Introduction

The purpose of this manual is to provide general guidelines for the design of the Murata™ Mechanical Stabilized Earth (MSE) retaining wall system. Segmental MSE walls, unlike gravity walls, require tensile grid to resist the lateral loads induced by the soil. The Murata™ MSE retaining wall is designed to have sufficient mass and overturning resistance from the Murata™ blocks and the reinforced soil mass to support the lateral earth loads applied by the retained soil mass, as well as any surface surcharge loads.

The Murata™ retaining wall system's advantage is that it is made with hollow masonry units that can be handled without special equipment. When the blocks are installed, the hollow cells are filled with crushed rock, which results in a heavier in-place block to resist soil forces.

The Murata™ retaining wall system accommodates almost any wall plan layout such as wavy, straight, convex and concave curves, or square corners. This versatility furnishes designers and installers with many options to create a wall plan layout that fits a site or other architectural requirements such as stairs, handicap ramps, tiered walls, and steps in grade along the wall, planters, or special geometry.

The Murata™ retaining wall system offers a choice between modular (blocks only) gravity wall construction and MSE wall construction. Gravity wall design is beyond the scope of this manual. Please refer to the Murata™ gravity retaining wall design manual for guidance in the design of gravity wall systems.

Performance

The Murata™ dry stack system offers significant performance advantages over conventional (more rigid) retaining wall systems. Mortarless construction allows the Murata™ retaining wall system blocks to move relative to each other in response to settlement or transient loadings, eliminating the most visible signs of movement such as stair step cracks, which commonly occur in mortared walls. Dry stacked gaps between blocks permit water to flow freely through the wall facing, reducing hydrostatic pressures behind the wall.

Installation

The installation procedures described in this manual are simple, repetitive, easily mastered, require no skilled tradesmen, and only modest equipment capabilities. Following the installation instructions as presented ensures that an acceptable quality of installation can be achieved. The learning curve to reach optimum production rates is relatively short (usually a few projects). Special installation training and job site assistance can be arranged by contacting your local Murata™ retaining wall system distributor.

Durability
Murata™ retaining wall system products are manufactured using high-strength, low-slump 5000 psi machine-formed concrete. The Murata™ retaining wall system has a typical life expectancy of over 50 years.

Value
The initial cost of the Murata™ retaining wall system is competitive with other wall systems and is significantly less expensive than most conventional concrete walls. The lasting aesthetics and structural durability of the concrete Murata™ retaining wall system makes it a cost-effective solution when life-cycle costs are considered. This value is created in part by the installation rates of the retaining wall system. The Murata™ retaining wall system does not require special tools to install and the blocks can be moved by hand. The self-aligning tabs allow for highly accurate and quick installation.

Soil Characteristics
The Murata™ retaining wall system is designed to resist a wedge of soil as illustrated in Figure 1. There are two types of soil in the Murata™ retaining wall system. The first type of soil is the Murata™ fill. Murata™ fill is given as road base from Oregon, Washington, or Idaho's Department of Transportation. Specifications of each Murata™ fill can be found in the Murata™ gravity wall specifications. The second type of soil is the retained soil. The retained soil may be native to the site or compacted fill due to regrading. Both types will have different properties.

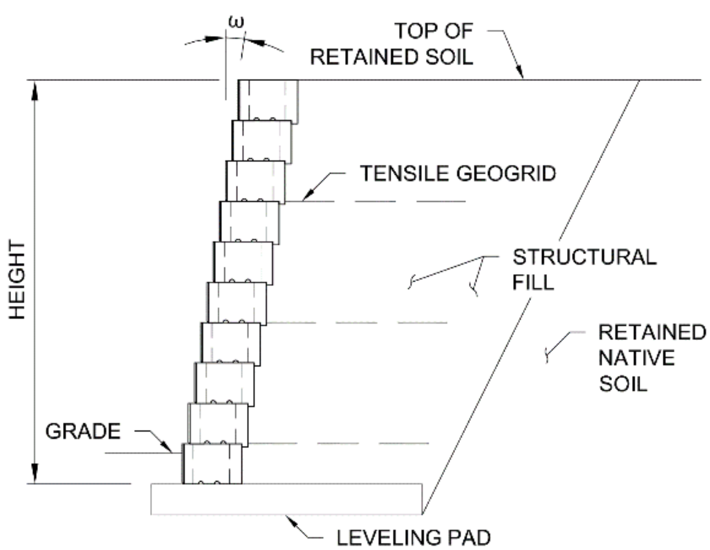


Figure 1

Properties of each soil type, including the internal angle of friction, wall friction angle, base friction angle, cohesion, and unit weight, should be defined by a geotechnical engineer. These properties should be used to calculate the active pressure, passive pressure, active seismic pressures, and soil-bearing capacity through procedures outlined in this manual.

