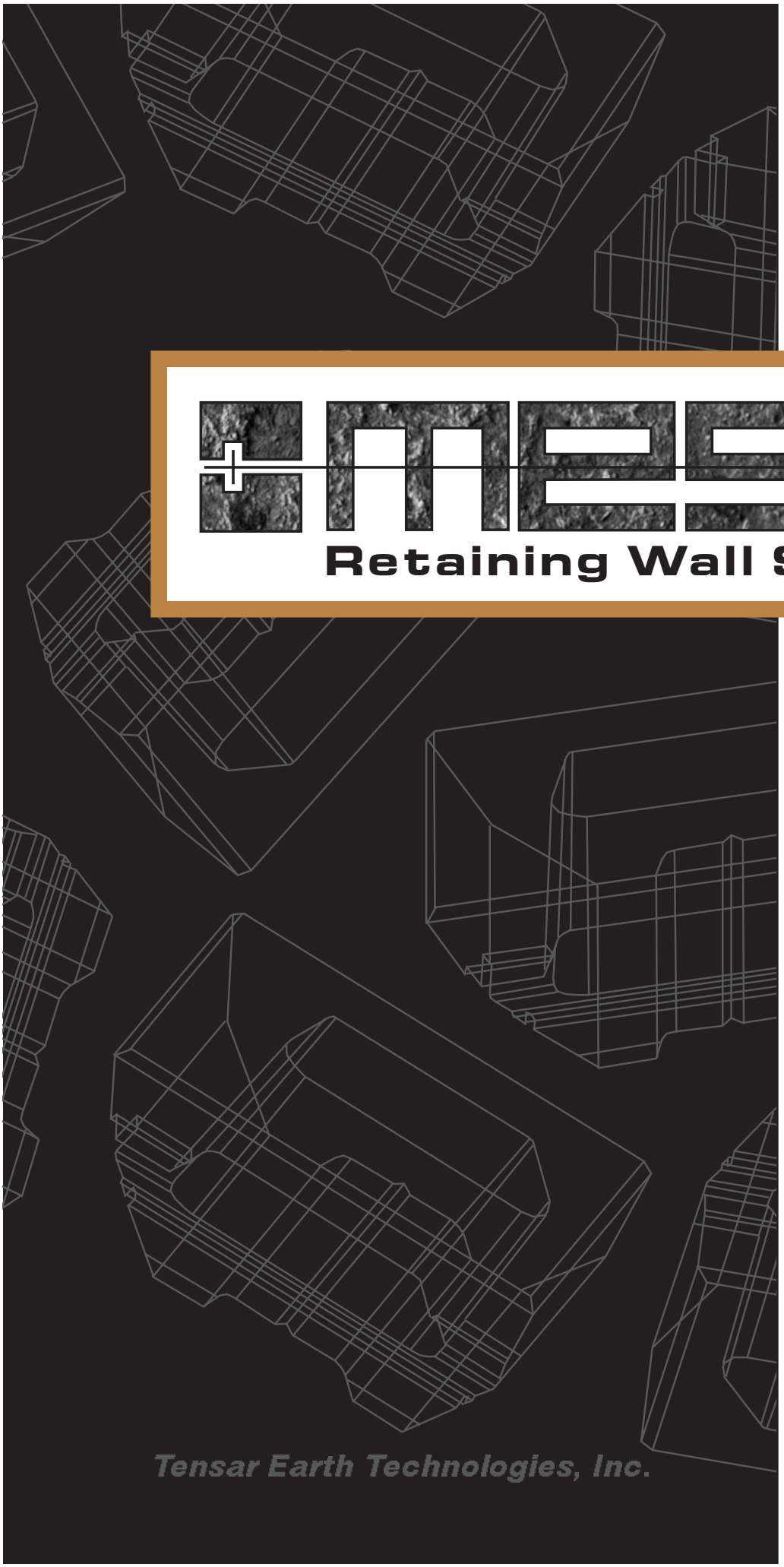

mesa®

Retaining Wall Systems

Design Guidelines for Mesa Retaining Wall Systems

Tensar Earth Technologies, Inc.

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1.0 INTRODUCTION

Mesa segmental concrete facing units, used in conjunction with Tensar Geogrids, provide an economical and aesthetically attractive alternative to conventional concrete retaining walls. Because Mesa Units do not require mortar, considerable time and labor associated with cast–in–place or block and mortar construction is eliminated. A mechanical connection provides a higher level of structural integrity than can be achieved with a typical Segmental Retaining Wall (SRW) "frictional" connection. The Mesa Units, combined with Tensar Geogrids and Mesa Connectors, form the Mesa Retaining Wall Systems. They are the only integrated SRW systems available to incorporate these three critical elements.

The Engineered Advantage™ of Tensar Geogrids combined with the unsurpassed connection strength of the Mesa Systems allow SRW to be constructed to heights of 50 feet and more with confidence. The resulting wall system is versatile, economical and relatively simple to install for even complex geometric and structural requirements.

The purpose of this Technical Note is to provide a guide for developing safe and economical designs for Mesa Retaining Wall Systems utilizing Tensar Geogrids. This guideline is based upon established design procedures that have been used for thousands of Tensar Geogrid reinforced retaining walls constructed since 1984. The procedures incorporate geogrid–soil interaction coefficients and design strengths established through extensive research and testing with Tensar Geogrids.

The stability of retaining wall structures designed with these guidelines and using Tensar Geogrids has been verified through the monitoring of instrumented wall structures since 1985.

The design guidelines and values recommended for Tensar Geogrids are not applicable for, and should not be used with, other types of soil reinforcement. The design tables presented are specifically for use with the Mesa Units and are not applicable to other types of facing systems.

The following topics are presented in this Technical Note:

- Design properties of structural geogrids, segmental concrete facing units and connectors
- Design methodology
- Design/construction considerations for Mesa segmental concrete facing units, Tensar Geogrid orientations, wall fill, design details, construction details, materials and construction specifications
- Design example
- Design charts (for preliminary designs and cost estimates)

This guideline covers the major considerations for designing a Mesa and/or Tensar structural geogrid reinforced wall but is not, nor should it be considered, comprehensive for any project or structure. The designer should only use this Technical Note to become familiar with the basic design principles for reinforced walls and to determine the suitability of these guidelines for each application.

2.0 DESIGN PROPERTIES FOR STRUCTURAL GEOGRID REINFORCEMENT

Each geogrid reinforced soil structure must be designed using structural geogrid properties, soil properties, loading parameters and concrete unit parameters established for the specific project. The geogrid properties used in a typical design are geogrid–soil interaction coefficients (C_i) and allowable strengths (T_a). Values for these properties will vary with project conditions.

The concrete unit parameters are block thickness, wall batter and connection of the block to the reinforcement.

2.1 GEOGRID-SOIL INTERACTION COEFFICIENTS (C_i)

Geogrid–soil interaction coefficients are determined from pullout tests as illustrated in Figure 2.1. The apparatus and procedures for this test are described in Geosynthetic Research Institute (GRI) GG5—"Test Method for Geogrid Pullout." This test should be performed with soils typical of project site conditions and each geogrid used in design. Pullout force should be determined for at least three levels of normal stress (confining pressure): 1) 1–2 psi, 2) 4–6 psi, and 3) 8–12 psi. Others may be required depending on project conditions.

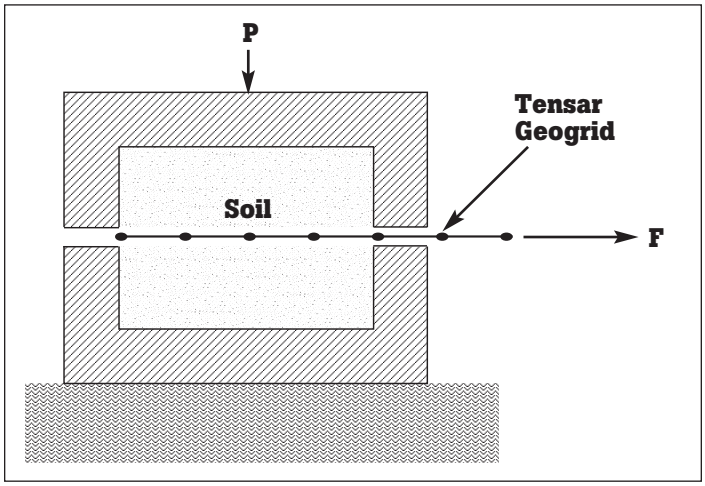


Figure 2.1 Pullout Test Apparatus

Geogrid–soil interaction coefficients (C_i) are calculated from test data using the following equation:

Equation 2.1

$$C_i = \frac{F}{2L\ \sigma'_n \tan \phi'}$$

where: F = pullout force (lb/ft)
L = geogrid embedment length (ft)
σ'_n = normal stress (lb/ft^2)
ϕ' = effective soil friction angle

If C_i is constant, the calculated value should be used throughout the design. If C_i is variable and influenced by normal stress or other factors, the minimum possible C_i value should be used throughout the design. Table 2–1 lists recommended values for Tensar Geogrid–Soil Interaction Coefficients. These are conservative values based on calculations from extensive pullout testing and are specific to Tensar Geogrids.

Table 2-1
Tensar Geogrid Design Parameters
Geogrid-Soil Interaction Coefficients (C_i)[1]

Soil Type[2]	Typical ø'[3]	C_i
Gravel, sandy gravel and gravel-sand-silt mixtures (GW & GM)	≥ 34°	0.80
Well-graded sands gravelly sands and sand-silt mixtures (SW & SM)	≥ 30°	0.75
Silts, very fine sands, clayey sands and clayey silts (SC & ML)	≥ 28°	0.58

1 For soil types other than those listed, contact Tensar Earth Technologies for design values.
2 Soils compacted to approximately 95% of the maximum dry density using the standard proctor test (unified soil classification in parentheses).
3 Typical ø' values are listed for respective soil types.

2.2 TENSAR GEOGRID DESIGN STRENGTH

Design Strength (T_d) is based on the long-term tension strain behavior of the geogrid structure which is influenced by:

1) construction induced damage
2) sustained load deformation (creep)
3) chemical and biological polymer degradation
4) dimensional stability of the geogrid structure (e.g., rib stiffness and junction integrity)

These factors must be accounted for in calculating long-term design strength.

The long-term design strength is determined as follows:

Equation 2.2

$$T_d = LTDS = \frac{T_l}{FS_{ID} \times FS_D}$$

where: T_l = creep limited strength as determined by ASTM D5262 Standard Test Method for Evaluating the Unconfined Tension Creep Behavior of Geosynthetics
FS_{ID} = partial factor of safety for installation damage
FS_D = partial factor of safety for durability (chemical and biological degradation)
FS_{UNC} = factor of safety for design uncertainties and tolerances

The long-term allowable strength is determined as:

$$T_a = \frac{LTDS}{FS_{UNC}}$$

For the most recent data on the design strengths of Tensar Geogrids accounting for all the factors of safety referenced in Equation 2.2. please visit www.tensarcorp.com.

2.3 MESA SEGMENTAL CONCRETE FACING UNITS

The design guidelines and methodology presented in this Technical Note for geogrid reinforced soil walls do not evaluate the stability of the units without geogrid reinforcement. Mesa segmental concrete facing units have their own unique features which allow walls to reach heights up to several feet without the use of soil reinforcement. The weight of the units including core fill, combined with the automatic setback, provides a resistance to sliding along the base of the stacked units and provides an overturning resistance sufficient for low wall heights. Additionally, setback, or batter of the units, can allow for a reduction in the lateral soil pressure which in turn decreases the amount of reinforcement required for taller walls.

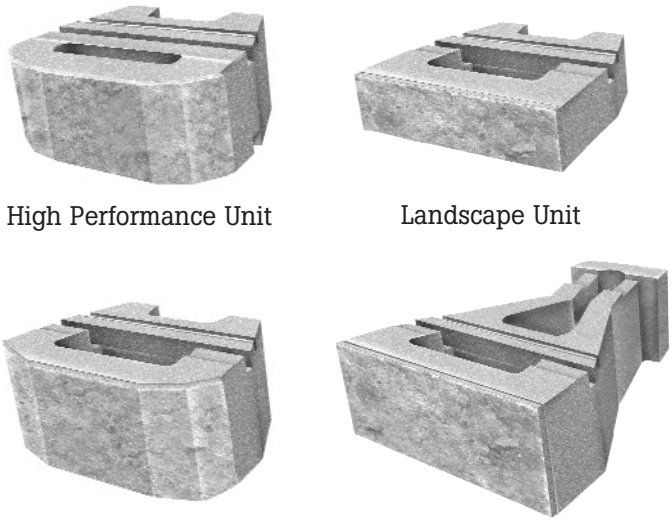


Figure 2.2 Mesa Units

Mesa Units (depicted in Figure 2.2 and described below) are manufactured to a height of 8 inches nominal. (Note: Landscape and Cap Units are manufactured to a height of 4 inches nominal.) For convenience of design, the lift placement should be designed for an 8 inch lift interval (or 4 inch lift interval when the Landscape Unit is used). Wall batter can be set to 4.5° or constructed near vertical by proper orientation placement of the Mesa Connector.

Mesa Unit	Dimensions (H x L x D)	Connector Type	Weight* (lbs.)
High Performance (HP)	8" x 18" x 11" (Nominal)	High Performance	85
Standard	8" x 18" x 11" (Nominal)	Standard	75
XL	8" x 18" x 22" (Nominal)	Standard	110
Landscape	4" x 18" x 11" (Nominal)	Standard	40
Cap	4" x 18" x 11" (Nominal)	N/A	40
Corner	8" x 18" x 9"	N/A	75

*Weight may vary by manufacturer

2.4 GEOGRID CONNECTION TO THE MESA UNITS

A secure connection between the Tensar Geogrid and the Mesa segmental concrete facing units is achieved through a positive, mechanical, end-bearing, structural connection. This system was specifically designed to take advantage of the high junction strength of Tensar Geogrids, providing a connection with high connection strength at very low deformation. The connection is accomplished by driving the Mesa Connector through the apertures of the geogrid and into the slot of the Mesa Unit. The geogrid transverse bar must engage the connector to help ensure the connection. The connection between the geogrid reinforcement and units will be sufficient to prevent excessive movement of the wall units during construction, as well as resisting the forces acting on the wall during its design life.

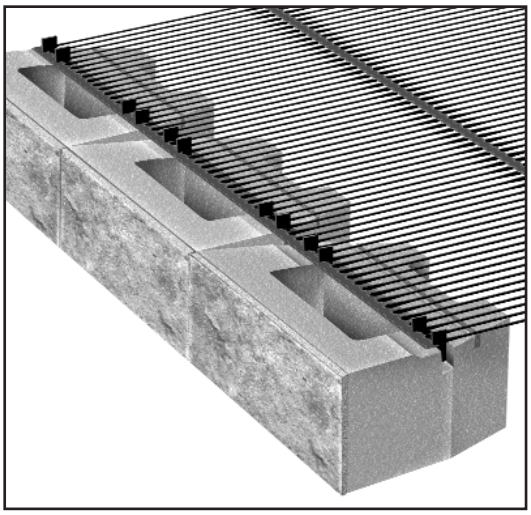


Figure 2.3 Tensar Geogrid connecting with Mesa Units

2.5 CONNECTION STRENGTH AND TEST DATA

Fourteen (14) connection test series were conducted to evaluate the strength of connections between the six Tensar UXMSE Geogrids and the two types of Mesa segmental concrete facing units. The tests were performed in general accordance with National Concrete Masonry Association (NCMA) Test Method SRWU-1, "Determination of Connection Strength between Geosynthetics and Segmental Concrete Units." For the data and tables that summarizes the connection strength test results as developed by Geosyntec Consultants please visit www.tensarcorp.com. For the full report please request Tensar Technical Note TTN:MESA-CONN.

3.0 DESIGN THEORY AND EQUATIONS

3.1 Background

A structural geogrid reinforced soil retaining wall consists of six major components (see Figure 3.1):

1) Mesa Units
2) Tensar Geogrids
3) Drainage fill
4) Reinforced wall fill
5) Retained backfill behind the reinforced zone
6) Foundation soil

Geogrids provide stability to the Mesa Retaining Wall Systems by reinforcing a prism of soil behind the concrete blocks.

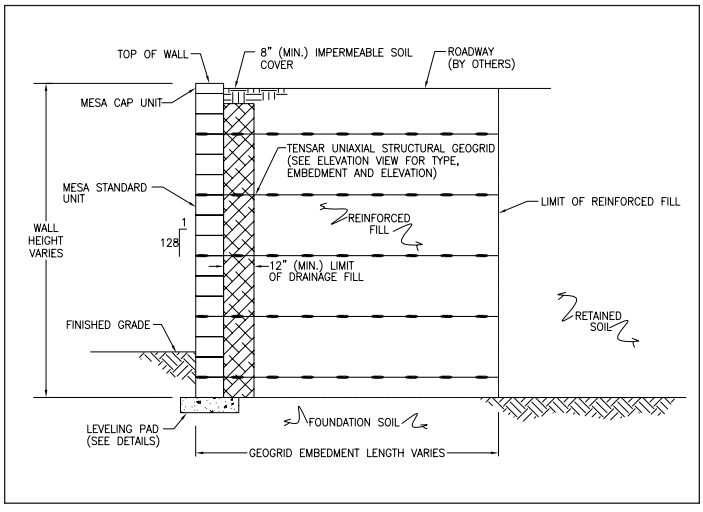


Figure 3.1 Wall Components

This reinforced soil mass becomes self-supporting and acts as a composite material to provide overall stability. The Mesa Units facilitate compaction within the wall fill, prevent surface sloughing of the wall fill and provide an aesthetic exterior finish.
The steps for the design of a Tensar Geogrid reinforced soil retaining wall include:

- qualifying design assumptions
- defining soil, reinforcement, geometry and loading parameters
- calculating external stability
- calculating internal stability
- developing construction drawings and specifications

A design example illustrating the use of this guideline is presented in Appendix A.

