REPORT OF REVIEW: THE GREENSTEEP REINFORCED SOIL SLOPE (RSS) FACING SYSTEM
August 2023
HIGHWAY INNOVATIONS, DEVELOPMENTS, ENHANCEMENTS AND ADVANCEMENTS (IDEA)

The Greensteep Segmental Block Facing/Revetment System for reinforced soil slope (RSS) structures has been evaluated by an IDEA Review Team. This review has been performed in accordance with the customized, Greensteep-specific IDEA protocol S2 – Greensteep 2021 Technical Evaluation Checklist for Reinforced Soil Slope (RSS) Facing System Used on RSS Structures with Extensible Reinforcement (appended to the Greensteep Submittal).

Key information regarding this facing system is presented in this final report of the review. Details of the system's components, design, construction and quality control measures are presented in the (attached) Greensteep Submittal. Recognizing the stage of development that this innovative system is at, the review concurs with the applicant that several items will need to be addressed during the specifying, design, and/or construction phases of RSS structures of upcoming projects as development progresses. Items and issues to be addressed on a project specific-basis, for upcoming projects, are listed in this report. Most of these items will need to be addressed by the project-specific RSS design engineer, construction contractor, and/or owner.

IDEA Introduction
In 2016 the FHWA published a protocol to further advance innovations in earth retention technology and encourage their use by public transportation agencies (Johnson and Valentine 2016). Under this protocol, earth retention systems are evaluated by a review team. Overall administration of the review program is performed by the Geo-Institute of the American Society of Civil Engineers.

Technical evaluations for the IDEA program are based upon information provided by the system applicant, as well as existing guidelines and specifications such as those published by the FHWA and AASHTO. These references serve as a baseline to assess a system's conformance with current engineering practices. **However, a fundamental objective of the IDEA program is to encourage advancements in earth retention technology.** Such advancements may not be contemplated by current design references. Thus, the IDEA program relies upon earth retention experts to evaluate potential innovations.

IDEA Review Process
The IDEA program is generally used to provide a technical evaluation of an earth retention system. In accordance with the IDEA protocol, an earth retention system is defined as a unit that comprises the following elements:

- Specific components and the materials used for their manufacture.
- Design methodologies.
- Construction procedures.
- Quality control measures.

Initially, the IDEA program provided for two types of reviews of comprehensive earth retention systems: an initial technical evaluation and an update technical evaluation. An update evaluation is performed five years after completion of the initial evaluation or in response to a notification of a change in an element of the system. However, the IDEA program has expanded to address innovations that are made to components of an earth retention system (and not just all-inclusive earth retention systems), such as this Greensteep RSS facing system.

This initial IDEA review is of a component of a reinforced soil slope structure system, and not of an all-inclusive package of specific components and materials, design methodologies, construction procedures, and quality control measures. Furthermore, this review is for a new innovation that has been demonstrated with three structures constructed to date. It is not a well-established system with broad based usage (typically in the private/commercial and/or transportation sectors), as addressed in other IDEA evaluations and reports.

An initial technical evaluation is performed in following four phases. The checklist used for the submittal and evaluation is an IDEA customized, Greensteep-specific protocol.

- Pre-submittal Review Phase – It is initiated when an applicant provides a request for an initial technical evaluation. A checklist is selected or designed based on the characteristics of the proposed earth retention system.
- Submittal Check Phase – It is initiated by the applicant. The submittal is checked for completeness and conformance to the evaluation checklist. A report of review is provided to the applicant that describes the review team's findings and recommendations.
- Initial Submittal Review Phase – The submittal is rigorously evaluated for its technical content with emphasis given to any innovations proposed by the applicant. A report of review is provided to the applicant that describes the review team's findings and recommendations.
- Final Submittal Review Phase – The applicant's response to the previous review comments are considered and final review comments are discussed with the applicant. A final report of review is completed and attached to the applicant's final submittal. The report and submittal are provided for use by transportation agencies.

The four phases of the initial technical evaluation of the Greensteep RSS facing system have been completed. This is the final technical evaluation report.

Applicant Information

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Review Summary

This review, report, and submittal vary considerably from other IDEA reviews, reports, and submittals that have been completed to date on mechanically stabilized earth (MSE) and gravity wall systems. These differentiations are due to:

- Greensteep is a facing component. It is not an all-inclusive earth retention "system." It is to be used with standard reinforced soil slope (RSS) structures with a face inclination of 0.5H:1V (i.e., 66 degrees).
- A Greensteep-specific protocol was developed, as none of the existing IDEA protocols directly applied, and was used for the submittal and review.

- Greensteep is a new innovation. It is not a well-established system with broad-based usage, as addressed in other IDEA reports to date. Thus, this IDEA report will be used to initiate use and demonstration projects with government agencies, in lieu of broadening use and obtaining approvals from more state transportation agencies that well established systems generally are seeking.
- Greensteep has demonstrated the feasibility of their facing system through construction of three different structures, built over the last thirteen years.
- The recognition of the early stage of commercialization that this facing system is at, and expectation of refinement of the system with commercial use and application by various design engineers and owners (e.g., transportation agencies, developers, etc.).

Submittal Checklist

The checklists used for the submittal and evaluation are presented in the IDEA customized, Greensteep-specific protocol: S2 – Greensteep 2021 Technical Evaluation Checklist for Reinforced Soil Slope (RSS) Facing System Used on a RSS with Extensible Reinforcement. This is the initial evaluation of the Greensteep RSS Facing System by the IDEA evaluation program. This protocol is appended to the (attached) Greensteep submittal.

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. Greensteep has designated some information on molding, handling, erection, and alignment as proprietary and, therefore, this information is not included in the submittal.

System Description

<u>Components</u>

The Greensteep block facing system consists of erosion resistant and vegetation hosting facing units that serve as a revetment to a conventional geogrid reinforced, RSS structure with a 66-degree angle of inclination. The blocks are 48-inches long, 18-inches high and 8 to 12-inches wide, and are fabricated on-site by compression of approximately 10 cubic-feet of common native or imported soil that is mixed with cement. A strong block is achieved by pressing the soil-cement mixture with Greensteep's specially-designed portable press. The press is configured to produce a cuboid-like shaped block that includes a bench platform and slots to secure ancillary planter panels that are added to the face during block installation. Block-on-block offset during placement, produces a bench platform that hosts the planter panels. Natural grasses self-emerge from topsoil that is borrowed from adjacent hillside areas and placed in the planters. The topsoil in the planter panels serve as a growing medium, thus generating a façade that blends the structure into the surrounding landscape. Alternatively, an owner can opt to plant other low growth vegetation, as desired.

<u>System History</u>

The Greensteep system has a 16-year history of evolution. All of the projects have been in the San Francisco Bay Area (California) and at a prototype level. The first project was a 10.5-foot high structure constructed in 2007, and remains in place with no visual deterioration. It employed solely rectangular blocks, without any provisions for vegetation. In 2014, a 6-foot high structure was constructed to test vegetation amendatory components and revised block arrangement, and was a successful demonstration. Grasses flourished unimpeded and produced a consistent natural façade. This structure was dismantled afterwards. In 2015, a structure was constructed in a Monastery, with a maximum height of 10.5-foot. It incorporated several advances in fabrication, block transport and provisions for vegetation. To date, Greensteep reports this structure has performed "impeccably" and is available to visitors.

Site Visits

Due to the early stage of application of this innovative reinforced soil facing system, the review team requested site visits of the two constructed structures (a third structure was dismantled after demonstrative construction). The lead IDEA reviewer visited the two structures on August 1 and 2, 2023, with the applicant. Field notes, photographs, and discussion of the two structures are attached to this IDEA report (immediately following and preceding the submittal). Findings and observations are summarized in the following paragraphs.

The initial structure was constructed in 2007, was inspected on August 1, 2023. These initial facing units were on-site, field produced soil-cement units; and the facing units were moved and placed in the reinforced soil structure as they were produced. The block face units were the initial, concept version of geometry, and were 18-inch high, 12-inch deep, 4-foot long units. These units were stacked vertically (i.e., no batter), with a layer of polyester geogrid between each vertically adjacent unit, and in 100% coverage. The geogrid was wrapped approximately 1-foot up the face of the vertically adjacent unit and anchored in place with screws and washers in the geogrid apertures, adjacent to the geogrid ribs. The structure was in excellent condition.

The structure constructed in 2015 was inspected on August 2, 2023 (see Figure 1). The facing units are field produced soil-cement facing units; and the facing units were moved and placed in the reinforced soil structure as they were produced. The block face units geometry is the same as the current, stepped-facing units; are stacked at a 66-degree inclination; and have precast planter panels attached. This structure was reinforced with biaxial polypropylene geogrid, that was attached to the facing units. The geogrid was placed in 100% coverage. The geogrid was anchored in place with screws and washers placed through the horizontal portion of the concrete planter panels. The structure was in excellent condition. The vegetative face had been replanted in 2021, to a native species that requires less watering.

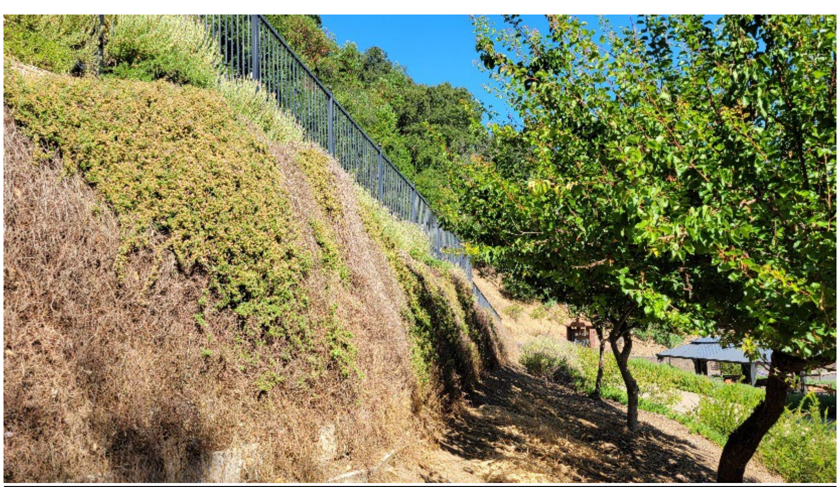

Figure 1. Photograph of the 2015 constructed Greensteep faced, reinforced soil slope (2 August 2023 photo).

System Innovations
This IDEA evaluation concurs with Greensteep that their system provides the following innovations:

- The addition of a compressed soil-cement block (facing unit) revetment to the exposed face of a conventional RSS structure. Theses facing units are:
    - produced on-site,
    - 48-inches in length, 8 to 12 inches in width and 18-inches in height
    - geometrically producing a 66-degree slope face angle (off horizontal) of inclination, and
    - faced with planter panels fastened on the block exterior faces, that house a planting medium that supports a grass-like vegetation facade.

Reinforced Soil Slope (RSS) Design
This IDEA evaluation notes that the Greensteep System is designed for use with reinforced soil slope (RSS) structures. RSS has traditionally been defined in FHWA guidance as mechanically stabilized earth (MSE) structures with a face batter of greater than 20 degrees from vertical (Elias and Christopher, 1997), and with a batter of 20 degrees or less classified as an MSE wall structure. The IDEA review notes that recently developed MSE wall analysis methods, such as the Limit Equilibrium Method (Allen and Bathurst, 2018) and the Simplified Stiffness Method (Leshchinsky et al. 2016), can be employed to analyze structures with batters greater than 20 degrees, including computation of facing connection loads.

The following RSS design items are reported by the applicant for Greensteep System's Segmental Block Facing/Revetment Units Applicable to Reinforced Soil Slope (RSS) Structures:

- The RSS design can be performed using standard reinforced slope computer-assisted design software that the design engineer deems appropriate. As such, there is no Greensteep innovation in design, as it incorporates a mature technology that is commonly implemented by practitioners and transportation agencies. The applicant states that the compressed soil-cement blocks (facing units) serve as a revetment to the RSS. As such, the block facing must tend to fall into the slope face and cannot apply tensile loads to the geogrid reinforcement; and thus, the facing unit connection to the geogrid reinforcement tension load, under static conditions is negligible.
- If the premise that connection capacity is not an issue under static loading is accepted by the design engineer (though it may be an issue under seismic or other extreme loading), geogrid to face unit connection capacity is not a design issue. If this premise is rejected by the design engineer, connection capacity is a design issue to be addressed. It is noted that the connection capacities of geogrid reinforcements and Greensteep units have not been evaluated by laboratory short-term connection strength testing. (Albeit some simple field connection load tests were performed on an anchor screw attachment of the geogrid to the block and an anchor strength based on these results was calculated, as presented in the submittal).

Reviewer Comments

<u>Development/Commercialization Process</u>
The process of developing and commercializing a product can be described as five phases. These phases are: (1) idea generation; (2) screening; (3) concept development; (4) product development; and (5)

commercialization. The Greensteep RSS Segmental Block Facing Revetment Units proof of concept (#3) and product development (#4) have been demonstrated with the successful fabrication of units and construction of three structures. The innovative Greensteep System of RSS Segmental Block Facing Revetment Units is now in its commercialization (#5) phase; and this IDEA evaluation and report support this effort. Greensteep can use this IDEA report to initiate use and demonstration projects with government agencies. Of course, some additional product refinement, or development (#4), should be anticipated with commercial use of the system and application by various design engineers and owners (e.g., transportation agencies, developers, etc.).

Review Process Comments

In the Initial Submittal Review Phase of the Greensteep RSS Facing System, the review team provided the applicant with 155 comments and requests for clarification on their January 28, 2022 submittal. A revised submittal, dated July 21, 2022 was then presented by Greensteep. The review team provided an additional 29 comments, and requests for additional clarification on some the prior comments, to be addressed in a subsequent revised submittal. This was followed with a third submittal, February 2023. Only a few comments and requests for clarification remained after review of the third submittal. These were addressed in the attached Greensteep RSS Facing System IDEA Submittal, dated August 2023, attached to this IDEA report.

The applicant has been forthright in their responses. Recognizing the stage of development that this innovative system is at, the review team concurs with the applicant that several items will need to be addressed during the specifying, design, and/or construction phases of RSS structures for upcoming projects as development progresses. Items and issues to be addressed on a project specific-basis, for upcoming projects, are listed below in Table 1. The items/issues are organized under four categories: design; construction; maintenance and longevity; and limitations. These items/issues should be addressed by the RSS design engineer, construction contractor, and/or owner, on a project-specific basis. Items noted with "(1)" are those which are addressed within the Greensteep submittal, however, the engineer, contractor, and/or owner may want to review and either accept as stated or modify for their specific project.

Table 1. Items and Issues to be Addressed for Project Designs, by Category

Category: Design Items/Issues	
Item #	Comment
1	Approval of borrow sources, stockpile gradation and PI requirements(1)
2	QC of mixing(1)
3	Full QC/QA requirements for unit fabrication, including strength(1)
4	Strength testing sample prep(1)
5	Specifications and QC requirements for planter panels; concrete strength, dimension tolerances, concrete additives, acceptance criteria
6	Specification for mortar fill(1)
7	If designing as a connected facing system, need to define the connection strength, i.e., geogrid strength that can be mobilized at the face of the structure (in the Greensteep unit and drain fill). No physical laboratory testing of connection has been performed.
8	Define required connection strength, using RSS, SSM, and/or LEM (wall design) methods.
9	How to model and incorporate the Greensteep face unit and adjacent chimney drain shear strength properties into the reinforced slope model and stability analysis
10	Structural requirements, or not, of concrete planter panels(1)
11	Define maximum allowable gap between units, based upon drain stone gradation and slot filter criteria.

12	Detailing corners and use of shortened, cut units
13	Detailing around appurtenant structures
14	Vegetation selection; seeded or natural reseeding
15	Vegetation growth and maintenance
16	Cost viability of the system for project specific application
Category: Construction Items/Issues	
Item #	Comment
1	Cost viability of the system for project specific application.
2	QC of soil-cement mixing[(1)]
3	Strength testing sample prep[(1)]
4	Unit production and construction schedule: If units will be placed as fabricated, and if so, how many manufacturing stations are needed? Alternatively, does unit production, and stockpiling, need to commence prior to RSS construction operation.
5	Address how to minimize unit rotation (C.G. is behind corner of lower unit) during erection and backfilling.[(1)]
6	Cutting of units for corners or shorter lengths - equipment and procedure(s)
7	Handling and erection of concrete planter panels
8	Soil placement procedures for filling planters.
9	Vegetation of planter boxes.
10	Vegetation placement and temporary watering
Category: Maintenance and Longevity Items/Issues	
Item #	Comment
1	Block durability for aggressive conditions (see Limitations, following)
2	What is longevity of screw fasteners, if deemed a structural element.[(1)]
3	Life of precast concrete planter panels.[(1)]
4	Vegetative face – selection of plants to match climate conditions.
5	How can grasses/vegetation be maintained on taller structures? Can workers climb the planter, or are ladders needed or should be used to prevent breaking concrete panel boxes?
Category: Limitations	
Item #	Comment
1	The use of the soil-cement units in the following conditions should be investigated, in regards to long-term durability and degradation concerns, prior to such application. a) Severe freeze-thaw environments b) Where deicing salts will be used c) In water retention applications d) Where block fabrication borrow source organic contents is 1% or higher
(1) Item is addressed within the Greensteep submittal, however, the engineer, contractor, and/or owner may want to review and either accept as stated or modify for their specific project.	

Transportation agencies, other owners/developers, design engineers, and contractors are encouraged to utilize the (attached) final Greensteep System's Segmental Block Facing/Revetment Units Applicable to Mechanically RSS Structures, and this report and listings of item/issues to be considered for projects where the Greensteep RSS Facing System is proposed.

Closing

An IDEA update technical evaluation should be performed for the Greensteep Reinforced Soil Slope Facing System in five years (i.e., September 2028) 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.

References

Allen, T.M. and Bathurst, R.J. (2018). *Application of the Simplified Stiffness Method to Design of Reinforced Soil Walls*, ASCE Journal of Geotechnical and Geoenvironmental Engineering, 144(5): 04018024.

Elias, V. and Christopher, B.R., (1997). Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Design and Construction Guidelines, Federal Highway Administration, FHWA SA-96-071, Washington, D.C., 371p.

Johnson, K. and Valentine, R. (2016). *Highway Innovations, Developments, Enhancements and Advancements (IDEA) – Protocol for Technical Evaluation of Earth Retention Systems*, FHWA-16-006, Washington, D.C.

Leshchinsky, D., Leshchinsky, O, Zelenko, B. and Horne, J. (2016). *Limit equilibrium Design Framework for MSE Structures with Extensible Reinforcement*, FHWA-HIF-17-004, 120p.

Site Visit Reports

2007 First Concept Wall, 1 August 2023

2015 Monastery Wall, 2 August 2023

Structure/Site/Project:	**2007 First Concept**
Height:	10.5 feet total; ~8 feet exposed
Face Angle:	near vertical
Facing Finish:	No vegetation
Facing Panels:	N/A
Facing Block Shape:	Rectangular
Facing Block Size:	18 inches high by 12 inches deep by 4 feet long
Facing Block Stacking:	Running bond along segment lengths
Block Corner Geometry:	Cut blocks, Stacked bond at corners
Block Cut Observations:	Clean cuts, no visual raveling or deterioration
Facing Condition:	Very good, no visual deterioration or erosion
Block Facing Mesh:	Mesh and finer screen used in combination
Condition of Steel Meshes:	Very good, generally no visual deterioration
Top of Wall Condition:	Level backfill, fencing recently removed for some renovation work
Geogrid Reinforcement:	Yes
Reinforcement Type:	Coated PET
Reinforcement Connection:	Wrapped up the face of upper block and screw/washer anchors
Connection Screw Condition:	Very good, no corrosion on majority of anchors screws. A little corrosion on a small portion of them. Did not find any torn geogrid around an anchor, or displaced anchor screws.
Condition of Vegetation:	N/A, non-vegetated
Face Foundation:	Concrete grade beam, supported on concrete piers
Facing pH Measurements:	Four pH measurements were made on a horizontal face of a two top blocks. Distilled water (pH = 7) and pH paper were used. Water was puddled at test location, and pH paper was applied after water was absorbed and when surface was still damp.

pH measurements – taken on the top face of the two units, where units above removed

Location/#:	1. First Unit	2. First Unit, adjacent to #1
Surface Prep:	scraped clean	crushed (with geologist pick) area
pH Value:	7	$\sim 9^{+}$
Location/#:	3. Second Unit	4. Second Unit, adjacent to #3
Surface Prep:	scraped clean	crushed (with geologist pick) area
pH Value:	7	9

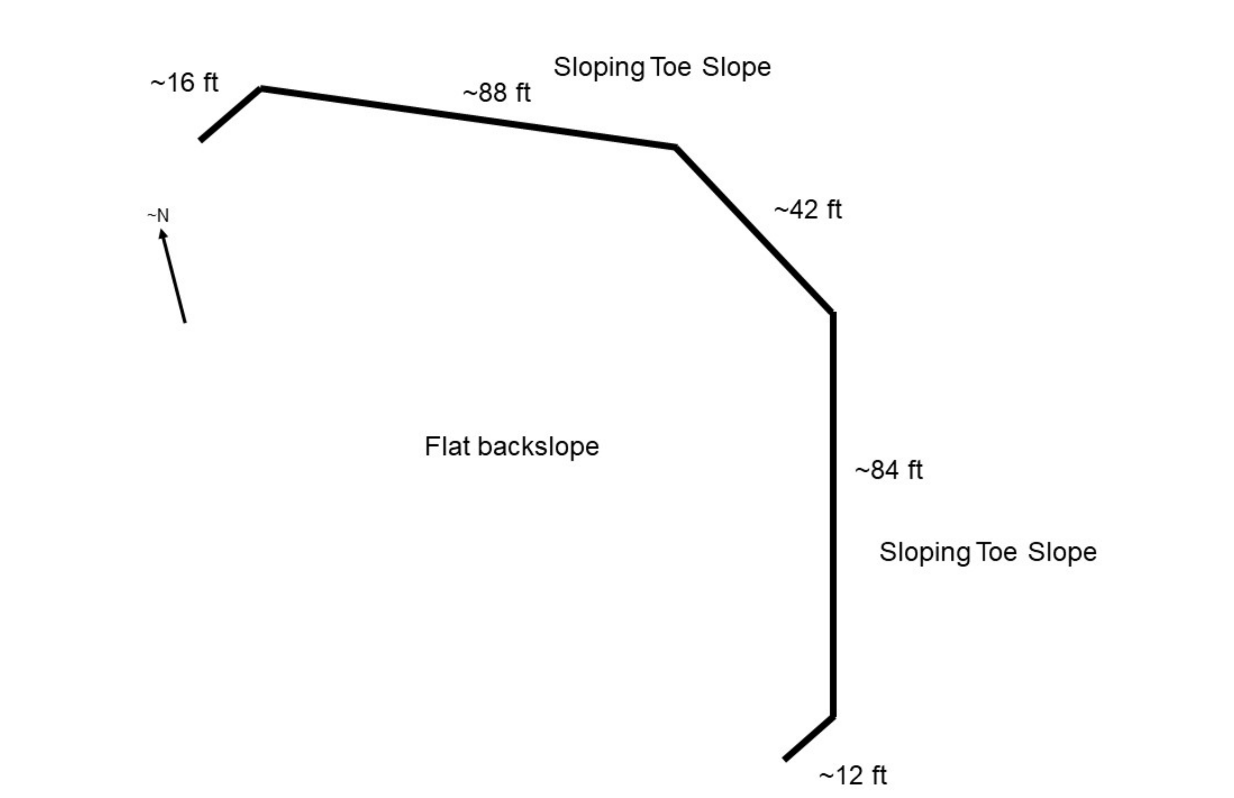

Figure 1. Plan view of 2007 Greensteep wall.

Photo List:

1. Front face view, southern corner of structure.
2. Front face, section where two units were recently removed.
3. Front face view, northern wall face.
4. Top of wall, level backfill (fence recently removed).
5. Face of wall close-up; face has metal screen and mesh, geogrid is wrapped up face of unit above.
6. Cut corner units, geogrid anchored with screws and washers.
7. Anchor screws and washers, one corroded.
8. Cut corner units.
9. Front eastern face.
10. Geogrid anchorage at corner.

Photo 1: Front face view, southern corner of structure.

Photo 2: Front face, section where two units were recently removed[1].

[1] Fencing and two units were removed by Owner, for some modification work.

Photo 3. Front face view, northern wall face.

Photo 4. Top of wall, level backfill (fence and vegetation recently removed for some modification work).

Photo 5. Face of wall close-up; face has metal screen and mesh, geogrid is wrapped up face of unit above.

Photo 6. Cut corner units, geogrid anchored with screws and washers.

Photo 7. Anchor screws and washers, one corroded.

Photo 8. Cut corner units.

	
Photo 9: Front eastern face.	Photo 10. Geogrid anchorage at corner.

Structure/Site/Project: **2015 Monastery**

Height: 10.5 feet

Face Angle: 66-degrees (off horizontal) - 8-inch setback on 18-inch high units

Facing Finish: Vegetated

Facing Panels: Yes

Panel Condition: Very good. No cracked or broken panels observed, one top panel slightly rotated outward.

Block Shape: Stepped, current geometry with panel holding notches

Block Bond: could not observe due to panels and vegetation

Block Corner Geometry: one angle corner joint in the wall

Block Cut Observations: could not observe due to panels and vegetation

Facing Condition: Could only observe some top corners of soil cement units, due to panels and vegetation. Expose areas looked very good, not visual deterioration or erosion

Condition of Steel Mesh: could not observe due to panels and vegetation

Top of Wall Condition: Decorative plants above the wall between top of wall and concrete driving wall supports; iron fencing in planting area

Geogrid Reinforcement: Yes

Reinforcement Type: biaxial polypropylene (PP) geogrid

Reinforcement Connection: could not observe due to panels and vegetation

Connection Screw Condition: could not observe due to panels and vegetation

Condition of Vegetation: Vegetated face, though some areas not covered. Owner stated they had replanted the wall facing, and that this is the second year of growth. Couple of areas to replant to fill-in entire wall. New vegetation is a native plant, that needs less water than previous vegetation.

Water Sprinkler or Drip: No. Hand watering of vegetation, as needed.

Face Foundation: Concrete grade beam, supported on concrete piers

Any Free Water: No / Yes

pH measurements – taken on the top face of an exposed top facing unit

Location/#:	1. Top Unit	2. Top Unit, adjacent to #1
Surface Prep:	scraped clean	crushed (with geologist pick) area
pH Value:	7^{-}	7

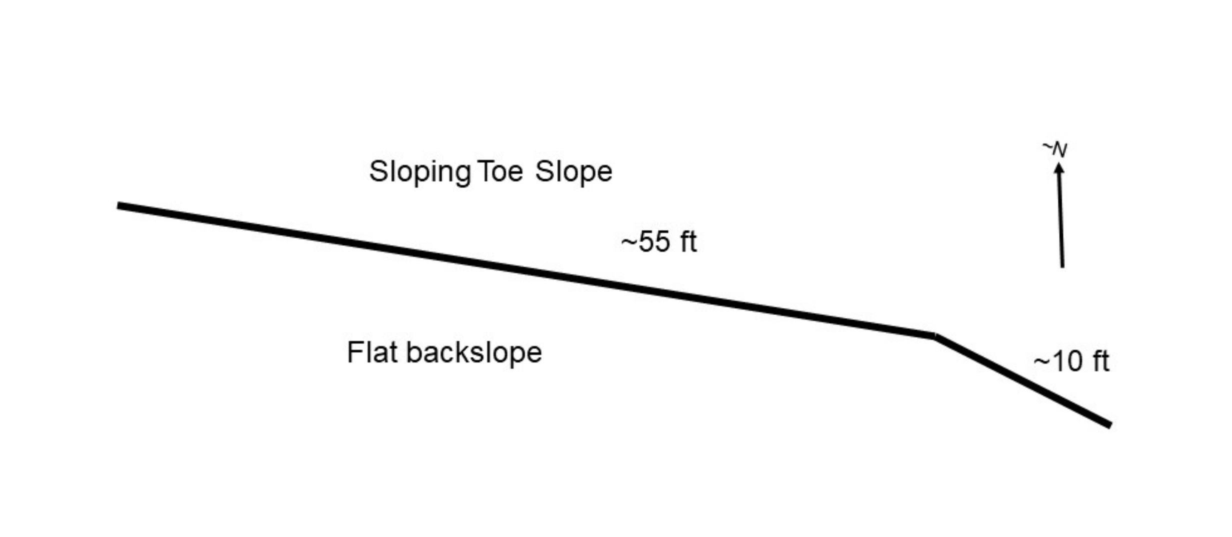

Figure 1. Plan view of 2015 Greensteep wall.

Photo List:

1. View along front of wall, facing west.
2. View along front of wall, facing west.
3. View of front of wall, facing south.
4. View along front of wall, facing east.
5. Toe of wall, where concrete panel exposed from vegetation.
6. Top of wall, at a step down, where geogrid wrap on face is exposed.
7. Face, where concrete panel exposed from vegetation.
8. View along fence line on top of wall, looking east.
9. Driveway on top of wall, looking west.
10. Top of wall, looking west.
11. ¾-inch thick precast concrete face panel.
12. Close-up of top of wall, looking west.

Photo 1. View along front of wall, facing west.

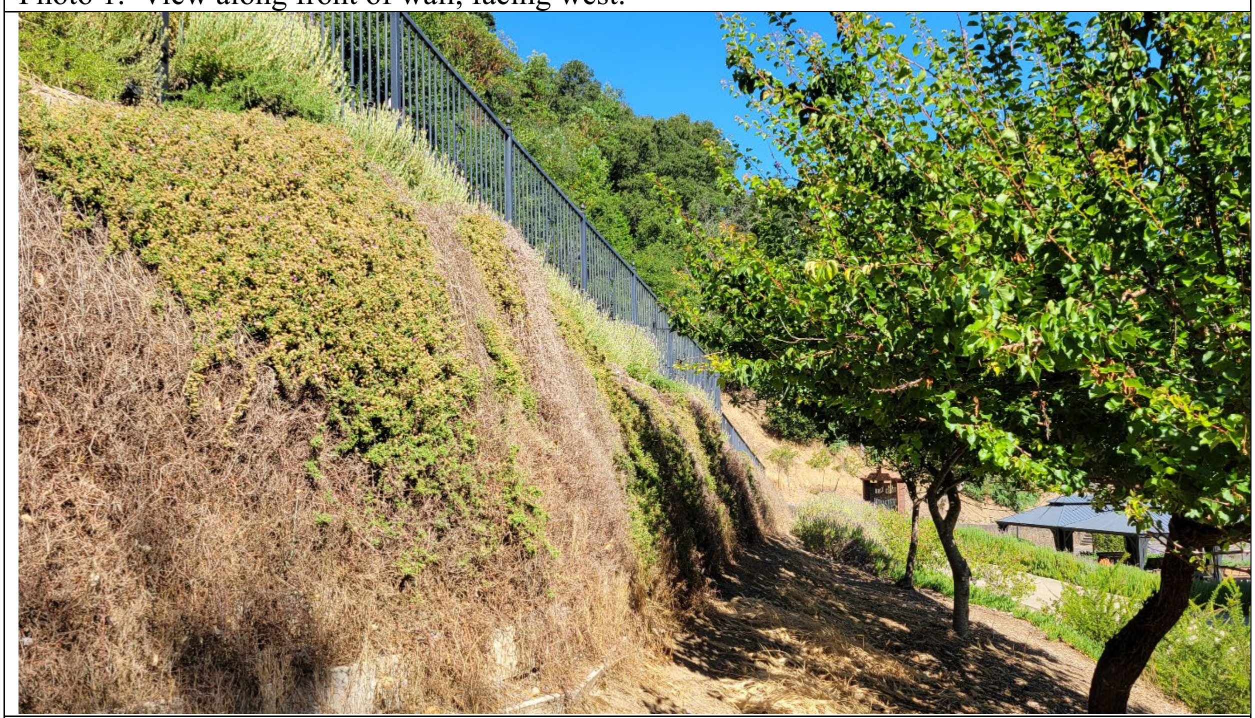

Photo 2. View along front of wall, facing west.

Photo 3. View of front of wall, facing south.

Photo 4. View along front of wall, facing east (top row of planter planter visible).

Photo 5. Toe of wall, where concrete planter panels exposed from vegetation.

Photo 6. Top of wall, at a step down, where geogrid wrap on face is exposed.

Photo 7. Face, where concrete panel exposed from vegetation.

Photo 8. View along fence line on top of wall, looking east.

Photo 9. Driveway on top of wall, looking west.

Photo 10. Top of wall, looking west.

Photo 11. ¾-inch thick precast concrete face planter panel.

Photo 12. Close-up of top of wall, looking west.

Greensteep System

IDEA PROGRAM (Innovations, Developments, Enhancements and Advancements) Evaluation Submittal

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August-2023
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IDEA EVALUATION SUBMITTAL

FOR

GREENSTEEP SYSTEM'S
SEGMENTAL BLOCK FACING/REVETMENT UNITS
APPLICABLE TO
MECHANICALLY REINFORCED SOIL SLOPE STRUCTURES

TABLE OF CONTENTS

INTRODUCTION

The Greensteep block facing system consists of erosion resistant and vegetation hosting facing units that serve as revetment to a conventional geogrid reinforced fill structure (RSS) with a 66-degree angle of inclination. The blocks are 48-inches long, 18-inches high and 8 to 12-inches wide and they are fabricated on-site, by compression of approximately 10 cubic-feet of common native or imported soil that is mixed with cement. A strong block is achieved by pressing the soil-cement mixture with Greensteep's specially designed portable press. Upon block fabrication, the blocks are placed on the structure's outer face, on an on-demand basis. The press is configured to produce a cuboid-like shaped block that includes a bench platform and slots to secure ancillary planter panels that are added to the face during final block installation. Block-on-block offset during placement produces a bench platform that hosts the planter panels (See Appendix 1 Figures 1.1.1 and 1.1.3).

The fabrication of Greensteep blocks requires soil sources that meet tight gradation and PI requirements; an efficient soil cement mixing apparatus; and a press with a 200-ton compression capacity, to ensure that block strength requirements are met. Detailed block unit fabrication specifications are provided in Appendix 1.1.4. In addition, the base of the blocks requires a reinforced concrete footing with an option to derive support from drilled caissons (piers), when on steep topography.

The system is applied as a revetment to a conventionally designed Reinforced Soil Slope (RSS) structure designed following procedures prescribed by FHWA NHI. The design of these slope systems is well developed, and various standards and computer tools are available to assist designers.

While the design of "Reinforced Soil Slope" (RSS) systems can be regarded as a mature technology that can achieve technically acceptable steep face designs (i.e., 0.5H:1V), in many instances, they have construction, vegetation, and long-term erosion limitations. Most notable is the difficulty of meeting soil compaction requirements along the edge of an unsupported, steepened fill slope. Provisions for vegetation growth and control of erosion also present immense challenges for designers of steep, conventional slopes.

Vertical or near vertical masonry segmental block MSE walls are popular and generally perform well, however, they are relatively expensive and do not produce a natural, aesthetically pleasing façade. In addition, because of their typical near vertical configuration, their design requires complex geogrid reinforcement connections to the blocks to resist pullout forces. In the case of the Greensteep system, because of the significant inclination, gravitational forces result in block pressures acting into the slope face.