It is essential to consult a qualified geotechnical engineer to obtain reasonable or optimal soil properties. Reliance on a geotechnical report will lead to an accurate and optimized wall design. In some cases, additional subsurface exploration and laboratory testing may be necessary to obtain reasonable soil properties for optimizing the wall design.

Soil strength parameters should be based on drained conditions for granular soils as well as fine-grained soils for long-term stability. In this manual all soil parameters are based on drained conditions, thus conforming to the effective stress analyses utilized in design.

Geogrid

Geogrid is a tensile reinforcement often added to granular soils. Granular soil has a very poor performance in tension. Geogrid is a reinforcement for Murata™ fill, manufactured with a high molecular weight polyester fiber that is a dimensionally stable uniform array of apertures to provide tensile capacity in two orthogonal directions. Geogrid is both mechanically and chemically stable in harsh construction and soil environments. Stratagrid SG350 is the only geogrid approved to be installed with the Murata™ retaining wall system. See the last page of the manual for the geogrid and block properties summary. The National Concrete and Masonry Association (NCMA) recommends the minimum length of geogrid be 70% of the height of the wall or 4'-0" (1200 millimeters), whichever is more (National Concrete Masonry Association, 2010).

Design Methodology

The sample calculations in this manual follow the methodology outlined in the NCMA Design Manual for Segmental Retaining Walls, Section 7 (National Concrete Masonry Association, 2010). A significant difference between the stability analyses for a gravity wall and an MSE wall is that the mass of the Murata™ fill within the reinforced zone is included as part of the total mass of the MSE wall. The lateral soil forces caused by the retained soil is assumed to act on the back face of the reinforced zone.

Forces on the Wall

Lateral forces acting upon a segmental MSE retaining wall arise from active soil pressure, active seismic pressure, and induced surcharge pressure, all acting on the back face of the reinforced zone, as shown in Figure 2. Passive earth pressure also acts on the front face of the leveling pad and the portion of the wall below grade.

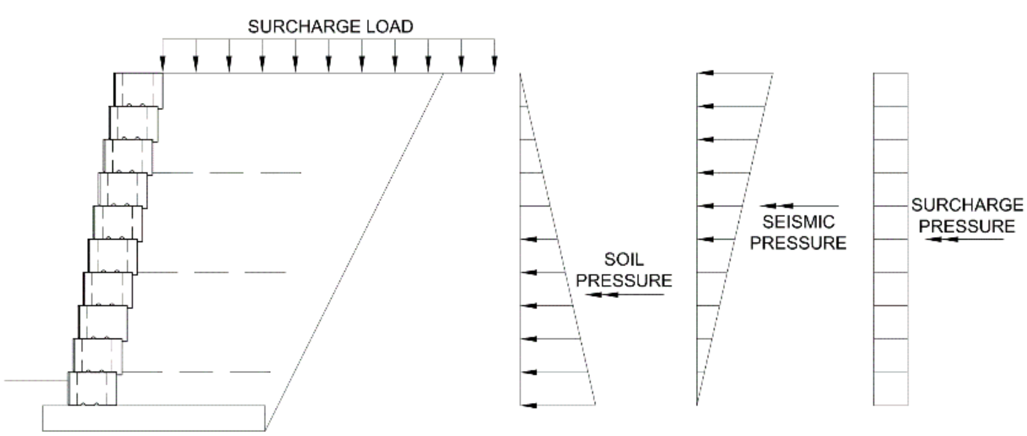


Figure 2

Soil Properties: The properties of both soil types, the Murata™ fill and the retained soil, are required to analyze the stability of the MSE wall. The global stability analyses, such as sliding, bearing, and overturning, use the retained soil properties to generate the driving forces, and internal stability analyses, such as tensile overstress, pullout of reinforcement, internal sliding, facing connection, and crest toppling, use the Murata™ fill properties to generate the driving forces.

Active Soil Pressure: Active soil pressure causes a horizontal force applied to the retaining wall from the weight of the soil pushing laterally on the back face of the reinforced zone (as shown in Figure 3). The active soil pressure is applied as an equivalent fluid pressure in the engineering design. It is a triangular pressure that increases from zero at the ground surface linearly with depth (as shown in Figure 2).