3.2 Assumptions

The following step-by-step method is directly applicable only to Tensar Geogrid reinforced Mesa Systems which meet all of the following assumptions:

1. Geogrid-soil interaction coefficients (C_i) are determined by pullout tests as described in Section 2.
2. Allowable strength (T_a) is determined by procedures outlined in Section 2 accounting for the influence of junction strength, creep, installation damage, durability and an overall factor of safety for design uncertainties.
3. Soil reinforcement consists of horizontal layers of Tensar Geogrids.
4. The connection between concrete units and geogrids is adequate to resist movement or pullout at the face both during and after soil backfill and compaction.
5. Wall foundation is competent. (An independent check of allowable foundation bearing pressures should be made by a registered professional geotechnical engineer.)
6. Reinforced and retained fills are constructed with low plastic to non-plastic, fine grained soils or granular soils and a ø' only ($c' = 0$) analysis is appropriate.
7. Uniform soil properties exist within each distinct zone (wall fill, retained backfill and foundation).
8. Surcharge loads, if any, act uniformly on top of the reinforced wall fill and retained backfill zones.
9. Seismic forces, if any, are accounted for in the design. (Seismic design is not discussed in this guideline.) Contact 800-TENSAR-1 for specific seismic design assistance.
10. Adequate surface and subsurface drainage is provided to assure no hydrostatic forces act on the wall facing.
11. A top slope on the reinforced wall is stable. (An independent check of stability of the top slope should be made by a registered professional geotechnical engineer.)

The design method and design charts presented in this Technical Note do not apply to tiered or benched wall systems or to any other geometry not specifically shown in the design charts. Global stability and subsequent reinforcement requirements must be calculated using slope stability analysis techniques for a multiple wall system. Please call 800-TENSAR-1 for details on the design of tiered wall systems and systems with other geometries not shown in the design charts.

3.3 DETERMINATION OF SOIL, REINFORCEMENT, GEOMETRY AND LOADING PARAMETERS

3.3.1 Soil Parameters

The moist unit weight (lb/ft^3) of the wall fill and backfill and the soil strengths of the wall fill, backfill and foundation should be determined with standard soil mechanics laboratory testing equipment. Alternatively, a qualified geotechnical engineer may establish parameters based on experience with the specific soil types. All soil strengths should be expressed in terms of effective strength (drained conditions) parameters unless otherwise required.

3.3.2 Reinforcement Parameters

The recommended values of geogrid–soil interaction coefficient (C_i) and design strength are listed in Tables 2–1 and 2–2. Values for C_i and geogrid design strength should be selected based on the geogrid and soil type used as the reinforced wall fill.

3.3.3 Geometry Parameters

The wall height (H), wall batter and slope angle, must be defined to determine the loading on the wall and the required number of geogrid reinforcement layers. The reinforcement coverage (P_c) used in internal stability calculations is usually 100% but may vary. The segmental concrete facing unit height is 8 inches for the Mesa High Performance, Standard and XL units and 4 inches for the Mesa Landscape unit. These dimensions should be used for lift spacing.

3.3.4 Loading Parameters

A uniformly distributed surcharge load, q (lb/ft^2), may be incorporated into the design. This
surcharge load is assumed to act upon the reinforced wall fill and retained backfill zones and is usually assumed to act on only the horizontal surfaces.

3.4 EXTERNAL STABILITY

It is generally assumed that reinforced soil retaining walls are subject to the same external stability design criteria as conventional gravity type retaining walls.

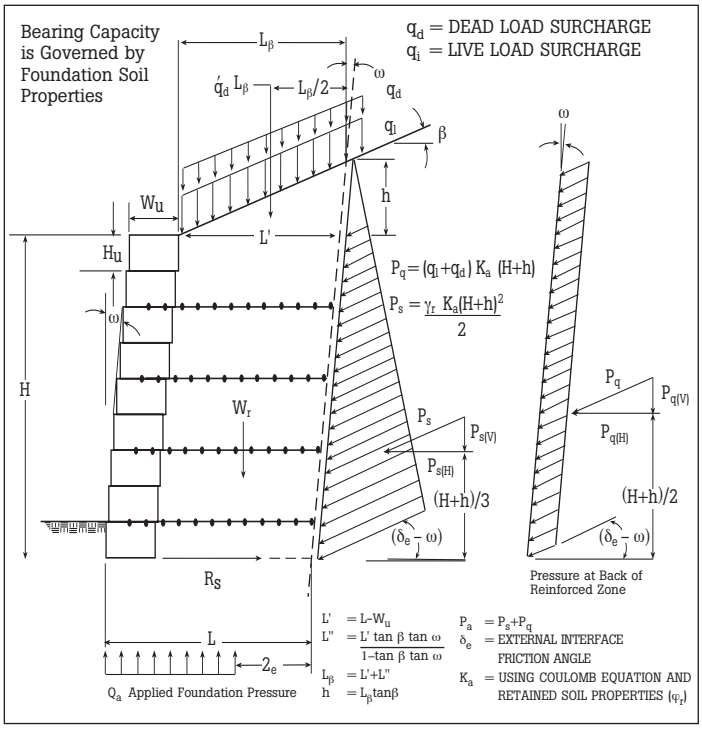


Figure 3.2 External Forces (NCMA, 1997)

External forces are summarized in Figure 3.2. The four modes of external failure (see Figures 3.3 to 3.6) usually considered include:

1) sliding
2) overturning
3) bearing
4) global stability

External stability analysis ensure that the reinforced structure is stable against the action of the lateral pressures applied by the retained backfill. The lateral pressures exerted by the retained backfill on the reinforced soil mass are illustrated in Figure 3.2. An active earth pressure coefficient, K_{ia}, is used to calculate the lateral pressure distribution due to the retained backfill. The vertical pressures within and at the base of the reinforced soil mass are due to soil weight, surcharge loads and overturning movement due to the lateral thrust of the retained backfill. Calculation of these vertical pressures assumes a pressure distribution similar to that assumed by Meyerhof for eccentrically loaded footings and is described by Equation 3.5.

A preliminary length of geogrid reinforcement, L, is determined during the external stability analysis. This overall length from the face of the wall to the tail of the geogrids is assumed to be constant throughout the height of the wall structure. The following paragraphs describe analysis for each respective mode of external stability calculations.

3.4.1 Sliding

Sliding stability (Figure 3.3) refers to the action of the entire reinforced wall fill prism or mass being driven outward by the lateral thrust of the retained backfill.

The factor of safety, FS_{SL}, against sliding is defined as the resisting frictional force at the base of the wall divided by this lateral thrust. A minimum factor of safety against sliding of 1.5 is typically used. Sliding failure should be checked at no less than two elevations.

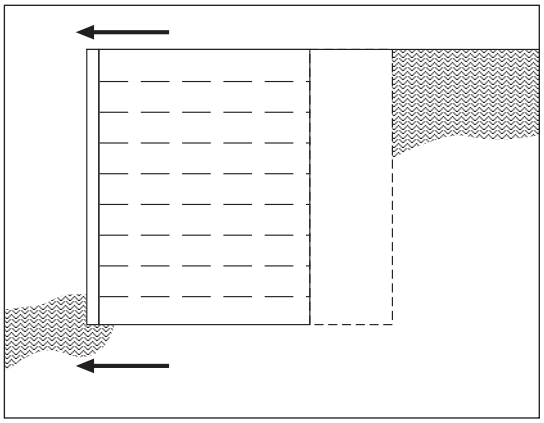


Figure 3.3 Sliding Failure

The factor of safety against sliding along a plane at the interface between the foundation soil and the reinforced fill can be calculated as follows:

Equation 3.1

$$FS_{SL} = \frac{R_s}{P_{s(H)} + P_{q(H)}} = \frac{C_{ds}[c_f L + (q_d L_\beta + W_{r(i)} + W_{r(\beta)}) \tan\phi'_f]}{[0.5\gamma_r (H+h) + q_l + q_d] K_a (H+h) \cos(\delta_e - \omega)}$$

where:

γ_r = Moist unit weight of retained backfill, lb/ft^3
c_f = Cohesion of foundation soil
ϕ'_f = Angle of internal friction of foundation soil, degrees
δ_e = External interface friction angle (lessor of $\phi_{i\ or}\ \phi_r$)
ϕ_r = Angle of internal friction of retained fill, degrees
ϕ'_i = Angle of internal friction of reinforced wall fill, degrees
C_{ds} = Interaction coefficient for direct sliding

See Figure 3.2 for information about other parameters

At this first elevation the C_{ds} value is equal to 1.0. The second elevation is along a plane at the interface of the lowest geogrid and the reinforced soil. It is usually assumed that this lowest geogrid layer occurs at a height above the base of the wall equal to at least one compacted soil lift thickness. An interaction coefficient for sliding, C_{ds}, is incorporated into equation 3.1 to check sliding at this depth. If no test data is available the typical C_i values for Tensar Geogrids as summarized in Table 2.1 can be used.

3.4.2 Overturning

Overturning stability is based upon the assumption that the reinforced soil mass behaves as a rigid body which resists the overturning forces exerted by the lateral thrust of the retained backfill (Figure 3.4). The factor of safety for overturning is defined as the resisting moment generated by the reinforced soil mass, about the wall toe, divided by the overturning moment due to the lateral thrust. A minimum factor of safety of 2.0 is typically used for overturning calculations.

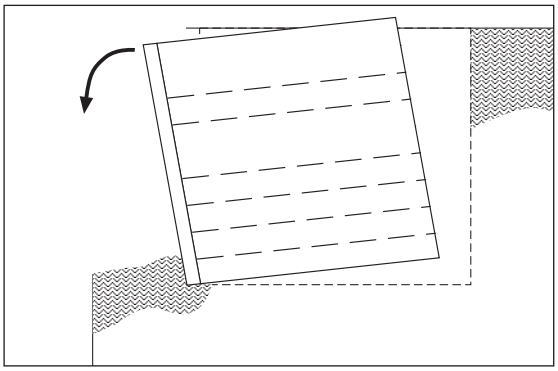


Figure 3.4 Overturning Failure

The factor of safety against overturning may be computed as follows:

Equation 3.2

$$FS = \frac{M_r}{M_o} = \frac{W_{r(i)}\, X_{r(i)} + W_{r(\beta)}\, X_{r(\beta)} + q_d\, L_\beta X_{q(\beta)}}{P_{s(H)} Y_s + P_{q(H)} Y_q}$$

where: M_r = The sum of the resisting moments

M_o = The sum of the driving moments due to the horizontal earth forces acting at the rear of the reinforced soil zone.

3.4.3 Bearing

Bearing capacity of the foundation is a measure of the ability of the foundation soils to support the imposed loading of the wall structure. A bearing capacity failure (Figure 3.5) can be either a "shear" failure of the foundation resulting in a loss of support and failure of the wall system, or may be excessive settlement of the foundation resulting in tilting. For Mechanically Stabilized Earth (MSE) wall structures, the ultimate bearing capacity based on shear failure will seldom govern. Even over soft foundations, settlement will generally govern. The ultimate bearing capacity can be estimated as follows:

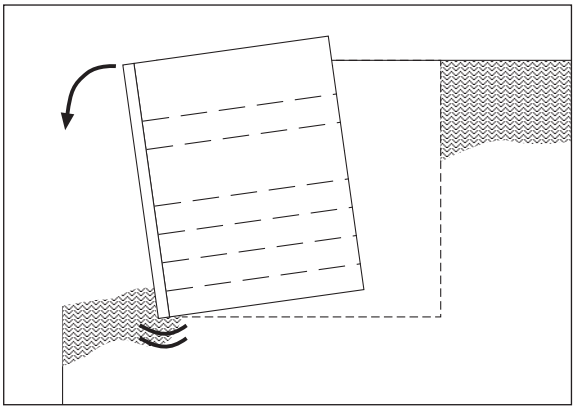


Figure 3.5 Bearing Failure

Equation 3.3 $q_{ult} = c_f N_c + 0.5\gamma_f B N_\gamma + \gamma_f H_{emb} N_q$

where:
$N_q = e^{\pi \tan \phi'_f} \cdot \tan^2 (45^\circ - \phi'_{f/2})$
$N_c = (N_q - 1) \cdot \cot \phi'_f$
$N_\gamma = 2 (N_q - 1) \cdot \tan \phi'_f$
B = equivalent foundation width ($B = L - 2e$)
H_{emb} = wall embedment depth
c_f = foundation cohesion
γ_f = unit weight of foundation soil

The eccentricity can be calculated as follows:

Equation 3.4
$$e = \frac{P_{s(H)} Y_s + P_{q(H)} Y_q - W_{r(i)} (X_{r(i)} - L/2) - W_{r(\beta)} (X_{r(\beta)} - L/2) - q_d L_\beta (X_{r(\beta)} - L/2)}{W_{r(i)} + W_{r(\beta)} + q_d L_\beta}$$

The applied bearing pressure $\boldsymbol{Q_a}$ acting over the equivalent bearing width $\boldsymbol{B}$ is

Equation 3.5 $Q_a = [W_{r(i)} + W_{r(\beta)} + (q_1 + q_1) L_\beta]/B$

The factor of safety against bearing capacity failure (shear failure) of the foundation may be estimated using a Meyerhof type of pressure distribution. A uniform bearing pressure is assumed to exist over a length equal to L–2e, where e is the eccentricity of the bearing pressure resultant from the vertical centerline of the wall fill.

The factor of safety for bearing failure is equal to the ultimate bearing capacity divided by the applied bearing pressure. The width of the footing used for the bearing analysis is equal to L–2e.

The minimum factor of safety required for bearing is usually taken as 2.0 to 3.0. Generally accepted recommendations for minimum embedment depths for MSE structures for adequate bearing are as follows:

Slope In Front of Structure		Minimum Embedment*
Horizontal	for walls	H/20
	for abutments	H/10
3H:1V	walls	H/10
2H:1V	walls	H/7
1.5H:1V	walls	H/5

* American Association of State Highway Transportation Officials (AASHTO) recommends: "The minimum embedment depth for all walls from the adjoining ground to the bottom of footings shall be based on the bearing capacity, settlement, and stability requirements including the effects of frost heave, scour, proximity to slopes, erosion and the potential for future excavation in front of the wall." National Concrete Masonry Association (NCMA) recommends a minimum block embedment depth of 0.5 feet.

The flexibility of the Mesa Systems allows walls to be designed for a minimum embedment of H/20 with a minimum embedment of one foot from adjacent ground to the bottom of footing. Potential for the following conditions should be evaluated on an individual basis:

a) disturbance of the soils in front of the wall by trenching
b) sloping toe conditions
c) problem soils such as collapsible or swelling soils, frost heave, or other foundation related problems

3.4.4 Global Stability

The global stability (Figure 3.6) refers to overall stability of the wall and retained soils. Slope stability safety factors ranging from 1.3 to 1.5 are typical in geotechnical engineering practice.

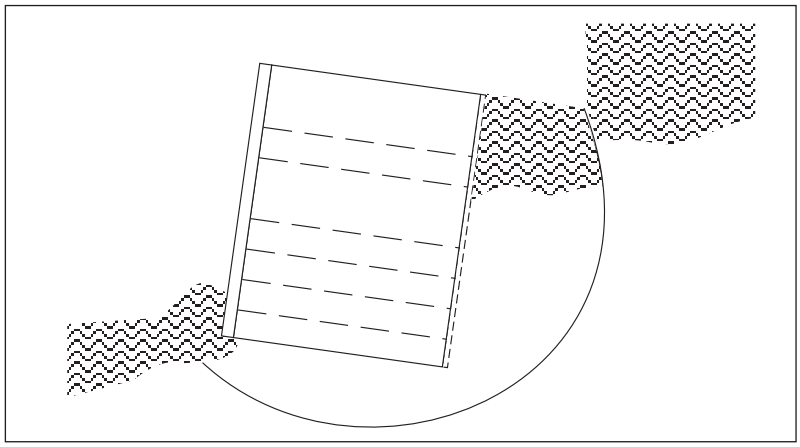


Figure 3.6 Global Failure

3.5 INTERNAL STABILITY

To be internally stable, a reinforced soil retaining wall must be coherent and self-supporting under the action of its own weight and any externally applied forces. This is accomplished through stress transfer from the soil to the geogrid reinforcement. The geogrid reinforcement must be selected and spaced to preclude tension rupture and to prevent pullout from the soil mass beyond the assumed failure plane. The purpose of the internal stability analysis is to verify that the geogrid is not over-stressed and that all geogrid lengths provide sufficient embedment.

The tie-back wedge method of analysis is used for analysis of geogrid reinforced soil retaining walls. With this method it is assumed that the full shear strength of the reinforced fill is mobilized and active lateral earth pressures are developed. These pressures must then be resisted by the reinforcement tensile force. The assumed failure plane is defined by the Coulomb failure surface occurring at an angle of α from the horizontal, which can be determined from the equation below. The following paragraphs describe the steps for internal stability calculations.

Equation 3.6

$$\tan(\alpha - \phi) = \frac{-\tan(\phi - \beta) + \sqrt{\tan(\phi - \beta)\,[\tan(\phi - \beta) + \cot(\phi + \omega)]\,[1 + \tan(\delta - \omega)\cot(\phi + \omega)]}}{1 + \tan(\delta - \omega)\,[\tan(\phi - \beta) + \cot(\phi + \omega)]}$$

3.5.1 Determination of Geogrid Design Strength

The design strength of the geogrid for the particular site conditions for the project may be determined from Table 2–2.

3.5.2 Tension Analysis

The calculated tensile stress in each layer of geogrid reinforcement must be equal to or less than the allowable design strength of the geogrid. The tensile force in the geogrid at depth h_i (per unit width) is given by:

Equation 3.7 $$T_i = K_{ar} R_{vi} V_i$$

where: T_i = Tension per unit width in geogrid layer located at depth h_i, lb/ft
K_{ar} = Coefficient of active earth pressure of the reinforced wall fill, dimension–less
R_{vi} = Vertical stress at plane of reinforcement, lbs/ft^2
V_i = Contributory heights of soil being reinforced by *i*th layer, ft

The vertical spacing of geogrid reinforcement is a function of the design strength, wall height, shear strength of the fill soils and internal and external loadings.

