



Installation Guidelines





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Revolutionary Soft Armour Solutions

1. Introduction: Changing the way we Build

FLEX MSE DESCRIPTION

Flex MSE is a second generation technology that leverages existing revolutionary soft armour systems to create a superior solution. This soft armour segmental system allows for construction of permanent slope, wall and shoreline protection installations while creating full vegetation of the wall face. No concrete, no rebar, no forming, and often no leveling pad are needed.

Flex MSE is a globally patented, fully engineered system that creates near vertical vegetated walls. It stabilizes hillsides, levels sites, and protects stream, lake and coastal banks from erosion; all while creating beautiful landscapes and re-establishing nature's strength.

The Flex MSE facing consists of only two components – a proprietary non-woven Polypropylene (PP) geotextile Bag, and an engineered 100% recycled PP Plate. The improved 2nd Generation Flex MSE Plate mechanically connects to the geosynthetic Bags and is then vegetated, creating a structure with great strength, resilience and range of application.

Flex MSE Plate

Raw material: 100% recycled postindustrial PP
100% recyclable



Height	42.2mm
Length	285 mm
Width	99 mm
# Spikes	11
Friction Strips	2
Geogrid Hooks	2
Weight	63 grams

The Flex MSE Plate provides a positive interconnection between every Bag. It also mechanically connects geogrid and the Flex MSE Bag using either the 8-spike array underneath or the Geogrid Hooks on top. Plates must be used at a 1:1 ratio to the Bag in all applications. Two teathed strips provide additional friction zones, improving Bag to Plate contact.

Flex MSE Bag



Raw material: 3.8oz/yd(128g/m2) New PP

100% recyclable

Unfilled Bag Size	Approx. Facing Area/Stacked Filled Bag*
15" X 35"	1.14 ft2
38cm X 89cm	0.09 m2

*Face area per Bag may vary based on volume/compaction of Bag fill material.

Face foot/metre Unit Estimations (contingency included) are:

1.2 Units per ft2 (13 Units per m2) for Stacked Gravity and Geosynthetic reinforced walls,

1.6 Units per ft2 (17 Units per m2) for Tie Back Walls, and

.3 Units per ft2 (4 Units per m2) for Mattress installations.

Optimally filled Flex MSE Bags should measure 75cm long x 30cm deep x 14cm High (30"x12"x5.5") when foot tamped on level ground.

Base weight to match ASTM testing 71lbs (32.2kg)

The Flex MSE nonwoven polypropylene Bag is the ideal planter block for permanent vegetation. It is engineered for excellent drainage, containment, filtration, and root growth. Composed of single source, high molecular weight, needle punched PP fibers; Flex MSE Bag material is also calendered on one side to add tensile resistance. Due to its chemical stability and non-toxicity, polypropylene is the material of choice in highly toxic, alkali, and acidic sites, as well as sensitive marine and freshwater environments. The material is 100% recyclable, 70% protected to 500 hrs. peak UV, and flexible to -30C.

FLEX MSE SPECIFICATIONS

Flex MSE follows established Segmental Retaining Wall (SRW) and Mechanically Stabilized Earth (MSE) principles. Standard engineering design and construction considerations apply in all installations. The use of additional reinforcement in the form of geosynthetics and/or Flex MSE units (Tie Back Method) shall be considered in all applications prior to the start of construction. For technical specifications, refer to the current *Flex MSE Specifications* document. Structural/Geotechnical design considerations may include, but are not limited to:

- *Installation height, including terraces, exceeding 3' to 5'/1-1.5m in height (depending upon jurisdictions and installation type)*
- *Presence of unstable soils, such as clays or organic materials*
- *Hydrostatic loading or erosion from wave action, scour, flow velocities, drainage, irrigation or site runoff*
- *Load resulting from construction, slopes or structures behind, or above the wall*
- *Installation slope/batter*
- *Geosynthetic soil reinforcement or other mechanical soil stabilization methods*
- *Government Guidelines (Environmental, Seismic)*

FLEX MSE ADVANTAGES

- 120 year ASTM lifetime rating
- Two components satisfy slopes from 0° - 85°
- Far superior vegetation results vs vegetated wire, concrete, and rock based facings
- Superior settlement/compression ratings vs other geosynthetic faced wall systems
- Installs in 60% of the time vs concrete and basket systems
- Can be 60% the cost of other systems installed

- Lightweight, compact components – 100 unfilled Units (100 Bags, 100 Plates) weigh under 30lbs (13.6kg), a Kitted Master pallet (1200 Units) weighs 500lbs (227kg)
- Simple crew training
- No forms, rebar, footings and often no leveling pad required
- No extra drainage systems required
- Much greater Differential Settlement capabilities over poured concrete or other hard armour and Flexible facings
- Cost effective engineering and construction vs other geosynthetic faced systems
- 3% the GHG profile of concrete blocks the equivalent size
- Ideal for use in poor/tight access sites
- Can reuse excavated material as soil component
- Reestablishes native vegetation and landforms
- Wide range of vegetation options

FLEX MSE APPLICATIONS

Environmental



- **Erosion and Sediment Control**
- **Steep Slope Stabilization**
- **Slip Repairs**
- **Culvert Headwalls**
- **Retention and Detention Ponds**
- **Riverbank Protection**
- **In Stream, Shoreline and Estuary Structures**
- **Open Pit Mining Restoration**

Infrastructure



- Highway Walls
- Bridge Abutments
- Levees/Dikes
- Sea walls
- Green ways and Bike paths
- Noise Barriers

Commercial, Industrial and Residential



- Site Leveling/Optimization
- Terraced Garden Walls
- Landscaping and Landforms
- Sensitive Sites

Please refer to Trexiana Wholesale and Distribution's complete package of *Flex MSE CADs* for further information on specific applications.

2. Installation: Engineered by Design

EQUIPMENT LIST

The following is a list of Equipment that may be required depending on the scale or type of installation. Every installation and contractor demands its own set of tools.

