 38 is utilized)
Ka (external stability) = 0.5243 (eq. 17 is utilized to calculate Ka for all batters)
(For external stability user specified $\delta = 20.00°$)

BEARING CAPACITY

Bearing capacity is controlled by general shear.
Bearing capacity factors (calculated by MSEW): Nc = 30.14 $N\gamma$= 22.40

SEISMICITY

Not Applicable

FOR EXTERNAL STABILITY

Ka = 0.5243 In Coulomb equation for Ka, Omega was taken as ZERO and backslope inclined at angle I.

INPUT DATA: Metal strips (Analysis)

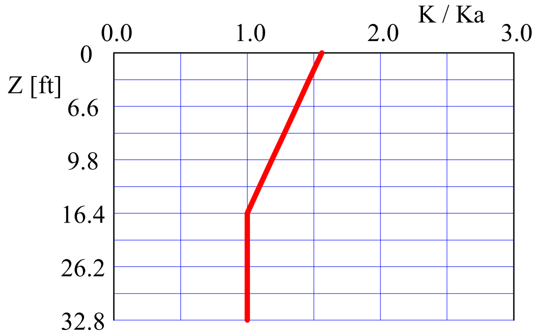
D A T A	Metal strip type #1	Metal strip type #2	Metal strip type #3	Metal strip type #4	Metal strip type #5
Yield strength of steel, Fy [kips/in ²]	65.0	N/A	N/A	N/A	N/A
Gross width of strip, b [in]	2.0	N/A	N/A	N/A	N/A
Vertical spacing, Sv [ft]	Varies	N/A	N/A	N/A	N/A
Design cross section area, Ac [in ²]	0.201	N/A	N/A	N/A	N/A

Ribbed steel strips.
Uniformity Coefficient of reinforced soil, Cu = D60/D10 = 4.0

Friction angle along reinforcement-soil interface,	ρ				
@ the top	60.97	N/A	N/A	N/A	N/A
@ 19.7 ft or below	34.00	N/A	N/A	N/A	N/A
Pullout resistance factor, F*					
@ the top	3.50	N/A	N/A	N/A	N/A
@ 19.7 ft or below	1.50	N/A	N/A	N/A	N/A
Scale-effect correction factor, α	1.00	N/A	N/A	N/A	N/A

Variation of Lateral Earth Pressure Coefficient With Depth (Coherent Mass)

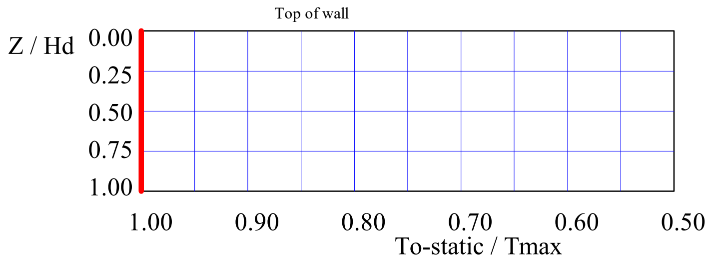
Z	K / Ka
0 ft	1.56
3.3 ft	1.47
6.6 ft	1.37
9.8 ft	1.28
13.1 ft	1.19
16.4 ft	1.09
19.7 ft	1.00



INPUT DATA: Facia and Connection (Analysis)

FACIA type: Segmental precast concrete panels.
Depth of panel is 0.50 ft. Horizontal distance to Center of Gravity of panel is 0.25 ft.
Average unit weight of panel is γ_f = 150.00 lb/ft ³

Z / Hd	To-static / Tmax
0.00	1.00
0.25	1.00
0.50	1.00
0.75	1.00
1.00	1.00



Connection strength, T-lot, is related to T-ult

D A T A (for connection only)	Type #1	Type #2	Type #3	Type #4	Type #5
Product Name	WAVE 2"	N/A	N/A	N/A	N/A
Strength reduction at the connection, CRu = Fyc / Fy	1.00	N/A	N/A	N/A	N/A

INPUT DATA: Geometry and Surcharge loads (of a SIMPLE STRUCTURE)

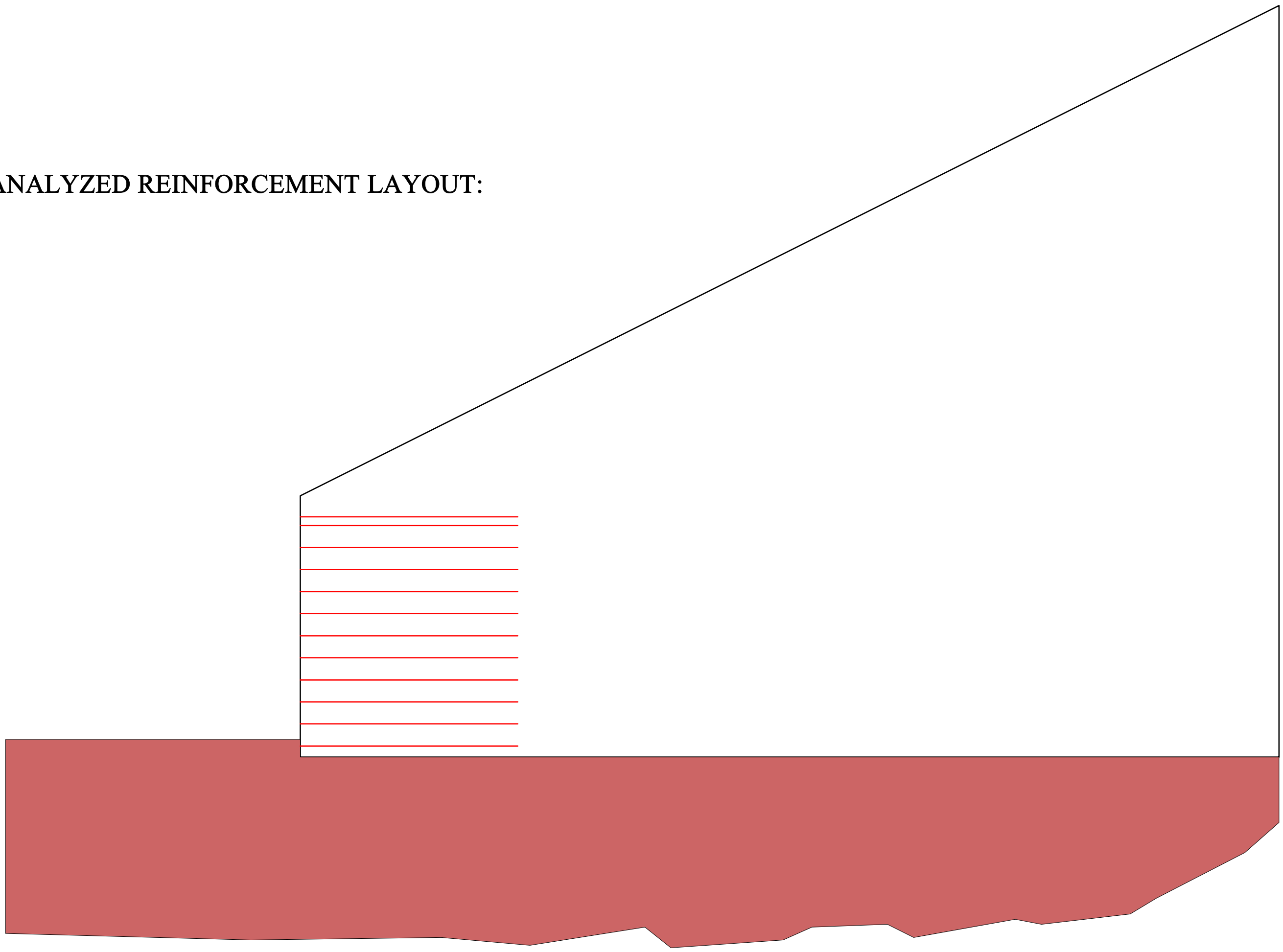
Design height, Hd 30.00 [ft] { Embedded depth is E = 2.00 ft, and height above top of finished bottom grade is H = 28.00 ft }

Soil in front of wall is Horizontal.