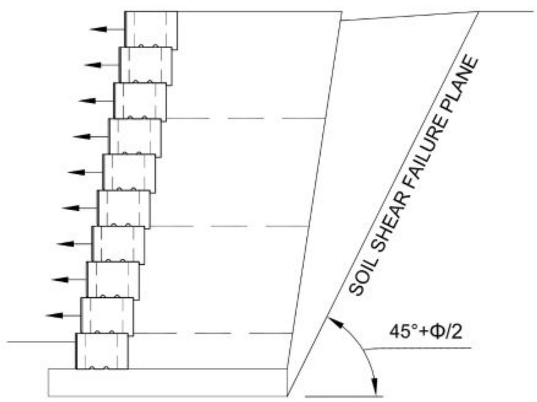
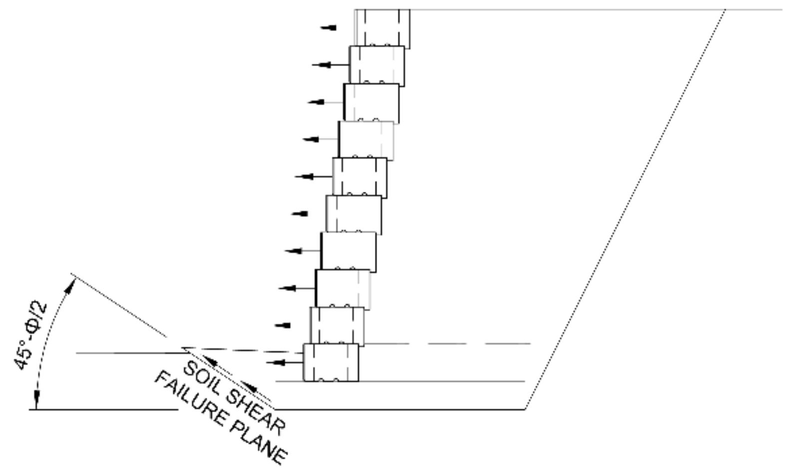


Figure 3

Active soil pressures are calculated based on the soil properties at the site. A geotechnical engineer should be consulted to determine the on-site soil and Murata™ fill properties, and how to apply the soil forces for your project. Once given the soil properties, the active pressure coefficient will be calculated using Coulomb's Theory of Active Lateral Earth Pressure.

It is important when calculating the active pressure on a retaining wall to compare the active pressure induced by the Murata™ fill to that of the retained soil. Murata™ fill may be heavier but has a higher internal friction angle, resulting in a smaller active pressure when compared to the lighter native retained soil with a typically lower internal friction angle. The higher active soil pressure shall be used.

Passive Soil Pressure: Passive soil pressure is generated when the wall moves into the soil at the toe (as shown in Figure 4), and results in a force resisting triangular increasing linearly from zero at the ground surface to the base of the leveling pad. The NCMA Design Manual suggests a minimum embedment of 6” (150 millimeters) and extend 6” out from the face of the base course (National Concrete Masonry Association, 2010). A geotechnical engineer should be consulted for embedment recommendations on your project.



Passive soil pressures are calculated based on the soil properties at the site. It is recommended that the passive soil pressure not be used in resisting active soil pressure, unless the embedment is permanent and the material at the base of the wall is compacted per the geotechnical engineer's recommendations. Embedment is often not permanent and soil in front of the toe of a wall can erode or be removed. For these reasons, a geotechnical engineer should be consulted for on-site soil properties and for guidance on how to apply the soil forces on your project. Once given the soil properties, the passive pressure coefficient will be calculated using Coulomb's Theory of Passive Lateral Earth Pressure.

Active Seismic Pressures: The active seismic pressure is caused by lateral soil movement during an earthquake. The active seismic pressure is often applied for design purposes as an inverted equivalent fluid pressure. The active seismic pressure is considered zero at the base of the wall and increases linearly to the ground surface. Because this is an overly conservative assumption, the resultant active seismic force is traditionally applied at 0.6H from the bottom of the retaining wall.

Active seismic pressures are calculated based on the soil properties and the seismicity at the site. The United States Geological Survey offers an online portal that produces seismic design criteria for any specific address (or latitudinal and longitudinal coordinates). A geotechnical engineer should be consulted for on-site soil properties, site ground motion, and active seismic pressure application. Once given the soil properties, the active pressure coefficient will be calculated using the Mononobe-Okabe equation.

It is important when calculating the active seismic pressure on a retaining wall to compare the active seismic pressure induced by the Murata™ fill and the native soil. The larger active seismic pressure shall be used.

