Mechanics of Retaining Walls

The growing scarcity of land that is affordable and easy to build upon is causing engineers, contractors, and developers to find innovative ways to use less desirable parcels of land. Areas with rough terrain and/or steep slopes were once considered as being unusable for development. Many of these areas can be made virtually flat, and thereby usable, through the employment of structures such as retaining walls and steepened slopes.

The two basic types of retaining walls are cantilever and gravity. Most cantilever retaining walls are made of cast-in-place, steel-reinforced concrete. This type of structure is able to retain the earth behind it by virtue of its internal strength and rigidity. Reinforced concrete retaining walls are expensive to build, cannot be built in very cold weather, and are not especially attractive. These walls are brittle, and if stresses resulting from differential settlement exceed the strength of the concrete, cracks develop affecting the structure’s stability and appearance.

Gravity retaining walls are constructed principally of soil that is stabilized with man-made materials such as EnviroGrid®. This type of structure is able to retain the earth behind it by virtue of its weight. Gravity retaining walls are typically inexpensive to build and can be built in nearly all weather conditions. In addition, they have a degree of flexibility that allows them to adjust to small amounts of differential settlement without suffering structural damage.
EnviroGrid® can also be used to create a steepened slope. Steepened slopes are slopes which are constructed much steeper than the soil alone would allow. A steepened slope made with EnviroGrid® can be considered to be a retaining wall with a face inclination greater than 70°.
The EnviroGrid® Solution

An EnviroGrid® retaining wall or steepened slope can be constructed in almost any situation where a rapid change of grade is desired. EnviroGrid® confines the soil or other fill material allowing the material to behave as a reinforced mass.

EnviroGrid® can be used in both fill and cut applications. In a project where the structure is built with fill material, it is usually more cost-effective to use EnviroGrid® in conjunction with a geogrid. The geogrid acts as a tieback in the reinforced zone. EnviroGrid® assumes the role of the facing element, such as concrete blocks in a modular block retaining wall. Unlike modular block, EnviroGrid® is easy to handle, flexible, and can be planted with grass or shrubbery to give the face a natural look.

In cut situations, the exposed face is unstable because the soil holding it in place has been removed. Some of this weight needs to be replaced but in a much smaller area. In this circumstance it is often more economical to use EnviroGrid® in lieu of other methods such as gabion baskets. When used in this manner, the stack of filled EnviroGrid® panels acts as a near vertical, heavy, reinforced mass.
Design Considerations

A gravity retaining wall must have sufficient weight and width or be otherwise supported so that it does not overturn or slide forward due to external forces being exerted upon it. The wall must also be able to hold together as a unit in order to function. That is, the wall must be stable with respect to both the external forces that might cause it to fall and the internal forces that might cause it to lose its shape and/or deformed

**External Stability**

EnviroGrid® retaining walls must be designed to be stable with respect to four potential external failure modes: global stability, base sliding, overturning, and bearing capacity.

GLOBAL STABILITY refers to the stability of the wall, the soil behind it, and the soil below it. The design engineer must be certain that the entire area including the wall does not collapse. A thorough soil analysis must be performed to eliminate the possibility of global failure.
BASE SLIDING refers to the outward movement of the bottom of the retaining wall as a result of the lateral forces generated by earth pressure and, if present, water pressure. The force resisting base sliding is the friction between the fill in the bottom layer of EnviroGrid® and the foundation soil beneath the bottom layer. The designer may increase the front-to-back dimension of the wall if calculations show that the resisting force is less than required. This will increase the area available to develop the resisting force. A second option would be to use a fill with greater frictional characteristics.

OVERTURNING refers to the tipping over of the retaining wall as it rotates about the toe of the structure. The overturning force is the sum of each destabilizing force times its moment arm. The stabilizing force, or righting moment, is the product of the weight of the retaining wall and its moment arm, which is the horizontal distance from the toe to the center of gravity of the wall. If calculations show that the righting moment is less than required, one option is to increase the front-to-back dimension of the wall, thereby increasing its overall weight and the magnitude of its moment arm.
**BEARING CAPACITY** refers to the ability of the foundation soil to support the weight of the retaining wall placed upon it. The analysis is the same as for shallow foundations. It is necessary to increase the area of the base if calculations show that the soil beneath the wall is too weak. This will decrease the pressure (force per unit of area) on the foundation. Another option is to increase the depth into the ground of the retaining wall, thus increasing the ability of the foundation soil to resist the imposed weight.

