The use of geosynthetics within these applications has expanded over the years as technologists and engineers have innovated and exploited the unique properties of the products that have been developed.

Geotextile filters can be deployed below marine breakwaters as an alternative to a traditional underlay, providing material savings and a reduction in overall construction costs. Specialist geocomposite cell structures can be used to provide effective erosion control and for the construction of rapid deployment flood defence systems.

**Typical Coastal and Waterway Applications**
- Foreshores
- Dams and flood bunds
- River and canal banks
- Lagoon, lake and reservoir shores
- Culverts and outfalls
- Ports, breakwaters, artificial islands and causeways

TERRAM has been the trusted name in Geosynthetic Innovation for over 40 years.

**Fiberweb and TERRAM™ products.**
Fiberweb is the UK’s largest manufacturer of geotextiles. Its product portfolio includes the original, trusted and proven TERRAM geotextiles, geocells and geocomposites together with the geonets and pavers manufactured by Boddingtons Ltd (acquired 2011). The UK manufacturing capability has been expanded and centralised at Maldon in Essex.

Fiberweb provides a unique range of value engineered solutions for the construction of highways, railways, landfills, pipelines, coastal/waterways defences and in landscape engineering.

With unrivalled expertise and experience in geosynthetics, accumulated over a 40 year period since the first TERRAM products were launched, the Company remains committed to the development of innovative and cost-effective geosynthetic solutions.

The Company is a market leader in the design and manufacture of geosynthetics, and continue to provide ground-breaking solutions.
Traditionally, revetment underlayers have comprised multiple filter layers of stone: grading down from largest stone at the surface. The stone sizes and the number of layers were dictated by the particle size distribution of the underlying soil.

Modern construction techniques utilise a single carefully-selected geotextile layer, to provide the necessary hydraulic and mechanical properties and to prevent leaching of the underlying soil. This geotextile is faster and easier to install than stone layers, and its factory-controlled properties means that it will perform more consistently.

In the same way as the stone size and grading were important for the traditional solution, the careful selection and specification of the correct geotextile is vital. The textile must be robust enough to withstand installation and service-life loads. It must have a suitable pore size and permeability, and be capable of providing sustained filtration. It must possess extensibility to adapt to point loads in order to avoid puncture and tearing. Not all geotextiles can provide this unique combination of performance properties.

The role of geotextiles in the provision of stability of hydraulic defence structures is vital and often undervalued. This is possibly due to their low unit cost in comparison with the overlying armour-stone. However, their incorrect selection and specification could risk the stability of the entire structure. When correctly specified and installed, geotextiles can provide significant benefits including savings in construction and whole life costs and increase in design life.
Key Advantages:
• Geotextiles can replace graded stone underlays, providing savings in materials, material transportation and placement costs.
• Geotextiles minimise the amount of lost material into soft subsoil at the toe.
• Geotextiles mitigate differential settlement.

The key attributes that require consideration when selecting and specifying a geotextile to be used in revetment type structures are:

Survivability
The geotextile must be robust enough during installation and in service so puncture resistance is very important.

Mechanical performance
The geotextile must have sufficient extensibility to wrap around point loads and avoid puncture and resist compression.

Hydraulic performance
The geotextile must allow water to pass effectively in both directions yet filter fine soil particles.

Durability
Depending on planned exposure times and required design life UV and antioxidant stabilisation will need to be considered.
In the same way as the stone size and grading were important for the traditional solution, the careful selection and specification of the correct geotextile is vital. TERRAM Robust Geotextiles provide an innovative alternative to traditional materials.

The geotextile must be sufficiently robust to withstand installation and service-life loads. It must have a suitable pore size and be capable of providing sustained permeability and filtration and must be more permeable than the underlying soil. It must also possess the necessary extensibility to conform intimately to the profile of the rocks above it and to adapt to point loads in order to avoid puncture and tearing. TERRAM Robust Geotextiles have been engineered to provide this combination of properties for this application.