Equation 3.8 $$V_{imax} = \frac{T_a}{K_{ar} R_{vi}}$$

Using the vertical load due to the overburden pressure for R_v within the reinforced soil mass, the above equation becomes:

Equation 3.9 $$V_{imax} = \frac{T_a}{K_{ar} (\gamma_i h_i + q)}$$

where: γ_i = Moist unit weight of reinforced backfill, lb/ft^3
q = Uniform surcharge on the top of the wall

The vertical spacing is determined at each geogrid location using equation 3.9, starting at the base of the wall and working toward the top of the wall. The first layer of reinforcement is placed at $V_{imax}/2$, with subsequent layers placed at a vertical spacing of V_{imax} incrementally to the top of the wall. For construction considerations (i.e., ability to maintain alignment), maximum vertical spacing of reinforcement has been found to be approximately 2.5 feet. Spacings greater than this tend to cause unit tilting during compaction of fill behind the blocks.

3.5.3 Determination of Required Embedment Length

The pullout resistance in each layer of reinforcement is a function of the length of reinforcement behind the failure plane, the overburden at h_i and the interaction coefficient of the geogrid and soil. The allowable geogrid pullout capacity for each geogrid, t_{ai}, is calculated as:

Equation 3.10 $$t_{ai} = \frac{2 (C_i L_{ai} R_{vi}) \tan\phi'_i}{FS_{po}} \leq T_a$$

where: ϕ'_i = Angle of internal friction of reinforced fill
L_{ai} = Length of geogrid past failure plane
R_{vi} = $(h_i \gamma_i) + q$
FS_{po} = Factor of safety against geogrid pullout

For each geogrid, the pullout capacity calculated t_{ai}, should be compared to T_a. The minimum of these values is used in subsequent calculations as t_{ai}. The factor of safety against pullout should be greater than or equal to 1.5.

For cases where the factor of safety for pullout is less than 1.5, the designer has two choices:
a) lengthen geogrids to increase embedment beyond the failure plane
b) increase the number of geogrids crossing the failure plane

3.5.4 Minimum Recommended Embedment Length

The minimum recommended embedment length for general wall design using Tensar Geogrids is 0.6 times the height of the wall, and minimum anchorage length passing the failure plane is 1 ft. (12"). Reinforcement lengths are typically longer than this as required by either internal or external stability requirements. Special cases, such as rock cuts where the retained fill will place little or no loads on the geogrid reinforcement, may utilize shorter geogrids. However, these wall cases must be analyzed for potential external failure modes and must be stable for ***all*** external and internal conditions.

3.5.5 Resistance to Bulging

Bulging of an SRW is caused by lateral earth pressures greater than interlock shear capacity between the segmental concrete facing units. The inclusion of a Mesa mechanical connector can significantly increase the interlock shear capacity and eliminate the possibility of bulging failure. The shear capacity $V_{u(i)}$ at any interface level can be determined using the following equation:

Equation 3.11 $V_{u(i)} = \alpha_u + W_{w(i)} \tan\lambda_u$

where: $W_{w(i)}$ = total weight above the *i* interface level
α_u and λ_u = determined from laboratory tests

The factor of safety against shear capacity FS_{sc} can be calculated as shown below. The minimum factor of safety for facing shear capacity is 1.5.

Equation 3.12 $FS_{sc(i)} = V_{u(i)} / [P_{a(h,i)} - (T_{i+1} + T_{i+2} + ...)]$

where: $P_{a(h,i)}$ = total horizontal earth force above the *i* interface level

4.0 DESIGN AND CONSTRUCTION CONSIDERATIONS

Specialized equipment is not required for a contractor to successfully build a low-to-medium height Tensar Geogrid reinforced soil retaining wall with Mesa Units. Construction and material specification guidelines are detailed in Section 5.0. Key components of design and construction are considered below.

4.1 MESA UNITS

Mesa segmental concrete facing units are available in a variety of facial textures (split face, plain face, radius), sizes and colors, providing a wide choice of architectural finishes. The configuration of the units allows construction of walls with concave and convex curves, a near vertical face and a 4.5° batter—all important characteristics for high visibility walls. The relatively low weight of the blocks facilitates construction without the need for heavy construction equipment. The walls can be erected with a small loader, a small compactor and a crew of three or four workers. The units are dry stacked (i.e., mortar or grout is not used to bond the units together).

Because the Mesa Connector provides a mechanical end-bearing structural connection which does not rely on friction for connection strength, unit (core) fill is not required within the Mesa Units, as is the case with other SRW units. The area between and behind the units should be filled with granular material such as crushed stone, or gravel. The granular fill should be placed for a minimum distance of one foot behind the units.

4.2 TENSAR GEOGRIDS

Two types of Tensar Geogrids are used in retaining walls: Uniaxial (UX) and Biaxial (BX). These terms refer to the number of directions in which a punched sheet of polymer has been drawn in the manufacturing process. UX Geogrids have one direction of draw and BX Geogrids have two. Drawing aligns the long-chain molecules of the polymer, giving the geogrid high tensile strength, high modulus and resistance to deformation.

4.2.1 Geogrid Orientation

For UX Geogrids, the long axis of the apertures must be oriented perpendicular to the wall face. For BX Geogrids, the transverse roll direction (cross machine direction) must be oriented perpendicular to the wall face (i.e. rolled out parallel to the wall face).

Figure 4.1 shows Tensar UX and BX Geogrids and their correct orientation in relation to a typical Mesa Unit. A simple check of geogrid orientation is needed to ensure that the longer of the two geogrid aperture axes is perpendicular to the wall face.

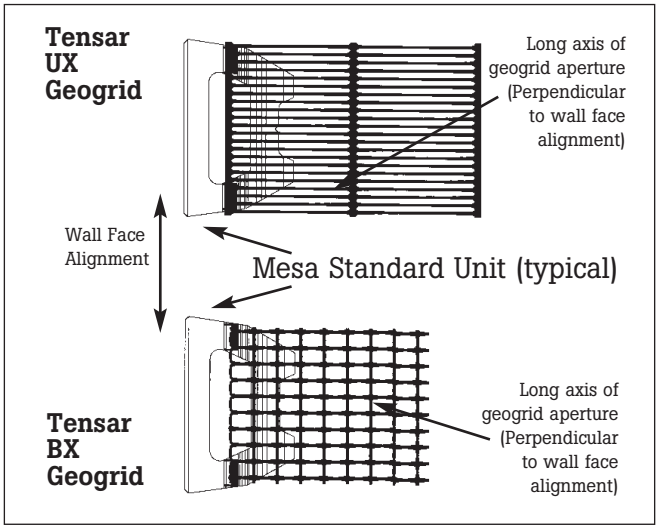


Figure 4.1 UX & BX Geogrid Orientation

4.2.2 Geogrid Connection to the Mesa Units

The geogrid is placed between the block layers. A positive, mechanical connection between the Tensar Geogrid and Mesa Unit is achieved by a Mesa Connector, manufactured from polyethylene resin. The geogrid should be installed with the transverse bar just past the connector slot on the

top of the Mesa Unit. Place the teeth of the connector such that they pass through the geogrid apertures and engage the rear of the first transverse bar. For the Mesa Standard Units, shown in Figure 4.1, a Mesa Standard Connector is placed in each of the connector slots (i.e., 2 connectors per unit). For the High Performance Unit, the connector must be placed to span the space between adjacent units, and side by side for the entire width of the geogrid. A minimum of two teeth must be engaged in each adjacent High Performance Mesa unit. Use a dead blow (rubber) hammer to seat the connector in the slot on the top of the unit. A 2" x 4" block, used as a setting tool, facilitates the installation of either connector. Slack must be removed from the geogrid prior to final setting of the connector. As with any segmental concrete facing unit, minimal lateral movement may occur during wall construction as the geogrid and soil "take up" the load. The fill should be placed and compacted in a uniform manner. This will help minimize differential lateral movement.

4.2.3 Geogrid Lengths and Types

On many wall projects, geogrid lengths vary from station to station due to changes in wall height. For construction expediency, the geogrid reinforcement is often cut to length in a staging area. These cut lengths are then stockpiled and marked or tagged in some manner to indicate their length. Different length geogrids should be stockpiled separately.

A potential problem may arise on projects where two different geogrids are utilized. For instance, Tensar UX1400MSE and UX1500MSE geogrids may look very much alike. Confusion between different geogrids can be eliminated by proper separation during stockpiling, precutting, and tagging operations. The geogrids may also be color coded with spray paint prior to removing product labels.

4.2.4 Geogrid Placement

Geogrids should be laid horizontally on compacted fill and pulled taut from their connection to the concrete units before wall fill is placed over them. Care must be taken to prevent slack from becoming trapped within the geogrid as fill is placed. Tracked construction equipment must not be operated directly upon the geogrid. Rubber-tired equipment may pass over the geogrid at slow speeds. However, sudden braking and sharp turning that can displace geogrids from their intended positions should be avoided.

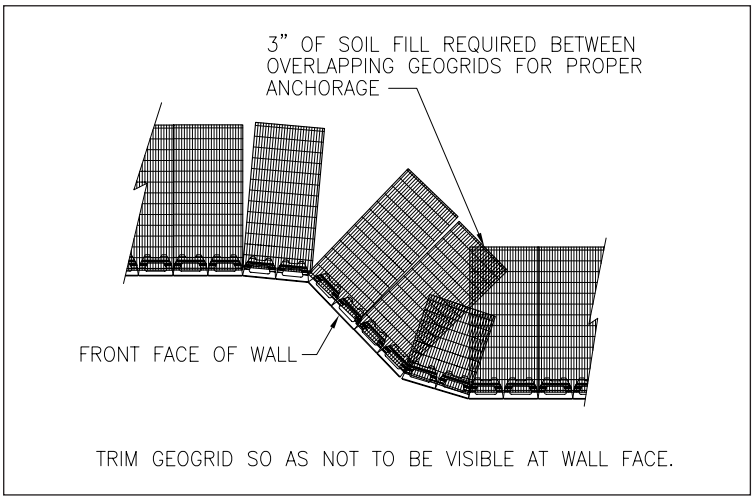


Figure 4.2 Placement of Geogrid

Overlapping geogrids on convex curves of wall alignments (see Figure 4.2) should be separated by at least 3 in. of compacted wall fill. Geogrids on concave curves of wall alignments may simply diverge from the face, see (Figure 4.2). Overlapping of the geogrid should not take place under the Mesa Units to help ensure that the units are level.

4.3 REINFORCED WALL FILL

The techniques utilized in placing and compacting the wall fill soil will affect the performance of the structure during and after construction. The following methods are suggested to prevent inconsistent and/or excessive wall unit movement:

- compaction equipment should be operated parallel to the wall face
- fill compaction should start at the wall units and be worked back towards the retained backfill
- only light-weight hand operated compaction equipment should be operated within 3 ft from the wall face
- Wall fill should be graded to drain away from wall units and rolled smooth at the end of each day's operation. In addition, intermediate geogrid should be used between primary reinforcement geogrid layers when the spacing is greater than twice the depth of the SRW unit. Intermediate geogrid reinforcements may also be used to help maintain alignment where necessary.

4.4 DRAINAGE FEATURES

Drainage of soil within a retaining wall structure is a vital design and construction detail that must not be overlooked. Groundwater infiltration or surface-water runoff can cause saturation of a wall fill which can significantly reduce soil strength, increase soil loads and jeopardize the stability of a wall structure. Key drainage features of a typical cross section are shown in Figure 4.3 and 4.3a.

If the wall is not designed for saturated conditions, drainage should be provided to prevent the fill from becoming saturated. A subdrain system can be placed at the back and/or bottom boundaries of the reinforced wall fill zone to provide positive flow. It is easy to install on backcut slopes, or even vertically. Sand and gravel blankets could alternatively be used to provide drainage. However, soil drainage layers require filter materials between zones of different soil types.

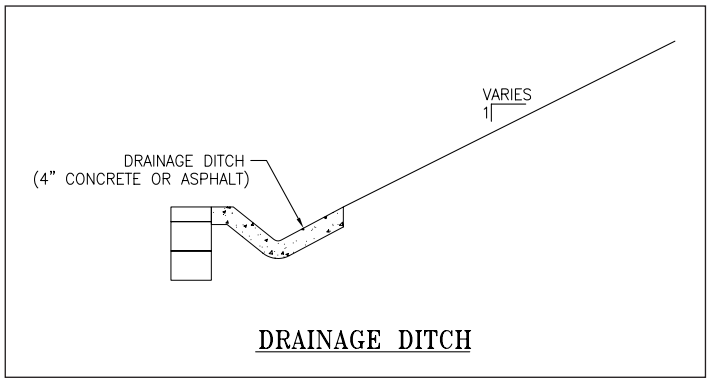


Figure 4.3 Drainage Features

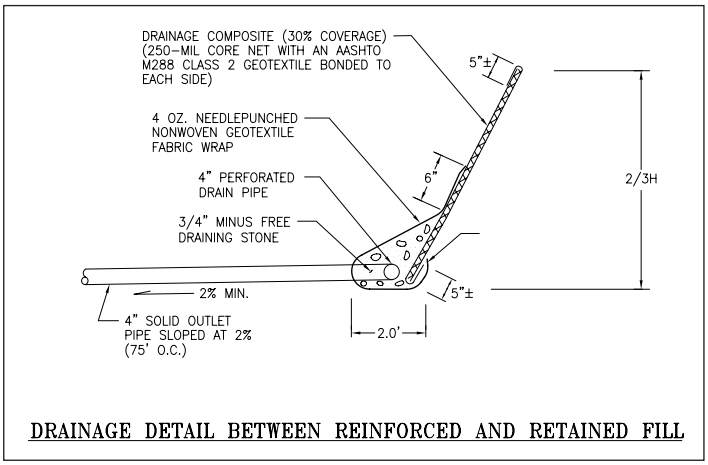


Figure 4.3a Drainage Features

4.5 LEVELING PAD

Horizontal and vertical alignments of the retaining wall are established by construction of a leveling pad at the base of the face. The pad is typically at least 6 inches thick and 24 inches wide (12 inches wider than the unit) and made of unreinforced concrete or crushed stone.

5.0 CONSTRUCTION AND MATERIAL SPECIFICATION GUIDELINES FOR GEOGRID REINFORCED SOIL RETAINING WALLS WITH MESA UNITS.

Note: For the most updated Specification Guidelines visit www.tensarcorp.com.

The following guidelines have been developed to aid in the preparation of construction and material specifications for specific projects. These guidelines should be modified to:

- incorporate specific Mesa Unit criteria
- incorporate any special project requirements
- delete any unnecessary requirements
- provide a format and wording consistent with other project specifications
- provide consistency with construction drawings

These specifications include guidelines for the physical and mechanical properties of Mesa units and Tensar Geogrid reinforcements. These properties are of primary importance in ensuring satisfactory long-term performance of these retaining walls.

THIS SECTION IS WRITTEN IN CSI 3-PART FORMAT AND IN CSI PAGE FORMAT. NOTES TO THE SPECIFIER, SUCH AS THIS, ARE INDICATED WITH A ## SYMBOL AND MUST BE DELETED FROM THE FINAL SPECIFICATION.

IT IS ASSUMED THAT THE GENERAL CONDITIONS BEING USED ARE AIA A201-87. SECTION NUMBERS ARE FROM THE 1995 EDITION OF MASTERFORMAT.

5.1 GENERAL

5.1.1 Summary

A. Section Includes – Mechanically Stabilized Earth (MSE) retaining wall system having high density polyethylene geogrids positively connected to Mesa Segmental Concrete Facing Units.

EDIT LIST BELOW TO CONFORM TO PROJECT REQUIREMENTS. VERIFY SECTION NUMBERS AND TITLES.

B. Related Sections
   1. Section 02200 – Site Preparation
   2. Section 02300 – Earthwork

5.1.2 References

DELETE REFERENCES NOT USED IN PART 2 OR PART 3.

A. American Association of State Highway and Transportation Officials (AASHTO)
   1. T289 – Determining pH of Soil for Use in Corrosion Testing
   2. M288-96 – Standard Specification for Geotextiles
   3. Standard Specification for Highway Bridges (2002 Interim)

B. American Society for Testing and Materials (ASTM)
   1. C1372–98 – Standard Specification for Segmental Retaining Wall Units
   2. C140–98b – Standard Test Methods of Sampling and Testing Concrete Masonry Units
   3. C150–97a – Standard Specification for Portland Cement
   4. C33–99 – Standard Specification for Concrete Aggregates
   5. C331–98b – Standard Specification for Lightweight Aggregates for Concrete Masonry Units
   6. C595–98/C595M–97 – Standard Specification for Blended Hydraulic Cements
   7. C618–98 – Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete
   8. C90–98 – Standard Specification for Load–Bearing Concrete Masonry Units
   9. C989–97b – Standard Specification for Ground Granulated Blast–Furnace Slag for Use in Concrete and Mortars
   10. D698–98 – Standard Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort.
   11. D4355–92 – Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon–Arc Type Apparatus)
   12. D4716–95 – Standard Test Method for Constant Head Hydraulic Transmissivity (In–Plane Flow) of Geotextiles and Geotextile Related Products
   13. D5035–95 – Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method)
   14. D6637 – Determining Tensile Properties of Geogrids by the Single or Multi–Rib Test Method
   15. F904–91 – Standard Test Method for Comparison of Bond Strength or Ply Adhesion of Similar Laminates Made from Flexible Materials

C. Geosynthetic Research Institute (GRI)
   1. GG2–87 – Standard Test Method for Geogrid Junction Strength
   2. GG4–91 – Determination of the Long–Term Design Strength of Geogrids
   3. GG5–91 – Standard Test Method for "Geogrid Pullout"

D. National Concrete Masonry Association (NCMA)
   1. TEK 2–4A – Specification for Segmental Retaining Wall Units
   2. Design Manual for Segmental Retaining Walls, Second Edition, 1997.