Greensteep promotes superior efficiency, performance, ease of construction and aesthetical benefits as well as offering a significant reduction in cost. Costs are reduced by using on-site or nearby imported soils to fabricate the blocks on an as-needed basis, thus eliminating the need to purchase, transport and stockpile masonry blocks. Compared to other systems, the aesthetics are improved by allowing natural grasses to self-emerge from topsoil that is borrowed from adjacent hillside areas and placed in the planters. The confined topsoil serves as a growing medium, thus generating a façade that blends the structure into the surrounding landscape. Nevertheless, the client can opt to plant any appropriate seeds, as desired.

The Greensteep block fabrication and installation procedures are intended for use by specialized construction contractors that are licensed and trained by Greensteep. Greensteep will supply a portable press; ancillary mixing and block placement equipment, along with the pre-cut, bent wire mesh inserts and the planter panels, to the affiliated contractors.

The Greensteep system is generally suitable for all geographical locations in the USA.

Section 1: RSS Components

1.1 Facing

1.1.1 Innovation

The innovation of the Greensteep system consists in adding compressed soil-cement block (facing unit) revetment to the exposed face of a conventional, mechanically "Reinforced Soil Slope" (RSS) structure (See Figure 1.1.2 and Appendix System Sample Plans). The facing units are created on-site, by compressing a 24-inch-thick layer of mixed soil and cement, in a 48-inch by 18-inch press box, down to 8 to 12 inches, to create a rigid block. The block is then removed from the press and rotated ninety degrees so that what was the bottom of the block in the press, becomes the outside face (See Figure 1.1.7). The fabricated blocks measure 48-inches in length, 8 to 12 inches in width and 18-inches in height after this rotation. Roughly 8% (by volume) of Type II/V Portland Cement (high sulfate resistance) is added to the soil to comfortably exceed estimates of block strength requirements. Additional tensile strength protection is supplied by a wire mesh lining on the block's exterior faces (See Figure 1.1.3), which also adds to the capacity of the grooves and anchoring screws that secure concrete planter panels. The wire mesh also serves to protect block integrity during transport and placement. The blocks are provided with 100% coverage of geogrid reinforcement that is incorporated into the embankment.

1.1.2 Types of Facing

There is only a standard unit, with dimensions 48-inch (L), 18-inch (H), 8 to 12-inch (W). Cut blocks and planter panels for mitered corners, will maintain a minimum block length of 30-inches, measured at the block center. The miter and block cutting are performed on "green" blocks, immediately after pressing. With the proper equipment, cutting is simple, but the measuring and computation for the distribution of block length reductions, as the block placement approaches a corner, demands accuracy. In previous projects, a special, concrete cutting chain saw was used, however, recently, ring saws with masonry blades that have the ability to cut 10.6-inches, are available and applicable.

1.1.3 Facing Options

The Greensteep system does not offer facing or batter options. However, the sole geometric block configuration (48-inch (L), 18-inch (H), 8 to 12-inch (W)) may have its length reduced by saw-cutting. They are consistently arranged to produce a 66-degree angle of inclination. Concrete planter panels are placed on the block exterior faces, to house a planting medium that supports an aesthetically pleasing vegetation facade and provides an additional layer of exterior block protection.

1.1.4 Greensteep Block Unit Specifications

The following specifications present the latest advancements in Greensteep's innovation that produces strong block units with long life expectancy, for facing application to Reinforced Soil Slopes (RSS). It is important to note that as the system is commercialized and incorporated into future projects, it can be anticipated that the technology will evolve, thus, future revisions to these specifications may be warranted.

These specification are duplicated in Appendix 1.1.4, as "Standalone Specifications" for practical use by others.

The structure's designer must identify, evaluate, and verify compliance with these specifications.

1. Block Fabrication Borrow Sources Identification

   Most common soils are generally acceptable for block fabrication; however, the material must meet specifications that enhance pulverization for the mixing of the soil-cement and limits for maximum particle size for strength testing. Sufficient clay binder is required to promote block integrity during transport before the cement hydration process generates significant strength and a organic content must be limited to 1% maximum.

   A. Gradation.

   The proposed source(s) of soil designated for the fabrication of blocks must be tested to ensure compliance with the following graduation.

   i. A screen on the mixer shall limit the maximum clod/fragment size to 1-1/2 inches.
   ii. The remaining material shall have a minimum 85 percent passing 3/4-inch sieve and a percent passing No. 200 sieve must be between 30-50 percent.

B. Plasticity.

i. The proposed source(s) of material must be tested to ensure that the Plasticity Index is in the range of 13-25. A minimum cohesion is necessary to promote block integrity of freshly pressed blocks during transport, while excessive cohesion limits pulverization for mixing with cement.

C. Stockpile replenishment.

i. Prior to exhaustion of the approved soil stockpile, if it is determined that a new source of soil material will be required, a source approval process by the designer of record for the new source, shall be initiated to approve or disapprove the proposed new material source. The proposed new source shall be sampled and tested for conformance with gradation and plasticity specifications, then its optimum cement content determined.

2. Optimum Block Cement Content Determination

Strength tests must be conducted on the selected borrow soils, which are screened through a 1-1/2-inch mesh, to establish the optimum Portland Cement Type II/V by volume.

A. Gradation

i. Perform Sieve Analysis per ASTM D422 on collected bulk native soil samples (no added cement).

B. Laboratory Maximum Density and Optimum Moisture Determination on collected bulk native soil sample (no added cement).

i. Perform Modified Proctor ASTM D1557 to establish maximum density and optimum moisture content.

C. Laboratory Optimum Cement Content Determination

Remold at least three separate test specimens at 1 to 2 percent above the optimum moisture content established by the Modified Proctor test ASTM D1557, on soil with 6, 8, and 10 percent cement by volume content, to within 90-95 percent of the maximum density of the soil. Cure in a moist room and after 7 days perform unconfined compression tests in accordance with ASTM D2166 on the test specimens, to establish the optimum cement content. If test results are inconclusive, or if desired by the designer, remold additional test specimens at higher, intermediate, or lower cement contents and test the unconfined strengths at 7 days to obtain the optimum cement content for providing the maximum soil-cement strength.

3. Soil/Cement Mixing for Block Fabrication

A. The mixing process may only commence if the press's confining box is fitted with mesh inserts and bottom planks, in preparation to receive mix without delay.

B. Mixing shall be performed with a skid-steer that is fitted with a self-loading mixer attachment that has a capacity to mix a ½ yard batch, to produce one block per batch. The mixer shall have a 1-1/2-inch metal screen to prevent larger fragments from being included in the mix.

C. If the soil moisture content from the stockpile is such that no dust emission is observed prior to cement addition during preparation for the mixing process (above the optimum moisture content per ASTM D1557), the soil must be spread out to dry, (to below optimum moisture content), prior to usage.

D. Initially, soil from the stockpile with below the optimum moisture content per ASTM D1557, shall be mixed until clods are broken down and the soil reaches its maximum degree of pulverization, established visually.

E. Apply the established optimum volume of cement (by volume) and then mix in a dry state.

F. Gradually introduce water while mixing, until it is visually observed that there is no dust emitted during mixing, which is indicative that the optimum moisture content of the mixture has been slightly exceeded.

G. Following the final moisture adjustment and completion of the batch mixing process for the single unit, immediately place a portion of the mixture in the press's confining box, as described in Section 1.1.4.5.

4. Confining Box

A. Insert the two full length, formed/bent pieces of 19 gage galvanized 1/2-inch meshes pieces provided by Greensteep and conforming to ASTM A 1060 specifications, into the confining box.

B. Place the 48-inch long, 8-1/4 inch wide, 4-inch high, full length wood plank with the attached 3/4 inch x 4-3/4 inch x 48 inch long steel plate and a 3/4-inch by 3/4-inch square steel tubing on the opposite side, as shown on Figure 1.1.4.4.

5. Compaction

A. Place a maximum of 10-inches (loose depth) of the soil-cement mixture in the press's 48-inch by 18-inch confining box. Bend the wire mesh's alternating segments at 45 degrees towards outer box's walls and complete pour of mixture, to achieve a total of 24-inches (loose depth) of the soil-cement mixture, in anticipation of its reduction in depth, to 8-12 inches (See Figure 1.1.4.5).

B. Apply load to the top of the confined soil-cement mixture surface with two 100 Ton Hydraulic Ram (70 Kip/SF)

C. Maintain the hydraulic pressure for a minimum of 1 minute once the needle of hydraulic pressure gauge becomes relatively stable.

D. Check to verify that the 8-inch minimum final thickness of the block is compliant. If not, unit is rejected.

6. Evaluation of Field Block Soil/Cement Strength

The volume of soil required for block fabrication will generally be less than 10% of the total volume of soil that is required for the structure. The project will commence with excavations to establish the base of the structure and prepare for the ensuing foundation construction. It can be anticipated that the initial foundation construction phase will provide ample time to setup the press and fabricate blocks for compressive strength sampling and obtain strength testing results.

The designated block fabrication soil from the initial excavation, or the select imported soil material, should be stockpiled in the immediate vicinity of the press, in a designated block fabrication area. The transport of designated soil and its stockpiling must promote thorough mixing of the soil to achieve a uniform appearance.

Following the stockpiling of designated soil, the fabrication of sample blocks commences by a temporary placement of a ½-inch screen on the mixer (for testing block strength only) for compliance with sample diameter that is six times larger than the largest particle size ASTM D2166. Then mixing soil-cement and pressing the mixture to produce test blocks for the collection of strength test specimens. The test specimen length must exceed 2.5 times the diameter after trimming and squaring the ends of the test specimen for laboratory strength testing.

While each block remains in the press's confining box, representative specimens from the freshly pressed blocks are collected by raising the press plate and placing on the exposed block's top surface, several vertically oriented, 3-inch diameter, minimum 8-inch long, brass, or stainless-steel sampler liner tubes that maintain a minimum 6-inch spacing from each other or block edges. The press plate is then carefully applied to the tops of the liners as it is used to push the liners to a full penetration into the block. This procedure is repeated on additional freshly pressed blocks, as necessary, to obtain a minimum of ten specimens.

The liners filled with specimens are then carefully removed from the sample block by breaking apart the block (block cutting tool may aide), then capping and sealing of the liners. The specimens are then placed in a manner that protects them from direct sunlight, near the base of the future structure. A minimum of 5 days after their collection, the specimens are transported and held in a humidified wet room, at the approved laboratory for trimming and ensuing strength testing.

A. Determine undrained shear strength of specimens.

   i. Remove sample from sampling tubes and perform Unconfined Compression tests in accordance with ASTM D2166 at 7 days.

   ii. Upon completion of each compression test, split the samples to determine compliance with the requirement that the maximum particle size cannot exceed 1/6 of the diameter or ½ inch. Discard samples that are non-compliant and perform additional tests until six compliant test results are produced.

7. Criteria for Acceptable Block Strength

Due to the potential for variations in soil characteristics and mixing efficiency, an effective LRFD (Load and Resistance Factor Design) is required. However, the calculated loads on the lower blocks are conservative because it is recommended that these loads be calculated by assuming the facing blocks are vertical, rather than offset and the acceptability of the block strength is governed by the 7-day strength, which can be expected to double or even triple in one years' time, because the compressive strength of the blocks will significantly increase as the soil cement continues to hydrate over time, thus a calculated Factor of Safety of 3.0 is more than adequate.

A. Determination of Maximum Normal Stress on the Blocks.

   Although the Greensteep facing blocks are offset at an angle of 24 degrees from vertical; a vertical configuration (conservative) is assumed to estimate the maximum possible vertical stress in the bottom block by simply multiplying the height of the wall, H, by the unit weight of the blocks, which can be taken as 130 pcf.

   Assuming a height of 30-feet and a block density of 130 pcf, the normal stress σv in the lowest block is:

$$\sigma v = 30 \times 130 = 3{,}900 \text{ psf } (0.187 \text{ MPa})$$

   For the case of structures exceeding 25-feet in height, the designer may follow the procedure provided in Figure 1.2.6.1, "Determination of hinge height for modular concrete block faced MSE walls," (NCMA, 1997), provided in Section 4, entitled "Design of MSE Walls" of FHWA NHI-10-024-Vol I.

B. Determination of Available Field Block Strength

   The Unconfined Compressive Strength (UCS) used to arrive at a LRFD, will be the average of the six, 7-day field sample results obtained per Section 1.1.6.A.ii of these Specifications (UCS ave).

C. Determination of the LRFD Against Crushing

   The LRFD is obtained by dividing by the available field strength (UCS ave) by vertical stress in the bottom block.

$$\textbf{LFRD} = \textbf{UCS}\text{ ave}/\ \sigma v$$

   If the LFRD, thus a calculated "Capacity to Demand Ratio" (CDR), (i.e., Factor of Safety) of 3 is exceeded, the design is acceptable and block fabrication for the project, may proceed.

   Should the LFRD fail to reach 3, either the height of the wall should be reduced, or the stockpiled block fabrication soil rejected and replaced by a select imported soil.

8. Foundation Design

The project engineer of record shall design the foundation based on an appropriate subsurface exploration and in consideration of the slope gradient below the toe of the structure.

In estimating the vertical load acting on the grade beam, the designer may consider the average of the load, resulting from a triangularly shaped tributary load distribution that extends horizontally inward, until a vertical plane from the uppermost block exterior corner, is intercepted. As such, for a slope structure with height "H" the horizontal tributary distance "D" can be estimated by assuming that it extends horizontally by:

D (horizontal tributary distance) = H (height) Tan 24

(See Figure 1.1.4.8)

Assuming a uniform 130 pcf for the block, the sand-gravel (chimney drain) and reinforced fill, the average load "P" on the grade beam or conventional footing foundation, can be estimated to be:

P psf = ½ (H x D) x 130 / D

Alternatively, the designer of record can implement the procedures prescribed in Figure 1.2.5, "Determination of hinge height for modular concrete block faced MSE walls," (NCMA, 1997), provided in Section 4, entitled "Design of MSE Walls" of FHWA NHI-10-024-Vol I, to estimate foundation load. Nevertheless, a factor of 2 to 3 should be applied to account for down drag on the back of the block units in conformance with a "Load Resistance Factor Design" LRFD.

As shown on Figure 1.2.6.1, the above referenced procedure establishes a hinge height encompassing two blocks, which serves to establish an LRFD "Inter-Block Pressure" of 988 psf.

1.1.5 Description of Facing Details

As illustrated in Figure 1.1.1, the facing block units are set back 4-inches from the lower block, to match the 4-inch horizontal bench at the mid-level of the blocks. Each 4-inch level bench receives an L-shaped concrete panel on their outer face that produces a 5-inch-wide vegetation growing surface, every 9 vertical inches. The panels are prevented from rotation by their insertion into a 3/4-inch groove along the rear of every 4-inch horizontal bench and sliding is resisted by 1/4-inch (W) x 2-1/2-inch (L) HDG corrosion resistant concrete anchor screws that derive support from embedment into the block’s exposed surface, at 12-inches on center (of which, the outer two screws on the top surface, pierce through fresh mortar filled planter alignment pin holes).

The eccentric block arrangement results in the generation of rotational forces into the chimney drain that is confined by the compacted fill. In addition, due to the 24-degree batter angle, the block facing units are subjected to the horizontal component of gravitational force that acts to press the blocks into the chimney drain that is confined by the compacted fill, thus pullout force considerations are significantly reduced. Nevertheless, the blocks are fully constrained both at the top and bottom (every 18-inches vertically), by 100% coverage of geogrid reinforcement (See Section 1.2.4 Facing Unit Reinforcement Connection). The geogrid is connected to the top of the block surface by being folded down over the exterior face and fastened by anchor screws with washers (See Figure 1.2.4). Top-of-block rotation is resisted by the connected geogrid and the eccentric loading from offset block above. At the bottom of the block, lateral support is derived from the concrete planter panels that are anchored by screws to the top of the block below. Additional resistance to lateral displacement is available from the geogrid reinforcement being sandwiched by the blocks, generating friction (See Figure 1.2.6).

1.1.6 Standard Dimensions and Tolerances

The block facing unit fabrication is performed on-site, using a press with a single confining press box that will consistently produce blocks with identical lengths and heights. However, the block width may vary slightly, but must achieve a minimum width of 8-inches (tolerance) at the top of the block (which limits the bottom of the block to 12-inches minimum). The slight variation in width can be expected as a result of the slightly variable volume of the soil/cement mixture poured in into the confining box, see Step 3, in Figure 1.1.4.5.

Immediately following block fabrication, two pinning holes are drilled on the top block surface. The holes are accurately located with the aid of a template (See Figure 1.1.6.1).

The blocks are transported to the structure’s outer face that is under construction and accurately positioned with the assistance of a block positioning template that is equipped with pegs that are inserted in the previously drilled pinning holes on the top of the exposed, lower block surface (See Figure 1.1.6.2).

1.1.7 Unit Fabrication Process

A skid-steer that is fitted with a self-loading mixer attachment with a minimum ½ yard batch capacity and 1-1/2-inch metal screen to prevent larger fragments from being loaded into the mixer, loads itself from the stockpile of approved soil for block production. Initially, sun exposed soil from the stockpile surface (below optimum moisture content, established visually by observing dust emittance while mixing) alone is mixed until clods are broken down and the soil reaches its maximum degree of pulverization, established visually. Subsequently, the designated volume of cement (See Specifications Section 1.1.4.2.C) is added and the mixing with the sun exposed soil (below optimum moisture content), is performed. Following several minutes of mixing, water is gradually added while mixing is continued, until it is visually determined that the optimum moisture content of the mixture has been slightly exceeded (dust emittance ceases). The soil-cement mixed batch is then introduced into the press's confining box to nearly fill it (1.8 x 4 x 1.5) - (0.67 x 0.33) = 10.6 ft.^{3} (loosely placed)). Prior to receiving the mixed materials, the box is fitted with two full length pieces of 19 gage galvanized 1/2-inch meshes that are bent to conform to the grooves and block faces, and placed over a 48-inch long, 8-1/4 inch wide, 4-inch high, full length wood plank that is fitted with a 3/4 inch by 4-3/4 inch by 48 inch long steel plate attached to its side, covering the bottom half of the box to produce the split-faced block configuration, with a groove at the back of the mid-level block bench and a 3/4-inch by 3/4-inch square steel tubing is placed on the opposite side of the confining box's bottom, to produce the groove at the lower block corner (See Figure 1.1.4.4). Once the confining box is filled with the soil-cement mixture, two 4" W x 4" H x 18" long, wood planks, are placed fully encapsulated into the soil-cement mixture, at the upper surface corners, over the 3/4-inch by 3/4-inch square steel tubing side, to produce two 4" x 4" indentations that serve as block transportation handles, leaving a 12-inch long continuous central segment that aides block stability during its placement at final destination on the structure face. Upon compression, the elements produce two exterior mesh lined, 9-inch vertical height faces that have 3/4-inch by 3/4-inch grooves at their base and are partitioned a mid-level by a 4-inch-wide level bench on the outer block exposed surface and two 4" W x 4" H x 18" rear base transport handles (See Figure 1.1.3).

Using its 200 Ton (73 Kip/SF) pressing capacity, Greensteep's specially designed press is used to compact the roughly 24-inch deep, soil-cement mixture that is loosely placed in its confining press box, down to the 8 to 12-inch minimum final top and bottom, correspondingly, of block thickness (width). The indicator that confirms that the press has exhausted its capacity to compress the soil, is when the needle on the hydraulic pressure gauge, becomes relatively stable for a period of 1 minute. Subsequently, the block is removed from the press (no stripping of forms is necessary) and rotated 90° (See Figure 1.1.7) in preparation for drilling of two pinning holes at the block's top surface and fitted with a Greensteep provided transport harness, for transport and placement on the outer edge of the progressing structure's face (See Figure 1.1.1).

1.1.8 Specified Strength and Design Life of Facing Components

The blocks are the main component of the Greensteep system. Their composition is a compacted mixture of native soil and cement. To elevate their longevity, the compressed blocks must achieve a minimum strength to carry the estimated loads with a Capacity to Demand Ratio (CDR) (i.e., Factor of Safety) of 3.0 at 7-days (Unconfined Compressive Strength (UCS) / estimated vertical stress at the bottom block (σv)).

Soil types and cement content can vary widely, nevertheless, available results from recent research suggest that typical 7-day compressive strength values are found to range from 200 to 600 psi (28,800-86,400 psf), while 28-day strengths range from 250 to 1,000 psi (36,000-144,000 psf). It is noteworthy to mention that block strength can double or even triple, in a years' time.
The primary limitation to Greensteep's block strength and design life reduction, is the potential for elevated levels of sulfates in the soil, which can be measured in pH. To guard against site-specific variables such as soil pH levels that can be anticipated on a project-to-project basis, Greensteep's specifications call for the use of Type II or V Portland Cement, to protect against elevated levels of sulfates in the soil (i.e., pH level variations).

Most research relating to the design life of various cement applications concentrates on the steel in reinforced concrete applications, with a sizable portion of it concentrating on chloride attack that causes the corrosion of the reinforcing steel. Other main considerations relate to exposure to frost attack where water freezes in pores, expanding to crack concrete and salt weathering, whereby salty water evaporates rapidly, causing salt crystals to grow within the pores and break the concrete. Greensteep's blocks do not include steel reinforcement, and the planters hosting soil the growth promoting vegetation façade, in front of the blocks, limit exposure to the aforementioned elements.

A small amount of research has been dedicated to the design life of soil-cement treated subgrade and base sections of highway pavements. However, these studies concentrate on the standard axle repetition endurance, relating to the highway traffic's wheel impact loads on the pavement surface. Indisputable evidence from the Roman Empire's employment of rudimentary techniques for cement treated soil application, include the fabrication of blocks that were applied to a vast number of civil projects which have endured 2,000 years.

In view of the foregoing, a designation of a 100-year block service life seems appropriate.
Ancillary components including geogrid for fill reinforcement, galvanized mesh to protect the block integrity during the green phase of the cement and transport, corrosion resistant concrete screw anchors to secure the concrete planters and the unreinforced concrete planters, provide compatible life expectancy.

The potential for the incidental human or animal abuse of the concrete planter panels or exposure to the elements, resulting in degradation of the panels, can be remedied by simple planter panel replacement. As such, the planter panel service life expectancy can be taken to be 10-20 years, for purposes of estimating maintenance cost.

1.1.9 Inter-Unit Shear

The design of vertical and/or near vertical MSE walls requires consideration of the inter-unit shear capacity, in computations related to pull-out resistance of the geogrid. However, with its face inclination of less than 70-degrees (66-degrees), under publication FHWA NHI-10-025, Vol II, Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, the Greensteep system falls into a design classification that is applicable to Reinforced Soil Slope (RSS) structures. Because it is primarily a facing, the Greensteep system requires that the RSS structure be designed as a stand-alone structure.

The attached figure (Figure 1.1.9) shows the separation of the overall system into the reinforced slope and the facing, with a buffer provided by a gravel blanket medium. Common sense indicates that the facing by itself will tend to fall backwards, rather than falling forward, thus pressures are applied to the slope face. Thus, inclusion of the facing in an overall analysis can only increase the factor of safety from that computed for the reinforced slope by itself. As such, the inter-unit forces generating pullout benefits can be neglected in routine designs.

However, there are nonetheless two sources of inter-unit shear capacity which are important in maintaining integrity of the facing system under unusual loading conditions such as earthquakes. Inter-unit shear capacity is available since all blocks have a layer of geogrid reinforcement that is "sandwiched" between them at both top and bottom of every facing unit, and the blocks are also mechanically integrated by planter panels, which are anchored to the upper surface of the block below, generating considerable resistance to pullout forces. The inter-unit design consideration is addressed in detail in Section 1.2.6.

1.1.10 Unit Shear, Alignment or Bearing Devices

A concrete foundation is provided at the base of the stacked blocks in order to evenly distribute the concentrated loads applied by the facing blocks. A protruding "stopper" is provided on the outer foundation edge to restrain the bottom of the lowermost block (See Figure 1.1.10).

The blocks are set using a block alignment template (See Figure 1.1.6.2) which includes pegs that are inserted into 1" dia., 1" deep holes. The block alignment template provides a ledge that guides the block placement to the specified 4-inch setback from the upper block's outer edge. Following block placement, the two holes are filled with concrete mortar followed by the placement of a planter panel, which is screwed to the lower block, including their penetration though the two mortar freshly filled holes. The screws provide shear strength to resist the upper block from pullout forces, relative to the lower block (See Sections 1.2.4 and 1.2.6 for detailed explanations).

1.1.11 Filter Preventing Fill Soil Migration Between Blocks

Efficient surface and subsurface water collection provisions will be essential in preventing soil migration from the structure into the chimney drain and eliminate any potential for piping.
The designer must consider ample provisions to prevent development of a phreatic surface within the structure. To guard against water intrusion into the structure, efficient surface drainage collectors at the structure's surface, along with a sufficient number of subdrains at the rear of the structure's contact with the undisturbed hillside, should be provided, per Plan Sheet No. 3.

Permeable filter material (free draining sand-gravel) conforming to AASHTO 703-10 Class C specifications, is placed to serve as a chimney drain behind the blocks and to provide a buffer from fill compaction equipment displacing the set blocks. Nevertheless, to ensure that the chimney drain filter material is confined, the above filter material specification must be checked by the designer, to ensure that the soil migration prevention from the structure to the chimney drain, is adequate. The structure designer should consider filter criteria [U.S. Army Engineers (1955)] for both piping and permeability compatibility. The filter in this instance will be chimney drain material placed behind the Greensteep facing blocks conforming to the specified grading. The filter criteria are shown below:

For Piping: $D_{15\ Filter}/D_{85}$ Soil < 5 and D_{50} Filter/D_{50} Soil =< 25

For Permeability D_{15} Filter/ D_{15} Soil > 4 – 2

Where the uncut block-to-block abutment gap exceeds 1/8-inch, and at every shortened, cut block surface, a 1-foot-wide strip of geotextile filter fabric that is centered about the interior block-to-block gap, must be provided to guard against chimney drain material migration (See Figure 1.1.11). The geotextile must conform to AASHTO M288-21 specifications.

Concrete planter panels are placed on the block exterior faces, to house a planting medium that will provide an additional layer of protection against soil migration. Geotextile filter fabric that conforms to AASHTO M288-21 specifications, is placed behind every planter-to-planter joint and extending over every exterior block-to-block abutment, to prevent planting medium soils from migrating.

1.1.12 Available Aesthetic Facing Options

The aesthetic facing is a naturally developed vegetation that avoids landscape planting. It is anticipated that in most applications, natural grasses will be allowed to grow as they do in the adjacent natural slopes, to produce a natural blending of the structure into the landscape. Nevertheless, in special applications that are more aesthetically demanding, select planting may be applied. This item would fall within the client's preference, but the landscape designer must consider root growth depth limitations, irrigation, and local climate.

1.1.13 Limits on Facing Units at Corners

To conform to a corner in the alignment, the blocks must be miter-cut (max. $45^{0)}$) at the joint that forms the (max. $90^{0)}$) corner. The blocks must maintain a minimum 30-inch length that is measured at the block center. For accuracy, it is recommended that the cuts be performed with a concrete-masonry saw, prior to transport from the press location. The maximum block-to-block abutment gap at miter-cut blocks, must not exceed 1/2-inch. Nevertheless, in consideration of the potential for imprecisions in miter-cut blocks that are designated to a structure's corners and those blocks cut to meet the minimum 30-inch length requirement as a corner is approached, a 1-foot-wide strip of geotextile filter fabric that is centered about the block-to-block gap, must be provided to guard against chimney material migration (See Figure 1.1.11). The geotextile must conform to AASHTO M288-21 specifications.

Section 1.2: Extensible Reinforcement

1.2.1 RSS Innovations

The Greensteep system employs a mature geogrid reinforcement technology. There is no innovation in this area of design. Local geotechnical consultants can apply current design standards in conformance with current AASHTO and U.S. Department of Transportation, Federal Highway Administration Publication No. FHWA-NHI-10-025, "Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes." to establish backfill material specifications for the primary geogrid reinforcement, including its type and length.

However, Greensteep's blocks are designed to be secured in place by independent, secondary geogrid layers that extend 7-feet horizontally, into the structure's outer zone (See Figures 1.1.2, 1.2.6 and 3.1.8).

1.2.2 Reinforcement Style or Type List

The Greensteep system assigns two types of geogrid reinforcement to the structure: 1) a primary reinforcement that serves to accomplish the overall structure's integrity and 2) a secondary reinforcement that integrates the Greensteep block facing units, to the structure.

The structure's primary reinforcement is established by the project designer, in accordance with AASHTO guideline, FHWA NHI manual, and NCMA manual, which should include a Long Term Design Strength LTDS analysis, to establish the allowable reinforcement design strength, T_a and a durability reduction factor, RFD, due to chemical and biological degradation. The primary reinforcement layers are placed near the block's mid-height (every 18-inches, See Figures 1.1.2 and 3.1.8)

The secondary reinforcement serves to integrate Greensteep's block facing units to the structure. As explained in Section 1.2.4, the reinforcement strength and anchorage length requirements to resist facing block pullout forces are minimal. Section 1.2.3 addresses the promotion of a longer service life of the secondary reinforcement for the resistance of block pullout forces, requiring HDPE type of geogrid reinforcement, such as the Tensar UX 1100 geogrid, is best suited.

1.2.3 Reinforcement Style or Type and Grade

The style or type and grade of the structure's primary geogrid reinforcement is to be established by the Project Engineer.

Because the secondary geogrid is sandwiched between the blocks, it is in direct contact with the block's top and bottom surfaces. This contact raises the concern for a reduction in service life of the geogrid, from its exposure to the leaching of alkali from the cement that is added to the cement-treated soil in the block's composition. As such, it is recommended that the most degradation resilient, Tensar UX1100 HDPE (High Density Polyethylene) geogrid be employed for the secondary reinforcement in resisting facing unit pullout forces. The Tensar UX1100 reinforcement is certified to be compliant with AASHTO'S NTPEP Committee Work Plan for "Evaluation of Geosynthetic Reinforcement for Walls and Fills."

1.2.4 Facing Unit-Reinforcement Connection

As explained in Section 1.1.9, under static loading the block facing tends to fall into the slope face and cannot apply tensile loads to the geogrid reinforcement. Nevertheless, as shown in Figure 1.2.4, for the case of seismic loads, each unit may be assumed to have a weight of 163 pounds per linear foot (plf), which along with an assumed seismic coefficient of 0.15, can be applied to establish a 24.5 plf of pullout (driving) seismic force.

As shown on Figure 1.2.4, the specified Tensar UX1100 geogrid is connected to the top of the block after being folded down a minimum of 5-inches over the upper exterior face and fastened by anchor screws and washers at every seventh rib/strand space and three rib/strand spaces from the ends of the block (equivalent to 6.5-inch center to center, spacing and 2.75 inch from block ends). The capacity of the screw's connection to the block is computed using the embedment area of the screw anchor multiplied by the shear capacity of the block's medium and a factor of 9 (dimensionless factor from standard engineering practice) to derive a 300 plf. lateral load screw head capacity for a single screw. The calculated screw capacity was confirmed by field test (See Figure 1.2.4.1) which reached a peak load of 330 lbs. By the application of seven screws on the 4-foot long face, with a 300 lbs. capacity of each screw, yields connection capacity of 525 plf. Thus, a conservative factor of safety for the facing unit-reinforcement connection under seismic conditions, can be estimated to be ∑Resisting Forces / ∑Driving Forces = 525 plf. / 24.5 plf = FoS 21

We note that our field testing indicates that the failure was caused by the bending of the screw at approximately 1-inch below the unrestrained screw head, establishing that the screw is the weak link of the connection and confirms that our estimated anchor screw capacity is conservative.

Testing of the anchor screw connection to the geogrid reached a load capacity on the order of 625 lbs. (See Figure 1.2.4.2), demonstrating that the geogrid has nearly double the capacity, relative to the lower load capacity of the anchor screw.

The anchorage capacity of the geogrid $AC_{(n)}$, can be computed using Equation 7-63 from the NCMA Segmental Retaining Wall Design Manual and a pullout interaction factor C_i = 0.8 obtained from Tensar, for their UX1100MSE geogrid:

Assuming: Anchorage length $L_{a(n)}$ = 6-feet
Coefficient of interaction for pullout C_i = .8
Depth of overburden over reinforcement $d_{(n)}$ = 2-feet
Soil density = 125 pcf
Surcharge Load = 0
Peak strength of anchorage soil = 22 degrees

$$AC_{(n)} = 2L_{a(n)}C_i\,(d_{(n)}\gamma_i + q_d)\tan\phi_i = 2(6)\,(.8)\,(2x125 + 0) \text{ x } .4 = 970 \text{ lbs./ft}$$

From Figure 1.2.6, the estimated seismic load F_s = 24.5 plf.

Per equation 7-66 from the NCMA Segmental Retaining Wall Design Manual, a conservative factor of safety against block pullout for the uppermost secondary geogrid layer can be obtained:

$$FS = AC/\,F_s = 970/24.5 = 39$$

The above FoS computations indicate that 6-foot anchorage is ample. The weakest point in the geogrid connection to the facing units is the upper vertical face's screw connection which has an estimated FoS 21, nevertheless, the designer may perform additional pullout resistance testing, as appropriate.

1.2.5 Facing-reinforcement Connection Strength Test

Section 1.2.4 above explains that under normal static design consideration, there is an absence of facing unit related pullout forces. Nevertheless, for special pullout considerations such as seismic loading, under conservative assumptions (supported by field verification testing), computations can demonstrate that the facing unit-reinforcement connection, under seismic conditions, approach FoS = 21, thus negating the need for more elaborate physical testing of the facing unit-reinforcement connection strength.

1.2.6 Inter-unit Shear Test Results and Design Shear Capacity Envelopes

Section 1.2.4 above explains that under static conditions, gravity forces act to press the facing units onto the slope, resulting in minimal inter-unit shear forces. But we still need to assess the inter-unit shear forces for the special case of seismic loading.
As shown on Figure 1.2.6, at the top of every block, a planter panel is anchored to the lower block and inserted into a groove located at the inboard side of upper block, to mechanically integrate the inter-block surfaces. The planter sliding resistance is accomplished by corrosion resistant screw anchors that pierce thru the planter panel's base, into the lower block's top exposed surface, with a 12-inch center to center, spacing. Additionally, resistance to the inter-unit shear pullout resistance can be accounted from the friction that is generated by the geogrid reinforcement being "sandwiched" between the wire mesh lined block surfaces. It is noteworthy that we have ignored the eccentric loading from the block above, which counters lateral forces that may otherwise cause block outward rotation.

To establish the number of blocks that are tributary to the inter-unit pressure, Figure 1.2.6.1 presents procedures prescribed by the NMCA (1997) in "Determination of hinge height for modular concrete block faced MSE walls." As shown, the computations derive an inter-block pressure of 988 plf.

As shown on Figure 1.2.6, for the case of seismic load, each unit may be assumed to have a weight of 163 pcf, which along with an assumed seismic coefficient of 0.15, can be applied to establish a 24.5 plf of driving seismic force.

The inter-block pullout resistance can be estimated assuming an inter-block pressure (988 psf) along with an assumed (wire mesh lined block surface to-geogrid) friction factor of 0.1. This gives a block pullout resistance F_f, which equals to 30 plf. Additional pullout resistance is provided by the anchoring of the planters to the lower block unit. This can be computed using the embedment area of the (restrained head) anchor screw, multiplied by the shear capacity of the block's medium and a factor of 9 (dimensionless factor from standard engineering practice). However, because this computation is an estimate of the screw anchor's lateral load capacity, for safety, it is reduced by 1/3 to derive a lateral anchor screw resistance capacity of 300 plf, in agreement with field test results on an unrestrained screw head reaching a peak load of 330 lbs. (Figure 1.2.4.1), which for the case of the planter's lateral resistance capacity, the anchor screw head is restrained from rotation, which is ignored.