- a. Flex MSE Bag Filling Jig
- b. Site specific safety protection
- c. Skid steer and/or excavator with appropriate attachments (bucket, scoop and forks for Bag pallets)
- d. Rounded digging and flat edge transfer shovels
- e. Utility knives
- f. Specified Bag closures (Cable Ties, galvanized loop ties, hog rings, industrial sewing head/thread)
- g. Pick and cutting spade for root removal
- h. 6' Pry bars for larger rock removal
- i. Hand tamper
- j. Wheel barrows
- k. Heavy duty 5 gallon Buckets
- l. 4 ft or laser level
- m. Batter board set up or Magnetic Protractor w/6' level
- n. Tape measure
- o. Light Weight plate compactor (under 1000lbs)
- p. String line and stakes
- q. Tarps for Bag pallets
- r. Dibber or Dibble if Live Planting

BASIC DESIGN METHODOLOGY

Retaining walls require careful analysis and solid installation practice to ensure long-term stability and safety. This includes an understanding of the retained and subgrade soils, terrain changes, surcharges, water effects (wave and tidal action, scour, volume and velocity, and hydrostatic pressure) and potential seismic loading.

Flex MSE's unique characteristics of being a permeable/soft armour/flexible/segmental facing add resilience and strength, but strong design and construction methods are necessary to provide generations of stability, functionality, and aesthetic enjoyment.

TYPES OF FLEX MSE WALLS

GRAVITY WALLS

Gravity walls are structures that depend on the facing's mass to resist the pressure from the retained soil behind. They often have a 'batter' or set back to improve stability by leaning back into a slope or fill soils being stabilized. Gravity walls can be solid facings or segmental. Flex MSE is considered a Segmental Retaining Wall system, and can be used in gravity wall applications up to certain heights and when no surcharge is present.

MECHANICALLY STABILIZED EARTH WALLS

MSE walls are composite structures made with Segmental Retaining Wall facings and artificial reinforcements. Geosynthetic materials such as geogrids are typically laid in sectioned lengths in continuous layers throughout the wall. Depending on the various design parameters, geogrid types and lengths can vary considerably even within the same structure.

MSE structures, and their sub set of Reinforced Soil Slopes (RSS), do not rely predominantly on facing mass for stability. Rather, they rely mostly on densely compacted layers of inorganic soil, contained by the geosynthetic reinforcement. Thanks to the additional friction and shear strength added by the geogrid, lateral soil pressures are much less than are found in traditional gravity walls. This permits the use of much lighter weight facing and reinforcement materials.

Geogrid lengths and strengths are determined by many different design factors, and should always be determined in concert with the designing engineer.

ENGINEERING

Engineering will be considered in the design and construction of any Flex MSE System application exceeding local regulations for total or exposed vertical height or as required by local authorities, under loading, and where it is to be used in any water related sites.

Engineering considerations, depending on the Flex MSE application, should include but not be limited to:

Application height, wall or slope face angle/ batter, site soils, backfill soils, slope above structure, slope below structure, surcharge loading, hydrostatic loading, seismic qualifications, site drainage & run off patterns, wave action, flow velocities and volumes, stream scour depths, anticipated settlement, geogrid soil

reinforcement or other mechanical soil stabilization devices included in the design of the wall.

The two main categories of engineering analysis for all retaining walls are:

Internal Stability: Analysis that addresses forces and reactions in the facing Units and the reinforcement layers. Designers check for block to reinforcement connection strength, reinforcement pullout from the soil, and other factors.

External Stability: Analysis that encompasses the forces outside of the facing and reinforcement, such as the strength of the backfill soil, the effects of friction between the soil and the structure, the slope of the backfill, and batter of the wall. There are several categories within External Stability, including overturning, bearing capacity, sliding, and global stability.

The necessary testing has been carried out to give engineers the correct data when designing with Flex MSE. This includes Connection Strength testing with industry leading geogrids, Shear Tests on the Bags and Plate, as well as Permeability Testing on typical Bag fill media. Pull Out data (the relationship between backfill soil and geogrid) is provided by grid manufacturers. Test data on all components, including Bag fill, is available for designers.

FLEX MSE BAG PREP

Contractors or others filling Flex MSE Bags shall follow the instructions laid out in the *Flex MSE Bag Filling Jig and Process* document and the *Flex MSE Bag Filling* video. The Jig is built to 30" table height, allowing for optimally filled Bags that rest level on the ground in groups after the tabletop and frame are moved. Building two or more Jigs will increase Filled Bag output. With two 18 hole Filling Jigs, three labourers and a skid steer, output is typically 600 or more filled Units/day. Jigs can easily be built with 27 holes as well (3 rows of 9 holes each).

When calculating total soils required: 22 Bags are optimally filled per yd³ of fill medium, or 30/m³. The number of Optimally Filled Units per face ft is 1.2/ft² (13/m²) for Standard Stacked layout walls, and 1.6/ft² (17/m²) for Tie Back Walls. Even if not using excavated materials in the Bag Fill Medium, it is recommended to fill Bags on site whenever possible to minimize transportation costs.

Optimally filled Units should measure 30"x12"x5.5" (762mmx305mmx140mm). Optimum filled Unit volumes are a minimum of 32L/1.14ft³/34qt. Weights vary depending on Bag fill mediums and moisture content. Optimum dry unit weights for engineered walls are a minimum of 71lbs. Fill Volumes and finished Filled Bag dimensions are primary measures of Quality Control when filling, with average

Weight used secondarily after establishment of proper Volume and Unit size. Under filling of Bags results in more Units being purchased, filled and installed, potentially higher grid quantities, and can also upset running bond spacing from row to row. **A consistent Bag filling process is very important to the efficiency and success of the Flex MSE system, from installation to long-term performance.*

Quality, consistent Bag Fill medium is also essential to the success of a Flex MSE installation. Bag fill medium provides mass and reliable structure, drainage, and nutrition for the vegetation. Bag fill medium must contain enough quality organic matter to promote the growth of the specified vegetation. The optimal standard for Bag Fill Medium is 66-70% Clean, Fine Sands and 30-34% mature Compost mix or amended high quality, clay free topsoil. If the structure is not to be vegetated (ie is completely covered, buried, or submerged for the life of the install), straight granular content can be used in the Bag. For example, Units in river or lakefront locales that are buried subgrade or will be continually underwater can be filled with only granular content.