Filter properties
The performance of a geotextile filter is dependent on a number of principal factors:

- the size, number and uniformity of the geotextiles pores in relation to the soil particle sizes
- the magnitude of the disturbing forces (the higher the forces - the greater potential for soil migration)
- the structure and inter-particle bonding of the in-situ soil particles - the greater the soil density and the greater the interparticle forces, the less potential there is for the soil to migrate
- the particle size distribution, structure and pH of the soil
- the permeability of the geotextile in relation to the soil

The universal approach to filtration is that each layer must be more permeable than the layer beneath. Rules adopted using a geotextile within a wave environment suggest that the coefficient of permeability of the geotextile used should be 10-100 times greater than that of the underlying soil. It is also important that the geotextile maintains or exceeds its required index permeability whilst under load, i.e. any reorientation of the fibres should not decrease permeability.

The characteristic pore size of the geotextile should be less than the average grain size of the soil to be filtered to ensure that any loss of material through the geotextile is mitigated. Established design rules for reverse flow applications, and for a typical geotextile, state that the opening size of the geotextile (O90) should be less than the sieve size (D50) of the soil to be filtered.

\[
\text{kg} > 10\text{-100ks}
\]

where: $\text{kg} = \text{coefficient of permeability for the geotextile}$

$\text{ks} = \text{coefficient of permeability for the soil}$

and:

\[
O_{90} < D_{50}
\]

where: $O_{90} = \text{apparent opening size for the geotextile}$

$D_{50} = \text{particle size fraction for the soil}$

TERRAM Robust Geotextiles are designed to provide sufficiently low pore size to prevent the migration of fines whilst ensuring the necessary permeability required for a wave environment.
Resistance to Damage

It is important that the geotextile incorporated into the design is able to withstand the stresses placed upon it both during the installation and in service. Loads placed upon the geotextiles by the overlying armour stone will be uneven, with the highest stress concentrations at localised points. TERRAM Robust Geotextiles are engineered to have an elongation at break which allows deformation around the armour stone without rupture or loss in hydraulic performance.

The mass, angularity and drop height of the armour stone being placed directly upon the geotextile, together with the method of installation, play a contributing factor in the potential for the geotextile to be punctured. Additional factors for consideration include movement of armour stone during wave action and differential settlement. TERRAM Robust Geotextiles are engineered to provide isotropic strength and elongation, this is important to ensure that point loads do not have any detrimental effect of filter performance.

It is recommended that, where possible, the designer performs a trial installation with the proposed rock. A designer can specify a site damage test such as a rock drop test where a pad of geotextile is laid on a prepared beach material and held taught around its perimeter. A rock similar to those proposed should then be dropped onto the surface from its maximum construction height. There should be no damage to the underlying geotextile. For further advice please contact the TERRAM technical team for assistance with the selection of an appropriate TERRAM Robust Geotextile.

Durability

A principal consideration in the selection of a geotextile should be its ability to perform within its environment for the full duration of its design life. TERRAM Robust Geotextiles are manufactured from UV Stabilised virgin polypropylene fibres that have been designed to perform in coastal applications. All TERRAM Robust Geotextiles are predicted to be durable for 100 years in standard specified acid and alkaline conditions.
TERRAM Geocell provides a cost-effective alternative to conventional earth retention structures due to its flexibility and suitability for use with a wide range of infill materials and foundation soils.

The system eliminates the potential for cracking, spalling, splintering or corrosion that can affect concrete, steel and timber based systems.

It can be installed almost vertically to form an effective, economical earth retention structure. TERRAM Geocell is used in horizontal layers to form a wall structure. This can either be the panels themselves to form a gravity structure or as a facing system in a composite wall working in conjunction with an earth reinforcement system to form a mechanically stabilised earth structure. TERRAM Geocell can be used with a variety of reinforcement techniques such as geotextile or geogrid earth reinforcement, soil nails, rock bolts, helical anchors etc.

Typically installations will utilise a composite wall construction creating a totally confined wall facing that is directly connected to the backfill using one of the earth reinforcement systems outlined above. Where construction restrictions do not allow this methodology, a gravity wall construction may be considered.

In this construction the TERRAM Geocell is built as a layered wall capable of resisting the internal loads and pressures to maintain structural integrity. Utilising the TERRAM Geocell in this application creates horizontal terracing on the facia of the wall. In some circumstances these can be utilised to create a vegetated cover for the facia.
As with slope protection, the individual cells maximise water collection and minimise run-off, by allowing precipitation to infiltrate the exposed surface; creating a suitable environment for vegetation growth.