In summary, a conservative factor of safety for the inter-unit shear capacity, even under seismic conditions, can be estimated to be ∑Resisting Forces / ∑Driving Forces = 30 lbs. + 300 lbs. / 24.5 lbs. = FoS 13.5. This level of safety that is supported by a field test suggests that more elaborate inter-unit shear testing is not warranted.

Once again, the designer may perform additional pullout resistance testing, as appropriate.

Section 1.3: Other Components

1.3.1 RSS System Component Innovation

There are no RSS component innovations. Local geotechnical consultants can apply current design standards in conformance with current AASHTO and U.S. Department of Transportation, Federal Highway Administration Publication No. FHWA-NHI-10-025, "Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes." to establish geogrid reinforcement type and length.

1.3.2 Footing/Bearing/Leveling Pad

The lowermost row of blocks is set upon a level concrete grade beam or footing with a protruding "stopper" on the outer. Caissons (piers) are generally required if there is downward sloping terrain below the structure's toe. Caissons are normally not required if there is level ground in front of the toe. Selection of the foundation type and its design must be carried out by the project engineer. Nevertheless, there is a requirement that the foundation footing or grade beam have a minimum width of 12-inches. The concrete should have a minimum 28-day strength of 2,500 psi.

1.3.3 Drainage

A chimney drain of permeable filter material (free draining sand-gravel) is placed behind the facing blocks that also serves to provide a buffer from fill compaction equipment displacing the set blocks, to prevent filter material migration through any space at the block-to-block abutments and to prevent soil migration into the chimney drain. The permeable filter material shall conform to AASHTO 703-10 Class C specifications. Detailed discussion of issues pertaining to prevention of soil and filter material migration, are presented in Section 1.1.11.

A perforated pipe is provided along the base of the interior side of the foundation and base of the sand-gravel chimney drain. Additional subsurface drains must include horizontal subdrains on the uphill side of the base keyway (when applicable) and intermittent levels of the structure. The location of the intermittent subdrains, must be established by the project designer or based on field conditions deemed to warrant additional subdrains. Surface drain vertical pipes may be installed within the blanket drain and extended to a designer approved discharge point fitted with a flow dissipater, near the base of the structure. The surface drainage of the improvements must be designed by the local project Civil Engineer and included in the project civil plans.

Concrete planter panels are placed on the block exterior faces, to house a planting medium that will provide an additional layer of protection preventing soil migration. An 8 x 12-inch piece of filter fabric is placed behind the planter joints, to prevent planting medium soils from migrating. The filling of the planters may be accomplished by sprinkling native topsoil down the face of the structure. Intermittent watering must be provided to promote the consolidation of the planter's growing medium, with periodical additional topsoil sprinkling until the planters are overflowing and filled to the bottom of the planter above. During placement of planting medium soil in the planters, the accumulation of topsoil over-flow from the planters is anticipated and can be lightly compacted with hand operated compaction equipment along the base of the structure, to produce a smooth slope-to-structure transition.

1.3.4 Irrigation

It is anticipated that most applications will not include provisions for irrigation, as the natural grasses will grow with precipitation, as with the adjacent natural terrain. Should the project designers select a specific vegetation, the designers may customize irrigation to meet those needs.

1.3.5 Coping

No coping features are included.

1.3.6 Traffic Barriers

A traffic barrier may be accomplished by a moment slab with a barrier for a Highway application or an asphaltic concrete curb applicable to private, low structure height, low traffic volume driveways. The traffic barrier application for Highways must be designed by and conform to the local highway transportation agency's standards.

1.3.7 Slip Joints

There is no rigid or flexible joint in the block-to-block connection, as their abutments provide structural independence. Each block receives 100 percent coverage of geogrid reinforcement, both at the top and bottom of the blocks and there are minimal forces acting on the blocks, thus the necessity of slip joint consideration is negligeable. In the event that an external feature such as a box culvert or pipe with headwall is included in the project, the structure should be specifically designed by the project engineer. The top of the external structure's transition to Greensteep's blocks, should include a suitable foundation that generally conforms to the concrete foundation criterion that is applicable to the base of a standard Greensteep slope revetment.

1.3.8 RSS Specific Foundation Treatment

The Greensteep system employs a 24^{o} batter angle and utilizes relatively heavy blocks that require a level concrete footing. As Greensteep is particularly well suited to highway widening projects that require a roadway edge extension onto slopes that require steepening to accommodate the additional lane, it is appropriate to provide foundation support by means of a grade beam supported by drilled caissons (piers) that are designed to carry the vertical loads, while the lateral load component can be assumed to be resisted by the geogrid. In the case of level ground in front of the structure, a conventional footing foundation will generally be appropriate.

1.3.9 Planter Panels

The "L" shaped planter panels are intended to retain a relatively minor volume of natural vegetation growth promoting soils (local topsoil), to generate a natural vegetation that blends into the surrounding natural slopes (See Figure 1.3.9). As a landscape component, the planter panels serve to host a small volume (7"x 4" cross sectional) of loosely deposited soil that can only be expected to generate minimal forces on the exposed, near upright face of the panels.

The panel construction employs unreinforced ¾-inch thick, 4,000 psi concrete. The configuration is designed to resist overturning forces, by insertion of the base toe, into a matching groove at the inboard side of every bench, along with sliding resistance provided by self-drilling, corrosion resistant, concrete screw anchors.

The structural capacity of the panels can be estimated by the following computations:

Assuming an active pressure of 65 pcf (vegetation supporting soil medium), acting over 7-inches.

$$P = 65\,(7/12) = 3.5 \text{ psf}$$
$$H = ½\,(3.5)\,(7/12) = 1.02 \text{ lbs}$$

Bending moment M_b about lower panel corner

$$M_b = ((1.02)\,(7/12))\,/\,3 = 0.20 \text{ lbs-ft}$$

Bending stress f_b at lower panel corner

$$F_b = ((0.2)\ (6)\ (12)\ /\ (12)\ (3/4)^2 = 2.13 \text{ psi}$$

Tensile capacity of concrete F_b

$$F_b = f'_c\ /\ 100 = 400 \text{ psi}$$

Thus, a panel that retains the soils that support the vegetation façade, can be expected to offer a factor of safety against breaking at the critical bending location, which occurs at the lower corner of the “L” configuration, is estimated as FoS = 400/2.13 = 188.

Section 2: Design Methodology

2.1.1 Innovation in Design Methodology

The "Reinforced Soil Slope" (RSS) design can be performed using computer-assisted design software such as Tencate's "Miraslope" or other computer design software program that the designer deems appropriate. As such, there is no innovation in the structure's design, as it incorporates mature technology that is commonly implemented by local geotechnical engineering practitioners or the local highway transportation agency, with the appropriate resources and experience.

The structure design for a particular project, must be based on a comprehensive subsurface exploration program, in conformance to U.S. Department of Transportation, Federal Highway Administration Publication No. FHWA-NHI-10-025, "Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes."

2.1.2 Incorporation of Facing Units into the RSS Design

The subject innovation pertains to compressed soil-cement blocks (facing units) that serve as revetment to a Reinforced Soil Slope's (RSS) exterior facing. Due to the considerable angle of face inclination, gravitational forces cause the blocks to act as a load on the RSS's exterior surface, thus increasing the stability factor of safety. However, because the factor of safety increase is relatively small, it can be ignored in routine design of the RSS. Each block receives 100 percent coverage of geogrid reinforcement, both at the top and bottom of the blocks

As shown on Figures 1.1.1, 1.1.10 and 1.3.9, at the exterior side of every inter-unit bench, a planter panel is anchored to the lower block, to restrain both the top and bottom of the block. The planter sliding resistance is accomplished by corrosion resistant screw anchors that pierce thru the planter panel's base, into the lower block's top exposed surface, with a 12-inch center to center, spacing. In addition, the geogrid reinforcement at the top of every block, is folded over the exterior block face and secured by additional screw anchors.

2.1.3 Contingencies for Obstructions in the Reinforced Zone

Any obstructions in the structure's reinforced zone must be addressed by the project designer in the design documentation.

2.2 Design Examples

2.2.1 Foundation Design for Level Toe

As an example, a 15-feet high (10 block) is illustrated in Figure 2.2.1 per design criteria presented in Section 1.1.4.8, entitled “Foundation Design.”

$$P = \frac{1}{2} (H \times D) \times 130/D = 975 \text{ psf}$$

The result of the design computations is presented in a printout of the common software program from Enercalc, in the attached Appendix 2.2.1.

Alternatively, the designer of record can implement the alternate procedures prescribed in Section 1.1.4.8 and illustrated in Figure 1.2.6.1, “Determination of hinge height for modular concrete block faced MSE walls,” (NCMA, 1997), provided in Section 4, entitled “Design of MSE Walls” of FHWA NHI-10-024-Vol I, to estimate foundation load. Nevertheless, a factor of 2 to 3 should be applied to account for down drag on the back of the block units.

2.2.2 Foundation Design for Steep Toe Slope

As an example, a 15-feet high (10 block) is illustrated in Figure 2.2.2 per design criteria presented in Section 1.1.4.8, entitled “Foundation Design.”

$$P = \frac{1}{2} (H \times D) \times 130/D = 975 \text{ psf}$$

The result of the design computations is presented in a printout of the common software program from Enercalc, in the attached Appendix 2.2.2.

2.3 Summary of Design Input Parameters

1. Block Minimum Compressive Strength = 200 psi (28,800 psf)
2. Block Density = 130 pcf
3. Block Weight = 650 lbs. (775 lbs. with soil filled planter)
4. Geogrid to Block Connection Strength = 525 plf

Section 3: Construction Procedures

3.1.1 Construction Innovation

Greensteep's innovation consists of on-site, field manufactured facing units. These are created by compressing a 24-inch-thick layer of mixed soil and cement, in a 24-inch deep, 48-inch long, by 18-inch wide, galvanized sheet metal lined press box (lubricant free), down to 8 to 12 inches, to create a rigid block (See Figures 1.1.4.4 and 1.1.4.5). Roughly 8% (by volume) of Type II/V Portland Cement (high sulfate resistance) is added to soil collected from an approved soil stockpile and mixed. Water is added and the mixture is introduced into a box fitted with elements on the bottom, to produce the required exterior face configuration. The box containing the soil-cement mixture is then introduced into Greensteep's specially designed press and compacted to produce the block. Subsequently, the block is removed from the press and rotated 90° in preparation for drilling of block location template's pinning holes at the block's top surface and transported for placement on the outer edge of the progressing structure's face.

3.1.2 Construction Manual

See Appendix 3.1.2.

3.1.3 Facing Installation

There are no curves, only straight sections, and corners in between (See Plan Sheet No. 5). Facing installation procedures are applicable to both, except that the block length varies as the straight section approaches a corner and the blocks are mitered at the corners. To conform to a corner in the alignment, the blocks must be miter-cut at the joint that forms the corner, with matching face angle of the two miter cut blocks. The maximum angle of miter cut is 45 degrees, for a maximum corner angle of 90 degrees.

Because each individual block is adequately secured by the geogrid, as the block structure and its planters progressively abut (catch) a sloping, irregular natural hillside at the edges, and due to the battered corners causing a continuous reduction in a layer's lateral extension, there is no need for consideration for a stacking or running bond arrangement. The planters are placed on each individual block, matching the end joints.

3.1.4 Limitations of Facing Installation at Corners

The Greensteep system does not produce curved sections, only corners with a maximum of 90 degrees. Approaching corners, the block length will vary, as the corner (position) is altered and the layer length is shortened by each block layer, vertical progression. As such, some blocks must be shortened/cut, to ensure that a minimum 30-inch length is maintained, as corners are approached. The minimum 30-inch block length must be measured at the block center. As the placement of blocks approaches a corner, precise measurements must be taken to distribute the necessary shortness amongst the blocks approaching the corner, as required, to meet the minimum 30-inch length criteria. The maximum block-to-block abutment gap at miter-cut block corners, must not exceed 1/2-inch, if exceeded, the block is rejected. A 1-foot-wide strip of geotextile filter fabric that is centered about the block-to-block gap, must be provided to guard against chimney material migration (See Figure 1.1.11).

3.1.5 Earth Reinforcement Installation at Corners

The designer must provide geogrid reinforcement installation procedures, for the structure. These shall conform to current AASHTO and U.S. Department of Transportation, Federal Highway Administration Publication No. FHWA-NHI-10-025, "Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes." to establish backfill material specifications and geogrid reinforcement type and length.

The overlap of the geogrid at inward corners reduces pullout resistance at the geogrid-to-geogrid contact, as it is far weaker than the geogrid-to-soil contact. As such, a minimum layer of 3-inches of fill soil between geogrid segments in the overlap zone, is required.

3.1.6 Vertical and Horizontal Alignment Control

The first course of blocks is placed on a level, concrete grade beam or footing that is aligned by the project survey crew. The block fabrication is performed on-site, using a press with only a single confining press box that will consistently produce blocks with identical lengths and heights that insure consistent block-top levelness. There is no requirement for block placement to consider either stack or running bond procedures.

The blocks are transported to the structure's outer face that is under construction and accurately positioned with the guidance of a special template (See Figure 1.1.6.2) that is temporarily affixed to pinning holes on the top of the exposed, lower block's surface, with the aid of the specially designed Greensteep hand operated block lifting tool. Top-of-block levelness must be insured, and the block must be secured in place by providing sufficient chimney drain material along the rear of the block, as necessary to prevent block rotation. Any displacement due to block rotation must be corrected, by adding or removing chimney drain material.

3.1.7 Required Contractor Qualifications

While the technology for RSS is well developed, at the present time, Greensteep's facing system is in a technical review phase, seeking a technical report with evaluation comments from the IDEA program.

The economic advantages of the system have yet to be demonstrated and the approval from the California Department of Transportation (CALTRANS) will be pursued in the next phase of the system's evolution. In the future, it is anticipated that licensed Contractors that have ample experience with RSS construction, who have an interest in becoming affiliated with the Greensteep organization, will receive the appropriate training in the use of Greensteep's proprietary equipment and all block facing unit fabrication and installation procedures, as a condition for obtaining a license from Greensteep. The licensed Contractor's will operate independent of Greensteep, and their method of operation or other internal affairs, will not be an issue with the licensing from Greensteep.

3.1.8 Fill Placement in the Reinforced Soil Zone Adjacent to Facing

The placement of fill soils behind the facing blocks and their compaction in the reinforced soil zone, includes provisions for a chimney drain of permeable filter material (conforming to AASHTO 703-10 Class C specifications) next to the blocks, followed by the structural fill (See Figure 3.1.8).

Following the block placement on the outer face, wherever the uncut block-to-block abutment gap exceeds 1/8-inch, and at every shortened, cut block surface (in particular mitered corner cuts), a 1-foot-wide strip of geotextile filter fabric that is centered about the interior block-to-block gap, is provided to guard against chimney drain material migration (See Figure 1.1.11). The geotextile must conform to AASHTO M288-21 specifications. Subsequently, a sufficient volume of chimney drain material should then be placed behind the blocks, to produce a minimum of 4-inch chimney drain width and provide lateral block support (See Figure 3.1.8). Push by hand or hand tool sufficient drain material to fully fill block transport cavity at the block's lower interior sides. The block levelness is then checked to determine if additional or removal of drain material is needed at the interior block base.

The placement of the main reinforced fill material may be conducted using heavy equipment, provided that it maintains a 2-feet setback from the chimney drain's interior edge. Subsequently, a relatively light, i.e., skid-steer or similar, can be used to push and level the fill soil surface extending to the chimney drain material, in preparation for compaction of both material surfaces. Compaction of the outer 2-feet wide strip of reinforced structural fill material zone, extending inward from the chimney drain material, must be compacted with light, hand operated compaction equipment, such as a "jumping jack" (See Figure 3.1.8). The fill material for the main body of the structure, may be compacted with heavy compaction equipment.

Section 4.1: Block Unit Fabrication Quality Control

Specifications for the fabrication of Greensteep's block units present the latest advancements in Greensteep's innovation that produces strong block units with long life expectancy, for facing application to Reinforced Soil Slopes (RSS). It is important to note that as the system is commercialized and incorporated into future projects, it can be anticipated that the technology will evolve, thus, future revisions to the specifications may be warranted.

The fabrication of block units must comply with rigorous specifications detailed in Appendix 1.1.4, which pertaining to:

1. Suitable Block Fabrication Borrow Source Identification
2. Optimum Block Cement Content Determination
3. Soil/Cement Mixing Criteria for Block Fabrication
4. Compaction for Block Fabrication
5. Optimum Field Block Soil/Cement Strength Determination
6. Criteria for Acceptable Block Strength

Appendix 3.1.2, entitled "Construction Manual" provides QA/QC procedures for field oversight during block unit fabrication and placement on the structure.

1. Block Fabrication
2. Soil/Cement Mixing for Single Block Unit Fabrication
3. Filling Press Confining Box
4. Pressing Block
5. Block Preparations for Transport to Structure
6. Block Placement
7. Backfill Placement Behind Block
8. Planter Panel Placement
9. Filling Planters

Section 5: Performance History

5.1.1-3 Development and Usage History

The Greensteep system has a 11-year history of evolution. All of the projects have been in the San Francisco Bay Area (California) and at a prototype level. The San Francisco Bay Area climate can be classified as "Mediterranean," with an average temperature of 55^0 F and 23-inches of average annual precipitation, mostly during the winter months.

The first project was a 9.5-feet high structure that was constructed in 2007 and remains in place with no visual deterioration (See Appendix 5.1.1). It employed solely rectangular blocks, without batter or any provisions for vegetation. This structure is on private property and may be available to visitors, with proper notice.

Four years later (2014), a small (6-foot high) structure was constructed to test vegetation amendatory components and revised block arrangement, with success (See Figures 5.1.4, 5.1.5 and 5.1.6). Grasses flourished unimpeded and produced a consistent natural façade. Shortly afterwards, the structure was dismantled.

In 2015, the last structure was constructed in a Monastery, with a maximum height of 11-feet high (See Figures 5.1.7, 5.1.8, 5.1.9, 5.1.10 and 5.1.11). It incorporated the many advances in fabrication, block transport and provisions for vegetation. To date, it has performed impeccably and is available to visitors.

5.1.4 Private and Public Agency Users.

There is no historic commercial or public agency use. All three above referenced projects were prototypes.

Section 6: Other Information

6.1.1 Aesthetics

Greensteep was developed in response to the modern-day rejection of the exposed concrete structure's aesthetical impact on natural landscapes, by upgrading to a natural grass façade that blends a structure into the surrounding landscape, at a reduced cost.

6.1.2 Technological Advantages

The available technologies applied to the Greensteep system demonstrate significant cost reductions, by the elimination of costly elements of a structure, when compared to that of conventional concrete walls, MSE systems, or conventional sliver slopes with a 2H:1V gradient. The system has not yet reached commercialization, nor has the organization developed a skilled workforce, hence, there are no records to substantiate records of productions and their costs. Our professional experience, as Engineers and Contractors, assures us that the system offers both construction time advantages and cost savings, relative to other alternatives for similar applications, with which we are thoroughly familiar.

6.1.3 Cost Comparison with Conventional Systems

Achieving a relatively level surface on projects such as a highway widening project that extends the roadway surface onto downward projecting sloping terrain, is normally very costly.

While all systems (except elevated structures) require structural fill. In the case of conventional concrete retaining stem wall structures, the rigorous foundation requirements and forms with reinforcing steel placed prior to concrete placement, plus the cost of the concrete, and transporting it and pumping it, or in the case of MSE walls where block cost, transportation, stockpiling and individual handling of blocks, the costs certainly add up.

Sliver fills typically require a minimum of commercially supplied items; however, they require substantial increases in earthworks, including keyway excavations and far greater fill volumes.
Greensteep's total cost is reduced by eliminating the number of items that need to be purchased from suppliers and transported to the project site. Greensteep's cost of block fabrication is

relatively low due to the small volume of cement that is used and the small wire mesh pieces. The planter panels are also of low cost.

One Greensteep press can easily produce 35 blocks per day, which translates to 6 ft^2 /block x 35 = 210 ft^2 of completed structure with facing daily progress. Of course, two presses would double the production and so on...

6.1.4 Market Applications

Greensteep is an innovation that will need a technical evaluation report from a reputable entity, such as the IDEA program, to promote acceptance by State Highway authorities.

We are privileged to have an abundance of working relationships with the local San Francisco Bay Area, Counties and Cities,' planning and building authorities that have decades long record of partnering with Greensteep's professionals, during earthwork related permit application approval processes and project oversight.

Upon receipt of the IDEA Evaluation Report for the Greensteep system, the application documentation would then be presented to DOTs such as California's CALTRANS (who have already been introduced to the system), Oregon's ODOT and Nevada's NDOT, as well as others.
The decision to bid on state and county projects would then be at Greensteep's licensed contractors' discretion and level of interest in a particular project.
Depending on the system's initial market performance and affiliated contractor's assessment, expansion into other markets would follow.

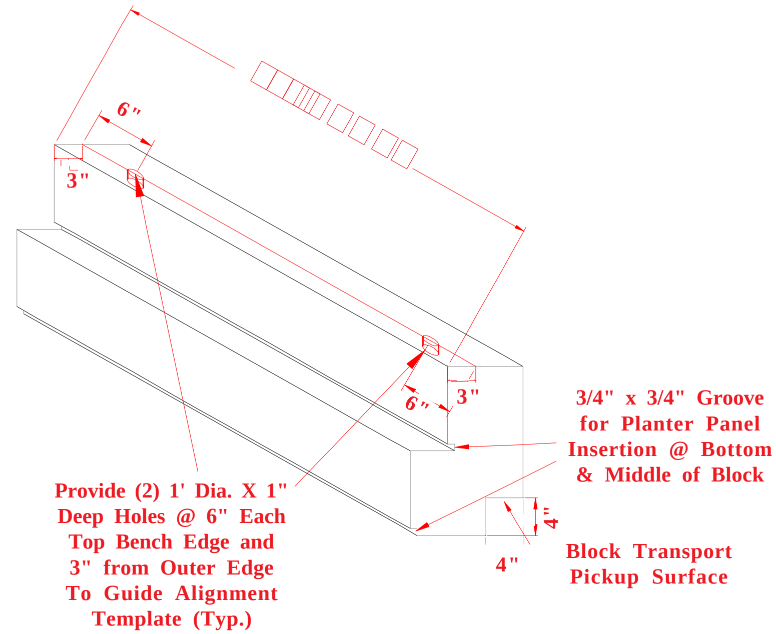
6.1.5 Contractor Licensing

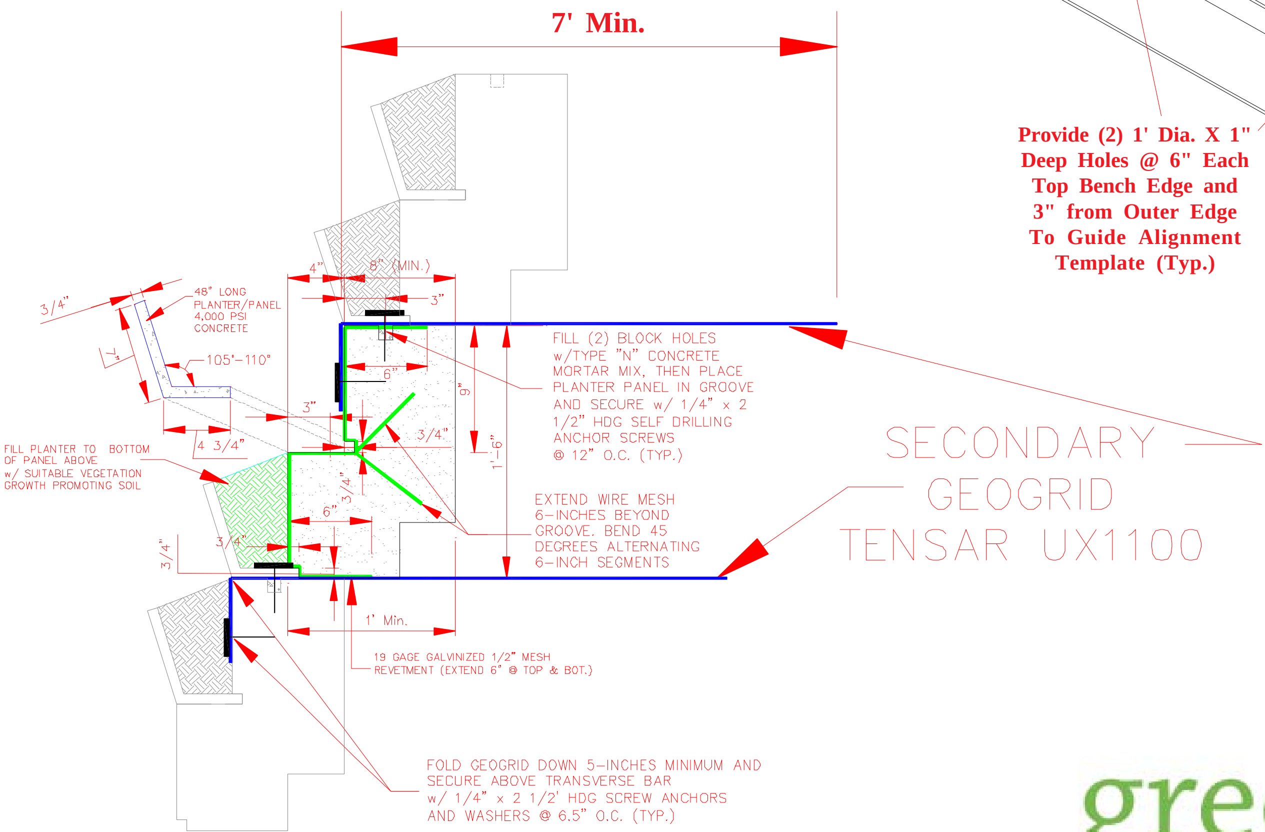
The licensing of highway construction contractors, business planning and marketing processes are pending subject to approval of this technical review application.

APPENDIX 1

Supporting Figures

NOTE:
Block & Planter Panel
Length 30" Min.

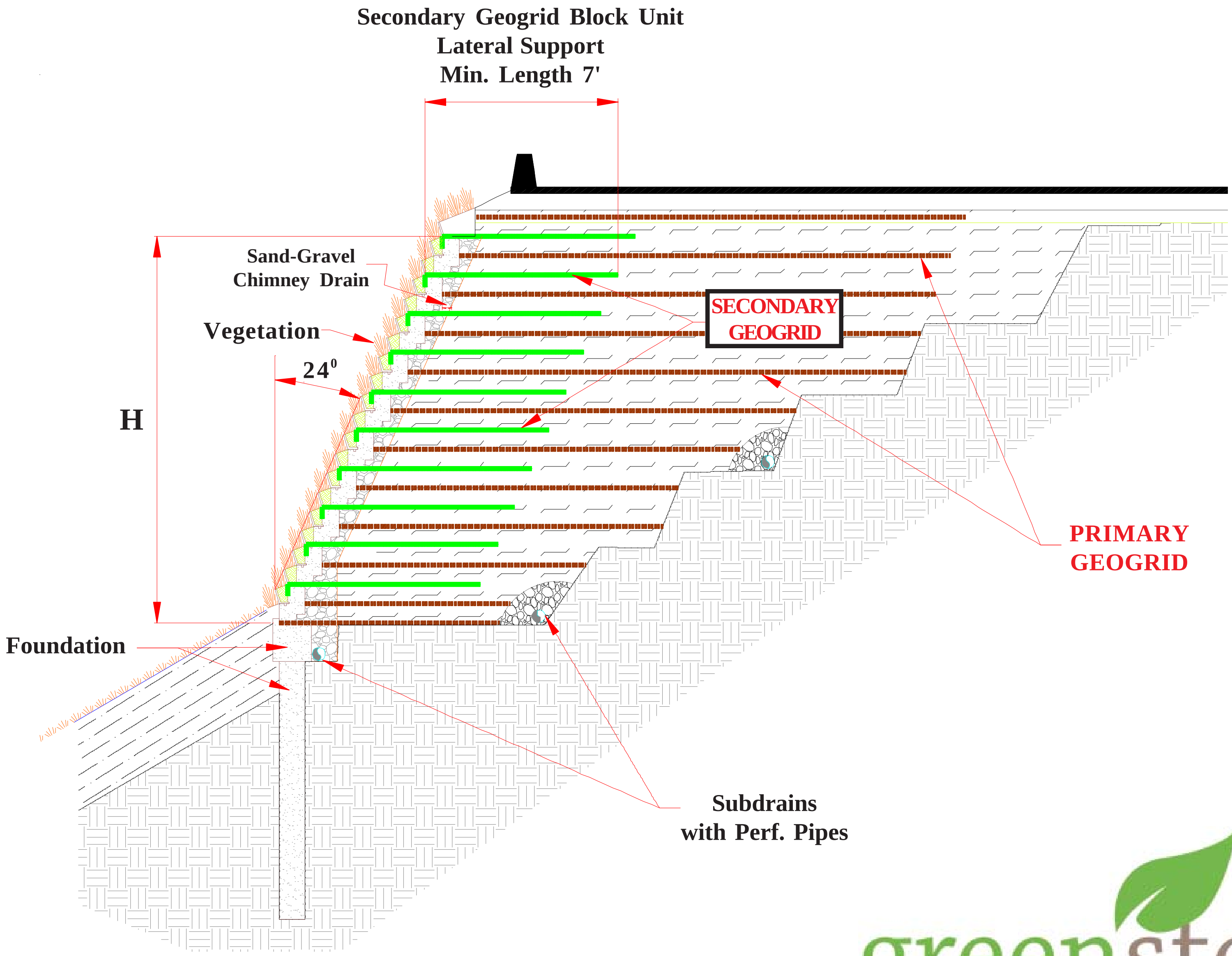




greensteep™
Sustainable Fill Support Structures

SPECIFICATIONS

Figure 1.1.1



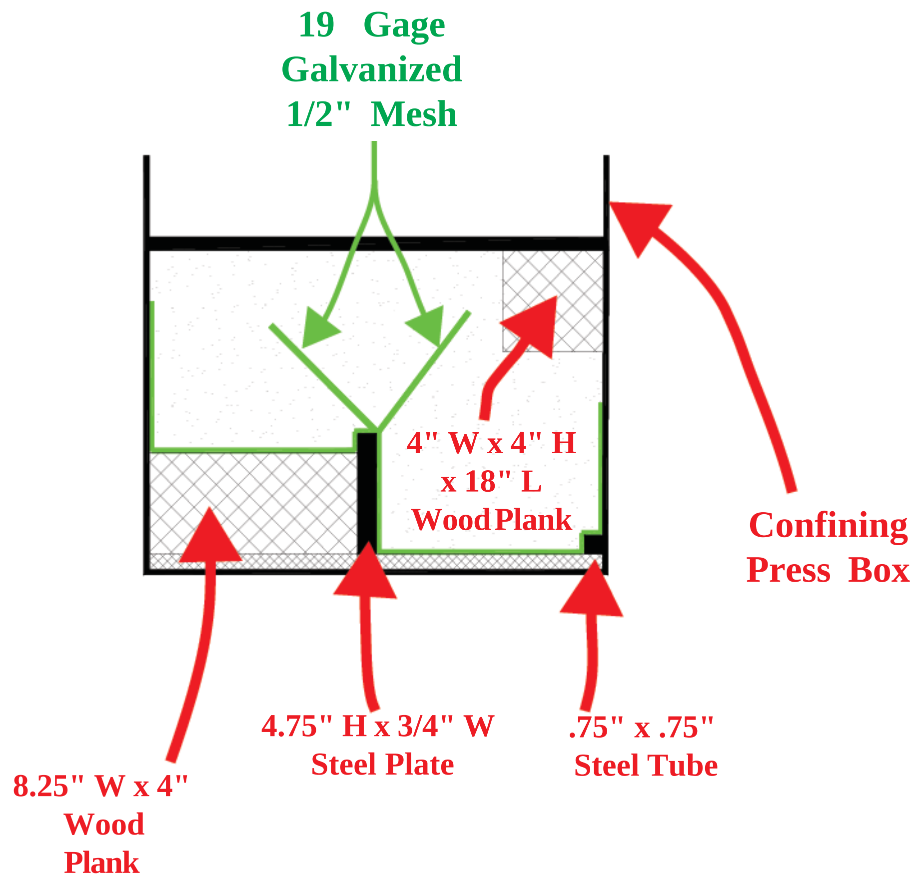
greensteep™ Sustainable Fill Support Structures

