Ten Cate Nicolon

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GEOLON®

A world of innovation





Ten Cate Nicolon

Ten Cate Nicolon - a world leader in geosynthetics

Ten Cate Nicolon manufacture the Geolon range of geosynthetics which are polymeric materials used to enhance the performance of a variety of soil and hydraulic structures. They comprise geotextiles, geogrids and geocomposites. With our worldwide expertise we are able to bring to design and construction engineers the many benefits of these materials.

Geolon - a geosynthetics pedigree

Since the early 1950's Geolon geosynthetics from Ten Cate Nicolon have been used to provide innovative solutions to a wide range of civil and marine engineering applications. This process first began with the use of Geolon in hydraulic structures to correct the damage caused by severe storms along exposed areas of the Dutch coastline. The provision of innovative solutions has continued into the 1990's where applications have expanded to a worldwide scale.

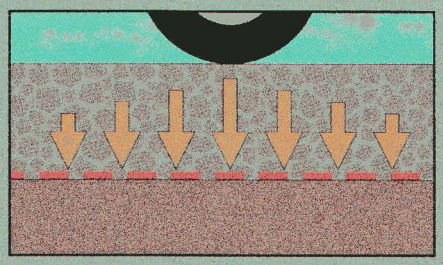
Over the last 40 years Ten Cate Nicolon has built an enviable international reputation for its ability to solve problems using geosynthetic solutions.

Geolon - the benefits

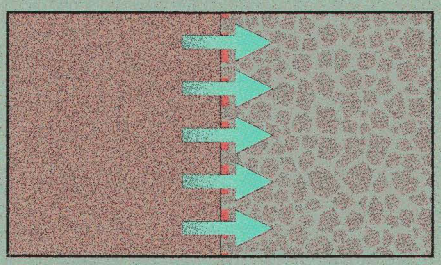
- They offer cost-effective solutions to a range of geotechnical and hydraulic problems.
- They have engineering characteristics that make them ideal for geotechnical and hydraulic applications.
- They can be utilised in permanent civil structures due to their composition of highly durable polymers.
- They are easy to install.
- They are environmentally friendly as they save on the extraction and depletion of sands and aggregates.

Geolon - the functions performed

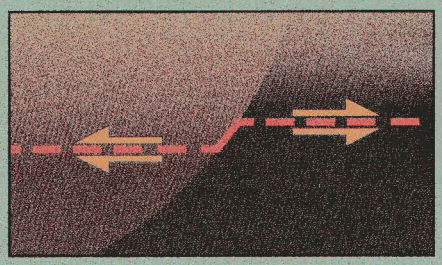
When Geolon geosynthetics are placed In soil and hydraulic structures they fulfil a range of functions that enhance the performance of those structures.



Separation: preventing the intermixing of soft foundation soils with granular materials thereby maintaining the structural integrity of the granular material.



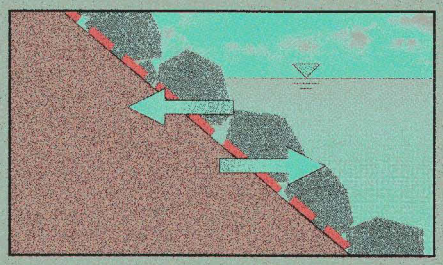
Filtration: allowing fluids to pass while preventing the migration of soil particles.

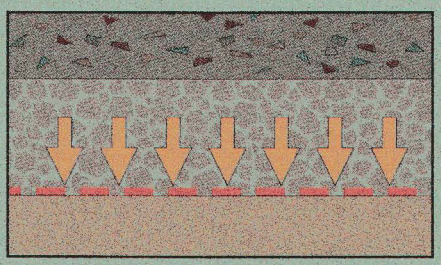


Reinforcement: maintaining the stability of soil by carrying tensile loads.

Erosion control: preventing the erosion of soil particles due to water flow, surface run-off, or wave and tidal action.

Protection: preventing or reducing the damage to a given surface or layer.



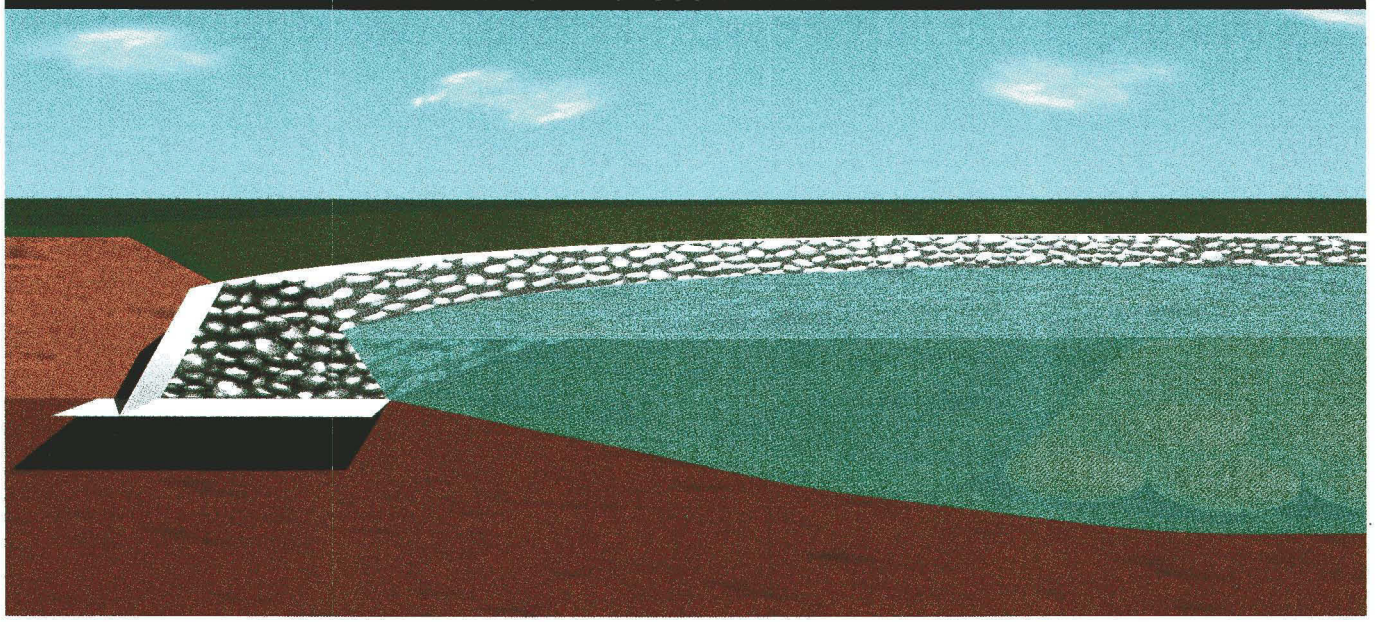


The range of functions fulfilled by Geolon geosynthetics make them suitable for a wide variety of civil engineering applications, namely transportation engineering, reinforced soil engineering, marine engineering and environmental engineering.

Marine engineering

Geolon geosynthetics are used as integral components in the design and construction of a variety of marine and hydraulic engineering structures such as revetments, rubble-mound breakwaters, tubular containment structures and marine spoil containment structures. The materials used are easy to install beneath the water surface, in difficult conditions, and once in place provide continued performance.

REVETMENTS • LAND RECLAMATION • GEOCONTAINERS • GEOTUBES • BREAKWATERS •

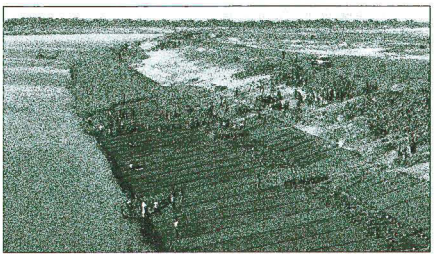


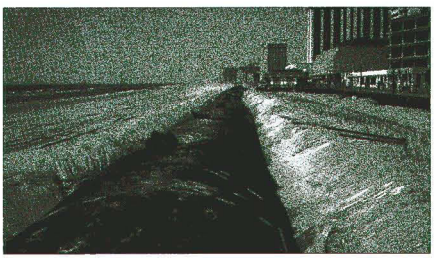
Geolon acts as a filter in revetments to prevent the erosion of soil. The armour protection on top of Geolon can be a wide range of materials such as rock, gabions and mattresses, concrete pattern-placed units, etc. Applications range from river bank protection to coastal defence works.

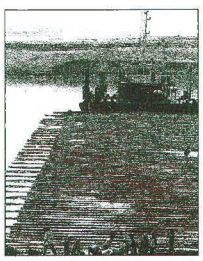
Geolon can also be used as a filter at the base of rubble-mound breakwaters. In this location, Geolon prevents the erosion of the foundation soil through the granular layers in the breakwater. In some instances, the geosynthetic may also be required to reinforce the base of the breakwater when it is constructed on soft foundation soils.

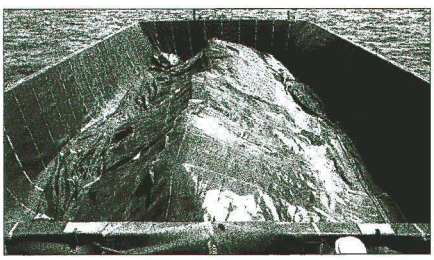
In marine applications our geosynthetics are used for geocontainers which enable the placement of fill and spoil materials on the seabed in an orderly and controlled manner. Geolon geocontainers prevent the loss of the contained fill and spoil material. Submerged structures such as breakwaters, groynes and spoil-containment areas can be cost-effectively constructed using this technique.

Geolon geosynthetics are used for geotubes that contain hydraulic fill to construct various shore stabilisation structures. Geolon geotubes, while containing the hydraulic fill, also give shape to the resulting structure. These structures are highly flexible and very economical as they utilise locally dredged materials.









TOP RIGHT: Rock armoured revetment.

CENTRE: Geotube installation for erosion control.

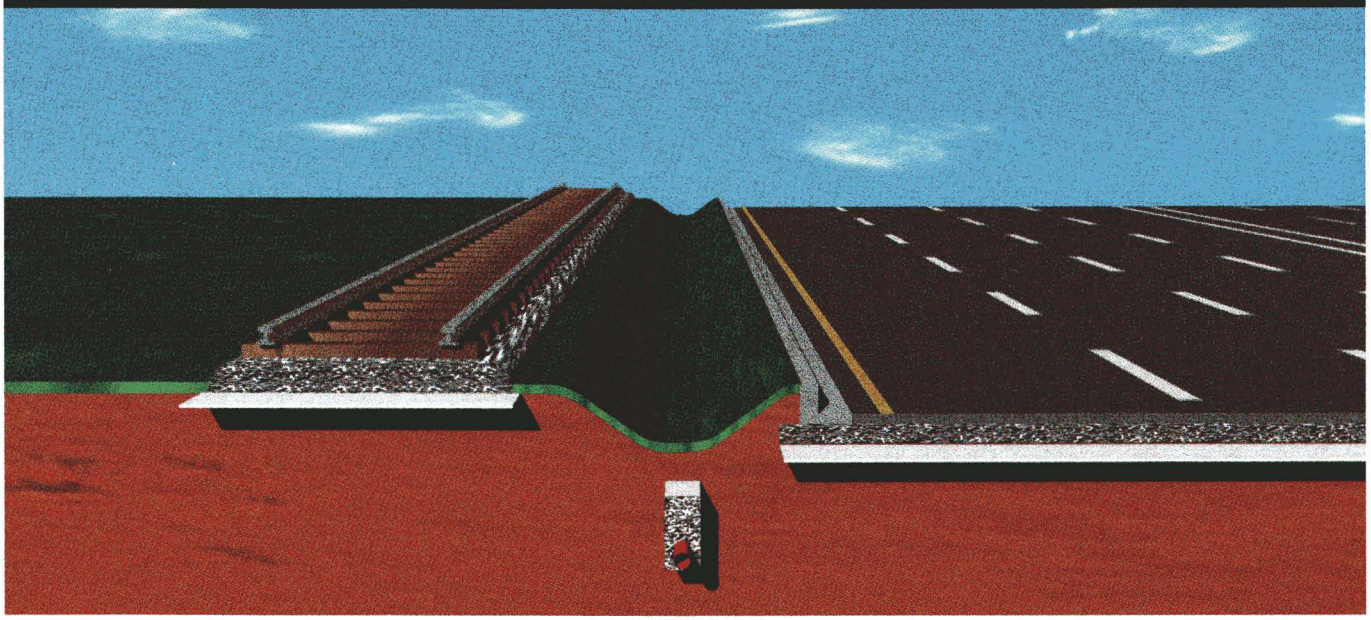
BELOW LEFT: Fascine mattress for erosion control.

BELOW RIGHT: Geocontainer in barge prior to placement.

Transportation engineering

Geolon geosynthetics enhance the performance and the design life of transportation engineering structures such as roads, railways, airfields and earthworks. For these applications, Geolon is installed as separation and filter layers in areas where groundwater is a problem. Geolon offers the ideal characteristics of robust mechanical properties coupled with high water flow capabilities.

ROADS • RAILWAYS • AIRFIELDS • EARTHWORKS • SUBSURFACE DRAINAGE • ROADS •

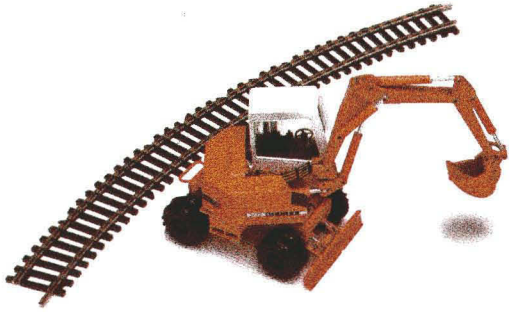


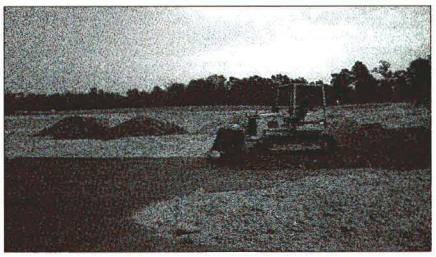
In road and airfield pavements Geolon is placed on top of soft subgrades prior to placement of the granular subbase layer. The geosynthetic prevents the loss of the granular subbase material into the soft subgrade, maintaining the structural integrity of the pavement. The use of Geolon thus extends the maintenance-free life of pavements constructed on soft subgrades.

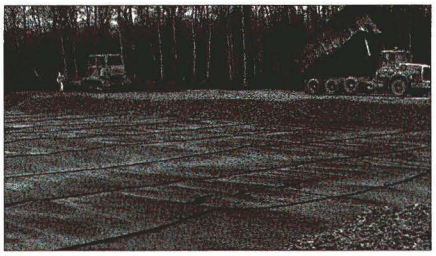
In railway tracks, Geolon is placed between the existing formation and the ballast layer to prevent the subgrade from pumping into the ballast layer, thereby maintaining the structural integrity. The use of Geolon significantly increases the periods between track maintenance with considerable savings on labour and material costs.

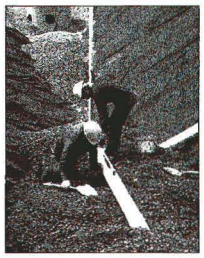
In earthworks construction Geolon is placed between two different kinds of fill to ensure that intermixing does not occur during placement and compaction. Geolon maintains the distinct layer boundaries between dissimilar adjacent earthfill materials, maintaining their structural integrity.

Geolon geosynthetics are used as filters for subsurface drainage to enhance the performance of pavement and earthworks structures. They allow the groundwater to pass into the subsurface drain without eroding the soil, and thus ensure long-term performance.









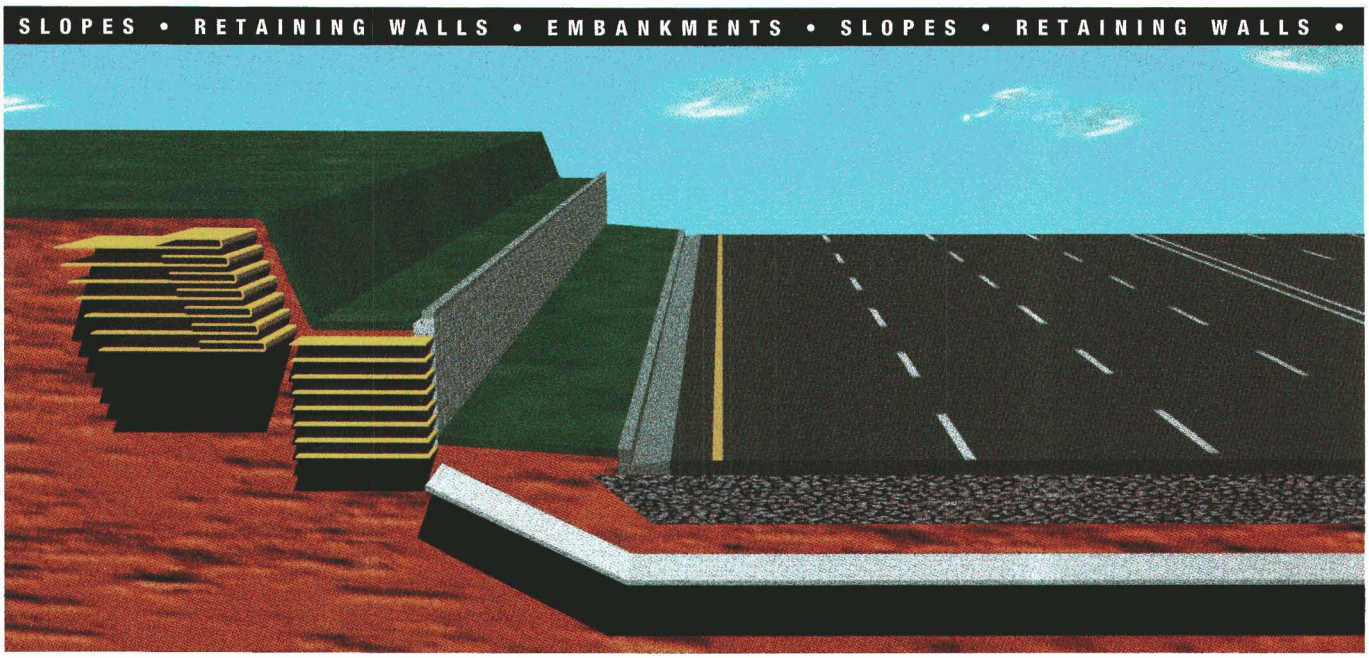
TOP: Area stabilisation over soft foundation.

CENTRE: Pavement construction over soft foundation.

BELOW: Subsurface trench drain.

Reinforced soil engineering

Geolon geosynthetics are used as integral components in reinforced soil structures such as retaining walls, slopes and embankments. They provide tensile resistance to the soil, thus enhancing its shear characteristics. This enables walls, slopes and embankments to be constructed cost-effectively and quickly. The Geolon geosynthetics used for soil reinforcement have been designed to offer the ideal characteristics of high tensile strength, low elongation and low creep.

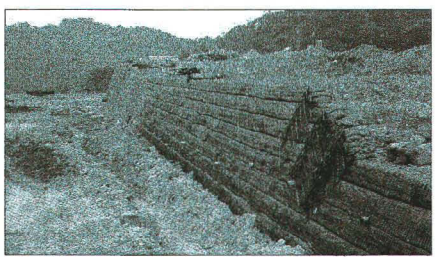


To steepen soil slopes Geolon geosynthetics are placed in layers during construction to provide tensile resistance and enhance stability. The facing of the slope can be grass or another facing material. This technique enables slopes to be constructed to any height at any slope angle.

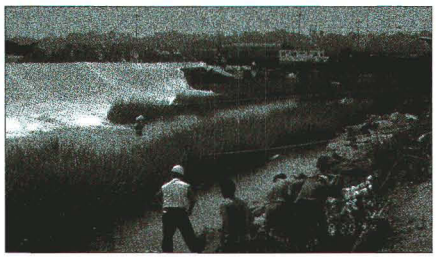
Geolon geosynthetics are used to provide stability to retaining walls constructed using concrete blocks or panels. Geolon is connected to the block facing and laid in layers in the backfill during construction of the wall. Retaining walls constructed in this manner are economical, efficient and aesthetic.

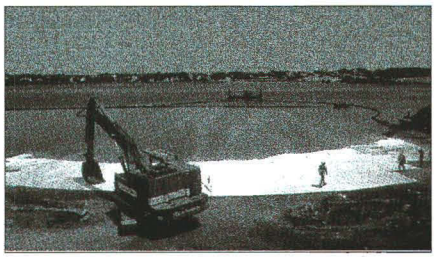
Geolon geosynthetics are placed at the base of embankments to provide stability and limit differential settlements. Depending on the specific application, the product may be placed directly on the soft foundation, over foundation piles, or over areas subject to void formation prior to the placement of the embankment fill.











ABOVE LEFT: Reinforced soil slope.

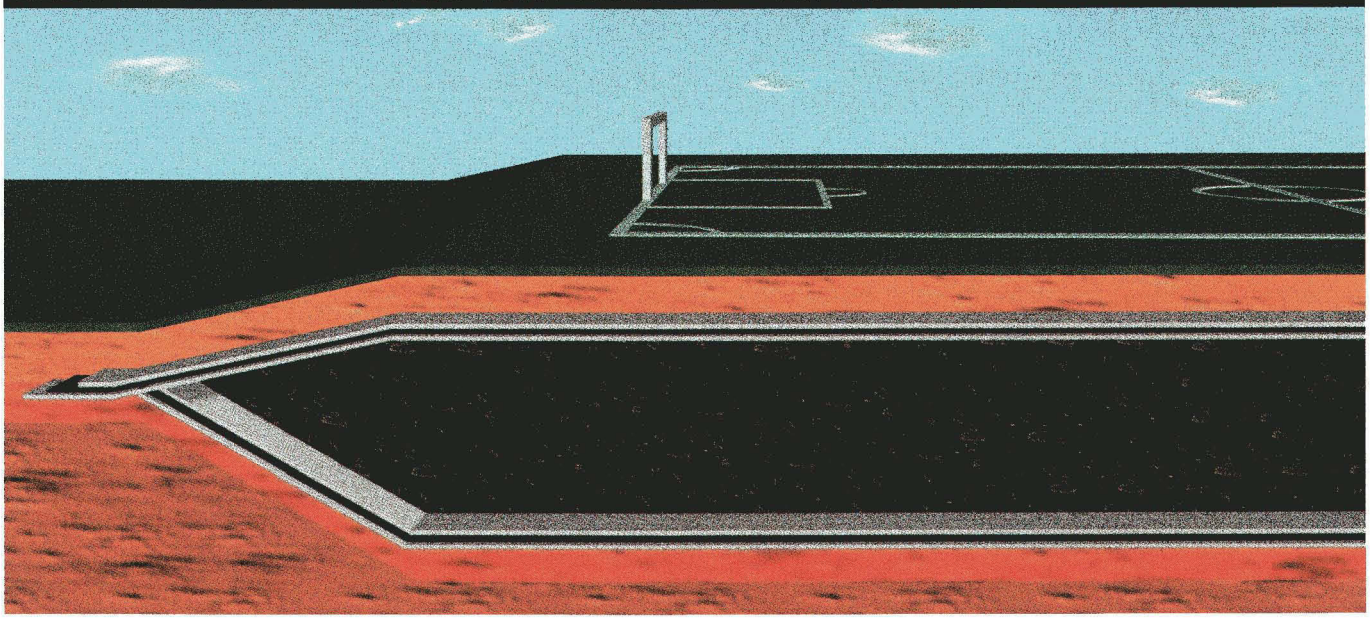
ABOVE RIGHT: Segmental block retaining wall with reinforced soil backfill.

BELOW: Installation of basal reinforcement on soft foundation.

Environmental engineering

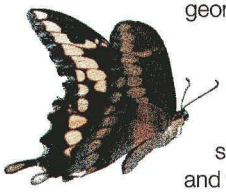
Our extensive product range is ideally suited to a variety of applications for landfill and waste-containment structures. Examples include protection layers for geomembrane liners, veneer reinforcement for the enhancement of material interface properties, reinforcement to steepen landfill containment slopes, reinforcement to support liner systems constructed over compressible foundations, reinforcement to reclaim tailings and other waste lagoons, and drainage for gas and liquid removal.

LINER PROTECTION • VENEER REINFORCEMENT • CAPPING • RECLAMATION • SLOPES •



Geolon acts as a protection layer for geomembrane liners in landfill and waste containment facilities. It protects the geomembrane from puncture enabling its installation adjacent to natural ground and granular layers.

Geolon geosynthetics are used as veneer reinforcement to improve the frictional interface between a sloping geomembrane liner and the adjacent soil layer. They are used to prevent the soil from sliding along the surface of the geomembrane liner. In addition, they support the disturbing forces in the soil layer thereby preventing them being transferred into the geomembrane liner.

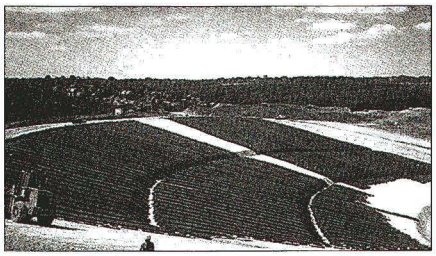


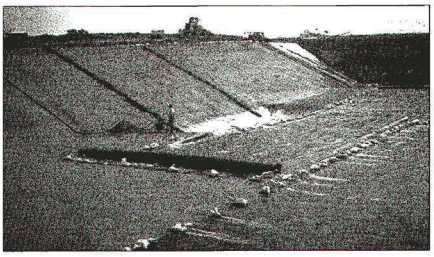
Geolon can also be used for reinforced soil to steepen slopes in landfill and waste-containment facilities. This enables the maximum volume to be made available for the storage of waste.

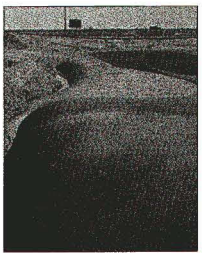
Geolon can be used to support liner systems when these are constructed over areas that are susceptible to differential settlements. The Geolon ensures the integrity of the liner system is maintained as the underlying layer undergoes deformation.

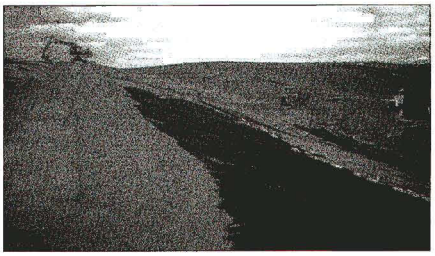
Geolon is also used as a filter in the drainage layers of landfill and waste facilities. Geolon facilitates the drainage of leachate and gases to outlet points.

The early reclamation of tailings and other waste lagoons can be performed using Geolon to facilitate the construction of capping layers. The use of Geolon with high tensile stiffness characteristics enables a capping layer to be economically constructed over disused tailings lagoons at an earlier stage than would be possible









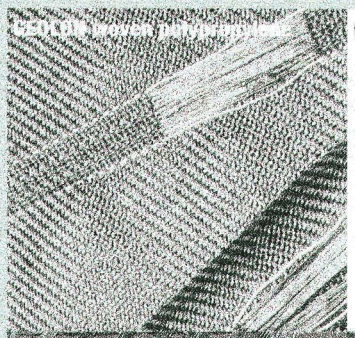
ABOVE LEFT: Protection layer prior to placement of geomembrane.

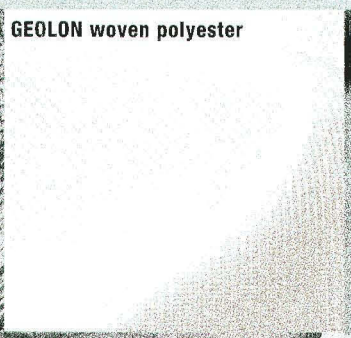
ABOVE RIGHT: Protection layer above geomembrane.

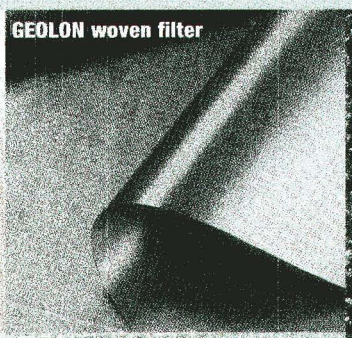
BELOW LEFT: Construction of capping layer over soft tailings.

BELOW RIGHT: Veneer reinforcement on landfill capping.

Geolon® geosynthetics range



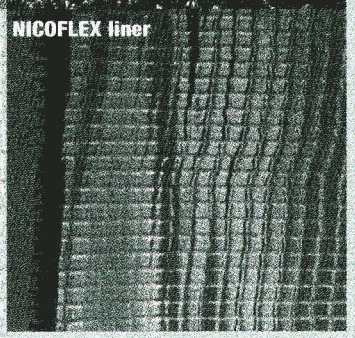












Geolon geosynthetics cover an extensive range of materials:

Geolon woven polypropylene geotextiles for heavy duty separation, and marine and hydraulic works. These materials are used as heavy duty separation layers in pavement and earthworks construction, filters and separation layers at the base of rubble-mound breakwaters. They are also prefabricated into geotubes and geocontainers for use in marine applications.

Geolon woven polyester geotextiles for basal reinforcement of embankments, slopes and walls. These products are used where the reinforcement of embankments is required across soft foundations, piled foundations and areas prone to subsidence.

Geolon woven filters of polypropylene and polyethylene for critical filtration applications involving problem soils.

Robulon geotextiles for surface erosion control of slopes and stream banks. Placed on the surface of slopes or along stream banks, they prevent the erosion of soil while at the same time promoting vegetation root growth.

Geolon geogrids for reinforced soil slopes and walls. These materials are placed in layers in the backfill to reinforce soil slopes and retaining walls.

Geolon nonwoven geotextiles for separation, filtration and protection applications. These materials are used for separation layers in pavement and earthworks construction, filters for subsurface drainage and gas removal, filters for revetment construction, and protection layers for geomembrane liners.

Ecolon biodegradable geotextiles of coconut fibre and sisal for temporary surfaces in erosion control.

Nicoflex liners for waste management, ponds without liners, artificial lakes and waterways.