For each of these considerations, the resisting or stabilizing forces must exceed the forces that would cause failure by a predetermined factor of safety for each of these considerations. The selected factors of safety should reflect the consequences of failure and the designer’s confidence in the accuracy of the input parameters. The following factors of safety are normally used in the design of gravity retaining walls:

- **Global Stability**  \( FS_{gl} = 1.3 \)
- **Base Sliding**  \( FS_{sl} = 1.5 \)
- **Overturning**  \( FS_{ot} = 2.0 \)
- **Bearing Capacity**  \( FS_{bc} = 2.0 \)

*If the minimum front-to-back dimension of a wall that uses EnviroGrid® is at least 0.6 times the wall height, the above factors of safety will be achieved in almost any design.*
Internal Stability

Internal stability refers to the ability of the individual parts of the wall to act as a single unit. The wall must be designed so that the individual pieces of the wall do not pullout, separate, or slide apart. In a modular block wall, the designer must be concerned with the potential of the tieback failing under tension or pulling out from the soil or the fascia. Also, a failure can occur if the fascia bulges out. The only internal stability consideration for walls consisting of EnviroGrid® and soil is the potential for sliding between panels. If a factor of safety of 1.5 or greater is not achieved with the initial design, the sections need to be made longer to increase the surface area or change the fill material to one with greater frictional characteristics.
NOTE: For detailed design guidelines for retaining walls using EnviroGrid®, please contact your local EnviroGrid® distributor or Geo Products, LLC. The final design of any retaining wall must be developed by an engineer registered in the state where the project is located.
Economics

In many projects such as highway widening, rapid changes in grade are a necessity. In other projects such as apartment complexes on a steep slope, a rapid change in grade is the most efficient means of putting the available land area to economic use. A cost effective way to achieve a rapid change in grade is to construct a reinforced earth gravity wall or slope.

EnviroGrid®, by itself or in combination with a geogrid, can be as effective as more expensive alternatives such as cast-in-place, steel-reinforced concrete retaining walls, modular block walls, or gabion baskets. EnviroGrid® is lightweight, easy to handle, can be filled with on-site materials, and does not require any special equipment for installation.

Aesthetics

The outer cells of an EnviroGrid® panel are available in non-perforated black, tan, or green cells that can be filled with topsoil and planted with grass, shrubs, or flowers. A vegetated EnviroGrid® wall or steepened slope can give a look that blends in with the local surroundings, adds color to the area, and softens the appearance of the wall face.

In addition, a vegetated wall will absorb much of the volume and force of any water that flows down the slope. This can have a significant impact on the potential consequences of a large quantity of water pouring down a steep wall face.
Environmental Merit

The EnviroGrid® geocell is designed and implemented in order to maximize environmental benefit. Geo Products recognizes that construction generally leaves a significant footprint upon the environment, and therefore seeks to reduce any impact that our EnviroGrid® incurs upon the landscape. The limited amount of infill required for EnviroGrid® as opposed to conventional construction methods, as well as the lower quality needed, offers not only a much softened blow to the environment but also reduces project engineering, length, and cost. In addition to a significantly lower construction and carbon footprint upon the environment, EnviroGrid® acts as a green building practice in diminishing erosion along slopes and embankments. The vegetative cover encouraged by EnviroGrid® is another source of soil stabilization as well as aesthetic value more difficult to achieve with conventional construction.

As an innovative method to facilitate green thinking, EnviroGrid® is an effective solution to protect and preserve the environment when such a mindset is growing ever more desirable.

**LEED® Green Building Credits**

The Leadership in Energy and Environmental Design (LEED®) system for designing and certifying environmentally sustainable buildings is the national standard for rating environmentally responsible construction. Introduced and enabled by the United States Green Building Council, LEED® takes into account materials and resources used, site location and development, air quality, and water and energy use in its evaluation of green buildings.

Geo Products' EnviroGrid cellular confinement system is designed and implemented with environmental merit as a top priority, and contributes heavily to a higher LEED® rating for your green building project. Please refer to the US Green Building Council Website for further details on the LEED® certification system at [www.usgbc.com](http://www.usgbc.com).

**LEED® Sustainable Site Credit 5.1: Site Development--Protect or Restore Habitat**

Requirements:
For Greenfield sites--sites not previously developed and remain in a natural state--limit all site disturbance to the specified parameters. For previously developed areas, restore or protect a specified area of the site with acceptable vegetation.
**Geo Products Solution and LEED® Credit Opportunities:**

EnviroGrid provides options for pervious paving in parking and access road functions, thus reducing disruption to existing ecosystems and minimizing the construction footprint. Also, through the stabilization of steepened slopes and of storm water detention facilities, EnviroGrid is able to reduce the construction footprint and keep site disturbance within the necessary parameters.