STRUCTURE CROSS SECTION

Figure 1.1.2

Sustainable Fill Support Structures

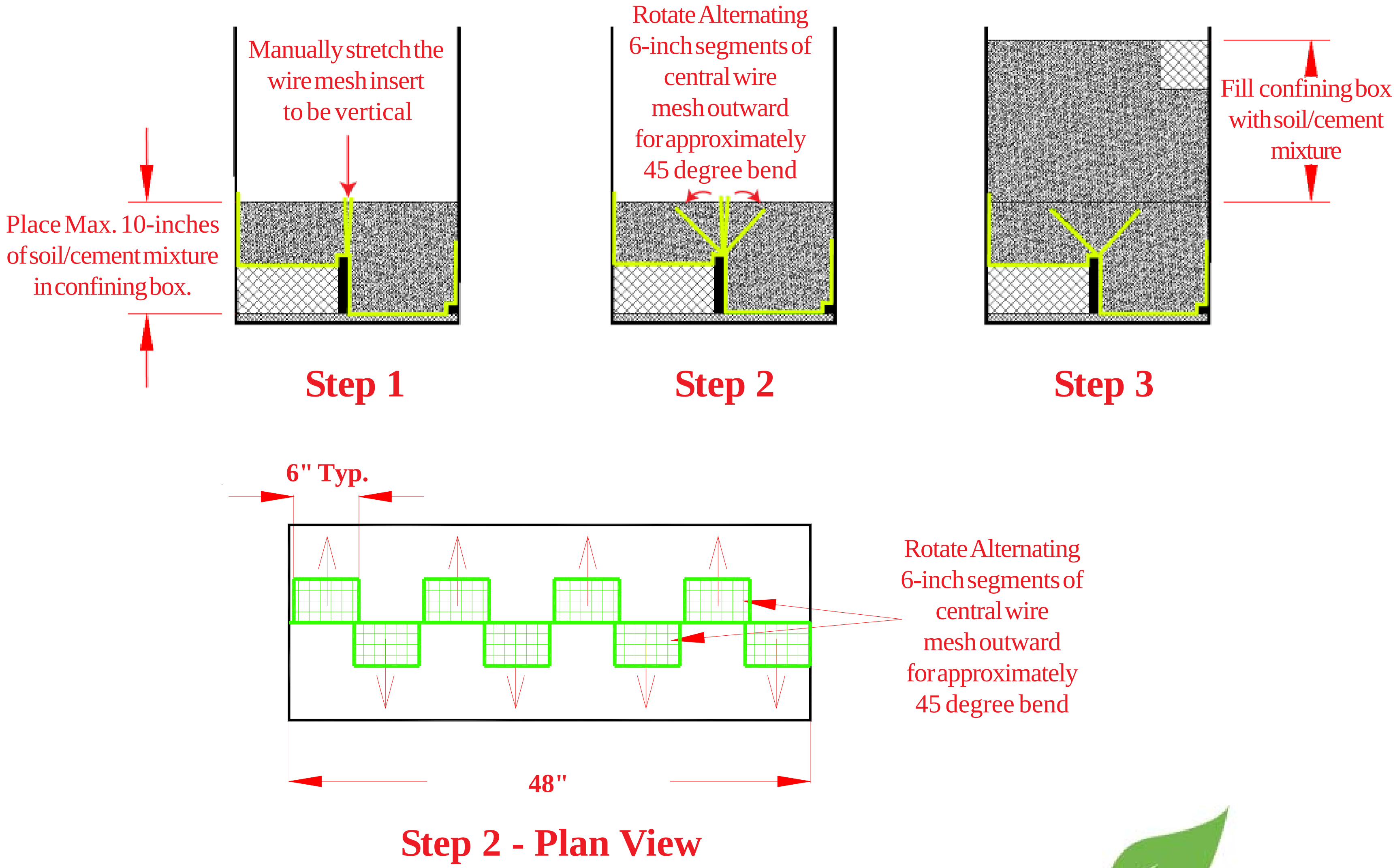
Figure 1.1.3



BLOCK INSERTS

greensteep
Sustainable Fill Support Structures

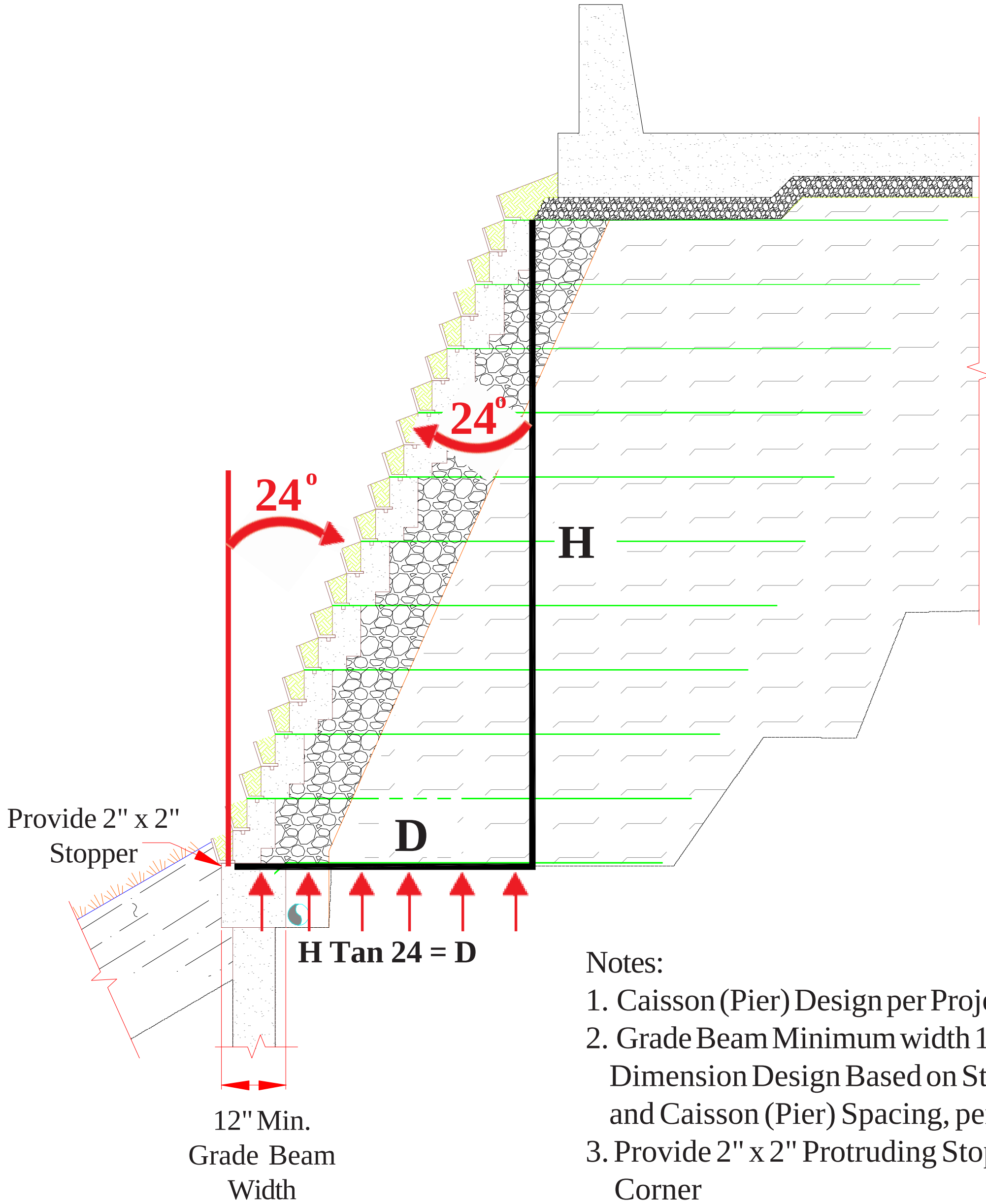
Figure 1.1.4.4



MIXTURE POURING SEQUENCE

greensteep™ Sustainable Fill Support Structures

Figure 1.1.4.5



Notes:

1. Caisson (Pier) Design per Project Engineer
2. Grade Beam Minimum width 12-inches. Actual Dimension Design Based on Structure Height and Caisson (Pier) Spacing, per Project Engineer.
3. Provide 2" x 2" Protruding Stopper at Upper, Outer Corner
4. Minimum 2,500 PSI Concrete

FOUNDATION DESIGN

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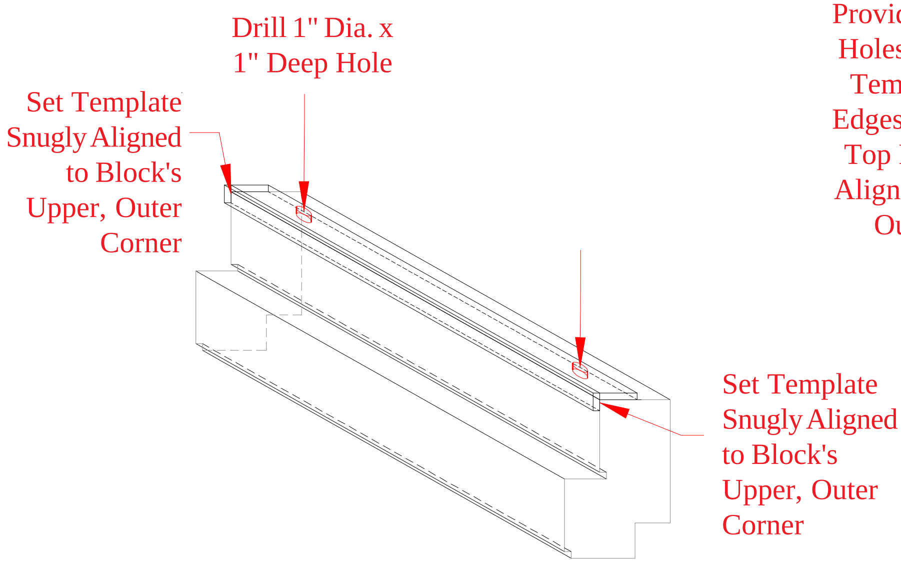
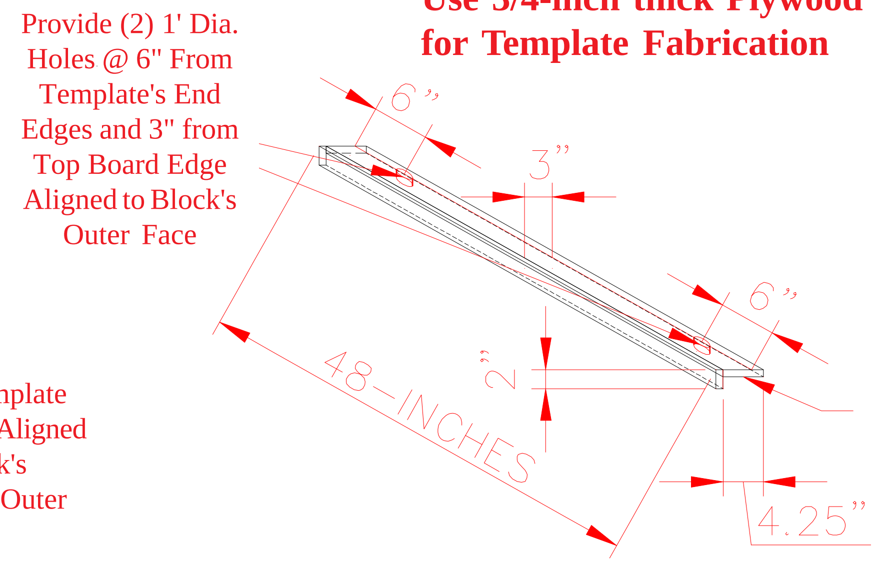
Figure 1.1.4.8

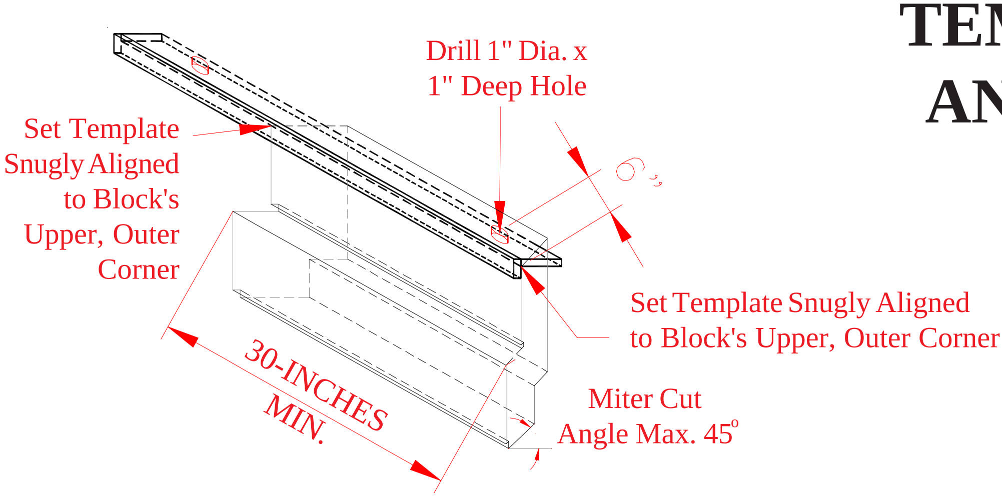
Note:
Use 3/4-inch thick Plywood for Template Fabrication



Full Length Block



TEMPLATE FABRICATION AND GUIDE FOR BLOCK HOLE LOCATION



Shortened & Miter Cut Blocks Block

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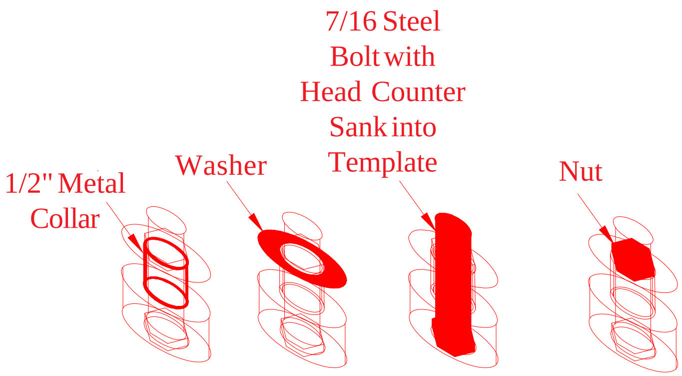
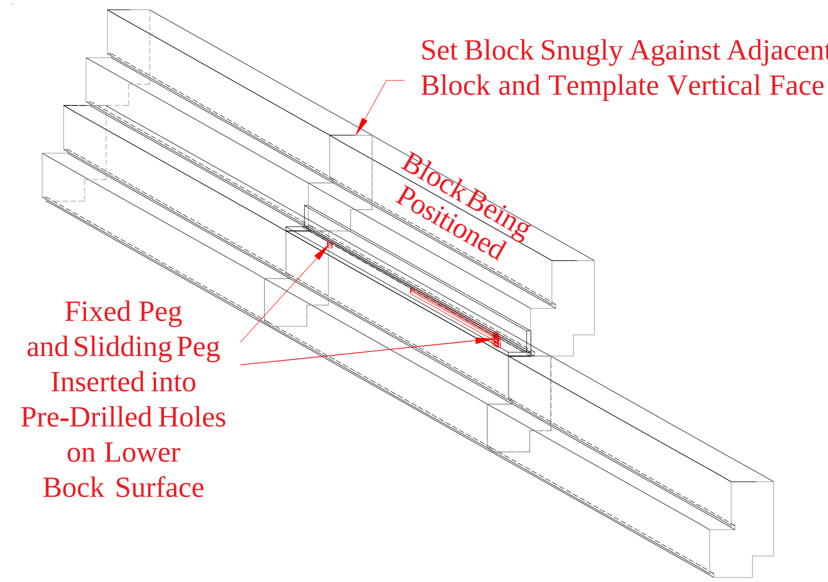
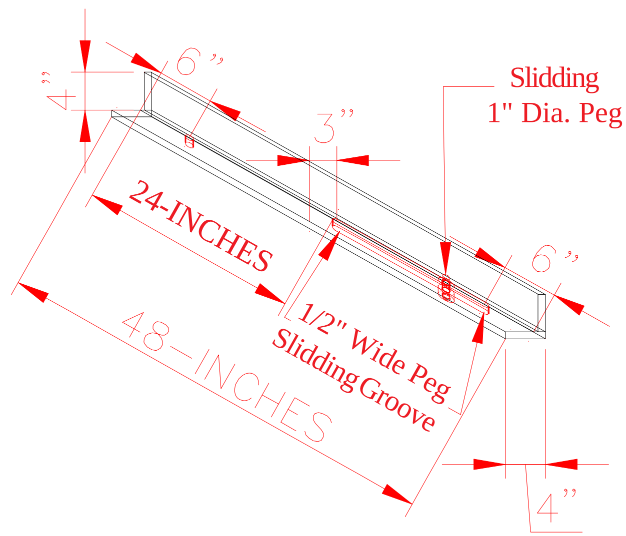
Figure 1.1.6.1



Peg Slidding on Template Groove





Template Dimensions

BLOCK POSITIONING TEMPLATE

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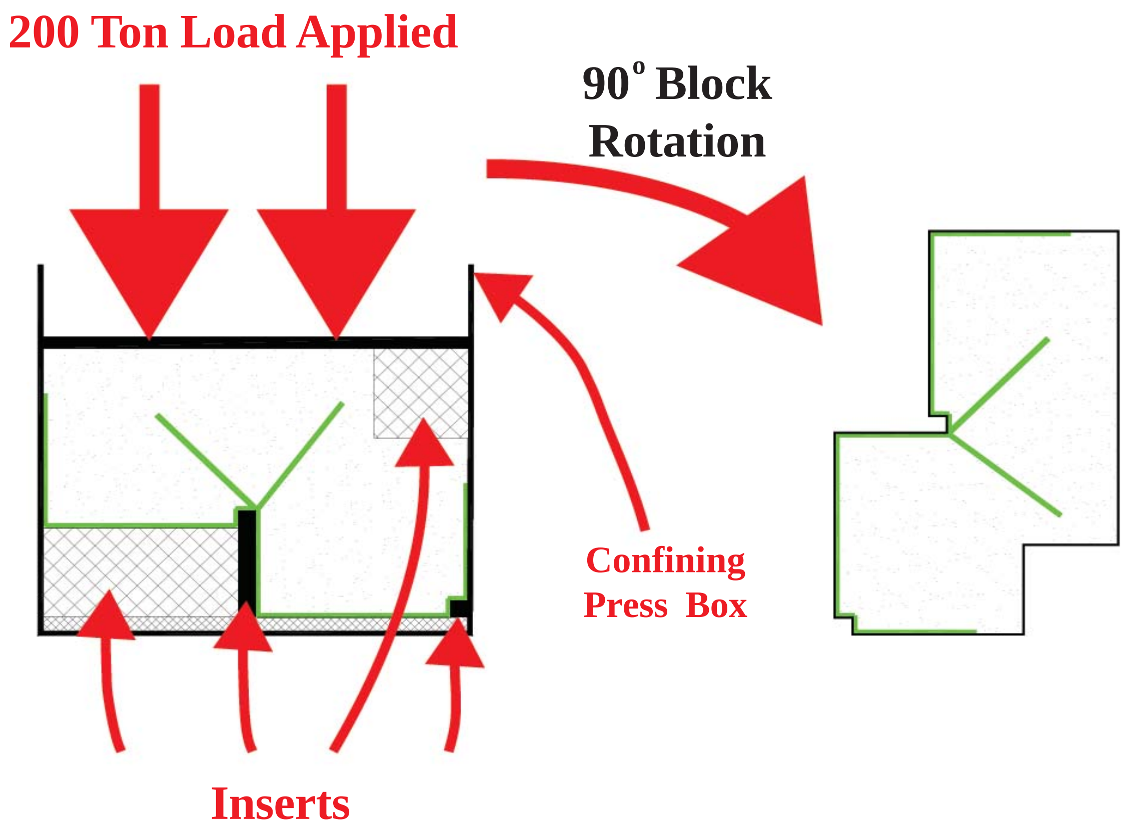
Figure 1.1.6.2



BLOCK ROTATION

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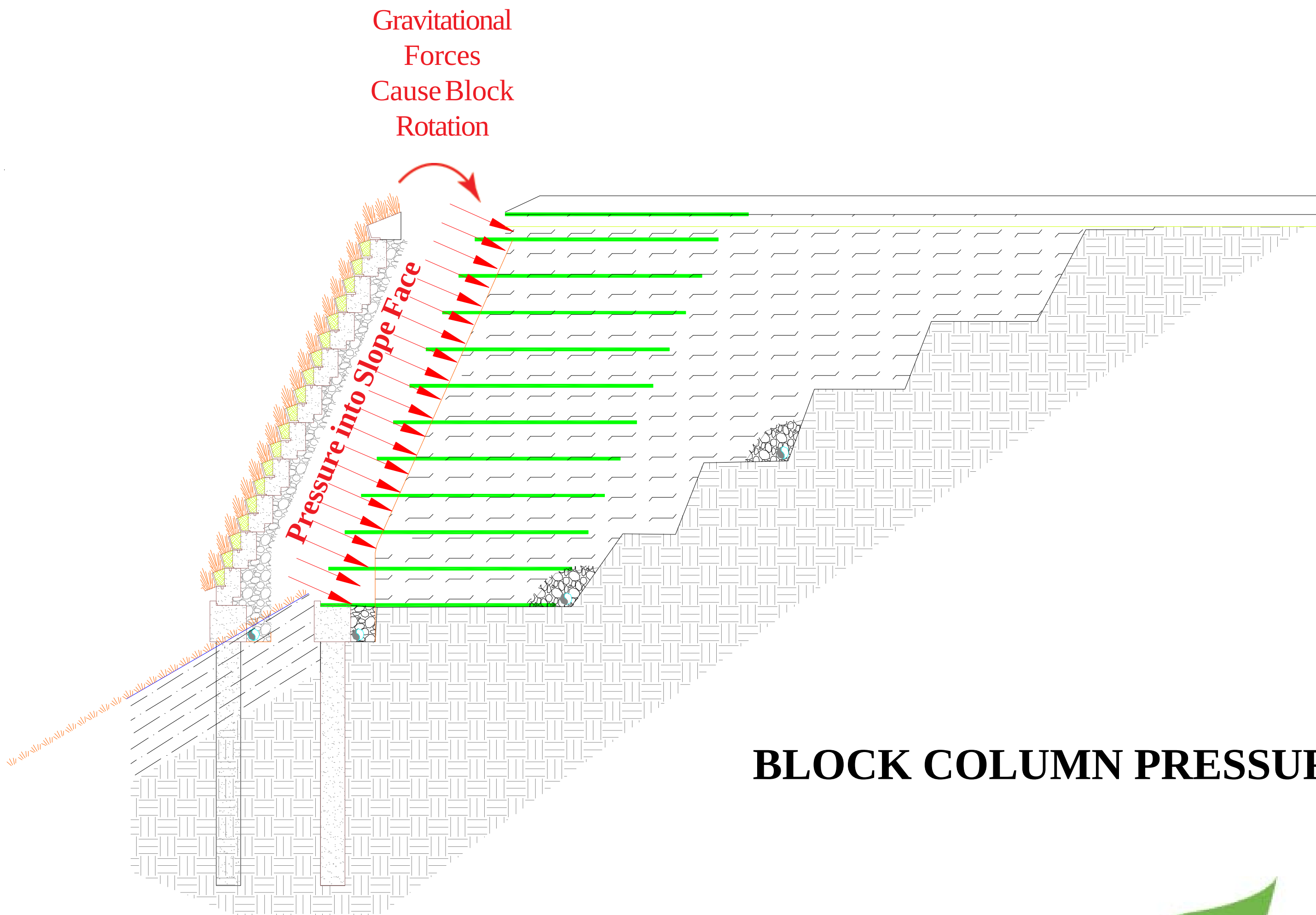
Figure 1.1.7



BLOCK COLUMN PRESSURE

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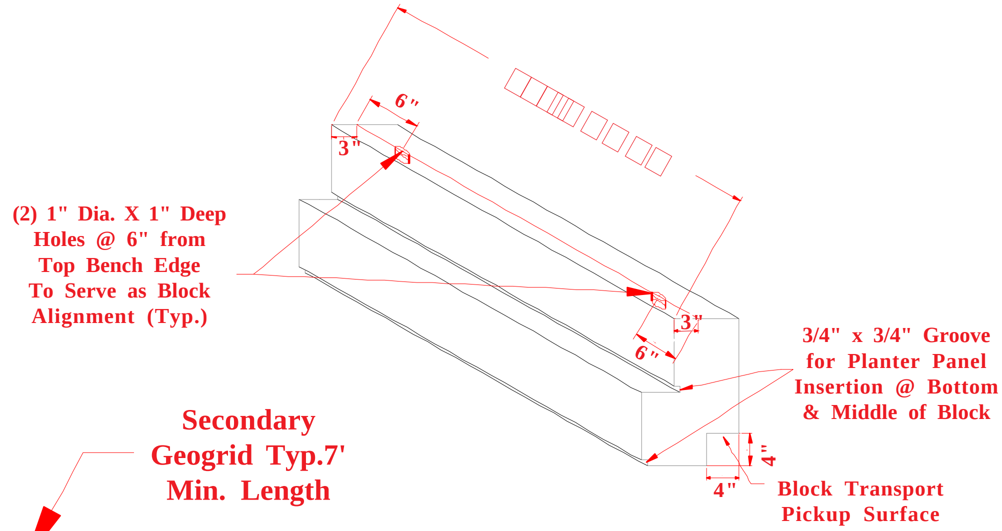
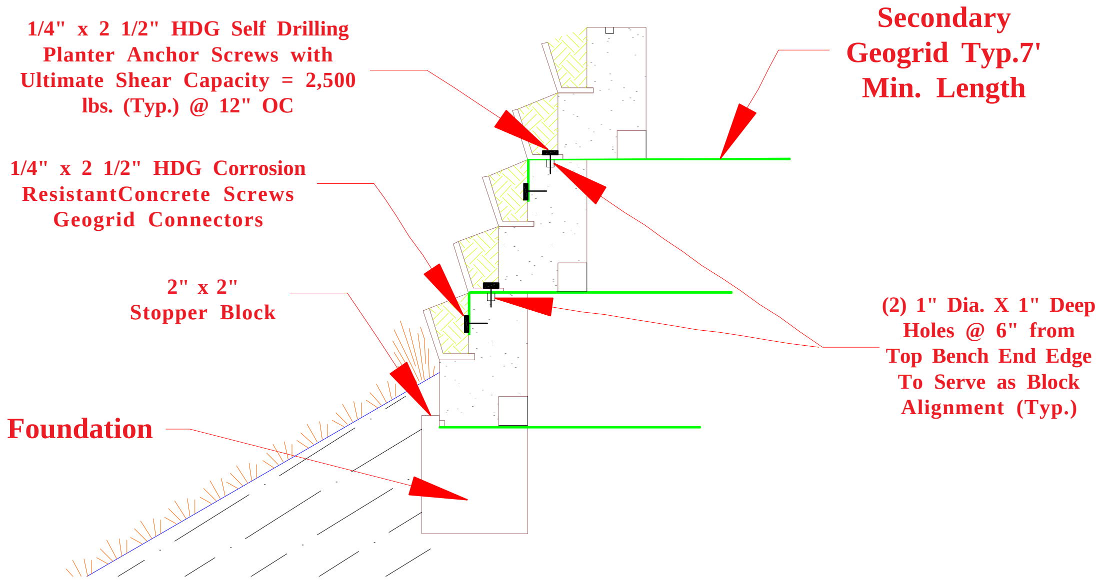
Figure 1.1.9

NOTE:
Block & Planter Panel Length 30" Min.





Alignment

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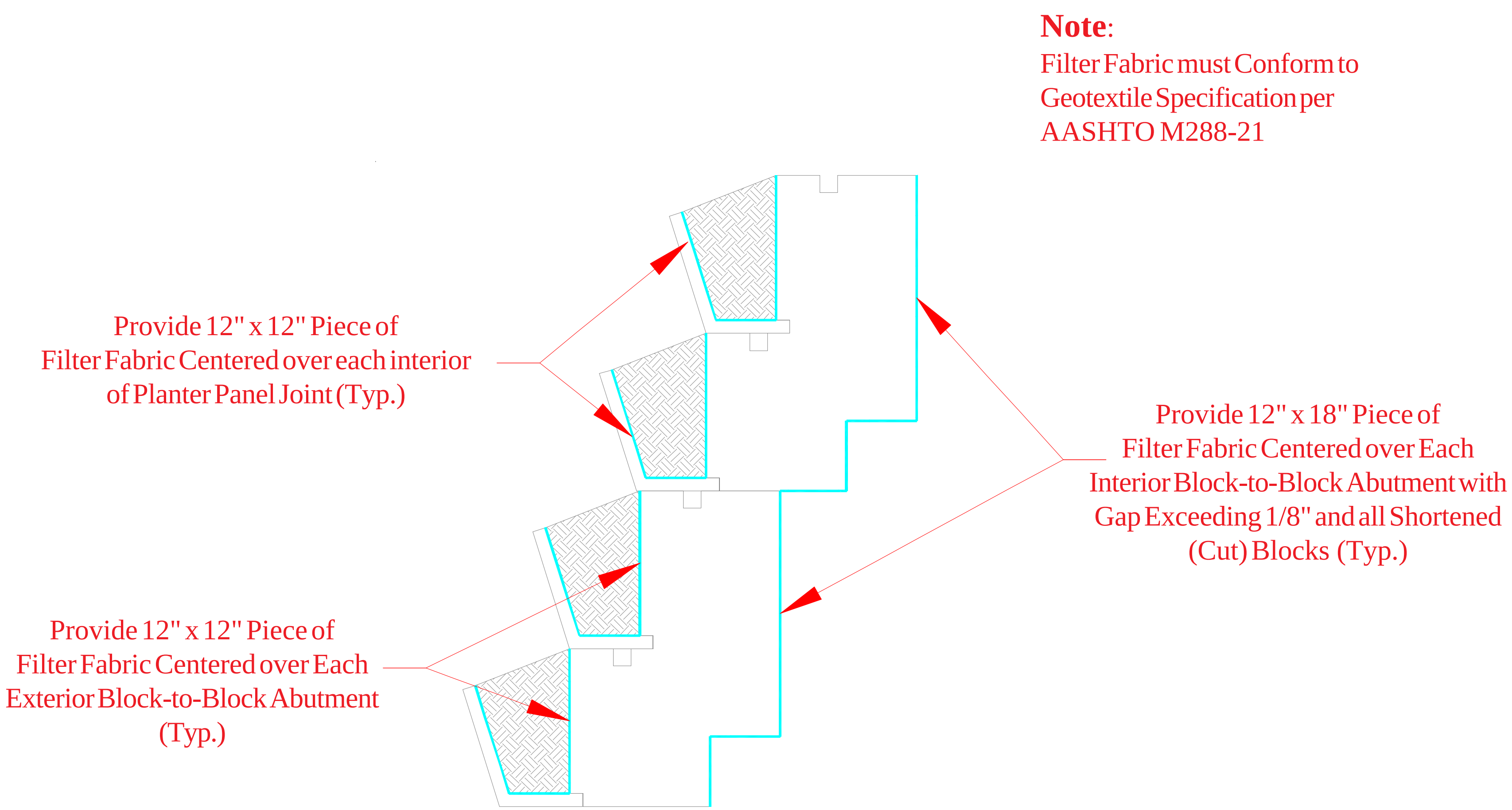
Figure 1.1.10



FILTER PREVENTING FILL SOIL MIGRATION BETWEEN BLOCKS

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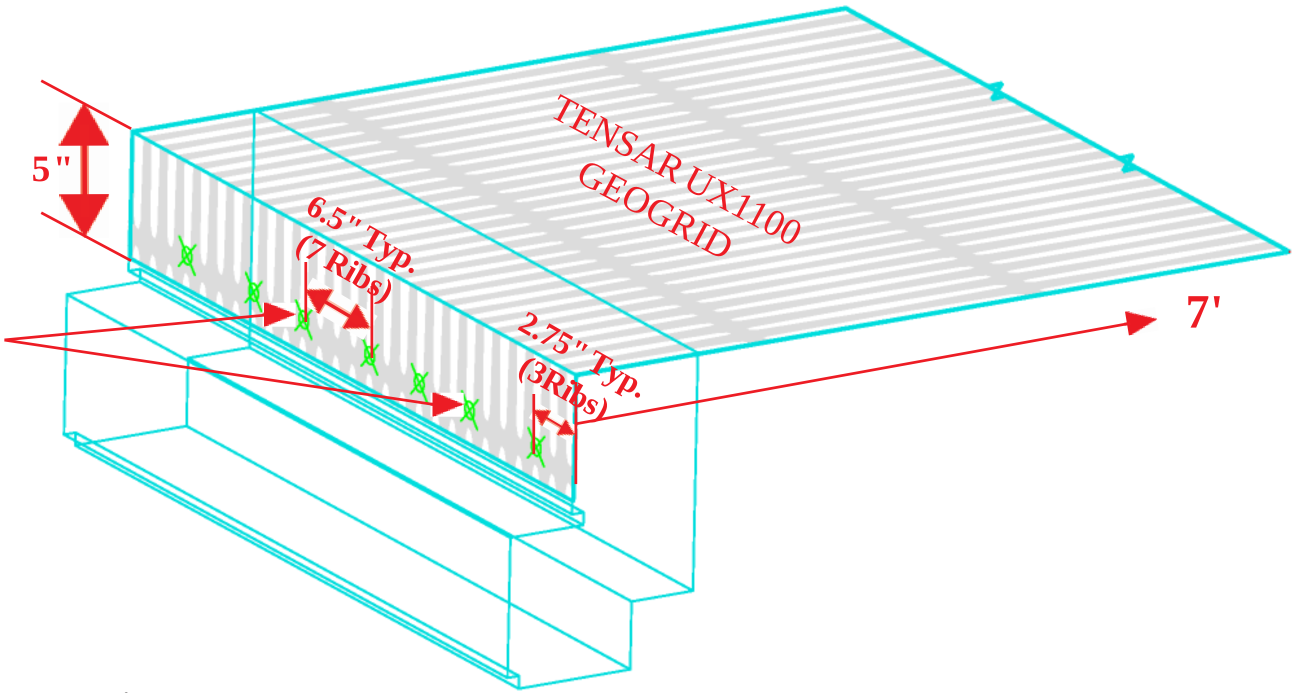
Figure 1.1.11

Assumption:
Ultimate Lateral Capacity of Screw Embedment into Bloc = 1/2 sq-inches x 200 psi x 9 = 900 lbs. / 3 (for safety) = 300 lbs.
Screw Resistance Capacity per Linear Foot of Geogrid = 7 screw/ 4 feet x 300 lbs./screw = 525 plf

FOLD THE GEOGRID DOWN THE UPPER VERTICAL FACE A MINIMUN OF 5-INCHES AND SECURE W/ 1/4" X 2 1/2" HDG CORROSION RESISTANT SCREW ANCHORS AND 1/4" X 1" HDG WASHERS, EVERY 7TH RIB SPACE AND 3RD RIB SPACE FROM BLOCK EDGES, TOUCHING THE GEOGRID'S UPPER TRANSVERSE BAR EDGE (TYP.)



Secondary Geogrid Connection to Block FoS for Seismic Forces

$$FoS = \frac{525\text{ plf}}{24.5\text{ plf}} = 21$$

Block Mass = 0.833' x 1.5' x 130 pcf = 163 lbs.

Seismic Load = 163 lbs. (0.15 g) = 24.5 plf

SECONDARY GEOGRID CONNECTION TO BLOCK

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Figure 1.2.4

Notes: At a peak load of 330 Lbs., bending of screw at approx. 1" below screw head, was established as the cause of failure.

PULLOUT TEST OF GEOGRID CONNECTION TO BLOCK

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Figure 1.2.4.1

Note: Screw bending slightly below head.