Geolon is a registered trade mark of Royal Ten Cate

In Europe contact:

Ten Cate Nicolon bv
Sluiskade NZ 1
PO Box 347
7000 AH Almelo
The Netherlands

Telephone: +31 546 544811
Fax: +31 546 544910

In North America contact:

TC Mirafi
365 South Holland Drive
Pendergrass
Georgia 30567
USA

Telephone: +1 706-693 2226
Fax: +1 706-693 4499

In Asia contact:

Ten Cate Nicolon Asia Sdn Bhd
11th Floor, Menara Glomac
Kelana Business Centre
97, Jalan SS 7/2
47301 Petaling Jaya
Selangor Darul Ensan
Malaysia

Telephone: +60-3 7492 2282
Fax: +60 3 7492 4280

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Ten Cate Nicolon

PRODUCT INFORMATION



The unrolling of a **GEOCONTAINER** in the hold of a split-bottom barge. The side of the hold is covered with slip and protection sheets made out of a woven geotextile to facilitate smooth discharge.



The **GEOCONTAINER** is unfolded and attached to the coaming.



The standard **GEOCONTAINER** closing system, is a portable sewing machine and high tenacity sewing thread.



A **GEOCONTAINER** closing system for extreme stresses, using ropes.



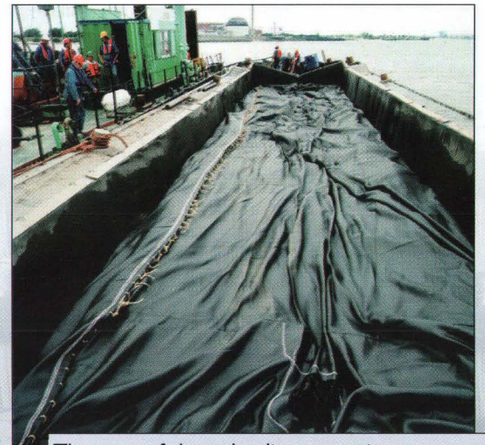
The **GEOCONTAINER** is filled with locally available material, placed mechanically. A sandy type of soil gives the best results.



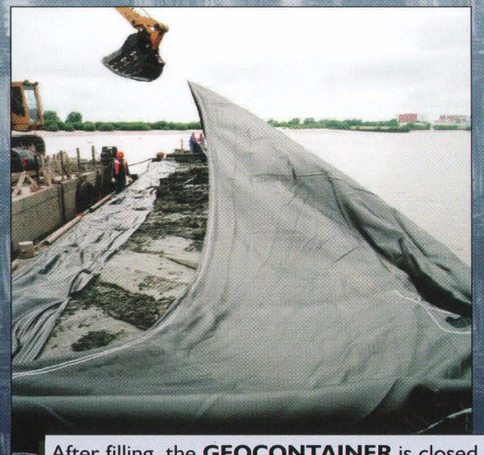
The **GEOCONTAINER** is filled to 80% of the hold capacity.



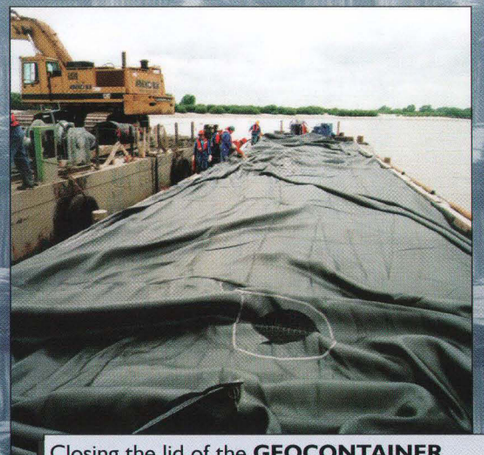
The split-bottom barge with the filled and closed **GEOCONTAINER** is positioned accurately over the drop zone.



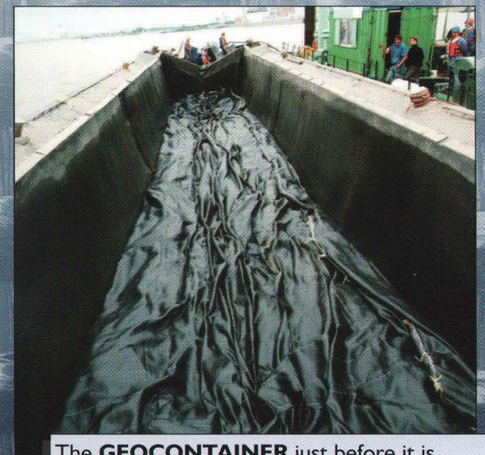
The start of the unloading operation.



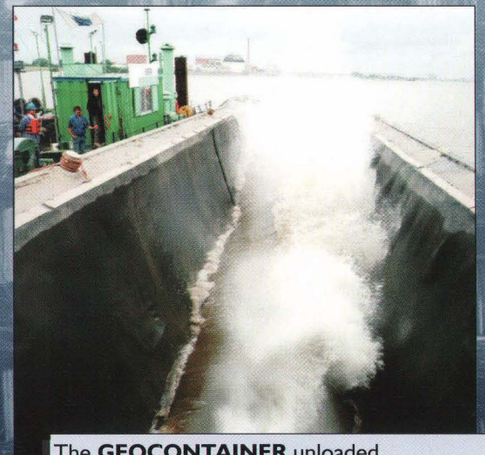
After filling, the **GEOCONTAINER** is closed with the extra geotextile material provided for the lid.



Closing the lid of the **GEOCONTAINER** can be done in several ways, this can depend on the stresses expected during unloading and upon impact on the bottom.



The **GEOCONTAINER** just before it is released from the hold.



The **GEOCONTAINER** unloaded completely.

GEOCONTAINER®

A large scale geotextile container for core construction of dams and the repair of erosion cavities and scour holes.

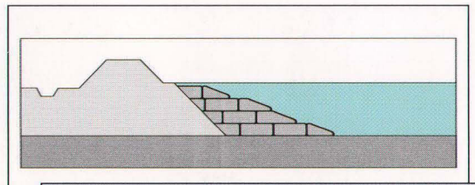
Ten Cate Nicolon's GEOCONTAINERS are used in marine engineering applications. The GEOCONTAINER is the ideal construction element for use in the core of dams, groynes, moles, piers, dikes and submerged berms. They are used also for filling large erosion cavities and holes caused by under water geotechnical slips.

Main advantages:

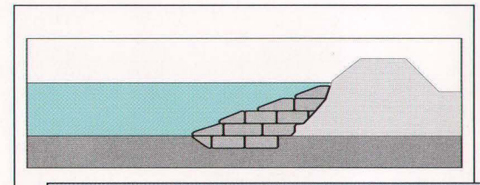
- ✓ GEOCONTAINERS are filled mechanically with locally available materials such as clay, sand or gravel as a replacement for imported materials like rock or rip-rap.
- ✓ GEOCONTAINERS can be dropped to form large under water stacks with side slopes of about 20 degrees.
- ✓ GEOCONTAINERS will be customised to fit the application, the fill material and the fill method. They are designed to fit the hold of any split-bottom barge currently in use.
- ✓ GEOCONTAINERS cause minimal disturbance to the environment, since the quantity of rock quarried for the construction is limited. The GEOCONTAINERS are filled with locally available material and there is no loss of material.
- ✓ GEOCONTAINERS were used successfully in various projects world-wide with contents of 110 m^3 to 500 m^3 in a water depths of up to 30 meters.
- ✓ GEOCONTAINERS are manufactured from the technically outstanding GEOLON range of polypropylene woven fabrics, with tensile strengths in both directions of 80, 100, 120 or 200 kN/m. GEOCONTAINERS employ the use of specially developed advanced seaming techniques for required strengths.
- ✓ GEOLON polypropylene fabrics can be completely recycled.
- ✓ GEOLON is chemically inert to alkalis and acids, providing a reliable long term geotextile strength. The yarns have been treated with special long life additives, to ensure lifetime expectation in seawater environments, of over 200 years.
- ✓ GEOCONTAINERS are very robust and have a high resistance against mechanical damage during and after installation.



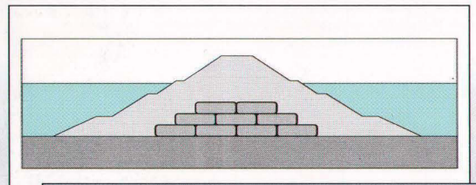
GEOCONTAINER® applications



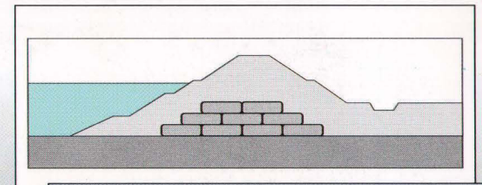
Submerged foreshores and support berms.



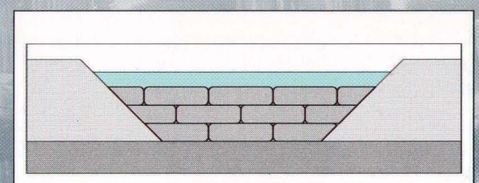
Stabilisation against geotechnical slips and filling of erosion cavities.



Core constructions for breakwaters, moles, piers and dams.



Core construction for dikes and reclamation areas.



Filling of breaches and dike closures.

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7600 AE Almelo.
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FAX: +31 546 544490

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Ten Cate Nicolon

PRODUCT INFORMATION

GEOTUBE®

Hydraulically sand filled flexible geotextile tube system for the core construction of dikes, dams and as shore protection.

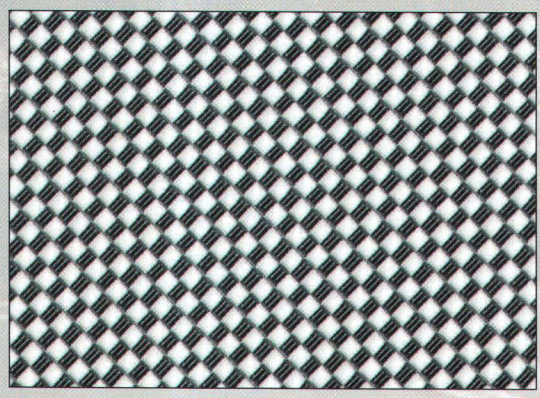
The Geotubes were designed by Ten Cate Nicolon for applications in marine engineering and are used as construction elements in the cores of piers, moles, groynes, dams, dikes and in shore protections.



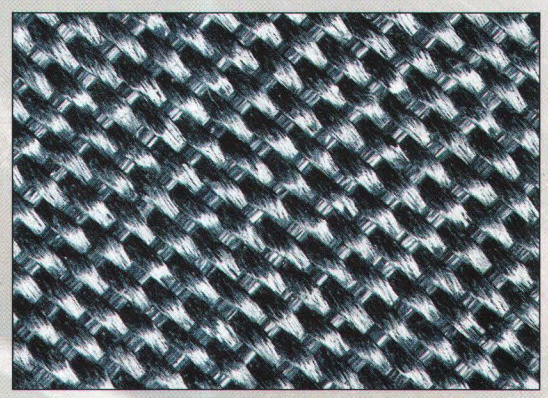


Main advantages:

- ✓ GEOTUBES are filled hydraulically with locally available sand.
- ✓ GEOTUBES will be tailor-made to fit the project by optimising diameter and length.
- ✓ GEOTUBES cause minimum impact on the environment. The system uses locally available sand, rather than imported stone.
- ✓ GEOTUBES can be installed on land or in water up to a depth of 3 m.
- ✓ GEOTUBES will be manufactured from the advanced GEOLON PET/PE 90, PP 80, PP 100S, PP 120S or PP 200S using specially designed high strength seaming techniques.
- ✓ GEOTUBES are very robust, UV-stabilised, have a high resistance against mechanical damage with a long life expectancy.
- ✓ GEOTUBES have a number of inlet ports over their entire length. These ports also act as outlet ports for excess water.
- ✓ GEOTUBES have been used successfully in many projects world-wide, their lengths varied between 20 and 200 m and the diameters between 1 and 4 m.
- ✓ GEOTUBES are supplied with sufficient anchoring straps to enable correct positioning prior to and during the filling operation.



GEOLON® PET/PE 90 is produced from Polyester and HD-polyethylene yarns with a very high sand-tightness.



GEOLON® PP 200S is produced from long life stabilised polypropylene yarns with extremely high tensile strengths.

Ten Cate Nicolon

GEOTUBE INSTALLATION

The surface on which the GEOTUBE is to be placed, must be prepared level and be free from obstacles and sharp objects that may damage it.
To prevent erosion of the subsoil during the filling of the GEOTUBE, it is recommended that a light weight GEOLON PP geotextile or impervious membrane is laid on the site before unrolling the GEOTUBE. Jointing of GEOTUBE ends should be made with a minimum overlap of 2 m.



A perfect joint is achieved if the GEOTUBE to be filled first is placed on top of the subsequent GEOTUBE to be filled.

UNDERWATER GEOTUBE INSTALLATION

The alignment of the GEOTUBE for underwater installation is achieved by placing temporary guides on both sides. The anchoring straps of the GEOTUBE can be fixed to these guides to position it accurately. Floats can be fixed to the ends of the GEOTUBE and to the inlet ports, for identification and ease of filling.



FILLING THE GEOTUBE

Filling is achieved by pumping a mixture of sand and water into the GEOTUBE. The ratio of water to sand should be approximately 85% to 15%.
The water helps moving the sand from the inlet port into the GEOTUBE.
The sand settles inside the GEOTUBE and the water "bleeds" from the pores of the GEOLON geotextile.



The inlet ports that are not used during the filling operation should be left open at top. This prevents high pressures inside of the GEOTUBE.
This pressure should be limited to a maximum of approximately 10 kN/m^2.
GEOTUBES should be filled to a maximum height of 60% of their theoretical diameter.
A GEOTUBE with a theoretical diameter of 3.25 m. may be filled to a height of nearly 2 m. and will have a width of approximately 4 m.

STACKING OF GEOTUBES



By stacking GEOTUBES it is possible to construct an efficient and solid core for dams, dikes, moles, etc. The voids between the GEOTUBES should be filled with sand and covered with a medium weight GEOLON geotextile. This prevents sand from being washed away when the next layer of GEOTUBES are filled.
When GEOTUBES are used as a temporary construction, damage that may be caused by vandalism can be prevented by covering the GEOTUBE with rip-rap, sand or a bitumen spray.

GEOTUBE and GEOLON are registered trademarks of **Ten Cate Nicolon bv** and distributed by:

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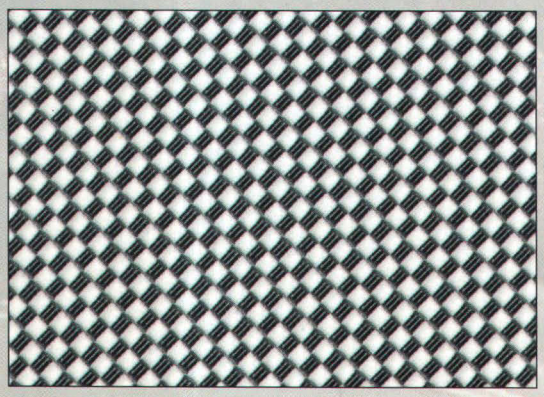
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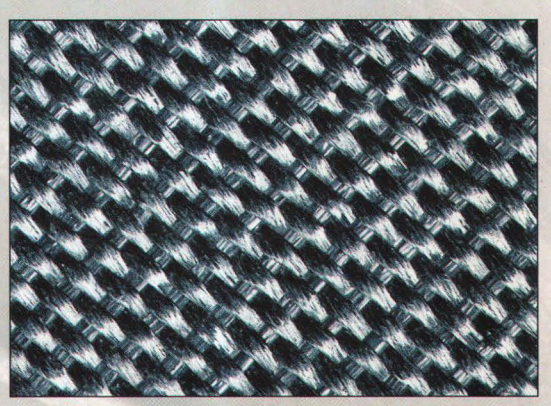


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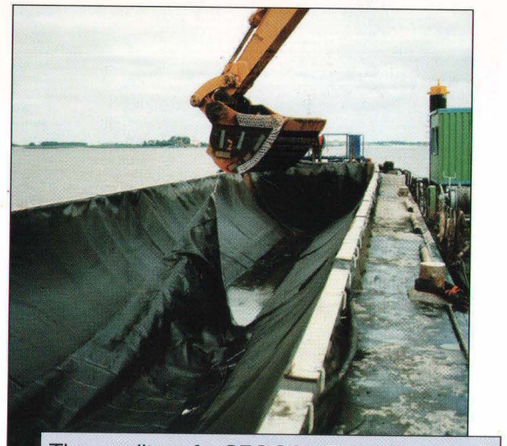
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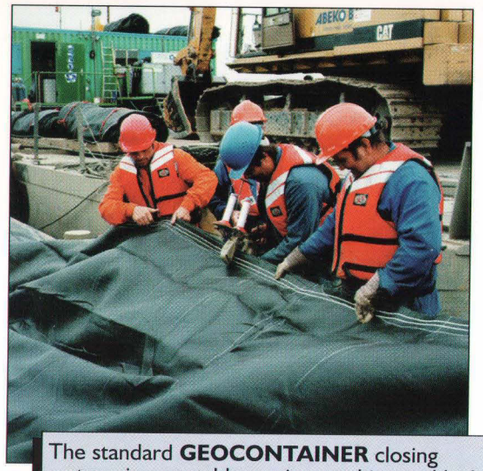
PRODUCT INFORMATION



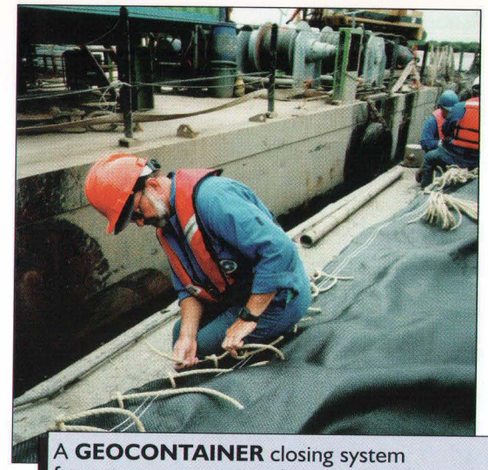
The unrolling of a **GEOCONTAINER** in the hold of a split-bottom barge. The side of the hold is covered with slip and protection sheets made out of a woven geotextile to facilitate smooth discharge.



The **GEOCONTAINER** is unfolded and attached to the coaming.



The standard **GEOCONTAINER** closing system, is a portable sewing machine and high tenacity sewing thread.



A **GEOCONTAINER** closing system for extreme stresses, using ropes.



The **GEOCONTAINER** is filled with locally available material, placed mechanically. A sandy type of soil gives the best results.



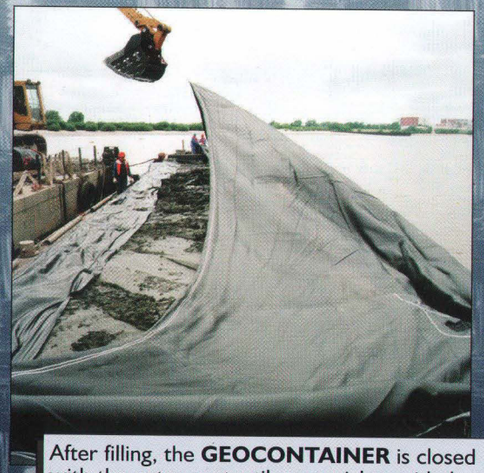
The **GEOCONTAINER** is filled to 80% of the hold capacity.



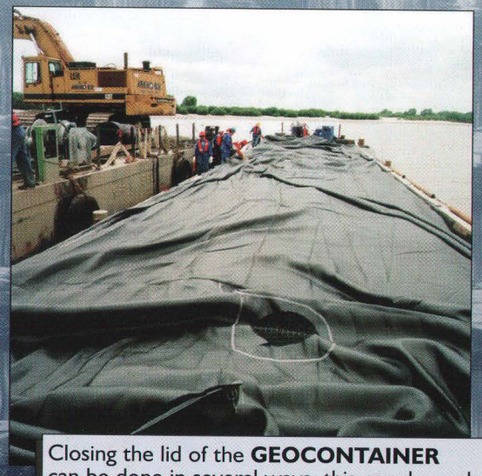
The split-bottom barge with the filled and closed **GEOCONTAINER** is positioned accurately over the drop zone.



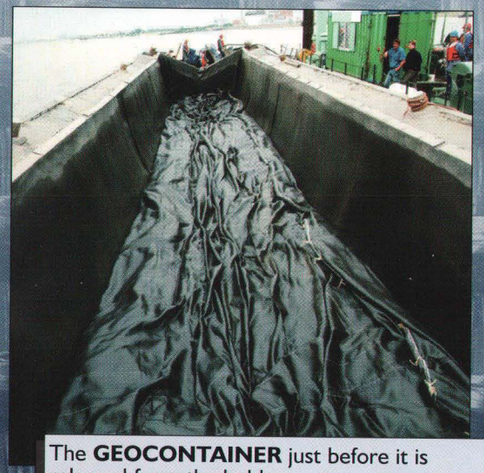
The start of the unloading operation.



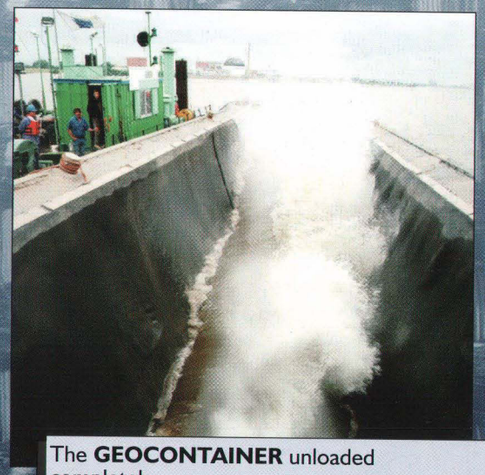
After filling, the **GEOCONTAINER** is closed with the extra geotextile material provided for the lid.



Closing the lid of the **GEOCONTAINER** can be done in several ways, this can depend on the stresses expected during unloading and upon impact on the bottom.



The **GEOCONTAINER** just before it is released from the hold.



The **GEOCONTAINER** unloaded completely.

GEOCONTAINER®

A large scale geotextile container for core construction of dams and the repair of erosion cavities and scour holes.

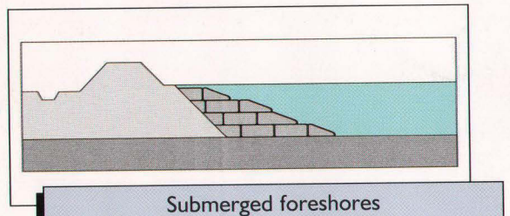
Ten Cate Nicolon's GEOCONTAINERS are used in marine engineering applications. The GEOCONTAINER is the ideal construction element for use in the core of dams, groynes, moles, piers, dikes and submerged berms. They are used also for filling large erosion cavities and holes caused by under water geotechnical slips.

Main advantages:

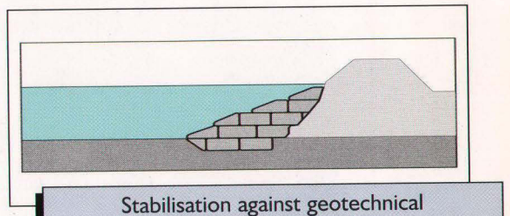
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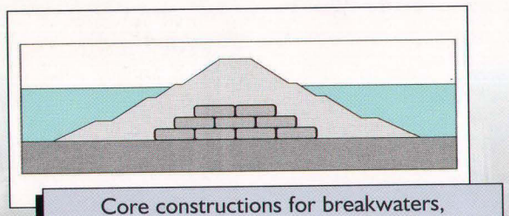
GEOCONTAINER® applications



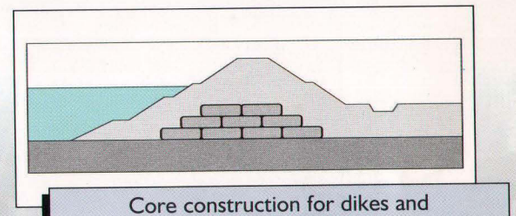
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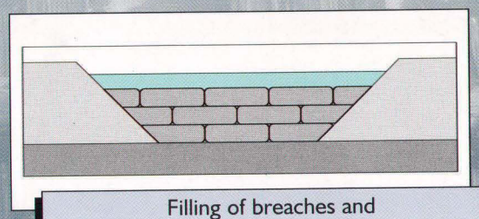
Stabilisation against geotechnical slips and filling of erosion cavities.



Core constructions for breakwaters, moles, piers and dams.



Core construction for dikes and reclamation areas.



Filling of breaches and dike closures.

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PRODUCT SPECIFICATIONS

GEOLON®

Woven Polypropylene Geoproducts

		GEOLON® PP 120S	GEOLON® PP 200S	STANDARD
CONSTRUCTION				
Construction type		woven	woven	
Yarn type length direction		split fibre	split fibre	
Yarn type cross direction		split fibre	split fibre	
Colour		black	black	
MECHANICAL PROPERTIES				
Length direction:				
Nominal tensile strength	kN/m	**120**	**200**	EN-ISO 10319
Elongation at nominal strength	%	**12**	**14**	EN-ISO 10319
Tensile strength at 10% elongation	kN/m	**100**	**150**	EN-ISO 10319
Tensile strength at 5% elongation	kN/m	**60**	**50**	EN-ISO 10319
Tensile strength at 2% elongation	kN/m	**20**	**10**	EN-ISO 10319
Cross direction:				
Nominal tensile strength	kN/m	**40**	**200**	EN-ISO 10319
Elongation at nominal strength	%	**7**	**13**	EN-ISO 10319
Static puncture (CBR):				
Push-through force	kN	**8**	**20**	EN-ISO 12236
Push-through displacement	mm	**30**	**40**	EN-ISO 12236
Dynamic perforation (Cone drop)	mm	**8**	**6**	EN 918
HYDRAULIC AND FILTER PROPERTIES				
Water flow at Δh = 100 mm	litre/m^{2}s	**30**	**25**	NEN 5167
Water head at v = 10 mm/s	mm	**17**	**20**	NEN 5167
Permittivity Ψ_s	1/s	**0,6**	**0,5**	NEN 5167
Water permeability	m/s	**0,030**	**0,010**	EN-ISO 11058
Characteristic pore size O_{90}(dry)	micron	**500**	**500**	NEN 5168
Characteristic opening size O_{90}	micron	**420**	**230**	EN-ISO 12956
DURABILITY				
Ultra Violet resistance:				
Xenon test (50 MJ/m^2)	U.T.S.	**>90%**	**>90%**	ENV 12224
Classification	class	**C**	**C**	ISO 4892-2
Thermo-oxidation resistance	class	**A**	**B**	NEN 5132
PHYSICAL PROPERTIES				
Mass per unit area	g/m^2	**360**	**940**	EN 965
Thickness (2 kN/m^2 pressure)	mm	**1,3**	**3,3**	EN 964-1
Roll width	m	**5,2**	**5,05**	
Roll length	m	**200**	**200**	
Roll diameter	m	**0,56**	**0,78**	
Roll weight	kg	**390**	**970**	
Ten Cate Nicolon code		**114**	**676**	

The technical data are obtained from in- and external test procedures, based upon the Evaluation Guideline KOMO BRL-K553.
The above listed geotextiles can be supplied in prefabricated panels.

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Subject to changes. Previously issued data are no longer valid.

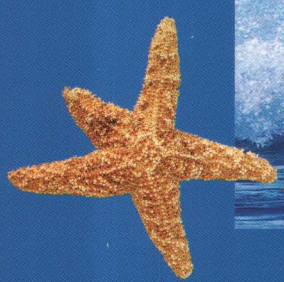
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GEOLON®

Geosystems-
case histories





Geotubes
Geocontainers
Geobags

Ten Cate Nicolon

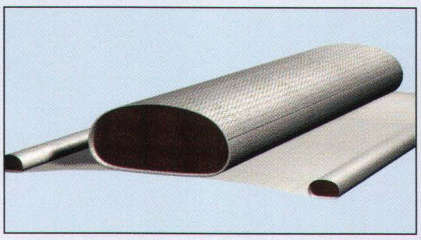
Geosystems for Marine & Hydraulic Engineering

Geosystems®

Geosystems are geotextile encapsulated soils that may be used to replace rock as conventional building blocks in marine and hydraulic engineering structures. **Geosystems** tend to be more stable hydraulically and geotechnically because they are heavier units with larger width to height ratio and have better boundary contacts with adjacent units.

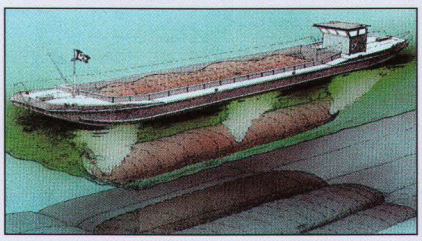
Rock may not be available within economical hauling distances in many river, lake, coastal or offshore marine construction projects. Sometimes the use of rock may be undesirable as it can pose high risk to cargo ships whereas **Geosystems** provide a soft contact. **Geosystems** are often competitive solutions in marine and hydraulic engineering by enabling the use of finer materials to be used as fill material for construction of marine and hydraulic engineering structures.

how it works:



Geotubes®

Geotubes are long geotextile tubes, hydraulically filled with soil to be used as marine and hydraulic structures. **Geotubes** are custom made and supplied in various sizes and lengths to suit design and installation requirements. They are ideal for installations on dry land or in water depths to 5m. The containment capacity may be from 2 to over 10m^3 per linear metre of **Geotube**.



Geocontainers®

Geocontainers are very large sized geotextile bags filled with soil. A split bottom hopper barge is used to form, transport and install the geocontainer. **Geocontainers** are custom made to fit the split bottom hopper barge. They are generally installed in water depths of over 5m. Each unit may contain 100 to over 1,000m^3 of soil.



Geobags

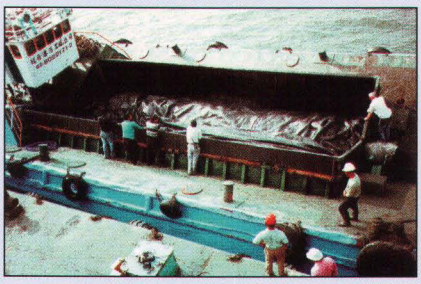
Geobags are geotextile bags designed to be filled with soil and installed for construction of marine and hydraulic structures. **Geobags** are custom made and supplied in various forms and sizes to suit design and installation requirements. They are ideal for installations on dry land or placed into water of any depth. Each unit may typically contain from 1 to over 10m^3 of soil.













® Geosystems, Geotubes and Geocontainers are registered trademarks of Royal Ten Cate.

Containment Dyke

Leybucht, Germany

Geotubes for **containment dyke** to enable under water backfilling for construction of a 9 m high sea defence dyke.

Geotubes were used to enable initial under water backfilling as part of the construction of a new sea defence dyke in the North Sea. The dyke of height 9 m and length 7 km was constructed close to Leybucht (Ley Bay) in North Germany.