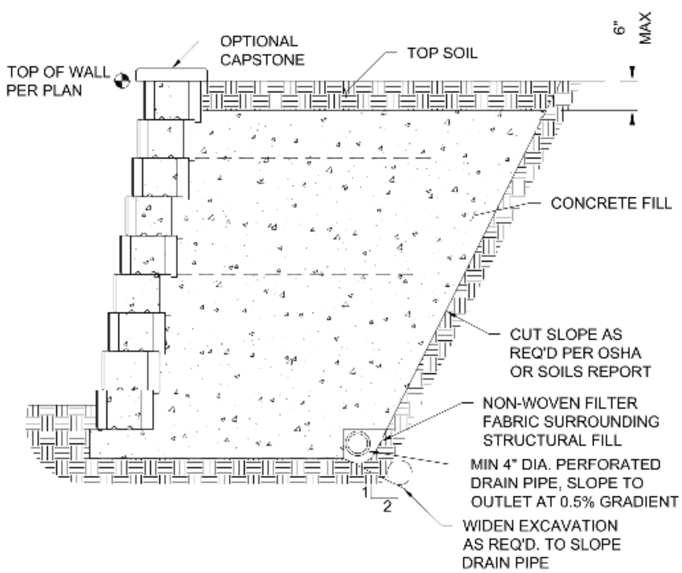
Uniform Surcharge Loads Above Retaining Wall: A uniform vertical load (psf) applied to the top surface of the retained soil induces a horizontal pressure on the backside of the reinforced zone. Surcharge pressures are calculated based on the soil properties at the site. A geotechnical engineer should be consulted for on-site soil properties and how to apply the surcharge forces on your project. Once given the soil properties, the active pressure coefficient will be calculated using Coulomb's Theory of Active Lateral Earth Pressure and multiplied by the vertical surcharge pressure to obtain the induced lateral pressure on the retaining wall. This pressure is uniform with the resultant halfway up the wall from the bottom (as shown in Figure 2).

Live load surcharge vertical component resultants are not recommended to be used when calculating the resistive forces and moments. The live load is considered too transient to contribute to the resistance of driving forces.

Typical light and heavy traffic surcharges are 125 psf and 250 psf respectively.

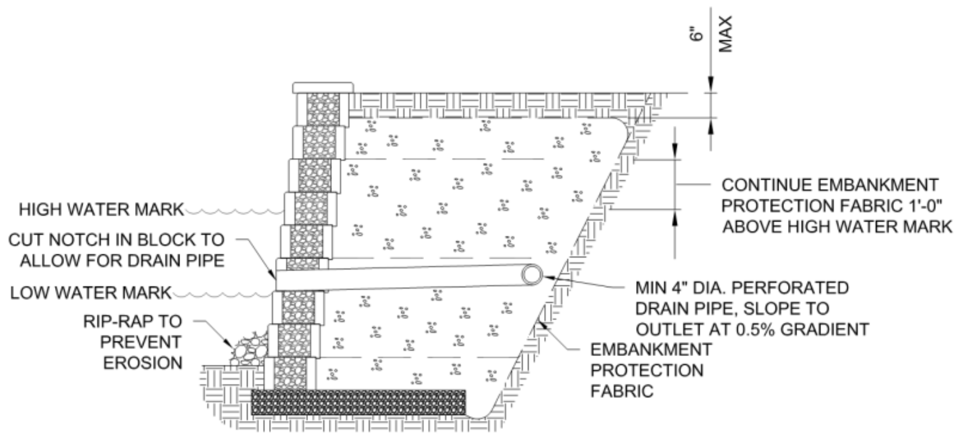
Special Design Considerations

No Fines Concrete
Some situations dictate the use of a stronger backfill. In this case, no fines concrete is recommended. No fines concrete has a density of 100-120 pounds per cubic foot and allows water to freely pass through in a manner similar to Murata™ fill. It would replace the Murata™ fill both behind the wall and in the cells of the Murata™ blocks. Your local concrete manufacturer should be contacted for available no fines concrete and its density for your specific project.



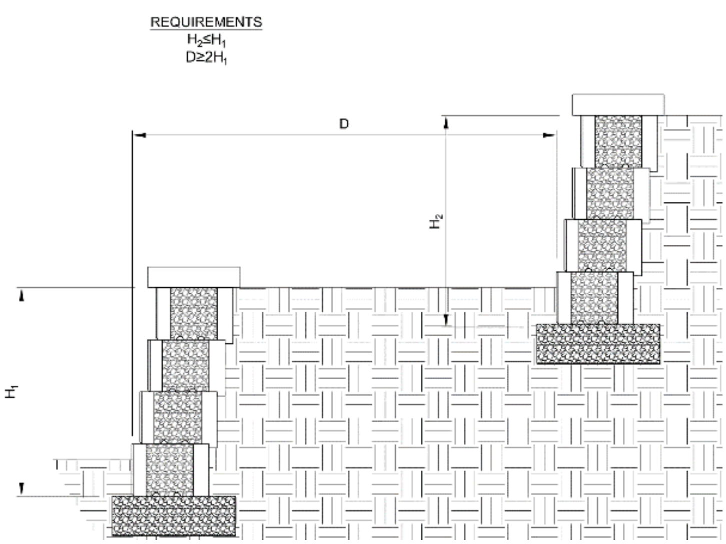
Water Application

The Murata™ retaining wall is well suited for water applications due to its high compressive strength contributing to its durability. Retaining walls where water is stagnant with wave action such as in lakes or retention ponds or moving such as along streams or culverts qualify as retaining walls in water applications. The drain pipe from the perforated drain at the rear of the structural fill shall empty at an elevation above the low water mark.