E. Tensar Earth Technologies, Inc. (TET)
   1. "Design Guidelines for Tensar Geogrid Reinforced Soil Walls with Mesa Segmental Concrete Facing units," TTN:MESA–DG.

5.1.3 Definitions

A. **Ultimate Tensile Strength** – Breaking tensile strength when tested in accordance with ASTM D6637. Values shown are minimum average roll values.

B. **Junction Strength** – Breaking tensile strength of junctions when tested in accordance with GRI–GG2–87 tested at a strain rate of 10 % per minute based on this gauge length. Values shown are minimum average roll values.

C. **Tensar Structural Geogrids** – A polymeric grid formed by a regular network of integrally connected tensile elements with apertures of sufficient size to allow interlocking with surrounding soil, rock or earth and function primarily as reinforcement.

D. **Mesa Segmental Concrete Facing Units** – A segmental concrete facing unit, machine–made from Portland Cement, water and mineral aggregates.

E. **Mesa Connector** – A mechanical connection device made of high density polyethylene with fiberglass inclusions to positively connect the Tensar Geogrid to the Mesa Units.

F. **Unit Fill (Core Fill)** – Free–draining, coarse–grained soil which is placed within the empty cores of the Segmental Concrete Facing Unit. Unit Fill may not be required within the Mesa Unit if the Contractor can provide the Engineer and/or Architect with connection testing performed without Unit Fill verifying that the connection strength of the system exceeds the requirements set forth in the Design Data.

G. **Drainage Fill** – Free–draining, coarse–grained soil which is placed behind and in the openings between the Mesa Units as specified on the Plans.

H. **Reinforced Backfill** – Compacted structural fill placed behind the Drainage Fill or directly behind the Mesa Units as outlined on the Plans.

I. **Long–Term Design Strength (LTDS or T_{al})** – The maximum allowable stress level of the polymeric grid used in the internal stability design calculations of the retaining wall. Ultimate Tensile Strength reduced by the effects of installation damage and durability.

J. **Long–Term Allowable Design Strength (T_a)** – The Long–Term Design Strength (LTDS or T_{al}) reduced by the Factor of Safety for design uncertainties ($T_a = T_{al}/FS_{UNC}$).

5.1.4 System Description

A. **Design Requirements** – Engage and pay for the services of a Designer to design and develop Design Data for the retaining wall system.

B. **Performance Requirements** – Design the retaining wall system in accordance with the design guidelines of Tensar Earth Technologies.

5.1.5 Submittals

A. Product Data – Manufacturer's materials specifications, installation instructions and general recommendations.

B. Certifications – The Mesa Retaining Wall Systems' supplier shall provide certification that the ultimate strength of the Tensar Geogrid, per Section 1.03 of GG1, is equal to or greater than the ultimate strength specified on the Plans.

C. Plans – Engineering drawings, elevations and large scale details of elevations, typical sections, details and connections.

D. Samples
   1. Geogrid – 4" by 14" piece
   2. Mesa Segmental Concrete Facing Unit – 8" by 18" piece of exposed face showing selected color and texture
   3. Connector – supply one connector

E. Quality Control Submittals
   1. Design Data – Design calculations and plans for the retaining wall system sealed by the Designer.
   2. Certificates – Manufacturer's certification that the properties of the geogrid are equal to or greater than those specified in Section 2.02A.

F. Code Requirements – The supplier of the Mesa Systems shall furnish the Engineer and/or Architect with a complete and current evaluation by ICBO/ICC.

5.1.6 Quality Assurance

A. Designer – A Professional Engineer, registered in the State where the project is located, who is employed by a firm that has designed at least 500,000 square feet of segmental retaining walls, and who can provide a certificate of Errors and Omissions insurance to the Engineer and/or Architect with a minimum value of $3,000,000 per occurrence and in the aggregate.

B. Mock–Ups
   1. Prior to erection of retaining walls, erect a sample wall using materials shown and specified. Build mock–up at the site, where directed, approximately 4 ft by 4 ft.
   2. Do not start masonry work until the mock–up is approved by the Architect and/or Engineer. Retain mock–up during construction as a standard for judging completed work. Do not alter or destroy mock–up until work is completed.

C. Pre–Construction Conference – Prior to erection of retaining walls, hold a meeting at the site with the retaining wall materials supplier, the retaining wall installer, and the Designer to review the retaining wall requirements. Notify the Owner, the Engineer and/or Architect at least 3 days in advance of the time of the meeting.

5.1.7 Delivery, Storage, and Handling

A. Storage and Protection
   1. General
      a. Prevent excessive mud, wet concrete, epoxy or other deleterious materials from coming in contact with and affixing to retaining wall materials.
   2. Polymeric Materials
      a. Store at temperatures above –20° F (–29° C).
      b. Rolled materials may be laid flat or stood on end.

5.2 PRODUCTS

5.2.1 Manufacturers

A. The Mesa Unit shall be manufactured by an approved Mesa Licensee and/or an authorized manufacturer of the Mesa Retaining Wall Systems.

B. Tensar Geogrid shall be manufactured by The Tensar Corporation located in Morrow, GA.

C. Substitutions – See Section 01600.

5.2.2 Materials

A. Tensar Geogrids

SELECT ONE OR MORE OF THE FOLLOWING:

1. UX800MSE:
   a. Long-Term Design Strength (Sand, Silt and Clay): 860 plf.
   b. Junction Strength: 3,180 plf.
2. UX1000MSE:
   a. Long-Term Design Strength (Sand, Silt and Clay): 1,210 plf.
   b. Junction Strength: 2,950 plf.
3. UX1100MSE:
   a. Long-Term Design Strength (Sand, Silt and Clay): 1,620 plf.
   b. Junction Strength: 3,690 plf.
4. UX1400MSE:
   a. Long-Term Design Strength (Sand, Silt and Clay): 2,070 plf.
   b. Junction Strength: 4,520 plf.
5. UX1500MSE:
   a. Long-Term Design Strength (Sand, Silt and Clay): 3,100 plf.
   b. Junction Strength: 7,200 plf.
6. UX1600MSE:
   a. Long-Term Design Strength (Sand, Silt and Clay): 4,110 plf.
   b. Junction Strength: 9,250 plf.
7. UX1700MSE:
   a. Long-Term Design Strength (Sand, Silt and Clay): 5,140 plf.
   b. Junction Strength: 10,970 plf.

LIGHTWEIGHT AND HEAVYWEIGHT UNITS ARE ALSO AVAILABLE. WEIGHTS ARE FOR NORMAL WEIGHT UNITS. APPROXIMATE UNIT WEIGHTS ARE BASED ON THE ACTUAL DENSITY OF THE MESA UNITS. DENSITIES MAY VARY DUE TO LOCAL RAW MATERIALS. MESA UNITS CAN BE MANUFACTURED IN CUSTOM COLORS. INSERT COLOR DESIGNATION.

B. Mesa Units – Hollow load-bearing units, ASTM C90–98, normal weight, Type II, minimum compressive strength of 4,000 psi, and produced by an approved Mesa Licensee conforming to TEK 2–4A, Section 3.1. Mesa Units shall have a maximum absorption rate of 8% by weight and shall have a minimum face shell of 2 in. For climates that exhibit daily low temperatures for 32° Fahrenheit or below for a total of 30 days or more in any calendar year, the maximum water absorption by weight shall be 6%.

1. Mesa High Performance Unit
    a. Size: 8" x 18" x 11"
    b. Weight: 80 lbs., nominal.
    c. Color
2. Mesa Standard Unit
    a. Size: 8" x 18" x 11"
    b. Weight: 75 lbs., nominal.
    c. Color
3. Mesa XL Unit
    a. Size: 8" x 18" x 22"
    b. Weight: 100 lbs., nominal.
    c. Color
4. Mesa Landscape Unit
    a. Size: 4" x 18" xx 11"
    b. Weight: 35 lbs., nominal.
    c. Color
5. Mesa Cap Unit
    a. Size: 4" x 18" x 11" minimum.
    b. Weight: 40 lbs., nominal.
    c. Color
6. Mesa Corner Unit
    a. Size: 8" x 18" x 9"
    b. Weight: 75 lbs., nominal.
    c. Color

C. Mesa Connectors – High density polyethylene with fiberglass inclusions

SELECT ONE OF THE CONNECTORS BELOW. NOTE THAT THE HIGH PERFORMANCE CONNECTOR IS COMPATIBLE ONLY WITH THE MESA HIGH PERFORMANCE UNIT.

1. High Performance Connector
2. DOT Connector
3. Standard Connector

5.2.3 Accessories

A. Drainage Composite – 6 oz. per sq. yd. polypropylene non–woven geotextile, AASHTO M288–96, Class 2, bonded to both sides of a polyethylene net structure.
   1. Minimum Allowable Transmissivity – Not less than 1.5 gal. per min. per ft. of width when tested in accordance with ASTM D4716–95 at a confirming pressure of 10,000 lbs. per sq. ft.
   2. Minimum Allowable Peel Strength of Geotextile from the Polyethylene Net – Not less than 250 gm. per in. of width when tested in accordance with ASTM F904–91.

B. Geotextile – 6 oz. per sq. yd. polypropylene non–woven geotextile, AASHTO M288–96, Class 2.

C. Turf Reinforcement Mat – Permanent turf reinforcement mat shall be used on all soil structures/slope facing adjacent to the retaining walls. Turf reinforcement mat shall be North American Green P300.

D. Adhesive – As recommended by Tensar Earth Technologies.

5.2.4 Backfill Materials

A. Fill Materials
   1. Unit Fill (Core Fill) – Free draining, coarse–grained soil that is placed within the empty cores of the Mesa Units.
      a. 100 to 75% passing a 1–in. sieve
      b. 50 to 75% passing a 3/4–in. sieve
      c. 0 to 60%t passing a No. 4 sieve
      d. 0 to 50% passing a No. 40 sieve
      e. 0 to 5% passing a No. 200 sieve

Note: Unit Fill may not be required for Mesa Units if the Contractor provides the Engineer with connection tests performed without Core Fill, which can verify that the connection capacity exceeds the design requirements.

   2. Drainage Fill – Free–draining, coarse–grained soil which is placed behind and in the openings between the Mesa Units as specified on the Plans.
      a. 100 to 75% passing in a 1–in. sieve
      b. 50 to 75% passing in a 3/4–in. sieve
      c. 0 to 60% passing in a No. 4 sieve
      d. 0 to 50% passing in a No. 40 sieve
      e. 0 to 5% passing in a No. 200 sieve

   3. Reinforced Backfill – Granular fill with a pH range of 2 to 12 and graded as follows:
      a. 100 to 75% passing a 2–in. sieve
      b. 100 to 75% passing a 3/4–in. sieve
      c. 100 to 20% passing a No. 4 sieve

d. 0 to 60% passing a No. 40 sieve
e. 0 to 35% passing a No. 200 sieve

Note: The Mesa Retaining Wall Systems shall include a Drainage Composite located behind the Reinforced Backfill volume (as defined on the Plans) together with an associated outlet pipe system whenever the percentage of Reinforced Backfill material passing the No. 200 sieve exceeds 15 percent.

5.3 CONSTRUCTION

5.3.1 Qualification

A. Contractor and site supervisor shall have proven qualified experience to complete the installation of the Mesa Systems.

5.3.2 Excavation

A. The subgrade shall be excavated vertically to the plan elevation and horizontally to the designed geogrid lengths.

B. Overexcavated and filled areas shall be compacted to a minimum of 95% Standard Proctor Dry Density in accordance with ASTM D698 and inspected by an Engineer.

C. Excavated materials that are used for backfilling the reinforcement zone shall be protected from the weather.

5.3.3 Foundation Preparation

A. Foundation trench shall be excavated to the dimensions indicated on the construction drawings.

B. The reinforced zone and leveling pad foundation soil shall be examined by an Engineer to ensure proper bearing strength.

C. Soils not meeting required strength shall be removed and replaced with the materials as approved by the Engineer.

D. Foundation materials shall be compacted to a minimum of 95% Standard Proctor Dry Density in accordance with ASTM D698–98 before placing the leveling pad.

5.3.4 Leveling Pad

A. The leveling pad shall consist of unreinforced concrete, unless specified as 3/4–in. minus well–graded aggregate, as indicated in the contract documents.

B. The leveling pad shall be level both horizontally and front–to–back to ensure the first course of units, and subsequent courses, are level.

5.3.5 Unit Installation

A. The first course of Mesa Units shall be carefully placed onto the leveling pad.

B. The first row of units shall be level from unit–to–unit and from front–to–back.

C. A string line can be used to align a straight wall, or flex pipes can be used to establish a smooth convex or concave curved wall.

D. Use the tail of the units for alignment and measurement.

E. All units shall be laid snugly together and parallel to the straight or curved line of the wall face.

F. The Mesa Units shall be swept clean of all debris before installing the next course of units and/or placing the geogrid materials.

G. A string line should be pulled after each course has been set to ensure that the walls geometry is being maintained. The string line can be referenced from the connector slot, rebar slot, or tail of the unit.

5.3.6 Connector And Geogrid Installation

A. Place the grid on the block, insert the connector teeth through the apertures of the grid into the slot in the underlying block, pull the grid snug against the teeth and hammer the connector into the slot.

B. Shim the overlying block course (in accordance with Tensar Earth Technologies recommendations) to maintain facing alignment and a level block surface.

C. For the Mesa Standard System:
   i. The grid shall be positioned laterally on the blocks such that all four Mesa Standard Connector teeth are driven into the slots.
   ii. The flags of the connectors shall be positioned forward for vertical walls and rearward for battered walls.
   iii. In the next course, each block shall be centered over the two underlying blocks such that the flags of the connectors extend up into the void of the overlying blocks.

D. For the Mesa High Performance System, the connector flags extend up into the slot in the bottom of the overlying blocks.

5.3.7 Drainage Fill and Unit Fill

A. Unit Fill, if required within the Mesa Unit voids, and Drainage Fill placed between the units and 12 inches behind the wall shall consist of a free–draining, coarse–grained soil meeting the requirements of Section 2.04.
B. Unit Fill, if required within the unit voids, and Drainage Fill shall be placed behind the wall before placing the geogrid materials.

5.3.8 Backfill

A. The Reinforced Backfill material shall be placed in maximum lifts of 10 in and shall be compacted to a minimum of 95% Standard Proctor Dry Density in accordance with ASTM D698–98.

B. Only hand–operated compaction equipment shall be used within 3 ft of the tail of the Mesa Units.

C. Soil density testing shall not be performed within 3 ft of the tail of the Mesa Units.

D. The backfill shall be smooth and level so that the geogrid lays flat.

E. The toe of the wall shall be filled and compacted as the wall is being constructed.

5.3.9 Cap Installation

A. The Mesa Cap Units, if required, shall be installed by attaching them to the units below using an approved exterior concrete.

B. Mesa Cap Units can be placed such that a nominal 1–in overhang is achieved.

C Mesa Cap Units and Segmental Concrete Facing Units shall be clear of all debris and standing water before placing the approved adhesive.

D. String line or flex pipes shall be used to align cap units.

5.3.10 Tolerances

A. Variation from Batter Indicated: Plus or minus 1/8 in. per ft., maximum.

6.0 REFERENCES

Koerner, Robert M., Designing with Geosynthetics, second edition, Prentice Hall, Englewood Cliffs, NJ, 1989, p. 306.

GRI–GG4 – Standard Test Method for Determination of the Long–Term Design Strength of Geogrids, Geosynthetic Research Institute, Drexel University, Philadelphia, PA, 1990.

GRI–GG5 – Test Method for Geogrid Pullout, Geosynthetic Research Institute, Drexel University, Philadelphia, PA, 1990.

Berg, R., and Swan, R., Pullout of Geosynthetics, (Draft) prepared for International Reinforced Soil Conference, University of Strathclyde, Glasgow, Scotland, September 1990. (Available through Tensar Earth Technologies, Inc.)

Bonaparte, R. and Berg, R., Long–Term Allowable Tension for Geosynthetic Reinforcement, Proceedings of Geosynthetics '87 Conference, Vol. 1, p. 181–192, New Orleans, LA, February 1987. Published by Industrial Fabrics Association International, St. Paul, MN, 1987.

Standard Specifications for Highway Bridges, Seventeenth Edition with Interim Specifications – Bridges – 2003, American Association of State Highway and Transportation Officials, Washington, D.C.

Elias, V., DiMaggio, J.A., and DiMillio, A., "FHWA Technical Note on the Degradation – Reduction Factors for Geosynthetics," Geotechnical Fabrics Report, August 1997.

National Concrete Masonry Association, Design Manual for Segmental Retaining Walls, second edition, 1997.

APPENDIX A
DESIGN EXAMPLE

OBJECTIVE:
Design Geogrid Reinforced Soil Wall to a height of 10 ft., using Mesa Concrete Units, top broken back slope with 100 psf surcharge.

METHOD:
National Concrete Masonry Association (NCMA) method.

REFERENCE:
National Concrete Masonry Association, Design Manual for Segmental Retaining Walls, Second Edition, 1997.