Batter, ω	0.0	[deg]	
Backslope, β	26.6	[deg]	
Backslope rise	100.0	[ft]	Broken back equivalent angle, I = 26.56° (see Fig. 25 in DEMO 82)

U N I F O R M S U R C H A R G E
Uniformly distributed dead load is 0.0 [lb/ft ²]

ANALYZED REINFORCEMENT LAYOUT:



SCALE:

0 2 4 6 8 10[ft]

AASHTO 2017-2020 – Load and Resisting Factors

INTERNAL STABILITY

Load factor for vertical earth pressure, EV:	$\gamma_{p\text{-}EV}$	1.35	
Load factor for earthquake loads, EQ:	$\gamma_{p\text{-}EQ}$	1.00	
Load factor for live load surcharge, LS: (Same as in External Stability).	$\gamma_{p\text{-}LS}$	1.75	
Load factor for dead load surcharge, ES: (Same as in External Stability).	$\gamma_{p\text{-}ES}$	1.50	
Resistance factor for reinforcement tension	ϕ	Static	Combined static/seismic
Metal Strips:		0.75	1.00
Resistance factor for reinforcement tension in connectors	ϕ	Static	Combined static/seismic
Metal Strips:		1.00	1.00
Resistance factor for Metal Strips pullout	ϕ	0.90	1.20

EXTERNAL STABILITY

Load factor for vertical earth pressure, EV		Static		Combined Static/Seismic
Sliding and Eccentricity	$\gamma_{p\text{-}EV}$	1.00	$\gamma_{p\text{-}EQ}$	1.00
Bearing Capacity	$\gamma_{p\text{-}EV}$	1.35	$\gamma_{p\text{-}EQ}$	1.35

Load factor of active lateral earth pressure, EH	$\gamma_{p\text{-}EH}$	1.50
Load factor for earthquake loads, EQ (multiplies P_{AE} and P_{IR}):	$\gamma_{p\text{-}EQ}$	1.00
Load factor for live load surcharge under seismic conditions:	$(\gamma_{p\text{-}LS})_{EQ}$	0.50
Load factor for dead load surcharge under seismic conditions:	$(\gamma_{p\text{-}ES})_{EQ}$	1.00

Resistance factor for shear resistance along common interfaces		Static	Combined Static/Seismic
Reinforced Soil and Foundation	ϕ_τ	1.00	1.00
Reinforced Soil and Reinforcement	ϕ_τ	1.00	1.00
Resistance factor for bearing capacity of shallow foundation		Static	Combined Static/Seismic
	ϕ_b	0.65	0.65

ANALYSIS: CALCULATED FACTORS (Static conditions)

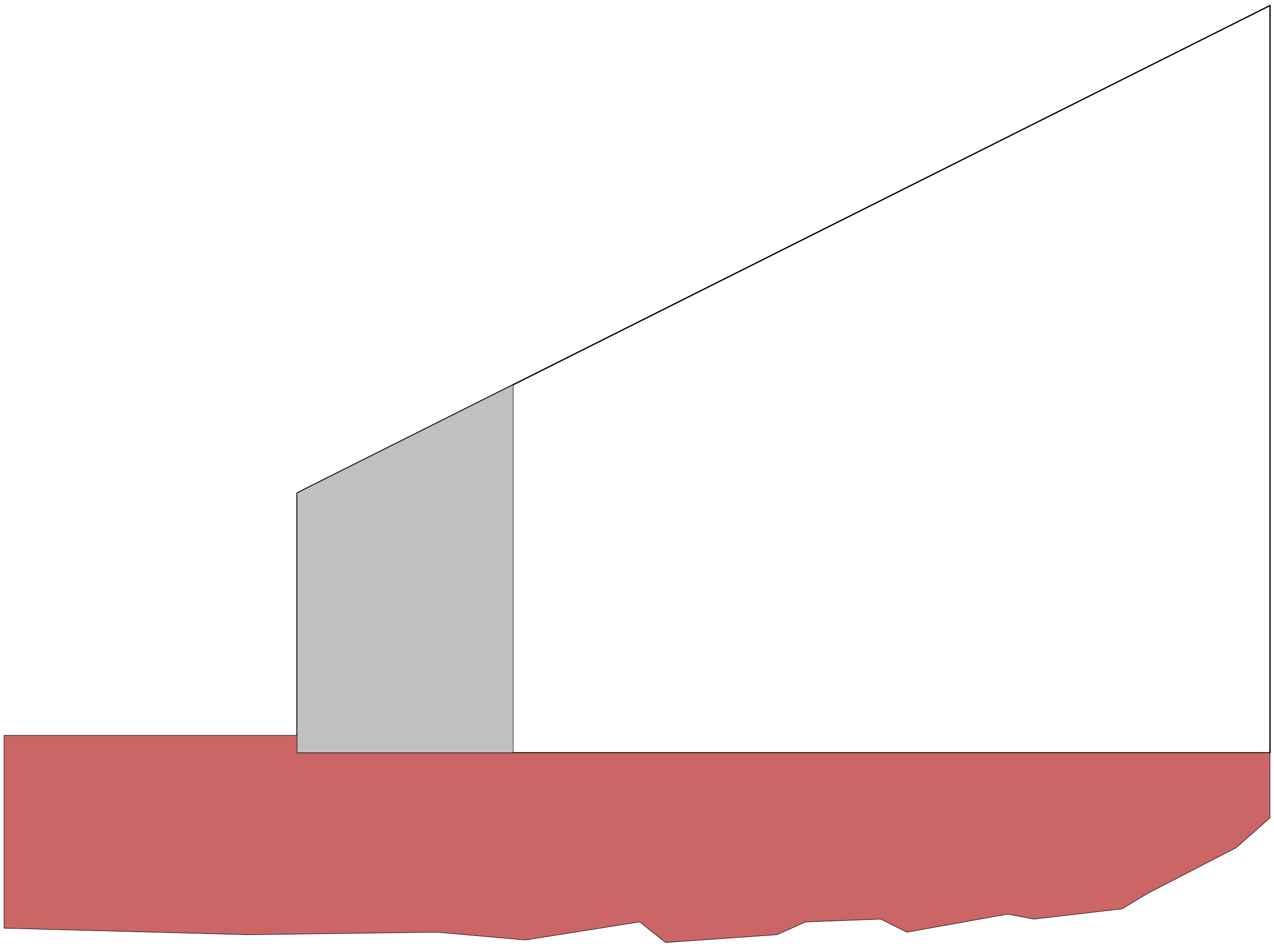
Bearing capacity, CDR = 1.51, factored bearing load = 10620 lb/ft².
Foundation Interface: Direct sliding, CDR = 1.092, Eccentricity, e/L = 0.1801, CDR-overturning = 2.07