Two parallel lines of geotubes were installed so that the space in-between could be backfilled hydraulically to construct the dyke above the water line. The biggest challenge was the channel closure which had to be completed within a few hours of low tide. This was achieved comfortably using the geotubes.

Once the initial backfilling to above water line was complete, earthworks could proceed in the dry in a conventional manner.



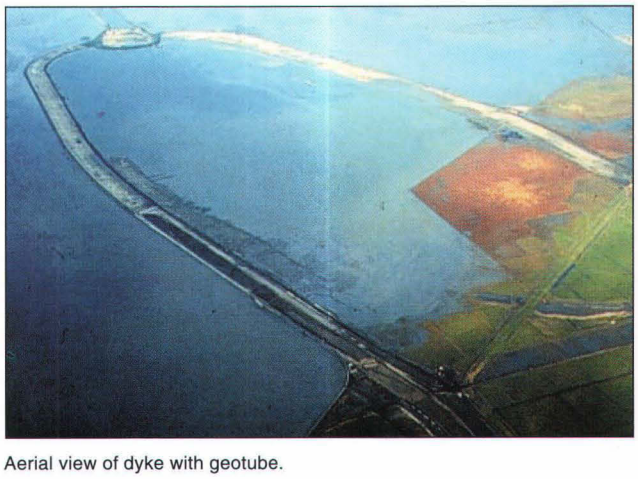
Geotube handling at site.



Sections of geotubes being installed.



Waves hitting geotube.



Aerial view of dyke with geotube.

Containment Dyke

Olympics 2000, Sydney, Australia

Geotubes for **containment dyke** for the construction of temporary beach volleyball courts at Bondi Beach Olympic beach volleyball site.

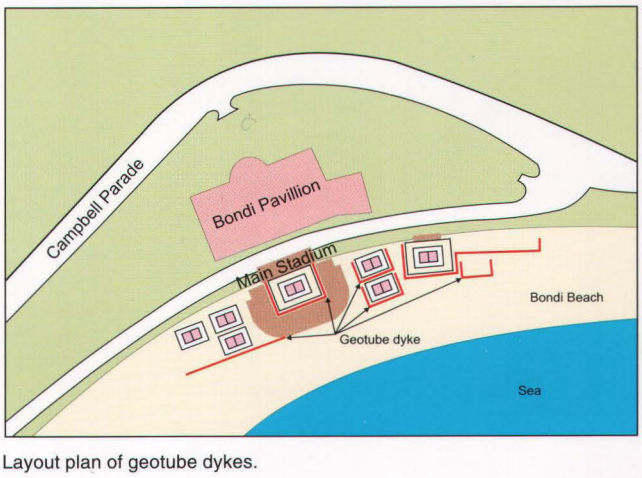
Geotubes were used to contain and protect temporary beach volleyball courts and associated parking areas at Bondi Beach for the beach volleyball tournament of the Sydney Olympics.

The geotube dykes were designed to retain sand fill for the creation of level playing platforms. Strict design and construction conditions were imposed due to the high profile nature of the project, which initially met with stiff resistance from the local community. Geotubes were ideal for the project because they could be constructed and removed very quickly with minimal impact on the beach environment.

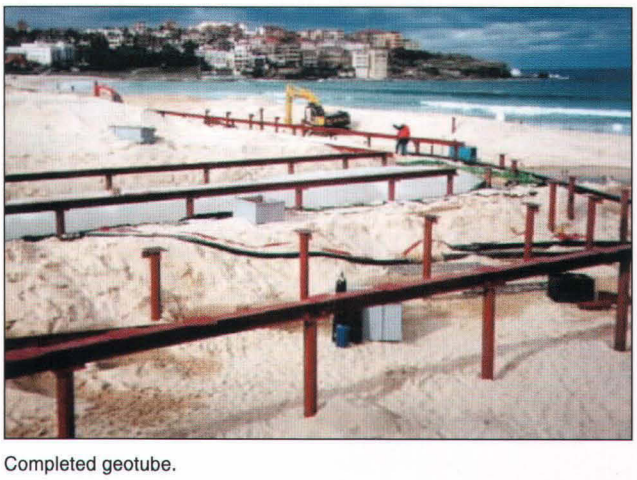
Following completion of the Olympics, the volleyball complex was fully dismantled and the beach restored to its original pristine condition.



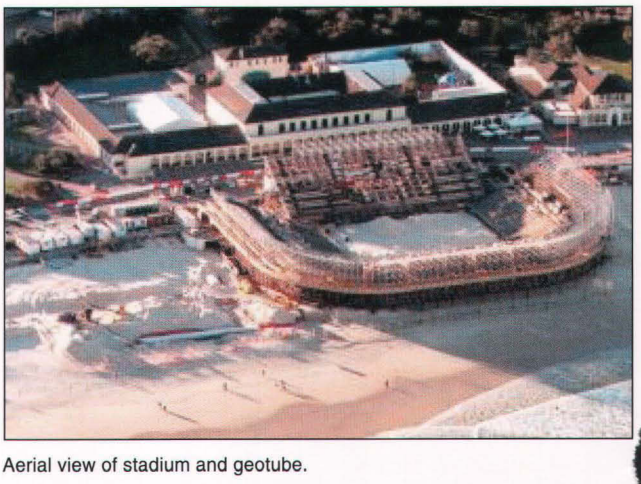
Geotube laid out prior to filling.



Layout plan of geotube dykes.



Completed geotube.



Aerial view of stadium and geotube.

Containment Dyke

Wack-Wack Golfcourse, Manila, Philippines

Geotubes for construction of a **dyke** to retain fresh water for a man-made lake in a golf course development.

Geotubes were used to construct a dyke in a man-made lake at the Wack-Wack Golf Course in Manila, Philippines.

An open municipal drain flows through the golf course and waste water was mixing with the fresh water at hole No. 7, resulting in a foul smell and unsightly environment.

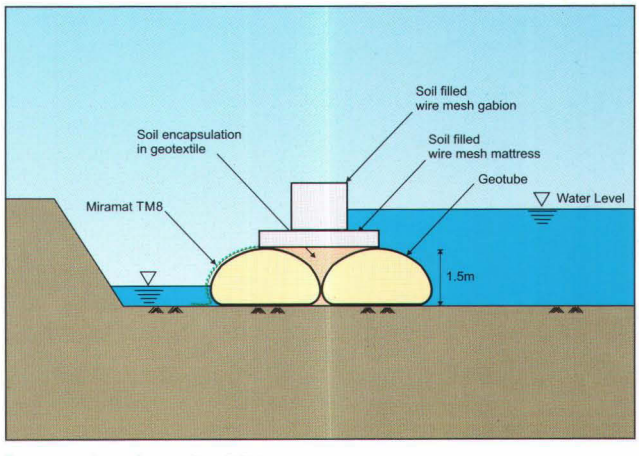
The function of the dyke was to separate and retain the fresh water in the lake while the municipal drain is drawn down to maximize flow during rain.

Tight construction conditions were laid down eg. golfing should not be disrupted, heavy equipment was not allowed, equipment movement was not allowed during regular golfing hours, noise had to be kept to a minimum and dewatering of the lake was not acceptable.

The geotube dyke enabled the project to be completed quickly and to the full satisfaction of the owners.



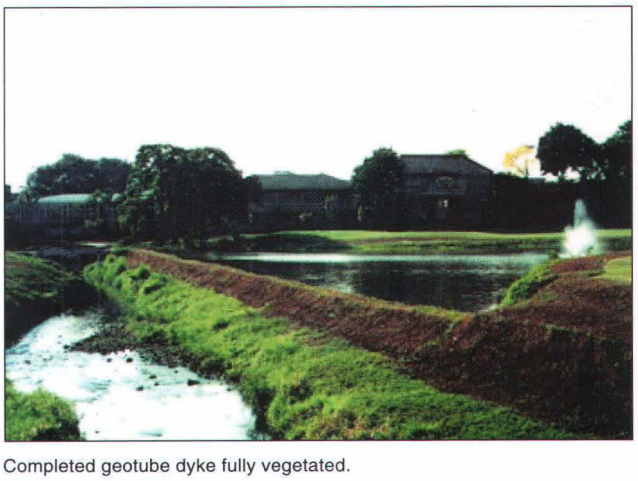
ing geotube prior to filling.



Cross section of geotube dyke.



Completed geotube dyke.



Completed geotube dyke fully vegetated.

Containment Dyke

Shamrock Island, Corpus Christi, Texas, USA

Geotubes for **containment dyke** to reclaim a rapidly eroding island.

Geotubes were used to construct containment dykes for land reclamation and coastal protection for Shamrock Island. Shamrock Island is rapidly eroding and is close to the point of vanishing completely.

Approximately 1 km of geotubes were installed as part of the works to rehabilitate the rapidly eroding island. After the geotubes were installed, sand was pumped to create a wetland habitat. March grass was planted to help establish the migratory bird sanctuary.

The project was extremely successful. The geotube protected coastline is no longer eroding and a bird habitat has been created from an island that was close to disappearing.



Installation of Geotube.



Creation of wetland habitat using geotube dyke.



Installed geotube dyke.



Reclaimed shore line of Shamrock Island.

Containment Dyke

Battery Island Bird Habitat, Southport, North Carolina, USA

Geotubes for **containment dyke** to reclaim a rapidly eroding island.

Geotubes were used to construct containment dykes for land reclamation and coastal protection for Battery Island bird habitat.

Heavy ship traffic in Cape Fear River leading to the Port of Wilmington was causing severe erosion to Battery Island. About 1.5 km of geotubes were installed as part of the reclamation works to rehabilitate the rapidly eroding island. Following geotube installation, sand was hydraulically placed to create a wetland habitat.

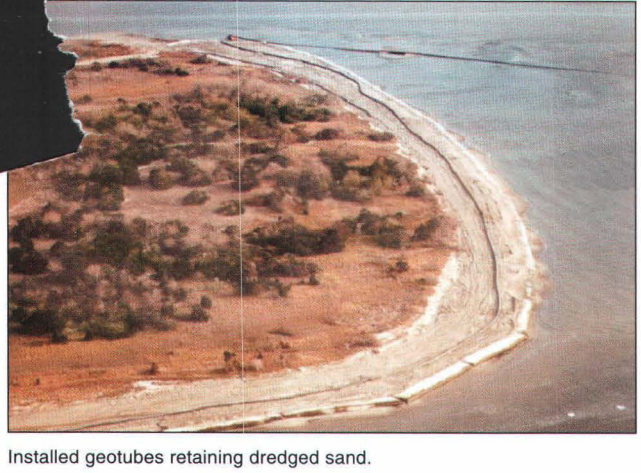
The project was extremely successful. The innovative programme was awarded the EPA Environmental Merit Award for the beneficial uses of dredged material.



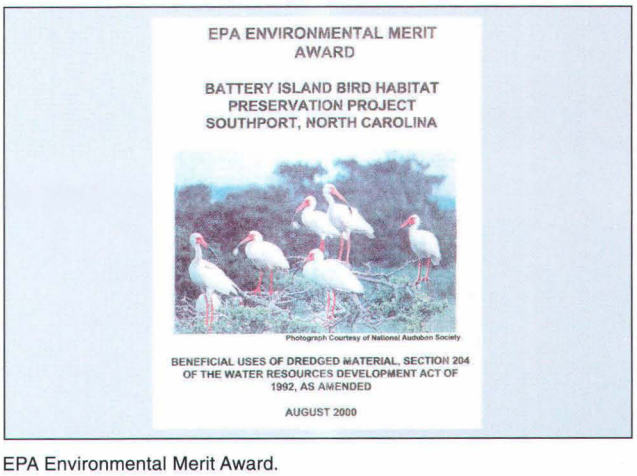
aying geotubes.



Installation of geotube.



Installed geotubes retaining dredged sand.



EPA Environmental Merit Award.

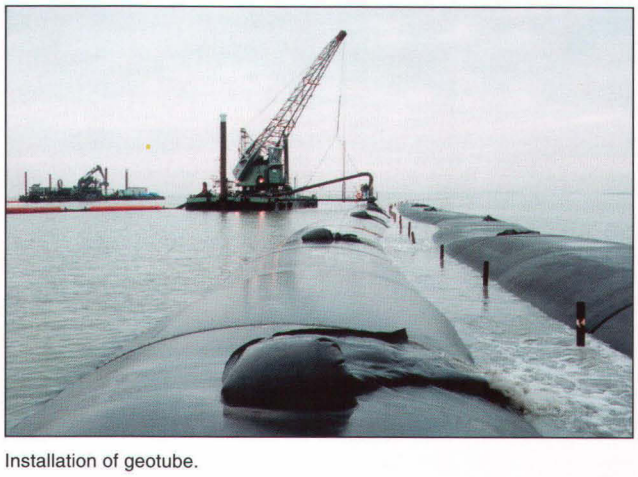
Containment Dyke

Naviduct, Lake IJssel, The Netherlands

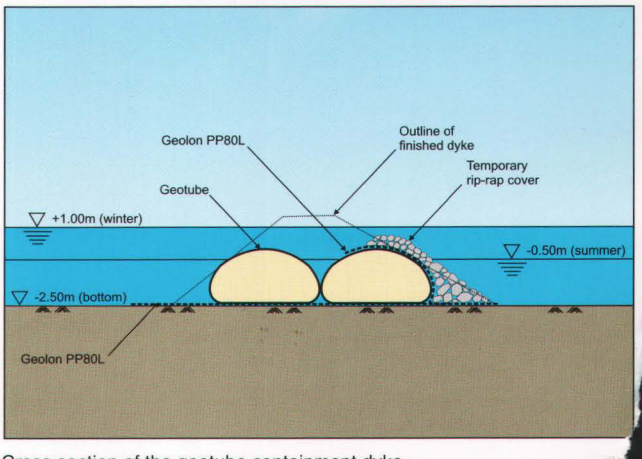
Geotubes for a **containment dyke** to retain dredged material from the Naviduct project.

A total of 3.75 km of dykes or 7.5 km of geotubes were used to contain dredged material. The geotubes had an initial theoretical diameter of nearly 4 m and were filled hydraulically at a rate of 1,800 m^3 per hour of sand slurry to attain a filled height of approximately 2.8 m. The tube lengths were manufactured such that each geotube could be completely filled within a working shift of between 8 to 10 hours.

Finally, a rip-rap cover was placed on the outer edge of the geotube containment dyke. The containment dyke project was completed within a relatively short period of 20 weeks.



Installation of geotube.



Cross section of the geotube containment dyke.



Placing of rip-rap cover.



Aerial view of Naviduct project.

Containment Dyke

Port of Buenaventura, Columbia

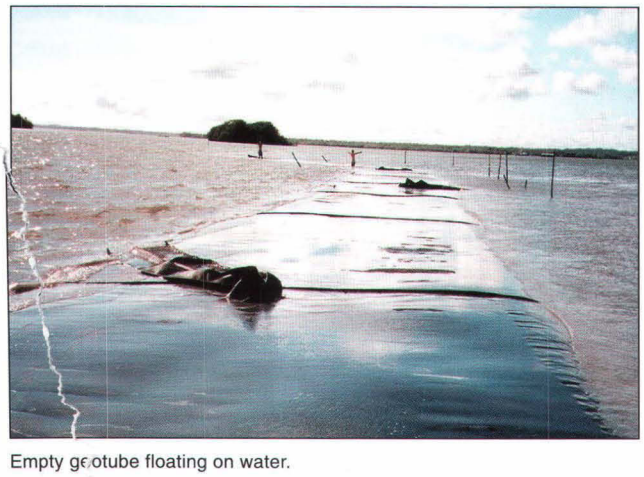
Geotubes for **containment dyke** to retain material from maintenance dredging of the navigation channel.

Geotubes were used to construct a containment dyke to retain dredged material near the port of Buenaventura in Columbia.

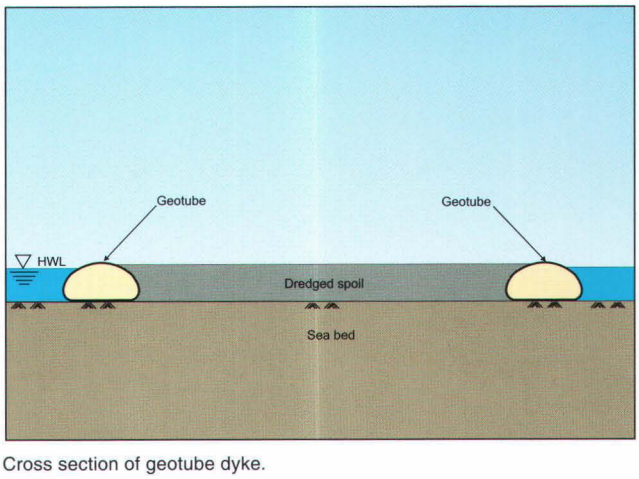
The total dyke length was 1.1 km in an oval shape. The containment area was oriented to minimize obstruction of river currents.

Construction of the dykes progressed quickly using geotubes. Marine growth on the geotube surface started almost immediately after installation.

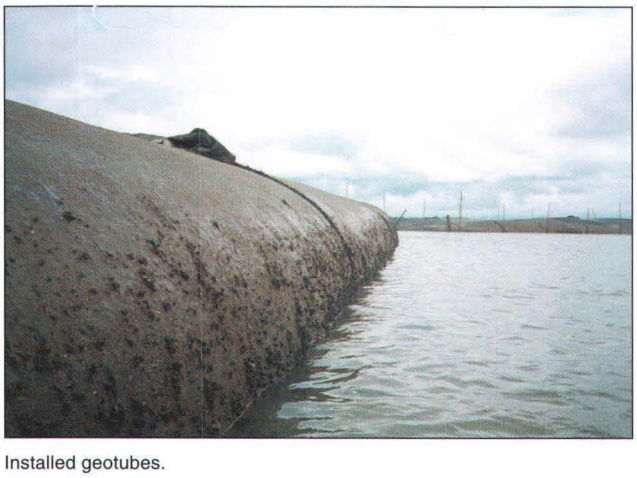
Following completion of the containment dyke, filling with dredged material began.



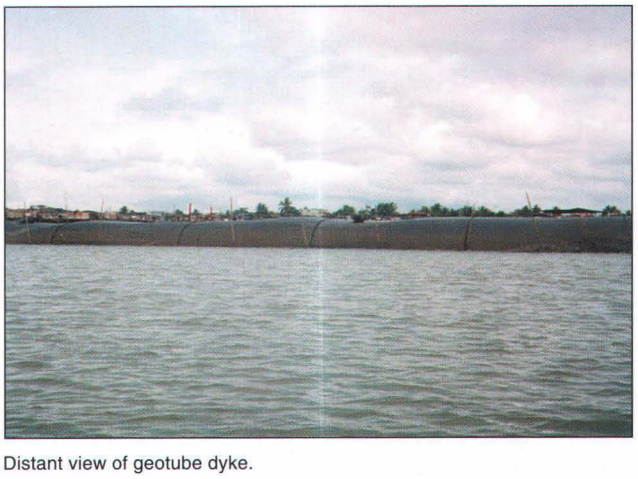
Empty geotube floating on water.



Cross section of geotube dyke.



Installed geotubes.



Distant view of geotube dyke.

Containment Dykes

Amwaj Islands, Bahrain

Geotubes for **containment dykes** to create artificial islands.

Geotubes were used for containment dykes to create artificial islands for the Amwaj Islands Project in Bahrain. This project is a prestige housing development site in the Persian Gulf.

Reclamation was carried out in two stages. The first stage involved the installation of a geotube of height approximately 2.6 m followed by hydraulic filling of sand behind the geotube. The second stage involved installation of another geotube, followed by further hydraulic filling of sand to achieve the finished platform level of CD + 3.6 m.

Upon completion of the reclamation, rock armour of 60-300 kg was placed in front of the geotube dyke.

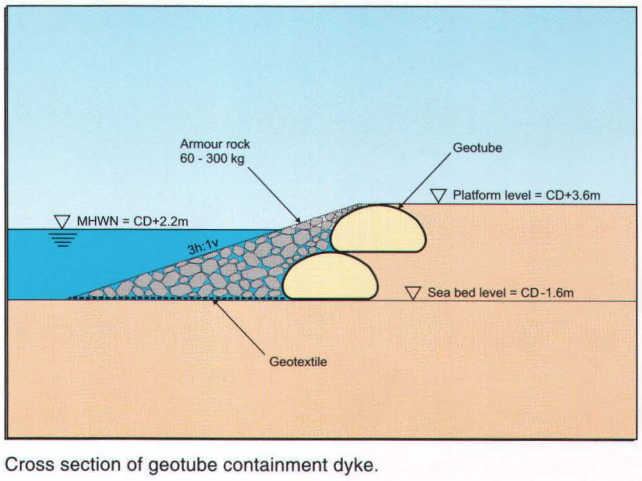
Eventually, submerged reef breakwaters are to be constructed about 300 m from the geotubes to create perched artificial beaches.



Aerial view of artificial islands under construction.



Laying of geotube.



Cross section of geotube containment dyke.



Installing upper geotube.

Protection Dyke

Sea Isle City, New Jersey, USA

Geotubes for construction of hidden **protection dyke** within a frontal sand dune to protect area behind the dyke from flooding.

Geotubes were used to internally reinforce a frontal sand dune to protect the coastal road and properties in Sea Isle City from flooding.

With each hurricane season, Sea Isle City, on the Atlantic coast, would be subjected to strong winds and waves that would cause extensive flooding along coastal areas. Damage costs were continually high.

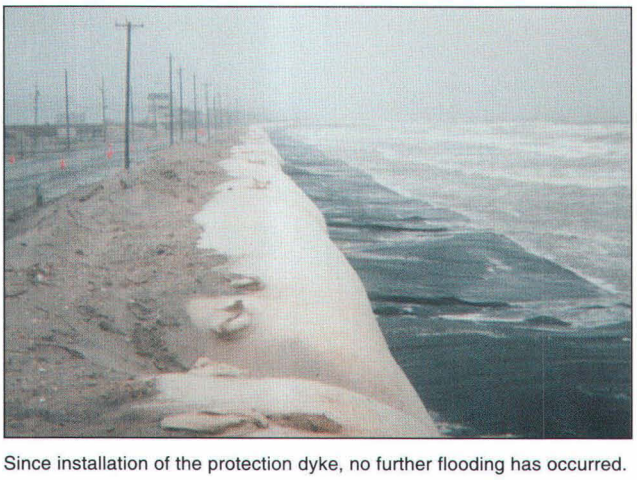
The geotubes, buried within the frontal sand dune, prevent breaching of the protection dyke during heavy storms. Furthermore, the geotubes prevent erosion of the dyke structure.



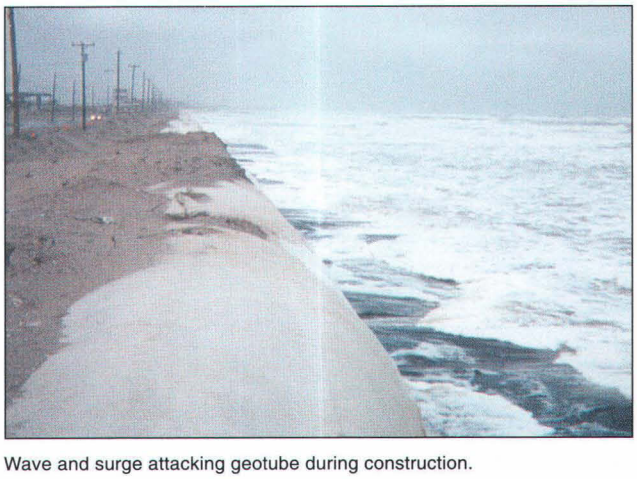
Installation of geotube.



Installation of geotube.



Since installation of the protection dyke, no further flooding has occurred.



Wave and surge attacking geotube during construction.

Shoreline Revetment

Tampa Bay, Florida, USA

Geotubes for **shoreline revetment** of an artificial island created from dredged spoil.

Geotubes were used for erosion protection and as a containment dyke for an artificial island created from dredged spoil in Tampa, Florida.

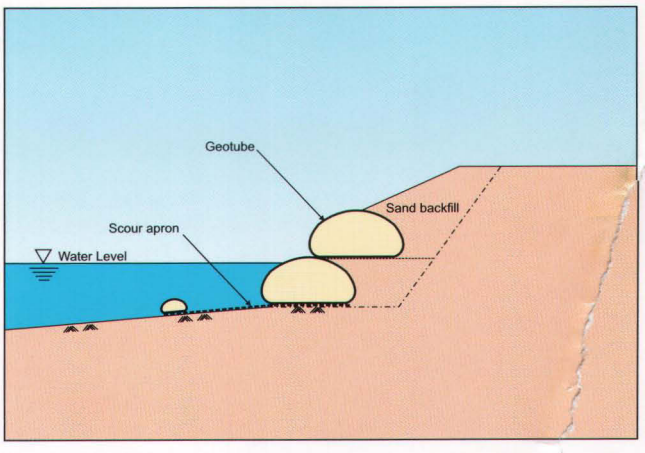
The containment dyke consisted of two tiers of geotubes with a scour protection apron at the bottom.

Geotubes were delivered to site rolled onto a steel core. This enabled easy handling and laying on site. The geotubes were filled with the local on site sand.

The area is subject to severe waves and the geotube structure has performed well.



Laying out of geotube at site.



Cross section of geotube dyke.



Installing geotube at site.



Frontal view of the protected island.

Shoreline Revetment

Shell Island, North Carolina, USA

Geotubes for **shoreline revetment** to reconstruct a badly eroded slope.

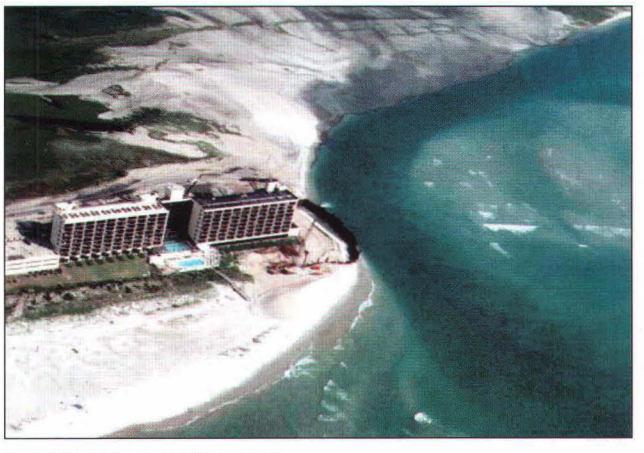
Geotubes were used for erosion protection to reconstruct a badly eroded shoreline slope on Shell Island, North Carolina.

The erosion was so bad that it was threatening an adjacent resort complex.

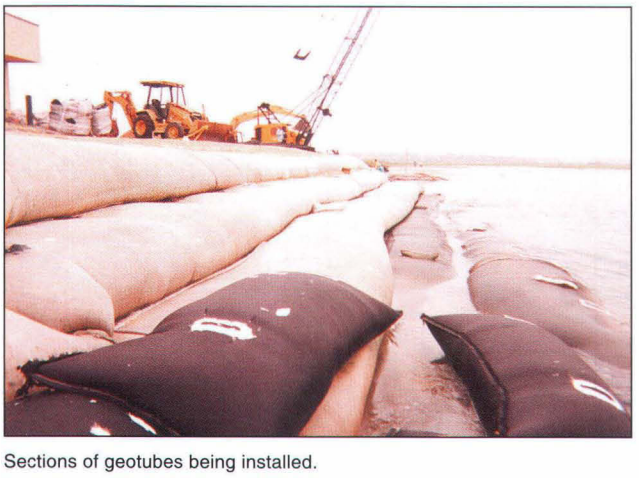
The slope reconstruction consisted of a seven tier geotube structure. The installed geotubes halted further erosion and maintained stability of the exposed structure.



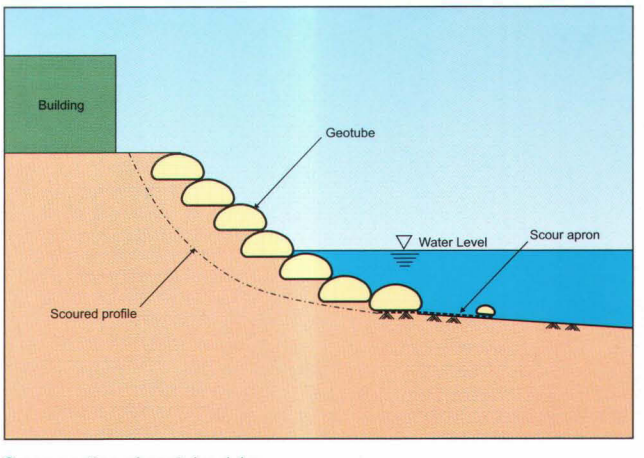
ng the sea.



Aerial view of area badly eroded.



Sections of geotubes being installed.



Cross section of geotube dyke.

Shoreline Revetment

Ocean Shores, Washington, USA

Geotubes for **shoreline revetment** to reconstruct a badly eroded shoreline slope.

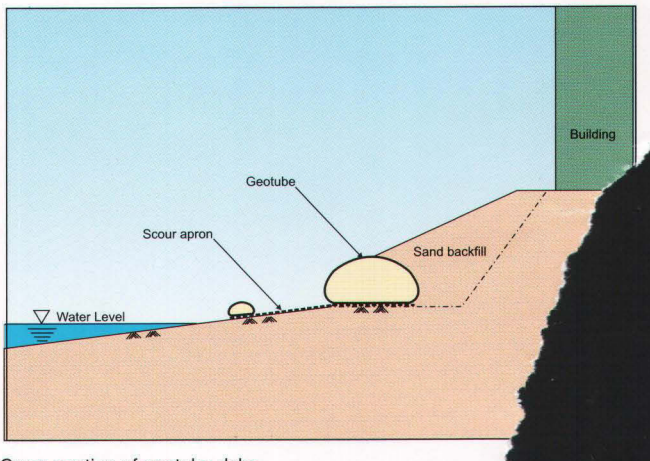
Geotubes were used for erosion protection and a retaining dyke to reconstruct a badly eroded shoreline slope in Washington, USA.

Homes built close to the ocean shores were in danger of collapse after the coastline was badly eroded.

Geotubes were installed to retain a backslope reconstructed using sand. In addition, the geotube dyke also serves to protect the shoreline against future storms.



Laying of geotube and scour apron.



Cross section of geotube dyke.



Pumping of sand slurry into geotube.



Completed geotube.

Shoreline Revetment

Pichangal, Ecuador

Geotubes for **shoreline revetment** to protect a rapidly eroding shoreline.