ASSUMPTIONS:
1. Drained conditions, no hydrostatic pressures

2. Homogeneous soil conditions having the following properties:

Reinforced Fill: Sandy Gravel	Retained Soil: Silty Sand	Foundation Soil: Silty Sand
$\phi_i' = 34^\circ$	$\phi_r' = 30^\circ$	$\phi_f' = 30^\circ$
$c_i' = 0$ psf	$c_r' = 0$ psf	$c_f' = 0$ psf
$\gamma_i = 125$ pcf	$\gamma_r = 125$ pcf	$\gamma_f = 125$ pcf

3. No seismic forces

4. Uniform live load over the entire surface on the top of the broken slope, $q_l = 100$ psf and no dead load, $q_d = 0$ psf

5. Factors of safety:

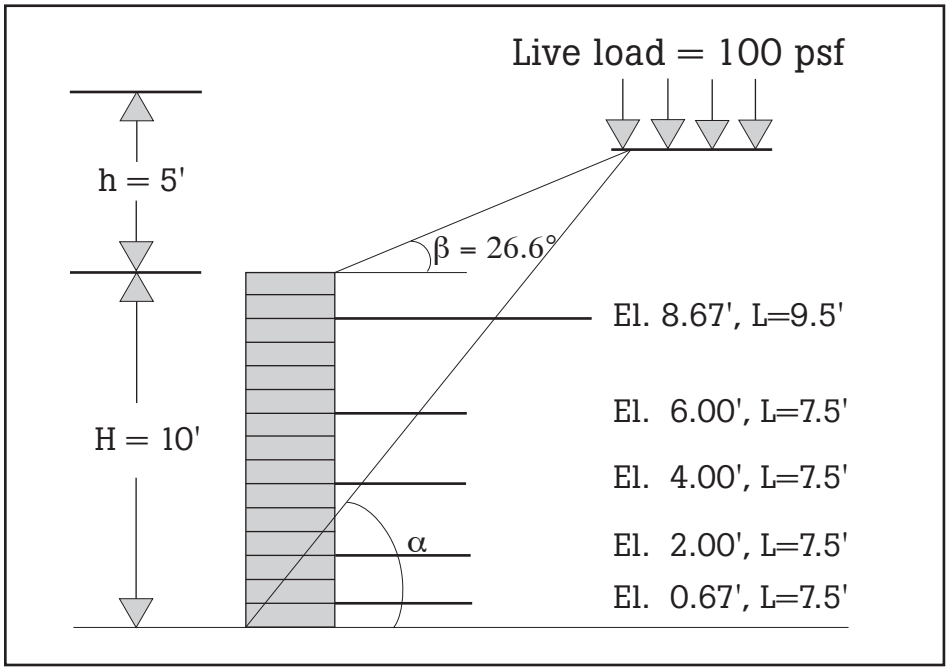
External stability	Internal and local stability
Base sliding, $FS_{bs} = 1.5$	Geogrid overstress, $FS_{os} = 1.0$
Overturning, $FS_{ot} = 2.0$	Pullout, $FS_{po} = 1.5$
Bearing, $FS_{bc} = 2.0$	Sliding along the lowest layer, $FS_{sl} = 1.5$
	Connection, $FS_{cn} = 1.5$
	Face shearing, $FS_{sc} = 1.5$
Uncertainties, $F_{unc} = 1.5$	Face overturning, $FS_{fot} = 2.0$

6. Coefficients of interaction and direct sliding:
   Coefficient of interaction (fill and geogrid), $C_i = 0.8$
   Coefficient of direct sliding (fill and geogrid), $C_{ds} = 0.8$

7. Mesa concrete unit – Standard unit

CALCULATION:

Step 1. Set up the layout of geogrids



The length of reinforced mass for external stability calculation is 7.5 ft. (i.e., L = 7.5 ft.).

Step 2. Calculate coefficients for active earth pressures for internal and external stability calculations. For calculations, use Coulomb equations for active earth pressures.

$$K_a = \frac{\cos^2(\phi' + \omega)}{\cos^2\omega\cos(\omega-\delta)\left[1+\sqrt{\frac{\sin(\phi'+\delta)\sin(\phi'-\beta)}{\cos(\omega-\delta)\cos(\omega+\beta)}}\right]^2}$$

where: ω = Face batter measured from vertical line.
ϕ' = Effective friction angle.
β = Slope angle above wall. For the case where the length of the slope above the wall is less than two times the height of the wall, the coefficient of active earth pressure from retained soil is calculated based on a slope angle by connecting the toe of the slope and the point on the top of the slope at 2H distance away from the back of the wall.
δ = Interface friction angle between wall and reinforced fill ($2\phi'_i/3$) or reinforced mass and retained soil (the lesser of ϕ'_i or ϕ'_r).

External Stability:
$\phi_r' = 30^\circ$, $\beta = 14.0^\circ$, $\omega = 0.45^\circ$, $\delta_{ext} = 30^\circ$, $K_{a(ext)} = 0.364$

Internal Stability:
$\phi_i' = 34^\circ$, $\beta = 26.6^\circ$, $\omega = 0.45^\circ$, $\delta_{int} = 2 \times 34^\circ/3 = 22.7^\circ$, $K_{a(int)} = 0.396$

Step 3: Solve for External Stability: Base Sliding, Overturning, and Bearing

Solve for base sliding: Calculate Factor of Safety for sliding at the base of the reinforced fill zone

$$FS = \frac{(W_1 + W_2)\tan\phi'_f}{P_{s(H)} + P_{q(H)}} = 1.52 \qquad OK$$

Item	Force (lbf/ft)	Item	Moment (lbf-ft/ft)
W_1	8945	M_1	35220
W_2	1328	M_2	7185
$P_{s(H)}$	3485	$M_{s(H)}$	15410
$P_{q(H)}$	420	$M_{q(H)}$	2790

Solve for overturning:

$$FS_{ot} = \frac{M_1 + M_2}{M_{s(H)} + M_{q(H)}} = 2.33 \qquad OK$$

Solve for eccentricity:

$$e = \frac{L}{2} + \frac{(M_1 + M_2) - (M_{s(H)} + M_{q(H)})}{W_1 + W_2} = 1.39 \qquad OK$$

Solve for bearing:

Applied bearing pressure:

$$p = \frac{W_1 + W_2}{L-2e} = 2180 psf$$

Ultimate bearing capacity:

$$q_{ult} = c'_f N_c + 0.5\gamma_f(L-2e)N_\gamma + \gamma_f H_{emb} N_q = 7748 \text{ lb/ft}^2$$

Factor of safety:

$$FS_{bc} = \frac{q_{ult}}{p} = 3.56 \qquad OK$$

Step 4. Solve for Internal and Local Stability: Overstress, Pullout, Sliding along the Lowest Geogrid Layer, Connection, Face Shearing and Face Overturning.

Solve for overstress:
Determination of geogrid type and spacing is based on calculated tension at each grid level. Grid placement is an iterative process checking tension against long-term design strength in each layer.

Horizontal pressure (R_{hi}) at each proposed geogrid elevation:

$$R_{hi} = (\gamma_i h_i + q_d + q_l)K_{a(int)} \cos(\delta_{int} - w)$$

Tension in each geogrid layer:

$$T_i = R_{hi}A_{ci}$$

where: A_{ci} = geogrid contributory area.

Factor of safety for overstress:

$$FS_{os} = \frac{T_{ai}}{T_i}$$

where: T_{ai} = long-term allowable design strength of geogrid.

Layer	Elevation (ft)	Depth (ft)	R_{hi} (lbf/ft^2)	A_{ci} (ft^2/ft)	T_i (lbf/ft)	T_{ai} (lbf/ft)	FS_{osi}	Geogrid
1	0.67	9.33	427	1.34	572	1030	1.80	UX1100MSE
2	2.00	8.00	359	1.67	598	1030	1.72	UX1100MSE
3	4.00	6.00	275	2.00	550	1030	1.87	UX1100MSE
4	6.00	4.00	176	2.34	411	1030	2.51	UX1100MSE
5	8.67	1.33	61	2.67	163	1030	6.32	UX1100MSE

Check pullout beyond α_i plane:
The orientation, α, of the critical Coulomb failure plane with respect to the horizontal is determined using the following equation:

$$\alpha = \phi' + \arctan\left(\frac{-\tan(\phi'-\beta) + \sqrt{\tan(\phi'-\beta)\left[\tan(\phi'-\beta)+\cot(\phi'+\omega)\right]\left[1+\tan(\delta-\omega)\cot(\phi'+\omega)\right]}}{1+\tan(\delta-\omega)\left[\tan(\phi'-\beta)+\cot(\phi'+\omega)\right]}\right)$$

Calculated internal α_i failure plane orientation, $\alpha_i = 49.1^\circ$.

The anchorage capacity of each geogrid layer:

$$T_{po_i} = 2C_iL_{a_i}\,(d_i\gamma_i)\,\tan(\phi'_i)$$

where: C_i = Interaction coefficient between geogrid and soil.
L_{ai} = Anchorage length beyond the α_i plane.
d_i = Average depth of overburden.

Factor of safety against pullout:

$$FS_{po} = \frac{T_{po_i}}{T_i}$$

Layer	L_{ai} (ft)	d_i (ft)	T_{poi} (lbf/ft)	T_i (lbf/ft)	FS_{po}
1	5.94	11.07	8843	572	15.47
2	4.78	10.03	6467	598	10.81
3	3.06	8.47	3497	550	6.35
4	1.34	6.90	1251	411	3.05
5	1.05	5.32	752	163	4.62

Solve for sliding along the lowest geogrid layer:
Similarly as sliding at the base of the reinforced fill zone, calculate factor of safety for sliding along the lowest geogrid layer.

$$FS_{sl} = \frac{C_{ds}(W'_1 + W'_2)\tan\phi'_i + V_{ul}}{P'_{sh} + P'_{qh}} = 2.03 \quad \text{OK}$$

where: V_{ul} = available segmental concrete unit shear capacity at the lowest geogrid layer elevation

Solve for connection strength at each geogrid layer elevation:
Ultimate connection strength:

$$T_{ultconn_i} = a_{cs_i} + W_{w_i}\tan(\lambda_{cs_i})$$

where: a_{cs_i}, λ_{cs_i} = connection strength envelope determined from connection test.
W_{w_i} = weight above the ith geogrid layer.

Layer	W_w (lbf/ft)	$T_{ultconni}$ (lbf/ft)	$T_{ai}\,FS_{unc}$ (lbf/ft)	T_{cn_i} (lbf/ft)	T_i (lbf/ft)	FS_{cn}
1	765	1310	1545	1310	571	2.29
2	656	1310	1545	1310	598	2.19
3	492	1310	1545	1310	550	2.38
4	328	1310	1545	1310	411	3.19
5	109	1310	1545	1310	163	8.04

T_{cn_i} = Lesser of $T_{ultconni}$ and $T_{ai}\,FS_{unc}$

Solve for wall face bulging at each geogrid layer elevation:

Horizontal active earth force at geogrid layer elevation, E_i

$$P_{aH} = 0.5K_{aint}\gamma_i(H - E_i)^2 \cos(\delta_{int} - \omega)$$

where: E_i = Elevation of geogrids

Available segmental concrete unit shear capacity:

$$V_{u_i} = a_u + W_{w_i} \tan(\lambda_u)$$

Factor of safety against shear failure:

$$FS_{sc_i} = \frac{V_{u_i}}{P_{aH_i} - \sum_{i+1}^{N} T_i}$$

Layer	P_{aHi} (lbf/ft)	V_{ui} (lbf/ft)	$\sum T_i$ (lbf/ft)	FS_{sci}
1	1997	2375	1723	8.65
2	1468	2039	1124	5.93
3	826	1534	574	6.08
4	367	1029	163	5.05
5	41	356	0	8.77

Solve for overturning of the unreinforced portion at the top of the wall:

Overturning moment:

$$M_{o(5)} = P_{aH(5)}Y_{s(5)} = 18 \text{ lbf-ft/ft}$$

where: $Y_{s(5)}$ = Moment arm for the horizontal active earth pressure at the unreinforced top of wall.

Resisting moment:

$$M_{R(5)} = W_{W(5)}X_{W(5)} = 37 \text{ lbf-ft/ft}$$

where: $X_{w(5)}$ = Moment arm for the weight of the concrete units.

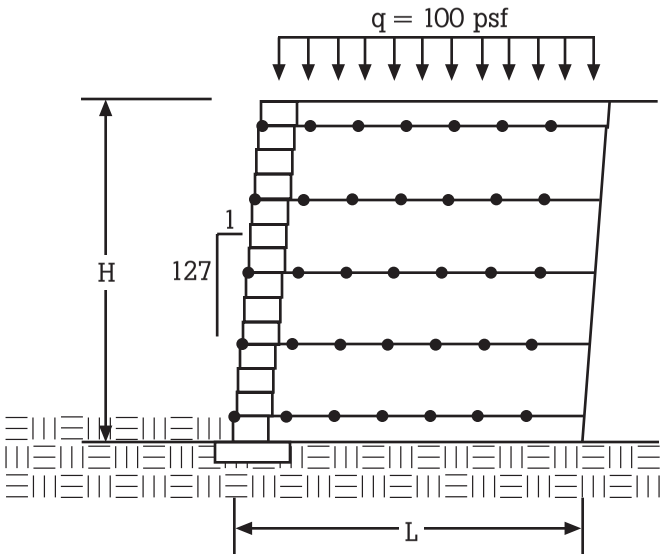
$$FS_{OT(5)} = \frac{M_{R(5)}}{M_{o(5)}} = 2.06 \quad \text{OK}$$

END OF CALCULATION

APPENDIX B:
DESIGN CHARTS

Design Chart

HORIZONTAL TOP, 100 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 34^{\circ}$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 30^{\circ}$
$\gamma = 125$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 30^{\circ}$
$\gamma = 125$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

HORIZONTAL TOP, 100 psf SURCHARGE

REINFORCED WALL FILL	ϕ = 34 deg.	γ = 125 pcf	c' = 0 psf
RETAINED AND FOUNDATION SOIL	ϕ = 30 deg.	γ = 125 pcf	c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)									
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10
4	UX1100MSE	1	3.7	0.67	2.67								
6	UX1100MSE	2	3.6	0.67	2.67								
	UX1100MSE	1	4.9			4.67							
8	UX1100MSE	3	4.8	0.67	2.67	4.67							
	UX1100MSE	1	6.2				6.67						
10	UX1100MSE	4	6	0.67	2.67	4.67	6.67						
	UX1100MSE	1	7.4					8.67					
12	UX1100MSE	5	7.2	0.67	2.67	4.67	6.67	8.67					
	UX1100MSE	1	8.6						10.67				
14	UX1100MSE	6	8.4	0.67	2.67	4.67	6.67	8.67	10.67				
	UX1100MSE	1	9.8							12.67			
16	UX1100MSE	7	9.6	0.67	2.67	4.67	6.67	8.67	10.67	12.67			
	UX1100MSE	1	11.1								14.67		
18	UX1100MSE	8	10.8	0.67	2.67	4.67	6.67	8.67	10.67	12.67	14.67		
	UX1100MSE	1	12.3									16.67	
20	UX1100MSE	9	12	0.67	2.00	4.00	6.00	8.00	10.00	12.00	14.00	16.00	
	UX1100MSE	1	13.5										18.00

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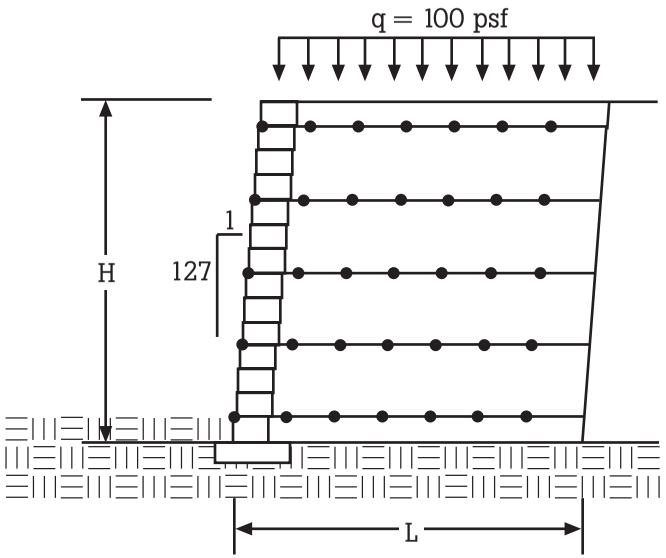
Design Chart

HORIZONTAL TOP, 100 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 32^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

HORIZONTAL TOP, 100 psf SURCHARGE

REINFORCED WALL FILL	ϕ' = 32 deg.	γ = 125 pcf	c' = 0 psf
RETAINED AND FOUNDATION SOIL	ϕ' = 30 deg.	γ = 125 pcf	c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)										
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10	11
4	UX1100MSE	1	4.1	0.67	2.67									
6	UX1100MSE	1	3.6	0.67										
	UX1100MSE	1	4.4		2.67									
	UX1100MSE	1	5.4			4.67								
8	UX1100MSE	2	4.8	0.67	2.67									
	UX1100MSE	1	5.0			4.67								
	UX1100MSE	1	6.6				6.67							
10	UX1100MSE	3	6.0	0.67	2.67	4.67								
	UX1100MSE	1	6.3				6.67							
	UX1100MSE	1	7.9					8.67						
12	UX1100MSE	4	7.2	0.67	2.67	4.67	6.67							
	UX1100MSE	1	7.5					8.67						
	UX1100MSE	1	9.2						10.67					
14	UX1100MSE	4	8.4	0.67	2.67	4.67	6.67							
	UX1100MSE	2	8.8					8.67	10.67					
	UX1100MSE	1	10.5							12.67				
16	UX1100MSE	5	9.6	0.67	2.67	4.67	6.67	8.67						
	UX1100MSE	2	10.1						10.67	12.67				
	UX1100MSE	1	11.8								14.67			
18	UX1100MSE	8	10.9	0.67	2.00	4.00	6.00	8.00	10.00	12.00	14.00			
	UX1100MSE	1	12.6									16.00		
20	UX1100MSE	9	12.0	0.67	2.00	3.33	5.33	7.33	9.33	11.33	13.33	15.33		
	UX1100MSE	2	14.0										17.33	18.67

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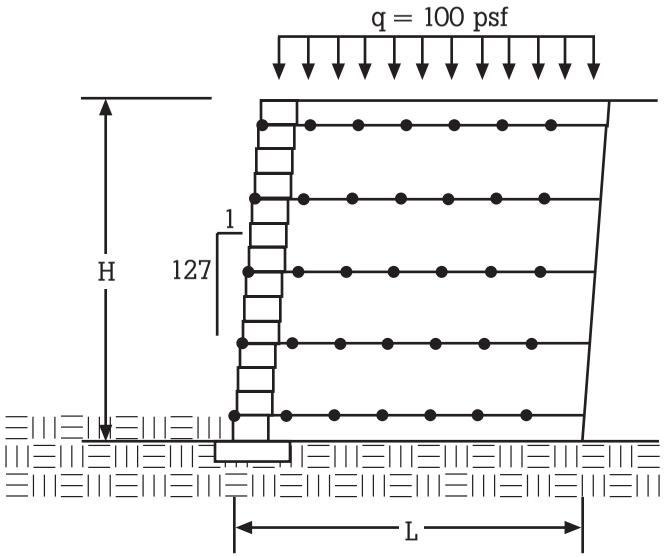
Design Chart