METAL STRIP				CONNECTION						
#	Elevation [ft]	Length [ft]	Type #	CDR [connection break]	CDR Strength	Metal strip strength CDR	Pullout resistance CDR	Direct sliding CDR	Eccentricity e/L	Product name
1	1.27	25.00	1	1.46	1.46	1.095	5.787	1.302	0.1663	WAVE 2"
2	3.80	25.00	1	1.48	1.48	1.110	5.162	1.358	0.1396	WAVE 2"
3	6.33	25.00	1	1.46	1.46	1.093	4.434	1.420	0.1138	WAVE 2"
4	8.86	25.00	1	1.40	1.40	1.047	3.670	1.488	0.0890	WAVE 2"
5	11.39	25.00	1	1.62	1.62	1.215	3.897	1.564	0.0650	WAVE 2"
6	13.92	25.00	1	1.50	1.50	1.128	3.533	1.649	0.0417	WAVE 2"
7	16.45	25.00	1	1.72	1.72	1.293	3.822	1.744	0.0187	WAVE 2"
8	18.98	25.00	1	1.82	1.82	1.361	3.843	1.849	-0.0043	WAVE 2"
9	21.51	25.00	1	1.92	1.92	1.442	3.938	1.964	-0.0282	WAVE 2"
10	24.04	25.00	1	1.58	1.58	1.183	3.028	2.085	-0.0545	WAVE 2"
11	26.57	25.00	1	2.55	2.55	1.911	4.420	2.204	-0.0863	WAVE 2"
12	27.57	25.00	1	1.57	1.57	1.179	2.587	2.245	-0.1018	WAVE 2"

BEARING CAPACITY for GIVEN LAYOUT – Using AASHTO 2017-2020 method

	STATIC	SEISMIC	UNITS
(Water table does not affect bearing capacity)			
Factored bearing resistance. q-n	15984	N/A	[lb/ft ²]
Factored bearing load, σ_V	10620.5	N/A	[lb/ft ²]
Eccentricity, e	3.35	N/A	[ft]
Eccentricity, e/L	0.134	N/A	
CDR calculated	1.51	N/A	
Base length	25.00	N/A	[ft]

Unfactored applied bearing pressure = (Unfactored R) / [L - 2 * (Unfactored e)] =
Unfactored R = 141769.08 [lb/ft], L = 25.00, Unfactored e = 3.00 [ft], and Sigma = 7462.45 [lb/ft ²]



SCALE:

0 2 4 6 8 10[ft]

DIRECT SLIDING for GIVEN LAYOUT (for METAL STRIPS reinforcements)

Along reinforced and foundation soils interface: CDR-static = 1.092

#	Metal strip Elevation [ft]	Metal strip Length [ft]	CDR Static	CDR Seismic	Metal strip Type #	Product name
1	1.27	25.00	1.302	N/A	1	WAVE 2"
2	3.80	25.00	1.358	N/A	1	WAVE 2"
3	6.33	25.00	1.420	N/A	1	WAVE 2"
4	8.86	25.00	1.488	N/A	1	WAVE 2"
5	11.39	25.00	1.564	N/A	1	WAVE 2"
6	13.92	25.00	1.649	N/A	1	WAVE 2"
7	16.45	25.00	1.744	N/A	1	WAVE 2"
8	18.98	25.00	1.849	N/A	1	WAVE 2"
9	21.51	25.00	1.964	N/A	1	WAVE 2"
10	24.04	25.00	2.085	N/A	1	WAVE 2"
11	26.57	25.00	2.204	N/A	1	WAVE 2"
12	27.57	25.00	2.245	N/A	1	WAVE 2"

ECCENTRICITY for GIVEN LAYOUT (for Coherent Gravity Mass Method)

At interface with foundation: e/L static = 0.1801; Overturning: CDR-static = 2.07

#	Metal strip Elevation [ft]	Metal strip Length [ft]	e / L Static	e / L Seismic	Metal strip Type #	Product name
1	1.27	25.00	0.1663	N/A	1	WAVE 2"
2	3.80	25.00	0.1396	N/A	1	WAVE 2"
3	6.33	25.00	0.1138	N/A	1	WAVE 2"
4	8.86	25.00	0.0890	N/A	1	WAVE 2"
5	11.39	25.00	0.0650	N/A	1	WAVE 2"
6	13.92	25.00	0.0417	N/A	1	WAVE 2"
7	16.45	25.00	0.0187	N/A	1	WAVE 2"
8	18.98	25.00	-0.0043	N/A	1	WAVE 2"
9	21.51	25.00	-0.0282	N/A	1	WAVE 2"
10	24.04	25.00	-0.0545	N/A	1	WAVE 2"
11	26.57	25.00	-0.0863	N/A	1	WAVE 2"
12	27.57	25.00	-0.1018	N/A	1	WAVE 2"

RESULTS for STRENGTH [Note: Actual CDR = (Yield stress) / (Actual stress)] For Coherent Mass Method, Option B

Live Load included in calculating Tmax

#	Metal strip Elevation [ft]	Coverage ratio, Rc=b/Sh	Horizontal spacing, Sh [ft]	LTDS = Fy·Ac·Rc/b [lb/ft]	Tmax [lb/ft]	Tmd [lb/ft]	Specified minimum CDR Static	Actual calculated CDR Static	Specified minimum CDR seismic	Actual calculated CDR seismic
1	1.27	0.132	1.260	7776.8	7101.2	N/A	N/A	1.095	N/A	N/A
2	3.80	0.117	1.430	6852.3	6172.2	N/A	N/A	1.110	N/A	N/A
3	6.33	0.100	1.670	5867.5	5368.0	N/A	N/A	1.093	N/A	N/A
4	8.86	0.083	2.010	4875.0	4653.9	N/A	N/A	1.047	N/A	N/A
5	11.39	0.083	2.010	4875.0	4013.8	N/A	N/A	1.215	N/A	N/A
6	13.92	0.066	2.530	3873.0	3435.0	N/A	N/A	1.128	N/A	N/A
7	16.45	0.066	2.530	3873.0	2994.3	N/A	N/A	1.293	N/A	N/A
8	18.98	0.066	2.530	3873.0	2845.2	N/A	N/A	1.361	N/A	N/A
9	21.51	0.066	2.530	3873.0	2685.9	N/A	N/A	1.442	N/A	N/A
10	24.04	0.050	3.350	2925.0	2473.3	N/A	N/A	1.183	N/A	N/A
11	26.57	0.050	3.350	2925.0	1530.7	N/A	N/A	1.911	N/A	N/A
12	27.57	0.050	3.350	2925.0	2480.6	N/A	N/A	1.179	N/A	N/A

RESULTS for PULLOUT

Live Load NOT included in calculating Tmax

#	Metal strip Elevation [ft]	Coverage Ratio Rc=b/Sh	Factored: Stat./Seis. Tmax [lb/ft]	Tmd [lb/ft]	Le [ft]	La [ft]	Avail.Static Pullout, Pr [lb/ft]	Specified Static CDR	Actual Static CDR	Avail.Seism. Pullout, Pr [lb/ft]	Specified seismic CDR	Actual seismic CDR
1	1.27	0.132	7101.2	N/A	24.24	0.76	41092.1	N/A	5.787	N/A	N/A	N/A
2	3.80	0.117	6172.2	N/A	22.72	2.28	31862.4	N/A	5.162	N/A	N/A	N/A
3	6.33	0.100	5368.0	N/A	21.20	3.80	23800.8	N/A	4.434	N/A	N/A	N/A
4	8.86	0.083	4653.9	N/A	19.68	5.32	17078.8	N/A	3.670	N/A	N/A	N/A
5	11.39	0.083	4013.8	N/A	18.17	6.83	15641.9	N/A	3.897	N/A	N/A	N/A
6	13.92	0.066	3435.0	N/A	16.65	8.35	12137.4	N/A	3.533	N/A	N/A	N/A
7	16.45	0.066	2994.3	N/A	15.13	9.87	11443.3	N/A	3.822	N/A	N/A	N/A
8	18.98	0.066	2845.2	N/A	14.41	10.59	10934.3	N/A	3.843	N/A	N/A	N/A
9	21.51	0.066	2685.9	N/A	14.41	10.59	10575.9	N/A	3.938	N/A	N/A	N/A
10	24.04	0.050	2473.3	N/A	14.41	10.59	7489.9	N/A	3.028	N/A	N/A	N/A
11	26.57	0.050	1530.7	N/A	14.41	10.59	6766.1	N/A	4.420	N/A	N/A	N/A
12	27.57	0.050	2480.6	N/A	14.41	10.59	6417.5	N/A	2.587	N/A	N/A	N/A