When used in these applications, TERRAM Geocell offers a solution that fulfils a broad range of design requirements and construction conditions. The unique nature of TERRAM Geocell structures offer flexibility and allow for infilling with a wide range of materials including site infill soils (if suitable), top soils, sand, aggregates and concrete.

**Design Considerations**

- Wall Height
- Facia Angle
- Surcharge load on the top of the wall
- Overturning Stability (the consideration of the turning moment around the toe of the structure)
- Sliding Stability (shear strength at the base of the gravity wall)
- Foundation Bearing Capacity (the substrate must be able to support the applied load of the wall structure).

TERRAM work with specialist partners to provide independently validated solutions in accordance with best practice guidelines.

**Typical Applications Include:**

- Steepened Embankments
- Dams and Flood Defence Bunds
- Retention Bunds
- Green Walls
- Culvert Head Walls
- Sound Barriers.

A complete design service including project design and on site technical support now available. Please contact us on 01621 874 200.

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TERRAM Geocell earth reinforcement see page 17
Controlling slope erosion

TERRAM Geocells are three-dimensional blankets of interconnected cells which are placed on slopes, secured in position using pins, and filled with soil.

Controlling erosion on coastal and waterway slopes

Once installed, a TERRAM Geocell provides immediate stability by confining the fill and greatly improves resistance to wind and surface run-off erosion.

With a topsoil fill, the stability is further enhanced as vegetation becomes established and a geocell can be used to establish vegetation on slopes where creating cover would otherwise have been problematic. The honeycomb of cells provides protection for the vegetation during the early, sensitive period of germination and growth.

The Geocells are formed from TERRAM Geotextile to confine the fill and the permeable walls allow drainage from cell to cell down the slope. Other geocells achieve this cell-to-cell drainage by perforating the walls but this process can lead to weaknesses. Geocells fabricated from impermeable materials suffer from weiring - water cascading down the slope from cell to cell - and this causes ongoing loss of soil from the cells.

Many variables affect the installation and performance of a slope-protection geocell, including slope angle, slope stability, the infill type, rainfall levels and irrigation (if included). It is important therefore that due consideration is given to all relevant criteria on a project by project basis.

Typical applications include:

• Cuttings and embankments
• Noise-deflection and environmental bunds
• Abutments
• Soil nailing cover
• Steepened slopes
• Drainage ditches
• Balancing ponds

TERRAM Geocells are anchored to slopes using U shaped - TERRAM Fixing Pins - these combined with the weight of the soil prevents slippage.
TERRAM Geocell slope erosion see page 16
The TERRAM geocellular system was originally developed for military defences. However, the US Corps of Engineers conducted tests with the system to determine whether it could be used to construct temporary flood defences. Their work concluded that the system significantly outperformed sandbags in terms of installation/removal time, water seepage control and overall endurance.

The TERRAM system is fabricated using a geotextile to form a series of interconnected cells which can be laid flat to form a compact unit for shipment. Once on site, the units are quickly unpacked, opened out, positioned, secured to each other and then filled with a locally-won fill or an imported fill such as sand. The units can be placed on top of each other to form taller structures and the resulting walls can be formed with angles and curves. On-site installation can be carried out by unskilled labour and the learning curve is short and shallow.

Installing at a rate of 20 plus units/hour within three hours of starting is typical - the equivalent protection afforded with 22,196 sandbags.
The hydraulic and filtration properties of TERRAM standard geotextiles makes them highly effective in replacing traditional filter layers. Typically, a single layer of geotextile can replace a succession of stone filter layers. A single bedding layer of stone is laid on the geotextile and this is followed by the rock armour.

TERRAM Robust Geotextiles are able to resist damage that could otherwise be caused during the placement of angular stone/rock and go on to deal with point loads in service life.

**Features & Benefits:**

Engineered to provide high strength and high elongation at break to ensure excellent resistance to damage during construction.

TERRAM Robust Geotextiles are manufactured to performance properties, not weight. Sufficient fibre will be added during production to achieve these properties.

Engineered to provide excellent protection properties in aggressive soils and liquids.

Manufactured from high tenacity UV stabilised virgin polypropylene fibres which have been heavily drawn to ensure excellent long term durability in a range of soil types.