Approved Bag closures are 50lb+ cable ('Zip') ties, 6" (150mm) galvanized loop/rebar ties and hog rings, and mechanical sewing with an appropriate industrial quality synthetic thread. Bags are filled and closed consistently to the same point to ensure consistent dimensions. Optimally Filled Unit Bag 'tails' are no greater than 4" in length. If sewing, a 4" (10cm) seam at the end is typical.

When palletizing Bags, ensure that pallets are of adequate load capacity, nail heads are buried and that the bottom layer of Bags does not overhang the edges or slip between the slats. 48"x48" Pallets fit 8 Units per row, 40" pallets take 6. The shrink wrap used must be appropriately rated for the total pallet weight. Appropriately weight rated bag totes can also be utilized.

Many areas serviced by Trexiana Wholesale and Distribution offer prefilled Flex MSE Units. Contact local retailers (<http://www.flexmse.com/find-a-flex-mse-dealer-global/>) for pricing and supply. These Units closely match the specifications found in the Flex MSE Specification and Best Practices and the typical Units/m². Slight variations that have no effect on the overall quality of the build and number of estimated Units can occur. Trexiana Wholesale and its network of partners are not responsible for variability in Units estimated and final numbers of Units installed.

For further details, please see the *Flex MSE Bag Filling Jig and Process* document and the *Flex MSE Bag Filling Videos*.

EXCAVATION

The project site may require excavation and removal of unsuitable foundation soils and should be done so to design-specified parameters. Foundation soil is the soil directly beneath the wall system and supports the wall weight. Usually, foundation soil is the existing, on-site soil. Foundation soil should be stiff or dense, so that it is strong enough to hold the wall's weight without settling. *Some Flex MSE installations can be installed directly over organic soils, but will need trenching and compaction of in situ soils directly under the facing to minimize settlement. Unacceptable soils should be excavated and replaced with properly compacted, preferably granular soils. During excavation, care should be taken not to disturb additional foundation materials and any surrounding structures.

If a wall needs to be built over previously placed fill, such as utility-trench backfill or side-cast fill near a basement wall, it is very important to ensure that this old backfill has been properly compacted. If unsure, it's best to replace the backfill.

The foundation must be adequately compacted (minimum 95% Standard Proctor [SP]) and proof-rolled to minimize wall settlement. The excavated area must be large enough to accommodate proscribed Flex MSE Bag embedment (.15-.3m [12"-24"] typical), the required reinforcement (ie: geogrid lengths) and sloped backfill cut depths.

Standard practice for embedment trenches on unengineered Flex MSE installs is to create a 12" (30cm) wide x 12" (30cm) deep trench to accommodate a 6" (15cm) layer of clean granular material and the first layer of Units. It is acceptable to build directly on top of compacted native materials or even bedrock, depending on design parameters.

When building walls that incorporate soil reinforcement, the soil that is placed and compacted around the layers of geosynthetic reinforcement is called reinforced soil. The reinforced soil creates a mass that becomes part of the retaining wall, so it is important that the reinforced soil is of high-quality material and is properly compacted. On-site soil may be acceptable to be re-used for reinforced fill. However, sometimes the reinforced fill must be imported from off-site.

Place the excavated materials in a convenient location if site materials have been approved for use as Bag fill. No poured footings are required for Flex MSE walls, only a reasonably level and compacted base layer of structural fill or foundation soil. Note that a drainage zone behind the wall face is typically not required because the wall face is completely water permeable. Chimney drains in particular are not recommended; as they drain any surface water behind and not over or through the permeable facing. The permeability of the wall face helps

eliminate hydrostatic pressure in the backfill zone and maintain vibrant vegetation by providing hydration to the root zone. Chimney drains may still be employed in near vertical walls subject to significant frost lensing (ie: with a high probability of bulging and becoming over batter), and are typically designed with irrigation to compensate for the lack of moisture behind the facing.

Engineer drawings may specify minor drainage details, depending on quality backfill availability and site conditions. Designers will typically specify either a heel drain to protect the backfill from head slope drainage or ephemeral streams, or a shallow toe drain (weeping tile) if the wall is in or around water.

BASE COURSE

1) BASE COURSE PREP:

Because of its excellent drainage capacity and adaptability to settlement, Flex MSE requires much less Base Course prep than concrete or other so-called 'flexible' systems. Unengineered landscaping walls will use the described 12" (30cm) deep and wide trench with 6" high of compacted gravel as a base. Engineered walls may require excavation and installation of Units and reinforcement below the finished grade and possibly more compacted gravel material to stabilize poor subsoils.

Water installations typically need 12-24" (30-60cm) of embedment below the existing bed, or more depending on expected scour or wave effects. Occasionally, Flex MSE river or shoreline installs can also have well graded large angular rock (rip rap) installed against the face as a protective 'falling or launch apron'. When excavating, account for any Flex MSE Units as well as depths of riprap that will be 'tied' or 'keyed in' to the upstream, toe and downstream ends of the installation. This 'keying in' prevents gradual undermining or unraveling of the facing from scour. The typical rule of thumb with keyed in water-seated walls is to install double Bag thick ends as deep into the existing bank as the wall is high and then cover them with excavated native material or rip rap. For example, a 6' tall shoreline or river bank installation would have two layers of Units keyed 6' back (approx. 2 Bag lengths) into the bank to protect against the scour that is common on ends of armoured sections.

2) Drainage Details:

Flex MSE Landscape walls with no head slope and above the water table should not include drainage details. The Flex MSE facing is designed to be free draining when prepped and installed according to Trexiana's Specifications and Best Practices.

In these cases, a perforated drainpipe at the base of a small field of drainage aggregate would be the most required, and will quickly remove large amounts of water.

If there is risk of significant water flowing into and collecting in the back fill zone, due to a long head slope, ephemeral streams, or clayey fill, a 'toe' drain (directly behind the Flex MSE facing) or 'heel' drain (at the back of the back fill/reinforcement zone) may be deemed necessary by an engineer. Specialty backfill should also be in place if this is the case.

If the wall is along a shoreline that experiences tidal surges, special backfill and solid drainage pipe may need to be installed. Also, filter fabric may be needed around the drainage aggregate to keep fine soil from migrating into and clogging the aggregate.