RESULTS for CONNECTION (static conditions)

Live Load included in calculating Tmax

#	Metal strip Elevation [ft]	Coverage ratio Rc=b/Sh	Horizontal spacing, Sh [ft]	Connection force, To [lb/ft]	Reduction factor for connection break, CRu	Long-term connection strength,Tac (break criterion) [lb/ft]	Metal strip long-term strength, [lb/ft]	CDR connection break Specified	CDR connection break Actual	CDR Metal strip strength Specified	CDR Metal strip strength Actual	Product name
1	1.27	0.132	1.260	7101	1.00	10369	10369	N/A	1.46	N/A	1.46	WAVE 2"
2	3.80	0.117	1.430	6172	1.00	9136	9136	N/A	1.48	N/A	1.48	WAVE 2"
3	6.33	0.100	1.670	5368	1.00	7823	7823	N/A	1.46	N/A	1.46	WAVE 2"
4	8.86	0.083	2.010	4654	1.00	6500	6500	N/A	1.40	N/A	1.40	WAVE 2"
5	11.39	0.083	2.010	4014	1.00	6500	6500	N/A	1.62	N/A	1.62	WAVE 2"
6	13.92	0.066	2.530	3435	1.00	5164	5164	N/A	1.50	N/A	1.50	WAVE 2"
7	16.45	0.066	2.530	2994	1.00	5164	5164	N/A	1.72	N/A	1.72	WAVE 2"
8	18.98	0.066	2.530	2845	1.00	5164	5164	N/A	1.82	N/A	1.82	WAVE 2"
9	21.51	0.066	2.530	2686	1.00	5164	5164	N/A	1.92	N/A	1.92	WAVE 2"
10	24.04	0.050	3.350	2473	1.00	3900	3900	N/A	1.58	N/A	1.58	WAVE 2"
11	26.57	0.050	3.350	1531	1.00	3900	3900	N/A	2.55	N/A	2.55	WAVE 2"
12	27.57	0.050	3.350	2481	1.00	3900	3900	N/A	1.57	N/A	1.57	WAVE 2"

Appendix A3.1.2

Elevate MSE Wall Construction Manual

Introduction

This manual provides guidance for the proper construction of the Elevate Mechanically Stabilized Earth (MSE) Wall System. Designed to reinforce a granular, free-draining soil mass, the system consists of precast panels and welded wire mesh, working together to resist lateral earth pressures.

While this document serves as a practical reference to ensure best construction practices, it is ultimately the contractor's responsibility to adhere to all contract plans, specifications, safety regulations, and federal, state, and local laws. Elevate Infrastructure supplies the necessary materials, engineering support, and guidance for system installation, while the contractor is responsible for labor, machinery, backfill, and tools needed for construction. Proper safety measures must be followed at all times. This manual is to be used in conjunction with the contract documents, shop drawings, and project specifications. In the event of any discrepancies between this manual and the contract documents, the more stringent requirements shall govern.

For additional information or assistance, contact your Elevate MSE wall representative.

MSE Wall Components

MSE retaining walls are engineered systems that reinforce a soil mass to withstand lateral earth pressures. Successful construction relies on both proper panel installation and meticulous backfill placement and compaction. The primary components of an Elevate MSE Panel Wall include:

- **Concrete Leveling Pad:** A 6-inch-thick, 12-inch-wide unreinforced concrete strip that runs the entire length of the wall. It provides a level foundation for the first row of panels but does not contribute structurally to the wall.
- **Concrete Panels:** Precast units, typically 5 feet tall by 5 or 10 feet wide. The first row consists of alternating full-height and half-height panels to stagger horizontal joints. Custom-sized panels are used at the top to create the required wall profile. Galvanized dual plate connectors protrude from the back of each panel to attach soil reinforcements.
- **Soil Reinforcement Elements:** Elevate Ladder and/or Wave Strips are galvanized strip-style soil reinforcement elements that attach to the precast concrete panels with a ½-inch nut & bolt. Each reinforcement is manufactured to the required length and galvanized per the design specifications.
- **Select Granular Backfill:** A free-draining granular material that meets project specifications and is used in the reinforced zone.
- **Bearing Pads:** ¾-inch-high pads made of EPDM rubber, placed atop each panel to maintain uniform horizontal joint spacing.
- **Geotextile Fabric:** Installed behind both horizontal and vertical panel joints, this fabric prevents soil migration and is typically secured with construction adhesive.
- **Nuts & Bolts:** Hot-dipped galvanized fasteners used to attach soil reinforcements to the precast panels.
- **Drainage System:** Typically includes plastic pipes and filter fabric, detailed per project requirements to manage water flow and prevent hydrostatic pressure buildup.

MSE walls require close coordination between Elevate Infrastructure and the contractor. Material responsibilities are divided as follows:

Supplied by Elevate Infrastructure:

- Engineered shop drawings
- Precast panels
- Soil reinforcements
- Nuts and bolts
- Panel joint filter fabric
- Construction adhesive
- Bearing pads
- Precast coping
- Ring clutches for panel lifting and setting
- Plastic shims
- On-site assistance

Supplied by the Contractor:

- Labor
- Construction tools (level, hammer, pry bar, etc)
- Foundation preparation
- Equipment for unloading panels and hardware
- Drainage system installation
- Select granular fill
- Leveling pad installation
- Wooden wedges, clamps, and alignment tools
- Cast-in-place concrete (if required)

Materials & Handling

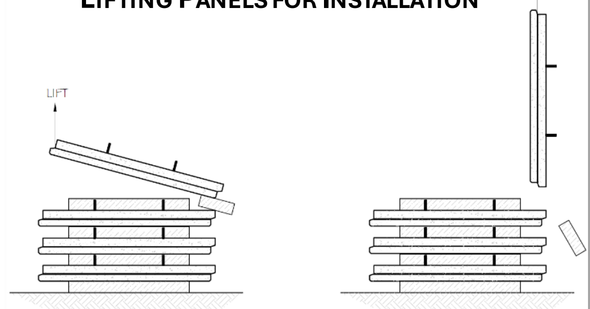
Materials are delivered to the construction site based on a mutually agreed schedule. These include precast panels, steel soil reinforcements, and incidental accessories. The contractor is responsible for unloading, securing, and storing all materials, as well as documenting deliveries. Any damaged, missing, or stolen materials must be reported to Elevate Infrastructure immediately.

Precast Panel Delivery & Handling

Panel delivery is coordinated prior to fabrication, with casting and sequencing aligned to the contractor's schedule. Panels arrive on flatbed trailers in stacks of four to five, secured with heavy-duty winch straps.

UNLOADING PANELS

LIFTING PANELS FOR INSTALLATION



Safety Precautions:

- Panels are large and heavy, requiring appropriate lifting equipment and safe handling practices.
- Flatbed trucks must be parked on solid, level ground before unloading begins.
- All lifting equipment should be inspected before use.
- Dunnage must be properly placed and spaced to avoid panel damage.

Panels should be stored face-down on firm, level ground using appropriate dunnage. Stacking panels directly on the ground should be avoided to prevent cracking and staining. Any cracks or defects must be documented and reported before unloading. Typically, heavy duty straps are used to unload multiple panels at a time. If forklifts are used, the metal forks are to be covered with filter fabric or a similar material to prevent damage to the face of the panel.