Manufactured using a randomly orientated web to provide isotropic properties, ensuring that high strength is not limited to a single direction.

Excellent uniformity with high permeability and low pore size for soil filtration.

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### Specifications

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TERRAM product specifications can be downloaded freely from [www.terram.com](http://www.terram.com)
TERRAM Geocell erosion control

TERRAM Geocell is a relatively shallow cellular confinement system which is used to combat erosion on slopes up to 1:1.

TERRAM Geocell is fabricated using a geotextile so it is permeable and allows water to flow between cells encouraging drainage and vegetation. It is supplied as compact man-handleable panels ready to be expanded on site to 5m x 7m or 6m x 3m areas with a honeycomb of diamond-shaped cells that are 100mm, 150mm or 200mm deep.

Once placed and secured on the slope, the geocell can be filled with soil or a mineral fill. The result is that the confined fill is able to better resist the erosive effects of wind and run-off. The expanded panels should be fixed at every perimeter cell and at 1m centres throughout using steel fixing pins.

The geocell is flexible enough to be formed around trees and other obstacles. Seeded topsoil is the most suitable fill for less-exposed slopes, with small shrubs offering improved protection, whilst a granular material offers the highest protection.

Applications include:

• Cut or fill embankments.
• Dams or spillways.
• Revetments.
• Abutment protection.
• Geomembrane protection.
• Soil-nailing cover.
• Landfill capping.

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TERRAM product specifications can be downloaded freely from www.terram.com.
TERRAM Geocell is flexible and can be filled with a wide range of fill materials. The TERRAM Geocell is fabricated from geotextile which means that the 0.58m wide x 0.53m long x 250mm deep cells have permeable walls and there is no potential for cracking, spalling, splintering or corrosion associated with concrete, steel and timber facings.

The system is supplied as compact panels which are expanded on site to form a honeycomb area of cells measuring up to 10.6m x 5.5m. This, the largest panel, weighs 28kg.

TERRAM Geocell Series 500 can be installed almost vertically by placing one horizontal layer on top of a filled layer. The cellular panels can be used to form the face or they can be used to face a composite wall in conjunction with horizontal reinforcement elements such as geogrids or with soil nails, rock bolts, helical anchors, etc.

One further facing detail is to step subsequent layers to form horizontal terracing which allows vegetative cover to be cultivated in topsoil-filled cells.

The cells can be filled with site-won materials (if suitable), topsoil, sand, aggregates and concrete.

Applications include:
- Steep slopes.
- Dams and flood bunds.
- Retention bunds.
- Green walls.
- Culvert head walls.
- Sound bunds.

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TERRAM product specifications can be downloaded freely from www.terram.com
TERRAM Geocell flood protection

TERRAM Geocell for floods provides a cost-effective and fast installation of temporary walls in emergency flood areas. The geotextile cells are filled with local material to build walls faster than conventional sand-bagging.

TERRAM geocells are designed as water containment barriers to help first responders construct flood protection much faster than traditional sandbag methods.

Our flood protection geocells have been tested by the U.S. Army Corps of Engineers and have been proven to significantly outperform sandbags through:

- Faster installation and removal time
- Less water seepage
- Better overall system endurance

Manufactured from permeable geotextile fabric, the geocell panels are lightweight, stackable and can be filled with local sand or soil on site. Being permeable there is no build-up of water, the flow-through of water or moisture helps improve compaction, leading to greater performance.

**TERRAM Geocells are engineered to provide:**

- Flexible design and contours to adapt to rugged terrain
- Ease of transportation - light weight and compact for remote installation

During the spring floods of 2011, Defencell Flood Walls were employed to defend municipalities along the flood zones from Canada down the Mississippi River to Louisiana

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TERRAM product specifications can be downloaded freely from [www.terram.com](http://www.terram.com)
A leader in material technology application

By intelligently applying our high-performance fibre technology, we are helping industry solve its most complex material challenges, and providing our customers with the answers they will need tomorrow.

Further market specific literature available:
- Railways
- Grass & Ground Reinforcement
- Landfill Engineering
- Roads & Highways
- Pipelines & Utilities

Application specific literature, product data sheets, case studies and installation guides are available on request or can be freely downloaded from www.terram.com. Please contact our technical sales team for reference projects, to organise a CPD seminar and for further advice.

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