3) Begin installing Flex MSE Units at the lowest point of the installation. Once the foundation/base material or trench and 6" (15cm) granular layer has been prepped (if required), place the Flex MSE Plates on the ground, lined up centered under the Bags to provide additional mechanical connection for your first course of Flex MSE Bags. Place filled and closed Bags with seams facing into the backfill zone and end to end with maximum 1" (2.5cm) gaps. Keep the 'tail' end of the Bag between (not over) the Units to ensure that the Plate engages fully to the Bag. Compaction by hand tamping or lightweight Vibrating Plate compaction (under 500lb) will cause the Bags to fill this small space and eliminate any minor settlement that might occur. There should be no holes for backfill to escape between.

To adapt to significant grade changes, step Bag layers into the in situ soils at appropriate points to meet the finished design parameters and desired elevations.

There must be no visible gaps between Units in order to prevent any loss of backfill material. If significant water velocities or daily changes in depth are expected, Bags below the bed and nominal water line may be filled with free draining 'clear' or 'clean' granular content. Armouring a few initial courses of Flex MSE Units with riprap or other rock can be undertaken to add another layer of protection against scour or projectiles in the most energetic zones of a water install. This hard armour apron guards against the effects of scour along the bottom of the wall. The initial layer of grid can also be installed below grade, extended up over the first few layers of placed Units, and continued back into the fill – thereby anchoring the toe of the wall into the backfill. This grid can also be further anchored with duckbill anchors into the in situ soil or other methods to increase facing shear strength.

Install the first row of Units reasonably level front to back and side to side. It is advised that Flex MSE walls built on bedrock be designed by a qualified Engineer to appropriately integrate the structure into the site materials.

4) On the next course, center and place a Flex MSE Plate lengthwise on top of each Bag joint so that a Plate equally spans every Bag. Situate the Plate on the Bag according your batter/set back, so that the next row of Bags will fully envelop the Plate below (See the [Flex MSE SLOPE BATTER SETBACK](#) document).

Engage the Plate's spikes by placing the next layer of Bags and walking along or hand tamping each course. For engineered or steeper walls, hand or plate compacting every row is recommended to create more uniform Units and eliminate any delayed compression or settlement of the facing. Maintaining the specified batter is a key component to the long term integrity of traditional MSE walls. It is less so for Flex MSE walls – but steeper, near vertical walls (more than .25h:1v), should always be constructed with a batter board, laser level, or other means of keeping the slope consistent.

*Note that the gentlest slope that Flex MSE Units are usually stacked in the typical end to end layout is 1.5h:1v. If the slope is lower than this, the Plate will not fully engage both Bags. For applications under this slope, Bags can be laid out in a mattress style layout, side by side and following the slope angle. If required, Plates and Geogrid can still be integrated into this style of installation, by engaging the sides of the Bags, as opposed to the top and bottom.

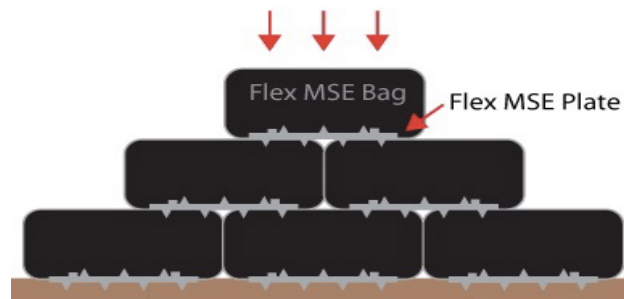
C) Backfill and compact every two rows of bags (10"/30mm), or the specified soil lift. Depending on soil conditions, this can be extended to every three courses. When coming to a backfill compaction level, it is safe to run a small vibratory plate compactor (100kg/220lbs) over the Bags on that row, speeding up the Bag tamping process. Walls with more gentle slopes may require placement of enough tamped backfill every row in order to support the back side of the overhanging Bag. When placing backfill, add at least enough to get to the height of the Bag. Under filling of backfill lifts at the wall face can result in Bag movement by the compactor carving against the back of the Bag, and also add more time.

D) As you add layers of Bags, pay strict attention to the 'running bond' pattern between the Bags on different layers. This running bond pattern is essential to all SRW systems' performance. The multiple points of contact of the Plate to the three surrounding Bags give the Flex MSE system its additional strength and considerable flexibility, but this basic segmental retaining wall precept still applies.

**Due to the occasional inconsistencies in filled Bags or changes in the installation's profile, the running bond spacing will sometimes change slightly as you lay Bags down the line. To correct this, you can turn a Bag 90 degrees to the face to reset the spacing as needed. Curves or corners added to the wall will also typically result in the bond requiring to be reset on each row.*

When the Bag Joint underneath your current working course gets within 8" of the end of the Bag, a Tie-Back Unit should be inserted to reset the offset running bond pattern. First, re-situate the last Bag laid down so it sits equally over the Bag joint underneath. This resets your running bond for the next Bags to be placed. There will now be a gap between your last two Bags. Fill this gap with a re-sized Bag placed in the standard manner, or turn a Bag 'Tie Back' (90 degrees). Continue placing Units as usual, paying attention to the bond as you move along the wall.

Fig.1 'Running Bond' Pattern



You can create sharp corners or returns by alternately laying the Bag or Bags 90 degrees to the face at the desired spot. Note that only occasional Tie Back Units are required to reset the bond or create a return or corner, there is no need to do entire Tie Back rows if geosynthetic reinforcement is being used in the same section. Depending on site characteristics, there can be instances when both Tie Back and Geogrid reinforced methods are employed in different areas of the same installation.

E) Continue systematically placing Bags, backfill, and reinforcement until the desired height is reached. Place the backfill from front to back of the excavated area to keep tension on the reinforcement. (Geogrid installation is covered in more detail below, but must default to the grid manufacturer's installation guidelines and the Engineer's specifications.) When the wall height reaches the level specified by the Designing Engineer (typically 1 Bag above grade), lay down the appropriate lengths of geogrid according to the manufacturer's guidelines. Contact the Engineer at every point required by the Design.

E) If the design calls for the Flex MSE Gravity Wall - Tie back method, follow the instructions as laid out in the *Flex MSE Gravity Wall – Tie Back CAD*. Tie back walls are ideal for smaller, low surcharge installations, particularly where excavation is difficult (forest trails, or culvert headwalls and root ball reinforcements on stream banks). Geosynthetic reinforced MSE walls can use Tie Back sections in lower, tighter areas on the ends to speed up installation. A few more Bags/m² are used (17 vs 13), but the time saved on excavation is often worth it.