HORIZONTAL TOP, 100 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

HORIZONTAL TOP, 100 psf SURCHARGE

REINFORCED WALL FILL	ϕ' = 30 deg.	γ = 125 pcf	c' = 0 psf
RETAINED AND FOUNDATION SOIL	ϕ' = 28 deg.	γ = 120 pcf	c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)									
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10
4	UX1100MSE	2	4.9	0.67	2.67								
6	UX1100MSE	1	3.6	0.67									
	UX1100MSE	2	6.2		2.67	4.67							
8	UX1100MSE	2	4.8	0.67	2.67								
	UX1100MSE	2	7.6			4.67	6.67						
10	UX1100MSE	3	6.0	0.67	2.67	4.67							
	UX1100MSE	2	8.9				6.67	8.67					
12	UX1100MSE	4	7.2	0.67	2.67	4.67	6.67						
	UX1100MSE	1	8.3					8.67					
	UX1100MSE	1	10.3						10.67				
14	UX1100MSE	3	8.4	0.67	2.67	4.67							
	UX1100MSE	3	9.7				6.67	8.67	10.67				
	UX1100MSE	1	11.6							12.67			
16	UX1100MSE	4	9.6	0.67	2.67	4.67	6.67						
	UX1100MSE	3	11.0					8.67	10.67	12.67			
	UX1100MSE	1	12.9								14.67		
18	UX1100MSE	3	10.8	0.67	2.00	4.00	6.00	8.00					
	UX1100MSE	3	11.8						10.00	12.00	14.00		
	UX1100MSE	1	13.8									16.00	
20	UX1400MSE	3	12.0	0.67	2.67	4.67							
	UX1100MSE	4	12.0				6.67	8.67	10.67	12.67			
	UX1100MSE	2	13.7								14.67	16.67	
	UX1100MSE	1	15.6										18.67

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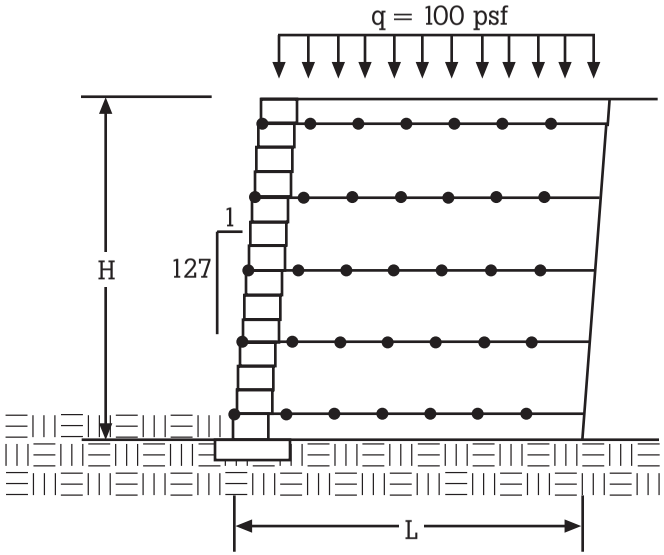
Design Chart

HORIZONTAL TOP, 100 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

HORIZONTAL TOP, 100 psf SURCHARGE

REINFORCED WALL FILL	ϕ' = 28 deg.	γ = 120 pcf	c' = 0 psf
RETAINED AND FOUNDATION SOIL	ϕ' = 28 deg.	γ = 120 pcf	c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)									
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10
4	UX1100MSE	2	5.4	0.67	2.67								
6	UX1100MSE	1	3.6	0.67									
	UX1100MSE	2	6.8		2.67	4.67							
8	UX1100MSE	2	4.8	0.67	2.67								
	UX1100MSE	2	8.2			4.67	6.67						
10	UX1100MSE	2	6.0	0.67	2.67								
	UX1100MSE	3	9.6			4.67	6.67	8.67					
12	UX1100MSE	2	7.2	0.67	2.67								
	UX1100MSE	3	8.9			4.67	6.67	8.67					
	UX1100MSE	1	11.0						10.67				
14	UX1100MSE	3	8.4	0.67	2.67	4.67							
	UX1100MSE	3	10.3				6.67	8.67	10.67				
	UX1100MSE	1	12.4							12.67			
16	UX1100MSE	5	9.6	0.67	2.00	4.00	6.00	8.00					
	UX1100MSE	2	11.2						10.00	12.00			
	UX1100MSE	1	13.4								14.00		
18	UX1100MSE	7	10.8	0.67	2.00	3.33	5.33	7.33	9.33	11.33			
	UX1100MSE	2	13.4								13.33	15.33	
	UX1100MSE	1	14.7										16.67
20	UX1400MSE	1	12.0	0.67									
	UX1400MSE	3	12.0		2.67	4.67	6.67						
	UX1100MSE	3	12.0					8.67	10.67	12.67			
	UX1100MSE	2	14.5								14.67	16.67	
	UX1100MSE	1	16.6										18.67

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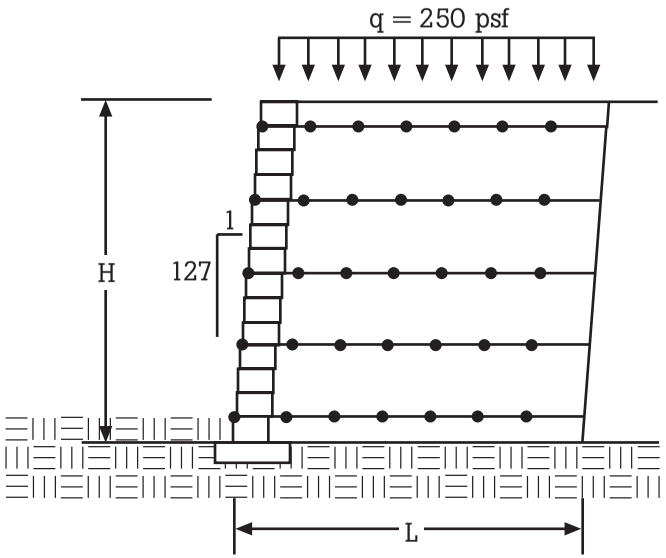
Design Chart

HORIZONTAL TOP, 250 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 34^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

HORIZONTAL TOP, 250 psf SURCHARGE

REINFORCED WALL FILL	ϕ' = 34 deg.	γ = 125 pcf	c' = 0 psf
RETAINED AND FOUNDATION SOIL	ϕ' = 30 deg.	γ = 125 pcf	c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)										
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10	11
4	UX1100MSE	2	4.4	0.67	2.67									
6	UX1100MSE	2	4.2	0.67	2.67									
	UX1100MSE	1	5.6			4.67								
8	UX1100MSE	3	5.2	0.67	2.67	4.67								
	UX1100MSE	1	6.8				6.67							
10	UX1100MSE	4	6.2	0.67	2.67	4.67	6.67							
	UX1100MSE	1	8.1					8.67						
12	UX1100MSE	5	7.3	0.67	2.67	4.67	6.67	8.67						
	UX1100MSE	1	9.3						10.67					
14	UX1100MSE	6	8.5	0.67	2.67	4.67	6.67	8.67	10.67					
	UX1100MSE	1	10.5							12.67				
16	UX1100MSE	5	9.6	0.67	2.67	4.67	6.67	8.67						
	UX1100MSE	2	9.8						10.67	12.67				
	UX1100MSE	1	11.8								14.67			
18	UX1100MSE	8	10.8	0.67	2.00	4.00	6.00	8.00	10.00	12.00	14.00			
	UX1100MSE	1	12.5									16.00		
20	UX1100MSE	8	12.0	0.67	2.00	3.33	5.33	7.33	9.33	11.33	13.33			
	UX1100MSE	2	12.7									15.33	17.33	
	UX1100MSE	1	15.1											19.33

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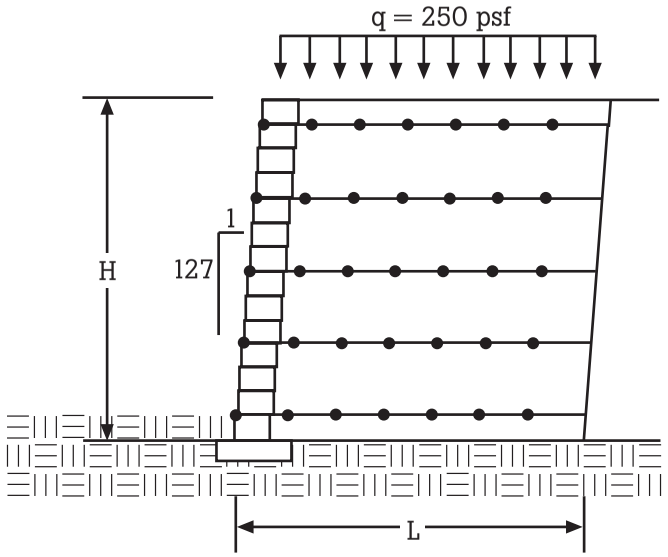
Design Chart

HORIZONTAL TOP, 250 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 32^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

HORIZONTAL TOP, 250 psf SURCHARGE

REINFORCED WALL FILL	ϕ' = 32 deg.	γ = 125 pcf	c' = 0 psf
RETAINED AND FOUNDATION SOIL	ϕ' = 30 deg.	γ = 125 pcf	c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)									
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10
4	UX1100MSE	2	4.9	0.67	2.67								
6	UX1100MSE	2	4.1	0.67	2.67								
	UX1100MSE	1	6.2			4.67							
8	UX1100MSE	3	5.3	0.67	2.67	4.67							
	UX1100MSE	1	7.5				6.67						
10	UX1100MSE	2	6.1	0.67	2.67								
	UX1100MSE	2	6.5			4.67	6.67						
	UX1100MSE	1	8.8					8.67					
12	UX1100MSE	3	7.2	0.67	2.67	4.67							
	UX1100MSE	2	7.7				6.67	8.67					
	UX1100MSE	1	9.9						10.67				
14	UX1100MSE	4	8.4	0.67	2.67	4.67	6.67						
	UX1100MSE	2	9.1					8.67	10.67				
	UX1100MSE	1	11.3							12.67			
16	UX1100MSE	5	9.6	0.67	2.67	4.67	6.67	8.67					
	UX1100MSE	2	10.4						10.67	12.67			
	UX1100MSE	1	12.7								14.67		
18	UX1100MSE	7	10.8	0.67	2.00	3.33	4.67	6.67	8.67	10.67			
	UX1100MSE	2	12.1								12.67	14.67	
	UX1100MSE	1	14.6										16.67
20	UX1100MSE	6	12.0	0.67	2.67	4.67	6.67	8.67	10.67				
	UX1100MSE	3	13.0							12.67	14.67	16.67	
	UX1100MSE	1	15.2										18.67

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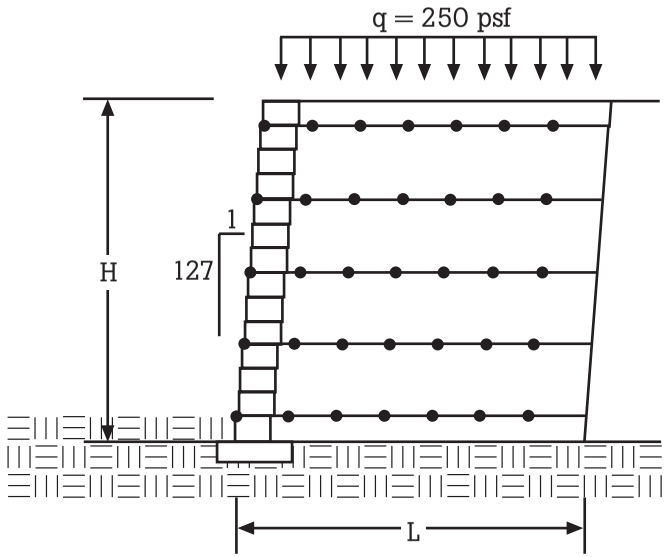
Design Chart

HORIZONTAL TOP, 250 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

HORIZONTAL TOP, 250 psf SURCHARGE
REINFORCED WALL FILL ϕ' = 30 deg. γ = 125 pcf c' = 0 psf
RETAINED AND FOUNDATION SOIL ϕ' = 28 deg. γ = 120 pcf c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)										
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10	11
4	UX1100MSE	2	6.2	0.67	2.67									
6	UX1100MSE	1	4.3	0.67										
	UX1100MSE	2	7.5		2.67	4.67								
8	UX1100MSE	1	5.3	0.67										
	UX1100MSE	2	6.1		2.67	4.67								
	UX1100MSE	1	8.9				6.67							
10	UX1100MSE	2	6.3	0.67	2.67									
	UX1100MSE	2	7.4			4.67	6.67							
	UX1100MSE	1	10.2					8.67						
12	UX1100MSE	3	7.4	0.67	2.67	4.67								
	UX1100MSE	2	8.8				6.67	8.67						
	UX1100MSE	1	11.6						10.67					
14	UX1100MSE	4	8.4	0.67	2.67	4.67	6.67							
	UX1100MSE	2	10.1					8.67	10.67					
	UX1100MSE	1	12.9							12.67				
16	UX1100MSE	4	9.6	0.67	2.00	4.00	6.00							
	UX1100MSE	3	11.5					8.00	10.00	12.00				
	UX1100MSE	1	14.2								14.00			
18	UX1100MSE	7	10.8	0.67	2.00	3.33	4.67	6.00	8.00	10.00				
	UX1100MSE	2	12.2								12.00	14.00		
	UX1100MSE	1	15.0										16.00	
30	UX1100MSE	7	12.0	0.67	2.00	3.33	4.67	6.00	8.00	10.00				
	UX1100MSE	2	12.2								12.00	14.00		
	UX1100MSE	1	13.6										16.00	
	UX1100MSE	1	16.3											18.00

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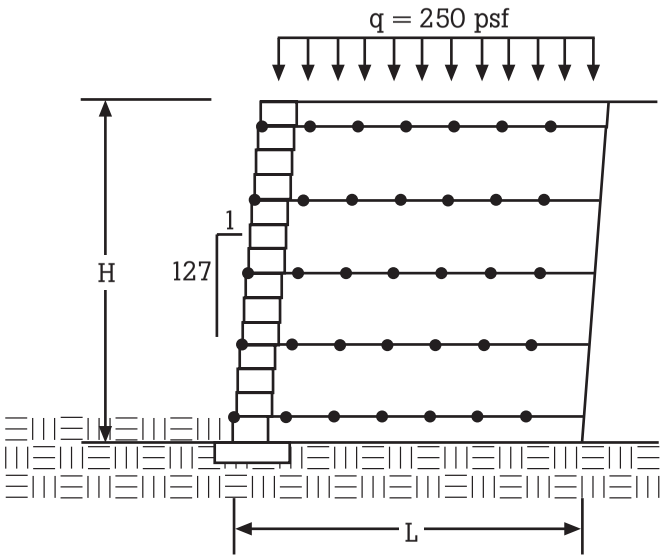
Design Chart

HORIZONTAL TOP, 250 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

HORIZONTAL TOP, 250 psf SURCHARGE
REINFORCED WALL FILL ϕ' = 28 deg. γ = 120 pcf c' = 0 psf
RETAINED AND FOUNDATION SOIL ϕ' = 28 deg. γ = 120 pcf c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)									
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10
4	UX1100MSE	2	7.0	0.67	2.67								
6	UX1100MSE	1	4.4	0.67									
	UX1100MSE	2	8.4		2.67	4.67							
8	UX1100MSE	1	5.4	0.67									
	UX1100MSE	2	6.6		2.67	4.67							
	UX1100MSE	1	9.8				6.67						
10	UX1100MSE	2	6.5	0.67	2.67								
	UX1100MSE	2	8.0			4.67	6.67						
	UX1100MSE	1	11.2					8.67					
12	UX1100MSE	3	7.5	0.67	2.67	4.67							
	UX1100MSE	2	9.4				6.6.7	8.67					
	UX1100MSE	1	12.6						10.67				
14	UX1100MSE	3	8.6	0.67	2.67	4.67							
	UX1100MSE	3	10.8				6.67	8.67	10.67				
	UX1100MSE	1	14.0							12.67			
16	UX1100MSE	5	9.6	0.67	2.00	4.00	6.00	8.00					
	UX1100MSE	2	11.6						10.00	12.00			
	UX1100MSE	1	14.7								14.00		
18	UX1400MSE	3	10.8	0.67	2.67	4.67							
	UX1100MSE	2	10.8				6.67	8.67					
	UX1100MSE	3	13.6						10.67	12.67	14.67		
	UX1100MSE	1	16.8									16.67	
20	UX1400MSE	5	12.0	0.67	2.00	4.00	6.00	8.00					
	UX1100MSE	1	20.0						10.00				
	UX1100MSE	3	14.4							12.00	14.00	16.00	
	UX1100MSE	1	17.5										18.00