Tiered Walls

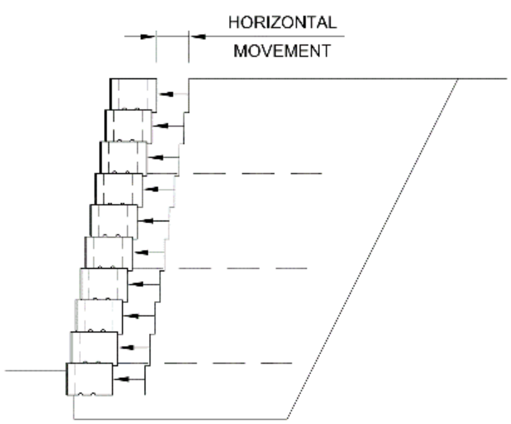
It is often advantageous to split one large retaining wall into two shorter walls offset by a tier due to architectural requirements, aesthetics, and site layout. This allows vegetation to be planted between the top of the lower wall and the bottom of the upper wall.



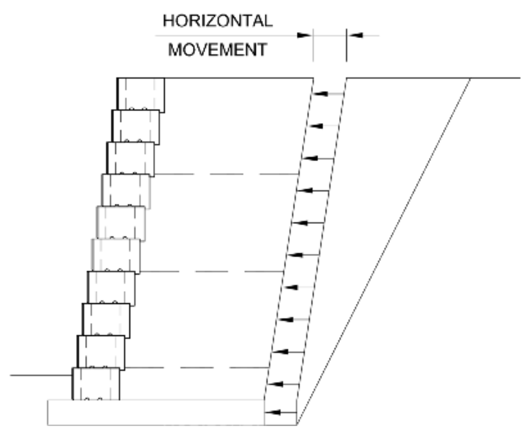
The lower wall shall have a greater height than the upper wall. The engineer of record shall consider the additional load on the lower wall imposed by the upper wall. In general, the face of the upper wall shall be set back from the face of the lower wall a minimum horizontal distance of twice the height of the lower wall in order for there to be no influence of the upper wall on the lower wall's stability. Consult the NCMA Design Manual for Segmental Retaining Walls, Section 5.9.2 for more information on tiered walls (National Concrete Masonry Association, 2010).

Wall Failure
When designing any retaining wall, there are many different failure modes the design professional has to consider. These include block sliding, foundation sliding, bearing failure, overturning, internal sliding, internal overturning, and global stability.

Base Sliding
Due to the application of lateral load on the back of the MSE section, resistance to sliding must be checked. Two types of failures may occur. The first is the MSE wall sliding on the leveling pad and the second is the leveling pad sliding on the native foundation soil. The lateral driving force originates from the active and seismic soil pressure, as well as the induced surcharge pressures.

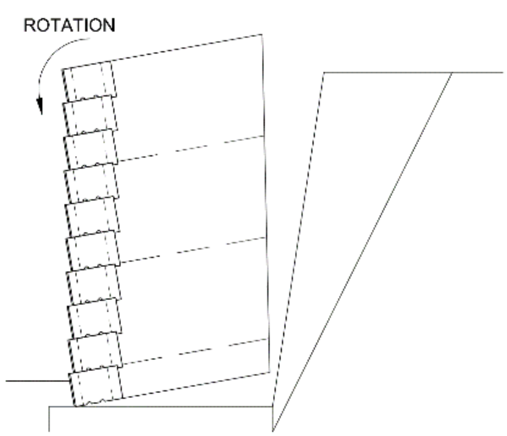


MSE Wall Sliding



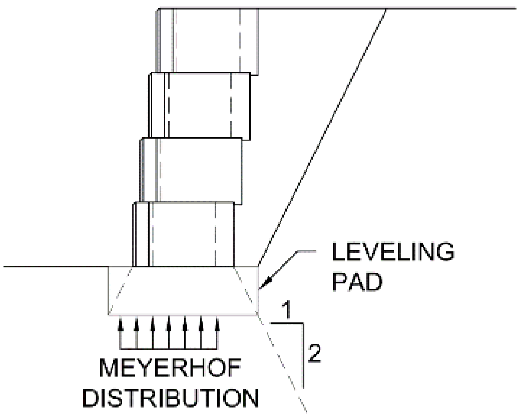
Leveling Pad Sliding

Overturning
Due to the application of lateral load at height, the resistance of the wall to rotation about a point on the front of the wall must be checked. The overturning point may be at the bottom front of the wall, but internal overturning must also be evaluated.