Fig.2 Gravity Wall Tie-Back

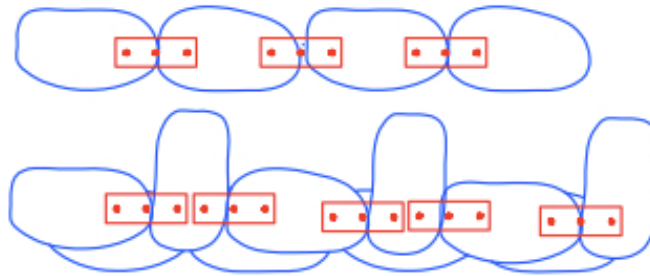
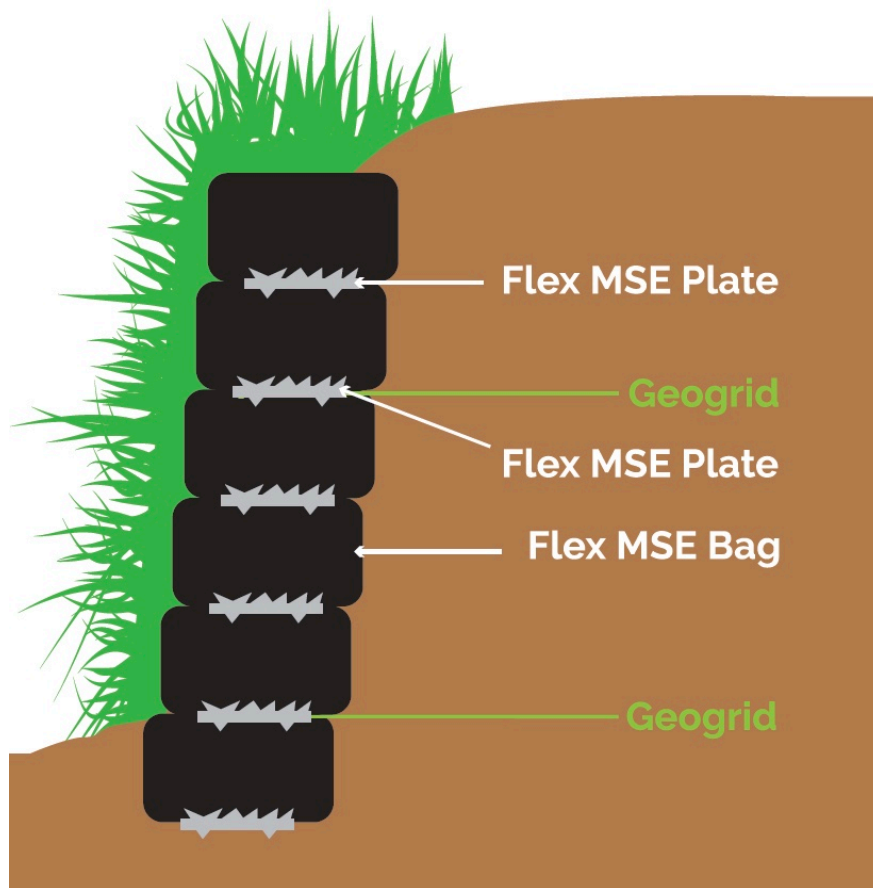


Fig. 3 Flex MSE Cross Section with Reinforcement



BACKFILL

Proper backfill and compaction are critical to the stability of Segmental Retaining and Mechanically Stabilized Earth Walls. Poorly compacted, clayey or silty backfill puts extra pressure on the wall, especially when overly wet. Backfill will also not compact properly if outside the specified optimal moisture content during construction.

Although it is possible to backfill and compact every two courses with Flex MSE (approx. 300mm), this can change to every course or every three courses, depending on application, grid type/elevation, and backfill type. The maximum thickness of material placed in a single lift is dependent on the type of soils, level of compaction required, and compaction equipment being used. Most in situ site soils are easily influenced by moisture levels and will be placed in smaller lifts

than engineered materials, requiring greater compaction effort, excavation depths and grid lengths.

Usually, coarse-grained soils such as free draining gravels provide the best working conditions because they are often easier to compact, have greater internal friction, require less reinforcement, and are less affected by water.

Flex MSE structures can be built with fine-grained or 'cohesive' silty and clayey soils if their characteristics are properly addressed during wall design and installation. The wall design is especially sensitive to the retained soil type if there is a slope behind the wall. All engineered installations will require up to date sieve analyses of the fill types used during construction.

Geogrid reinforcement and facing materials will not function properly if the soil around them is not properly compacted at the specified minimum soil lifts. Backfill soils for Flex MSE installs are typically compacted to a minimum 98% SP. Engineers can specify 95% or 100% as well. The type of material and the compaction equipment needed must be considered to achieve this minimum standard. Trexiana recommends using well compacted, free draining, engineered fill for a solid installation, minimizing site excavation and keeping grid lengths to the norm.

Consult an engineer for specific recommendations and use these basic guidelines for Backfill:

- a) Backfill material must have the proper moisture content for optimum performance when compacting.
- b) High Organic or heavy clay material should only be used under the supervision of an engineer. These materials hold excessive moisture and can be challenging to compact properly.
- c) Larger walk-behind mechanical compaction equipment may be used to compact soils at some levels.
- d) Hand operated compaction equipment 500lb and under should be operated within 1 meter (3') of the wall face.
- e) Avoid over-compaction of soils and lifts less than the Bag height next to the wall face (or Bag displacement may occur).
- f) Do not use heavy (500lb+), self-propelled compaction equipment within 3 feet of the back of the wall face because it could push the Units out of alignment. "Jumping jack"-style tampers should also not be used behind walls for the same reason.

- g) Two or three passes with the plate compactor is typically required to reach the desired compaction.
- h) Qualified Technical Personnel should perform all soil testing.

GEOGRID

Geogrid is a high-strength polymer product used as soil reinforcement for retaining walls. It is supplied in rolls of various widths, can last in upwards of 100 years in reinforced soil applications, comes in many strength ratings, and often is stronger in one direction (known as uniaxial grids). Horizontal layers of geogrid provide tensile strength to hold the reinforced soil together, so it behaves as one mass. Geogrid also connects the wall Units to the reinforced soil.