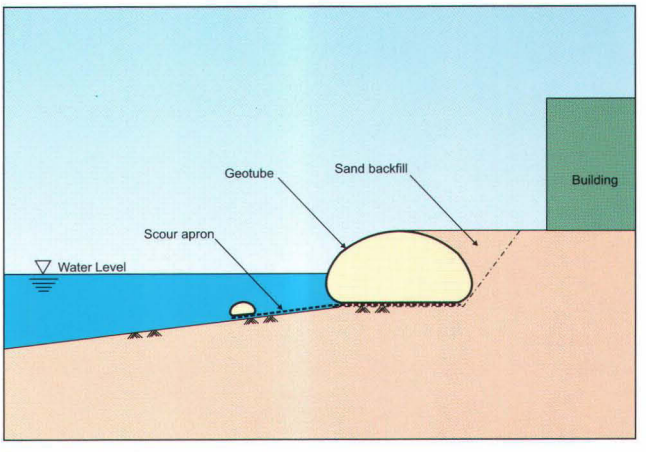
The geotube protection serves both as shoreline protection and a reclamation dyke to prevent future erosion of the reconstructed shoreline.

Site access was difficult with the existing shoreline vegetated and houses built close to the water.

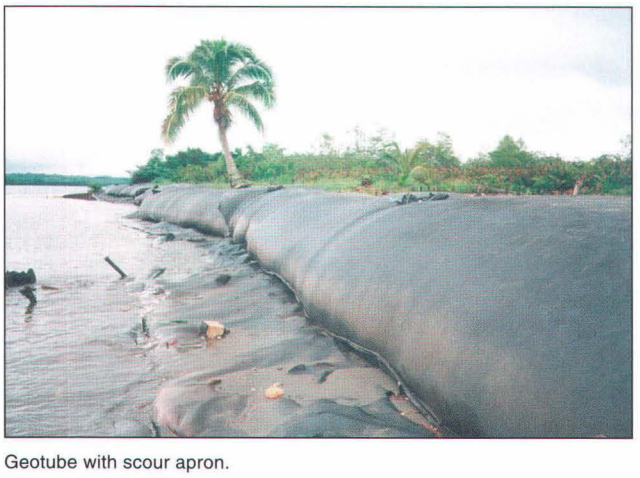
Material was dredged from the river bed and pumped into the geotube. Dredged material was also placed behind the protection revetment.



Backfill behind installed geotube.



Cross section of geotube revetment.



Geotube with scour apron.



Frontal view of protected area.

Submerged Revetment

Atlantic City, New Jersey, USA

Geotubes for construction of a **submerged revetment** within the frontal sand dune.

Geotubes were used to reinforce the frontal sand dune along the beach front coastline of the Atlantic City boardwalk in 1994.

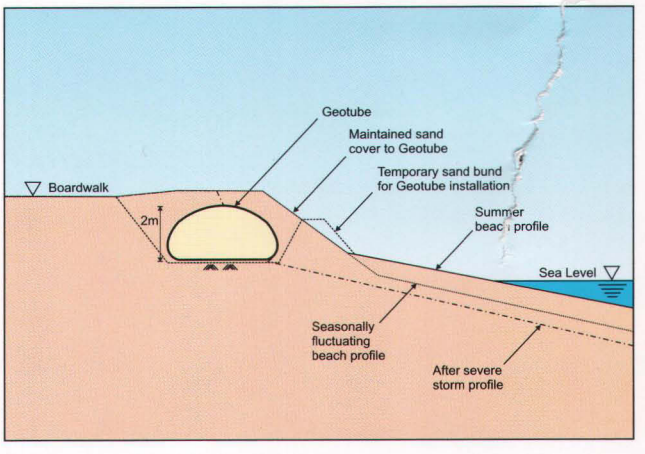
With each hurricane season, Atlantic City would brace itself against the strong winds and waves that would create havoc for the boardwalk, roads, services and prime properties along the coast. Damage costs ran in the millions of dollars each time a hurricane hit the area.

The geotubes , buried within the frontal sand dune prevented any damage to the rear of the beach. Following major storms the beach is renourished to return it to its original condition.

This project was so successful and cost effective that it has become a standard solution where long stretches of developed coastline needs protection.



Geotube as submerged revetment within sand dune.



Cross section of geotube revetment.



Exposed geotube after hurricane attack.



Geotube protected sand dune and beach, following beach renourishment.

Submerged Revetment

Bolivar Peninsular, Texas, USA

Geotubes for construction of a **submerged revetment** within the sand dune flood protection.

With each hurricane season, homes built along the coastline of the Bolivar Peninsular would be subject to damage by the sea. During bad seasons, homes would be lost through erosion and undermining of foundations.

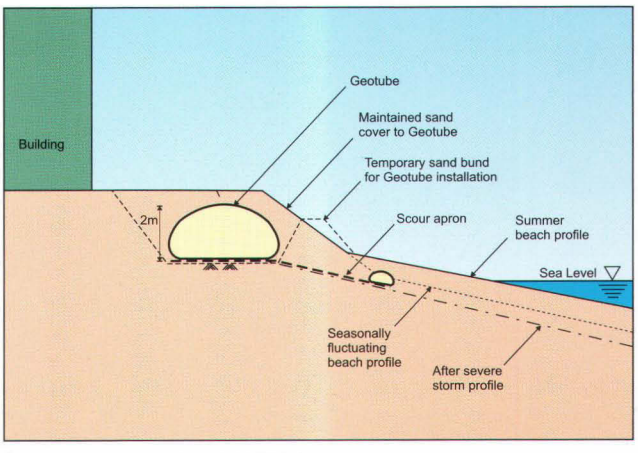
Geotubes were used to reinforce the frontal sand dune along approximately 6 km of the beach front coastline to prevent further damage and erosion.

Tropical storm Allison made a direct hit on the area in June, 2001 and the geotube revetments performed extremely well. This prevented millions of dollars in damage.

The project was so successful that an additional 5 km of geotube shoreline was constructed.



Installation of Geotube.



Cross section of geotube revetment.



Coastline under wave attack during a storm.



The aftermath of Tropical Storm Allison.

Groynes

Bald Head Island, North Carolina, USA

Geotubes for construction of **groynes** to protect the coastline from erosion.

Geotubes were used as groynes to protect an eroding coastline at Bald Head Island in North Carolina, USA.

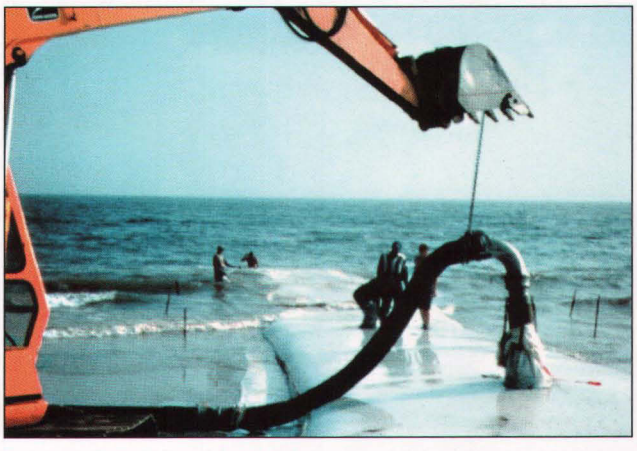
A total of 14 groynes, each 100 m long and spaced 150 m apart were installed on a rapidly eroding coastline adjacent to an established resort. Previous attempts at beach nourishment were not successful as the sand was again eroded in a matter of months.

The geotube groynes served to trap the lateral movement of sand and the beach subsequently widened.

This project won the American Shore and Beach Preservation Association (ASBPA) 1997 O'Brien Award.



Geotube in place for pumping.



Pumping of sand slurry into geotube.



Installed geotube groyne.



Aerial view of geotube groyne field for coastal protection.

Groynes

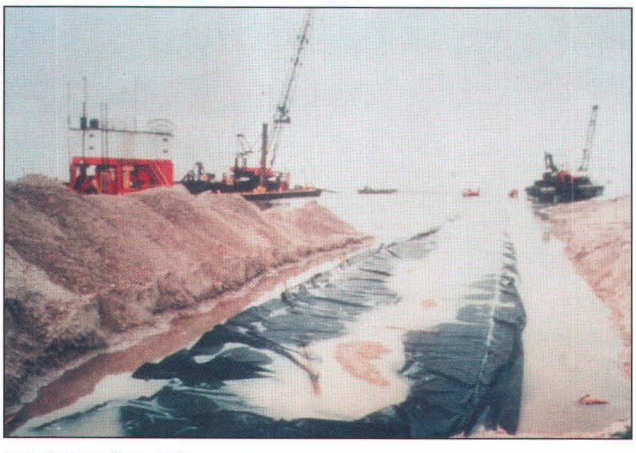
Sundown Island Bird Habitat, Matagorda Bay, Texas, USA

Geotubes for **groynes** to stop erosion of island and regain land area through accretion over time.

Geotubes were used to construct groynes to stop erosion of an island which is known as Bird Island as it is a sanctuary to many bird species. The island was diminishing in size through shoreline erosion due to high velocity tidal currents and wave action from marine traffic.

A total of 3 geotube groynes of lengths 80, 100 and 120 m, spaced approximately 100 m apart were installed. The geotube groynes were anchored onto the beach in shallow trenches of approximately 15 m lengths. The installation of the geotubes was completed in only 4 days.

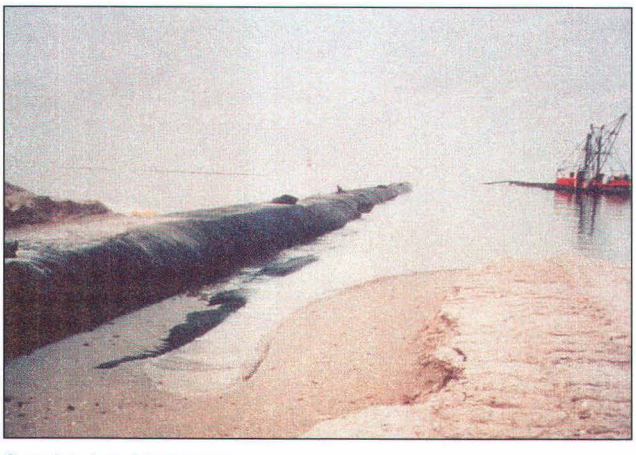
The project has been an unqualified success. The island started regaining land from the sea almost immediately and the birds simply love the geotubes.



Installation of geotube groyne.



Aerial view of Sundown Island with geotube groynes.



Completed geotube groyne.



Geotube six months after installtion.

Jetty

Amatique Bay, Guatamala

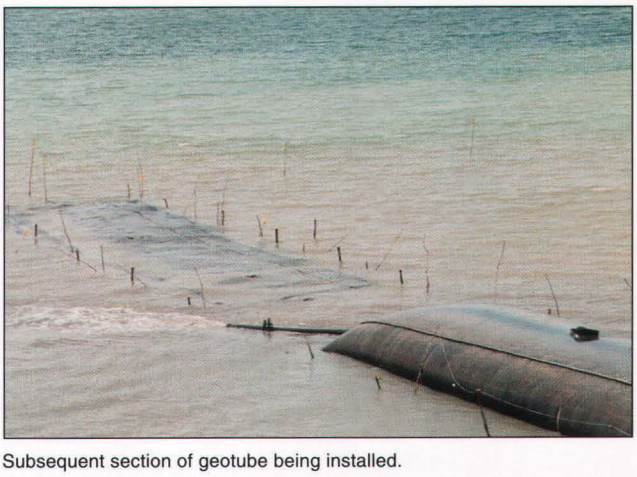
Geotubes for a 250 m long **jetty** for a marina inlet and to protect a new beach resort area.

The geotube used had a circumference of 15 m and filled hydraulically to a height of approximately 2.7 m. Filling was done using a 250 mm cutter head dredge.

The geotube option was very economical and construction time was short compared to conventional rubble mound structures.



First section of geotube being installed.



Subsequent section of geotube being installed.



2.7 m high geotube.



View of completed geotube jetty.

Intake Jetties

Pacific Coast, Mexico

Geotubes for **jetties** and bunds to construct the water intake channel to the pump station of a shrimp farm in Mexico.

Geotubes were used for jetties to protect the water intake channel to the pump station of a shrimp farm located on the Pacific coast of Mexico.

The jetties were constructed to heights of 4 m, using a 1-2-3 stacked geotube structure. Sand from the beach was used to fill the geotubes using sand slurry pumps.

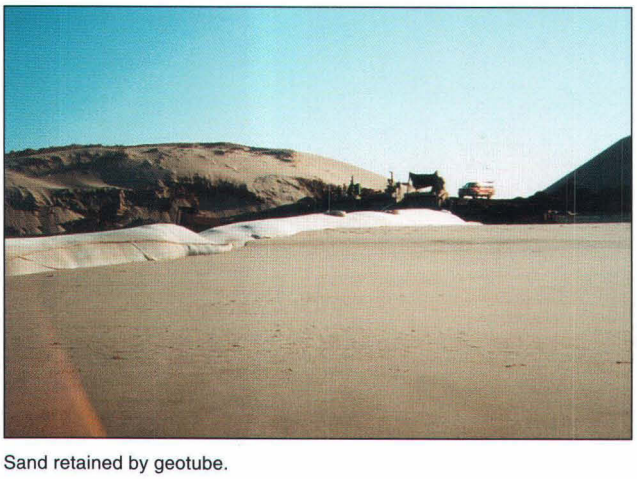
The portion of geotube jetty on shore also serves to prevent sand from being washed into the intake channel.



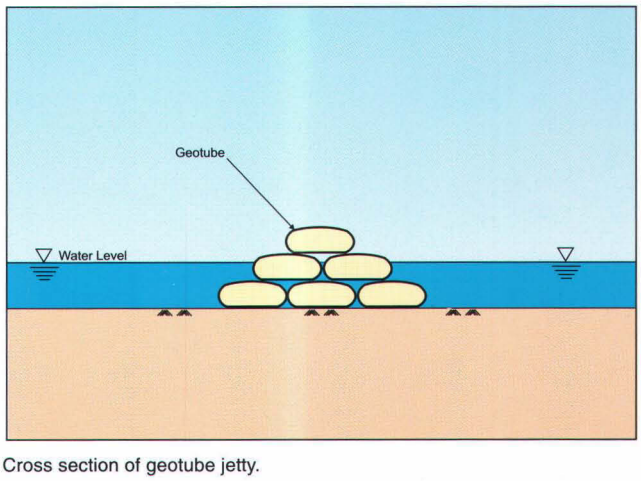
Geotube as jetty.



View of shrimp farm.



Sand retained by geotube.



Cross section of geotube jetty.

Breakwater

Lake Marken, The Netherlands

Geotubes for construction of a **breakwater** to shelter a man-made wetland bird habitat.

Geotubes were installed as the core of a breakwater constructed on Lake Marken to shelter a man-made wetland habitat for birds and other wildlife.

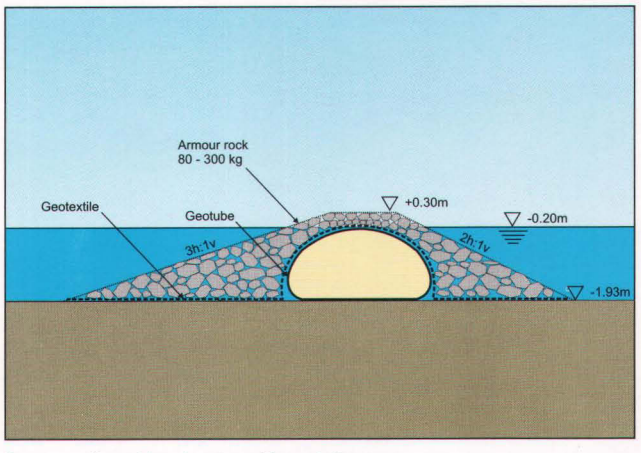
Two breakwaters with the shape of hockey sticks were constructed. The gap between the two breakwaters serves to allow free tidal flow into the sanctuary to constantly nourish it with nutrients from Lake Marken.

The geotubes were installed underwater. Guide posts were used to keep the alignment of the geotube during filling.

Local vegetation grew quickly and the site quickly became a habitat for birds and other wild life.



Installation of geotube.



Cross section of breakwater with geotube core.



Installation of geotube.



Completed breakwater with habitat.

Offshore Breakwater

Bahia Principe, Tulum, Mexico

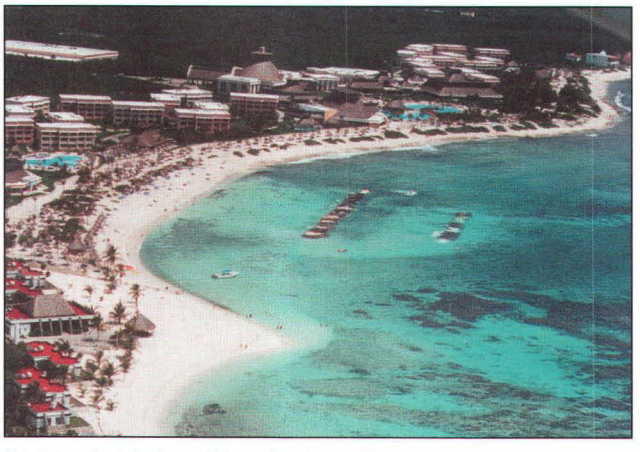
Geotubes for construction of offshore **breakwaters** to protect and enhance a sandy beach.

Geotubes were used to construct two offshore breakwaters to protect the beach front of a resort in Tulum, Mexico.

The Geotubes were installed about 100 m offshore in water depths greater than 2 m. The geotubes were filled hydraulically using a sand slurry pump that extracted sand directly from the seabed.

Marine growth was evident even during the construction period giving the geotube breakwater the appearance of a natural reef that shelters swimmers and other recreational pursuits close to the beach.

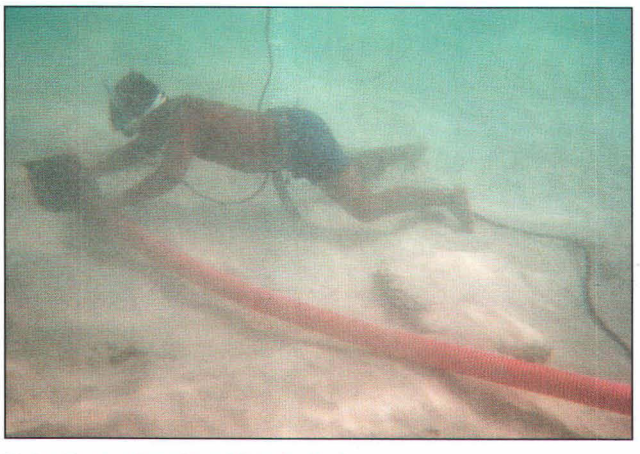
Sand accretion on the beach was evident following installation of the geotubes.



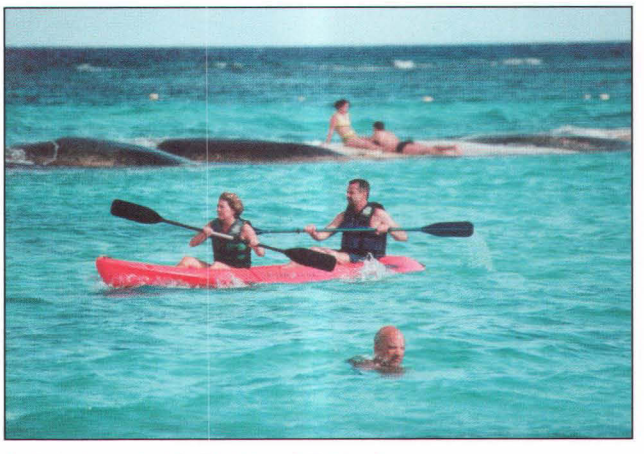
Geotubes installed as offshore breakwaters.



Marine growth on surface of geotube.



Hydraulic pumping of sand from seabed.



Geotube serves as sheltered recreation area.

Offshore Breakwater

El Dorado Royale, Mexico

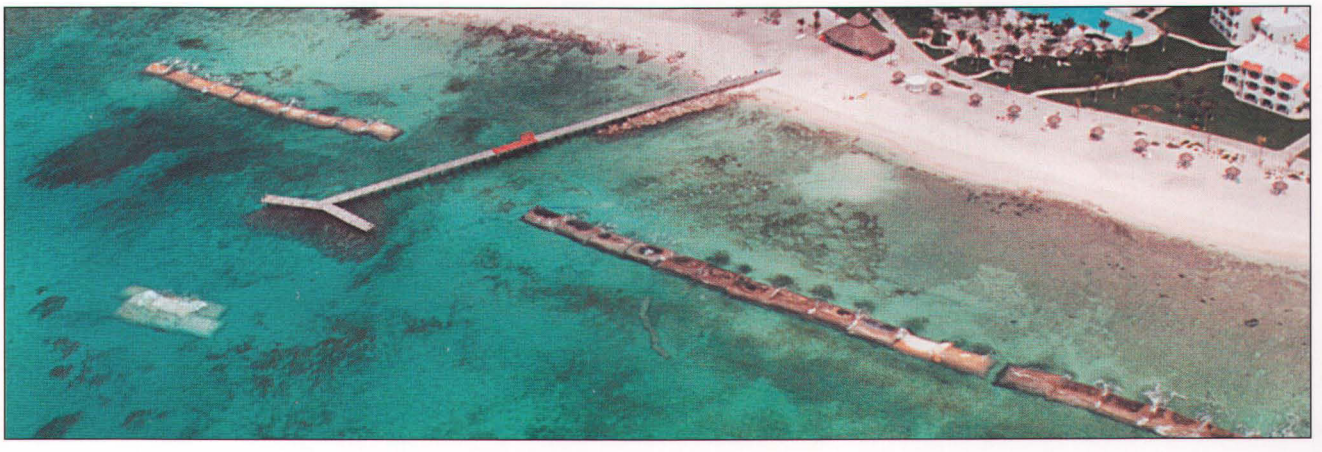
Geotubes for construction of an **offshore breakwater** to retain a perched beach.

Geotubes were used to construct offshore breakwaters to widen the beach front and protect the jetty of the El Dorado Royale resort in Mexico.

The geotubes were installed offshore in waters about 2 m in depth to protect the beach. An additional geotube breakwater was constructed in a water depth of 4 m to protect the foundation of the jetty.

Marine growth was evident even during the construction period helping the geotube breakwater to appear as a natural reef sheltering swimmers and other users along the beach.

Sand accretion was evident following installation of the geotubes and a new perched beach is the result.



View of beach and jetty protection using submerged geotube breakwaters.



Underwater stacked geotubes.



Outer breakwater to protect jetty.

Offshore Breakwater

Young Jin Beach, Gang Neung City, Korea

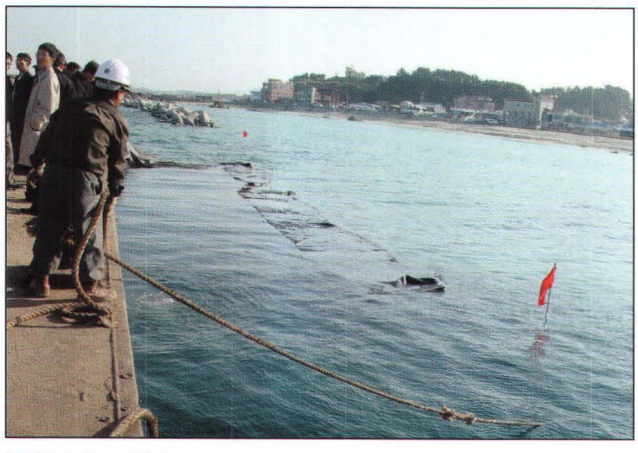
Geotubes for construction of submerged **offshore breakwater** to protect and enhance sandy beach.

Geotubes were used to construct four submerged breakwaters to protect the rapidly eroding recreational Young Jin beach in Gang Neung City along the eastern coastline of Korea.

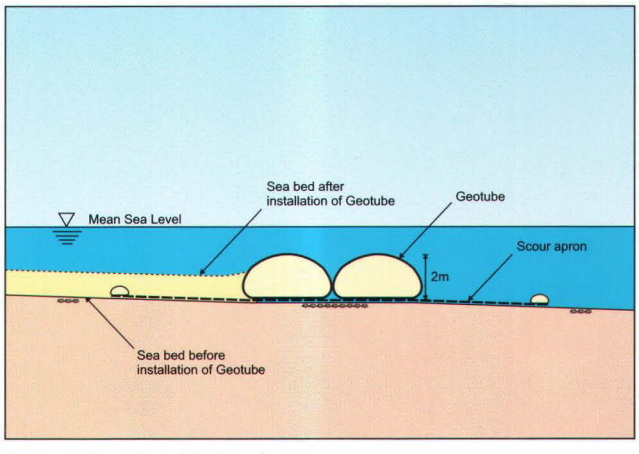
The geotubes were installed in pairs; each pair was separated by 20 m from the next to form a series of four submerged breakwaters. Each breakwater section was 50 m in length. The geotubes were located about 100 m offshore, in 3 m of water.

Scour aprons of 20 m by 60 m were placed on the seabed prior to installation of the geotubes. Construction was rapid. Geotubes were installed at the rate of one per day.

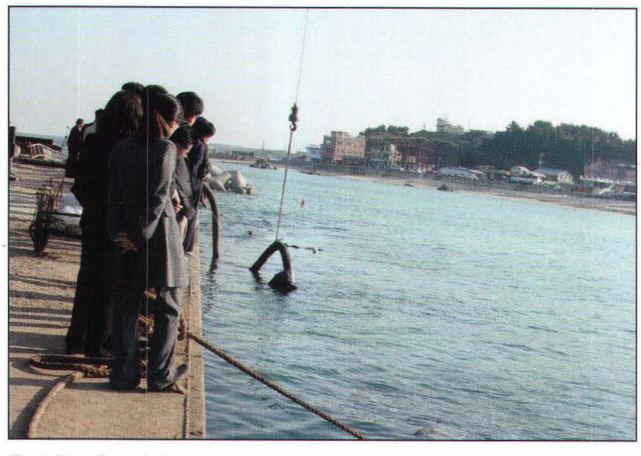
Within one month of completion, the coastline was observed to have extended seawards. Sand accumulation of about 1 m thickness was recorded behind the installed geotube breakwater.



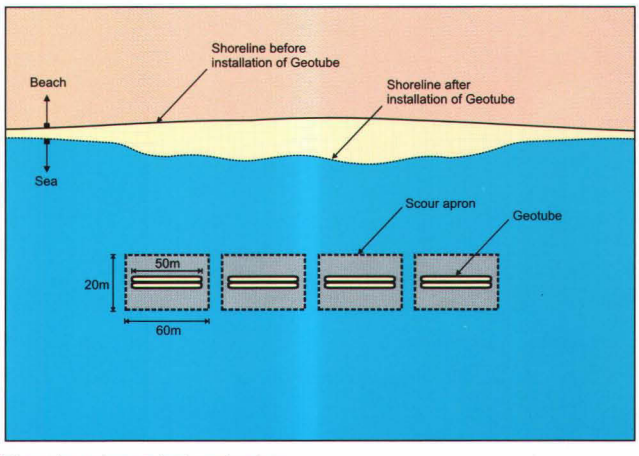
Laying out geotube.



Cross section of geotube breakwater.



Pumping of geotube.



Plan view of geotube breakwaters.

Cavity Sealing

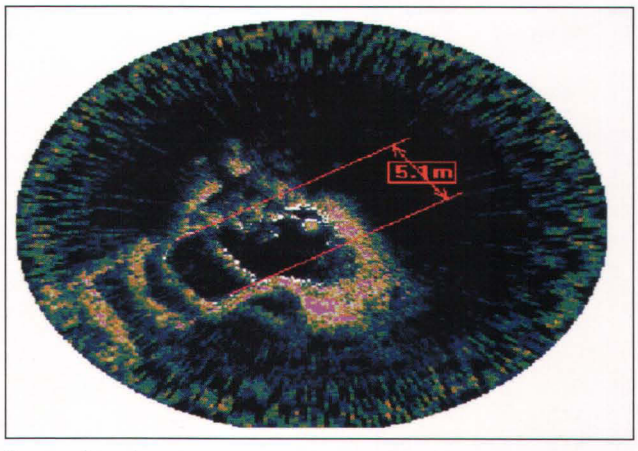
Chivor Dam, Columbia

Geotubes as **closure units** to seal the opening of a bypass construction tunnel inadvertently left open.

During maintenance and inspection of the generator turbine blades of the Chivor Dam it was found that undue wear and damage had occurred. The source of the problem was traced to the impact and abrasion of reservoir bottom sediments entering the bypass construction tunnel that was inadvertently left open since the construction and filling of the reservoir.

The opening, which had to be closed, was located 100 m below water surface. Closure was carried out using geotubes filled with concrete and lowered using four winches to the reservoir bottom. The concrete was pumped through pipes on floating rafts to the barge where the geotubes were filled.

Since completion of the sealing using geotubes sealing solids passing the turbine blades have reduced significantly and the solution has been deemed highly successful.



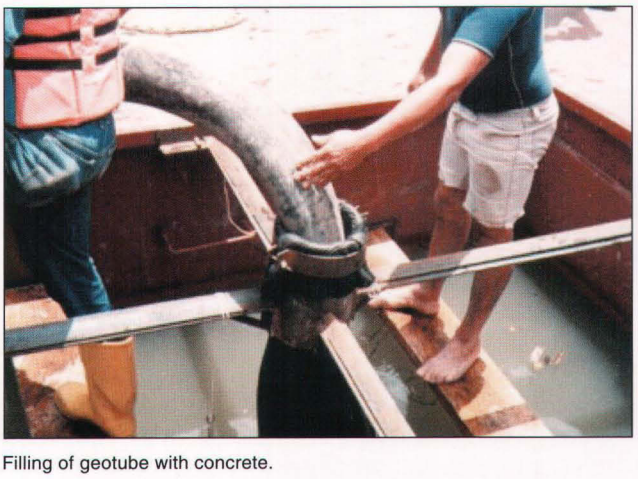
Survey of opening.



Aerial view of Chivor dam, Columbia.



Pumping of concrete to geotube.



Filling of geotube with concrete.

Containment Dyke

Cornelis Douwe Canal, Amsterdam, The Netherlands

Geocontainers and **Geotubes** for **containment dykes** to build up a dam in a canal.

Geocontainers were used to construct containment dykes to build up a dam in the Cornelis Douwe Canal in Amsterdam.