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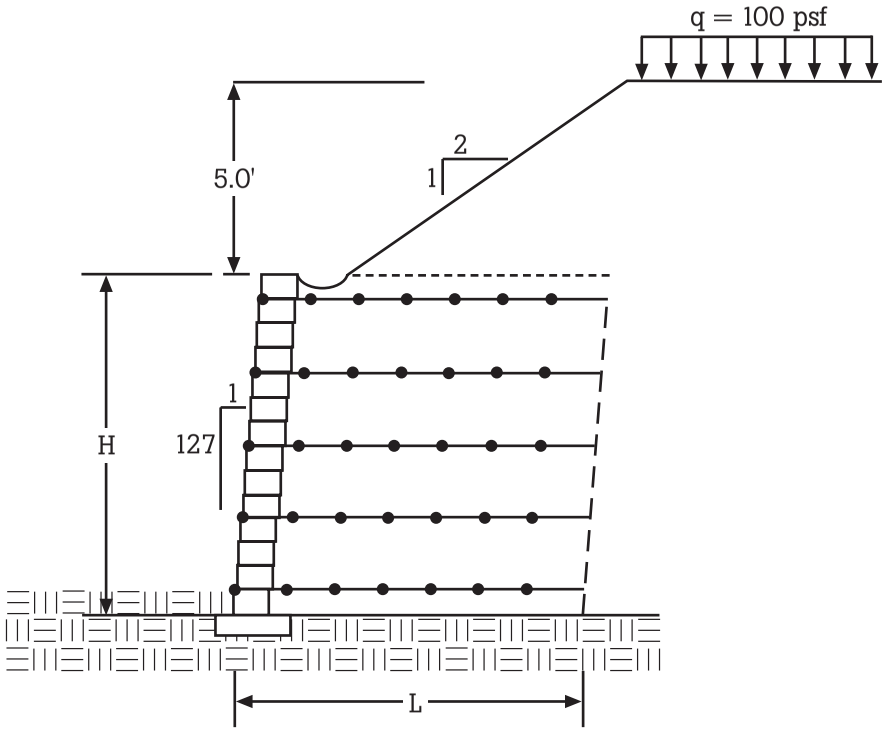
Design Chart

2:1 SLOPE, 100 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 34^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

5ft TOP 2:1 SLOPE, 100 psf SURCHARGE
REINFORCED WALL FILL ϕ' = 34 deg. γ = 125 pcf c' = 0 psf
RETAINED AND FOUNDATION SOIL ϕ' = 30 deg. γ = 125 pcf c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)										
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10	11
4	UX1100MSE	2	7.7	0.67	2.67									
6	UX1100MSE	1	7.0	0.67										
	UX1100MSE	2	4.1		2.67	4.67								
8	UX1100MSE	1	7.0	0.67										
	UX1100MSE	2	4.8		2.67	4.67								
	UX1100MSE	1	5.8				6.67							
10	UX1100MSE	1	8.3	0.67										
	UX1100MSE	3	6.2		2.67	4.67	6.67							
	UX1100MSE	1	7.5					8.67						
12	UX1100MSE	1	9.5	0.67										
	UX1100MSE	4	7.5		2.67	4.67	6.67	8.67						
	UX1100MSE	1	9.2						10.67					
14	UX1100MSE	1	10.5	0.67										
	UX1100MSE	3	8.9		2.67	4.67	6.67							
	UX1100MSE	2	9.2					8.67	10.67					
	UX1100MSE	1	11.0							12.67				
16	UX1100MSE	1	11.4	0.67										
	UX1100MSE	4	10.1		2.67	4.67	6.67	8.67						
	UX1100MSE	2	11.0						10.67	12.67				
	UX1100MSE	1	12.7								14.67			
18	UX1100MSE	1	12.3	0.67										
	UX1100MSE	2	11.3		2.00	4.00								
	UX1100MSE	3	10.8				6.00	8.00	10.00					
	UX1100MSE	2	12.1							12.00	14.00			
	UX1100MSE	1	13.8									16.00		
20	UX1100MSE	1	13.5	0.67										
	UX1100MSE	3	12.8		1.33	2.67	4.00							
	UX1100MSE	4	12.0					6.00	8.00	10.00	12.00			
	UX1100MSE	2	13.8									14.00	16.00	
	UX1100MSE	1	15.5											18.00

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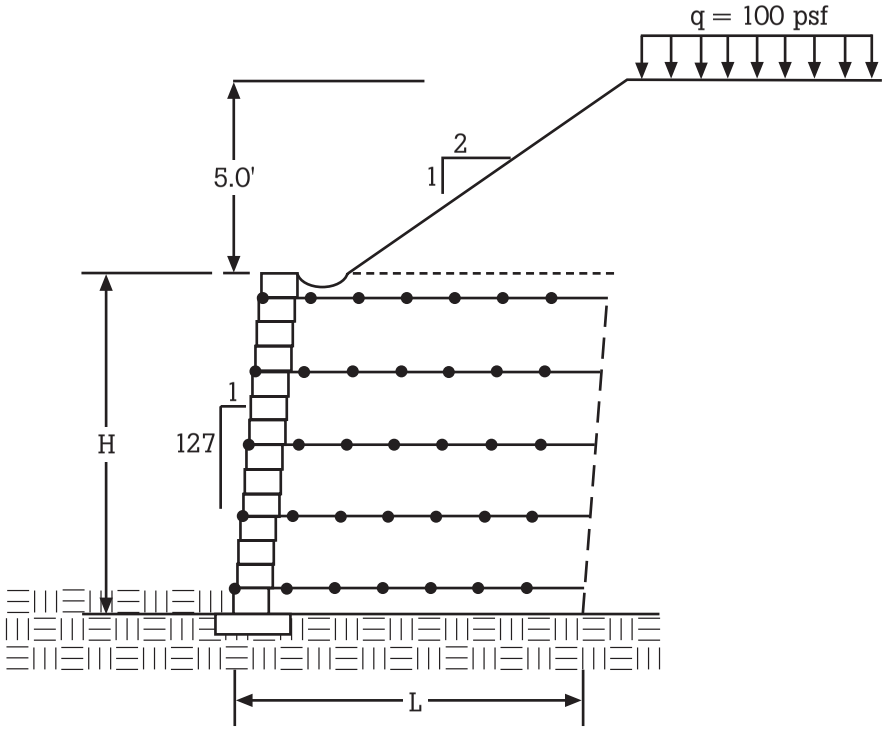
Design Chart

2:1 SLOPE, 100 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 32^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

5ft TOP 2:1 SLOPE, 100 psf SURCHARGE

REINFORCED WALL FILL	ϕ' = 32 deg.	γ = 125 pcf	c' = 0 psf
RETAINED AND FOUNDATION SOIL	ϕ' = 30 deg.	γ = 125 pcf	c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)									
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10
4	UX1100MSE	2	7.7	0.67	2.67								
6	UX1100MSE	1	7.0	0.67									
	UX1100MSE	2	4.6		2.67	4.67							
8	UX1100MSE	1	6.9	0.67									
	UX1100MSE	2	4.8		2.67	4.67							
	UX1100MSE	1	6.5				6.67						
10	UX1100MSE	1	8.1	0.67									
	UX1100MSE	3	6.5		2.67	4.67	6.67						
	UX1100MSE	1	8.4					8.67					
12	UX1100MSE	1	9.3	0.67									
	UX1100MSE	3	7.3		2.67	4.6.7	6.67						
	UX1100MSE	2	10.3					8.67	10.67				
14	UX1100MSE	1	10.1	0.67									
	UX1100MSE	4	8.6		2.67	4.67	6.67	8.67					
	UX1100MSE	2	12.2						10.67	12.67			
16	UX1100MSE	2	11.2	0.67	2.67								
	UX1100MSE	3	9.6			4.67	6.67	8.67					
	UX1100MSE	2	12.2						10.67	12.67			
	UX1100MSE	1	14.1								14.67		
18	UX1100MSE	2	12.1	0.67	2.00								
	UX1100MSE	4	10.8			4.00	6.00	8.00	10.00				
	UX1100MSE	2	13.5							12.00	14.00		
	UX1100MSE	1	15.4									16.00	
20	UX1400MSE	2	13.0	0.67	2.67								
	UX1400MSE	2	12.0			4.67	6.67						
	UX1100MSE	3	12.2					8.67	10.67	12.67			
	UX1100MSE	2	16.1								14.67	16.67	
	UX1100MSE	1	18.0										18.67

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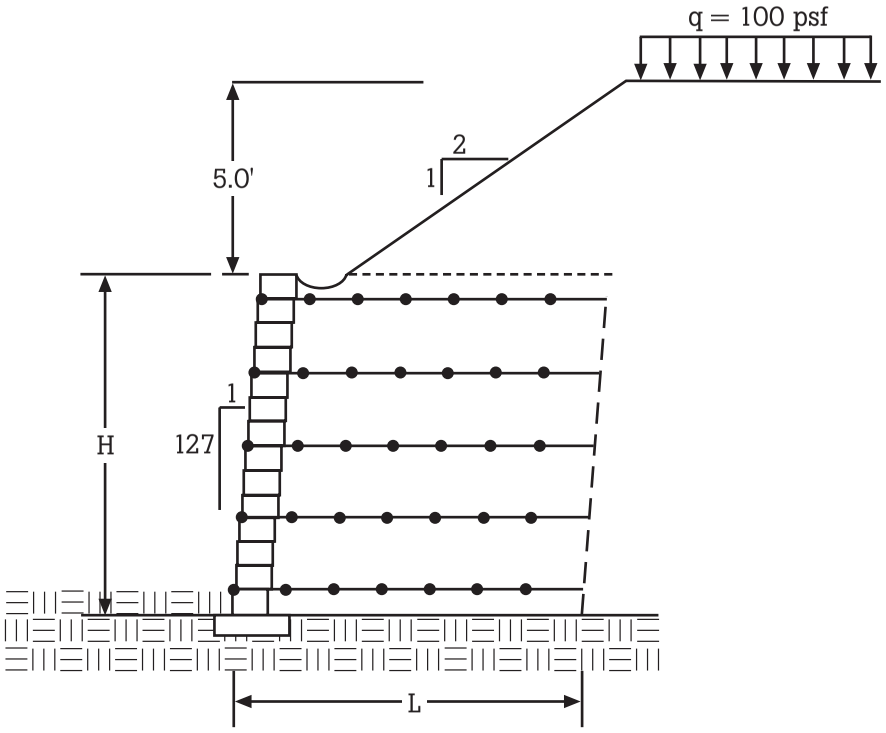
Design Chart

2:1 SLOPE, 100 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

5ft TOP 2:1 SLOPE, 100 psf SURCHARGE

REINFORCED WALL FILL	ϕ' = 30 deg.	γ = 125 pcf	c' = 0 psf
RETAINED AND FOUNDATION SOIL	ϕ' = 30 deg.	γ = 125 pcf	c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)									
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10
4	UX1100MSE	2	7.7	0.67	2.67								
6	UX1100MSE	3	7.7	0.67	2.67	4.67							
8	UX1100MSE	4	7.4	0.67	2.67	4.67	6.67						
10	UX1100MSE	1	8.4	0.67									
	UX1100MSE	2	7.2		2.67	4.67							
	UX1100MSE	2	9.6				6.67	8.67					
12	UX1100MSE	5	9.6	0.67	2.67	4.67	6.67	8.67					
	UX1100MSE	1	11.8						10.67				
14	UX1400MSE	1	10.3	0.67									
	UX1400MSE	1	9.6		2.67								
	UX1100MSE	3	9.6			4.67	6.67	8.67					
	UX1100MSE	2	14.0						10.67	12.67			
16	UX1400MSE	2	11.4	0.67	2.67								
	UX1100MSE	3	11.4			4.67	6.67	8.67					
	UX1100MSE	2	14.0						10.67	12.67			
	UX1100MSE	1	16.2								14.67		
18	UX1400MSE	1	12.3	0.67									
	UX1400MSE	2	11.1		2.67	4.67							
	UX1100MSE	1	11.1				6.67						
	UX1100MSE	2	11.8					8.67	10.67				
	UX1100MSE	2	16.2							12.67	14.67		
	UX1100MSE	1	18.4									16.67	
20	UX1400MSE	2	13.2	0.67	2.67								
	UX1400MSE	2	12.0			4.67	6.67						
	UX1100MSE	3	14.0					8.67	10.67	12.67			
	UX1100MSE	2	18.4								14.67	16.67	
	UX1100MSE	1	20.6										18.67

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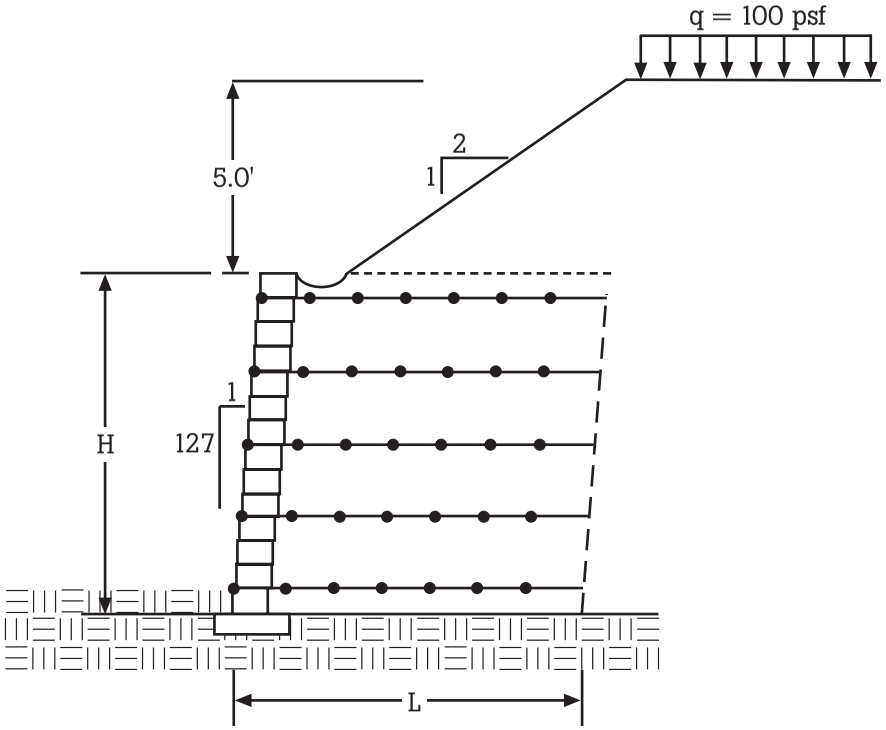
Design Chart

2:1 SLOPE, 100 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

5ft TOP 2:1 SLOPE, 100 psf SURCHARGE

REINFORCED WALL FILL $\phi' = 28$ deg. $\gamma = 120$ pcf c' = 0 psf

RETAINED AND FOUNDATION SOIL $\phi' = 28$ deg. $\gamma = 120$ pcf c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)									
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10
4	UX1100MSE	2	11.6	0.67	2.67								
6	UX1100MSE	1	10.1	0.67									
	UX1100MSE	2	8.4		2.67	4.67							
8	UX1100MSE	1	9.7	0.67									
	UX1100MSE	3	9.0		2.67	4.67	6.67						
10	UX1100MSE	3	10.3	0.67	2.67	4.67							
	UX1100MSE	2	11.7				6.67	8.67					
12	UX1100MSE	1	11.3	0.67									
	UX1100MSE	2	9.8		2.67	4.67							
	UX1100MSE	2	11.7				6.67	8.67					
	UX1100MSE	1	14.4						10.67				
14	UX1100MSE	1	12.1	0.67									
	UX1100MSE	3	11.1		2.67	4.67	6.67						
	UX1100MSE	2	14.4					8.6.7	10.67				
	UX1100MSE	1	17.1							12.67			
16	UX1400MSE	2	12.9	0.67	2.67								
	UX1100MSE	3	13.7			4.67	6.67	8.67					
	UX1100MSE	2	17.1						10.67	12.67			
	UX1100MSE	1	19.8								14.67		
18	UX1400MSE	2	13.8	0.67	2.67								
	UX1400MSE	1	11.7			4.67							
	UX1100MSE	1	11.7				6.67						
	UX1100MSE	4	19.8					8.67	10.67	12.67	14.67		
	UX1100MSE	1	22.5									16.67	
20	UX1400MSE	2	14.6	0.67	2.00								
	UX1400MSE	2	12.9			4.00	6.00						
	UX1100MSE	1	12.9					8.00					
	UX1100MSE	3	20.8						10.00	12.00	14.00		
	UX1100MSE	2	24.2									16.00	18.00

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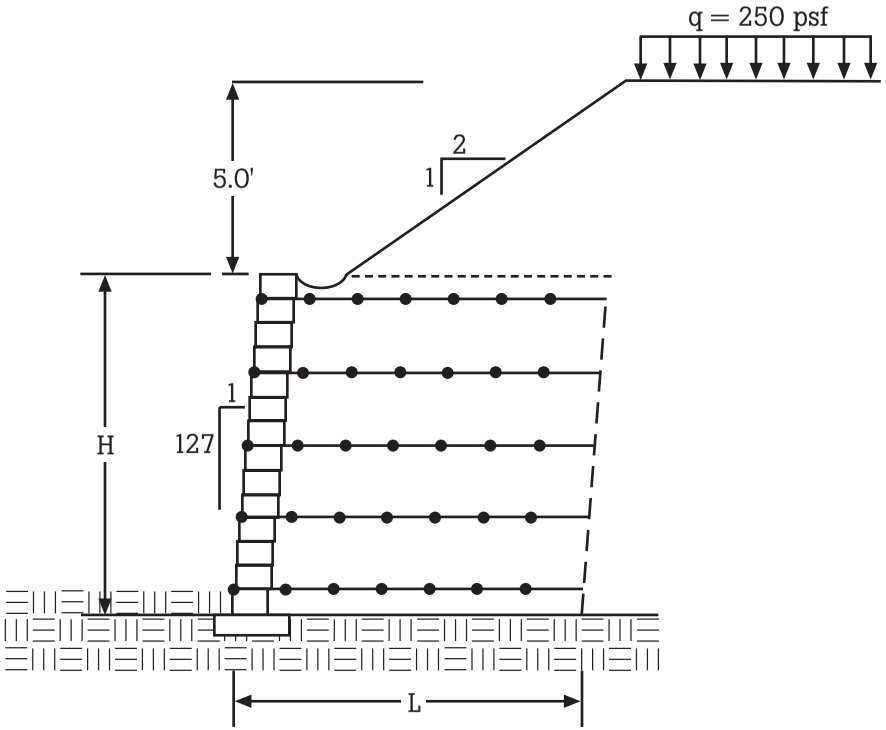
Design Chart