The required geogrid length, vertical spacing and strength will vary with each project depending on site characteristics, wall height, loading, head slopes, soil types, and seismic conditions. A professional civil engineer should prepare the final geogrid-reinforced wall design for each project.

The uniaxial geogrid typically used for retaining walls is stronger in one direction than the other, so it is critical to install it correctly. Uniaxial grid is laid on the compacted soil from the back of the fill zone to the front of the wall face in the direction that it came off the roll. The length and spacing of grid may change in the same wall, depending on the design. Certain grids (biaxial and triaxial) may be laid lengthwise off the roll (parallel to the wall face) depending on the application, but it is critical to follow engineer and grid manufacturer guidelines on orientation and overlap in all cases.

When placing the grid, allow for at least 1-2" extra to extend over the front edge of the Bag for inspection purposes and place the Flex MSE Plate on top (or underneath), providing a mechanical connection to the Bags. When Geogrid is placed on top of the Plate, the Geogrid Hooks on top to catch the apertures. This 'Grid Over' method can be more convenient when using ovoid aperture uniaxial grids (because there is more open space on top of the Plate) or when the grid used is more rigid (and its 'curl' may dislodge the Plate prior to Bag placement).

Reinforcement, either using the Tie Back Method or regular intervals of geogrid, is required on all Flex MSE structures over 24" (60cm) in height or when loading is present. A 4' tall (1.2m), no surcharge Flex MSE wall with 9 coursers of Bags will typically include three layers of geogrid – at the 1st, 4th, and 6th courses above grade. Grid lengths and spacing will vary depending on wall heights, surcharge, presence of water, and backfill type. The absolute minimum length of grid in an MSE structure is typically 1m, as defined by the grid manufacturer.

Once the geogrid is anchored by the Plate and Bag, lay the required length tightly and without wrinkles onto the level backfill. Pin the grid in place at the back of fill zone with a landscape staple. Next, place and compact backfill on top of the geogrid to match the level of the Bag. By placing fill from the wall face to the back of the backfill zone, the weight of the backfill material will also help to keep the geogrid straight and tense. Grid lengths should not overlap more than is minimally required for 100% coverage.

When installing fenceposts/ fixtures that pass through grid layers, it is typical to cut only enough grid threads in the secondary strength direction to allow insertion of the fixture into the backfill. Design details for intrusions/obstructions in reinforced structures are provided by the civil/geotechnical engineer, and grid manufacturers.

Tracked equipment shall not be operated directly upon the geogrid. A minimum fill soil thickness of six (6) inches is typically required prior to operation of tracked vehicles over the grid. Turning of tracked vehicles should be kept to a minimum to prevent tracks from displacing the fill and damaging the geosynthetic.

If site conditions do not allow for typical geogrid embedment lengths, Flex MSE can be deployed differently by a qualified engineer. The following alternative layouts/methods should be undertaken with the assistance of a design engineer:

- Tie Back orientation
- Double stacked or 'End Out' Bag oriented wall
- Earth or Rock Anchored Wall
- Concrete Cladding
- Soil Nailing with Flex MSE facing

See Trexiana's Full CAD set for design details on these methods.

**Note: The above recommendations are general and not applicable in all cases. Reference the manufacturer's installation guideline for each geogrid product and the Notes in the Engineer's drawing for important information on spacing and lengths, as they may differ throughout the wall.*

PRE-CONSTRUCTION CHECKLIST

- 'Issued for Construction' shop drawings approved by all Engineers
- All stakeholders in possession of up to date and approved drawings
- Geotechnical inspector apprised of start date
- All changes and addenda submitted, approved, and distributed

- Landscaping/vegetation/irrigation plans in place and in accordance with Flex MSE Best Practices (contact info@flexmse.com)
- Flex MSE procured from a licensed retailer (<http://www.flexmse.com/find-a-flex-mse-dealer-global/>)
- Flex MSE Full Installation Guide distributed to Key Personnel
- Geogrid Manufacturer's Product Installation Guide and Specifications also distributed
- Flex MSE Bag Fill Analyses (Sieve and Nutritional) approval
- All Backfills' certification and approval
- Backfill compaction standard, method and lift height given by engineer
- Correct strengths, lengths, and orientation of geosynthetic reinforcement
- Hydraulic Mulch product Specifications matched to key install characteristics (slope, aspect, etc)
- Flex MSE Units and reinforcements properly stored
- Ground prep and compaction testing of installation base material
- Confirm survey points and grade staking, seamless interpretation of Top of Wall, Bottom of wall
- Sediment and Erosion Control and any Environmental Plan in place

VEGETATION BEST PRACTICES

Flex MSE structures are essentially built like retaining walls and finished like a landscaping project. The two aspects are integral to the system's unique strengths and lifetime rating. Typical practical considerations can include: application type, growing Zone, local invasive plant control programs, exposure to sunlight, wind and fauna, medium nutrients, wave action and inundation. Vegetation planning for Flex MSE is often a balance between the practical and the aesthetic concerns. Engineers, Landscape Architects/Designers, plant/seed providers, and contractors should ideally develop the vegetation plan together (and in compliance with Flex MSE Best Practices), so as to take into account all expectations and timelines. For example, some live planted plugs or harvested natives seeds may only be available at certain times of the year – which can affect project timelines. Some plant species can also be toxic to animals who may browse on the Flex MSE installation.

A successful mixture of plants in a Flex MSE installation will increase the long term viability of vegetation, as well as contribute to the sustainability of the local environment. Nitrogen binding varieties such as legumes (clover and trefoil) should be considered when developing a Vegetation Plan. A low growing combination of rhizomatous or spreading varieties, hardy fibrous rooting species, and crawling woody species (ground cover) creates a resilient, low impact and attractive mix of plants. Vegetation Plans should also limit the amount of annual species such as cover crops to a minimal amount.

Tailor the selection of plants and planting method to the site characteristics. For example, exposed south facing walls will do better with full sun, drought tolerant species. Irrigation may be considered in full sun applications, particularly on steeper walls and dryer climates. Owner expectations/tolerance for dormancy and local water restrictions need to be taken into account as well.