For previously developed building areas, use of the EnviroGrid geocell allows for the restoration or promotion of vegetation, thus contributing to the ecosystem and further minimizing site disturbance.

The retaining wall and slope stabilization features of EnviroGrid reduce valuable land consumption in an environmentally-friendly fashion.

**LEED® Sustainable Site Credit 5.2: Site Development--Maximize Open Space**

Requirements:
To provide acceptable, vegetated open space within the project boundary in accordance with specified parameters, and to reduce development footprint.

**Geo Products Solution and LEED® Credit Opportunities:**

EnviroGrid is ideal for encouraging useful vegetated open space whether with green parking areas through load support functions or by reducing land consumption with environmentally friendly slope stabilization and earth retention purposes. In any application, EnviroGrid is designed to provide the most open space by eliminating the need for further drainage facilities or by allowing for steeper slopes with minimized environmental damage.

**LEED® Sustainable Site Credit 6.1 and 6.2: Stormwater Design--Quantity and Quality Control**

Requirements:
Implement a stormwater management plan to limit disruption of the ecosystem by limiting the area of impervious cover and increasing the area's drainage capability according to specified guidelines. Also, to reduce the pollution and erosion associated with stormwater runoff.

**Geo Products Solution and LEED® Credit Opportunities:**

EnviroGrid is designed to ensure natural water flows--porous pavement, earth retention, and slope stabilization applications all allow stormwater to drain in an environmentally responsible manner. Use of EnviroGrid reduces the use of impervious cover and impervious concrete retention walls, thereby reducing pollutant loadings. EnviroGrid is also useful in creating natural treatment systems of stormwater runoff.
LEED® Sustainable Site Credit 7.1: Heat Island Effect--Nonroof

Requirements:
To reduce the heat island impact on microclimates and surrounding habitat, measures must be taken to reduce the heat absorption of exterior materials.

Geo Products Solution and LEED® Credit Opportunities:
US Green Builders Council suggests the use of vegetated or permeable surfaces such as EnviroGrid instead of constructed hardscape, thereby reducing the area's tendency to absorb heat significantly. The promotion of vegetative cover also contributes to the overall reduction of heat island effects.
LEED® Materials & Resources Credit 5.1 and 5.2: Regional Materials

Requirements:
To reduce the environmental impact resulting from transportation of construction materials by using materials and products that are extracted and manufactured within the region.

Geo Products Solution and LEED® Credit Opportunities:
EnviroGrid allows the use of virtually any local aggregate, eliminating the need to import higher quality infill materials. Construction within 500 miles of GeoProducts' Houston, Texas manufacturing facility can also apply the EnviroGrid geocell itself to the percentage contributing to LEED credit.

Please visit our website (http://www.geoproducts.org/EnvironmentalMerit.aspx) for additional information on the sustainability and environmental merit of EnviroGrid including LEED® Green Building Credits and more.
Installation Procedures

**Before Starting**

1. Ensure that the site conditions and the EnviroGrid® earth retention system layout are as indicated on the construction drawings.

2. Ensure that all specified materials and system components are delivered to the site.

**Site and Subgrade Preparation**

1. Start site preparation for the EnviroGrid® earth retention system installation by removing debris and vegetative cover from the installation area.

2. Complete initial earthworks, excavation, or fills, according to plans.

3. Remove in-situ soils that are unacceptable for the EnviroGrid® earth retention system foundation and replace with suitable materials.

4. Prepare the foundation soils as specified prior to base material placement.

**Installation of the Footing**

1. Expand the specified EnviroGrid® footing section into its designated position.

2. Hold the expanded EnviroGrid® footing section open using one of the following options:
   - Straight stakes or J-Pins
   - Envirobars
   - Other options are also acceptable.

![Envirobars Image](image-url)
3. Overfill the EnviroGrid® footing section with the specified infill material and level to approximately 50 mm (2 inches) above the cell wall.

4. Place infill material around the EnviroGrid® footing section. Ensure that placement of this material does not conflict with placement of the drainage system.

5. Compact fill and infill material to 95% of SPDD (Standard Proctor Dry Density) using conventional equipment and materials.

**Installation of the Drainage System**

1. Install specified sub-drain pipe at the location and elevation shown on the construction drawings ensuring that a minimum gradient of 2% is maintained to all free outlets.

2. Ensure that all pipe connections are properly made and that the sub-drain pipe is connected to outlet pipes or an existing and functional subsurface drainage system.