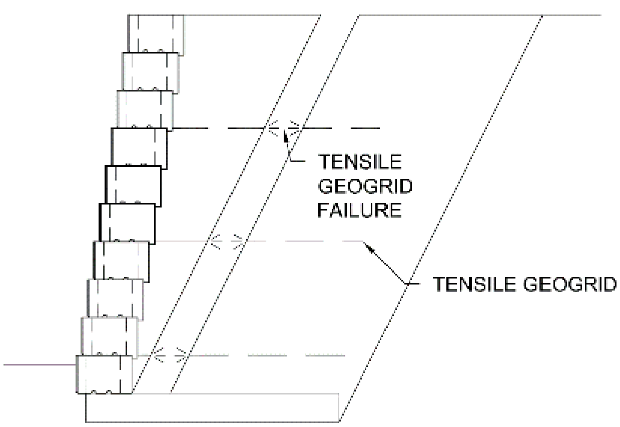
Bearing Stresses on Foundation Soils

The bearing pressure imparted on the soil must be less than the foundation soil's bearing capacity. A Meyerhof distribution analysis should be utilized. This method calculates an equivalent bearing pressure distribution needed to balance the vertical loads (the weight of the wall itself including the reinforced zone and the vertical component of earth pressure), the overturning moments created by lateral and vertical earth pressures, and vertical load eccentricity. A geotechnical engineer should be consulted regarding the bearing capacity of the foundation soil, and the necessary size of the leveling pad required to maintain overturning stability.



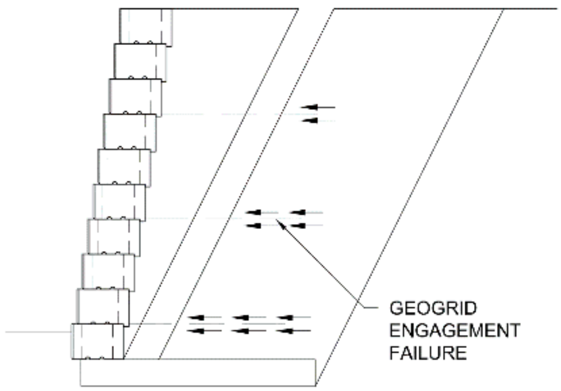
Tensile Overstress

The stability of the reinforced zone comes from the tensile stresses in the geogrid that resist horizontal soil forces. The designer must verify that the tension in the geogrid is less than the manufacturer specified tension capacity. The tension loads are calculated using Murata™ fill properties.



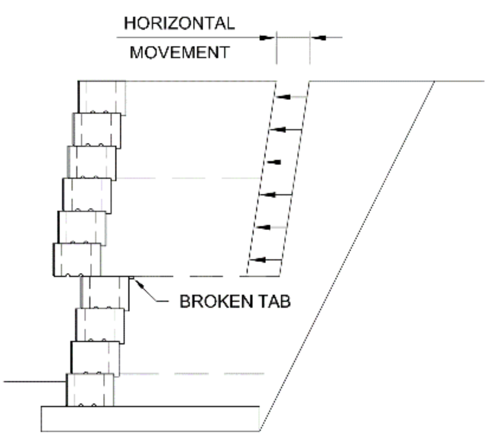
Pullout of Reinforcement

When under tension, shear stresses develop between the geogrid and the soil in contact with it. The interface between the soil and geogrid may slip under excessive shear stress. It is important to verify the long-term design shear strength from the manufacturer matches the Murata™ fill being used. The Murata™ fill specifications insure that a granular soil is used.