East and North facing installations will do better with mostly shade tolerant species. Installations shaded by trees or structures should also incorporate shade tolerant species. Marine installations will require local, salt tolerant species, and specific planting methods. All water installations with portions temporarily under water will require inundation tolerant plants up to those levels. Live staking or brush layering these water installs is done during construction in a manner to not damage the Bag facing. Portions of the wall permanently under water or ground, or otherwise not exposed to UV, will not require vegetation.

For civil infrastructural and industrial installs, the lowest maintenance and most financially prudent solution is hydroseeding. Hydroseeding is often used for Flex MSE roadway projects thanks to its cost effectiveness, easy customization, and low long term maintenance. Attention must be paid to wall slope and aspect, ideal planting windows and cycles, invasive species introduction, salinity issues, periods of drought, nitrogen fixing for long term soil viability, germination times, and plant competition.

Residential and architectural applications often incorporate more elaborate planting and irrigation plans. Long term maintenance and water access should always be considered when planning a Flex MSE install. For obvious reasons, planting a cedar tree on the face or directly on top of a Flex MSE wall is not advised. That being said, root structures of established willow stands 6-9' tall in Vegetated GeoModular walls actually contribute to the long term viability of the installation. Consulting with a horticulturalist, seed provider, or nursery with experience in living walls, native species, and suitable cultivars for your area is advised for all Flex MSE installs.

Depending on the project timing and vegetation method, plants are installed into the structure during construction or upon completion of the project. It is recommended that full vegetation be achieved within 6 months of completion, but this may vary according to application, site characteristics and local climate. Flex MSE structures are typically designed for permanence and are exposed to UV, so vegetation must be self sustaining.

Depending on the local climate, installation timing, plant choice, and application, consider installing an irrigation system or adhering to a set watering schedule to guarantee the initial establishment of vegetation. A spray head, drip, emitter, or soaker style irrigation system located on select rows can be specified. When deemed necessary, spacing of drip lines is typically every two or three courses

on larger, south facing walls. Application of liquid fertilizer at periodic intervals might be necessary, depending on initial Bag fill medium characteristics, plant choice, and environmental concerns.

Listed below are the five methods for sustainable vegetation along with common applications where such methods are utilized. For all vegetation methods, please saturate the structure prior to all planting.

Hydroseeding

Hydroseeding is the most common vegetation method, being cost effective and providing fast, consistent growth. Standard mulch with native, drought resistant blends are very inexpensive and can achieve full vegetation within 60 days under optimal conditions. Engineered mulch varieties for steeper walls are only nominally more expensive and provide very consistent results in even tough situations.

Seed germination rates for species vary broadly, and it is very important to consider this when customizing seed blends. Certain native species require over-wintering (vernalization) to stimulate germination, while others can take a few growing seasons to get started. Custom blends may occasionally be warranted depending on local climate and environmental concerns. Respect local seeding time windows to increase success rates. Always request a certificate of germination and seed mix contents from seed suppliers.

For the best results, saturate Flex MSE Bags with water before applying the hydro seed mulch. This will help to ensure water from the mix is not drawn into the Flex MSE Bag, causing the mulch and seed to dehydrate. Mulch and tackifier type must be consistent with the application slope. Proprietary mulch products engineered for Extreme Slopes are to be used in applications steeper than 1V:1H. Typical mulches used on steeper slopes include tackified wood fibre, Bonded Fibre Matrix (BFM), and Flexible Growth Medium (FGM). A mulch appropriate for extreme slope applications dramatically improves vegetation results and provides a maintenance free finish.

Watering hydroseeded Flex MSE structures should be done under 'Frequent Light Watering' guidelines standard to hydroseeding Best Practices. Truck or manual watering should be done with a low pressure attachment in order to not wash off mulches or damage live plants.

Common Applications:

- All applications except those affected by significantly changing water levels during germination and initial root development stage, and grazing/picking by wildlife.
- Examples: Walls, Slopes, Land & Water Erosion control

Live Staking

Live Staking is often used in Shoreline and Stream bank applications, erosion control sites, or when the desired outcome is for a more 'rugged/wilder' slope or wall. Live Staking can be done during or after the Flex MSE System placement is complete and is often used in combination with hydroseeding. Install the appropriate frequency of stakes in order to gain full vegetation within the recommended times to maintain Flex MSE's full System Longevity of 100+ years.

Proper timing, collection, and preparation of live stakes, whether they be willows, dogwood, or similar low growing hardy woody species, is key. The stakes should be cut from mature stems and used within 8-10 days of being harvested. Use a sharp pair of shears. The side branches should be trimmed making sure not to damage the bark. The stake should be cut to the needed length (a minimum of 24") and an angle cut should be made at the bottom. It is important to make sure the angle cut is done at the bottom so that the stake is not planted upside down. Keep the stake bottoms wet in a solution (with rooting hormone if available). Stakes should be a minimum of 1" in diameter for greater plant viability.

When placing stakes during the construction process, simply lay or insert cut stakes between Flex MSE Bags leaving only 20% of the length of the stake exposed. Up to 3 sharpened stakes can also be pierced directly into the exposed material of each Bag. As with live planting, the entry point should be above the halfway mark of the Bag to prevent medium loss. Do not puncture Bags that are beneath the high water mark, as any holes will lead to medium loss through hydraulic effects. When live staking structures subject to variable water levels, only insert stakes between Bags that are below the high water mark. Do not puncture Bags below the high water mark.

When Live Staking in between Flex MSE Units after their placement, it may be necessary to use a rounded tool slightly larger in diameter than the live stakes to make a pilot hole for the stakes to be inserted into (ie: re-bar with a rounded nose). Use a dead blow hammer/mallet to minimize damage to the stake. Repack any soil displaced by the pilot tool.

For best results, saturate the structure thoroughly before or after live staking.

Common Applications:

- Shorelines & Stream banks.
- Erosion Control Applications calling for significant subsurface root development.

Live Planting

Plants/plugs with smaller root balls (under 4") can be inserted directly into the Flex MSE Bag. When Live Planting the face of the installed Flex MSE Unit, up to three inverted 'T' cuts 2-3" in width and height are permitted per Bag. Minimize the size of the hole cut for the root ball. Situate the horizontal cuts in the top 1/3 of the Bag face to prevent medium loss. Seedling plugs can be up to 4", but smaller (2-2 1/2") are easier to install and decrease the planting's hole size. After cutting the material, make a 45° sloping cavity in the Bag fill medium large enough for the plug and fully embed it into the hole. If the 'T' cut is too big, the Bag material can be closed by sewing or stapling around the plant stem.