When the panels are staged on the construction site, it is important to maintain equal dunnage spacing to prevent cracking. The dunnage blocks should align vertically between the panels as shown.

Steel Soil Reinforcement Delivery & Handling

Elevate steel soil reinforcements consist of either 2-inch wide wave-shaped galvanized steel OR 4-inch-wide welded wire ladders. Strips are delivered to site sorted by type and length. Upon arrival, the contractor must verify that the bill of lading matches the delivery and store reinforcements in a secure, dry area.

Soil reinforcements are to be stored on level ground supported with dunnage at regular intervals.

Incidental Accessories

Filter fabric, nuts, bolts, bearing pads, adhesives, plastic shims, and other accessories are shipped separately before wall construction begins. These materials should be stored in a secure location, such as a job site trailer, to prevent loss or damage.

Wall Construction Process

Step 1: Site Excavation & Foundation Preparation

Excavation must conform to project specifications and ensure the foundation is level across the full reinforcement length. The foundation should be compacted using a smooth-wheel vibratory roller and proof-rolled to meet bearing pressure requirements. Any unsuitable soils must be removed and replaced with structural fill.

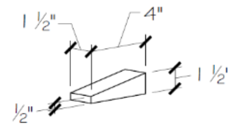
Step 2: Leveling Pad Installation

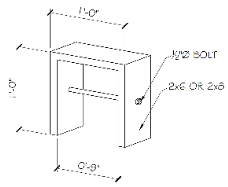
The leveling pad must be poured to the specified lines and grades, ensuring a smooth, level working surface. Concrete pads must cure for at least 12 hours before panel placement. Drainage systems, if required, are typically installed alongside the leveling pad per project plans.

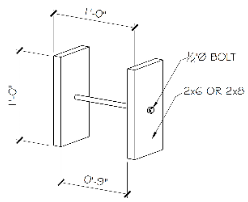
Step 3: Panel Installation

Panels are lifted using designated rigging points and placed in alternating full-height and half-height sequences. Once positioned, C-clamps and turnbuckles secure panels to maintain alignment. A consistent batter should be established to compensate for outward rotation caused by backfill operations.

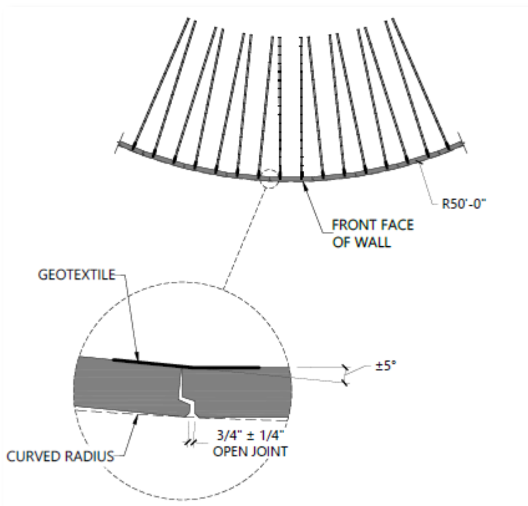
Clamps are typically constructed with 2x4's, threaded tie rods, & washers. Turnbuckles are often used in conjunction with the C-clamps to help fine-tune the batter of the panels. The use of ground-anchored C-Clamps vs. H-Clamps shall be governed by the Owner or installing contractor's safety manual.







Wooden wedges are installed in conjunction with the clamps in the horizontal and vertical joints between the panels to ensure alignment during construction activities. Wedges are removed from the vertical joints once the entire panel is backfilled and compacted. Wooden wedges remain in the horizontal joints at the exposed face of the wall until wall construction is complete.



CONVEX CURVE DETAIL
NO SCALE

Where there are curves and corners, the wall can be installed according to the design mostly without modifications. Depending on the severity of the radius, alternative backfill material and/or compaction efforts may be required to ensure internal stability and meet construction quality standards. For example, a crushed stone similar to AASTHO #57 stone may be more beneficial than a well-graded aggregate in a tight area since the #57 Stone will require minimal compaction efforts

Panels can be placed on curves of varying radii by placing them in a series of cords. The size of the radius will also dictate the length of the panel and the required panel joint configuration. The tighter the radius the smaller the panel length will be. The minimum radius (without bevels) for 5'x10' panels is 100-ft and for 5'x5' panels is 50-ft.

Care should be taken to ensure the joint spacing in the front of the wall is maintained to promote flexibility and anticipated-settlement without damaging the panels. A vertical 3/4" joint is to be maintained at the face of the wall. If the desired radius cannot be accomplished with standard panels, the rear-face corner of the panels may need to be beveled to accommodate radial alignment.

Step 4: Soil Reinforcement & Backfill

Ensuring proper installation of the Elevate Steel Strip soil reinforcements is critical to the performance and stability of the MSE wall. Each steel strip must be installed perpendicular to the precast panel to achieve the intended load transfer and soil interaction. Misalignment or skewed placement can compromise the structural integrity of the system. To maintain proper spacing and prevent interference, a minimum 2-inch separation should be kept between adjacent steel strips and other elements within the backfill. This spacing prevents overlapping, allows for even stress distribution, and ensures that each reinforcement functions independently as designed.

Before fastening the reinforcements, the select granular backfill should be placed and compacted 1" – 2" above the connection. Elevate Steel Soil Reinforcement Strips are then secured to the dual plate connectors using a ½-inch nut and bolt. During installation, it is important to verify that all nuts and bolts are properly tightened to prevent movement during backfill placement. Installing the bolts with nuts-up ensures easy visual inspection.

Backfill should be placed in uniform lifts not exceeding 12 inches in loose thickness before compaction. Compaction must meet project specifications, typically a minimum of 95% of standard Proctor density. Within three feet of the panel face, only hand-operated compactors should be used to avoid excessive force on the wall. Beyond this zone, heavier vibratory rollers may be used to achieve proper compaction. Care should be taken to avoid direct contact between steel reinforcements and heavy equipment to prevent deformation or damage to the soil reinforcement elements.

For areas where utilities, foundations, or other obstructions interfere with standard reinforcement placement, adjustments may be necessary. If reinforcements must be skewed, the maximum allowable skew angle should not exceed 15 degrees unless otherwise specified in the project plans. Any modifications should be reviewed and approved by the project engineer to ensure compliance with design requirements.

At curved sections, soil reinforcements must be carefully arranged to maintain structural integrity and load distribution. When panels are placed in a series of chords to accommodate curves, the soil reinforcements should be slightly staggered to ensure proper engagement with the backfill.

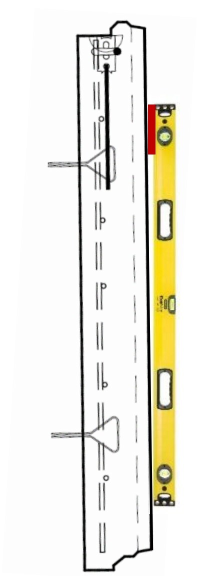
Step 5: Continued Backfill & Panel Placement

Backfilling and compaction continue in uniform lifts until the final wall height is achieved. Panels are installed in sequence, maintaining proper joint spacing. Before the panels are backfilled, geotextile fabric should be applied over all panel joints to prevent soil loss. Typical fabric width is 12" or 18" wide. Adhesive is supplied to the installing contractor to secure the geotextile fabric to the concrete wall. It is important to apply the adhesive to the panel rather than the geotextile fabric.

Quality Assurance – Wall Alignment

In order to achieve vertical wall construction, each panel is to be set with a consistent amount of batter to counteract the lateral forces exerted by the backfilling & compaction operations. This batter is typically measured on a 4' level. One way to ensure consistent batter across all panels is to attach (non-wooden) shims to a 4' level with the desired amount of batter (typically between ½" – ¾"). Place the level vertically on the outside face with shims on the top edge. When the desired batter is achieved, the level-bubble wil lfall squareline in the middle of the level lines. As wall construction continues it is important to go back and verify the vertical alignment of previous courses to judge whether the amount of batter needs to be increased, decreased, or maintained.