3. Where specified, encapsulate the sub-drain pipe with a geotextile wrapped bedding material. (e.g. sand, pea gravel, clear stone, etc.)

4. Wrap all outlet pipes passing through the wall face with a suitable geotextile to prevent loss of the cell infill material.

5. Ensure that the discharge of the outlet end will not cause localized erosion that may affect the stability of the EnviroGrid® wall.
**Excavation Protection and Drainage**

1. Where specified, place a suitable geotextile over the base and on the cut slope behind the EnviroGrid® wall.

2. Where specified, install the appropriate drainage composite materials. Ensure that the system is functional and connected to a suitable outlet or sub-drain system.

**Installation of the EnviroGrid® Sections**

1. Expand the specified EnviroGrid® wall section into its designated position.

2. Hold the expanded EnviroGrid® wall section open using one of the following options. Other options are also acceptable.

   Straight stakes or J-Pins
   Evirobars

3. Check each EnviroGrid® wall section to ensure that it is fully expanded.

4. Correctly align and interleaf edges of adjoining EnviroGrid® wall sections and ensure that the upper surface of the adjoining sections is flush.

5. Fasten EnviroGrid® wall sections together with staples or as specified on the construction drawings.

6. Overfill the EnviroGrid® wall section with the specified infill material and level to approximately 50 mm (2 inches) above the cell wall.
7. Compact the infill material to 95% of SPDD using conventional compaction equipment and methods.

8. Place specified backfill material behind the EnviroGrid® wall sections and compact to 95% of SPDD.

   In cut areas, extend the backfill materials back to the cut slope.

   In fill areas, place backfill materials as specified on the construction drawings.

9. Heavy compaction equipment can be used to compact backfill materials to within 1 meter (3 feet) of the EnviroGrid® wall sections. Use lighter walk-behind compaction equipment to compact infill and backfill materials directly behind the wall sections.

10. After compaction of each layer, remove excess materials off the top of the EnviroGrid® wall section so that the top of the cellular structure is visible.

11. When positioning the next layer, ensure that:

    * The proper setback of each layer is maintained.

    * Proper side-to-side cell alignment is maintained to prevent loss of cell infill material.

12. When installing freestanding or very steep EnviroGrid® wall structures, a 40 cm (16 inch) strip of non-woven geotextile should be laid over the outer row of cells in each layer to prevent loss of infill material.

13. When special infill material (such as topsoil) is required in the exposed row of face cells, the following construction techniques may be employed:

    Cover the outer cells with movable boards to prevent the interior-cell infill material from spilling into the cells requiring the special infill. After completing compaction remove the boards and fill the empty cells with the special infill.

    Each layer should be opened and infilled separately starting with the lowest layer and working to the upper layers.
Installation of Geosynthetic Reinforcement (when required by design)

1. Place precut sections of geosynthetic reinforcement (woven geotextiles or geogrids), dimensioned and oriented according to construction drawings, between the specified EnviroGrid® layers. It is important that reinforcement layers are:

   Placed horizontally with the high-strength axis perpendicular to the wall face.

   Flat and free from folds after placement.

   Placed so that the leading edge is within 150 mm (6 inches) minimum of the front of the wall and extend horizontally into the compacted backfill zone.

   Place and infill the next EnviroGrid® wall section layer.

   Manually tension the reinforcement by pulling it back from the in filled EnviroGrid® wall sections.

   Pin the back edge of the reinforcement layer so that it is taut and free from loose folds.
Tracked equipment should operate within the reinforced backfill zone only after a minimum 150 mm (6 inches) have been placed over each reinforcement layer.

Rubber tired equipment can operate directly on the reinforcement using care to avoid sudden stops and sharp turns.

Place backfill over the reinforcement in lifts of 250 mm (10 inches) starting from behind the EnviroGrid® wall sections and spreading the backfill towards the back of the reinforced zone.

Ensure that excessive displacement of the reinforcement does not occur during backfill placement.

Shape and compact the infill material to 95% SPDD using conventional equipment and methods.

Continue with this sequence until the EnviroGrid® retaining wall is complete.

*Geo Products, LLC provides this information only as an accommodation to our customers. No warranty or other representation regarding the suitability of the application procedures is made due to the fact that each installation has specific requirements that may not have been considered in this generalized procedure. Geo Products, LLC makes no warranties or representations regarding the suitability of its EnviroGrid for specific uses or applications. Our liability is limited to furnishing, without charge, a replacement for any EnviroGrid that is proven defective under normal use and service.*