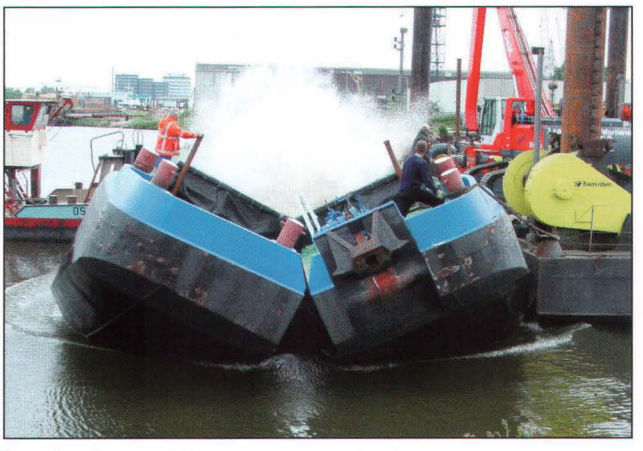
On the outside of the dam two geocontainers were placed next to each other while on the inside face one geocontainer was placed per layer of construction lift. The outside face and inside face of the dam were constructed to 1:3 and 1:1 slopes respectively.

Geotubes were used to finish off the top of the dam. The installation of the geotubes was carried out in shallow waters.

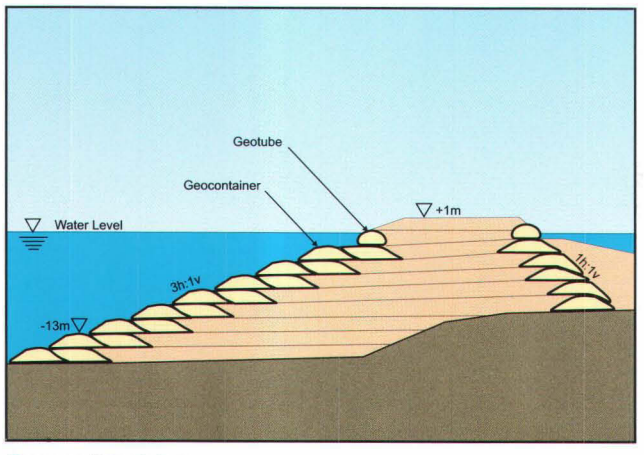
The solution saved the city of Amsterdam a total amount of 100,000 m^3 of sand when compared to conventional techniques of construction. A total of 73 geocontainers and about 250 linear metres of geotubes were used.



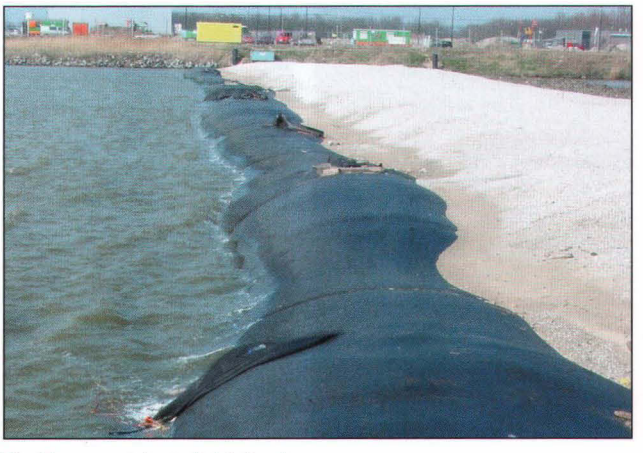
Filling of geocontainer with sand.



Dropping of geocontainer.



Cross section of dam.



Final layer geotube to finish the dam.

Submerged Containment Dyke

Southern Islands, Singapore

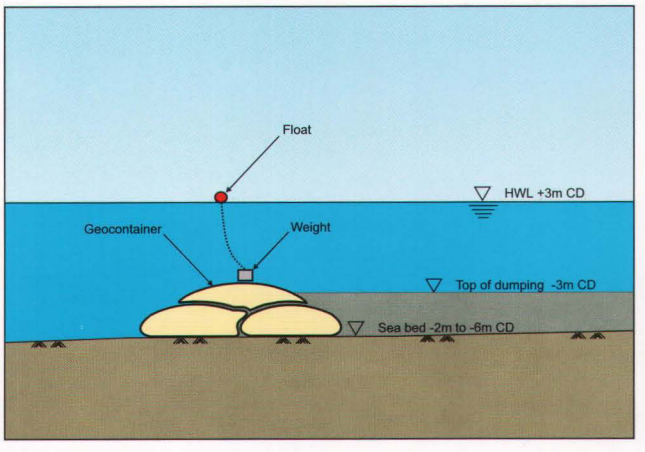
Geocontainers to form a **submerged containment dyke** for the construction of a 45 hectare disposal area for excavated spoil.

Geocontainers were used to construct a submerged perimeter containment dyke to create a 45 hectare disposal site with a capacity to hold 420,000 m^3 of excavated spoil for the reclamation and infrastructure works at Southern Islands in Singapore. Various types of dyke construction were considered. One option involved imported sand using gentle slopes of 1:10. Rocks were not considered due to the risk posed to passing ships.

The alternative using geocontainers to form the containment dyke allowed excavated spoil to be used as the structural fill of the dyke. It also removed the risk of dyke breaching, which was inherent in the other solutions. Construction time for creation of the dyke was also shorter using the geocontainer solution as well as being more economical than conventional sand dykes.



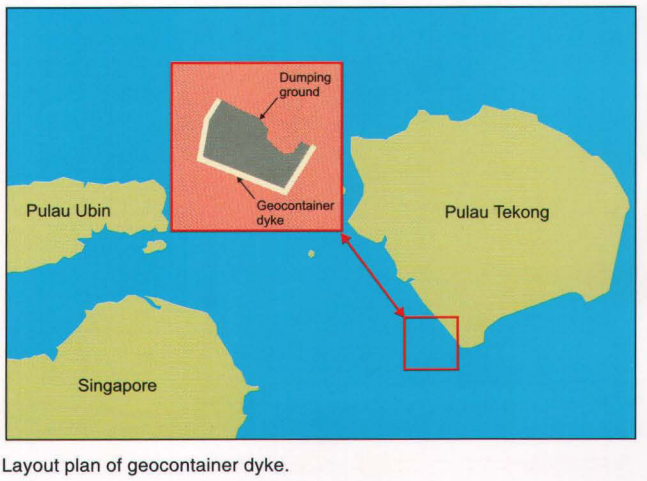
Filling of geocontainer in split bottom barge.



Cross section of submerged dyke.



Dropping of filled geocontainer.



Layout plan of geocontainer dyke.

Containment Dyke

Lukang Port Reclamation, Lukang, Taiwan

Geocontainers to form a submerged **containment dyke** for reclamation works to enlarge an existing man-made island.

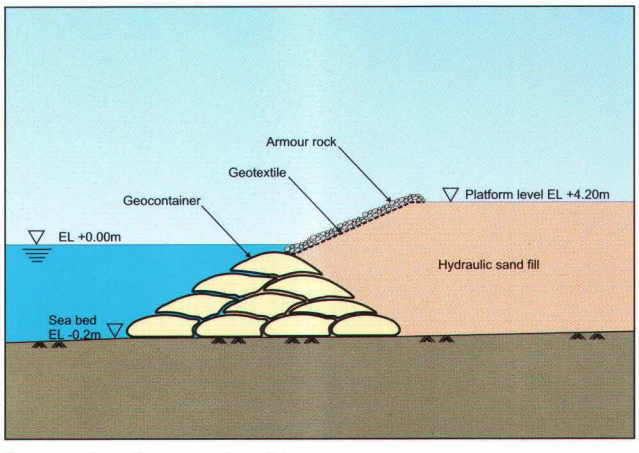
Geocontainers were used to construct a containment dyke to enlarge an existing man-made island at the Port of Lukang, on the West coast of Taiwan.

The reclamation was carried out over very soft foundation soils. The conventional solution of dumping rocks to construct the dyke would have resulted in excessive loss of rock through punching into the soft foundation. The geocontainer solution was considered more economical as nearby sea sand could be used as the geocontainer fill material.

A total of 490 geocontainers, each holding about 110 m^3 of sand were installed to construct the containment dyke for the reclamation.



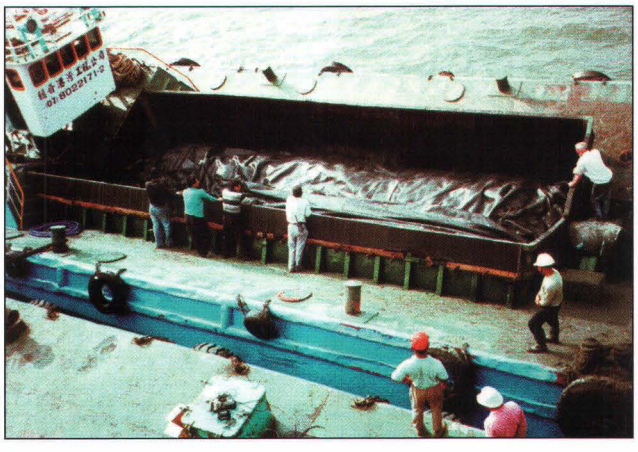
Placing of geocontainer into barge.



Cross section of geocontainer dyke.



Closure of geocontainer.



Dropping of filled geocontainer.

Submerged Containment Dyke

River Elbe, Twielenfleth, Germany

Geocontainers to form a **submerged containment dyke** for construction of a disposal area for excavated spoil.

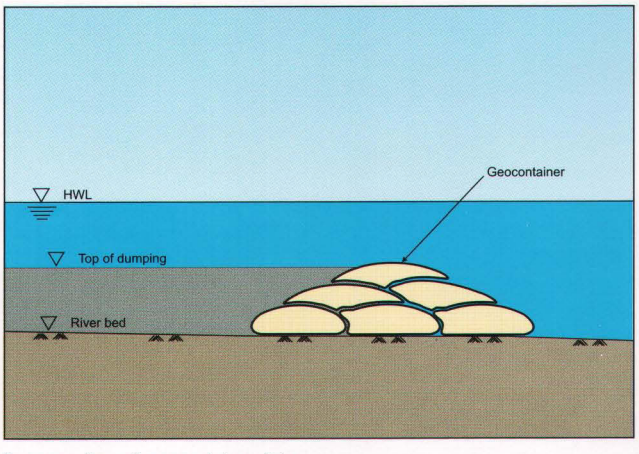
Geocontainers were used to construct a submerged containment dyke between two existing breakwaters to create a disposal area for excavated spoil.

The river sediments of the River Elbe consist of sand and silt, and this material was used to fill the geocontainers. Over 600 geocontainers of 300 m^3 each were installed over a period of 6 months.

The project was extremely cost effective and successful, demonstrating the beneficial use of dredged spoil to construct stable hydraulic structures.



Placing of fill into geocontainer.



Cross section of geocontainer dyke.



Closure of geocontainer.



Dropping of filled geocontainer.

Submerged Training Dykes

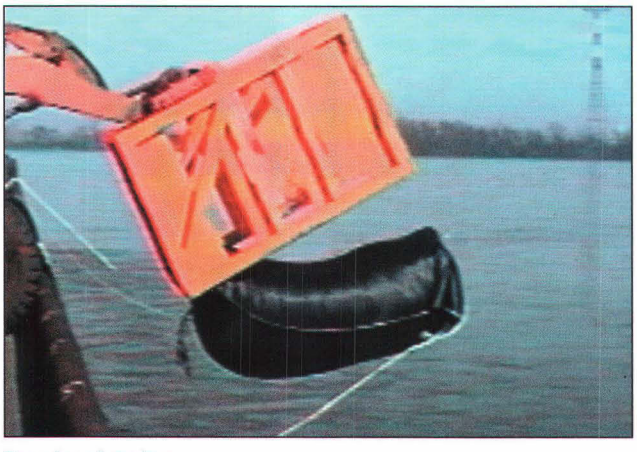
Red Eye Crossing, Mississippi River, USA

Geocontainers and **Geobags** to form **submerged training dykes** to constrict and deepen the navigational channel in a river.

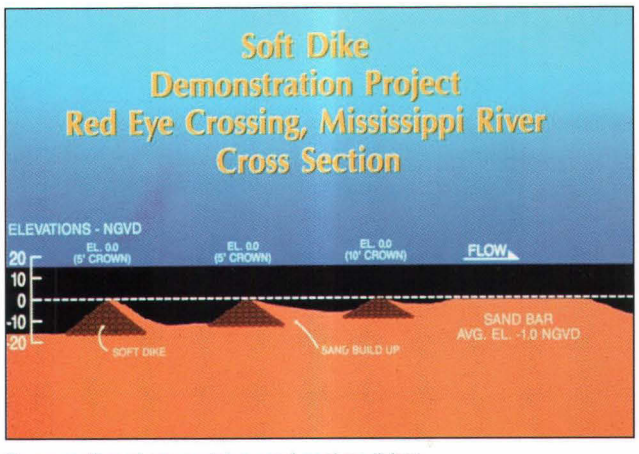
The Mississippi River widens out at Red Eye Crossing near Baton Rouge and becomes shallow as river sediments are deposited on the river bed. To maintain sufficient water depth at Red Eye Crossing a dredger had to be engaged permanently to keep the channel open to navigation.

Rubble mound submerged river training dykes would normally be used to constrict the channel, thereby increasing water velocities and flushing sediments downstream continuously. However, rubble mound dykes were not allowed as they pose a high risk to ships carrying chemicals and petroleum products to the refineries located nearby.

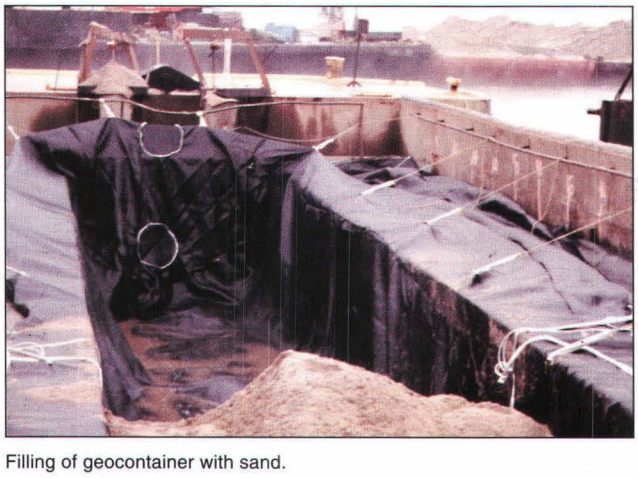
Geocontainers and geobags were used successfully to construct the underwater river training dykes. These materials provided a "soft" solution and could not damage passing ship traffic.



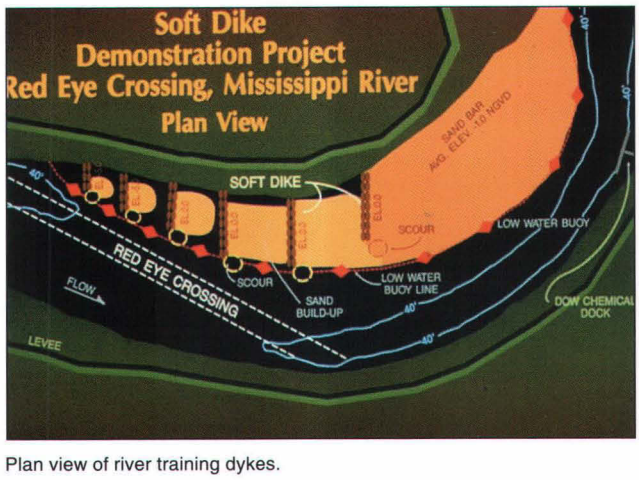
Dropping of geobag.



Cross section of geocontainer and geobag dykes.



Filling of geocontainer with sand.



Plan view of river training dykes.

Buttress Support

Zoutkamp, The Netherlands

Geocontainers to form a submerged **buttress support** for reconstructuring a scoured slope underwater.

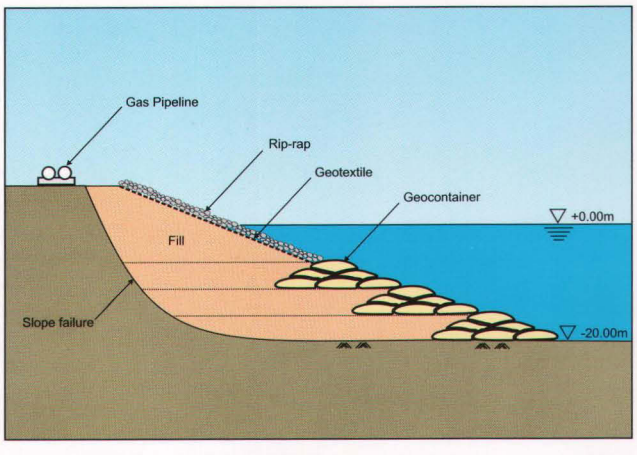
Geocontainers were used to construct submerged containment dykes to reconstruct a failed underwater slope that was threatening to undermine an adjacent gas pipeline.

The reconstruction of the slope involved several tiers of geocontainer dykes and backfilling combinations. The containment dykes were constructed using geocontainers, with sand used as the fill material. The lowest tier of geocontainers was founded about 20 m below water surface level.

The project was extremely cost effective and successful. The slope has been stabilized with the innovative use of geocontainers.



Placing of sand fill into geocontainer.



Cross section of geocontainer dyke.



Opening of split bottom barge.



Dropping of filled geocontainer.

Buttress Support

River Old Meusse, The Netherlands

Geocontainers to form a submerged **buttress** to stabilise a scoured dyke toe.

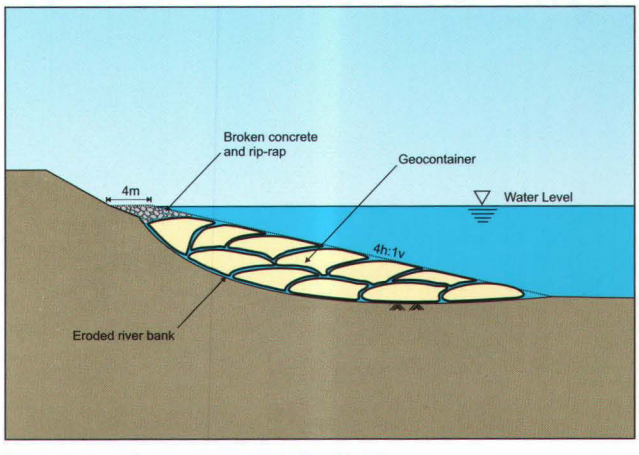
Geocontainers were installed as a submerged buttress to stabilize the badly scoured dyke toe along the River Old Meusse in The Netherlands.

The underwater scour was so severe that it was threatening to undermine the dyke designed to keep the surrounding land from being inundated by the river.

The geocontainers were designed specifically to fit the split bottom barges used for installation. Sand was used to fill the geocontainers.



Filling of geocontainer.



Cross section of geocontainer stabilised bank.



Geocontainer ready for drop.



Dropping of geocontainer.

Breakwater

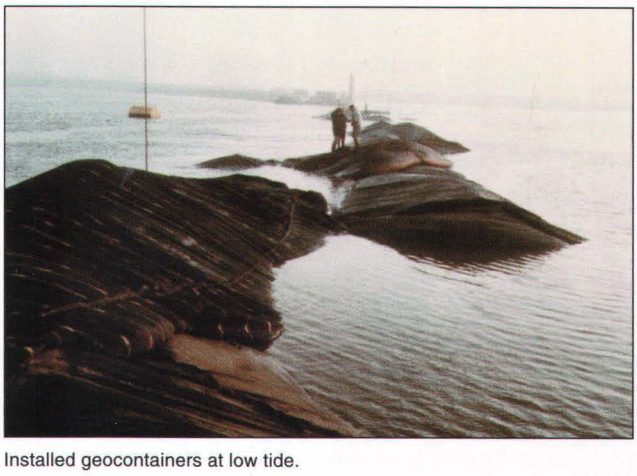
River Ems, Germany

Geocontainers as the core material in the construction of a **breakwater**.

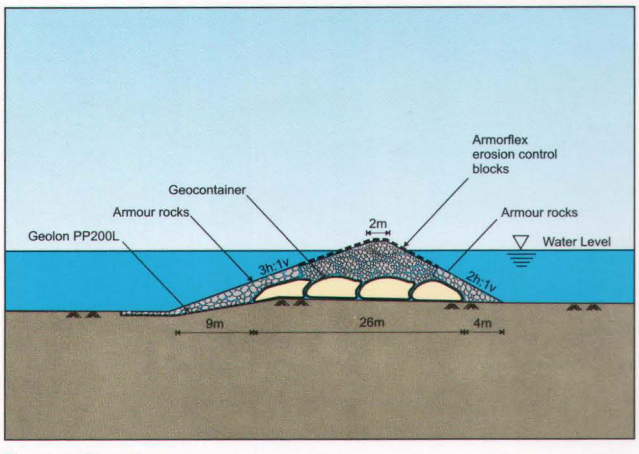
Geocontainers were used as the core material to construct a breakwater on the River Ems in Germany.

The area concerned is generally low lying tidal flats. Quarried rock is not available locally and has to be brought in from far away sources. Consequently, any form of construction that can effectively replace rock as a construction component will be economically attractive.

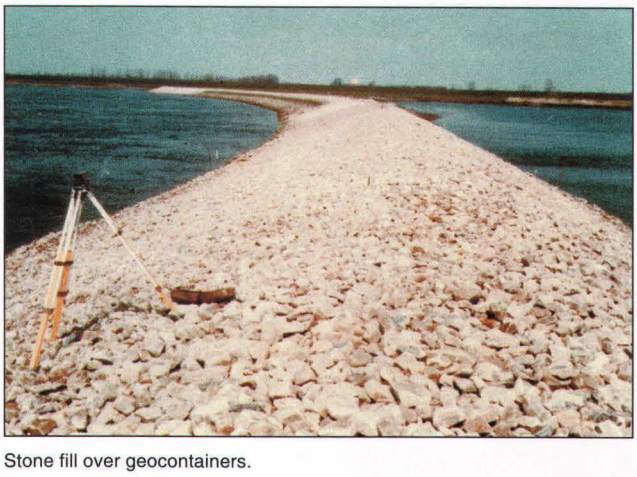
This project was one of the first applications of geocontainers and its success has led to many more innovative geocontainer applications in marine and hydraulic engineering.



Installed geocontainers at low tide.



Cross section diagram.



Stone fill over geocontainers.



Completed breakwater.

Shoreline Revetment

Artificial Island, Middle East

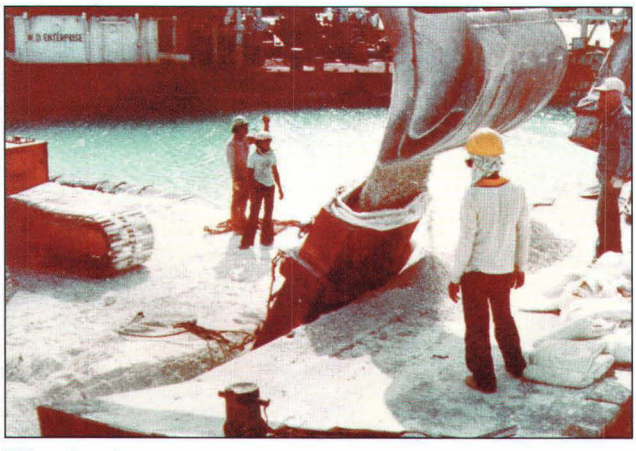
Geobags as a **revetment** to protect an artificial island from erosion.

Geobags were used as armour units for the revetment protection of an artificial island.

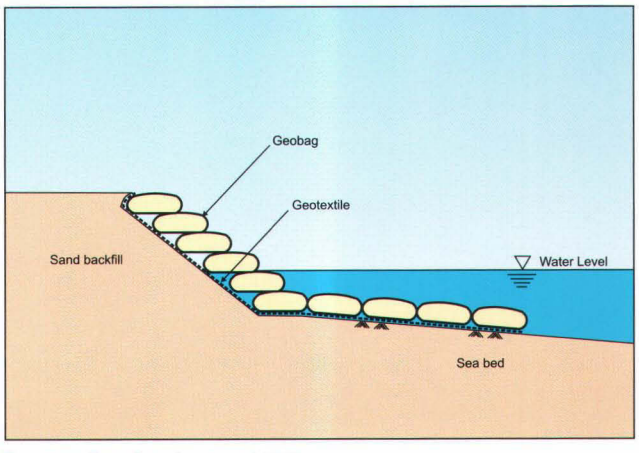
Oil is found in the most remote locations. Many of the oil production sites occur in the sea. One such installation was constructed in the Middle East. Sand is abundant but rock would have to be hauled from very far away and would be costly.

An artificial island was created from sand dredged to create a navigational channel leading to the facilities. The shoreline of the island was protected using large geobags filled with sand.

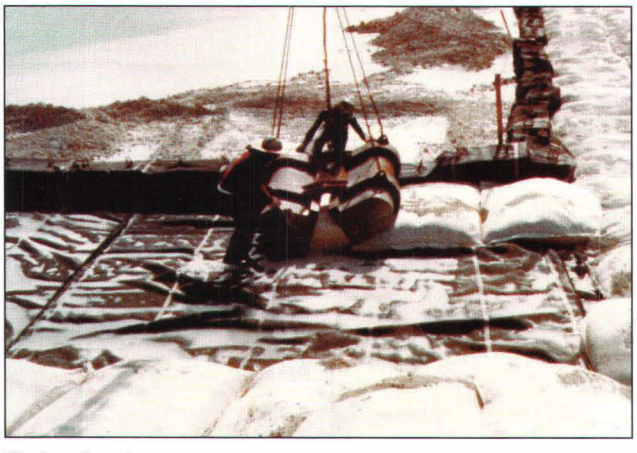
The use of geobags in remote construction areas is a very cost effective erosion protection solution.



Filling of geobag.



Cross section of geobag revetment.



Placing of geobags.



Aerial veiw of artificial island under construction.

Shoreline Revetment

Artificial Island, Prudoe Bay, Alaska, USA

Geobags as a **revetment** to protect an artificial island from erosion.

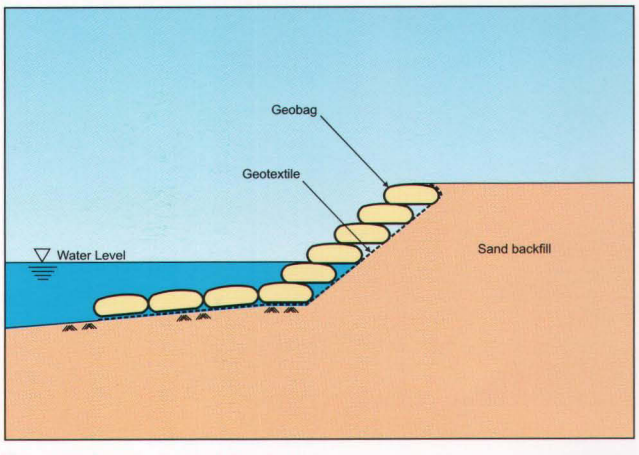
Geobags were used as armour units for the revetment protection of an artificial island in Prudoe Bay, Alaska.

An artificial island was created to house an industrial facility. The shoreline of the island was protected using large geobags filled with sand.

This application demonstrated that the use of geobags in remote construction is a very cost effective erosion protection solution. It is also an ideal solution in environmentally sensitive areas.



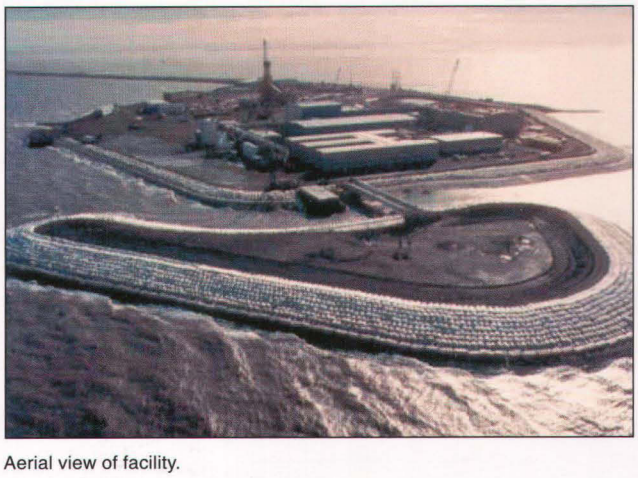
Construction of geobag revetment.



Cross section of geobag revetment.



Geobag revetment.



Aerial view of facility.

Buttress Support

Guadalupe Shoreline, California, USA

Geobags for **buttress protection** for an eroding shoreline slope along the Pacific Coast.

Geobags were used for buttress protection to stabilise an eroding shoreline slope along the Pacific Coast.

The geobags were placed on a dump-truck bed and then taken to a local ready mixed concrete plant, where they were dry filled with sand. The filling ports of the geobags were then closed using hog rings. At site, the geobags were lifted and placed using a lifting harness and spreader beam arrangement.

Under California law, the geobags cannot be permitted to be placed at the toe of a slope. Consequently, to prevent further erosion of the coastline, the geobags were placed on the top of the slope, so when the next storm occurred, the sand under the geobags was scoured away, and the geobags literally moved en-mass downslope by themselves.



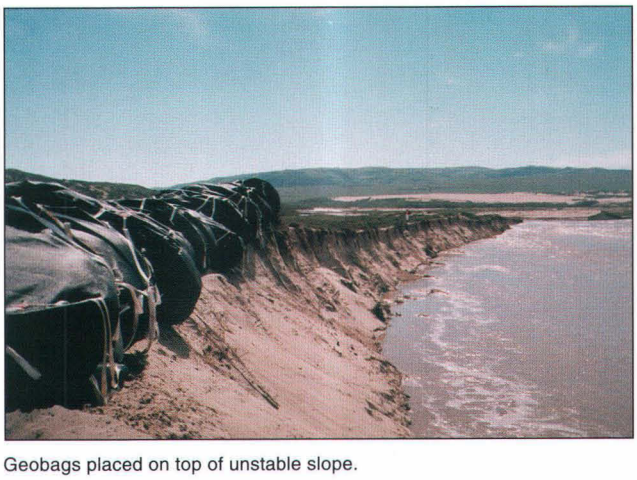
Filling of geobag with sand.



Placement of geobags.



Lifting of geobag.



Geobags placed on top of unstable slope.

Artificial Reef

Pratts Reef, El Segundo, California, USA

Geobags to construct an **artificial reef** to create surfing conditions for recreational purposes.

Geobags were used to construct an artificial surfing reef at El Segundo in California.