Bearing pads are used to create consistent vertical separation between panels. In order to ensure the completed wall has consistent joint spacing, it is recommended ≥ 2 wooden wedges are driven in the horizontal joints to alleviate the stress on the bearing pads until the reinforced fill behind the panel is placed and compacted. Contractor should remove wooden wedges after wall has been constructed, and backfilled to t finished grade.



Quality Assurance – Erosion & Water

Proper erosion control measures must be implemented to prevent soil loss and maintain stability behind and in front of the MSE panel wall during construction. Behind the wall grading should direct surface runoff away from the reinforced backfill zone to prevent water infiltration and erosion. Installing silt fences, wattles, or erosion control blankets along the backfill area can help stabilize the soil and minimize washout. If heavy rainfall is expected, temporary drainage measures such as interceptor ditches or sandbags may be necessary to divert water flow away from the face of the wall.

In front of the wall, controlling runoff and sediment accumulation is equally important. The area at the base of the wall should be properly graded to channel water away, reducing the risk of undermining. Elevate recommends front-filling the fill at the face of the wall as quickly as possible. To ensure stability, the proposed grade at the front of the wall shall be met before the MSE panel wall reaches 20' tall.

If construction is occurring on a slope, installing check dams or temporary diversion swales can help slow water flow and prevent excessive erosion. Additionally, protecting exposed soils with mulch, straw, or geotextiles will help maintain soil integrity until permanent vegetation or erosion control measures can be established. These proactive steps will ensure the long-term stability of the MSE wall and minimize potential construction-related issues. To accommodate curves, panels are placed in a series of chords, with smaller panels used for tighter radii to maintain alignment. In some cases, special edge treatments such as beveled or tapered joints may be required to ensure proper fit and minimize gaps.

Quality Control & Inspection

Ensuring proper alignment, batter, and compaction is critical for wall performance. Regular field inspections should confirm:

- Panel alignment and joint spacing
- Adequate compaction of each backfill lift
- Drainage system functionality

A final walkthrough should verify that all elements meet specifications. Any necessary corrections should be addressed before project acceptance.

Maintenance & Long-Term Performance

When properly designed and constructed, MSE walls require zero-to-no maintenance. However, periodic inspections should be conducted to check for:

- Soil loss through panel joints, which may require grout injection
- Cracked or chipped panels, which should be evaluated and patched if necessary
- Joint movement in excess of construction tolerances, which may indicate settlement or drainage issues

For any concerns, contact Elevate Infrastructure for evaluation and recommendations.

Appendix A4.1.1

Precast Panels – Quality Assurance/Quality Control

This manual is intended as an instruction guide to the Precaster responsible for manufacturing precast panels for use with the Elevate Infrastructure MSE wall system. While Elevate provides guidance, it is the ultimate responsibility of the Precaster to meet the requirements and schedule of the project that is agreed to prior to production. This manual references—and should be used in conjunction with—Elevate Infrastructure's "Precast Panel—Material Production Standards". It is imperative that the Precaster review each project's specifications. Project requirements may differ from the Elevate Infrastructure standard specifications. If the Precaster, inspector, Owner, or Owner's representative has any questions concerning this manual or the drawings and specifications provided please contact Elevate Infrastructure.

Shop Drawing & Purchase Order Verification

Elevate Infrastructure is to provide the Precaster with a complete bill of materials for each project. The purchase order and bill of materials will include the following:

- ASTM designations
- Certification Requirements
- Panel dimensions
- Quantity

The Precast facility and Elevate will agree on the scheduled delivery date to the project jobsite, and it will be the responsibility of the Precaster to reach this deadline.

Form Preparation Prior to Placement of Reinforcement

Precast panels are typically cast face down on a steel-faced form. All films, debris, dirt, concrete, etc. should be removed such that the casting surface is smooth. The forms shall be cleaned after each use such that fabrication tolerances can be achieved, and the panel dimensions are consistent. Ensure that the casting surface is level, smooth and rigid such that the panel is supported properly during casting to avoid warping, racking or bending. Clean the casting surface thoroughly with steel wool and a scraper to ensure a quality finished product. Check the approved shop drawings of the panel carefully to be sure the dimensions of the form, thickness of the wall, chamfers and the locations of the connectors are accurate. Check that the corners are square. Once the form measurements are verified and recorded, a fine mist of form release oil should be applied. Tolerance for the panel dimensions is 0.25 inch, and panel squareness (as determined by the difference between the two diagonals) shall not exceed 0.50 inch.

Reinforcement, Connectors and Lifting Hardware

The approved shop drawings showing the welded wire reinforcing sizes or bar sizes and spacing should be used to assemble a reinforcing cage that is properly wire tied for ease of installation into the form. The reinforcing size and spacing should be verified prior to tying. The panel reinforcing should be placed in the form such that the vertical bars are closest to the back face (soil side) of the panel. The reinforcement should be set on plastic spacers/chairs or hung by wire ties such that the clear cover indicated on the approved shop drawings is achieved. Prior to continuing, the shop drawing for the panel being produced should be reviewed to be sure no additional reinforcing or hardware is necessary before casting. The connectors shall be located and placed according to the approved shop drawings. The connectors shall be placed such that they extend outside the back face (soil side) of the finished panel (typically 3.5 inch +/-0.25 inch). An overhang frame is used to hold the connectors in place above the form. The lateral and vertical position of the connectors should not exceed 1.0 inch difference from the locations shown on the approved shop drawings and the connectors should be placed in such a way that they do not come into contact with any of the panel reinforcement.

The panels will be handled and installed using lifting inserts placed in the top face of the panel. The locations of the lifting inserts are provided on the approved shop drawings. The lifting insert should be sized to safely lift the panel per the manufacturer's recommendations. Prior to casting, the precaster should verify the lift insert size and embedment.

Record all verifications of reinforcement sizes, spacing, clear distances, reinforcement locations, lifting insert locations and embedments on a quality control checklist.

FORM PREPARATION AFTER PLACEMENT OF REINFORCEMENT

Prior to placing concrete in the form, it is important to confirm that the form dimensions, panel thickness, reinforcing, lifting hardware and connectors agree with the approved shop drawings. In the event that the forms shifted during placement of the reinforcement, verify that the forms are square, the clear spacing and edge spacing is correct and record the final dimensions on a quality control checklist. It is important to then check that the form is tight to avoid leakage of the concrete.

CASTING THE PANEL

Verify the concrete mix meets the project specifications before pouring concrete into the forms. Quality control tests need to be conducted on the fresh concrete to test workability (slump), air entrainment and the temperature per the project specifications. Unless otherwise specified by the Owner, Elevate Infrastructure specifications call for 6% (+/- 2%) air entrainment.

Test cylinders should be poured per ASTM standards (or governing specifications) for evaluating the concrete's compressive strength. The concrete can then be poured into the form. Vibration of the concrete is necessary for proper consolidation unless an approved self-consolidating concrete is used.

The back face (soil side) of the panel should be trowel finished if an SCC mix is not utilized. The back face shall be free from open pockets of aggregate or surface distortions in excess of 0.5 inch. Re-verify the panel dimensions (width, height, squareness and thickness) immediately after casting to be sure no shifting has occurred during the placement and consolidation of the concrete. It is important that the concrete is adequately placed around the connectors. Be sure that the connectors are aligned properly and located per the approved shop drawings within tolerance.