2:1 SLOPE, 250 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 34^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

5ft TOP 2:1 SLOPE, 250 psf SURCHARGE

REINFORCED WALL FILL $\phi' = 34$ deg. $\gamma = 125$ pcf c' = 0 psf

RETAINED AND FOUNDATION SOIL $\phi' = 30$ deg. $\gamma = 125$ pcf c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)									
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10
4	UX1100MSE	2	10.9	0.67	2.67								
6	UX1100MSE	1	10.0	0.67									
	UX1100MSE	2	5.9		2.67	4.67							
8	UX1100MSE	1	9.0	0.67									
	UX1100MSE	3	6.1		2.67	4.67	6.67						
10	UX1100MSE	1	9.6	0.67									
	UX1100MSE	1	7.5		2.67								
	UX1100MSE	2	5.8			4.67	6.67						
	UX1100MSE	1	7.5					8.67					
12	UX1100MSE	1	10.0	0.67									
	UX1100MSE	2	8.5		2.67	4.67							
	UX1100MSE	2	7.5				6.6.7	8.67					
	UX1100MSE	1	9.2						10.67				
14	UX1100MSE	1	10.7	0.67									
	UX1100MSE	2	9.8		2.67	4.67							
	UX1100MSE	3	9.2				6.67	8.67	10.67				
	UX1100MSE	1	11.0							12.67			
16	UX1100MSE	1	12.0	0.67									
	UX1100MSE	3	10.5		2.67	4.67	6.67						
	UX1100MSE	3	11.0					8.67	10.67	12.67			
	UX1100MSE	1	12.7								14.67		
18	UX1100MSE	2	12.9	0.67	2.00								
	UX1100MSE	5	11.0			4.00	6.00	8.00	10.00	12.00			
	UX1100MSE	2	14.4								14.00	16.00	
20	UX1400MSE	2	13.8	0.67	2.67								
	UX1400MSE	1	11.0			4.67							
	UX1100MSE	4	11.0				6.67	8.67	10.67	12.67			
	UX1100MSE	2	14.4								14.67	16.67	
	UX1100MSE	1	16.1										18.67

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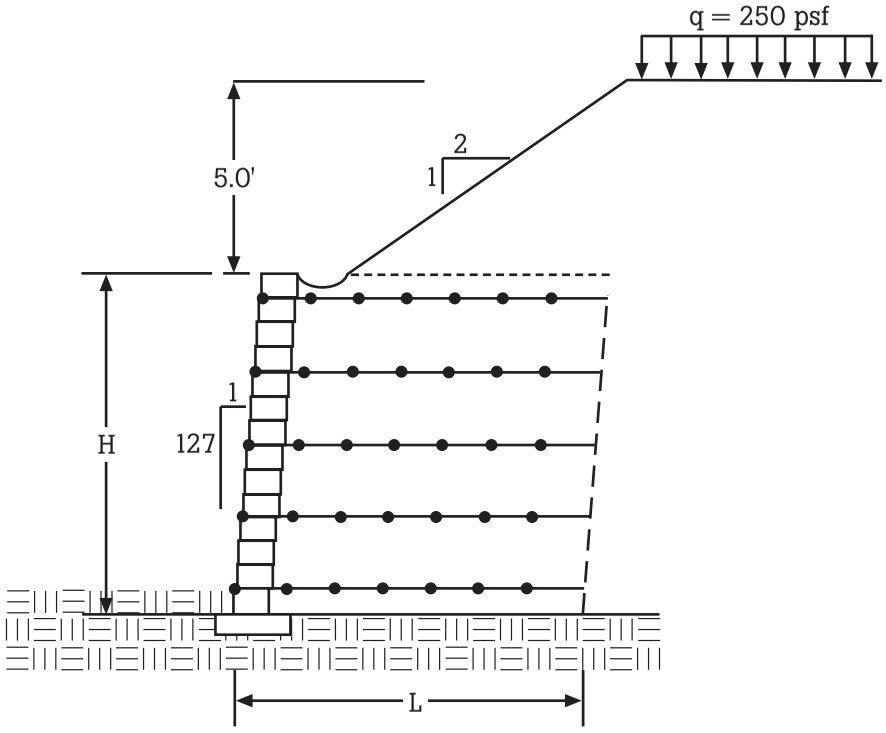
Design Chart

2:1 SLOPE, 250 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 32^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

5ft TOP 2:1 SLOPE, 250 psf SURCHARGE

REINFORCED WALL FILL	ϕ' = 32 deg.	γ = 125 pcf	c' = 0 psf
RETAINED AND FOUNDATION SOIL	ϕ' = 30 deg.	γ = 125 pcf	c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)									
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10
4	UX1100MSE	2	10.9	0.67	2.67								
6	UX1100MSE	1	10.0	0.67									
	UX1100MSE	2	6.6		2.67	4.67							
8	UX1100MSE	1	9.0	0.67									
	UX1100MSE	3	6.5		2.67	4.67	6.67						
10	UX1100MSE	1	9.3	0.67									
	UX1100MSE	3	7.2		2.67	4.67	6.67						
	UX1100MSE	1	8.4					8.67					
12	UX1100MSE	1	10.1	0.67									
	UX1100MSE	4	8.5		2.67	4.67	6.67	8.67					
	UX1100MSE	1	10.3						10.67				
14	UX1100MSE	1	11.1	0.67									
	UX1100MSE	3	9.8		2.67	4.67	6.67						
	UX1100MSE	2	10.3					8.67	10.67				
	UX1100MSE	1	12.2							12.67			
16	UX1100MSE	1	12.0	0.67									
	UX1100MSE	5	11.0		2.00	4.00	6.00	8.00	10.00				
	UX1100MSE	2	14.1							12.00	14.00		
18	UX1400MSE	2	12.9	0.67	2.67								
	UX1400MSE	1	10.8			4.67							
	UX1100MSE	3	10.8				6.67	8.67	10.67				
	UX1100MSE	2	14.1							12.67	14.67		
	UX1100MSE	1	16.1									16.67	
20	UX1400MSE	1	13.8	0.67									
	UX1400MSE	3	12.5		2.67	4.67	6.67						
	UX1100MSE	2	12.5					8.67	10.67				
	UX1100MSE	2	14.1							12.67	14.67		
	UX1100MSE	2	18.0									16.67	18.67

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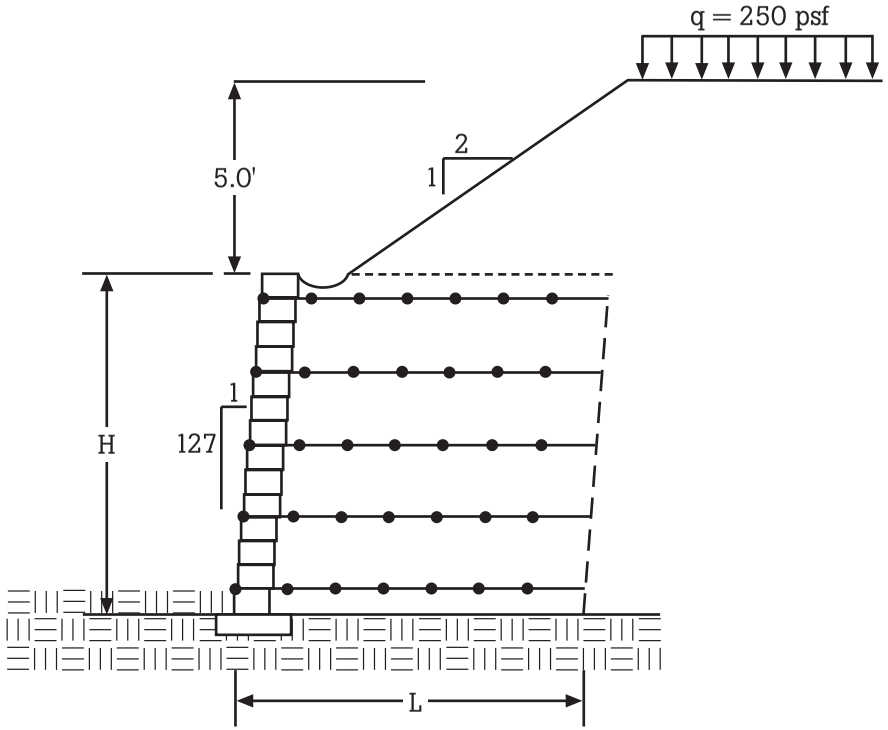
Design Chart

2:1 SLOPE, 250 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 30^\circ$
$\gamma = 125$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

5ft TOP 2:1 SLOPE, 250 psf SURCHARGE

REINFORCED WALL FILL	ϕ' = 30 deg.	γ = 125 pcf	c' = 0 psf
RETAINED AND FOUNDATION SOIL	ϕ' = 30 deg.	γ = 125 pcf	c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)									
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10
4	UX1100MSE	2	10.9	0.67	2.67								
6	UX1100MSE	1	10.0	0.67									
	UX1100MSE	2	7.7		2.67	4.67							
8	UX1100MSE	4	9.4	0.67	2.67	4.67	6.67						
10	UX1100MSE	1	10.1	0.67									
	UX1100MSE	2	8.0		2.67	4.67							
	UX1100MSE	2	9.6				6.67	8.67					
12	UX1100MSE	1	10.8	0.67									
	UX1100MSE	3	9.5		2.67	4.67	6.67						
	UX1100MSE	2	11.8					8.67	10.67				
14	UX1100MSE	1	11.5	0.67									
	UX1100MSE	3	10.9		2.00	4.00	6.00						
	UX1100MSE	2	12.9					8.00	10.00				
	UX1100MSE	1	15.2							12.00			
16	UX1400MSE	1	12.1	0.67									
	UX1400MSE	1	11.3		2.67								
	UX1100MSE	2	11.3			4.67	6.67	8.67					
	UX1100MSE	3	14.0						10.67	12.67			
	UX1100MSE	1	16.2								14.67		
18	UX1400MSE	1	12.9	0.67									
	UX1400MSE	2	12.0		2.67	4.67							
	UX1100MSE	2	12.0				6.67	8.67					
	UX1100MSE	3	16.2						10.67	12.67	14.67		
	UX1100MSE	1	18.4									16.67	
20	UX1400MSE	2	13.8	0.67	2.00								
	UX1400MSE	3	12.1			4.00	6.00	8.00					
	UX1100MSE	4	17.7						10.00	12.00	14.00	16.00	
	UX1100MSE	1	21.8										18.00

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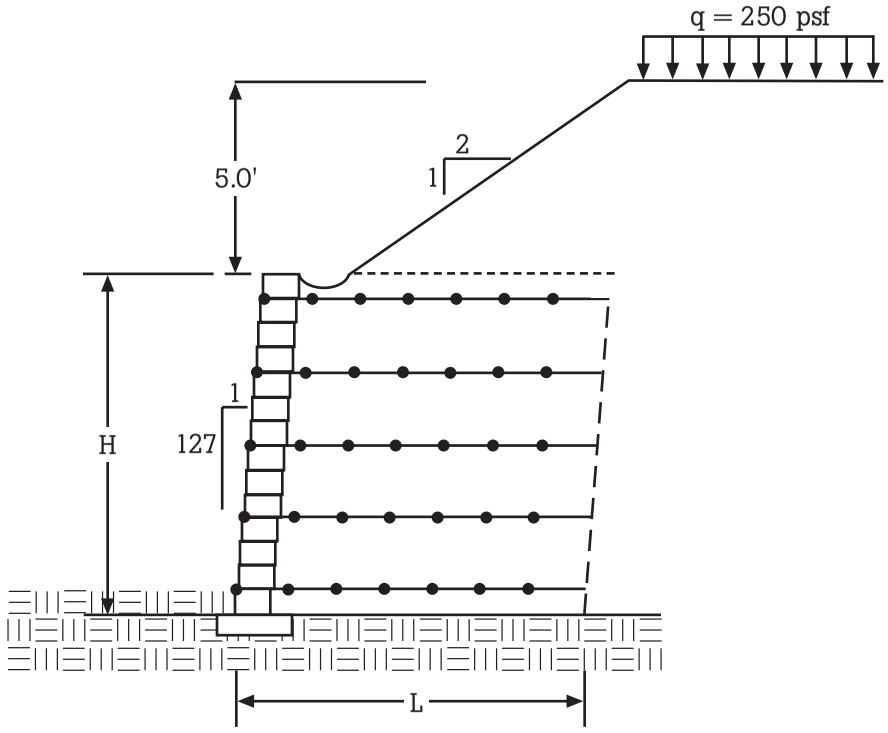
Design Chart

2:1 SLOPE, 250 psf SURCHARGE



Not to Scale

REINFORCED
WALL FILL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

RETAINED BACKFILL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

FOUNDATION SOIL
$\varnothing' = 28^\circ$
$\gamma = 120$ pcf
$C' = 0$ psf

HEIGHT CONVERSION			
UNITS ABOVE LEVELING PAD	GEOGRID LEVEL	UNITS ABOVE LEVELING PAD	GEOGRID LEVEL
1	0.67'	16	10.67'
2	1.33'	17	11.33'
3	2.00'	18	12.00'
4	2.67'	19	12.67'
5	3.33'	20	13.33'
6	4.00'	21	14.00'
7	4.67'	22	14.67'
8	5.33'	23	15.33'
9	6.00'	24	16.00'
10	6.67'	25	16.67'
11	7.33'	26	17.33'
12	8.00'	27	18.00'
13	8.67'	28	18.67'
14	9.33'	29	19.33'
15	10.00'	30	20.00'

DESIGN CHART FOR MESA RETAINING WALL SYSTEMS

5ft TOP 2:1 SLOPE, 250 psf SURCHARGE

REINFORCED WALL FILL	ϕ' = 28 deg.	γ = 120 pcf	c' = 0 psf
RETAINED AND FOUNDATION SOIL	ϕ' = 28 deg.	γ = 120 pcf	c' = 0 psf

WALL	GEOGRID			GEOGRID POSITION (HEIGHT ABOVE LEVELING PAD, FT.)										
H (FT.)	TYPE	No. LAYERS	L (FT.)	1	2	3	4	5	6	7	8	9	10	11
4	UX1100MSE	2	14.0	0.67	2.67									
6	UX1100MSE	1	12.5	0.67										
	UX1100MSE	2	11.2		2.67	4.67								
8	UX1100MSE	1	11.9	0.67										
	UX1100MSE	3	11.1		2.67	4.67	6.67							
10	UX1100MSE	1	12.2	0.67										
	UX1100MSE	3	11.1		2.67	4.67	6.67							
	UX1100MSE	1	13.7					8.67						
12	UX1100MSE	1	12.8	0.67										
	UX1100MSE	3	11.7		2.67	4.67	6.67							
	UX1100MSE	2	16.4					8.67	10.67					
14	UX1100MSE	1	13.5	0.67										
	UX1100MSE	3	12.8		2.00	4.00	6.00							
	UX1100MSE	2	16.4					8.00	10.00					
	UX1100MSE	1	18.4							12.00				
16	UX1400MSE	1	14.3	0.67										
	UX1400MSE	2	13.9		2.67	4.67								
	UX1100MSE	2	13.9				6.67	8.67						
	UX1100MSE	2	19.1						10.67	12.67				
	UX1100MSE	1	21.7								14.67			
18	UX1400MSE	1	15.2	0.67										
	UX1400MSE	3	14.4		2.00	4.00	6.00							
	UX1100MSE	1	14.4					8.00						
	UX1100MSE	3	20.9						10.00	12.00	14.00			
	UX1100MSE	1	23.7									16.00		
20	UX1400MSE	2	16.0	0.67	2.00									
	UX1400MSE	3	14.8			3.33	5.33	7.33						
	UX1100MSE	1	14.8						9.33					
	UX1100MSE	4	23.4							11.33	13.33	15.33	17.33	
	UX1100MSE	1	25.6											18.67

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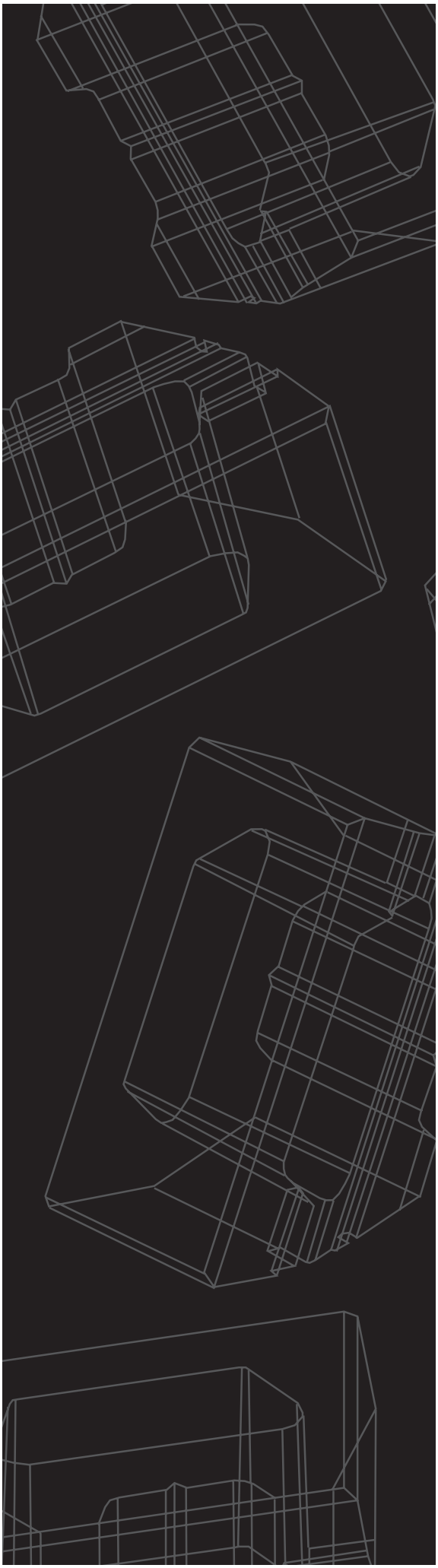

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