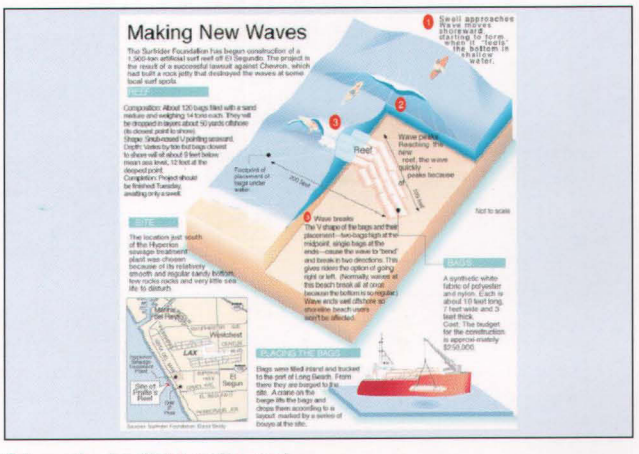
The geometry of the reef was designed to intensify wave heights to allow recreational surfing activities on the coast.

Geobags were chosen because they were easy to install and, unlike rock fill, would not injure surfers. Also, submerged geobags do not pose any danger to other recreational activities.

The project was so successful that it literally as well as metaphorically made new waves.



Lifting of geobag.



Schematic of artificial surfing reef.



Installation of geobag.



Aerial view of project site.

In Europe contact:

Ten Cate Nicolon Europe
Sluiskade NZ 14
Postbus 236
7600 AE Almelo
The Netherlands

Telephone: +31-546-544811
Fax: +31-546-544490

In North America contact:

Ten Cate Nicolon USA
365 South Holland Drive
Pendergrass
Georgia 30567
USA

Telephone: +1-706-693 2226
Fax: +1-706-693 4400

In Asia contact:

Ten Cate Nicolon Asia Sdn Bhd
11th Floor, Menara Glomac
Kelana Business Centre
97, Jalan SS 7/2
47301 Petaling Jaya
Selangor Darul Ehsan
Malaysia

Telephone: +60-3-7492 8283
Fax: +60-3-7492 8285

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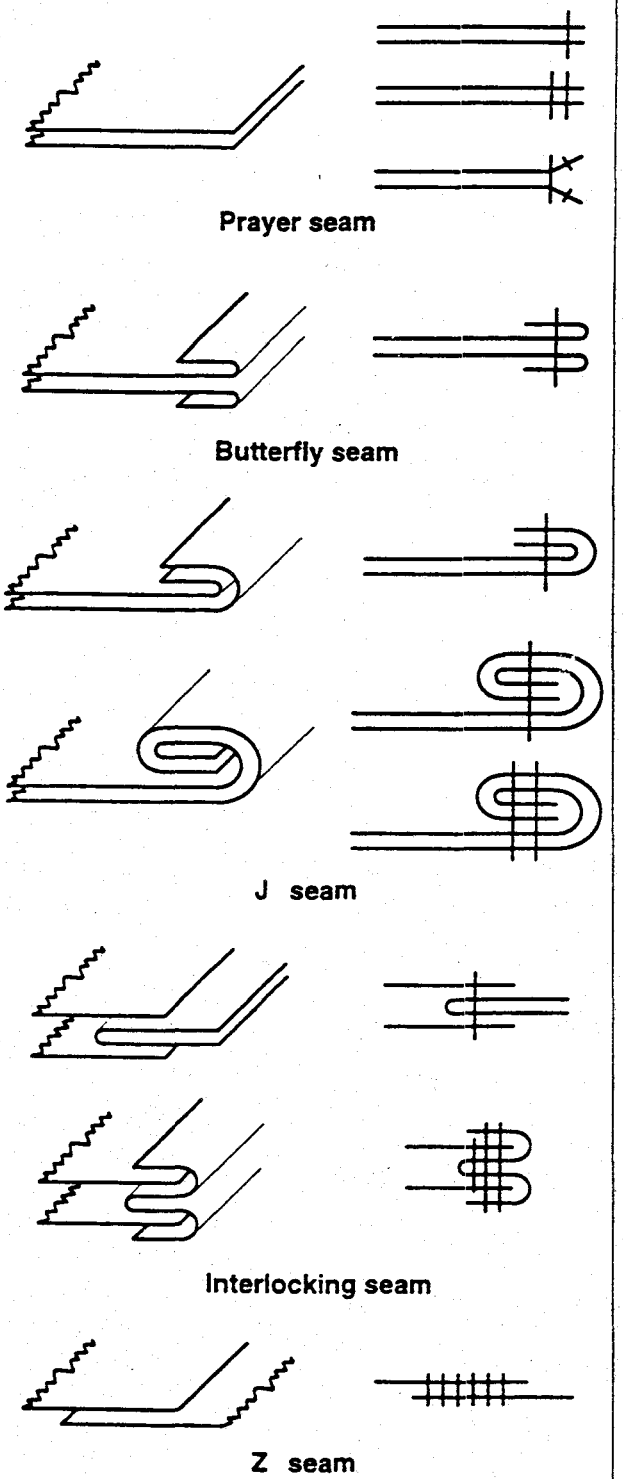


Figure 5. Types of seams

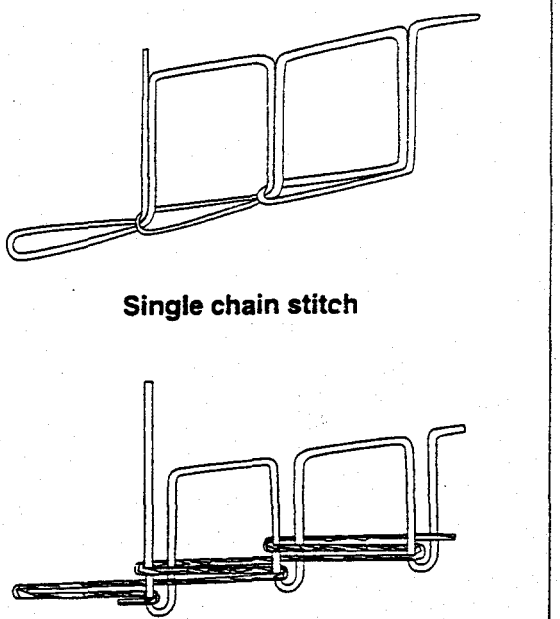


Figure 6. Stitch configuration

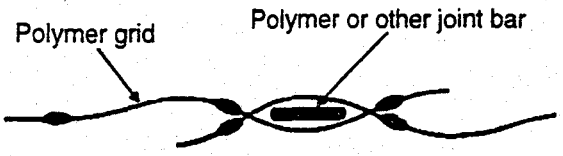


Figure 7. Bodkin joint

ISO 9001
KEMA
CERT. NR. 56002
DUTCH COUNCIL FOR ACCREDITATION

Samplenumber 1983
TCN Order-rol nr. 0

Geotextiles–Tensile test for joints/seams by wide-width method **NEN-EN-ISO 10321:1996**

Laboratory Ten Cate Nicolon Special Fabrics Seamstrength

Sample name: GEOLON PP 120S naainaad 13st/dm

General information

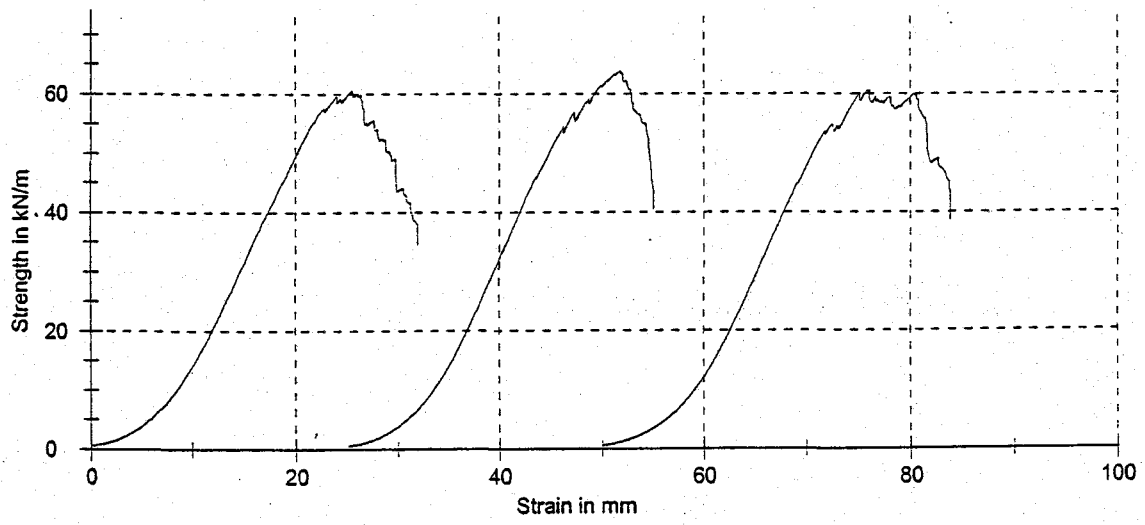
TCN code	: R112091506	Tensile testing machine	: Zwick Z250/SN5A
Test direction	: XD Cross direction	Jaw type	: Demgen M200
Specimen condition	: Dry	Jaw face	: Flat + vulcolan 310x135mm
Joint/Seam contruction	:	Extensometer	: Crosshead travelmonitor
Operator	: OH	Atmosphere	: ISO 554 20±2°C humidity not conditioned
Date	: 02-nov-2001		

Remarks : -

Statistics

n = 3	Fmax kN/m	εFmax %	Strain rate %L0/min
$\bar{x}$	61.59	24.1	33.08
v	3.03	2.96	0.02
s	1.869	0.7129	0.006499
n	3	3	3

Series graphics



Results

Nr	Fmax kN/m	εFmax %	Strain rate %L0/min	st/10cm	Failure
1	60.46	23.36	33.08	13	The material
2	63.75	24.79	33.09	13	The material
3	60.57	24.14	33.08	13	The material

Released by .....

These test results are valid for this specific sample..
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Special Fabrics

Ten Cate Nicolon

Laboratory Tensile Test

08.06.2001

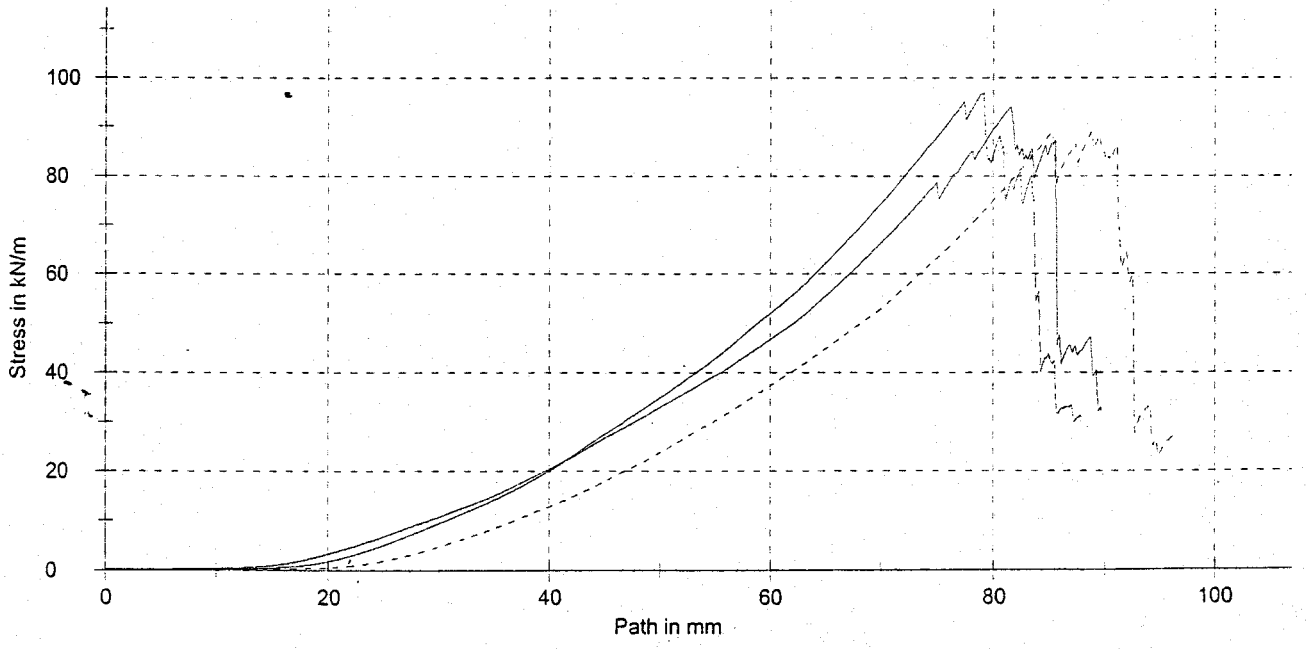
TEST INFORMATION Geolon PP200S - Seamstrength

Samplenumber	: 1511	Machine	: Zwick Z250/SN5A
Ten Cate Nicolon code	: R676091510	Extensometer	: Crosshead travel monitor
Operator	: OH	Specimen grips	: Demgen M200 HY-ME-2 XL
Test standard	: NEN-EN-ISO 10321	Grip to grip separation	: 100 mm
Pre load	: 1% Fmax	Grip pressure	: 300 bar
Specimen condition	: Dry	Jaw face	: Flat 310*135 (w*h) mm
Test direction	: Cross direction XD	Atmosphere	: Humidity not conditioned
		Opmerkingen	: stuiknaad met zelfkant PES 6 garen

RESULTS

Nr	Fmax kN/m
1	94.3
2	97.0
3	89.1

SERIES GRAPHICS



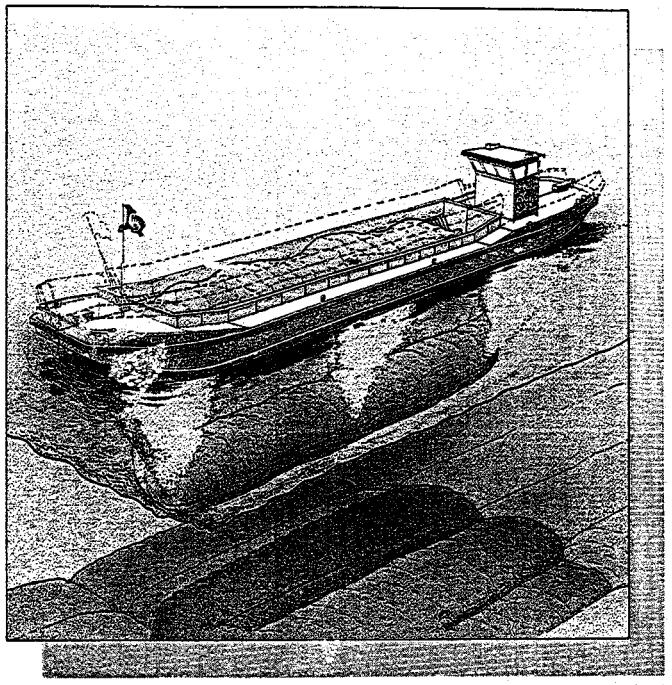
STATISTICS

n = 3	Fmax kN/m
$\bar{x}$	93.4
s	4.0
min.	89.1
max.	97.0

Laboratory: _____

GEOSYSTEMS

Geosystems



Ten Cate Nicolon

Ten Cate Nicolon

Ten Cate Nicolon B.V., located in Almelo, the Netherlands, and Nicolon Corp. at Atlanta, USA, are well known manufacturers and marketeers of technical and industrial synthetic fabrics.

Nicolon were the first to develop geotextiles for durable applications in hydraulic engineering and road construction throughout the world. As early as 1957, the company manufactured sandbags of nylon geotextile, which were used in the dam structure needed to close the final gap in the Pluimpot barrier, part of the Delta works in the Dutch province of Zeeland.

Since that time, many geotextiles and geotextile systems have been evolved and used in quantities amounting to many millions of square metres, systems which are continually adapted to the latest requirements in civil engineering.

A new development that embodies the company's vast civil engineering experience and product knowledge is the **Geocontainer®**.



Geocontainer®

Geocontainers are manufactured from high-grade geotextiles, and put together by means of special seams. Their size depends on the equipment to be used in positioning. If the installation depth and/or the filling material will cause extreme forces to develop, special provisions are made to absorb such forces without trouble.

The container contents consist of granular material recovered locally or produced elsewhere. Other filling materials can be employed when required.

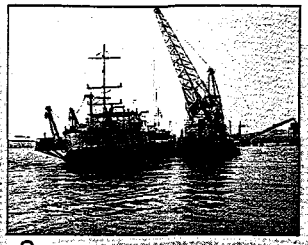
Geocontainers are perfectly manageable and controllable when being sunk in position.

The Geocontainer is an ideal alternative to traditional construction systems, because it offers a wide range of benefits:

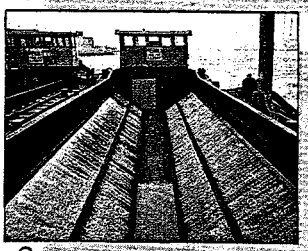
- Cost-saving, as it is possible to make the filling part of another operation. For example, where dredging is carried out the material removed can be used in filling Geocontainers.
- Geocontainers have been designed for accurate positioning to fractions of a metre.
- Installation is possible regardless of weather conditions at varying current velocities and tidal movements, and to great depths.
- Geocontainers make the user free of imported material, because they can be filled with locally available soil.
- Efficient use of material, as no fill is lost by erosion during and after installation.
- Rapid system build-up.
- Competitive in comparison with traditional methods.



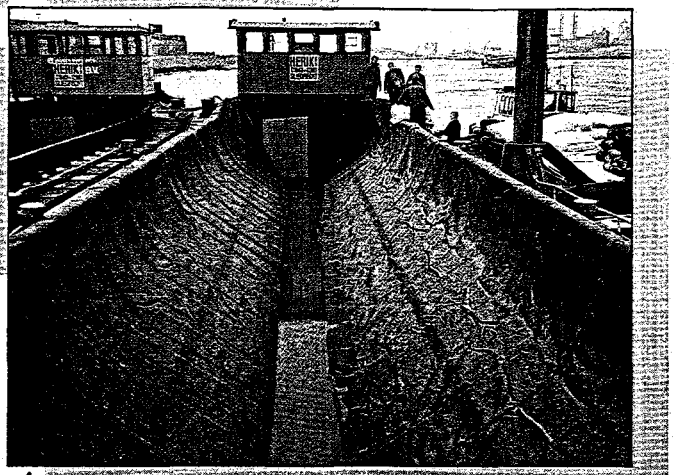
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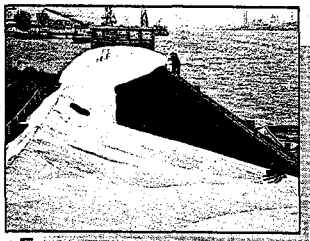
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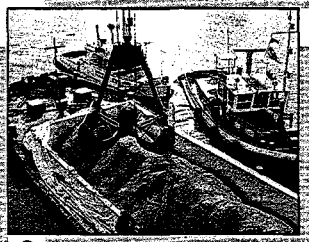
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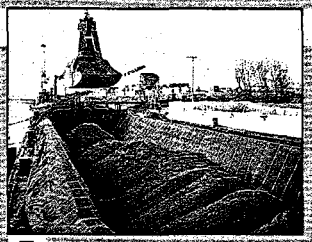
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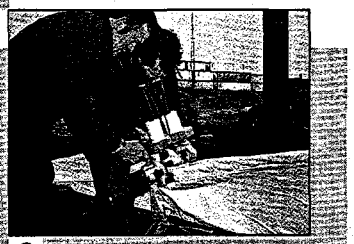
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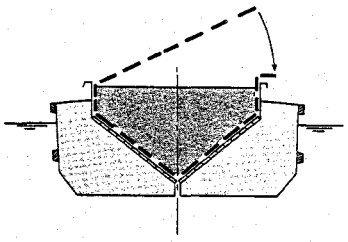
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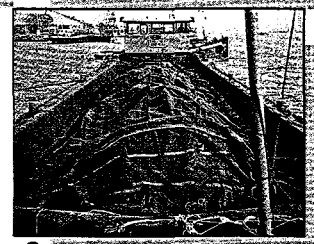


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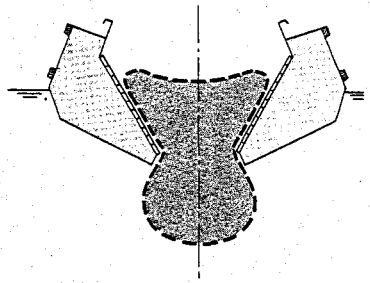
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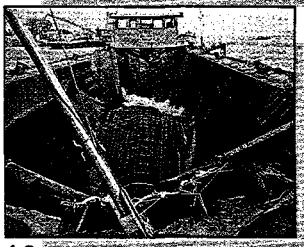




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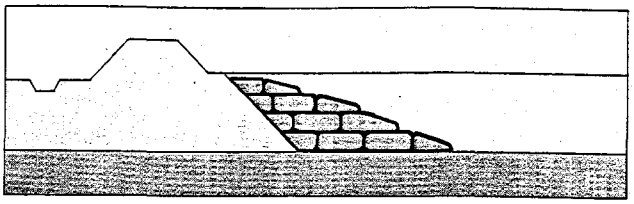
1 Geocontainers transported to the site
2 Filling equipment
3 Split barge 240 cu.m.
4 Preparation of split barge
5 Geocontainer type 130 being suspended in the barge
6/7 Filling a Geocontainer type 130
8 Closing a filled Geocontainer
9/10/11 Geocontainer type 180 being sunk in position
12 Deaeration after installation



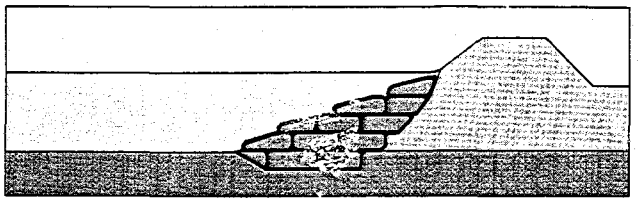
12

Geocontainer® the new system for:

- **Placing on:**

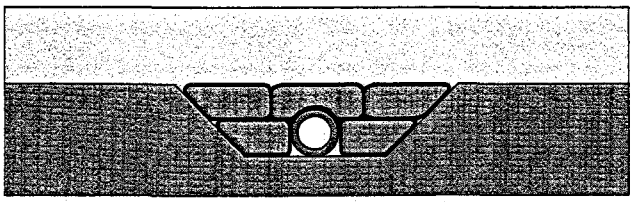


Underwater revetments

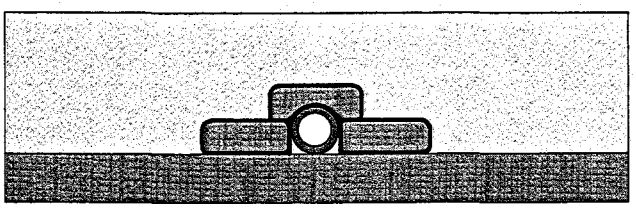


Slip stabilisation

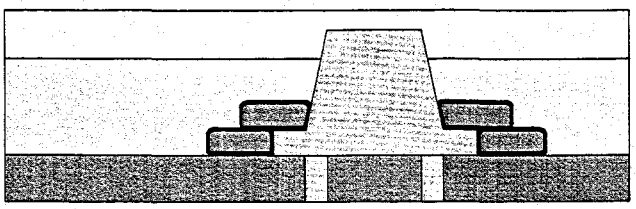
- **Protection of:**



River and channel pipe crossings



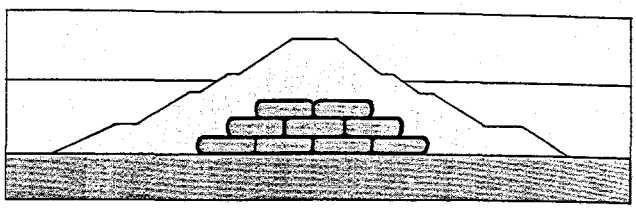
Pipelines



Pile caps

River- and seabeds

- **Core construction of:**

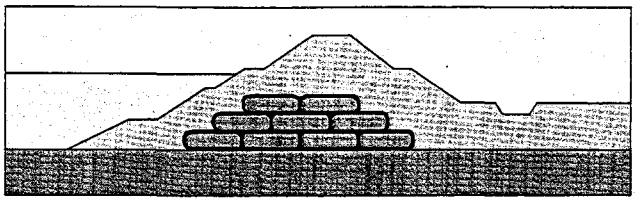


Groynes

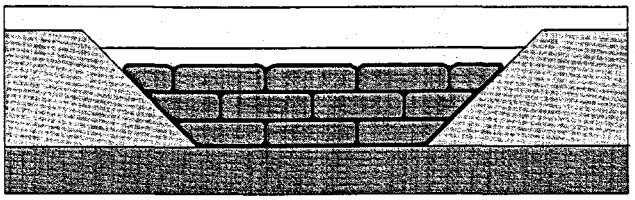
Sills

Training walls

Breakwaters

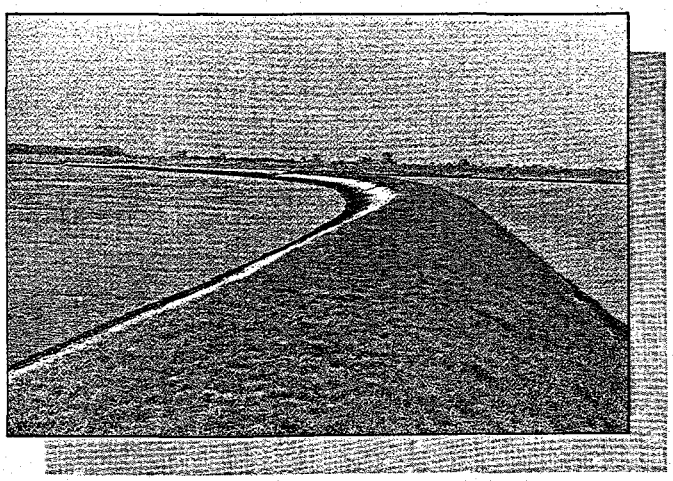


Flood banks



Closing flood banks and breach repairs

- **Containment of polluted soils**



Training wall with core constructed with Geocontainers (Project river Ems)

Completion of bank protection

After the last Geocontainer has been sunk in position the bank is reinforced up to the requiste level with an anti-scour layer of, e.g. rip-rap.

Completion of bed protection

If the design calls for the installation of Geocontainers in places where shipping is expected, the upper tier of Geocontainers can be protected against the risk of damage from, say, emergency anchoring, by adding cement or bitumen to the fill, or by dumping gravel, slag or rip-rap onto the Geocontainers.

Reference projects

Project Ems, Federal Republic of Germany

Training wall at Weekeborger Bocht for bend correction in the river Ems near Leer (German Federal Republic). The wall was constructed with the aid of Geocontainers over a length of approx. 900 metres.

Client: Department of Waterways and Drainage, Emden District.

Contractors: Bohlen & Doyen at Wiesmoor

Construction: The core of the training wall was constructed from Geocontainers type 180, installed at a maximum water depth of 6.- m.
The Geocontainers were filled with material originating from maintenance dredging operations conducted in the vicinity.
Current conditions in this tidal area were variable, the max. current velocity being 1.5 m/s.
Slopes and crest were protected with Armorflex concrete block mattresses, among other materials.

Quantities used:
- Geocontainers type 180: 200 units
- Dredged materials: 40,000 cu.m.
- Concrete block mattresses Armorflex 180: 7,200 sq.m.

Project Oude Maas, the Netherlands

Bed and bank protection on the river Oude Maas, Rotterdam, constructed by means of Geocontainers.

Client: Netherlands Department of Public Works, Lower River Directorate
Dordrecht District

Contractors: Aannemersbedrijf Van den Herik Kust- en Oeverwerken BV at Sliedrecht

Construction: The work was subdivided as follows:
a. Geocontainers for bed protection at a depth of approx. 20 m-.
b. Geocontainers for bank revetment at a gradient of 1:3, from a depth of 18 m-.

The use of Geocontainers was an alternative solution adopted instead of the protection with steel slag initially specified by the Department of Public Works.
The Geocontainers were filled with sand recovered by a trailing suction dredger from a location for nautical dredging work on the Nieuwe Waterweg, Rotterdam.

On the site involved there is tidal movement, and a current velocity of 2 m/s.

The underwater slope was restored with Geocontainers types 130 and 180, including provisions to absorb extreme forces at great depth.
When the Geocontainers had been sunk in position, the upper part of the slope was protected with a rip-rap revetment.

Through close cooperation between the Department of Public Works which commissioned the project, the producer Nicolon BV and the contractor Van den Herik BV, the Geocontainer has in the course of this project been developed into a construction system that will preserve its dependability and efficiency even under extreme loads.

Quantities used:
- Geocontainers (types 130 and 180): 250 units
- River sand: 90,000 tonnes.

Other Geosystems

Nicolon bv has also evolved derived geotextile systems based on the principle of "packaged building materials", in close collaboration with various clients.

Geotube®

For projects "in the dry" or projects involving a continuous underwater system in which the granular material must be permanently trapped (e.g. hydraulic fill dams), Nicolon bv produces the Geotube system.

The Geotube consists of a high-grade geotextile woven and formed into a tube whose diameter and length varies with requirements. The tube is filled by direct coupling to a hydraulic piping system. The tube material is so dimensioned that the water carrying the fill wil be ejected, whilst the fill itself remains inside the tube. The structural height of a filled Geotube is approx. 80% cf the theoretical tube diameter.

The Geotubes will follow the horizontal and vertical alignment both above and below the water surface with perfect ease.

Tipper

It is possible to collect and enclose the load from a tipping lorry in geotextile, so that it can be used in hydraulic engineering. This method was employed in 1987 on a Department of Public Works Project to build an anti-scour floor in the river Vecht, Holland.

Asphalt/Concrete Container

The Asphalt/Concrete Container is composed of several Geotextile layers. One of the layers contains a film that makes the container asphalt/concrete-tight. The container is resistant to high (processing) temperatures and can be filled with asphalt or concrete up to a weight of 25,000 kg.

To protect the pier bases of the Oosterschelde storm surge barrier, part of the Deltaworks, Holland, 2600 asphalt-filled containers were used.

Gravel Bag

To construct the Oosterschelde storm surge barrier synthetic bags filled with gravel were placed around the bases of all piers.
These bags had a dual function:
Owing to the shape of the pier base, voids were formed between pier bottom and foundation bed. These voids had to be filled with a sand/cement grout afterwards. Thus the first function served by the gravel bags around the pier bases was that of formwork for the grout, i.e. the bags had to provide an inward seal.