PULLOUT TEST OF GEOGRID CONNECTION TO SCREW

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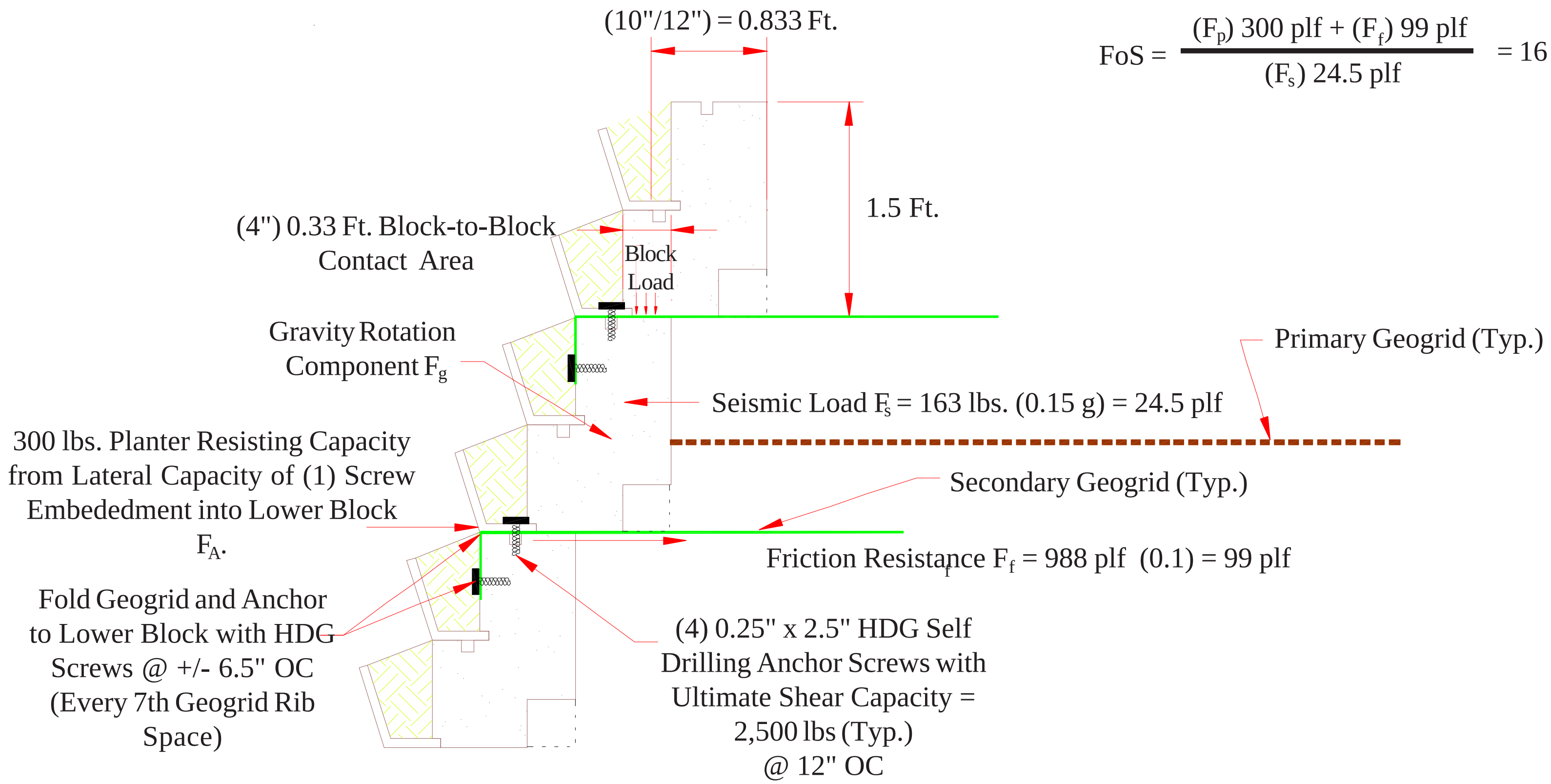
Figure 1.2.4.2

Block Unit Weight = 0.833' x 1.5' x 130 pcf = 163 plf.
Consider Two Tributary Blocks (per NMCA, 1997)
Inter-Block Pressure = (2) (163 plf / 0.33' x 1') = 988 psf

Inter-Unit Shear Capacity FoS for Seismic Forces

$$FoS = \frac{(F_p)\ 300\ plf + (F_f)\ 99\ plf}{(F_s)\ 24.5\ plf} = 16$$



Assumptions:
Seismic Coefficient = 0.15 g
Friction Factor for Block Mesh Lining "Sandwish" of geogrid = 0.1
F_A = 1/2 sq-inches x 200 psi x 9 = 900 lbs. / 3 (for Safety) = 300 lbs. (Test Confirmed
See Figure 1.2.4.1 for Unrestraind Screw Head)
F_P = 300 lbs./screw x 4 screws/4 Ft. = 300 plf

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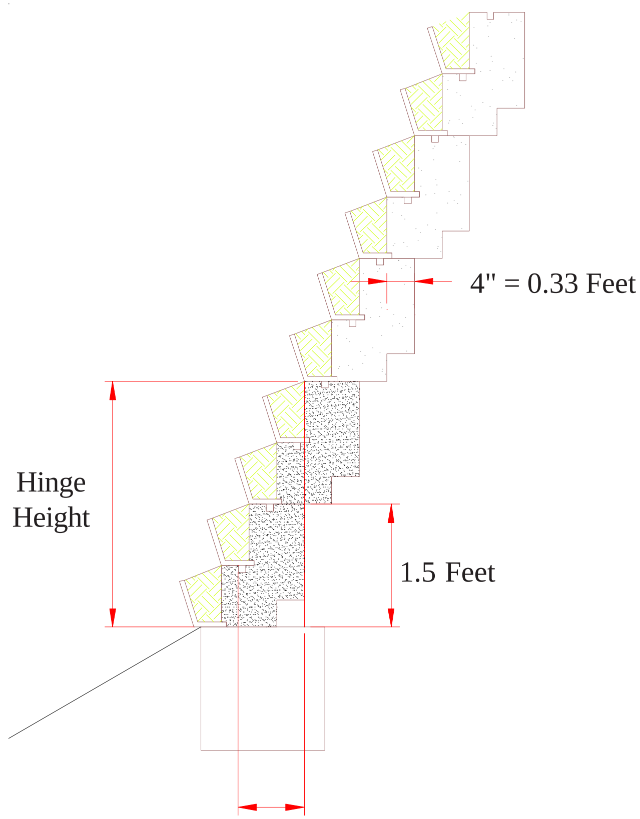
Figure 1.2.6



Based on NMCA, 1997 procedure for "Determination of hinge height for modular concrete block faced MSE walls"
Two Tributary Blocks

Weight over the base unit

W_w = 2 (0.833' x 1' x 1.5' x 130 pcf) = 325 lbs.

Block Unit Weight

0.833' x 1.5' x 130 pcf = 163 plf

Inter-Block Pressure (LRFD)

(2) (163 lbs. / 0.33' x 1') = **988 PSF**

Block Weight

4' x 163 plf = 652 lbs.

Note:
Assumed Block Density = 130 PCF

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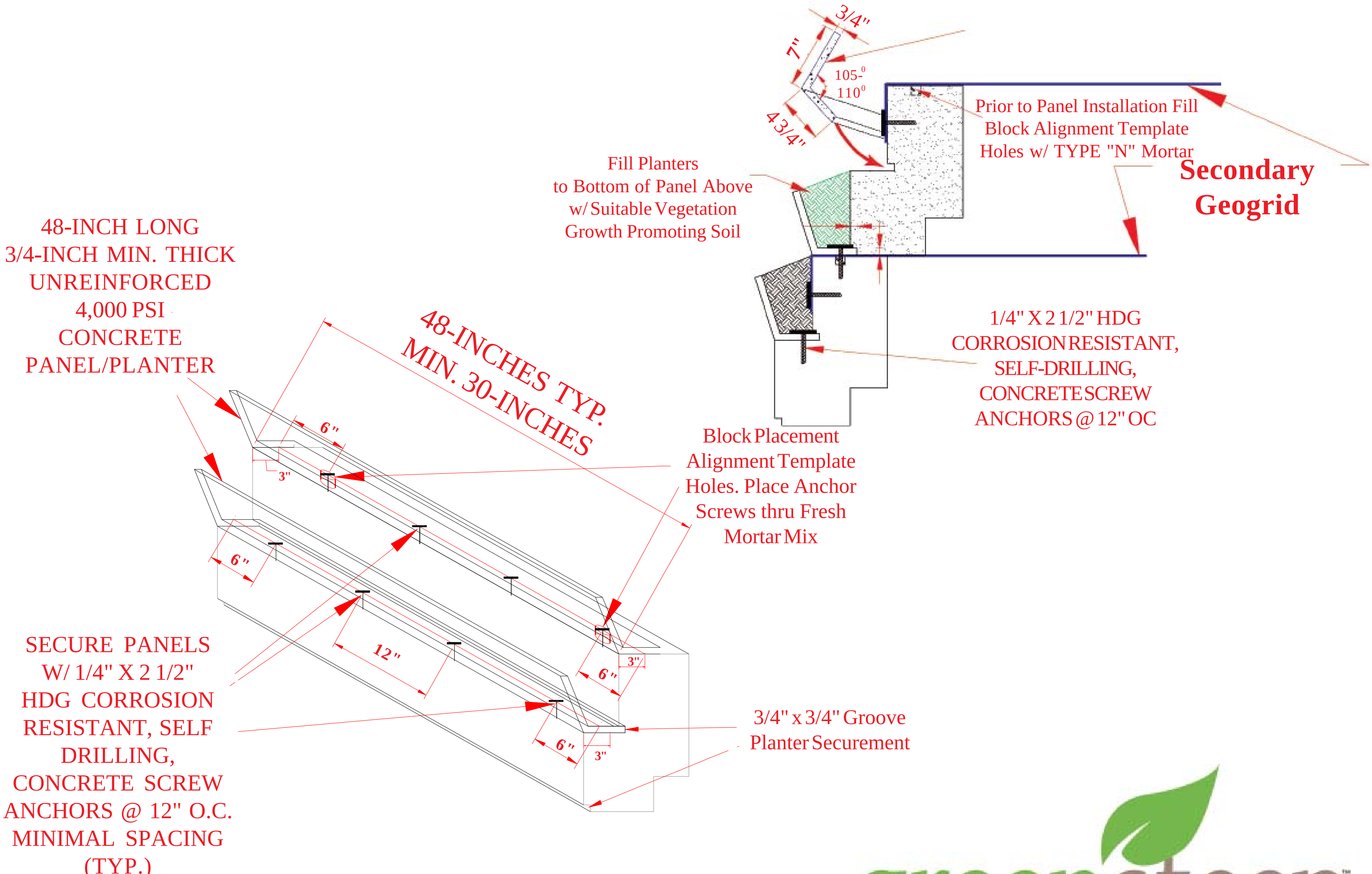
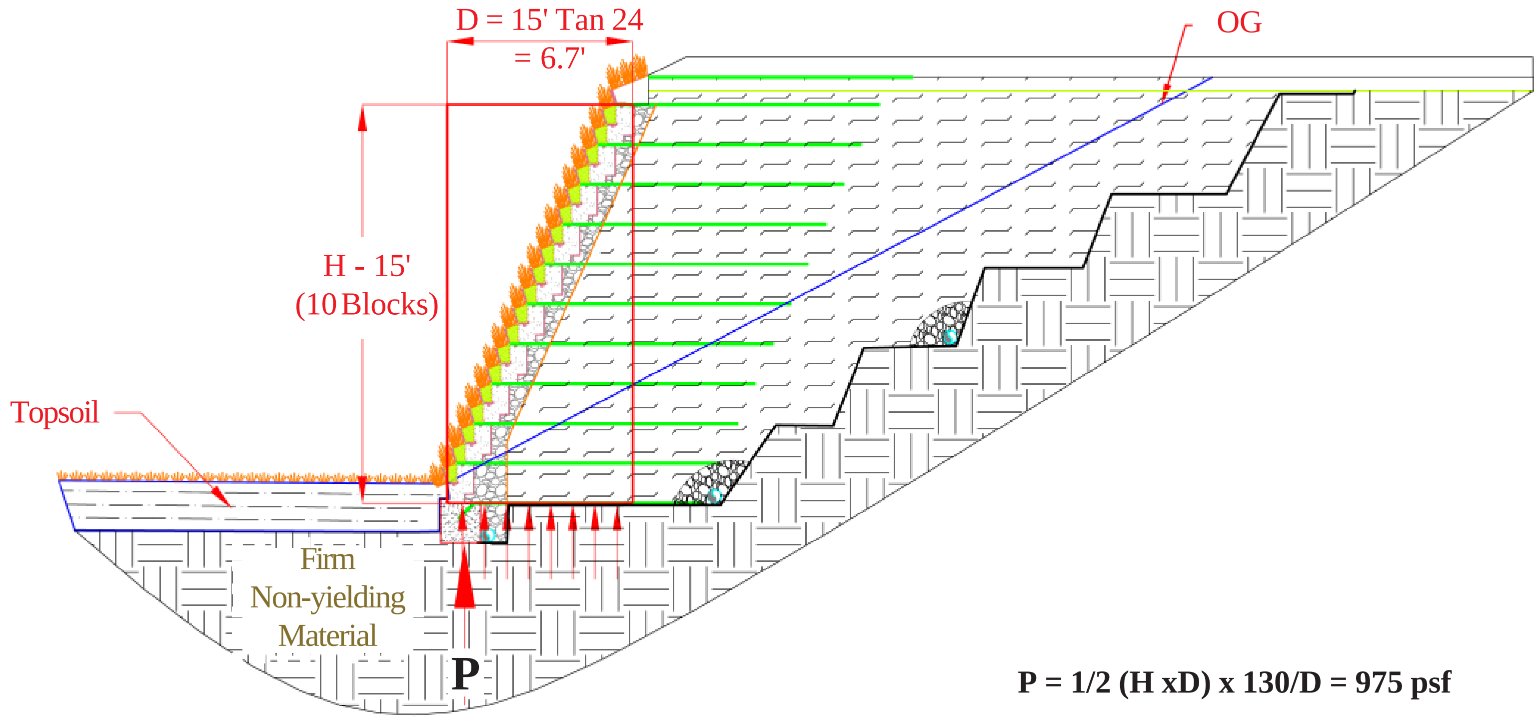
Figure 1.2.6.1



PLANTER PANELS

Figure 1.3.9



P = 1/2 (H xD) x 130/D = 975 psf

FOUNDATION DESIGN FOR LEVEL TOE

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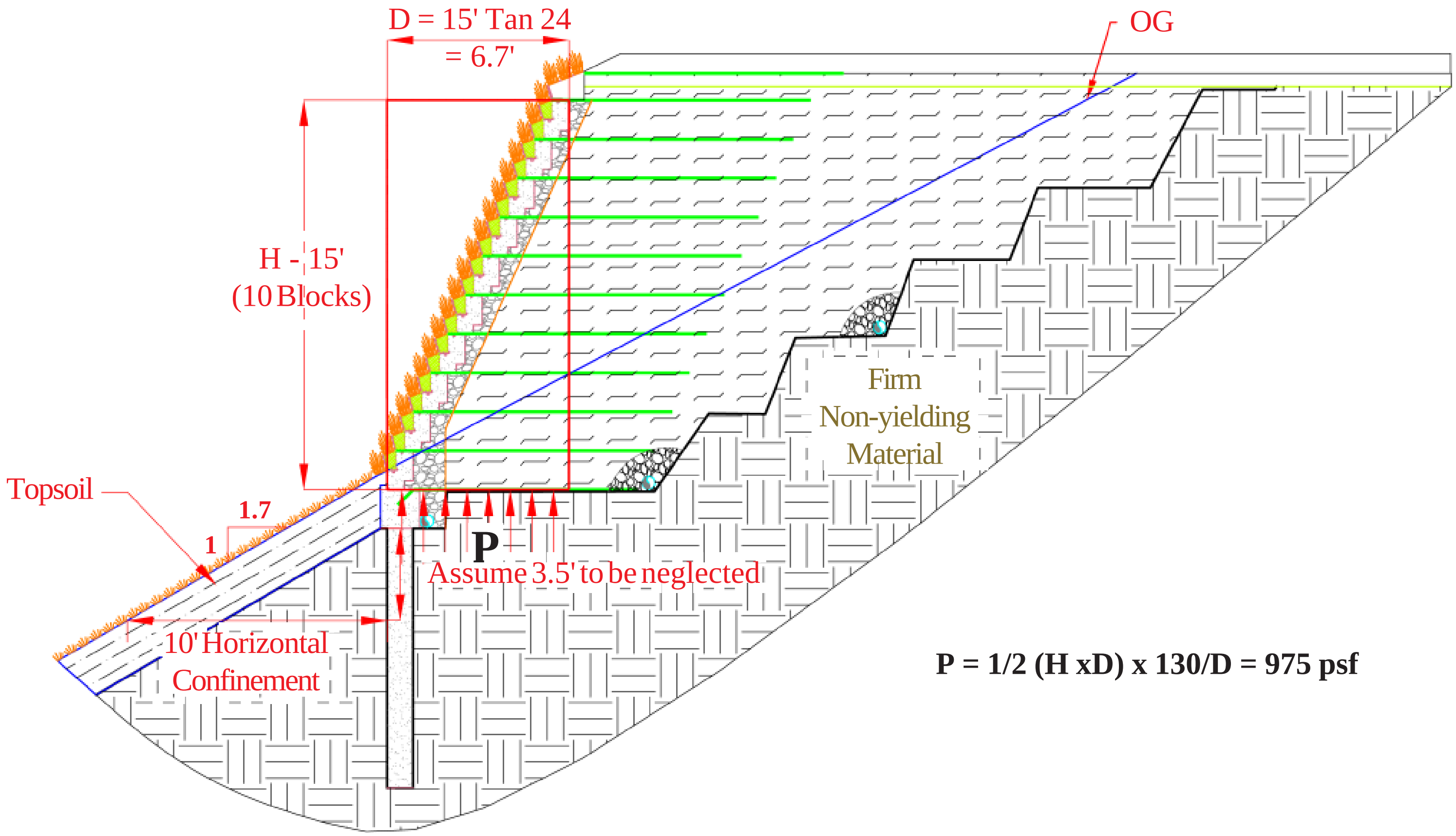
Figure 2.2.1



FOUNDATION DESIGN FOR STEEP TOE SLOPE

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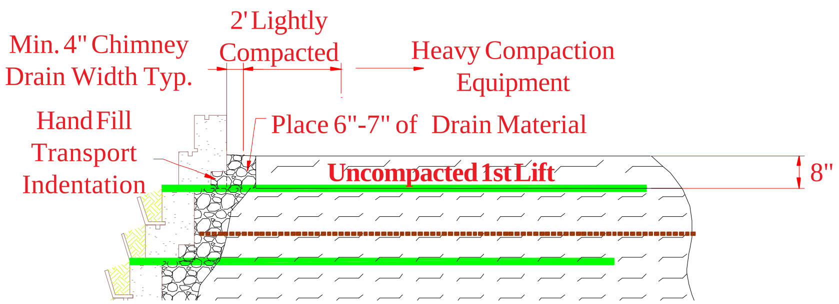
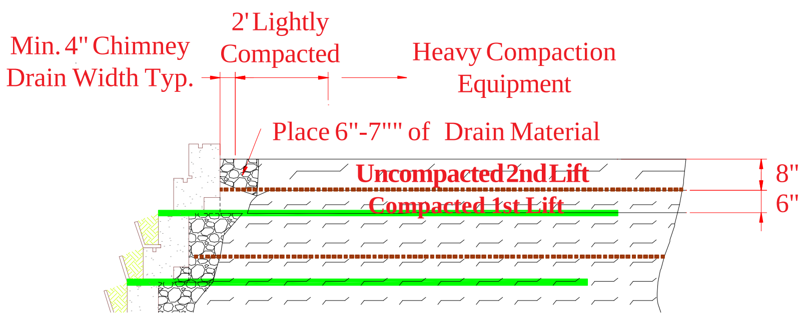
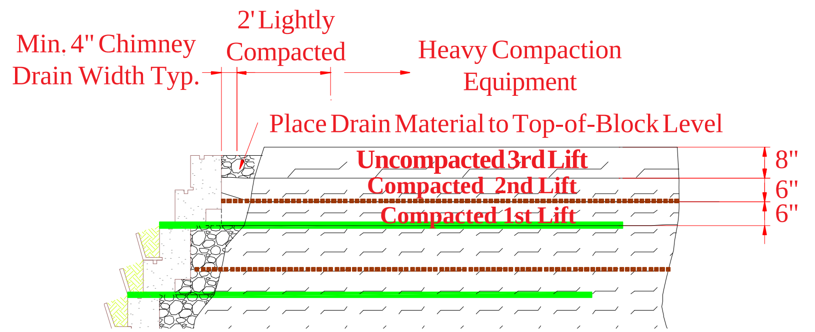
Figure 2.2.2



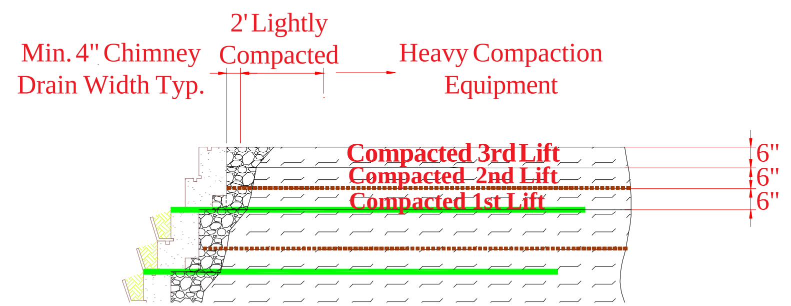
1st Lift



2nd Lift



3rd Lift



Ready for New Layer of Geogrid & Blocks

Notes:

1. Prior to 1st lift, provide a 1-feet wide strip of Geotextile Filter Fabric that is centered about the interior of uncut block-to-block abutment gaps exceeding 1/8-inch and at every shortened (cut) block abutment approaching and including all mitered corners.

2. Place Primary Geogrid on compacted 1st lift surface

FILL PLACEMENT SEQUENCE

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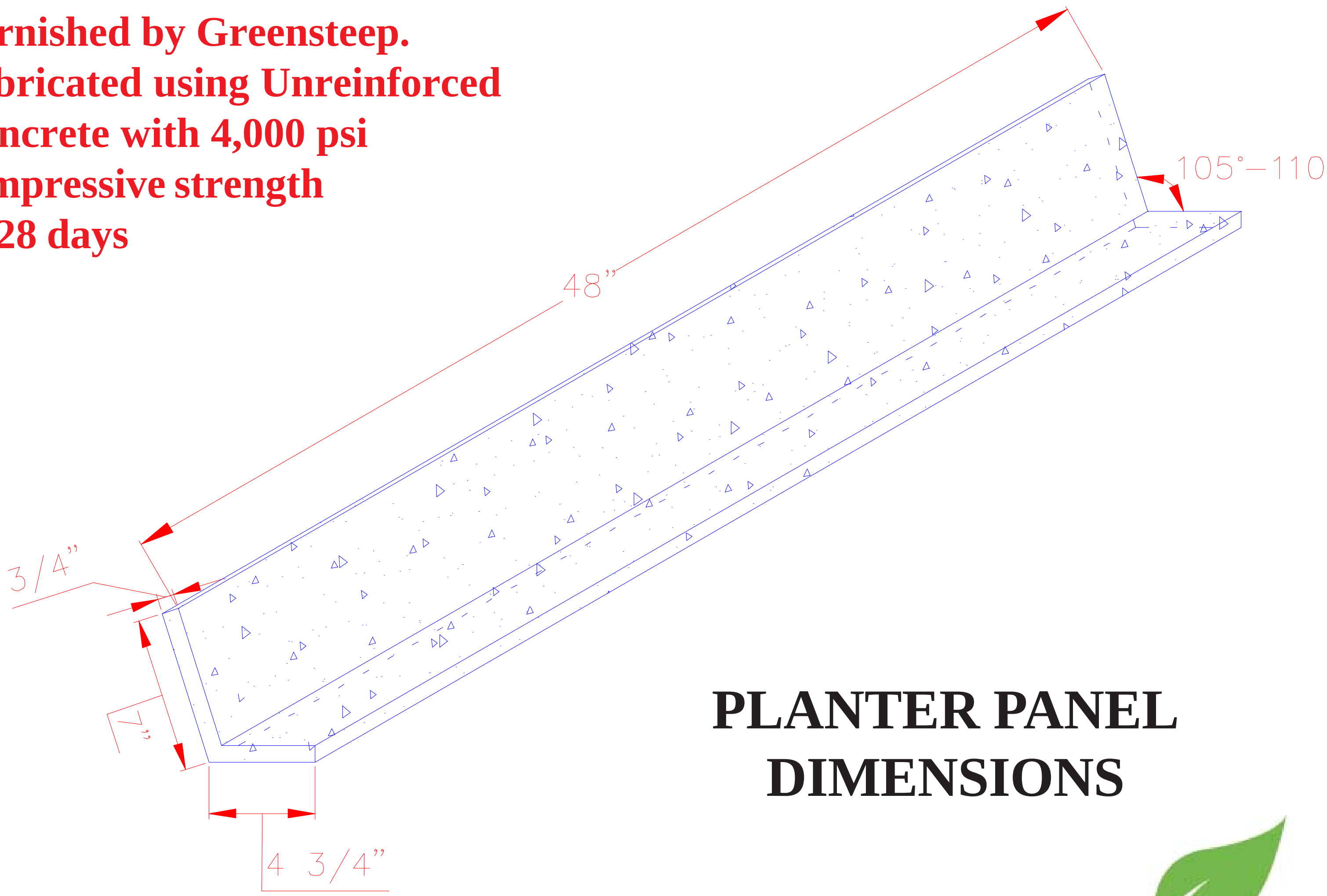
Figure 3.1.8

Note:
Furnished by Greensteep.
Fabricated using Unreinforced Concrete with 4,000 psi compressive strength @ 28 days



PLANTER PANEL DIMENSIONS

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Figure 4.1.2

APPENDIX 1.1.4

Block Unit Specifications

APPENDIX 1.1.4
Block Unit Fabrication Specifications

The structure's designer must identify, evaluate, and verify compliance with these specifications.

1. Block Fabrication Borrow Sources Identification

Most common soils are generally acceptable for block fabrication; however, the material must meet specifications that enhance pulverization for the mixing of the soil-cement and limits for maximum particle size for strength testing. Sufficient clay binder is required to promote block integrity during transport before the cement hydration process generates significant strength. Limit of organic content 1% maximum.

A. Gradation.

The proposed source(s) of soil designated for the fabrication of blocks must be tested to ensure compliance with the following graduation.

i. A screen on the mixer shall limit the maximum clod/fragment size to 1-1/2 inches.
ii. The remaining material shall have a minimum 85 percent passing 3/4-inch sieve and a percent passing No. 200 sieve must be between 30-50 percent.

B. Plasticity.

i. The proposed source(s) of material must be tested to ensure that the Plasticity Index is in the range of 13-25. A minimum cohesion is necessary to promote block integrity of freshly pressed blocks during transport, while excessive cohesion limits pulverization for mixing with cement.

C. Stockpile replenishment.

i. Prior to exhaustion of the approved soil stockpile, if it is determined that a new source of soil material will be required, a source approval process by the designer of record for the new source, shall be initiated to approve or disapprove the proposed new material source. The proposed new source shall be sampled and tested for conformance with gradation and plasticity specifications, then its optimum cement content will be determined.

2. Optimum Block Cement Content Determination

Strength tests must be conducted on the selected borrow soils, which are screened through a 1-1/2-inch mesh, to establish the optimum Portland Cement Type II/V by volume.

A. Gradation

i. Perform Sieve Analysis per ASTM D422 on collected bulk native soil samples (no added cement).

B. Laboratory Maximum Density and Optimum Moisture Determination on collected bulk native soil sample (no added cement).

i. Perform Modified Proctor ASTM D1557 to establish maximum density and optimum moisture content.

C. Laboratory Optimum Cement Content Determination

Remold at least three separate test specimens at 1 to 2 percent above the optimum moisture content established by the Modified Proctor test ASTM D1557, on soil with 6, 8, and 10 percent cement by volume content, to within 90-95 percent of the maximum density of the soil. Cure in a moist room and after 7 days perform unconfined compression tests in accordance with ASTM D2166 on the test specimens, to establish the optimum cement content. If test results are inconclusive, or if desired by the designer, remold additional test specimens at higher, intermediate, or lower cement contents and test the unconfined strengths at 7 days to obtain the optimum cement content for providing the maximum soil-cement strength.

3. Soil/Cement Mixing for Block Fabrication

A. The mixing process may only commence if the press's confining box is fitted with mesh inserts and bottom planks, in preparation to receive mix without delay.

B. Mixing shall be performed with a skid-steer that is fitted with a self-loading mixer attachment that has a capacity to mix a ½ yard batch, to produce one block per batch. The mixer shall have a 1-1/2-inch metal screen to prevent larger fragments from being included in the mix.

C. If the soil moisture content from the stockpile is such that no dust emission is observed prior to cement addition during preparation for the mixing process (above the optimum moisture content per ASTM D1557), the soil must be spread out to dry, (to below optimum moisture content), prior to usage.

D. Initially, soil from the stockpile with below the optimum moisture content per ASTM D1557, shall be mixed until clods are broken down and the soil reaches its maximum degree of pulverization, established visually.

E. Apply the established optimum volume of cement (by volume) and then mix in a dry state.

F. Gradually introduce water while mixing, until it is visually observed that there is no dust emitted during mixing, which is indicative that the optimum moisture content of the mixture has been slightly exceeded.

G. Following the final moisture adjustment and completion of the batch mixing process for the single unit, immediately place a portion of the mixture in the press's confining box, as described in Section 1.1.4.5.

4. Confining Box

1. Insert the two full length, formed/bent pieces of 19 gage galvanized 1/2-inch meshes pieces provided by Greensteep and conforming to ASTM A 1060 specifications, into the confining box.

2. Place the 48-inch long, 8-1/4 inch wide, 4-inch high, full length wood plank with the attached 3/4 inch x 4-3/4 inch x 48 inch long steel plate and a 3/4-inch by 3/4-inch square steel tubing on the opposite side, as shown on Figure 1.1.4.4.

5. Compaction

A. Place a maximum of 10-inches (loose depth) of the soil-cement mixture in the press's 48-inch by 18-inch confining box (no wetting or anti-adhesion agent needed). Bend the wire mesh's alternating segments at 45 degrees towards outer box's walls and complete pour of mixture, to achieve a total of 24-inches (loose depth) of the soil-cement mixture, in anticipation of its reduction in depth, to 8-12 inches (See Figure 1.1.4.5).

B. Apply load to the top of the confined soil-cement mixture surface with two 100 Ton Hydraulic Ram (70 Kip/SF)

C. Maintain the hydraulic pressure for a minimum of 1 minute once the needle of hydraulic pressure gauge becomes relatively stable.

D. Check to verify that the 8-inch minimum final thickness of the block is compliant. If not, the unit is rejected.

.

6. Evaluation of Field Block Soil/Cement Strength

The volume of soil required for block fabrication will generally be less than 10% of the total volume of soil that is required for the structure. The project will commence with excavations to establish the base of the structure and prepare for the ensuing foundation construction. It can be anticipated that the initial foundation construction phase will provide ample time to set up the press and fabricate blocks for compressive strength sampling and obtain strength testing results.

The designated block fabrication soil from the initial excavation, or the select imported soil material, should be stockpiled in the immediate vicinity of the press, in a designated block fabrication area. The transport of designated soil and its stockpiling must promote thorough mixing of the soil to achieve a uniform appearance.

Following the stockpiling of designated soil, the fabrication of sample blocks commences by a temporary placement of a ½-inch screen on the mixer (for testing of initial block strength only) for compliance with sample diameter that is six times larger than the largest particle size ASTM D2166. Then mixing soil-cement and pressing the mixture to produce test blocks for the collection of strength test specimens. The test specimen length must exceed 2.5 times the diameter after trimming and squaring the ends of the test specimen for laboratory strength testing.

While each block remains in the press's confining box, representative specimens from the freshly pressed blocks are collected by raising the press plate and placing on the exposed block's top surface, several vertically oriented, 3-inch diameter, minimum 8-inch long, brass, or stainless-steel sampler liner tubes that maintain a minimum 6-inch spacing from each other or block edges. The press plate is then carefully applied to the tops of the liners as it is used to push the liners to a full penetration into the block. This procedure is repeated on additional freshly pressed blocks, as necessary, to obtain a minimum of ten specimens.

The liners filled with specimens are then carefully removed from the sample block by breaking apart the block (block cutting tool may aide), then capping and sealing of the liners. The specimens are then placed in a manner that protects them from direct sunlight, near the base of the future structure. A minimum of 5 days after their collection, the specimens are transported and held in a humidified wet room, at the approved laboratory for trimming and ensuing strength testing.

A. Determine undrained shear strength of specimens.

   i. Remove sample from sampling tubes and perform Unconfined Compression tests in accordance with ASTM D2166 at 7 days.

   ii. Upon completion of each compression test, split the samples to determine compliance with the requirement that the maximum particle size cannot exceed 1/6 of the diameter or ½ inch. Discard samples that are non-compliant and perform additional tests until six compliant test results are produced.

7. Criteria for Acceptable Block Strength

Due to the potential for variations in soil characteristics and mixing efficiency, an effective LRFD (Load and Resistance Factor Design) is required. However, the calculated loads on the lower blocks are conservative because it is recommended that these loads be calculated by assuming the facing blocks are vertical, rather than offset and the acceptability of the block strength is governed by the 7-day strength, which can be expected to double or even triple in one years' time, because the compressive strength of the blocks will significantly increase as the soil cement continues to hydrate over time, thus a calculated Factor of Safety of 3.0 is more than adequate.

A. Determination of Maximum Normal Stress on the Blocks.

   Although the Greensteep facing blocks are offset at an angle of 24 degrees from vertical; a vertical configuration (conservative) is assumed to estimate the maximum possible vertical stress in the bottom block by simply multiplying the height of the wall, H, by the unit weight of the blocks, which can be taken as 130 pcf.

   Assuming a height of 30-feet and a block density of 130 pcf, the normal stress σv in the lowest block is:

$$\sigma v = 30 \times 130 = 3{,}900 \text{ psf } (0.187 \text{ MPa})$$

   For the case of structures exceeding 25-feet in height, the designer may follow the procedure provided in Figure 1.2.6.1, "Determination of hinge height for modular concrete block faced MSE walls," (NCMA, 1997), provided in Section 4, entitled "Design of MSE Walls" of FHWA NHI-10-024-Vol I.

B. Determination of Available Field Block Strength

   The Unconfined Compressive Strength (UCS) used to arrive at a LRFD, will be the average of the six, 7-day field sample results obtained per Section 1.1.6.A.ii of these Specifications (UCS ave).

C. Determination of the LRFD Against Crushing

   The LRFD is obtained by dividing by the available field strength (UCS ave) by vertical stress in the bottom block.

LFRD = **UCS** ave/ σv

If the LFRD, thus a calculated “Capacity to Demand Ratio” (CDR), (i.e., Factor of Safety) of 3 is exceeded, the design is acceptable and block fabrication for the project, may proceed.

Should the LFRD fail to reach 3, either the height of the wall should be reduced, or the stockpiled block fabrication soil rejected and replaced by a select imported soil.

APPENDIX 1.1.10

Anchor Screw Connector Specifications

SELF-DRILLING SCREWS

Self-drilling fasteners eliminate separate drilling and tapping operations for faster, more economical installations. Tanner Bolt & Nut Corp. offers the most complete selection of self-drilling fasteners made in the United States by Elco®. Self-drilling screws are designed to speed construction, improve building integrity and ensure performance.

- ***Starts Exactly Where It Is Placed*** – State of the art forging process technology and tooling produced to strict specifications provide a sharp, clean and consistent drill point.
- ***Broad Selection of Sizes and Applications*** – A variety of head styles and drive systems are available for specialized application and installations. Self-drilling screws are able to penetrate thin sheet metal through 1/2" thick steel.

Stalgard® Protective Coatings

Stalgard® high-performance protective coatings provide consistent, high corrosion resistance in construction applications. Stalgard® durable, multi-layer, corrosion-resistant coatings are engineered to provide optimal performance in demanding construction applications. These environmentally-friendly finishes are free of chromates and silicates and any process, like electroplating, that might induce hydrogen embrittlement, preventing structural failures.

Stalgard Coating for Induction Heat-Treated Fasteners

- Proven, outstanding corrosion resistance for most construction applications, including metal and wood
- Salt spray resistance: 1000 hours per ASTM B117
- Colors: silver, black, blue, white, yellow, red, gray & brown

Stalgard GB (Galvanic Barrier) Coating

- Standard on all Elco stainless steel fasteners
- Prevents a galvanic reaction between the stainless steel and dissimilar application materials, which could lead to fastener and/or joint failure
- Salt spray resistance: 1000 hours per ASTM B117
- Available color: Silver

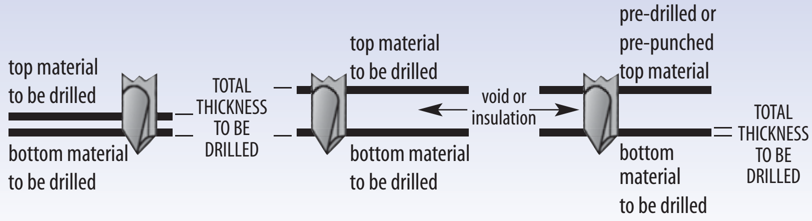
Stalgard SUB Ultimate Barrier Coating

- For more severely-corrosive environments
- Salt spray 2,000 hours per ASTM B117
- Available color: Silver

TECHNICAL INFORMATION

Point Size Selection

Maximum Combined Material Thickness By Point Type



Recommended Installation RPM

Diameter	RPM
#8	2500
#10	
#12	1800
1/4"	
5/16"	1200

Standard Sheet Metal Sizes

Gauge	Decimal
26	0.018
24	0.024
22	0.030
20	0.038
18	0.048
16	0.060
14	0.075
12	0.106

Nominal Screw Sizes

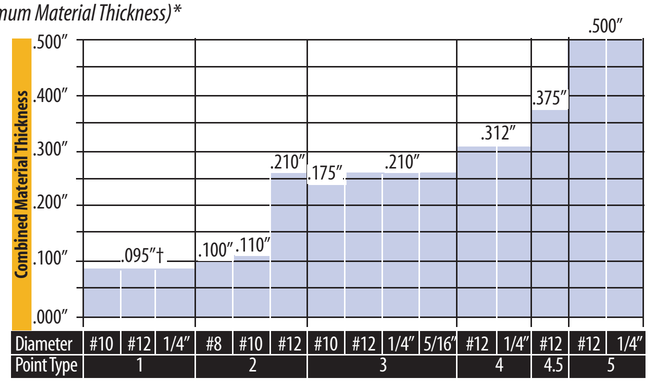
Thread Dia.	Decimal
#6	.140
#7	.150
#8	.160
#9	.180
#10	.190
#11	.200
#12	.210
1/4	.240
#14	.250

Threads Per Inch

Screw Diameter	TPI
#8	18
#10	16
#11	16
#12	14
#14	14
1/4"	20
5/16"	18

Drilling and Tapping Capacity

*(Maximum Material Thickness)**



† Lapped panels: 18 ga. to 18 ga.