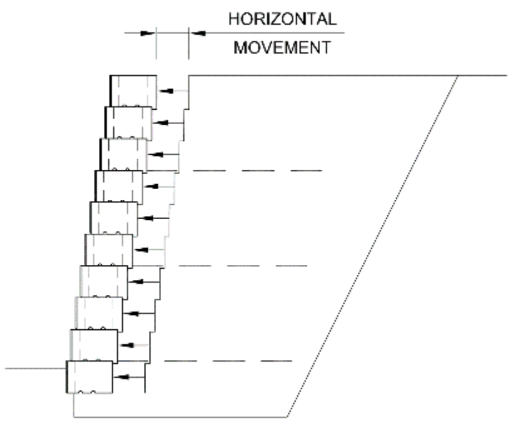


Internal Sliding

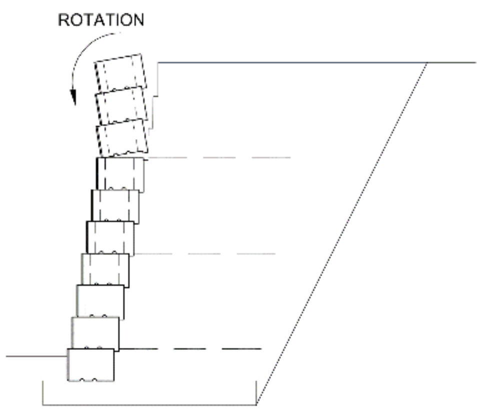
The blocks can slide in relation to one another due to the lateral forces induced by the soil on the wall. The lateral forces are resisted by the friction developed from the weight of the wall and the vertical component of earth pressure. This can happen on any level. The design professional should check that each level of block cannot slide laterally off the front of the wall. Friction and a positive connection can be used to resist lateral sliding. Murata™ wall systems provide a positive connection resistance with the addition of a concrete alignment tab on the bottom rear of the block.



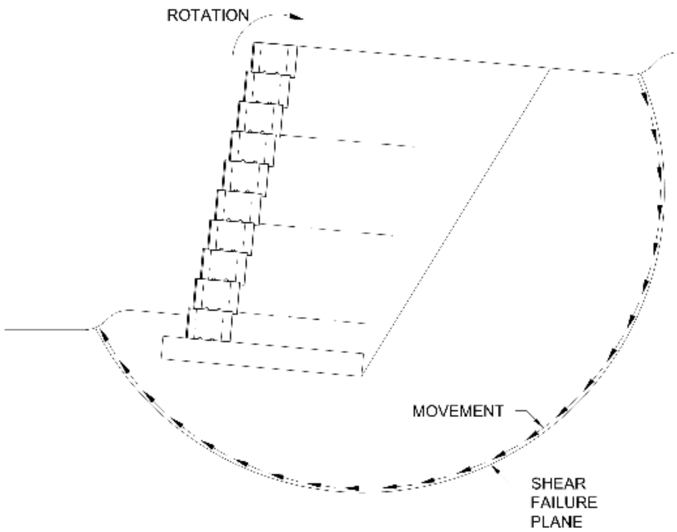
Facing Connection
When the applied lateral load on the face blocks of the MSE wall exceeds the connection strength between the geogrid and blocks, the blocks will slide away from the MSE soil.



Crest Toppling
Due to the unreinforced nature of the wall above the upper most geogrid layer, the designer must check the capacity of the crest of the MSE wall to resist overturning from the forces generated from the Murata™ fill.



Global Stability
The last mode of failure for an MSE retaining wall is the global stability of the surrounding soil. This results in a failure surface in the soil around the retaining wall. A geotechnical engineer should be consulted for requirements to avoid global soil instabilities.



Testing
The Murata™ MSE retaining wall system conforms to all American Society of Testing and Materials (ASTM) standards.

The Murata™ MSE retaining wall system utilized StrataGrid SG350. The geogrid manufacturer has provided the results from the following standards:

ASTM D4595 - Tensile Properties of Geotextiles by the Wide-Width Strip Method
ASTM D5262 - Test Method for Evaluating the Unconfined Creep Behavior of Geogrids
GRI-GG4 - Grid Allowable Long-Term Design Strength (LTDS)
ASTM D6706 - Grid Pullout of Soil

The results from the above-aforementioned standards can be found summarized below. All geogrid to soil interface data is relevant to the applicable structural fill as defined in the specifications:

Ultimate Tensile Strength = T_{ULT} = 4800 lbs per foot of width
Reduction Factor for Creep = RF_{CR} = 1.55
Reduction Factor for Durability = RF_{D} = 1.1
Reduction Factor for Installation Damage = RF_{ID} = 1.4

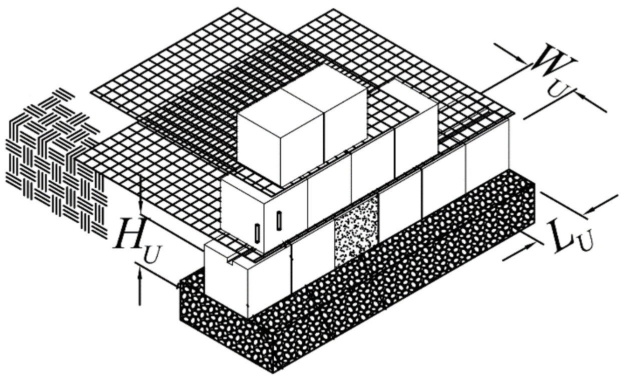
Murata™ blocks have gone through the following ASTM standards and testing:

ASTM C1372 Standard Specification for Segmental Retaining Wall Units
ASTM C1262 Evaluating the Freeze-Thaw Durability of Manufactured CMUs and Related Concrete Units

ASTM D6638 Grid Connection Strength (SRW-U1)
ASTM D6916 SRW Block Shear Strength (SRW-U2)

The results from the above-listed standards are summarized below:

Block Height = H_u = 7 ⅞”
Block Depth = D_u = 15 ¾”
Block Width = W_u = 11 ⅝”
Offset = 1 $^3/_{16}$”
Average Block Density w/ Murata™ Fill = γ_u = 120.8 lbs/ft^3

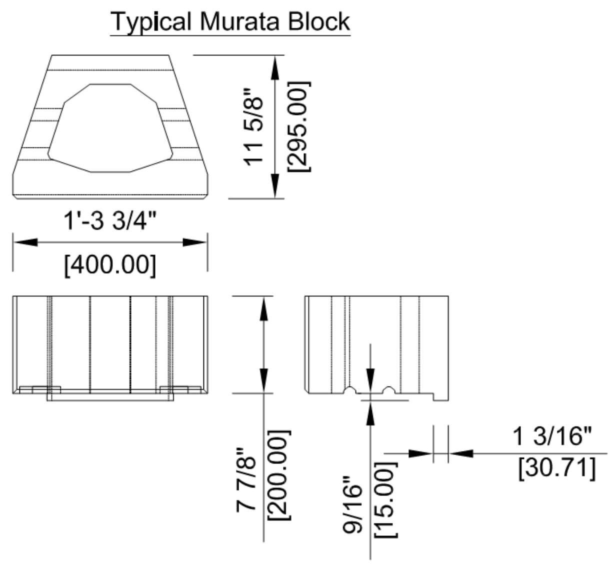


Block to Block Peak Shear Strength = 0.74N+449.46 lbs/ft
Block to Block Service Shear Strength = 1.01N+166.77 lbs/ft
Block to Block w/ Geogrid Peak Shear Strength = 0.59N+474.56 lbs/ft
Block to Block w/ Geogrid Service Shear Strength = 0.67N+317.60 lbs/ft
Geogrid Facing Connection Peak Shear Strength = 0.68N+550.16 lbs/ft
Geogrid Facing Connection Service Shear Strength = 0.34N+532.38 lbs/ft

Maximum Facing Connection Tensile Capacity = 1046 lbs

Block Properties

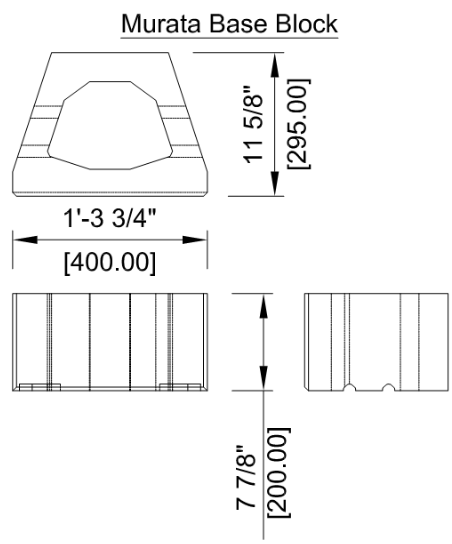
The Murata™ retaining wall system has two individual block designs. The difference between the two designs is the presence or absence of the alignment shear tab on the back side of the block.



The shear tab allows for easy alignment in the field during construction. However, where the base block is sitting on a leveling pad of compacted Murata™ fill, the shear tab is not needed.

The shear tab contributes to the strength of the Murata™ retaining wall system to resist horizontal lateral movement between courses.

Using formulas from the American Concrete Institute (ACI) 318-11 code, the apparent shear capacity that the shear tab contributes to the strength of the Murata™ retaining wall system to resist horizontal lateral movement between courses can be calculated (American Concrete Institute, 2012).



The concrete used to manufacture the Murata™ blocks has a density of 136.5 pounds per cubic foot (pcf).

When the central portion of the block is filled with loosely placed Murata™ fill, the resulting average density of the core fill and block is 120.8 pcf based on laboratory testing performed using ODOT (Oregon Department of Transportation) ¾-inch minus road base. See the Murata™ MSE Wall Specifications for ODOT road base. This is the density that is used in the following example analysis. Note: The average density will vary based on the specific Murata™ fill source and may need to be checked by a geotechnical engineer.