CURING

Concrete panels shall be cured in the steel form for a sufficient length of time that allows the panel to be stripped without causing undue stress or damage to the panel. The panel shall be kept sufficiently wet and protected in order to prevent excessive heat loss and/or shrinkage. If necessary, a wet burlap or other preapproved moisture control system can be used to assist the curing process. Concrete panels shall be cured in the steel form a minimum of 6" off the ground.

STRIPPING HANDLING AND STORING

The panels shall be fully supported until the concrete reaches a minimum compressive strength of 2,000psi. The forms can be removed once the concrete has adequately cured. The dimensions of the finished panel should be recorded on a quality control checklist. The squareness should be checked & locations of the connectors verified. Any issues or concerns with the panel should be documented. Unless otherwise indicated, the manufacturer, date of manufacture, panel type, and the production lot number shall be clearly scribed on the back face of each panel.

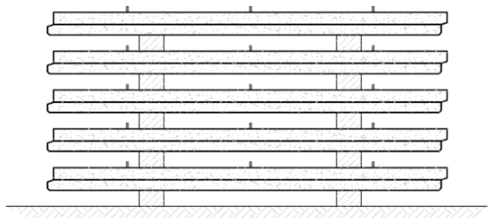


FIGURE 1

Before storage, check the face of the panel to ensure a quality finish. Prepare a level storage surface for the panels. The panels can be lifted and stacked using a crane or boom truck. The panels can be lifted using an appropriate sling or by using the lifting devices in the top of the panel. The connectors can also be used to lift the panel in conjunction with a preassembled frame, however extreme caution is to be exercised to avoid bending or stressing the connector tabs. Bent connector tabs can be cause for panel rejection by the Owner. Please note that care must also be taken when stacking panels, else it will often lead to chipping on the panel edges. The panels should be stacked on a firm and level surface. As shown in Figure 1, the panels should always be stacked using the necessary dunnage to avoid concrete staining or bending the connectors protruding from the face of the panel. Dunnage should also include plastic spacers to avoid staining of the finished panel surface.

Figure 2 illustrates the proper technique for lifting individual panels to avoid chipping and cracking. The supplied dunnage will remain the property of the Precaster and will be returned after the panels are installed. The Contractor will be responsible for any damaged or misplaced dunnage.

The panels may be shipped after reaching a minimum compressive strength of 3,000 psi. All panels shall be handled, stored and shipped in such a manner as to eliminate the dangers of chipping, discoloration, cracks, fractures, and excessive bending stresses. Panels in storage shall be supported on firm blocking to protect the panel connection devices and the exposed exterior finish.

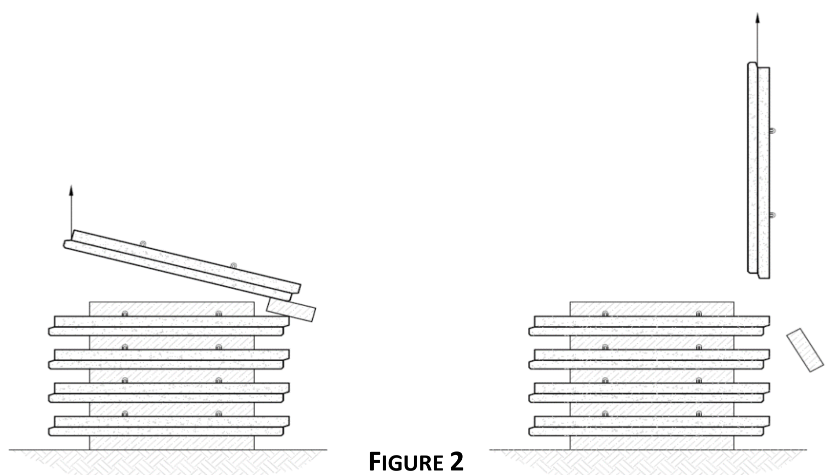


FIGURE 2

SHIPPING

Loading the panels for shipment will require padded straps, padded contact areas, padded supports and corner protection where necessary. Care should be taken to minimize handling. Supports shall be adequate, firm and placed evenly to prevent sagging. Panels shall be loaded and secured to the truck bed such that the center of gravity of the load is as close as possible to the truck's center of gravity. Dunnage shall be provided by the Precaster and shipped to the project location for the contractors use in offloading and restacking.

PRECAST PARTNERSHIPS

Elevate Infrastructure partners with a select group of pre-qualified precasters meeting strict NPCA and/or PCI standards as well as necessary DOT-approvals.

Appendix A4.1.2

STEEL SOIL REINFORCEMENTS – QUALITY ASSURANCE/QUALITY CONTROL (1064)

This manual is intended as an instruction guide to the Steel Processing Company responsible for manufacturing the welded wire soil reinforcements for Elevate Infrastructure. While Elevate provides guidance, it is the ultimate responsibility of the Steel Processing Company to meet the requirements and schedule of the project that is agreed to prior to production. This manual references—and should be used in conjunction with the "Steel Soil Reinforcements—Material Production Standards." It is imperative that the Steel Processing Company review each project's specifications. Project requirements may differ from the Elevate Infrastructure standard specifications. If the Steel Processing Company, inspector, owner, or owner's representative has any questions concerning this manual or the drawings and specifications provided by Elevate Infrastructure for a particular project please contact the proper Elevate representative.

SHOP DRAWING & PURCHASE ORDER VERIFICATION

Elevate Infrastructure is to provide the Steel Processing Company with a complete bill of materials for each project. The purchase order and bill of materials will include the following:

- ASTM designation
- Tensile Requirements
- Width
- Length
- Gauge
- Quantity

The Steel Processing Company and Elevate will agree on the scheduled delivery date to the project jobsite, and it will be the responsibility of the Steel Processing Company to reach this deadline.

STEEL CERTIFICATION, GRADE, WELDING, & PURCHASING

The standard ASTM designation for the Elevate Infrastructure's welded wire soil reinforcement is ASTM A1064. Smooth wire to have minimum tensile strength 75ksi & minimum yield strength 65ksi. Deformed wire to have minimum tensile strength of 80ksi and a minimum yield strength of 70ksi.

After the welded wire reinforcement is fabricated a 1.5" x 5.5" flat bar connector is to be welded to the leading end of the wire configuration. The weld is to be a minimum of 1.5" in length. The thickness of the bar is to be 7 gauge (0.1875"). The bar connector is to be manufactured per ASTM A1011 HSLAS Grade 55 Class 2. Welding the flat bar connector to the wire can be either robotically or manually welded per American Welding Society D1.4 Standards.

Unless otherwise noted in the plans, all steel is to be sourced and manufactured in the United States of America. No foreign steel or billets to be used in the manufacturing of any coils or wire. Proof of "Buy America" compliance is to be provided with every production run.

WELDED WIRE SOIL REINFORCEMENT MANUFACTURING

The steel soil reinforcement gauges may vary based on retaining wall design parameters, however the standard configuration uses W11 longitudinal & transverse bars. The Steel Processing Company will be responsible for manufacturing the proper quantities and lengths for each reinforcement type.

The final configuration of the welded wire soil reinforcements shall conform to the approved shop drawing dimensions, gauges, and lengths as stipulated in the contract documents. Elevate Infrastructure will provide the Steel Processing Company with a detailed breakdown of the types & lengths to be manufactured for each project as well as a list of required certifications.

Individual soil reinforcement grids can be manufactured independently or derived from a larger welded wire sheet. If soil reinforcements are manufactured as part of a sheet with a wider overall width before being parsed into their final configuration, care must be taken to ensure individual soil reinforcements are in conformance with the tolerance dimensions as specified by Elevate Infrastructure.