** NOTE: Some drill and tap capacities may vary due to special features on some fasteners. Refer to product performance specifications for any individual fastener to confirm performance and capabilities. ICC Evaluation Report ESR-3294*

The information and data contained on this page is current as of publication date.

800 456-2658 email: sales@tannerbolt.com www.shoptanner.com
714 Montauk Ave., Brooklyn, NY 11208 718 434-4500 Fax: 718 434-3215
60-01 55th Drive, Maspeth, NY 11378 718 786-2050 Fax: 718 228-7297
800 3rd Ave., Brooklyn, NY 11232 929 337-1821

BI-METAL SELF-DRILLING SCREWS

Bi-Flex™ 300 Series Stainless Steel

Bi-metal technology provides outstanding corrosion resistance and long service life. Bi-Flex™ fasteners provide the corrosion resistance of 300 series stainless steel and the efficiency of drill screws.

Specifications:

- Diameters: #10 to 1/4"
- Lengths: 3/4" to 8"
- Drive Systems: Hex and phillips
- Material: Hardened steel tapping threads and point fused onto an 18-8 stainless steel shank and head
- Finish: Stalgard® GB (Galvanic Barrier) coating

Features & Benefits:

- High strength, ductility and reliability
- Virtually immune to delayed embrittlement failures
- Greater galvanic compatibility in dissimilar metal applications involving aluminum
- High in-place value over the life of application

PERFORMANCE DATA

BI-FLEX™ 300 Series Stainless Steel Self-Drilling Fasteners

Pull-Out Values (Lbs)†

T5 Screw		Drill Capacity	Pull-Out (Lbs.) Steel RB60-75 50-66KSI							Aluminum 6063- 22KSI	
8-18	#2	0.100	499	558	875	1425					
10-16	#2	0.110	595	633	943	1433	—	—	—	994	—
10-16	#3	0.187	—	616	684	1242	1605	1527	—	961	—
12-14	#2	0.110	528	750	892	1536	—	—	—	1132	—
12-14	#3	0.230	417	679	802	1371	2028	2499	—	974	—
12-24	#5	0.500	—	—	—	—	—	2110	2781	538	1995
1/4-14	#2	0.110	619	885	1082	1830	2943	—	—	1310	—
1/4-20	#3	0.230	—	680	780	1442	2623	3684	4069	1037	—
1/4-20	#5	0.500	—	—	—	—	—	—	2622	—	1724

Ultimate Strengths**

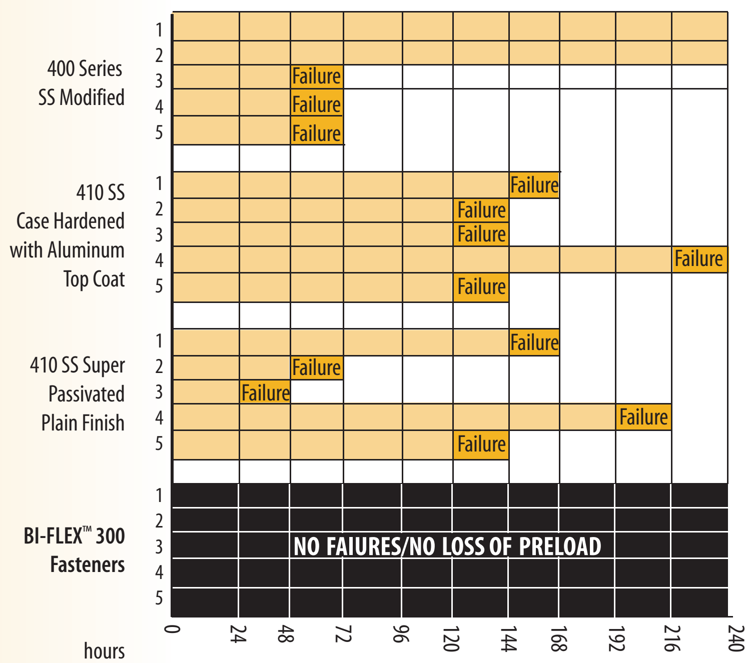
Size	Tensile (Lbs)	Shear Average Lbs Ultimate
10-16	1847	1282
12-14	2628	1950
12-24	2734	2284
1/4-14	3459	2676
1/4-20	4124	2860

*** Values are for 300 series stainless fastener threaded shank*

Susceptibility To Embrittlement Failures

In head to head testing, Bi-Flex™ 300 fasteners and three different types of 400 series martensitic stainless, self-drilling screws were installed in identical test coupons of unplated steel and aluminum. They were then subjected to a mildly corrosive environment of 5% neutral salt spray testing per ASTM B117. At the start of the test all samples were torqued (preloaded) to 75 in lbs. Every 24 hours the samples were inspected for torque value and retorqued to 75 in lbs. The parts were evaluated by scanning electron microscope (S.E.M.) to determine the type of fracture that had occurred. The three 400 series fasteners showed an intergranular type failure, indicative of fracturing that occurs from hydrogen assisted stress corrosion cracking. ***No failures or loss of preload***

All fasteners were placed through a clear hole in 6061 T6 aluminum with a thickness of 0.125" and drilled into an unplated steel strip measuring a thickness of 0.125". A strip of 0.060" aluminum was placed in between the 0.125" aluminum and steel strip on one side, to simulate a fastener placed under load.



Failure = Catastrophic Failure

The information and data contained on this page is current as of publication date.

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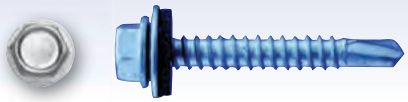
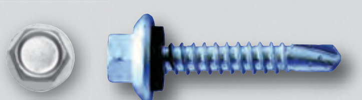
SELF-DRILLING SCREWS Globally Sourced

Corrosion Resistant Coating



Hex Washer Head Self-Drilling Screws w/Neoprene Bonded Washers Tanner-Guard Coating

ITEM CODE	SIZE	PT. SIZE	DRIVE SIZE	WASHER O.D.	CTN. QTY.
8N50UHWNBC/BULK	#8 x 1/2"	#2	1/4"	1/2"	5000
8N75UHWNBC/BULK	#8 x 3/4"	#2	1/4"	1/2"	3500
8N100UHWNBC/BULK	#8 x 1"	#2	1/4"	1/2"	3500
8N125UHWNBC/BULK	#8 x 1-1/4"	#2	1/4"	1/2"	3000
8N150UHWNBC/BULK	#8 x 1-1/2"	#2	1/4"	1/2"	2500
10N62UHWNBC/BULK	#10 x 5/8	#3	5/16"	1/2"	5000
10N75UHWNBC/BULK	#10 x 3/4"	#3	5/16"	1/2"	5000
10N100UHWNBC/BULK	#10 x 1"	#3	5/16"	1/2"	4000
10N125UHWNBC/BULK	#10 x 1-1/4"	#3	5/16"	1/2"	3500
10N150UHWNBC/BULK	#10 x 1-1/2"	#3	5/16"	1/2"	3000
10N200UHWNBC/BULK	#10 x 2"	#3	5/16"	1/2"	2000
10N300UHWNBC/BULK	#10 x 3"	#3	5/16"	1/2"	1000
12N75UHWNBC/BULK	#12 x 3/4"	#3	5/16"	9/16"	3000
12N100UHWNBC/BULK	#12 x 1"	#3	5/16"	9/16"	3000
12N125UHWNBC/BULK	#12 x 1-1/4"	#3	5/16"	9/16"	3000
12N150UHWNBC/BULK	#12 x 1-1/2"	#3	5/16"	9/16"	2500
12N200UHWNBC/BULK	#12 x 2"	#3	5/16"	9/16"	1500
12N250UHWNBC/BULK	#12 x 2-1/2"	#3	5/16"	9/16"	1000
12N300UHWNBC/BULK	#12 x 3"	#3	5/16"	9/16"	1000
12N400UHWNBC/BULK	#12 x 4"	#3	5/16"	9/16"	500
14N75UHWNBC/BULK	#14 x 3/4"	#3	3/8"	5/8"	3000
14N100UHWNBC/BULK	#14 x 1"	#3	3/8"	5/8"	2500
14N125UHWNBC/BULK	#14 x 1-1/4"	#3	3/8"	5/8"	2000
14N150UHWNBC/BULK	#14 x 1-1/2"	#3	3/8"	5/8"	1500
14N200UHWNBC/BULK	#14 x 2"	#3	3/8"	5/8"	1500
14N250UHWNBC/BULK	#14 x 2-1/2"	#3	3/8"	5/8"	1000
14N300UHWNBC/BULK	#14 x 3"	#3	3/8"	5/8"	1000
14N400UHWNBC/BULK	#14 x 4"	#3	3/8"	5/8"	500
14N500UHWNBC/BULK	#14 x 5"	#3	3/8"	5/8"	500
14N600UHWNBC/BULK	#14 x 6"	#3	3/8"	5/8"	500
14N700UHWNBC/BULK	#14 x 7"	#3	3/8"	5/8"	250
14N800UHWNBC/BULK	#14 x 8"	#3	3/8"	5/8"	250

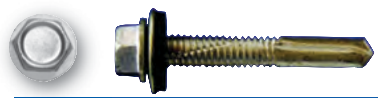


Hex Flange Head Self-Drilling Screws w/Rubber Washers Tanner-Guard Coating

ITEM CODE	SIZE	PT. SIZE	DRIVE SIZE	WASHER O.D.	CTN. QTY.
10N75UHFBC/BULK	#10 x 3/4"	#3	5/16"		4000
10N100UHFBC/BULK	#10 x 1"	#3	5/16"		3000
10N150UHFBC/BULK	#10 x 1-1/2"	#3	5/16"		3000
12N75UHFBC/BULK	#12 x 3/4"	#3	5/16"		3000
12N100UHFBC/BULK	#12 x 1"	#3	5/16"		3000
12N125UHFBC/BULK	#12 x 1-1/4"	#3	5/16"		2500
12N150UHFBC/BULK	#12 x 1-1/2"	#3	5/16"		2000
12N200UHFBC/BULK	#12 x 2"	#3	5/16"		1500
14N75UHFBC/BULK	#14 x 3/4"	#3	3/8"		2500
14N100UHFBC/BULK	#14 x 1"	#3	3/8"		2000
14N125UHFBC/BULK	#14 x 1-1/4"	#3	3/8"		1500
14N150UHFBC/BULK	#14 x 1-1/2"	#3	3/8"		1000
14N200UHFBC/BULK	#14 x 2"	#3	3/8"		1000

Hex Washer Head Self Drilling Screws-Extended Drilling Capacity Tanner-Guard Coating

ITEM CODE	SIZE	PT. SIZE	DRIVE SIZE	WASHER O.D.	CTN. QTY.
12C87UHW4C/BULK	12-24 x 7/8"	#4	5/16"		4000
12C125UHW5C/BULK	12-24 x 1-1/4"	#5	5/16"		4000
12C150UHW5C/BULK	12-24 x 1-1/2"	#5	5/16"		2000
12C200UHW5C/BULK	12-24 x 2"	#5	5/16"		2000
25C300UHW5C/BULK	1/4"-20 x 3"	#5	5/16"		1000
25C400UHW5C/BULK	1/4"-20 x 4"	#5	3/8"		500
25C500UHW5C/BULK	1/4"-20 x 5"	#5	3/8"		250
25C600UHW5C/BULK	1/4"-20 x 6"	#5	3/8"		250
25C700UHW5C/BULK	1/4"-20 x 7"	#5	3/8"		250
25C800UHW5C/BULK	1/4"-20 x 8"	#5	3/8"		250



Hex Washer Head Self Drilling Screws w/Neoprene Bonded Washers Extended Drilling Capacity-Tanner-Guard Coating

ITEM CODE	SIZE	PT. SIZE	DRIVE SIZE	WASHER O.D.	CTN. QTY.
12C87UHWB4C/BULK	12-24 x 7/8"	#4	5/16"		4000
12C125UHWB5C/BULK	12-24 x 1-1/4"	#5	5/16"		2000
12C150UHWB5C/BULK	12-24 x 1-1/2"	#5	5/16"		2000
12C200UHWB5C/BULK	12-24 x 2"	#5	5/16"		2000
25C300UHWB5C/BULK	1/4"-20 x 3"	#5	5/16"		1000
25C400UHWB5C/BULK	1/4"-20 x 4"	#5	3/8"		500
25C500UHWB5C/BULK	1/4"-20 x 5"	#5	3/8"		250
25C600UHWB5C/BULK	1/4"-20 x 6"	#5	3/8"		250
25C700UHWB5C/BULK	1/4"-20 x 7"	#5	3/8"		250
25C800UHWB5C/BULK	1/4"-20 x 8"	#5	3/8"		250

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APPENDIX 2.2.1

Foundation Design Example

For Level Toe

General Footing

DESCRIPTION: Greensteep footing example

Code References

Calculations per ACI 318-14, IBC 2018, CBC 2019, ASCE 7-16
Load Combinations Used : ASCE 7-16

General Information

Material Properties

f'c : Concrete 28 day strength	=	2.50 ksi
fy : Rebar Yield	=	60.0 ksi
Ec : Concrete Elastic Modulus	=	3,122.0 ksi
Concrete Density	=	145.0 pcf
φ Values Flexure	=	0.90
Shear	=	0.850

Analysis Settings

Min Steel % Bending Reinf.	=	
Min Allow % Temp Reinf.	=	0.00180
Min. Overturning Safety Factor	=	1.50 : 1
Min. Sliding Safety Factor	=	1.50 : 1
Add Ftg Wt for Soil Pressure	:	No
Use ftg wt for stability, moments & shears	:	No
Add Pedestal Wt for Soil Pressure	:	No
Use Pedestal wt for stability, mom & shear	:	No

Soil Design Values

Allowable Soil Bearing	=	1.0 ksf
Increase Bearing By Footing Weight	=	No
Soil Passive Resistance (for Sliding)	=	250.0 pcf
Soil/Concrete Friction Coeff.	=	0.30

Increases based on footing Depth

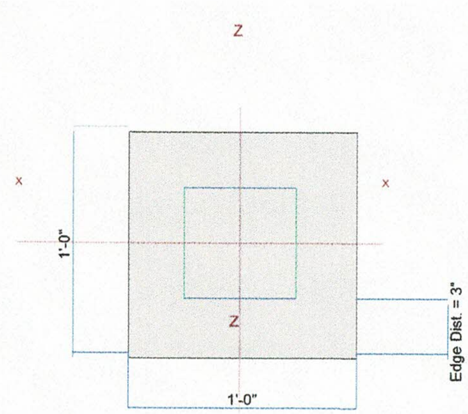
Footing base depth below soil surface	=	1.0 ft
Allow press. increase per foot of depth	=	1.50 ksf
when footing base is below	=	ft

Increases based on footing plan dimension

Allowable pressure increase per foot of depth	=	ksf
when max. length or width is greater than	=	ft

Dimensions

Width parallel to X-X Axis	=	1.0 ft
Length parallel to Z-Z Axis	=	1.0 ft
Footing Thickness	=	12.0 in



Pedestal dimensions...

px : parallel to X-X Axis	=	in
pz : parallel to Z-Z Axis	=	in
Height	=	in

Rebar Centerline to Edge of Concrete...

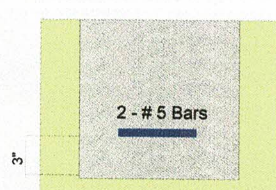
at Bottom of footing	=	3.0 in

Reinforcing

Bars parallel to X-X Axis		
Number of Bars	=	2.0
Reinforcing Bar Size	=	# 5
Bars parallel to Z-Z Axis		
Number of Bars	=	2.0
Reinforcing Bar Size	=	# 5

Bandwidth Distribution Check (ACI 15.4.4.2)

Direction Requiring Closer Separation	n/a
# Bars required within zone	n/a
# Bars required on each side of zone	n/a



X-X Section Looking to +Z

Z-Z Section Looking to +X

Applied Loads

		D	Lr	L	S	W	E	H	
P : Column Load	=	0.9750							k
OB : Overburden	=								ksf
M-xx	=								k-ft
M-zz	=								k-ft
V-x	=								k
V-z	=								k

General Footing

DESCRIPTION: Greensteep footing example

DESIGN SUMMARY

Design OK

	Min. Ratio	Item	Applied	Capacity	Governing Load Combination
PASS	0.390	Soil Bearing	0.9750 ksf	2.50 ksf	D Only about Z-Z axis
PASS	n/a	Overturning - X-X	0.0 k-ft	0.0 k-ft	No Overturning
PASS	n/a	Overturning - Z-Z	0.0 k-ft	0.0 k-ft	No Overturning
PASS	n/a	Sliding - X-X	0.0 k	0.0 k	No Sliding
PASS	n/a	Sliding - Z-Z	0.0 k	0.0 k	No Sliding
PASS	n/a	Uplift	0.0 k	0.0 k	No Uplift
PASS	0.007394	Z Flexure (+X)	0.1706 k-ft/ft	23.075 k-ft/ft	+1.40D
PASS	0.007394	Z Flexure (-X)	0.1706 k-ft/ft	23.075 k-ft/ft	+1.40D
PASS	0.007394	X Flexure (+Z)	0.1706 k-ft/ft	23.075 k-ft/ft	+1.40D
PASS	0.007394	X Flexure (-Z)	0.1706 k-ft/ft	23.075 k-ft/ft	+1.40D
PASS	n/a	1-way Shear (+X)	0.0 psi	85.0 psi	n/a
PASS	0.0	1-way Shear (-X)	0.0 psi	0.0 psi	n/a
PASS	n/a	1-way Shear (+Z)	0.0 psi	85.0 psi	n/a
PASS	n/a	1-way Shear (-Z)	0.0 psi	85.0 psi	n/a
PASS	n/a	2-way Punching	1.780 psi	85.0 psi	+1.40D

Detailed Results

Soil Bearing

Rotation Axis & Load Combination...	Gross Allowable	Xecc (in)	Zecc (in)	Actual Soil Bearing Stress @ Location: Bottom, -Z	Top, +Z	Left, -X	Right, +X	Actual / Allow Ratio
X-X, D Only	2.50	n/a	0.0	0.9750	0.9750	n/a	n/a	0.390
X-X, +0.60D	2.50	n/a	0.0	0.5850	0.5850	n/a	n/a	0.234
Z-Z, D Only	2.50	0.0	n/a	n/a	n/a	0.9750	0.9750	0.390
Z-Z, +0.60D	2.50	0.0	n/a	n/a	n/a	0.5850	0.5850	0.234

Overturning Stability

Rotation Axis & Load Combination...	Overturning Moment	Resisting Moment	Stability Ratio	Status

Footing Has NO Overturning

One Way Shear

Load Combination...	Vu @ -X	Vu @ +X	Vu @ -Z	Vu @ +Z	Vu:Max	Phi Vn	Vu / Phi*Vn	Status
+1.40D	0.00 psi	0.00 psi	0.00 psi	0.00 psi	0.00 psi	85.00 psi	0.00	OK
+1.20D	0.00 psi	0.00 psi	0.00 psi	0.00 psi	0.00 psi	85.00 psi	0.00	OK
+0.90D	0.00 psi	0.00 psi	0.00 psi	0.00 psi	0.00 psi	85.00 psi	0.00	OK

All units k

Two-Way "Punching" Shear

Load Combination...	Vu	Phi*Vn	Vu / Phi*Vn	Status
+1.40D	1.78 psi	170.00psi	0.01047	OK
+1.20D	1.53 psi	170.00psi	0.008973	OK
+0.90D	1.14 psi	170.00psi	0.006729	OK

APPENDIX 2.2.2

Foundation Design Example

For Steep Slope

Project Title: Greensteep example calc
Engineer:
Project ID:
Project Descr:

Printed: 6 DEC 2021, 11:47AM

Multiple Simple Beam

File: green steep.ec6

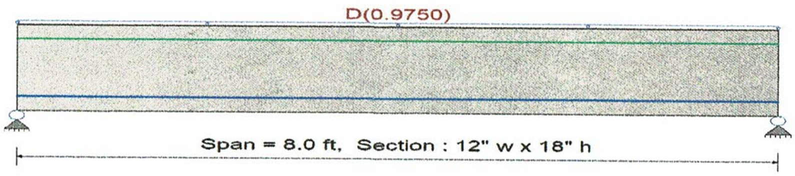
Description :

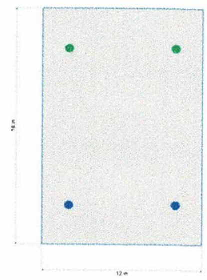
Concrete Beam Design : grade beam

Calculations per ACI 318-14, IBC 2018, CBC 2019, ASCE 7-16

Rectangular Beam : 12.0 in wide x 18 in high
Using Ultimate Strength Design with ASCE 7-16 Load Combinations, Major Axis Bending

f'c =	2.50 ksi	fy Main Stl =	60.0 ksi	E Main Stl =	29,000.0 ksi	Density	145.0 pcf
E Conc =	3,122.0 ksi	fy Stirrups =	40.0 ksi	E Stirrups =	29,000.0 ksi	ϕ Values Bending	0.90
fr =	375.0 ksi	β =	0.850			Shear	0.750





Cross Section & Reinforcing Details
2-#5 at 3.0 in from Bottom, from 0.0 to 8.0 ft in this span
2-#5 at 3.0 in from Top, from 0.0 to 8.0 ft in this span

Shear Stirrup Requirements
Stirrup Bar Size = # 3
Number of Resisting Legs Per Stirrup = 2
No Stirrups Required from 0.00 to 8.00 ft along span, Condition : Vu < PhiVc/2

Applied Loads
Beam self weight calculated and added to loads
Unif Load: D = 0.9750 k/ft, Trib= 1.0 ft

Design Summary

Max fb/Fb Ratio =	**0.324** : 1		
Mu : Applied	13.356 k-ft	at	4.000 ft in Span # 1
Mn * Phi : Allowable	41.163 k-ft		
Load Comb :	+1.40D+1.60H		

Reactions (k)	D	Lr	L	S	W	E	H
Left Support	4.77						
Right Support	4.77						

Max Deflections

Transient Downward	0.000 in	Total Downward	0.006 in
Ratio	9999	Ratio	9999
	LC:		LC: +D+H
Transient Upward	0.000 in	Total Upward	0.000 in
Ratio	9999	Ratio	9999
	LC:		LC:

PIER CALC:

P = 4770 lbs

$$L = \frac{4770 \text{ lbs} \times 4.57\,(8')}{2\pi\,(0.67')\,500 \text{ psf}} + 3.5 = 6.36 \text{ ft} < 8'$$

Per LATERAL DESIGN

Project Title: Greensteep example calc
Engineer:
Project ID:
Project Descr:

Printed: 6 DEC 2021, 11:48AM

Pole Footing Embedded in Soil

File: green steep.ec6
Software copyright ENERCALC, INC. 1983-2020, Build:12.20.8.24

DESCRIPTION: Greensteep example

Code References

Calculations per IBC 2018 1807.3, CBC 2019, ASCE 7-16
Load Combinations Used : ASCE 7-16

General Information

Pole Footing Shape	Circular
Pole Footing Diameter	16.0 in
Calculate Min. Depth for Allowable Pressures	
No Lateral Restraint at Ground Surface	
Allow Passive	350.0 pcf
Max Passive	350.0 psf

Controlling Values

Governing Load Combination : D Only

Lateral Load	0.4770 k
Moment	1.670 k-ft

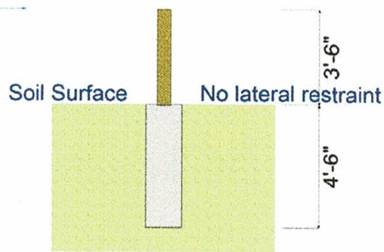
NO Ground Surface Restraint

Pressures at 1/3 Depth

Actual	**350.0** psf
Allowable	**350.0** psf

Minimum Required Depth **4.50 ft**

Footing Base Area	1.396 ft^2
Maximum Soil Pressure	0.0 ksf



Applied Loads

Lateral Concentrated Load (k)		Lateral Distributed Loads (klf)	Vertical Load (k)
D : Dead Load	0.4770 k	k/ft	k
Lr : Roof Live	k	k/ft	k
L : Live	k	k/ft	k
S : Snow	k	k/ft	k
W : Wind	k	k/ft	k
E : Earthquake	k	k/ft	k
H : Lateral Earth	k	k/ft	k
Load distance above ground surface	3.50 ft		

TOP of Load above ground surface ft

BOTTOM of Load above ground surface ft

Load Combination Results

Load Combination	Forces @ Ground Surface Loads - (k)	Forces @ Ground Surface Moments - (ft-k)	Required Depth - (ft)	Pressure at 1/3 Depth Actual - (psf)	Pressure at 1/3 Depth Allow - (psf)	Soil Increase Factor
D Only	0.477	1.670	4.50	350.0	350.0	1.000
+0.60D	0.286	1.002	3.25	348.3	350.0	1.000

APPLIED LOADS

M (DL)	=	**0.0**	**KIP-FT.**
M (LL)	=	**2.5**	**KIP-FT.**
M(E)	=	**0.0**	**KIP-FT.**
Mu	=	**4.0**	**KIP-FT.**
V (DL)	=	**0.0**	**KIPS**
V (LL)	=	**0.5**	**KIPS**
V (E)	=	**0.0**	**KIPS**
Vu	=	**0.8**	**KIPS**

BENDING ANALYSIS

Concrete Shear Strength ϕV_c = 10.62 Kips > Vu OK

b = 11.312 in.
d = 11.05 in.
f_y = 60,000 psi
f'_c = 2,500 psi
M_u = 3.96 ft-kips
A_s = 0.08 sq. in.

p_{max} = 0.0302
p_{min} = 0.0033
p = As/bd 0.0006
a = As*fy/(.85*f'c*b) = 0.20
phi = 0.90
c = a/B_1 = 0.24
B_1 = 0.85

==> **USE :** 2- # 4 Each Face

A_s Supplied	0.40 sq. in.

check phi
Et = .003*(d-c)/c = 0.1376
phi = 0.483+(83.3*Et) = 0.90

ΦM_n =phi*As*fy(d-a/2)/12= **19.71 K-ft**

SHEAR REINFORCEMENT

1/2f'c = 4687 lbs. > Vu, NO SHEAR REINFORCEMENT REQUIRED
IF SHEAR REINF. IS REQ'D. USE: * 3 TIES @ 7.50 IN OC
(Vc + Vs) = 27214 lbs. > Vu, O.K.

APPENDIX 3.1.2

Construction Manual

APPENDIX 3.1.2
CONSTRUCTION MANUAL

The QC procedures that are applicable to the structure's foundation, main fill placement, geogrid reinforcement placement, must be provided by the design Engineer. The following Construction Manual procedures pertain to the block unit fabrication and their installation. These are as follows:

1. Checklist Summary

    1. Are the base keyway excavation and foundation approved by the project engineer?
    2. Has the density of the fill surface been approved by compaction testing, prior to block placement?
    3. Is the geogrid reinforcement type in conformance with project specifications?
    4. Is the geogrid reinforcement properly extended and secured with anchor screws on the block's exterior face and at the rear, by stakes?
    5. Is the integrity of the blocks maintained after transportation to the slope edge?
    6. Is the block placement procedure producing proper alignment and levelness?
    7. Is the minimum block length being observed when approaching inward corners?
    8. Is the filter fabric being provided at the interior of the block-to-block abutments?
    9. Is there sufficient drain rock being provided behind the newly placed block?
    10. During placement of chimney drain material, are the transport cavities being hand filled with drain material?
    11. Is the outer 2-feet wide zone of the structural fill that abuts to the chimney drain being compacted with light, hand operated compaction equipment?
    12. Are the planters being properly aligned and secured?
    13. Are the planter joints being provided with filter fabric prior to receiving topsoil filling?
    14. Are topsoil filled planters being watered soon after filling?

2. Block Fabrication

    1. Upon completion of strength testing and approval of the stockpile of designated block fabrication soil, the fabrication of blocks may commence.

a. The press's confining box must be fitted with wire mesh and bottom plank inserts, in preparation to receive mix without delay.

b. Verify the block placement crew is ready to receive blocks for a new layer.

2. Soil/Cement Mixing for Single Block Unit Fabrication

a. Load mixer with appropriately ½ cu yard of dry soil (batch for single unit) and mix until clods are broken down and the soil reaches its maximum degree of pulverization, established visually.

b. Apply the established design volume of cement and then mix in a dry state.

c. Gradually introduce water while mixing, until dust emanation is visually observed to cease during the mixing, and it is visually estimated that the optimum moisture content of the mixture has been slightly exceeded. Minor excess moisture can be expected to be extruded during the pressing of the block, which should be minimized. Ideally, the personnel adding the water is maintained consistent, to allow for development of a sense of the appropriate moisture content.

d. Following the final moisture adjustment and completion of the mixing process, immediately place a portion of the mixture in the press's confining box to reach a maximum of 10-inches (loose depth). Bend the wire mesh's alternating segments at 45 degrees towards outer box's walls and complete pour of mixture, to achieve a total of 24-inches (loose depth). Discard excess.

3. Filling Press Confining Box

a. Place a sufficient mixture to roughly reach a maximum of 10-inches (loose depth) in the deeper side and 6-inches (loose depth) on the shallow side of the confining box to produce a relatively level surface.

b. Straighten the upward projecting central wire mesh and fold the cut mesh segments in alternate direction at 45 degrees to project outward, towards the box's long side walls.

c. Complete pour of the mixture into the confining box as required to achieve a total filling of the press's confining box (24-inches, loose depth). Place (2) 4" x 4" x

18” wood planks at the box’s surface corners, over the deeper side of the filled box. Discard all excess mixture material.

d. Slide confining box into press’s pressing position. Precisely locate with the press’s removable guides.

4. Pressing Block

a. Lower pressing chamber apparatus over the confining box.

b. Apply load to the top of the confined soil-cement mixture surface with Hydraulic Rams

c. Maintain the hydraulic pressure for 1 minute once the needle of hydraulic pressure gauge becomes relatively stable.

d. Raise the chamber apparatus and slide confining box out of press.

5. Block Preparations for Transport to Structure

a. Dismantle confining box and check to verify that the block’s 8-inch minimum final width, is complainant.

b. Rotate to accurately drill the two corresponding block placement alignment template holes on the block’s top surface and to cut block when required. When block is cut, drill the hole closest to the cut end, with a 6-inch setback from the cut end and 3-inch setback from the block’s exterior edge. Use of a diamond tip masonry bit is recommended.

c. Attach the Greensteep provided transportation attachment with straps for block transport to face of structure.

6. Block Placement

a. Adjust levelness of chimney drain material surface manually in preparation for geogrid and block placement.

b. Check front to back and adjust block levelness. Adjust as necessary by lifting/rotating block forward and adding or removing chimney drain material to the rear block base, until levelness is accomplished.

c. Place the 7-feet long piece of geogrid over the top surface of lower block and fold it down on the upper exterior block face, to accomplish a minimum of 5-inch down position of the geogrid's transverse bar. Adjust the position of the geogrid as necessary, by moving it slightly to minimize its interference with the two guide holes on the ends of the top surface of lower block that serve to host the template pegs. Check to confirm avoidance of interference of geogrid on the two peg guide holes, by placement of block alignment template over the geogrid and confirming unimpeded peg access into the two holes. Secure the folded portion of the geogrid with screw anchors and washers every 7^{th} rib space (approx. 6.5-inches) and on 3^{rd} rib space (approx.. 2.75-inches) from the block ends, touching the geogrid's transverse bar's upper side. Subsequently, stretch the geogrid into the structure's surface and pin into position with stakes.

d. With the Greensteep provided block alignment template still in place over the geogrid and inserted pegs in their corresponding holes on the of lower block's top surface, lower the block from transportation equipment, in close proximity to destination. Where applicable, slide the sliding peg to align with the shortened/cut and/or mitered block,

e. Lift block with Greensteep's provided, custom lifting apparatus and precisely locate block in its final position touching the block alignment template and force toward the adjacent block to accomplish minimal gap width.

f. Remove the template.

7. Backfill Placement Behind Block

a. Check block abutment gap against adjacent block to determine whether gap exceeds 1/8-inch. If the minimum gap is exceeded, an attempt to move the block closer to adjacent block can be performed. If gap excess remains, provide 12 x 18-inch piece of filter fabric centered over gap. Provide filter fabric piece over all cut and/or mitered blocks.

b. Place approximately 6 to7-inches of chimney drain material against lower block's interior vertical surface, with care to maintain the 4-inch minimum chimney drain width. Subsequently, hand push drain material into transport pickup cavity at the block's lower interior sides.

c. Check block's top surface levelness and adjust by tilting block outward and removing or adding drain material to the interior block's base.

d. Place a minimum 2-feet wide strip layer of structural fill material over the geogrid, with a maximum thickness of 8-inches paralleling the chimney drain and compact both material surfaces with hand operated, light compactor (jumping jack).

e. Place an additional 6 to 7-inches (vertically) of chimney drain material against the back of block, while maintaining the 4-inch minimum width of drain material, in preparation for placement of additional 8-inch layer of 2-feet wide fill strip.

f. Continue alternate chimney drain material and compacted fill strip placement until the top of block level is achieved. Mass grading structural fill placement may proceed concurrently, with the chimney drain material and 2-feet wide strip layer placement.

g. Prior to structural fill placement, ensure that a minimum of 6-inches of geogrid is folded down on the upper exterior face of blocks and secured by screw anchors, prior to being stretched into fill, by manually stretching to ensure absence of wrinkles and by commencing with placement structural fill along outer fill edge (abutting 2-feet wide strip layer of structural fill adjacent to chimney drain material) and progressing inward.

8. Planter Panel Placement

a. Fill the pre-drilled holes on the top of the lower block with Type "N" concrete mortar mix. Mark the location of the mortar filled holes, by scratching a small line aligned with the hole, on the adjacent block's vertical face.

b. When dealing with shortened/cut and/or mitered blocks, cut the planter panel to conform to the block's cut surface.

c. Remove loose debris from the benches and lower block groove. Immediately place the panel insuring full penetration into the groove (tap with rubber mallet).

d. Immediately drill corrosion resistant concrete screw anchors through the panel at 12-inches on center, starting at 6-inches from the uncut end, while maintaining a 1-inch setback from the block's vertical face. When dealing with a cut block, drill at the pre-marked longitudinal location, maintaining a 1-inch setback from the block's vertical face and so as to coincide with the previously placed wet mortar mix filled holes (screw anchors extending thru mortar and penetrating into block). On shorter cut blocks, where the length between filled end holes is less than 24-inches, place the third screw at the middle of the space between the end screws

e. Proceed with placement of planter panel on the middle bench and provide two screws anchors through the panel base extending/penetrating into block with a 6-in setback from the panel ends and two at 12-inches on center in between, while maintaining a 1-inch setback from the block's vertical face.