The second function was to prevent sand, silt or animal organisms from entering the voids before the grouting operation. Hence in this case the bags had to provide an outward seal.
The gravel bags, each with a length of 160 m and a section of 2 m were not finally positioned until the piers had been installed. To facilitate positioning, the bags had been provided with a remote release mechanism which, along with an ingenious attachment system, enabled them to assume the proper shape and thus seal off the voids under the piers. In this way all 65 piers of the barrier were surrounded by a gravel bag at the base. The sill between the piers was built by dumping stones from the waterline. During this operation, the gravel bags were of course hit by falling stones, but they had been made strong enough to withstand the resulting impact.

Nicobag®

Nicolon sandbags are seamless.

Dimensions: small 0.40 x 0.80 m large 1.48 x 2.20 m

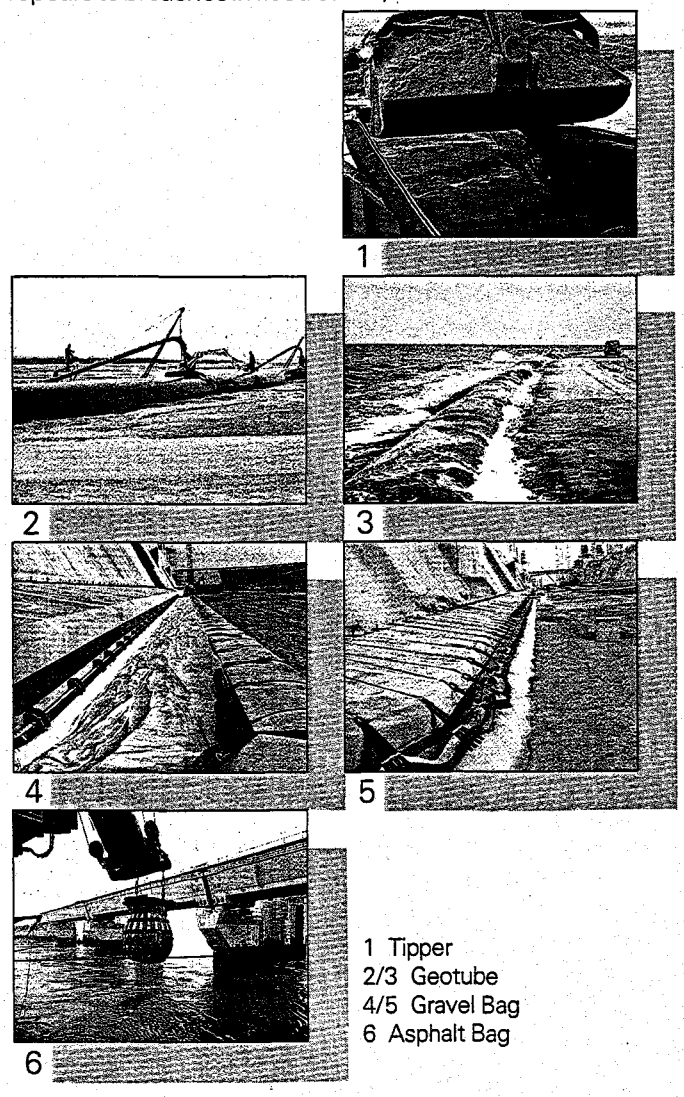
Filling weight: abt. 40 kg and abt. 1.300 kg

The filling of the sandbags can be done by means of a funnel. The sandbags are sewn up by the aid of a hand sewing machine.

The small filled sandbags are stored as materials for emergency. Sandbags should be stored covered.

Extra services

In consultation with the client, Geocontainers can be kept in stock by local authorities, or stored by maintenance engineers for rapid and effective use for repears to breaches in flood banks, and other disasters.



1 Tipper
2/3 Geotube
4/5 Gravel Bag
6 Asphalt Bag

The field-tested Nicolon Geotextile systems offer new cost-effective and efficient solutions that will also benefit your civil engineering projects.

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Ten Cate Nicolon

Ten Cate Nicolon bv
Sluiskade N.Z. 14
P.O. Box 236, 7600 AE Almelo,
Holland
Tel: +31 (0)546-544453
Fax: +31 (0)546-544490

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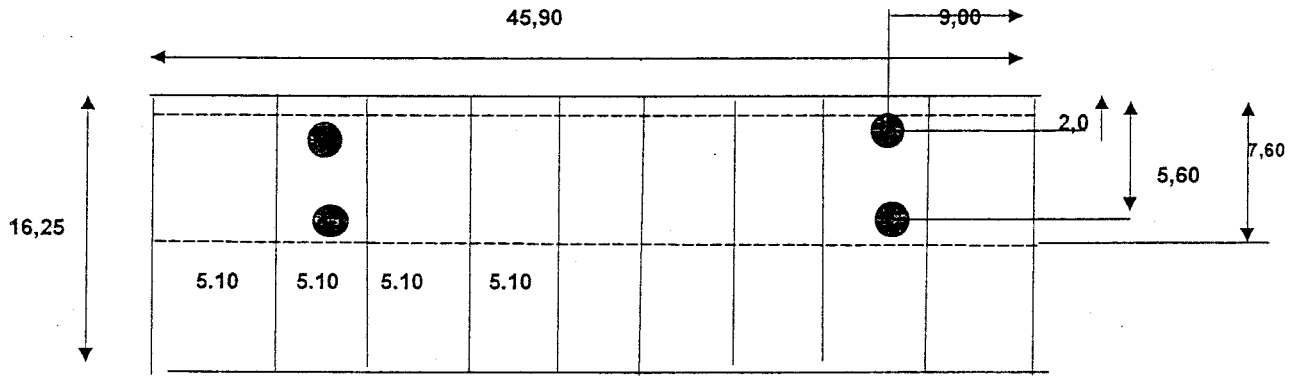
Ten Cate Nicolon b.v.

K112110273 — Geo - container 45,90 x 15,90

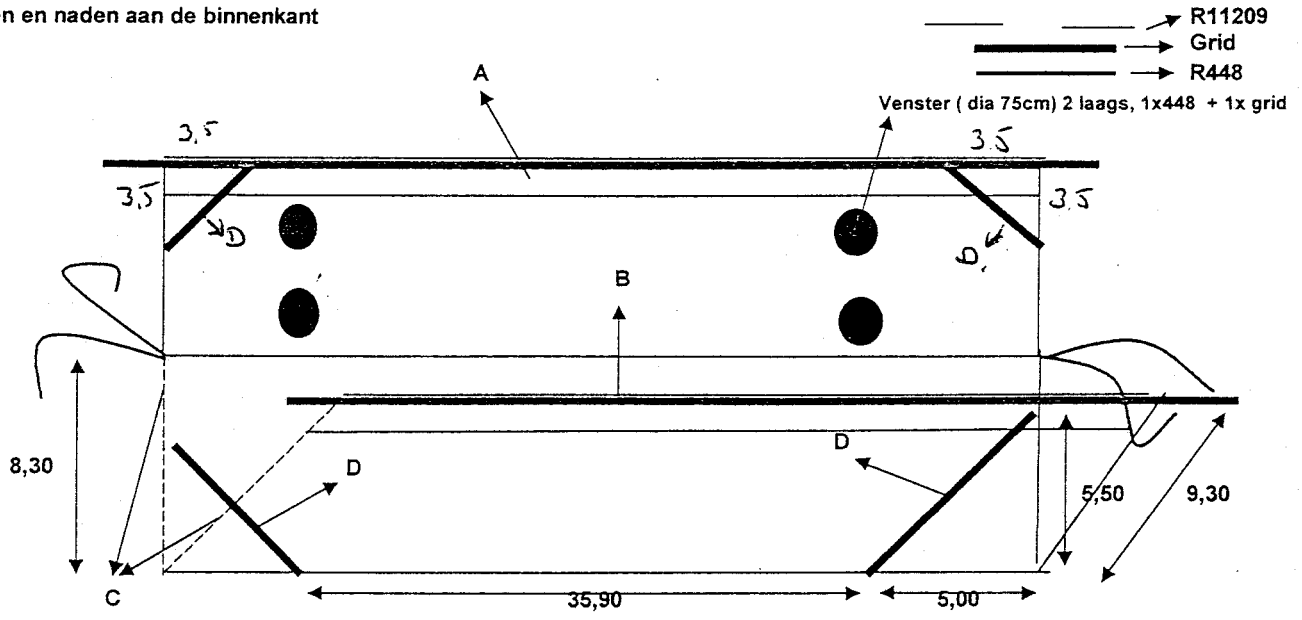
Geo Calc. Prod. TW

POS 1	R112091006	GEOLON PP 120 S 5.20
POS 2	R448091015	PE WEEFSEL ZWART 5.05
POS 3	R059021001	NICOGRIT 50/50 3.60
POS 4	F731006001	PES 6 WIT
POS 5	F604180001	PE touw oranje 18 mm
POS 6	F605000002	PP Paktouw wit 4/440
POS 7		
POS 8		

	AFMETINGEN	AANTAL	MACHINES	NAADTYPE
POS 1	26,20 X 5.20	9	Adler 477 2 nld.	17 steken
POS 2	0.90 X 0.90	4		
POS 3	0.90 X 0.90	4		
POS 5	49 mtr.	2		
POS 6	4 mtr.	2		
POS 7				
POS 8				
POS 9				



Lussen en naden aan de binnenkant



paraaf	Hiermee vervalt spec. d.d.	datum
		16-05-2000

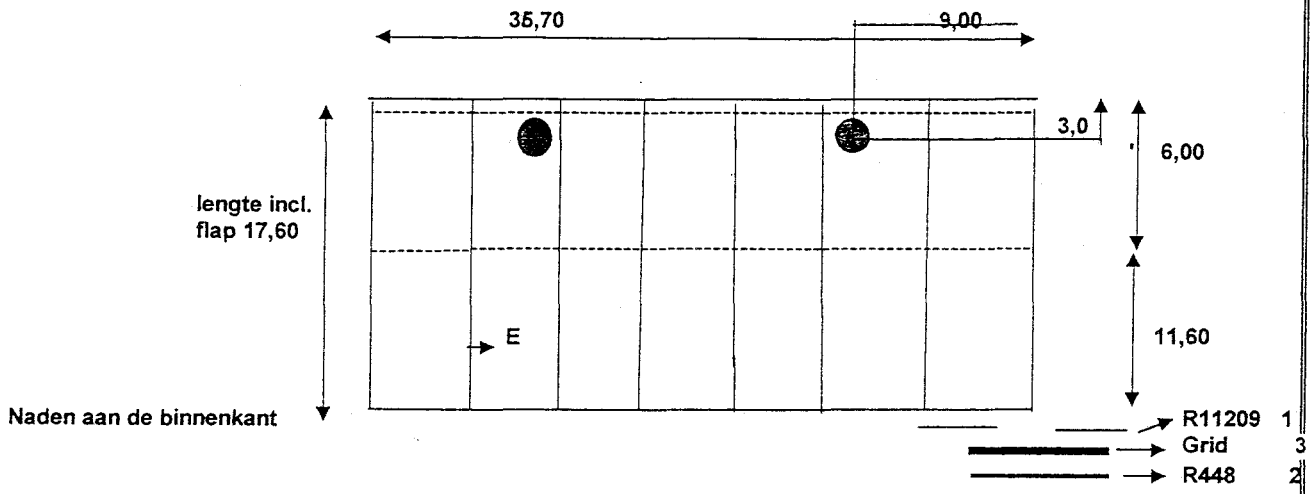
Ten Cate Nicolon b.v.

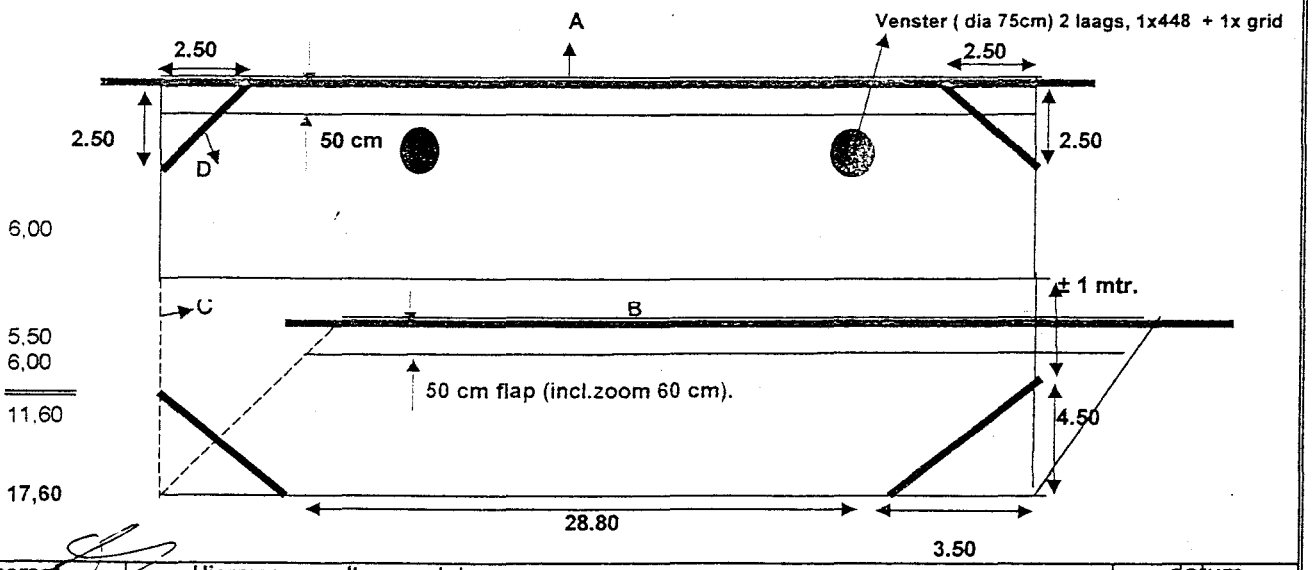
K112110280 — Geo - container 35.70 x 17.60

Geo Calc. Prod. TW

POS 1	R112092530	GEOLON PP 120 S 200 x 5.20
POS 2	R448091015	PE WEEFSEL ZWART 5.05
POS 3	R059021001	NICOGRID 50/50 3.60
POS 4	F731006001	PES 6 WIT
POS 5	F604180001	PE touw oranje 18 mm
POS 6		
POS 7		
POS 8		

	AFMETINGEN	AANTAL	MACHINES	NAADTYPE
POS 1	17,60 X 5.20	7	Adler 477 2 nld.	17 steken
POS 2	0.90 X 0.90	2		
POS 3	0.90 X 0.90	2		
POS 5	42 mtr.	2		
POS 6				
POS 7				
POS 8				
POS 9				





paraaf	Hiermee vervalt spec. d.d.	datum
		20-10-2000

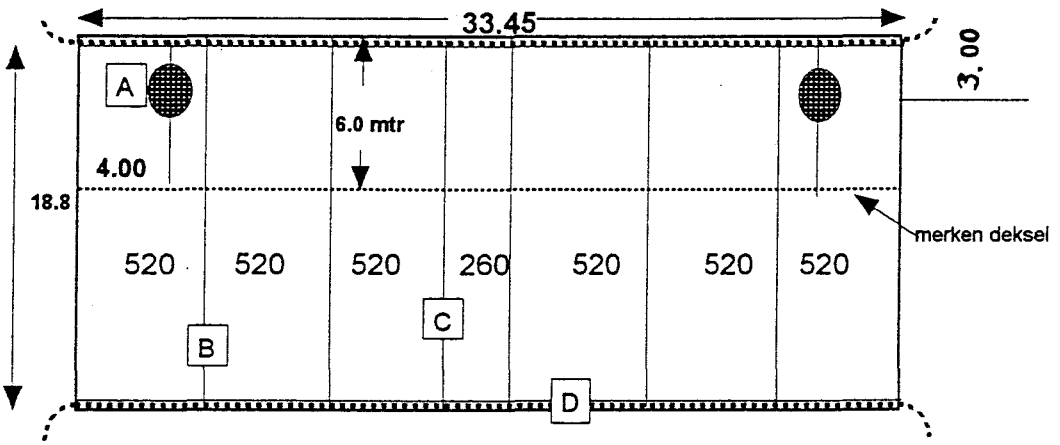
TEN CATE NICOLON B.V.

K101110243 GEO-CONTAINER 18.80 x 34 m Colcrete

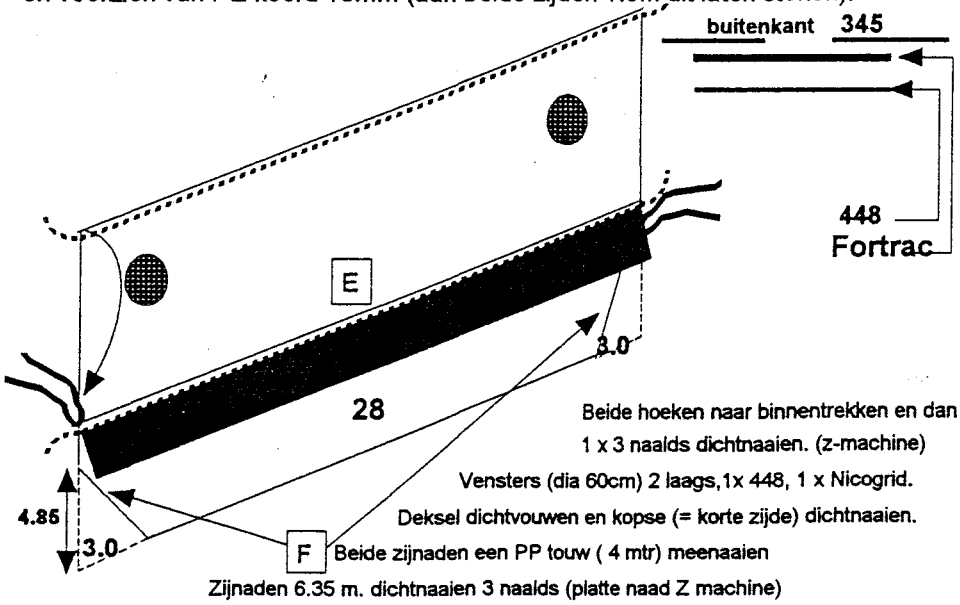
Geo - Cal.- Constr.Afd.- HZ

POS 1	R101091001	Geolon PP 100 S 5.20
POS 2	R448091012	PE WEEFSEL 5.05 m.
POS 3	R088092002	Geolon grid PET 55/30-25 100x3.60
POS 3a	R641091009	Geolon PP 40 100x2mtr
POS 4	F604180001	PE touw oranje 18mm
POS 5	F731037001	PES No 9
POS 6	F731006001	PES No 6
POS 7	F605000002	PP paktouw wit 4/440

		AANTAL	MACHINES	NAADTYPE	steken/10cm
POS 1	19.1 x 5.20 m.	6	Adler 477	stuiknaad	19 st
POS 1	19.1 x 2.60m.	1	Adler 477	stuiknaad	12 st
POS 2	0.90 x 0.90 m.	2	US 38200 C	stuiknaad	19 st
POS 3	0.90 x 0.90 m.	2			
POS 3a	33.5 mtr	1			
POS 4	37 m.	2			
POS 7	4 mtr	2			



..... = pe touw oranje 18mm
boven en onderzijde 15cm omvouwen en open zoom van 10cm maken ,
en voorzien van PE koord 18mm (aan beide zijden 1.5m uit laten steken).



Beide hoeken naar binnentrekken en dan
1 x 3 naalds dichtnaaien. (z-machine)
Vensters (dia 60cm) 2 laags,1x 448, 1 x Nicogrid.
Deksel dichtvouwen en kopse (= korte zijde) dichtnaaien.
Beide zijnaden een PP touw (4 mtr) meenaaien
Zijnaden 6.35 m. dichtnaaien 3 naalds (platte naad Z machine)

MATEN IN METERS LUSSEN EN NADEN AAN DE BINNENKANT.

paraaf	Hiermee vervalt spec. d.d. 02-06-1999	datum 11-06-1999

OVERVIEW OF GEOCONTAINER PROJECTS IN THE UNITED STATES

Jack Fowler[1] and Ed Trainer[2]

ABSTRACT

This paper discusses design and cost parameters for several geotextile geocontainer projects where geocontainers have been successfully filled with sandy materials and placed in water depths up to 70-ft using split hull bottom dump barges. Two very successful geocontainer projects in the U. S. were the Red Eye Crossing, U.S. Army Engineer District, New Orleans, and the Marina Del Rey project, U.S. Army Engineer District, Los Angeles. Two geocontainer projects in New York that were filled with fine grained maintenance dredged material were not as successful. It was determined from this study that the cost of geocontainer structures are about one half to two-thirds the cost of rock structures. It was also determined that with the proper equipment and geotextile fabrics, contaminated dredged material could be contained successfully and economically in geocontainers.

Keywords: Dredging, geotextile containment, dredged material, split hull bottom dump barge.

INTRODUCTION

A number of geocontainers have been successfully filled with sandy materials and placed in water depths up to 70 ft using split hull bottom dump barges in Europe, Malaysia, Taiwan, Japan, and the U. S. Two very successful geocontainer projects in the U. S. were the Red Eye Crossing, U.S. Army Engineer District, New Orleans, and the Marina Del Rey project, U.S. Army Engineer District, Los Angeles. The Red Eye Crossing project was located two miles south of Baton Rouge, LA, on the Mississippi River and the Marina Del Rey project was located in Los Angeles, CA.

Attempts to contain highly plastic, fine-grained, maintenance dredged material in geocontainers during two demonstration projects in New York Harbor for The Port Authority of New York and New Jersey experienced minor problems with seam failures. These failures were due to the containers being under designed, over filled, or not protected from sharp edges by fabric protection slip sheets when deployed in less than desirable bottom dump split hull barges. To overcome some of these problems and misconceptions with design, costs, filling and placement methods, an overview of U. S. projects is discussed in this paper. There have been several fabric seam improvements and improved geocontainer deployment methods developed as a result of these projects. Several projects are in the planning and design stages. One large sand filled container project is to be constructed during the summer of 1997.

[1] Jack Fowler, Ph.D., PE, GEOTEC Associates, 5000 Lowery Road, Vicksburg, MS 39180, 601-636-5475

[2] Ed Trainer, TC Mirafi Corporation, Geocontainer Group, 365 South Holland Drive, Pendergrass, GA 30567, 800-234-0484

RED EYE CROSSING PROJECT, JULY 1993 - JULY 1994

The Red Eye Crossing project consisted of construction of six underwater bendway weir dikes for a total length of 7,000 ft of channel training structures to reduce dredging costs. Three cubic yard Geobags were placed from a flat top barges with front end loaders whereas the geocontainers were placed with split hull bottom dump barges.

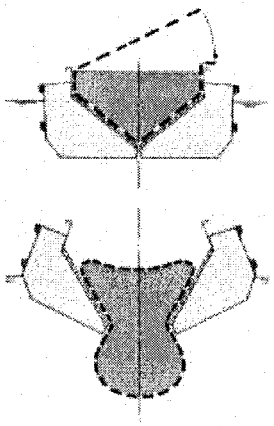


Figure 1. Split Hull Bottom Dump Barge in the Closed and Opened Positions

Details concerning quantities and cost for the Red Eye Crossing project are based on unit cost per volume of fill material. This project consisted of 38,000 three cubic yard woven polypropylene geobags that were mechanically filled with sand for a total unit cost of $28.00 per cubic yard (cy). The bags were 12 ft in circumference and 12 ft long, but when filled and sewn closed they were about 4 ft in diameter and 8 ft long.

The project also contained 556 geocontainers that were mechanically filled (clam shell) with sand. These geocontainers contained between 100 cy to 550 cy of sand for a total unit cost of $16.41/cy for the geocontainer and filling. The containers were 45 ft in circumference and varied in length from 40 to 115 ft. The bin width was 12 ft and the barge opening was 9 ft, therefore the percent opening was 75 percent. The maximum length to width ratio varied from 3.3 to 9.6. The woven polypropylene geocontainers had air vents constructed in the center top and at each end. There was no barge liner specified for this project.

To prevent failure the geocontainers were filled to about 60 to 70 percent of the theoretical fill volume. The theoretical volume is defined as the cylindrical volume of the container. Prior to placement of the geocontainer in the barge, the barge bottom vee was filled with about 150 cy of sand because the geocontainer dimensions supplied by the contractor were too short for the depth of the bin. Placement of sand in the barge vee raised the geocontainer to a better position to accommodate sewing of the top.

As the barge opened this layer of sand was eroded out of the vee by the 4-ft/sec river currents. The geocontainers fell down and out of the barge very uniformly without twisting or diving.

In the beginning of the project there was evidence that perhaps three of the 556 geocontainers had failed. Failure was suspected because floats installed inside the containers floated to the water surface after deployment. This problem was remedied when the dredged material fill volume was lowered to the 70 percent of the theoretical fill volume of the container as specified in the contract.

The other alternative construction method for the Red Eye Crossing project was to use rock fill at a cost of $16.00 to $20.00 per ton (0.67 cy/ton) or a cost of $24 to $30 per cy. The cost of the 3 cy sand bags was about the same as the cost of rock by volume but the cost of the geocontainers filled with sand was 50 percent more economical than rock fill by volume.

The geocontainers were not only more cost effective than rock but they did not pose any potential navigation hazards for large ships carrying oil to refineries in Baton Rouge, LA. The total project cost of $6,000,000 was theoretically recovered in less than two years after completion because of reduced maintenance dredging costs. The project is operating beyond expectations and three more sand filled geocontainer projects are planned further down stream in the near future. The New Orleans Corps of Engineers will not allow rock filled sedimentation training dikes on the Mississippi River south of the Baton Rouge, LA bridge.

After about five months into the project three of the geocontainers were instrumented with strain gages and pressure cells with funds provide by the U. S. Army Engineers, Waterways Experiment Station (WES), Vicksburg, MS, Construction Productivity Research Program (CPAR). The WES and TC Mirafi Corporation both contributed $400,000 each to this program. These costs were not included in the project cost. The geocontainers were dropped in water depths of 60 ft. The strain gage data indicated that the geocontainers had a factor of safety very close to 1.0. Since the completion of this project some of the geobags and containers located near the riverbank have lost a small amount of sand because of the very open geotextile fabric but this loss of sand has not caused any problems. This problem will be remedied in the future with tighter and stronger fabrics to prevent the loss of sand.

MARINA DEL REY PROJECT, OCT - NOV 1994

The Marina Del Rey project consisted of mechanically filling 44 geocontainers with an average volume of 1300 cy of contaminated dredged sand. The outer geocontainer consisted of a woven polyester geotextile with an ultimate tensile strength of 1000 pounds per linear inch width (pli) in both the warp and weft. The inner liner was a 16-oz non-woven polyester geotextile that served as a filter to prevent contaminated soil from escaping. The 7 to 8 percent fine-grained soil in the dredged sand was contaminated with lead, zinc, and copper.

The total project cost for mobilization and demobilization, cost of the geocontainers, cost of dredging and filling the geocontainers with 55,100 cy of dredged material was $4,374,098 or a unit cost $79 per cubic yard. These high cost were attributed to delays caused by a long hauling distance, difficulty in

deployment of the first geocontainer when it became lodged in the barge opening for a one week delay. Also cold, wet, weather conditions and delays caused delays by the contractor's frequent changes in personnel and getting them up on the learning curve.

The cost for forty-three of the geotextile containers was $25,950 per container or a unit cost of $20 per cubic yard. The first container cost $21,620 or about $17 per cubic yard. The original plan was to fill the geocontainers with 2500 cy of dredged material for a unit cost of $10 per cubic yard for the geocontainer. When the very coarse and moist dredged sand would not flow freely out of the narrow opening in the split hull bottom dump barge the fill volume was reduced to 1300 cubic yards, therefore increasing the geocontainer unit cost to $20/cy.

The geocontainers were 200 ft long and 120 ft in circumference. The initial circumference was 90 ft but was increased to 120 ft after the first geocontainer became lodged in the barge narrow opening. The sand in the geocontainer was finally liquefied and the container was deployed.
It was assumed that additional fabric slack in the bottom vee of the barge would facilitate deployment of the geocontainer. The geocontainers were only filled to about 15 to 22 percent of their theoretical fill volume. The bin length was 176 ft and the modified width was 22 ft. The length to width aspect ratio was 8.0. The barge opening width to bin width ratio was 50 percent.

The barge was lined with a woven polypropylene fabric but was removed after the first container became lodged. There was no geocontainer instrumentation at Marina Del Rey and there was no evidence of geocontainer failure.

NEW YORK GEOCONTAINER, APRIL 1995

The Port Authority of New York and New Jersey mechanically filled one geocontainer with about 3600 cubic yards of highly plastic fine grained maintenance dredged material with a clam shell dredge. There was very little evidence of debris. The outer container consisted of the same woven polyester fabric that was used at Marina Del Rey. The inner liner consisted of a 12 oz non-woven polypropylene fabric to prevent loss of fines. The density of the material in the geocontainer was about 1.23. The in situ density was about 1.3.

Bulking Ratio. To compute the saturated bulking ratio for the in situ volume to the volume placed in the barge, either of the following equations may be used when the saturated density, void ratio or moisture content are known:

$$\text{Bulking Ratio} = \frac{V_o}{V_i} = \frac{\rho_i - 1}{\rho_o - 1} \text{ or } \frac{e_o + 1}{e_i + 1} \text{ or } \frac{\rho_o G_s + 1}{\rho_i G_s + 1} \quad (1)$$

Where:

V_o = volume of dredged material after excavation and disposal in the barge
V_i = volume of in situ channel sediments prior to dredging
ρ_o = density of dredged material in the barge

γ_i = in situ density of channel sediments prior to dredging
e_o = void ratio of dredged material in the barge
e_i = void ratio of in situ channel sediments prior to dredging
$\omega_o G_s$ = moisture content of dredged material in the barge times the specific gravity
$\omega_i G_s$ = in situ moisture content of channel sediments times the specific gravity

Where the in situ saturated density, γ_i, and the density in the barge, γ_o, are known, then the bulking factor for the dredged material in the barge is calculated as follows:

$$\frac{V_o}{V_i} = \frac{1.30 - 1}{1.23 - 1} = 1.30 \text{ or } 130 \text{ percent bulking ratio} \quad (2)$$

Therefore, the bulking ratio of the dredged material in the container and barge was about 130 percent. Dredged materials dropped in geocontainers will not bulk an appreciable amount when dropped through the water column. But, if allowed to drop through the water column without containment the bulking ratios may increase by orders of magnitude greater than the bulking ratio calculated due to excavation and placement in the barge and geocontainer. It was estimated from laboratory model and field tests conducted during the Dredged Research Program at WES that bulking ratios of 200 to 1000 percent are not uncommon depending on the type dredged material, grain size, salinity, drop depths and current conditions. Sand capping of these highly plastic fine-grained materials is impossible at these very low densities, fluid mud consistencies and high void ratios. Dredged material contained in geocontainers may be capped without any difficulty or loss of material or they may not be capped at all and simply allowed to consolidation without capping.