HANDLING & DELIVERY

The Steel Processing Company will deliver the welded wire reinforcements to the galvanizer bundled and tagged according to type & length. The soil reinforcements are to be rotated on their side (perpendicular to the plane of installation) and bound with industrial plastic strapping to simplify material handling. Dunnage is to be used in conjunction with the strapping to provide support while loading & unloading the material.

Elevate Infrastructure recommends using heavy duty construction slings to handle the bundles of soil reinforcements. If forklifts are used to handle the bundles, care must be taken to avoid damaging the overhangs.

Once bound, each bundle is to be tagged with a heavy-duty label identifying the quantity, length, and type of soil reinforcements in each bundle. The galvanizer will use an identical set of tags to reconcile quantities and identify the bundles to the Contractor on site.

Soil reinforcements to be hot dip galvanized per ASTM A123 / AASHTO M111. Once the zinc has dried, soil reinforcements are to be bundled & bound with industrial plastic strapping and wooden dunnage in the same rigid manner as described above. Each bundle will be tagged with heavy duty labels identifying the quantity, length, wall identification/number, and type of soil reinforcements contained in each bundle.

Appendix A4.2.1

APPENDIX A4.2.1 – MSE PANEL WALL CONSTRUCTION QA

1. General Information

Mechanically Stabilized Earth (MSE) walls are a widely used solution in civil engineering for retaining soil in roadway, bridge, and large infrastructure projects. Proper installation is critical to ensuring the longevity and stability of these walls. This manual outlines the recommended practices for constructing MSE panel walls, emphasizing structural integrity, material selection, and compliance with industry standards. In addition to all federal, local, and company-specific QA procedures, this manual can be incorporated as part of a plan for ensuring proper measures are taken to properly construct an Elevate MSE Panel Wall.

2. Site Preparation

Proper site preparation is essential to the success of an MSE wall system. Before construction begins:

- Conduct a detailed site survey to confirm that existing ground conditions align with design assumptions. This includes verifying soil bearing capacity, groundwater conditions, and any potential obstructions.
- Excavate to the required elevations and ensure the foundation area is free of organic material, debris, or loose soil.
- Install any contract-specific ground improvements per the Ground Improvement Design Engineer specifications.
- Establish a level and compacted foundation, achieving the required soil compaction per project specifications.
- Verify that any necessary drainage infrastructure is installed to prevent water accumulation behind the wall.
- Cast an unreinforced concrete leveling pad to provide a uniform base for panel installation. Typical dimensions are a minimum of 12” wide and 6” deep.

3. Panel Installation

The installation of precast concrete facing panels is a crucial step that determines the alignment and appearance of the wall.

- Begin by placing the first row of panels carefully on the prepared leveling pad. Proper alignment and verticality are essential, as errors in the first row will be amplified in subsequent rows. Install 1/16” plastic shims as necessary to correct any imperfections in the CIP leveling pad.
- Use temporary bracing to secure panels until soil reinforcement and backfill provide structural stability.
- Ensure panel joints are properly aligned, and any specified geotextile filters are installed at panel joints to prevent soil migration.
- Maintain proper batter (wall inclination) as specified in design drawings, adjusting bracing as needed.

4. Soil Reinforcement Placement

The proper installation of soil reinforcement elements, such as steel strips or geogrids, ensures the stability and load-bearing capacity of the wall.

- Verify that reinforcement lengths, spacing, and orientation match design specifications.

- Place reinforcement strips perpendicular to the wall face, ensuring they extend the full required length into the reinforced soil zone.
- Ensure that the reinforcement elements are securely connected to the precast panel's embedded anchor.
- In cases where obstructions such as foundations or utility structures exist, consult with the engineer for approved modifications to the reinforcement layout.

5. Backfill Operations

Proper backfilling is key to maintaining the stability and structural performance of the MSE wall.

- Use only approved select fill material that meets project specifications, free of excessive fines, organics, or large debris.
- Backfill in uniform lifts, typically 6" – 12" in loose thickness, to ensure proper compaction and reinforcement embedment.
- Compact each lift to the specified density, typically 95% of AASHTO T99 standard proctor, using appropriate vibratory compaction equipment.
- Avoid compaction with heavy equipment within 3' of the rear-face of the panel, as excessive force may cause misalignment.
- Heavy construction equipment should maintain a minimum setback from the wall face to prevent excessive lateral pressure or displacement.

6. Drainage Considerations

Managing water behind the MSE wall is critical for long-term stability.

- Install proper drainage components, such as weep holes, perforated drain pipes, and granular drainage layers, per project specifications.
- Ensure drainage outlets remain clear and unobstructed to prevent hydrostatic pressure buildup.
- Grade the backfill surface at the end of each workday to prevent ponding or erosion from unexpected rainfall.

7. Quality Control & Inspection

Regular inspections throughout construction ensure that the wall meets design and performance expectations.

- Verify panel alignment, verticality, and batter at each lift of construction.
- Confirm proper soil reinforcement placement, including tensioning and embedment depth.
- Conduct field density tests to ensure compaction meets project specifications.
- Inspect drainage systems and ensure geotextiles, pipes, and weep holes are correctly installed.
- Any observed deviations should be addressed promptly to avoid costly rework or structural deficiencies.

8. Safety Guidelines

Construction safety is paramount in MSE wall installation.

- All workers must wear appropriate personal protective equipment (PPE), including helmets, gloves, and high-visibility vests.
- Heavy lifting and panel placement should only be performed with properly rated equipment operated by trained personnel.
- Maintain clear communication between operators, inspectors, and ground crews to prevent accidents.
- Follow OSHA regulations and site-specific safety plans to minimize risks during excavation, backfilling, and panel installation.

9. Final Inspection & Project Completion

Before the wall is considered complete, a final inspection should be conducted to ensure compliance with design requirements.

- Perform a detailed walkthrough to check for any panel misalignments, reinforcement issues, or drainage concerns.
- Remove all temporary bracing and verify that backfill has been placed and compacted to final grades.
- Confirm that all drainage components are functioning correctly and that surface runoff is directed away from the wall.
- Document as-built conditions, including any approved field modifications, for project records and future maintenance reference.

By following these guidelines, contractors can ensure that Elevate MSE Walls are constructed safely, efficiently, and in compliance with engineering standards. For any questions or clarifications, refer to the project drawings & specifications..

Appendix A5.1.4

APPENDIX A5.1.4 – LIST OF ELEVATE INFRASTRUCTURE MSE WALL APPROVED AGENCIES

For over a decade, Elevate Infrastructure has partnered with Transportation Owners & contractors to supply high quality retaining walls for heavy highway & railway projects across the country including precast counterfort walls, post & panel walls, large block gravity walls, and temporary wire walls. Today, Elevate Infrastructure is expanding their ability to rebuild American infrastructure by providing an unrivaled level of customer service & quality to the MSE panel wall market. A list of approved municipalities where the Elevate MSE Panel Wall System is approved is included here for reference. The Elevate MSE Panel Wall System has never been revoked by any government agency.

State	Contact	Phone #	Email
Illinois	Kevin Riechers	(217) 782-9109	Kevin.Riechers@illinois.gov
Wisconsin	John Rublein	(608) 246-7953	John.Rublein@dot.wi.gov
Iowa	Mahbub Khoda	(515) 239-1649	Mahbub.Khoda@dot.iowa.gov
Nebraska	Nikolas Glennie	(402) 479-4752	Nikolas.Glennie@Nebraska.gov
Missouri	Suresh Patel	(573) 526-3030	Suresh.Patel@modot.mo.gov
South Dakota	Mike Behm	(605) 773-2078	Michael.Behm@state.sd.us
Ohio	Evan Holcombe	(614) 387-1262	Evan.Holcombe@dot.ohio.gov
Kentucky	Adam Ross	(502) 782-5155	Adam.Ross@ky.gov