9. Filling Planters

a. After a 3-day curing period of the mortar filled holes, provide 12 x 12-inch pieces of filter fabric, centered over all planter panel joint and exterior block-to-block abutment.

b. sprinkle the designated topsoil by means of a small skid steer or similar equipment into the planters until they overflow onto the lower planters.

c. Provide water to the filled planter and those below, to promote consolidation of the topsoil in the planters.

d. As the structure's construction progresses continue to fill and water planters, until the top elevation planters are filled and consolidated.

e. Upon completion, remove excess spillover topsoil at the base of the structure and lightly compact and rake remainder of surface to produce a smooth transition from the hillside below to the lowermost planter.

APPENDIX 5.1.1

Development and Usage History Photos

Pleasanton California
Constructed 2007
Current Condition

greensteep
Sustainable Fill Support Structures

Figure 5.1.1

Pleasanton, California
Constructed 2007
Current Condition

greensteep
Sustainable Fill Support Structures

Figure 5.1.2

Pleasanton, California
Constructed 2007
Current Condition

greensteep™
Sustainable Fill Support Structures

Figure 5.1.3

Danville, California
Constructed 2014
Dismantled

greensteep™
Sustainable Fill Support Structures

Figure 5.1.4

Danville, California
Constructed 2014
Dismantled

Figure 5.1.5

Danville, California
Constructed 2014
Dismantled

greensteep™ Sustainable Fill Support Structures

Figure 5.1.6

Sunol, California
Constructed 2015

greensteep™
Sustainable Fill Support Structures

Figure 5.1.7

Sunol, California
Constructed 2015

greensteep™
Sustainable Fill Support Structures

Figure 5.1.8

Sunol, California
Constructed 2015

greensteep™
Sustainable Fill Support Structures

Figure 5.1.9

Sunol, California
Constructed 2015
Current Condition

greensteep™
Sustainable Fill Support Structures

Figure 5.1.10

Sunol, California
Constructed 2015
Current Condition

greensteep™
Sustainable Fill Support Structures

Figure 5.1.11

APPENDIX

System Sample Plans

GREENSTEEP

SUSTAINABLE FILL SUPPORT STRUCTURES

PROJECT DIR.

SOIL ENGINEER OF RECORD

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INDEX TO DRAWINGS

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BLOCK FABRICATION SPECIFICATIONS

CONSTRUCTION PROCEDURES SHALL CONFORM TO ALL APPLICABLE FHWA, AASHTO AND ASTM STANDARDS, AS DOCUMENTED IN THE EDITION OF THE STANDARDS IN FORCE AT THE START OF THE CONSTRUCTION, OR BY THE SPECIFIC STANDARDS QUOTED IN THESE SPECIFICATIONS.

1. BLOCK FABRICATION BORROW SOURCES IDENTIFICATION

THE MATERIAL MUST MEET GRADATION SPECIFICATIONS THAT ENHANCE PULVERIZATION FOR THE MIXING OF THE SOIL-CEMENT AND LIMITS MAXIMUM PARTICLE SIZE FOR STRENGTH TESTING. SUFFICIENT CLAY BINDER IS REQUIRED TO PROMOTE BLOCK INTEGRITY DURING TRANSPORT BEFORE THE CEMENT HYDRATION PROCESS GENERATES FULL STRENGTH.

A. GRADATION.

THE PROPOSED SOURCE(S) OF SOIL DESIGNATED FOR THE FABRICATION OF BLOCKS, MUST BE TESTED TO ENSURE COMPLIANCE WITH THE FOLLOWING GRADATION.

i. A SCREEN ON THE MIXER SHALL LIMIT THE MAXIMUM CLOD/FRAGMENT SIZE TO 1-1/2 INCHES.
ii. MINIMUM 85 PERCENT PASSING 3/4-INCH SIEVE.
iii. PERCENT PASSING NO. 200 SIEVE MUST BE BETWEEN 30-50 PERCENT.

B. PLASTICITY.

i. THE PROPOSED SOURCE(S) OF MATERIAL MUST BE TESTED TO ENSURE THAT THE PLASTICITY INDEX IS IN THE RANGE OF 13-25.

C. STOCKPILE REPLENISHMENT.

i. PRIOR TO EXHAUSTION OF THE APPROVED SOIL STOCKPILE IN USE, IF IT IS DETERMINED THAT A NEW SOURCE OF SOIL MATERIAL WILL BE REQUIRED, A SOURCE APPROVAL PROCESS FOR THE NEW SOURCE SHALL BE INITIATED. THE PROPOSED NEW SOURCE SHALL BE SAMPLED AND TESTED FOR CONFORMANCE WITH GRADATION AND PLASTICITY SPECIFICATIONS, THEN ITS OPTIMUM CEMENT CONTENT DETERMINED.

2. OPTIMUM BLOCK CEMENT CONTENT DETERMINATION

STRENGTH TESTS MUST BE CONDUCTED ON THE SELECTED BORROW SOILS, TO ESTABLISH THE OPTIMUM PORTLAND CEMENT TYPE II/V BY VOLUME.

A. GRADATION

i. PERFORM SIEVE ANALYSIS PER ASTM D422 ON COLLECTED BULK NATIVE SOIL SAMPLES.

B. LABORATORY MAXIMUM DENSITY AND OPTIMUM MOISTURE DETERMINATION

i. IF GRADATION RESULTS SHOW < 5% PASSING ¾" SIEVE AND < 25% PASSING 3/8" SIEVE, RUN MODIFIED PROCTOR ASTM D1557 METHOD B.
ii. IF GRADATION RESULTS SHOW > 5% PASSING ¾" SIEVE AND > 25% PASSING 3/8" SIEVE, RUN MODIFIED PROCTOR ASTM D1557 METHOD C.

C. LABORATORY OPTIMUM CEMENT DETERMINATION

REMOLD THREE SEPARATE TEST SPECIMENS AT THE OPTIMUM MOISTURE CONTENT WITH 6, 8, AND 10 PERCENT CEMENT CONTENT, TO WITHIN 95-100 PERCENT OF THE MAXIMUM DENSITY. CURE IN A MOIST ROOM AND AFTER 7 DAYS PERFORM UNCONFINED COMPRESSION TESTS IN ACCORDANCE WITH ASTM D2166 ON THE TEST SPECIMENS. AS NECESSARY, REMOLD ADDITIONAL TEST SPECIMENS AT INTERMEDIATE MOISTURE CONTENTS AND TEST THE UNCONFINED STRENGTHS AT 7 DAYS TO OBTAIN THE OPTIMUM CEMENT CONTENT FOR PROVIDING THE MAXIMUM SOIL-CEMENT STRENGTH.

3. SOIL/CEMENT MIXING FOR BLOCK FABRICATION

A. THE MIXING PROCESS MAY ONLY COMMENCE IF THE PRESS'S CONFINING BOX IS FITTED WITH BOTTOM PLANK AND MESH INSERTS, IN PREPARATION TO RECEIVE MIX WITHOUT DELAY.

B. MIXING SHALL BE PERFORMED WITH A SKID-STEER THAT IS FITTED WITH A SELF-LOADING MIXER ATTACHMENT THAT HAS A CAPACITY TO MIX A ½ YARD BATCH. THE MIXER SHALL HAVE A 1-1/2-INCH METAL SCREEN TO PREVENT LARGER FRAGMENTS BEING INCLUDED IN THE MIX.

C. INITIALLY, DRY SOIL ALONE SHALL BE MIXED UNTIL CLODS ARE BROKEN DOWN AND THE SOIL REACHES ITS MAXIMUM DEGREE OF PULVERIZATION, ESTABLISHED VISUALLY.

D. APPLY THE ESTABLISHED OPTIMUM VOLUME OF CEMENT AND THEN MIX IN A DRY STATE.

E. GRADUALLY INTRODUCE WATER WHILE MIXING, UNTIL IT IS VISUALLY DETERMINED THAT THE OPTIMUM MOISTURE CONTENT OF THE MIXTURE HAS BEEN SLIGHTLY EXCEEDED.

F. FOLLOWING THE FINAL MOISTURE ADJUSTMENT AND COMPLETION OF THE MIXING PROCESS, IMMEDIATELY PLACE THE MIXTURE IN THE PRESS'S CONFINING BOX.

4. COMPACTION

A. PLACE A MINIMUM OF 24-INCHES (DEPTH) OF THE SOIL-CEMENT MIXTURE IN THE PRESS'S 48-INCH BY 18-INCH CONFINING BOX, IN ANTICIPATION OF ITS REDUCTION IN DEPTH, TO 8-12 INCHES.

B. APPLY LOAD TO THE TOP OF THE CONFINED SOIL-CEMENT MIXTURE SURFACE WITH 200 TON HYDRAULIC RAM (70 KIP/SF)

C. MAINTAIN LOAD FOR 1 MINUTE THE HYDRAULIC PRESSURE FOR 1 MINUTE ONCE THE NEEDLE OF HYDRAULIC PRESSURE GAUGE BECOMES RELATIVELY STABLE.

D. CHECK TO VERIFY THAT THE 8-INCH MINIMUM FINAL THICKNESS OF THE BLOCK HAS BEEN ACHIEVED.

5. EVALUATION OF FIELD BLOCK SOIL CEMENT STRENGTH

THE VOLUME OF SOIL REQUIRED FOR BLOCK FABRICATION WILL GENERALLY BE LESS THAN 10% OF THE TOTAL VOLUME OF SOIL THAT IS REQUIRED FOR THE STRUCTURE. THE PROJECT WILL COMMENCE WITH EXCAVATIONS TO ESTABLISH THE BASE OF THE STRUCTURE AND ENSUING FOUNDATION CONSTRUCTION. IT CAN BE ANTICIPATED THAT THE INITIAL FOUNDATION CONSTRUCTION PHASE, WILL PROVIDE AMPLE TIME TO SETUP THE PRESS AND FABRICATE BLOCKS FOR COMPRESSIVE STRENGTH SAMPLING AND OBTAIN STRENGTH TESTING RESULTS.
THE DESIGNATED BLOCK FABRICATION SOIL FROM THE INITIAL EXCAVATION, OR THE SELECT IMPORTED SOIL MATERIAL, SHOULD BE STOCKPILED IN THE IMMEDIATE VICINITY OF THE PRESS, IN A DESIGNATED BLOCK FABRICATION AREA. THE TRANSPORT OF DESIGNATED SOIL AND ITS STOCKPILING MUST PROMOTE THOROUGH MIXING OF THE SOIL TO ACHIEVE A UNIFORM APPEARANCE.
FOLLOWING THE STOCKPILING OF DESIGNATED SOIL, THE FABRICATION OF SAMPLE BLOCKS COMMENCES BY MIXING SOIL-CEMENT AND PRESSING THE MIXTURE TO PRODUCE TEST BLOCKS FOR THE COLLECTION OF STRENGTH TEST SPECIMENS. THE TEST SPECIMEN LENGTH MUST EXCEED 2.5 TIMES THE DIAMETER AFTER TRIMMING AND SQUARING THE ENDS OF THE TEST SPECIMEN FOR LABORATORY STRENGTH TESTING.
WHILE EACH BLOCK REMAINS IN THE PRESS'S CONFINING BOX, REPRESENTATIVE SPECIMENS FROM THE FRESHLY PRESSED BLOCKS ARE COLLECTED BY RAISING THE PRESS PLATE AND PLACING SEVERAL EVENLY SPACED, VERTICALLY ORIENTED, 3-INCH DIAMETER, MINIMUM 8-INCH LONG, BRASS OR STAINLESS-STEEL LINER SAMPLER TUBES ON THE EXPOSED BLOCK'S TOP SURFACE. THE PRESS PLATE IS THEN CAREFULLY APPLIED TO THE TOPS OF THE LINERS AND USED TO PUSH THE LINERS TO A FULL PENETRATION INTO THE BLOCK. THIS PROCEDURE IS REPEATED ON ADDITIONAL FRESHLY PRESSED BLOCKS, AS NECESSARY, TO OBTAIN A MINIMUM OF TWENTY SPECIMENS.
THE LINERS FILLED WITH SPECIMENS ARE THEN CAREFULLY REMOVED FROM THE SAMPLE BLOCK BY BREAKING APART THE BLOCK, THEN CAPPING AND SEALING OF THE LINERS. THE SPECIMENS ARE THEN PLACED IN A MANNER THAT PROTECTS THEM FROM DIRECT SUNLIGHT, NEAR THE BASE OF THE FUTURE STRUCTURE. A MINIMUM OF 5 DAYS AFTER THEIR COLLECTION, THE SPECIMENS ARE TRANSPORTED TO THE APPROVED LABORATORY FOR STRENGTH TESTING.

A. DETERMINE UNDRAINED SHEAR STRENGTH OF SPECIMENS.

i. PERFORM UNCONFINED COMPRESSION TESTS IN ACCORDANCE WITH ASTM D2166 AT 7 DAYS.

ii. UPON COMPLETION OF EACH COMPRESSION TEST, SPLIT THE SAMPLES TO DETERMINE COMPLIANCE WITH THE REQUIREMENT THAT THE MAXIMUM PARTICLE SIZE CANNOT EXCEED 1/6 OF THE DIAMETER OR ½ INCH. DISCARD SAMPLES THAT ARE NON-COMPLIANT AND PERFORM ADDITIONAL TESTS UNTIL SIX COMPLIANT TEST RESULTS ARE PRODUCED.

6. CRITERIA FOR ACCEPTABLE BLOCK STRENGTH

DUE TO THE POTENTIAL FOR VARIATIONS IN SOIL CHARACTERISTICS AND MIXING EFFICIENCY, THE REQUIRED FACTOR OF SAFETY IS LARGER THAN NORMAL. FURTHERMORE, THE CALCULATED LOADS ON THE LOWER BLOCKS ARE CONSERVATIVE BECAUSE IT IS RECOMMENDED THAT THESE LOADS BE CALCULATED BY ASSUMING THE FACING BLOCKS ARE VERTICAL, RATHER THAN OFFSET AND THE ACCEPTABILITY OF THE BLOCK STRENGTH IS GOVERNED BY THE 7-DAY STRENGTH, WHICH CAN BE EXPECTED TO DOUBLE OR EVEN TRIPLE IN ONE YEARS' TIME, BECAUSE THE COMPRESSIVE STRENGTH OF THE BLOCKS WILL SIGNIFICANTLY INCREASE AS THE SOIL CEMENT CONTINUES TO HYDRATE OVER TIME.

A. DETERMINATION OF MAXIMUM NORMAL STRESS ON THE BLOCKS.
ALTHOUGH THE GREENSTEEP FACING BLOCKS ARE OFFSET AT AN ANGLE OF 24 DEGREES FROM VERTICAL; A VERTICAL CONFIGURATION (CONSERVATIVE) IS ASSUMED TO ESTIMATE THE MAXIMUM POSSIBLE VERTICAL STRESS IN THE BOTTOM BLOCK BY SIMPLY MULTIPLYING THE HEIGHT OF THE WALL, H, BY THE UNIT WEIGHT OF THE BLOCKS, WHICH CAN BE TAKEN AS 130 PCF. ASSUMING A HEIGHT OF 30-FEET AND A BLOCK DENSITY OF 130 PCF, THE NORMAL STRESS σ_V IN THE LOWEST BLOCK IS:

$$(30)\,(130) = 3{,}900 \text{ PSF } (0.187 \text{ MPA}) = \sigma_V$$

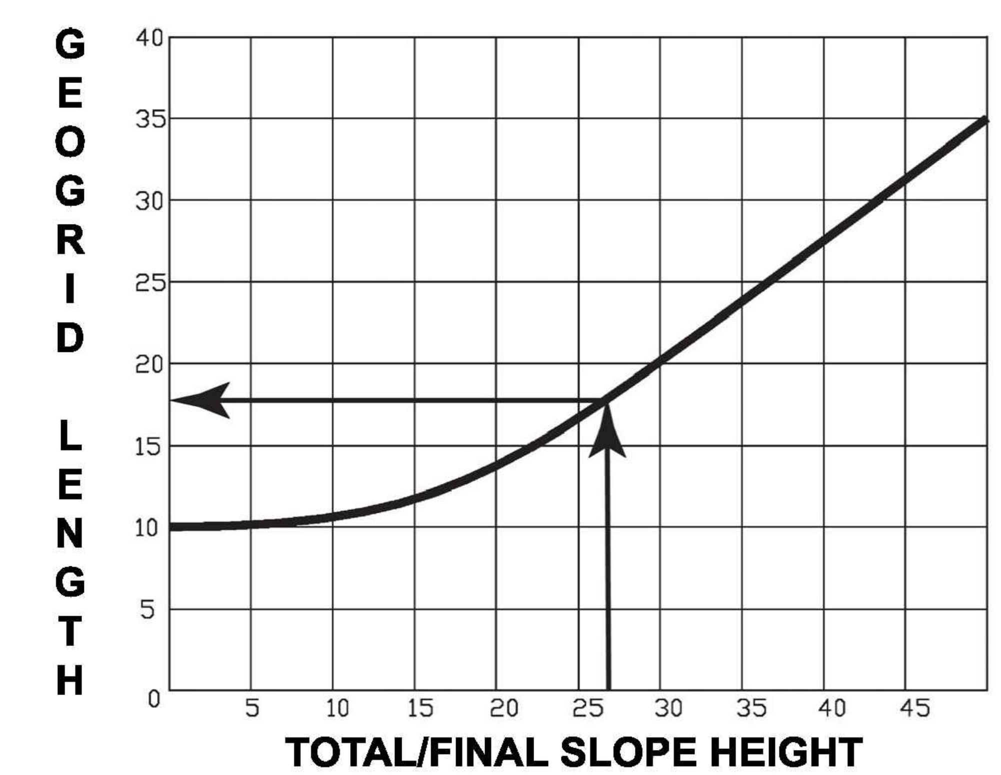
B. DETERMINATION OF AVAILABLE FIELD BLOCK STRENGTH
THE UNCONFINED COMPRESSIVE STRENGTH (UCS) USED TO ARRIVE AT A FACTOR OF SAFETY, WILL BE THE AVERAGE OF THE SIX, 7-DAY FIELD SAMPLE RESULTS OBTAINED PER SECTION 1.1.5.A.II OF THESE SPECIFICATIONS (UCS_{AVE}).

C. DETERMINATION OF THE FACTOR OF SAFETY (FOS) AGAINST CRUSHING
THE FACTOR OF SAFETY IS OBTAINED BY DIVIDING BY THE AVAILABLE FIELD STRENGTH (UCS_{AVE}) BY VERTICAL STRESS IN THE BOTTOM BLOCK.

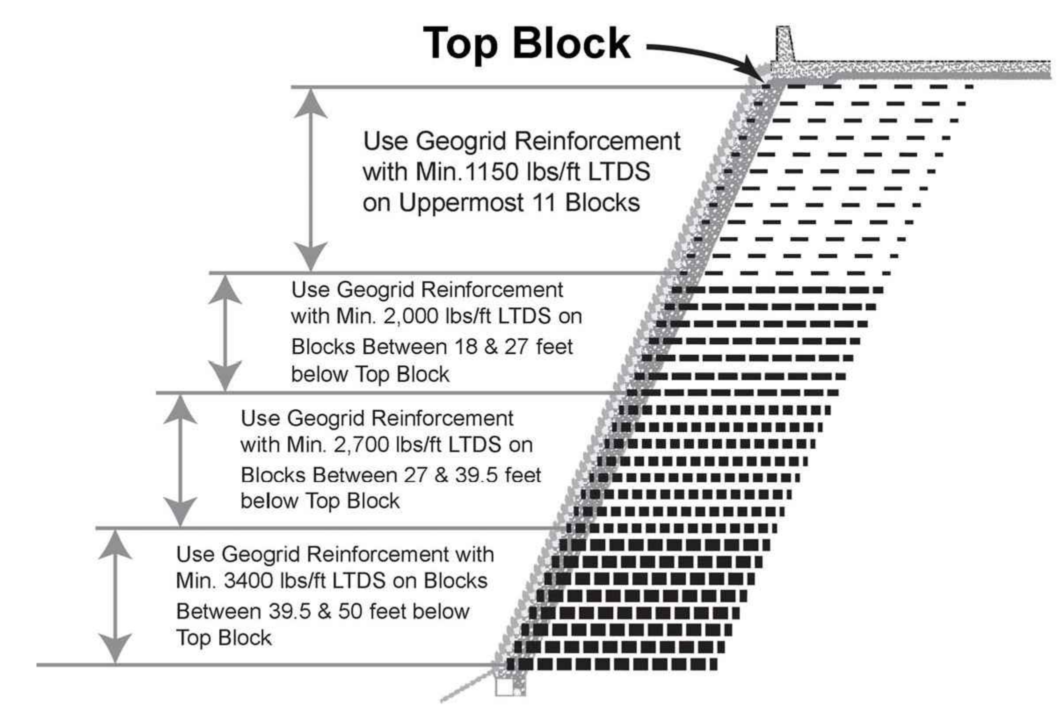
$$\textbf{FOS} = \textbf{UCS}_{AVE} / \sigma_V$$

IF THE FACTOR OF SAFETY EXCEEDS 3, THE DESIGN IS ACCEPTABLE AND BLOCK FABRICATION FOR THE PROJECT, MAY PROCEED.
SHOULD THE FACTOR OF SAFETY FAIL TO REACH 3, EITHER THE HEIGHT OF THE WALL SHOULD BE REDUCED, OR THE STOCKPILED BLOCK FABRICATION SOIL REJECTED AND REPLACED BY A SELECT IMPORTED SOIL.

Reinforcement for the Grensteep Block Units
Must Implement HDPE
TENSAR UX1100 Geogrid



L CONCEPTUAL GEOGRID LENGTH CHART
NOT TO SCALE



M CONCEPTUAL GEOGRID REINFORCEMENT STRENGTH SPECIFICATIONS
NOT TO SCALE

SPECIFICATIONS

DATE	REVISIONS
△	
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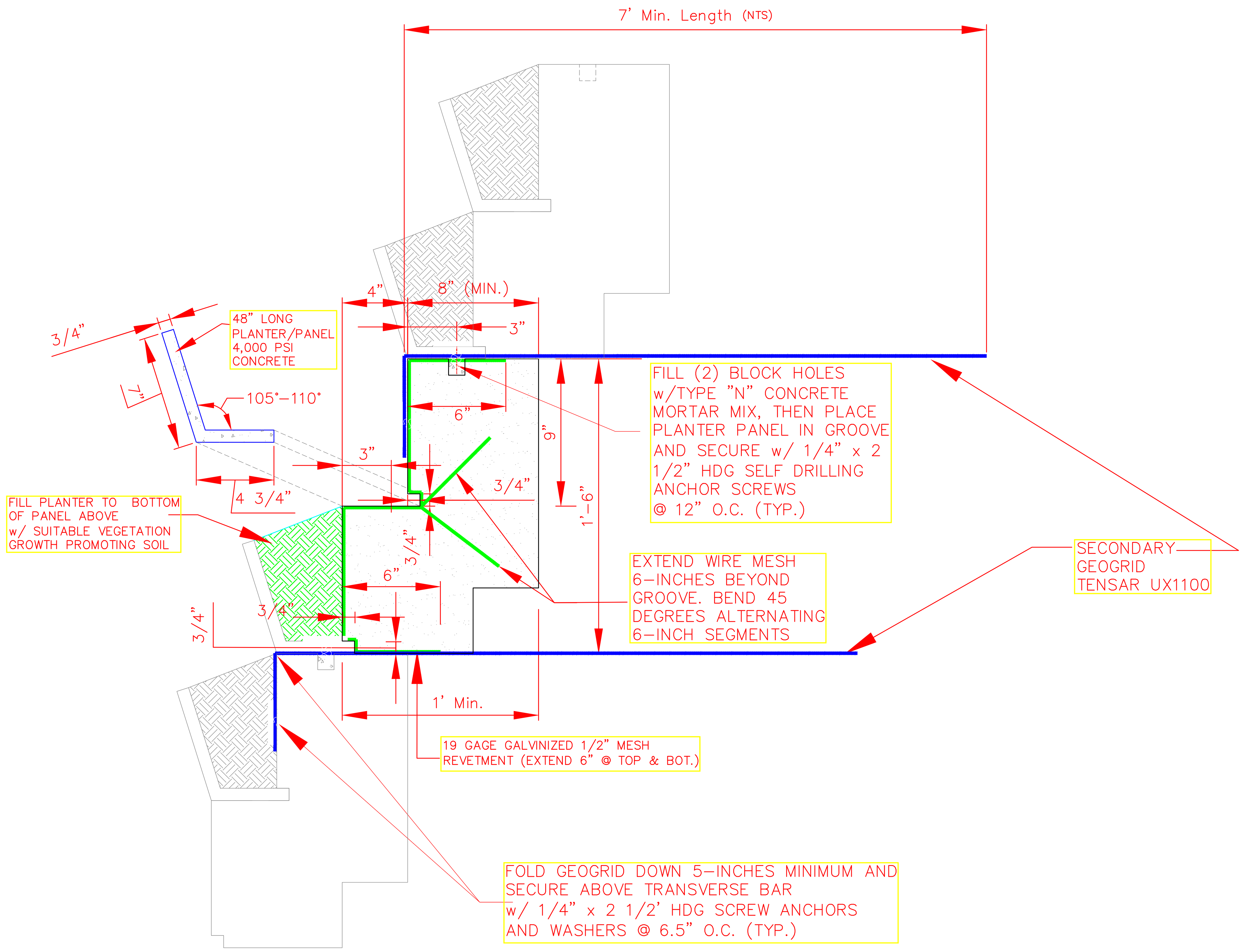
DATE

SCALE SHOWN

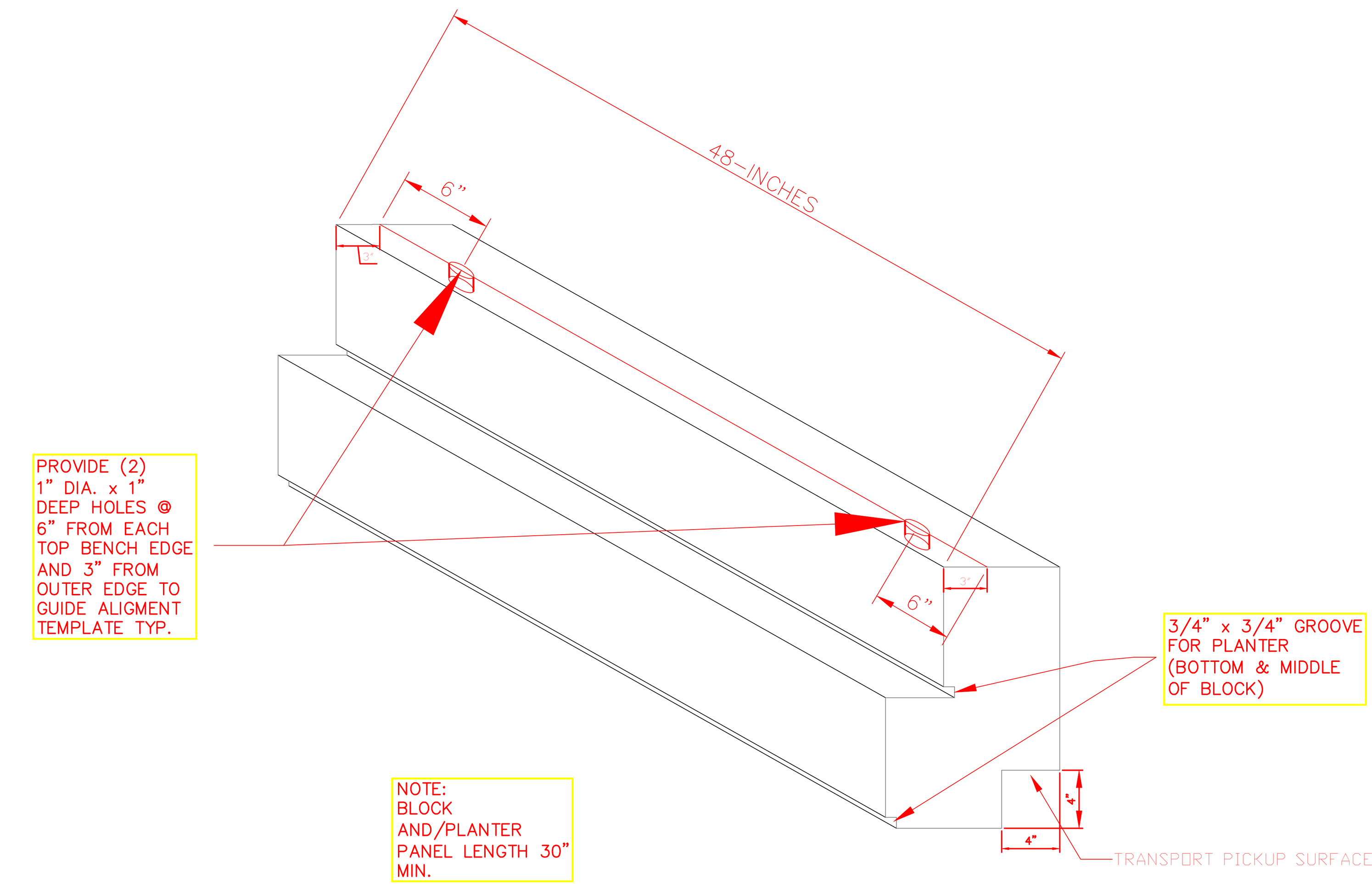
SHEET

1

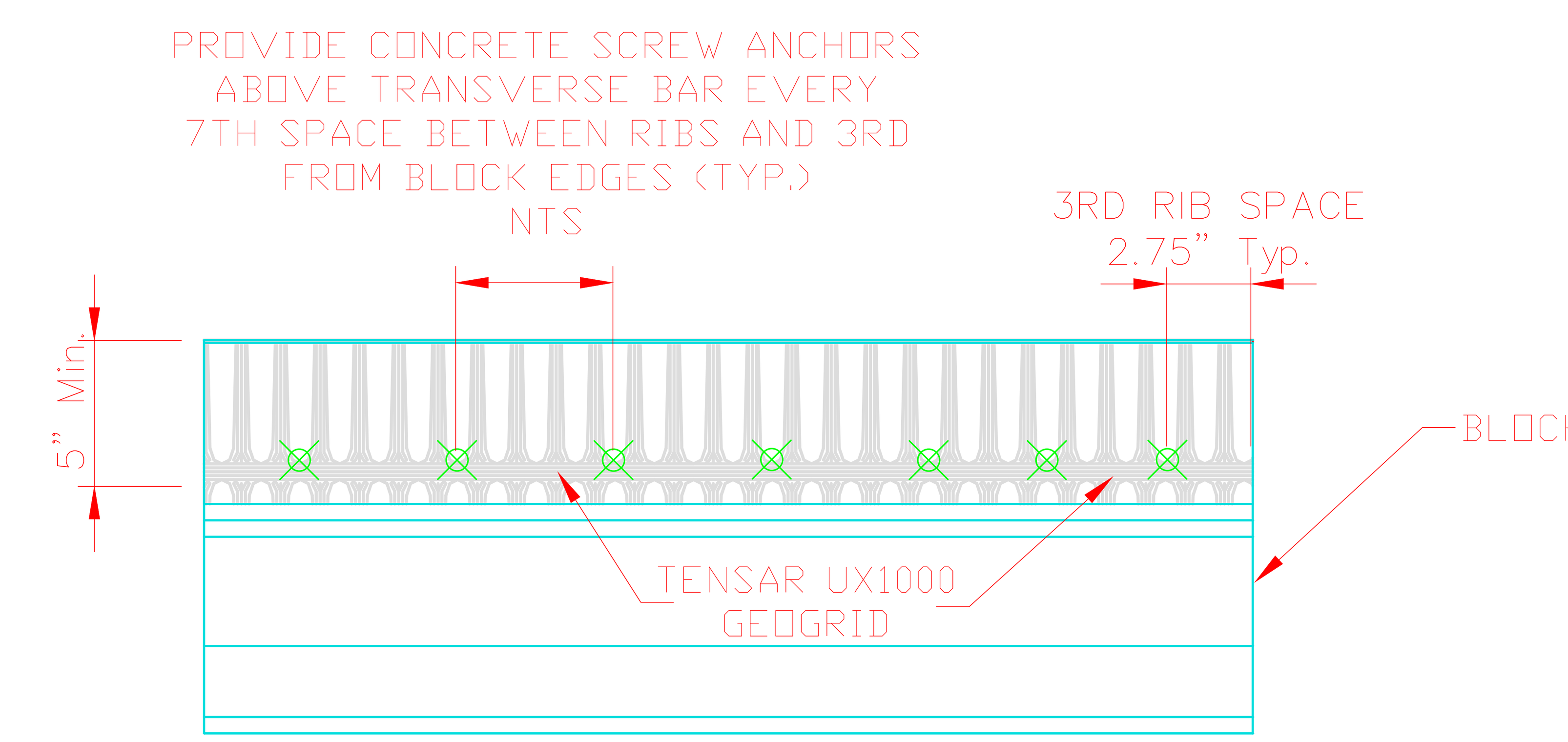
PLOT DATE:



A BLOCK AND PLANTER/PANEL DETAILS
4" = 1'-0"



B BLOCK AND PLANTER/PANEL PERSPECTIVE VIEW
N.T.S.