A spiked planting tool such as a dibble or dibber may also be used to create the hole, and is often more efficient and precise than the 'T' cut. Position the tool on the upper 1/3 of the Bag and insert at a 45° angle. Ensure the full root ball is embedded in the opening. A sharpened 2" stake and hammer can also be used.

Use a 'spacer' guide such as a string to appropriately space live vegetation. Depending on the vegetation it may be necessary to place a fertilizer pellet in with the root ball to help promote initial root growth.

As with all methods, saturate the Flex MSE structure and root ball before placement to encourage initial growth.

**Note: When designing for Live Planting, it is necessary to limit plant holes per Bag to three, and to not cut Bags below the water line.*

Common Application:

- Landscape walls & slopes
- Restoration / reintroduction of cultivated Native Plant species

Brush Layering

A similar practice to Live Staking between Bags – this method plants the root ball into the backfill behind face of the Flex MSE system. Brush Layering needs to be completed during Bag placement. When inserting plants, angle brush layers downward into the fill or native material. When using larger root balls on Walls and Slopes, insert the plant after completing every second layer of Bags (ie before infilling and compacting the specified soil lift). More established plants may be used when Brush Layering (up to 1 gallon standard pot). It is recommended to use an approved Structural Soil when Brush Layering to increase the root development of the plant and provide nutrition.

Common Applications:

- Shorelines & Stream banks (Semi – aquatic plants)
- Landscaping walls
- Any Flex MSE structure requiring larger plants at the outset

Preseeding

Mixing grass seeds with the growing medium in the Bag is another method, although it is not considered a primary one. Vegetation outcomes for preseeding vary widely due to plant type, UV exposure, and variable seed distribution in the medium. Only seeds close to the surface of the Bags will emerge through the Flex MSE Bag material. For this reason, an increased estimate of seed volume for the coverage area is recommended. Increase the g/m³ seed application in the Bag Fill Medium to minimum 10x that of the g/m² rate. For example, if the prescribed seed coverage for a flat surface were 10g/m², consider mixing 100g of seed into 1m³ of Flex MSE Bag fill medium. Favour seed selection to smaller seeds with fibrous rooting, rhizomatous and spreading characteristics. Over seeding can lead to overgrowth and competition. As with all methods, saturate Pre-seeded Bags thoroughly after installation is complete.

Common Applications:

- Shorelines where varying water height or birds can strip hydraulically applied seeds on the outside of the Bag.
- Remote areas or areas where vehicle access to the site is restricted.
- Sites where exposed seed could be eaten by local birds or animals.
- Often combined with live staking or brush layering vegetation methods, or sometimes as supplementation to hydroseeding (depending on designer preference).

PRE-VEGETATION INSTALLATION CHECKLIST

- Landscaping/Vegetation Plan approved by all Engineers
- All stakeholders in possession of up to date and approved drawings and Specifications
- All changes and addenda submitted, approved, and distributed
- Landscaping/vegetation/irrigation plans in place and in accordance with Flex MSE Best Practices (contact info@flexmse.com)
- Flex MSE Vegetation Best Practices distributed to Key Personnel
- Hydraulic Mulch product Specifications matched to key install characteristics (slope, aspect, etc)
- Sediment and Erosion Control and any Environmental Plan in place
- All Plant material properly harvested, stored and maintained

INSPECTION AND MAINTENANCE

Properly designed and constructed Flex MSE structures provide a very low maintenance, resilient, and attractive solution. As with all building systems, a periodic inspection and maintenance routine is suggested.

Inspect the structure annually and after any major climatic or seismic event. It is also recommended to keep a photo record, showing the application from similar viewpoints for year-to-year comparisons. Annual inspection reports should ideally include Structural and Aesthetic components, along with any additional criteria recommended by the Engineer or Designer.

Structural Inspection:

- **Bulging:** are there any localized areas where Flex MSE Bags seem to be bulging out of the structure? It may be necessary to trim vegetation cover for a closer inspection.
- **Rotation:** Flex MSE can be safely constructed to many slope angles in the same install; note if there are noticeable changes in the face slope angles at the time of inspection from the slope angles at completion of construction.
- **Excessive water flow through the Flex MSE structure:** the system allows for superior drainage, however excessive water flowing through the structure, especially at localized areas should be reviewed for cause. Often the solution is as simple as auguring through the face and inserting a perforated pipe to relieve the hydrostatic pressure in the wall.
- **Differential settlement of the structure:** the Flex MSE system allows for significant differential settlement, but always confer with the Engineer of record regarding the stability of any wall experiencing differential settlement.
- **Ripped or damaged Bags:** Due to Flex MSE's capacity for differential settlement, Bag Fill medium loss from single Bags is not a great concern. Repair by sewing, stapling or replacing or re-apply vegetation through Live Planting or spot seed mulch application.

The Engineer of Record should be notified of any significant irregularities, so they may evaluate the cause and recommend any need for remedial action.

Vegetation Inspection and Maintenance:

If complete coverage of a Flex MSE installation has not occurred within the Vegetation Plan's expectations, it is recommended to consider the following remedial measures:

- Irrigate: Vegetation may need water; spray, soaker, or drip irrigation is advised.
- Fertilize: Vegetation may need nutrients; liquid fertilizer is recommended.
- Re-apply Vegetation: Pay attention to particular varieties that did well, and the method of failure. Occasionally quick germinating or robust plants or can stifle slower perennial varieties.

Do not over-maintain the vegetation on Flex MSE walls – particularly grasses. Many grasses do not regrow well after close cutting, and evaporation increases with lower grass lengths. Allow at least one full year to pass before considering trimming grass lengths. Take care when trimming with a high powered line trimmer to maintain a safe distance from Bag facing material.

Consult with a qualified horticulturist or contact the local Flex MSE Distributor for further assistance.

For further information on Flex MSE, please email us at info@FlexMSE.com, call 1-877-349-5945, or visit the website at www.FlexMSE.com