C SECONDARY GEOGRID CONNECTION TO BLOCK
N.T.S.

greensteepsystem@gmail.com

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925.831.9092

BLOCK DETAILS

DATE	REVISIONS

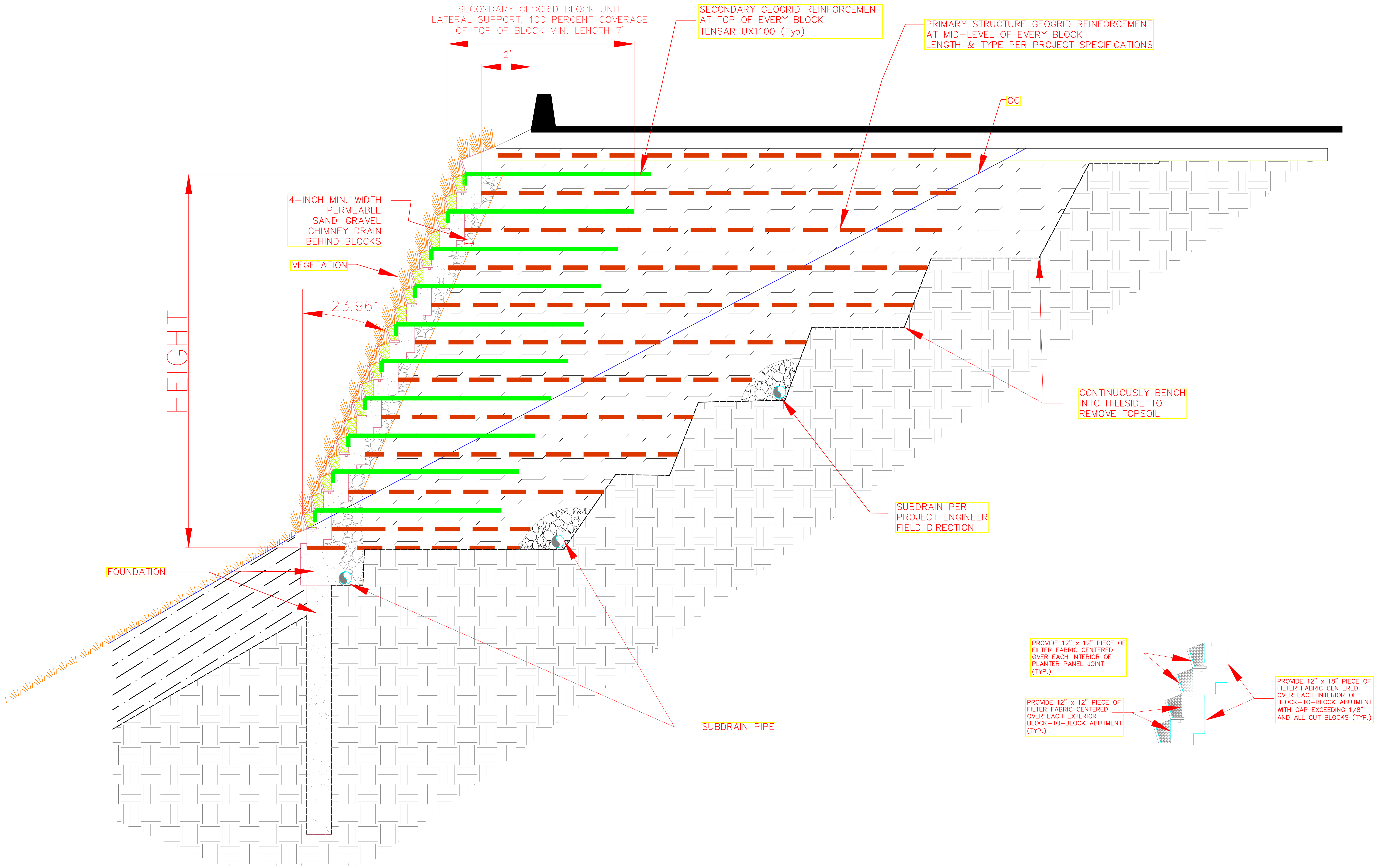
DATE

SCALE SHOWN

SHEET

2

PLOT DATE:



D

STRUCTURE CROSS SECTION VIEW

1/2" = 1'-0"

C:\Documents and Settings\Henry\Desktop\Greensteep CAD\greensteep logo.jpg

greensteepsystem@gmail.com

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STRUCTURE CROSS SECTION

DATE	REVISIONS

DATE

SCALE SHOWN

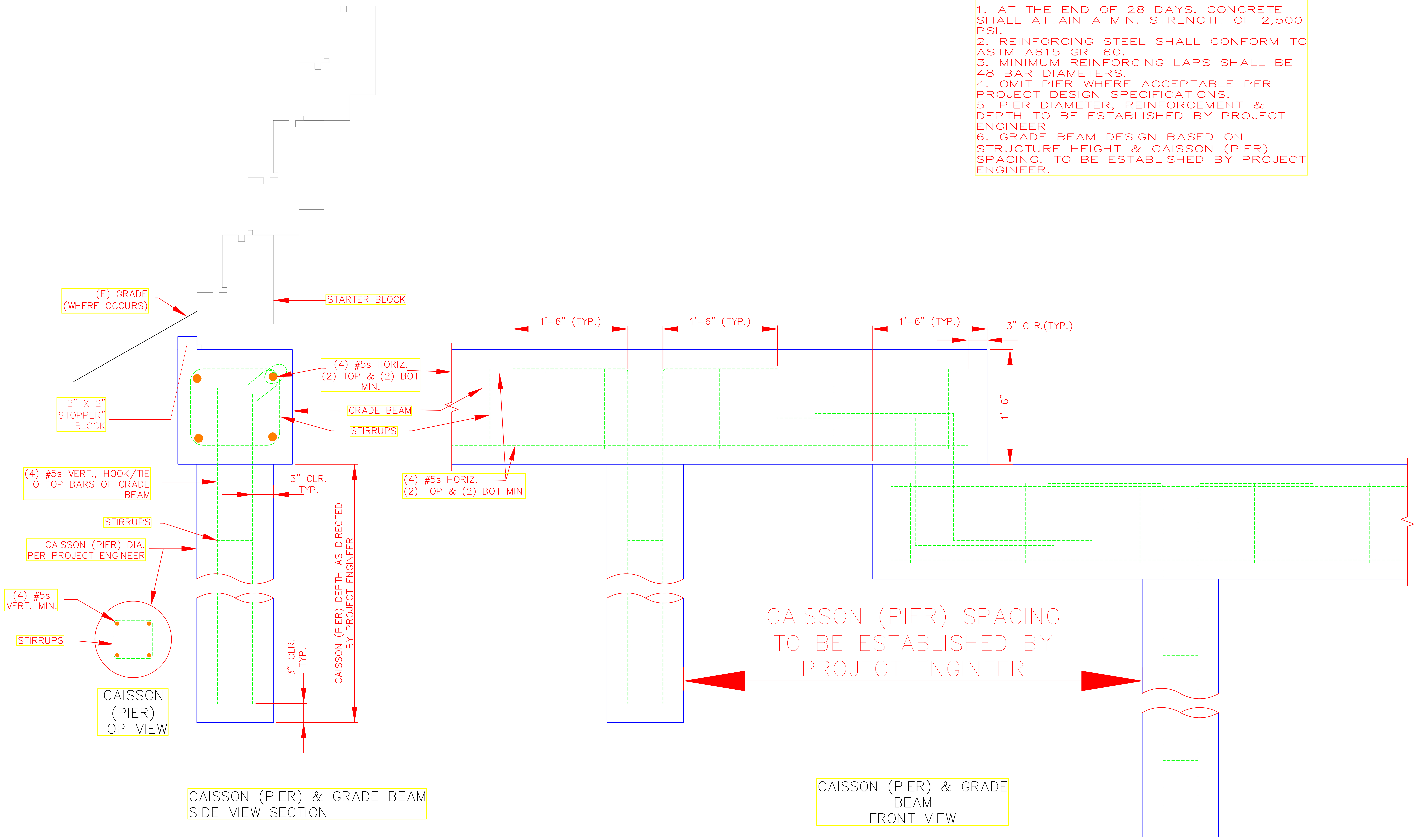
SHEET

3

PLOT DATE:

NOTES:

1. AT THE END OF 28 DAYS, CONCRETE SHALL ATTAIN A MIN. STRENGTH OF 2,500 PSI.
2. REINFORCING STEEL SHALL CONFORM TO ASTM A615 GR. 60.
3. MINIMUM REINFORCING LAPS SHALL BE 48 BAR DIAMETERS.
4. OMIT PIER WHERE ACCEPTABLE PER PROJECT DESIGN SPECIFICATIONS.
5. PIER DIAMETER, REINFORCEMENT & DEPTH TO BE ESTABLISHED BY PROJECT ENGINEER
6. GRADE BEAM DESIGN BASED ON STRUCTURE HEIGHT & CAISSON (PIER) SPACING. TO BE ESTABLISHED BY PROJECT ENGINEER.



E PIER AND GRADE BEAM DETAILS

1-1/2" = 1'-0"

C:\Documents and Settings\Henry\Desktop\Greensteep CAD\greensteep logo.jpg

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FOUNDATION DETAILS

DATE	REVISIONS

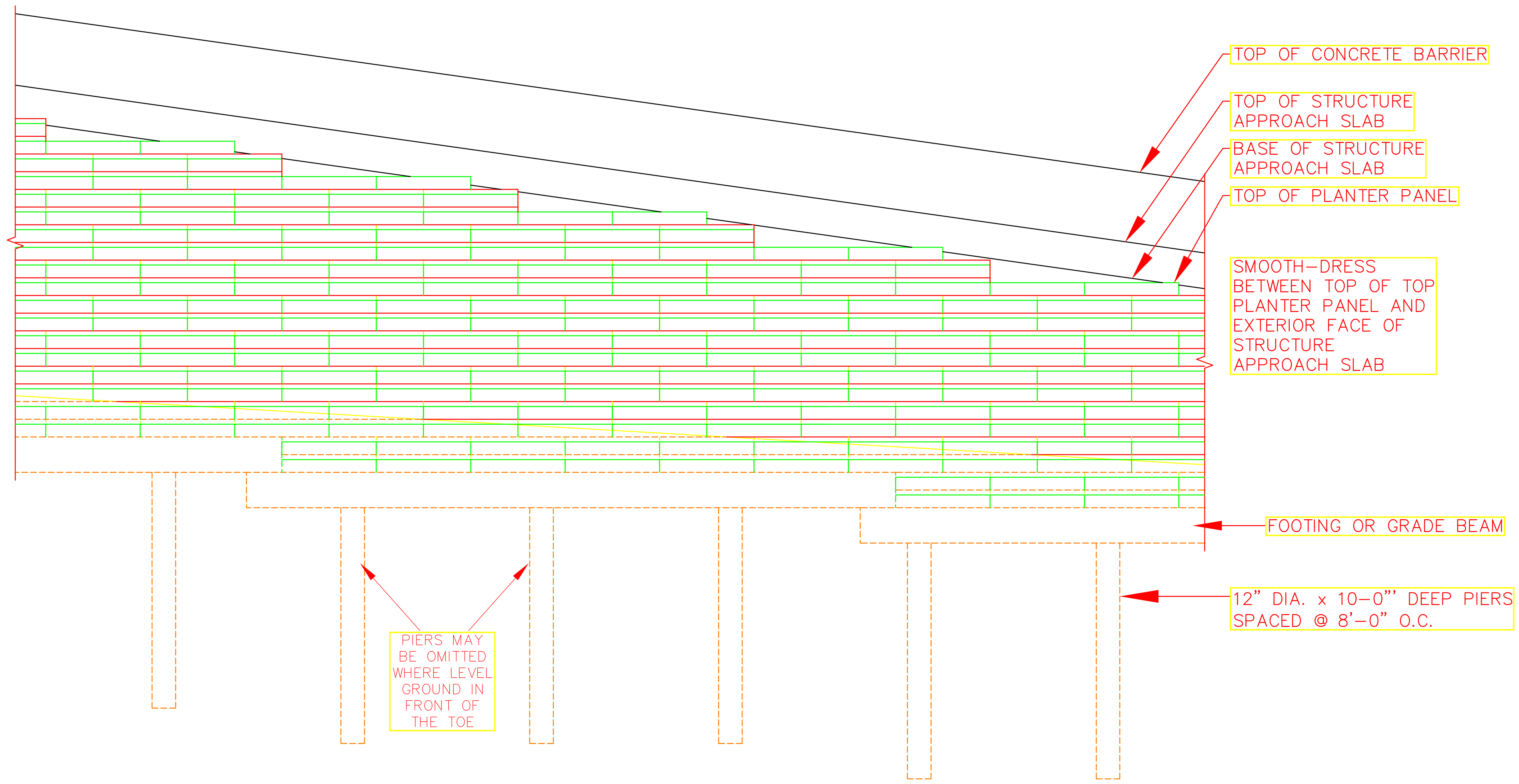
DATE

SCALE SHOWN

SHEET

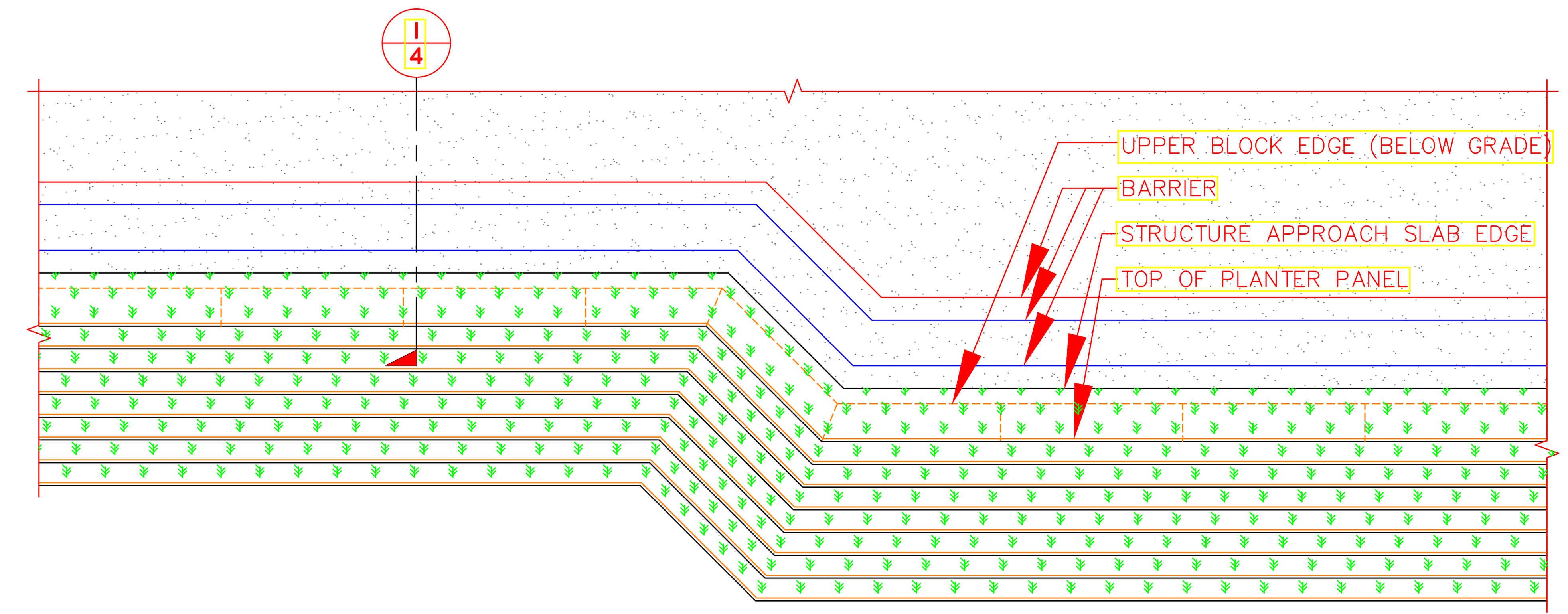
4

PLOT DATE:

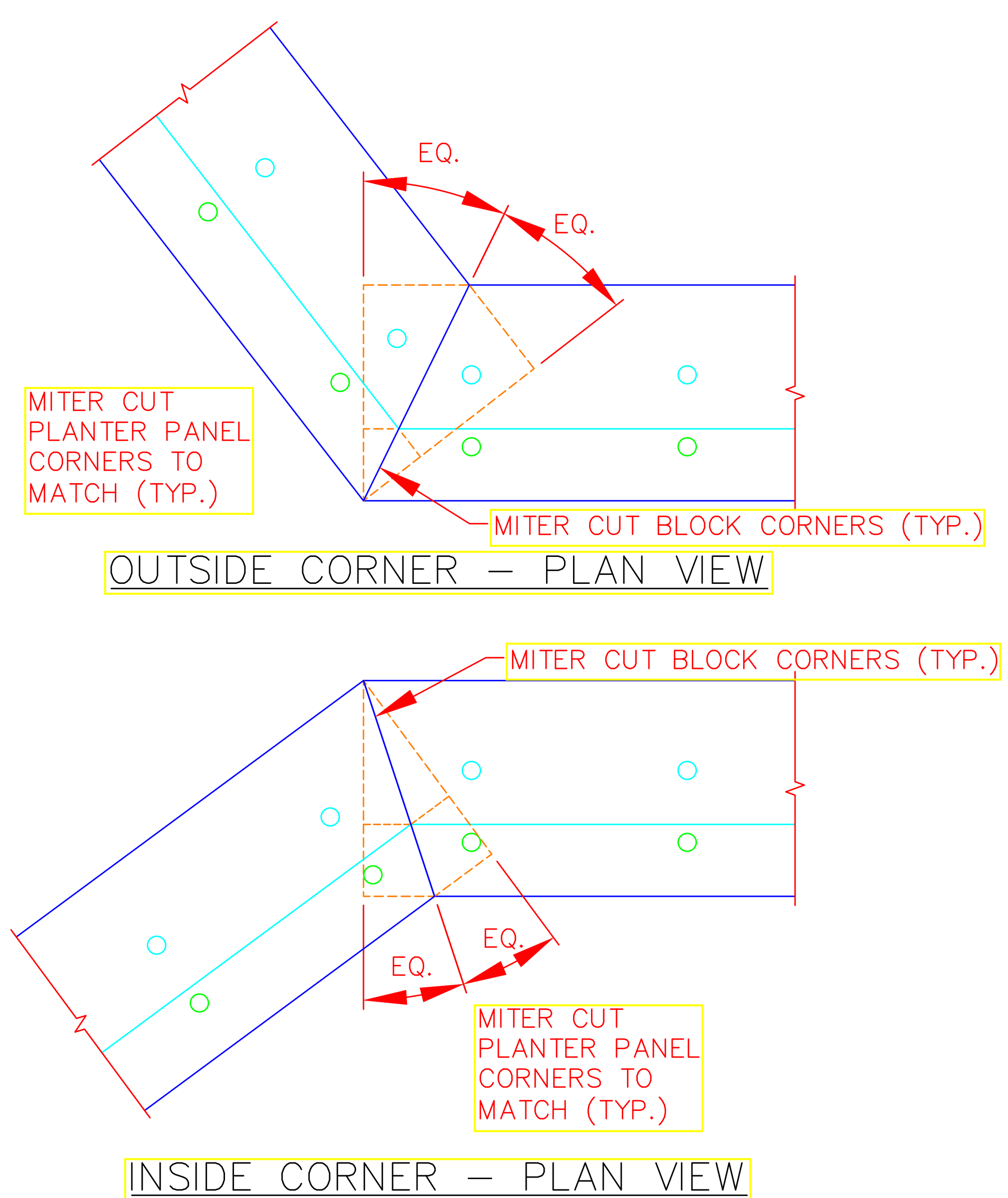


F FRONT ELEVATION VIEW
1/4" = 1'-0"

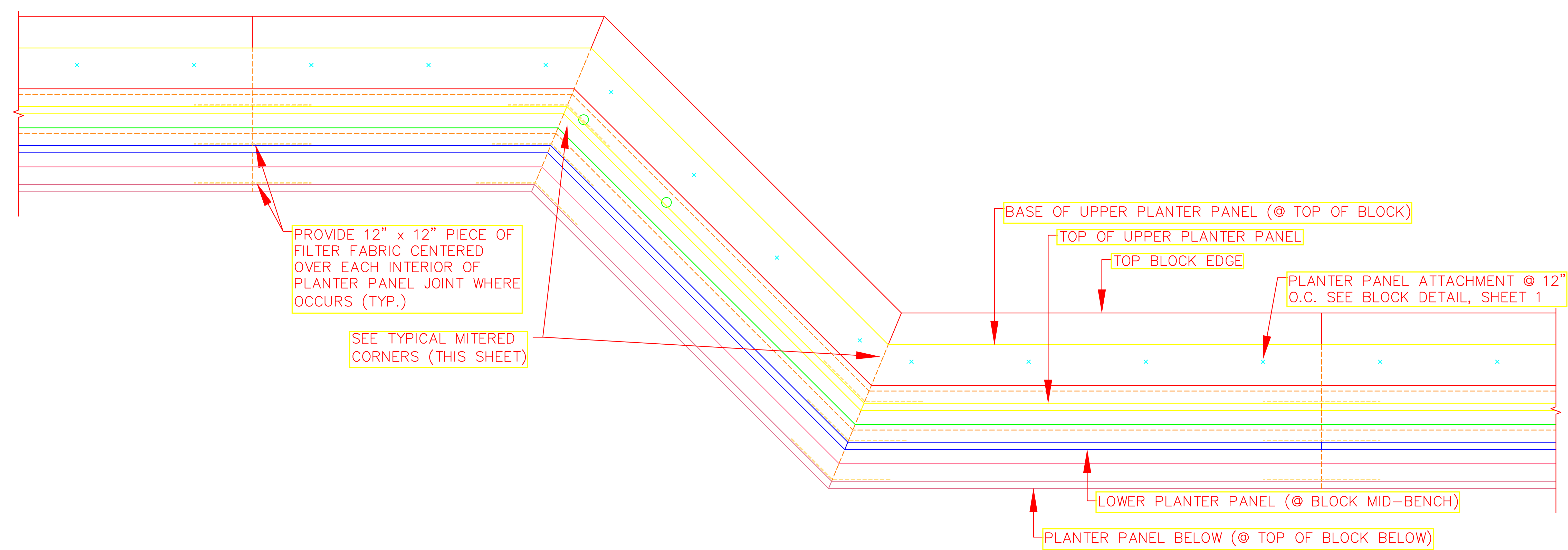
Note:
Maximum Miter Cut Angle 45
Block and Planter Panel Length 30" Min."



H PLAN VIEW
3/8" = 1'-0"



G MITERED CORNER JOINT DETAIL
1-1/2" = 1'-0"



I PLANTER PANEL JOINTS
1-1/2" = 1'-0"

greensteepsystem@gmail.com
P.O.BOX 2338
SAN RAMON, CA 94583
925.831.9092

CROSS SECTIONS AND PLAN VIEW

DATE	REVISIONS

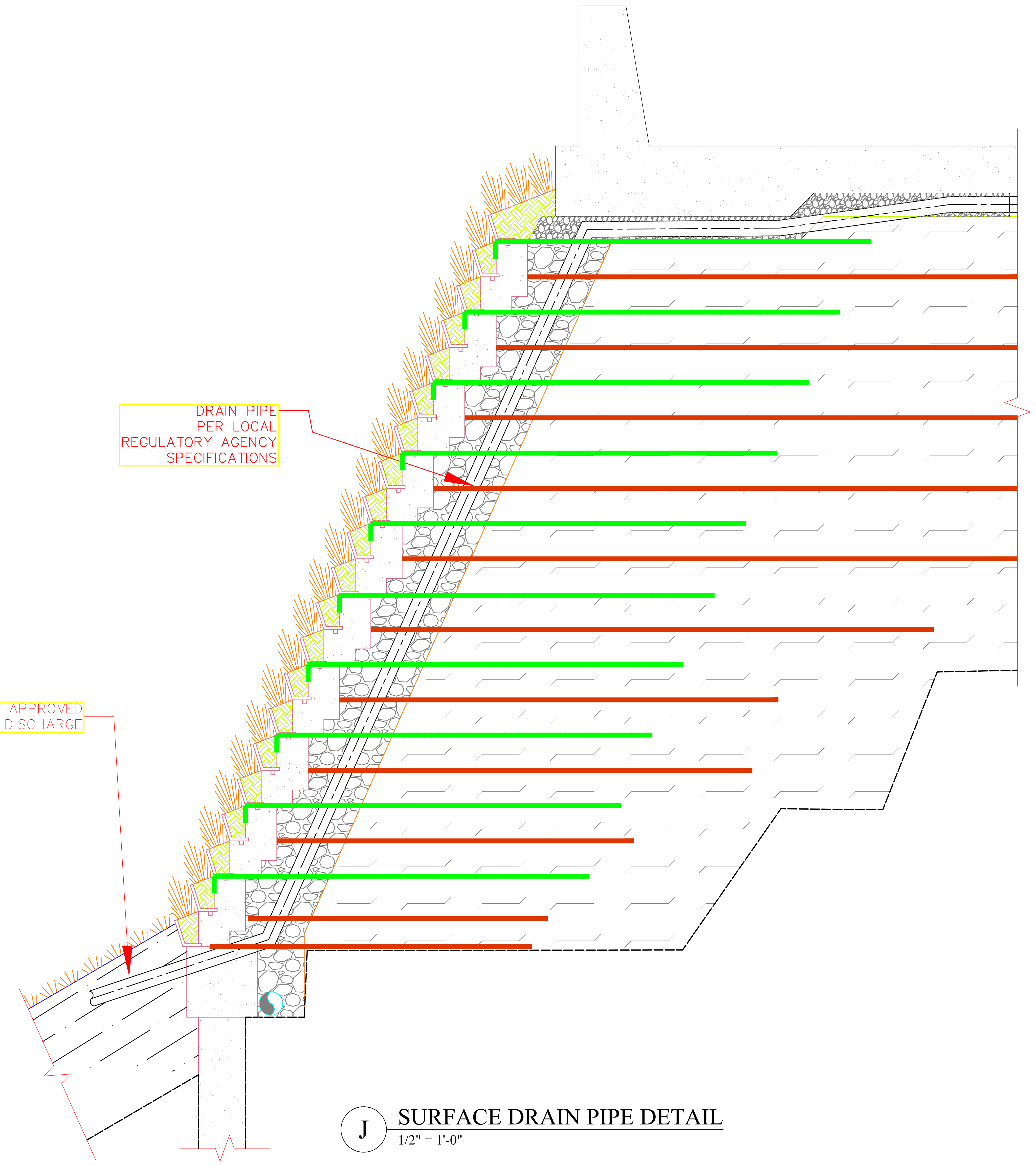
DATE

SCALE SHOWN

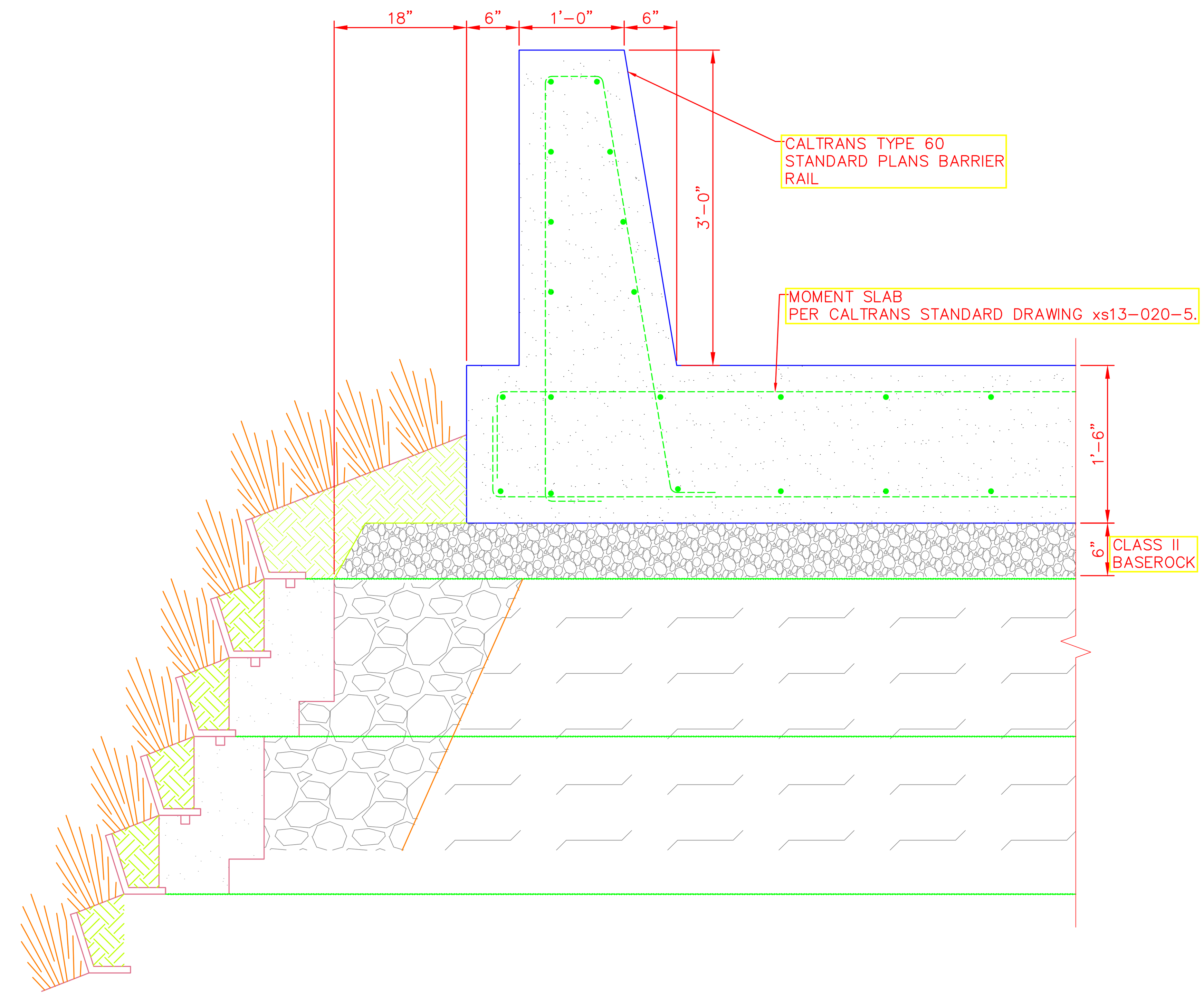
SHEET

5

PLOT DATE:



J SURFACE DRAIN PIPE DETAIL
1/2" = 1'-0"



K HIGHWAY BARRIER RAIL
1" = 1'-0"

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925.831.9092

HIGHWAY BARRIER RAIL AND DRAINAGE DETAILS

DATE	REVISIONS

DATE

SCALE SHOWN

SHEET

6

PLOT DATE:

Appendix S2 – GreenSteep 2021
Technical Evaluation Checklist for Reinforced Soil Slope (RSS) Facing System
Used on a RSS with Extensible Reinforcement

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 as 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. Provide reports, drawings, calculations, and supporting references 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.

Introduction

Report	Provide a succinct description of the facing system that is being submitted for review. Should reference an appended Introduction TAB where the Facing System Specification is presented.
Appendix	Present full Facing System specification.

Section 1: RSS Components

1.1	Tab 1.1		Facing
	Yes	No	Item
1.1.1	☒	☐	Does the system contain what you consider to be an innovation that is related to the facing? 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 the types of facing (e.g., standard, bottom, top, corner, etc.).
1.1.3	☒	☐	List facing finish options (e.g., vegetated, non-vegetated, etc.)
1.1.4	☒	☐	Provide specification(s) for each facing type, and finish options.
1.1.5	☒	☐	Provide description of Facing Details, including connection to soil reinforcements details.
1.1.6	☒	☐	Provide standard dimensions, and tolerances, for each type of facing in plan and section drawings.
1.1.7	☒	☐	Describe fabrication process for all facing components.
1.1.8	☒	☐	Provide the specified strength(s) and design life of plastic, cement based, steel, etc. facing components. Document design life computations, including service environment assumptions.
1.1.9	☒	☐	Provide inter-unit shear test results and design shear capacity envelopes, with and without geosynthetics between facing units.
1.1.10	☒	☐	Describe with text any unit shear, alignment or bearing devices. Provide specifications and detail drawings.
1.1.11	☒	☐	Describe with text and drawings on details used to prevent migration of fill soil through the RSS face. Provide specification(s).

1.1.12	☒	☐	Describe with text the aesthetic facing options that are available. Provide photos, drawings and brochures as appropriate.
1.1.13	☒	☐	Describe any limits on the facing units that are created by curved RSS sections and tapers into non-reinforced slopes.

1.2	Tab 1.2		Extensible Soil Reinforcement
	Yes	No	Item
1.2.1	☒	☐	Does the RSS 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 style or type that can be used with the facing system.
1.2.3	☐	☐	Provide specifications for each style or type and grade that can be used with the facing system.
1.2.4	☒	☐	Describe the facing unit-reinforcement connection with text and drawings.
1.2.5	☒	☐	List facing-reinforcement connection strength tests performed, provide test results and strength envelopes the Applicant recommends for design; if applicable.
1.2.6	☒	☐	Provide inter-unit shear test results and design shear capacity envelopes, with soil reinforcements between facing units.

1.3	Tab 1.3		Other Components
	Yes	No	Item
1.3.1	☒	☐	Does the RSS contain what you consider to be an innovation that is related to a system 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	☒	☐	Footing/Bearing/Leveling Pad for support of facing units - Provide specifications including dimensions, concrete strength requirements and concrete reinforcement, if required.
1.3.3	☒	☐	Drainage - Describe with text any internal and external drainage measures that are inherent in the system. That is, they are not optional measures such as blanket and chimney drains or drainage swales, but are built-into RSS components.
1.3.4	☒	☐	Irrigation - Describe with text, and drawings, face irrigation measures that are inherent in the system and vegetated facing.
1.3.5	☒	☐	Coping - Describe with text coping that may be used with the RSS. Provide specifications, dimensions, dimensional tolerances and plan and section view drawings.
1.3.6	☒	☐	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.

1.3.7	☒	☐	Slip Joints—describe with text how slip joints are made to accommodate potential differential settlement. Provide applicable typical plan and elevation view drawings.
1.3.8	☒	☐	Does the RSS require and specific foundation treatment(s)? If yes, please provide description(s), drawings, and details.

Section 2: RSS Design

2.1	Tab 2.1		Design Methodology
	Yes	No	Item
2.1.1	☒	☐	Does the 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 how the facing unit is incorporated into the RSS design. Provide design values for the facing unit (e.g., unit weight, shear strength, interface shear strengths, connection strength properties, etc.)
2.1.3	☒	☐	Provide typical plan and detail drawings of how vertical and horizontal obstructions in the reinforced zone are handled.
2.2	Tab 2.2		Design Example
	Yes	No	Item
2.2.1	☒	☐	Problem 1 — provide complete example calculations for facing foundation design, including computation of loading, when bearing on a level toe slope. 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.
2.2.2	☒	☐	Problem 2 — provide complete example calculations for facing foundation design, including computation of loading, when bearing on a steep toe slope, and drilled shafts are used. 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.
2.3	Tab 2.3		Summary of Design Input Parameters
	Yes	No	Item
2.3.1	☒	☐	Summary table of facing unit design input parameters for use with commercially available limit equilibrium slope stability computer programs.

Appendix C8
Initial Technical Evaluation Checklist for Reinforced Soil Slope (RSS) System (RSS) with Extensible Reinforcement

Section 3: Construction

3.1	Tab 3.1		Construction Procedures
	Yes	No	Item
3.1.1	☒	☐	Does the Facing 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 RSS Facing System and at a minimum it should include the following items.
3.1.3	☒	☐	Describe facing installation both at straight and curved sections of the structure.
3.1.4	☒	☐	Describe any limitations of facing 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.
3.1.5	☒	☐	Describe procedures to install earth reinforcement at curved sections of the RSS and at corners. Specifically address any measures that are to be taken at intersection or overlapping panels of reinforcement.
3.1.6	☒	☐	Describe measures that are required to maintain the design vertical and horizontal alignment of the RSS face.
3.1.7	☒	☐	Describe experience or other special qualifications that are required of the RSS construction contractor.
3.1.8	☒	☐	Describe the procedures to install soil in the reinforced soil zone, adjacent to the facing.

Section 4: Quality Control

4.1	Tab 4.1		Manufacturing
	Yes	No	Item
4.1.1	☒	☐	Describe the quality control measures that are required for the manufacturing of facing units. Mix design, QC testing of soil-cement mix, water content control, cure time, etc. should be addressed. A manufacturing QC manual should be provided.
4.1.2	☒	☐	Describe the quality control measures that are required for the manufacturing of facing unit planter components. Manufacturing QC manual(s) should be provided.
4.1.3	☒	☐	Describe the quality control measures that are required for the manufacturing of any facing drainage components. You may do this by providing a manufacturing QC manual(s).
4.2	Tab 4.2		Construction
	Yes	No	Item
4.2.1	☒	☐	Describe the quality control measures that are required during erection and backfilling of the Facing System during construction of the RSS. 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.

Appendix C8
Initial Technical Evaluation Checklist for Reinforced Soil Slope (RSS) System (RSS)
with Extensible Reinforcement

Section 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.

Section 6: Other Information

6.1	Other Information		
6.1.1	☒	☐	In this section, please include anything you think will better help a reviewer understand your Facing System that has not been adequately addressed in the previous questions.
6.1.2	☒	☐	Provide typical unit cost, or cost range, of units and of installed units; with and without optional facing planters.