The container was 206 ft long and 150 ft in circumference. The geocontainer was only filled to 30 percent of its theoretical volume. The bin was 168 ft long and 41 ft wide. The length to width aspect ratio was 4.1. The barge opening width to bin width ratio was 33 percent.

The barge was lined with a 40 mil thick high density polyethylene (HDPE) liner to prevent excessive frictional forces in the fabric. The HDPE that was lapped in the barge vee bottom was not long enough to protect the geocontainer from the closing bars during deployment.

The geocontainer was dropped in about 57 ft of water. There was evidence from one float coming to the surface and a dredged material plume near the water surface that the geocontainer had separated. The geocontainer was instrumented with both strain gages and pressure cells. The strain gages indicated that the geocontainer experienced higher strains than predicted during deployment and impact with the ocean floor. Diver inspections also confirmed that the geocontainer had separated along a major longitudinal bottom seam.

The primary causes of failure were attributed to too much dredged material in the geocontainer and not enough protection for the geotextile fabric during deployment. A stronger fabric may have more successful. The polyester fabric may have partially failed when the barge was closed onto the fabric

prior to filling. As the barge was towed to the mud dumpsite the fabric that was clamped between the barge halves could have been further damaged due to abrasion during transport. These barge halves are very flexible and the two halves could have abraded the fabric during the four-hour trip to the mud dumpsite.

Cost of the geocontainer was $10 per cubic yard and the cost of dredging was $5 per cubic yard. The cost for design and instrumentation installation was not included.

TWO NEW YORK GEOCONTAINERS, JUNE 1996

The Port Authority of New York and New Jersey mechanically filled a 4000 cy barge with maintenance dredged material that was then hydraulically dredged into a geocontainer located in a bottom dump split hull barge. Two geocontainers were filled with about 1700 cy of dredged material. The first container for the first drop consisted of only a woven polyester fabric like that used at Marina Del Rey and New York. The second geocontainer and second drop had a 12-oz non-woven polypropylene inner liner to control the loss of fines during deployment. The inner liner was installed to determine if an inner liner would be necessary to prevent the escape of fines. The split hull bottom dump barge was painted to provide a slick surface instead of using a HDPE liner for container protection. The containers were pre-assembled with three hydraulic filling ports that were tied and sewn closed in the field. Only the center filling port was used during this demonstration.

The first container was 120 ft in circumference and 195 ft long. The geocontainer was only filled to about 21 percent of its theoretical volume. The bin was 168 ft long and 35 ft wide and the length to width aspect ratio was 4.8. The barge opening width to bin width ratio was 33 percent.

The second container was 105 ft in circumference and 195 ft long and it was filled to 27 percent of its theoretical volume.

The wet bulk density for both drops was about 1.17 gm/cc in the barge and geocontainer. The in situ density of the dredged material in the channel was 1.3 gm/cc. The bulking factor from the in situ volume to the volume in the barge and geocontainer was calculated to be 176 percent.

During cleaning and painting of the barge in dry dock the contractor simply could not afford to spend the amount of time and money necessary to properly prepare the barge. Old pieces of concrete stuck to the barge closing bars and jagged metal parts had to be chipped and ground down the best that they could in the time allowed. It was observed that the barge had been damaged when it was used as a rock barge. Where split hull barges have been used to haul rock, they become deformed in the bottom vee area and cannot be properly closed. During normal dredging activities these damaged barges are often sealed with sandbags placed in the bottom vee to prevent the loss of fine-grained loose or fluid dredged materials.

When these barges are maintained properly and are not misused they have a large rubber seal and steel plate welded in the bottom vee to prevent the lost of dredged material. When this seal is damaged or

has been removed, such as in the case with the barge used for this project, this size opening will allow dredged material to escape. But, when these barges are used to haul rock and after the two, barge halves have been damaged due to excessive loading with rock, this opening could be much wider. This barge was not inspected in the closed position, which is a very important observation that should be made prior to geocontainer placement.

During transport of the first geocontainer to the dumpsite a tremendous amount of water was observed entering and exiting between the barge halves at either end of the bin around the end of the geocontainer. There was less water and pumping action during transport of the second geocontainer. This pumping action during transport could have possibly caused the fabric to enter the opening between the barge halves causing abrasion and fabric damage.

The first geocontainer fell uniformly from one end of the barge to the other without twisting or turning. Inspection after placement and review of the instrumentation data indicated that the first geocontainers might have failed prior to or during release from the barge. During deployment the strain gage data indicated very little strain which meant that the geocontainer had possibly failed prior to or during opening of the barge. Diver inspection revealed a 40-ft long failure adjacent to a seam.

The second geocontainer twisted near the bow during deployment and went down at an angle of about 25 degrees from the horizontal. Inspection of the second geocontainer after placement and review of the instrumentation data indicated that the container exited the barge satisfactorily but the geocontainer seemed to have sustained damage on impact with the bottom. The outer woven polyester liner was damaged in four locations that varied in length of only a few feet. The largest opening and loss of material occurred at the bow end at the left corner. The container maintained a definite shape and curvature on the bottom indicating very little loss of material during deployment and impact. The divers found that most of these failures occurred in seams but one occurred in a panel. Both the inner and outer liners appeared to have failed in the bow end of the container.

The strain gage data indicated strains approaching fabric failure during impact with the sea floor. The factor of safety was considered to be only slightly less than 1.0.

The second container may have survived impact if it had not sustained partial damage during deployment. Unprotected sharp edges from the close bars and concrete may have contributed to weakening the geocontainer prior to impact.

SUMMARY

Table 1 is a summary of the container volumes, theoretical volume versus fill volume ratios, bin length versus width ratios, bin width to opening width ratios, container unit cost, total unit cost for the container and dredged material fill and rock fill volume cost.

Table 1. Summary of Geocontainer Information

Project Name	Volume cy	Theoretical Vol/Fill Vol & Opening Width/Bin Width	Aspect Ratio Container Length to Width	Fabric Cost/cy of Contain-ment	Total Cost for Geocontainer and Dredge Sand Fill per cubic yard	Total Cost for Rip Rap Rock Fill per cubic yard
Red Eye Crossing Geobags	3.0	80% to 75%	NA	$9.00	$28.00	$24 to $30
Red Eye Crossing Geocontainers	550	60 to 70% to 75%	3.3 to 9.6	$5.00	$16.41	$24 to $30
Marina Del Rey	1300	15 to 22 % to 50%	8.0	$16.63 to $19.96	$79.38	Disposal Contaminated Sand
New York April 1995	4000	30% to 33%	4.1	$10.00	$15.00	Disposal of Maintenance Dredged Mat.
New York Cont. #1 June 1996	1700	21% to 33%	4.8	$10.00	$15.00	Disposal of Maintenance Dredged Mat.
New York Cont. # 2 June 1996	1700	27% to 33%	4.8	$10.00	$15.00	Disposal of Maintenance Dredged Mat.

CONCLUSIONS

It was concluded that when geocontainers are not overfilled beyond a certain ratio which has not been determined for fluid mud dredged materials or designed beyond their seam strength limits then they can be placed successfully. It was also concluded that when proper placement equipment and fabric protection measures are utilized, the geocontainers can be successfully deployed from split hull bottom barges without damage. It was concluded that this new and innovative containment technique is technically and economically feasible and geocontainers can be properly designed for containment of dredged material, especially contaminated sediments. Depending on the nature of the project cost for the geocontainers and dredged material the cost varied from a low $16 per cubic yard at Red Eye Crossing to a high of $79 per cubic yard at Marina Del Rey. The cost for the geocontainers at New

York were about $10 per cubic for the container and $5 for dredging for a total cost of $15 per cubic yard, but there was considerably more cost involved because this was a demonstration project.

One very important observation was the bulking factors for a geocontainer filled with highly plastic fine-grained dredged material. The bulking factors at New York ranged from 130 percent for mechanical fill and 183 percent for combined mechanical and hydraulic fill. Placement of these types of dredged materials through the water column could be orders of magnitude higher than these values (1300 to 1830 percent).

RECOMMENDATIONS

The following recommendations should be considered during design and implementation of future geocontainer projects:

1. It is recommended that the barge opening be constructed as wide as possible. The minimum opening widths should be established for different types of fill materials and geotextile fabrics. The opening width to bin width for Red Eye Crossing was 75 percent, for Marina Del Rey was 50 percent, and for New York was 33 percent. It is recommended that the fill height ratio to bin width opening be less than 1.3.

2. The rate of opening should be investigated as to its effect on geocontainer loading. The current opening rate for most all bottom dump barges encountered is about one minute.

3. Long barge bins should be partitioned to reduce the length to width aspect ratio in an attempt to prevent long geocontainers from twisting during deployment. The ratio for Red Eye Crossing varied from 3.3 to 9.6, Marina Del Rey was about 8.0, and New York varied from 4.1 to 4.8. It is recommended that an aspect ratio of 2.0 or less be used for geocontainers.

4. The geocontainers need to be filled to an optimal fill volume similar to what was achieved at the Red Eye Crossing project, which was about 60 to 70 percent.. The ratios used for the Marina Del Rey and New York geocontainers were entirely too low to be economically feasible. To make this concept economically attractive this ratio needs to be greater than 50 percent. It must be noted that the Marina Del Rey and New York projects were considered to be research demonstration projects and never reached full production like the Rey Eye Crossing Project.

5. It is recommended that very stiff fabrics such as woven polypropylenes be used to construct geocontainers that are filled with very fine grained maintenance dredged materials and sandy materials. When fluid dredged material mud is contained in very hydrophilic and flimsy polyester fabrics, they have a tendency to find and fill into every nook and cranny in the barge when under pressure. Polyester yarns are much more subject to abrasion damage than polypropylene yarns. The polypropylene fabrics are less subject to yarn abrasion and are more robust and have a higher survivability to construction damage. The use of polypropylene yarns has been shown to reduce the amount abrasion damage during placement, filling, and transport.

6. It is also recommended that the influence of different types of dredged materials be evaluated as to their influence on geocontainer survivability during impact. The use a clamshell versus a hydraulic pump may also need to be evaluated for each location.

7. When using split hull bottom dump barges the geocontainer must be protected from the closing bars and all sharp and rough edges that might damage the geocontainer fabric. It is recommended that a very durable and robust geosynthetic liner or sleeve be constructed to protect the geocontainer as it passes through the barge opening.

8. Recommend that higher seam strengths be investigated to lower geocontainer cost and to reduce seam failures. New seaming techniques have shown that seam strengths of near 100 percent of the fabric strength can be achieved. Past experience has only been 50 to 60 percent.

9. Recommend that fabric friction tests be conducted for woven polypropylene fabrics on steel, HDPE and other proposed geotextile liners.

10. Do not recommend indiscriminate barge modification without an analysis of its geometry and probability of successful deployment of geocontainers. Bin width modifications are generally not recommended for successful deployment. Existing equipment can be used to deploy geocontainers and it is not necessary to design specialized equipment for spit hull or pocket barge placement.

11. Recommend that GPS systems be used to locate the geocontainers after placement to evaluate any drift or skating effects due to currents or shape effects during free fall through the water column. Accurate placement of geocontainers during construction of sub-aqueous structures such as Red Eye Crossing or for deep-water disposal of contaminated materials is very important.

ACKNOWLEDGMENTS

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Geocontainer projects KRAUTSAND and TWIELENFLETH

River Elbe , Germany 1998

In 1998 two projects were executed in the river Elbe, using a large number of Geocontainers manufactured and supplied by Ten Cate Nicolon.
Dredging International from Belgium, through its subsidiary Nordsee Nassbagger- und Tiefbau, had a project in Twielenfleth where 115 units were dumped. The second project was located in Krautsand and was executed by Hamburg-Bergdorfer Baugesellschaft, with an initial contract of 260 units. Due to the success of the first phase, the works were extended to a total number of 437 Geocontainers.

General

The waterways authorities WSA Hamburg and WSA Nord invited bids late 1997 for the construction of two underwater dams parallel to the shoreline of the Elbe estuary. Connected to the shore by groins, these dams will create a depot for dredged sand from nearby shipping channels in the river. For many years continuous maintenance dredging is needed to guarantee access to the main port of Germany.
By constructing these depots, the authority expects to reduce the cost of the maintenance dredging by reducing the sailing time to disposal grounds, but also by reducing siltation of the channels itself. Narrowing down the river width at the location of existing problem areas, will result in an increase of the average current of the river, in turn resulting in a reduction of siltation.

At Twielenfleth and Krautsand are recreational beaches, which are very popular in weekends and holiday season. These depots will enlarge the existing beaches as an additional advantage.

Design

The underwater dams were designed to have a crest level at CD – 4 m, permitting barges to pass over, while some spill of dredged material over the crest was found acceptable. Existing depth at the sites varied between CD – 6 and – 10 m, while tides varied between CD and CD + 3 m.

Both contractors won their contract with alternative designs based on Geocontainers. Per cross-section the dam was constructed by stacking 3 Geocontainers in two layers, 2 units down and a third on top. In deeper areas of the Krautsand project an extra layer of 3 units was placed underneath.

The Geocontainers were designed by Ten Cate Nicolon specifically for the dimensions of the available barges of the contractors. The barge of DI had a capacity of 315 m3, resulting in Geocontainers with a fill of 250 m3. The two barges of HBB were of 350 m3 capacity, the fill per unit was put at 280 m3.
Based on filling with proper sand, a single unit after dumping with DI had a maximum height and width of 1.9 and 7.6 m, with an effective length of 28.9 m, equal to the length of the barge hold. For HBB these sizes were res. 1.9 x 8.0 x 26.9 m.
The fabric used on both projects was Geolon PP80, DI used for the underlayer also PP120.

Construction method

The equipment spreads used for the construction of the underwater dams consisted of:

DI:
- 1 backhoe dredge Caterpillar 245 on anchors
- 1 splitbottom barge 315 m3
- 1 survey launch / tug
- 1 DGPS positioning system on dredge and survey launch

HBB
- 1 backhoe dredge Caterpillar 245
- 2 splitbottom barges 350 m3
- 1 tug
- 1 spudpontoon for Geocontainer handling
- 1 transport launch
- 1 DGPS positioning system on tug
- 1 survey launch on stand-by

The main difference between the construction methods was that DI used only 1 pontoon for both dredging and dumping with 1 barge, while the dredge of HBB was kept stationary with the tug shuttling 2 barges to the different locations.

After a unit was filled by DI, the dredge shifted to the dump location using its anchors. At the same time the Geocontainer was closed with a handsewing machine. After dumping, the dredge repositioned to the dredge area, while the next Geocontainer was installed in the barge.

HBB shuttled a first barge from dredge to spudpontoon, where the filled Geocontainer was closed. In the meantime the tug pushed the second barge to the dredge, after which it took again the first barge to sail it to the dump location.
After dumping it returned to the spudpontoon where the next Geocontainer was installed in the barge. The tug went than collecting the second barge with filled Geocontainer at the dredge, to bring it to the spudpontoon, etc.

DI reached net cycle times of 3 hours, resulting normally in 3 units per day in single shift of 12 hours. The 115 units were dumped in a total period of 47 days, working 7 days per week.
The cycle per barge at HBB took a little longer, about 3.25 hours. Per day 5 dumps could be made, working in extended dayshift. Average was reached of 20 units per week of 5 days.
During the extended part of the works the production was reduced by working with 1 barge only, net cycle times became less than 3 hours. Apart from major delays for bad weather periods and structural equipment damage, an average of 14 units per week of 4.5 days was achieved.

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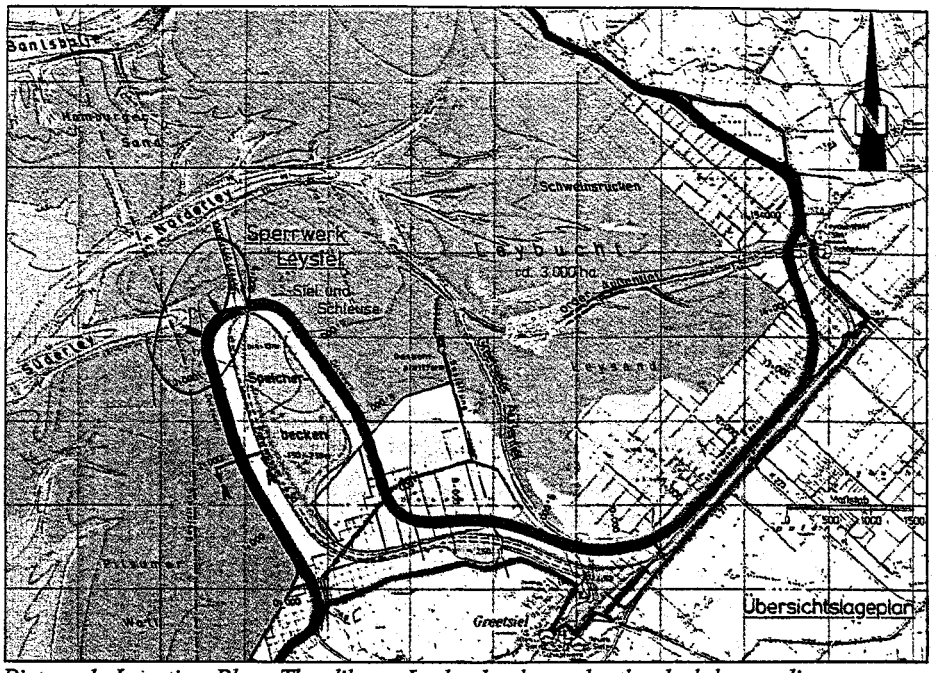
The use of Geotubes as an essential part of an 8.8m high North Sea dike and embankment, Leybucht, Germany.

Peter de Bruin and Chris Loos, Almelo, The Netherlands.

Hydraulic construction, particularly at, or below, sea level presents engineers with a significant challenge.

In this article the authors explain the reasons why there was a need to build a new dike, and overlying embankment, at Leybucht, and how the construction was assisted by the use of approximately 15km of sandfilled Geotubes. In addition it is noted that for the first time ever a Geotube was used in the closure section of the inlet-outlet channel, despite the fact that tides caused a twice daily flow of four million cubic metres of water.

Clearly the use of sandfilled tubes in hydraulic engineering is an exciting innovation and we thank the authors for providing this article. **GW.**



Picture 1. Location Plan. The dike at Leybucht shown by the dark brown line.

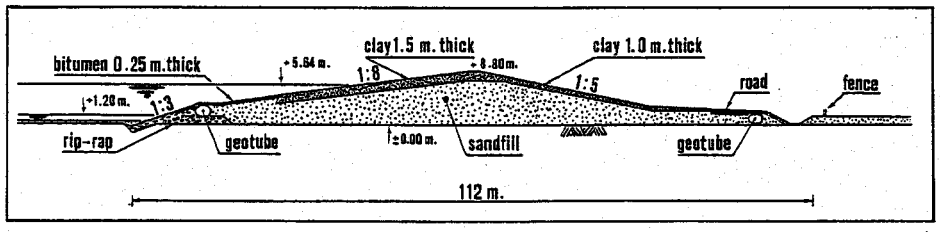


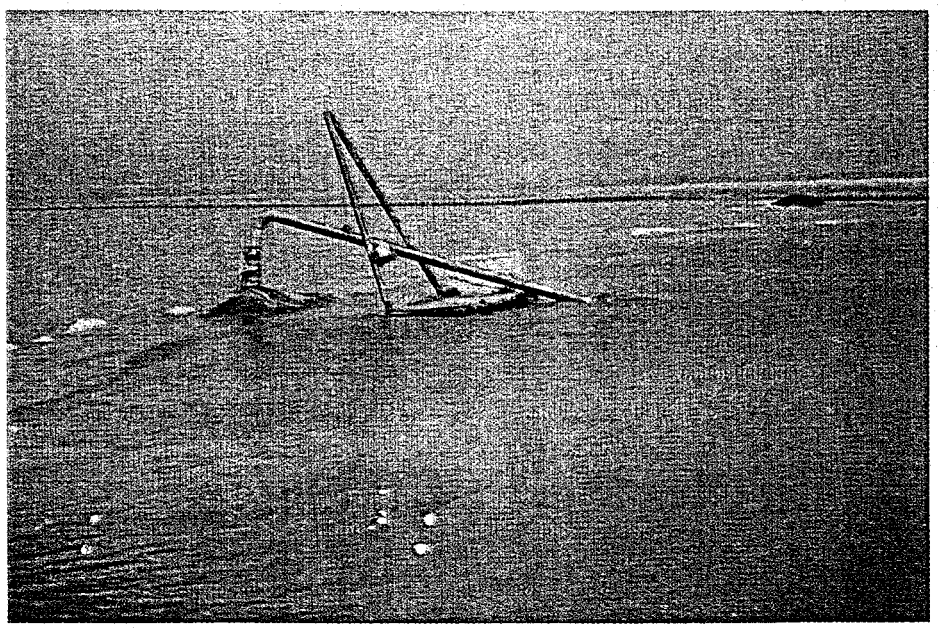
Figure 1. Cross Section A-A through the dike showing general details. Construction started at the left side with the placement of the rock rip-rap and the Geotube. The "circle" was then completed by installation of the Geotube on the right and sand filling advanced the structure upwards and inwards towards the crest.

Overview

The hurricane driven North Sea floods of 1953 and 1962 killed almost 2000 people, in northern Germany and the Netherlands, and inflicted severe damage to land and property. As a result, major defence works have been undertaken including improvements to storm water locks and raising and strengthening flood protection dikes and embankments.

One of the more recent large scale undertakings has been the construction of a 7 kilometre long rock dike, an overlying embankment and associated structures, to close Leybucht (Leybay), Germany. Work on the rock section was completed in September/October 1992 and, at the time

"Leybucht" is continued on the next page.



Picture 2. The final stages of filling a nearly submerged section of Geotube.

of writing this article, March 1995, the embankment, sluice gates and weir gates are now substantially complete. Please see Picture 1., on the previous page - Location plan and Picture 9., on the last page of this article - An aerial view during construction at Leybucht.

This low lying coastal section is usually under frequent storm attack from the autumn to the spring and in January 1962 a flood level of about 4.65 metres above mean sea level (MSL) was recorded. On January 3rd. 1976, seas again surged to levels almost equal to this.

Leybucht is an area of some 31 square kilometres with a tidal range of up to 2.7 metres. The region is home to about 100000 birds and catchment for approximately 350 square km of hinterland which, in the vicinity of the coast, is only about 1m above MSL and is protected by dikes nearly 8 metres high. These dikes prevent floods from spreading inland for distances of up to 31 km.

Design and construction

Major considerations facing the designers, Wasserwirtschaft Aurich, Germany, were:

° construction in a tidal area comprising soft mud flats;

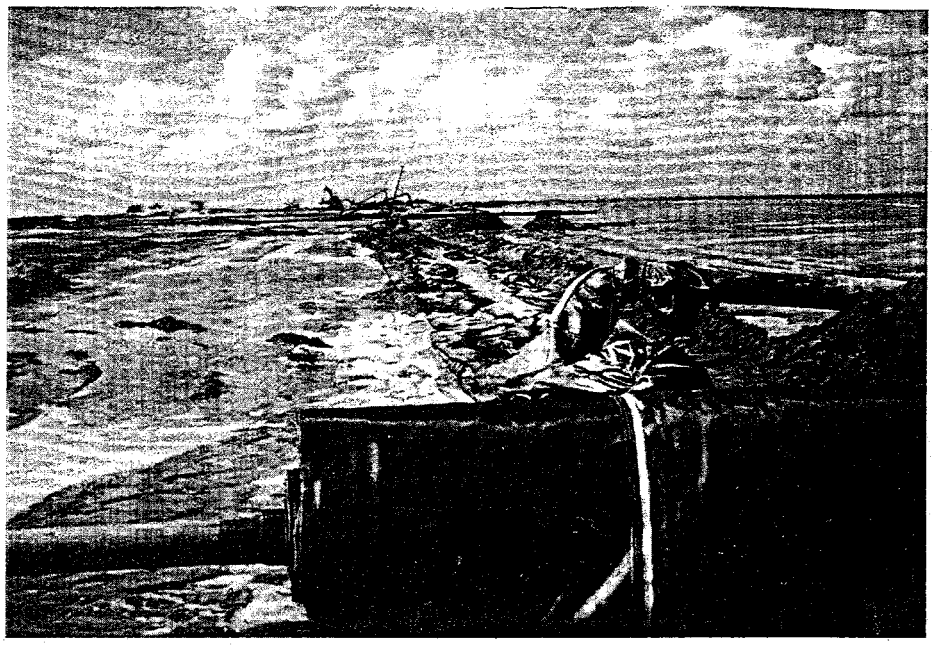
° prevention of silting of the fishing harbour of Greetsiel, used by close on thirty boats, and important to the livelihood of quite a number of people;

° maintenance of the hinterland's drainage, and

° preservation of the ecological value of the bay and its adjacent mud flats, rich in shrimp and other sea life.

The bulk of the design of the actual dike and embankment provided for the use of natural materials and, in order to work with the more erodible elements of these, in an area flooded twice daily, extensive use was made of sand filled Geotubes manufactured from Geolon woven geotextiles and developed by Nicolon B.V., in co-operation with the Dutch Rijkswaterstaat and the Deltadienst, as well as the soil mechanics laboratory in Delft and the German authority for Water and Waste in Aurich/Niedersachsen.

The principal components of the new dike and embankment at Leybucht are a sandfill core faced with clay on the inland slope, and on the upper portion of the sea facing side, where a 250mm thick bitumen/ asphalt concrete layer protects the middle section. The toe defence and support is formed from a heavy rock rip-rap facing, and under layer, to the sand filled Geotube toe core.



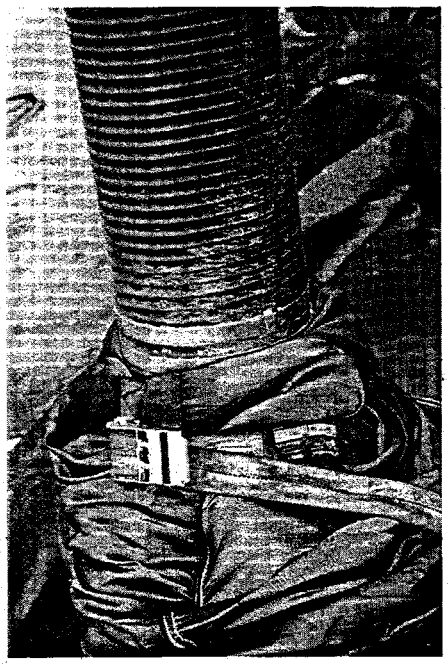
Picture 3. The Geotube delivery format, with a weight of some 1100kg. Despite this the delivery and on site handling was trouble free.

On the inland side the toe core is also provided by a Geotube. In this case it underpins the foundations to a paved road constructed adjacent to a drainage channel.

As can be see from Figure 1., on the previous page, the embankment has a crest height of 8.8m and a cross sectional base width of 112m. (Outside toe to outside toe of the rip-rap).

At the dike closure location, a section of some 40 - 50 metres in the 100 metre wide inlet-outlet channel, a bed and bank protection was provided by means of rock rubble resting on fascine mattresses, formed from panels of a heavy duty Geolon geotextile fastened, on site, to transverse reinforcement elements. Each mattress measured 30m x 40m and, after preparation, they were floated out and then sunk into position by means of dumping stone rubble on them. Picture 7., on the last page of the article.

The actual channel closure was extremely notable as, for the first time ever, it was achieved completely by means of a Geotube, overlaid with rock. Due to the fact that twice daily some 400 million cubic metres of water flowed through the channel, the work had to be undertaken in just a few hours, at low tide, and was successful due to the well planned construction programme, of tube filling and continuous follow up work with heavy trucks dumping rocks.



Picture 4. A Geotube inlet with a filler pipe connected. The actual pipe needs to be both tough and flexible. Sand with a particle size of 0.10mm and pumped in a ratio of 1 part sand to 4 parts water has been found to provide the best results.

The Geotubes

The Geotubes used at Leybucht were potentially ca. 1.7m in diameter, when filled, and were manufactured from 400m lengths of 5.3m wide Geolon geotextile, sewn longitudinally. (Please see Figure 2).

Each 400m length was delivered to site rolled on steel cores. Picture 3.

Tube filler pipes were accommodated by inlets of 500mm diameter, which were

factory formed at 75m intervals. Pictures 4 and 5.

Once the separate lengths were on site they were joined together, using hand held sewing machines. Despite the weight of each roll and core, approximately 1100kg, the delivery and on site handling was trouble free and each stage proceeded smoothly.

Installing the Geotubes

Sections of Geotube were rolled out and connected to a branch pipeline from a dredger barge. A slurry 1:4 of sand and water was then pumped into the tube section and excess water escaped through the geotextile as well as through specially formed outlet pipes attached to the Geotube.

In general, when the Geotubes were installed on the inland side (right of Figure 1. on the first page), they were bedded on a plastic sheet, in a shallow excavation. The purpose of the sheet was to prevent washout of the underlying fine materials, which could be caused by water escaping from the tubes during the hydraulic filling process.

Conclusions

Hydraulically sand filled Geotubes, manufactured from high strength, low strain, woven geotextiles, with the correct degree of porosity have proved to be a most effective and extremely durable foundation component at the Leybucht dike and embankment.

Once the factory manufactured modules are on site they can be joined quickly together, positioned and hydraulically filled and, without further work, each completed section of tube is then immediately ready for service.

The tubes have demonstrated that they can safely withstand major storms, wave action, rapid currents and the ebb flow of tides, sustained over many months, whilst ancillary construction continues. (Picture 8 on the next page).

At the Leybucht site Geotubes have been successfully used, for the first time, to achieve the closure section of an inlet - outlet channel, thus providing a completely new technique in this type of hydraulic work.

"Leybucht" is continued on the next page.



Picture 5. General view of a filler pipe connected to an inlet on a Geotube.



Picture 6. A filled length of Geotube. Experience has shown that a 400m section of a 1.7m diameter tube can be filled hydraulically in about 5 hours.

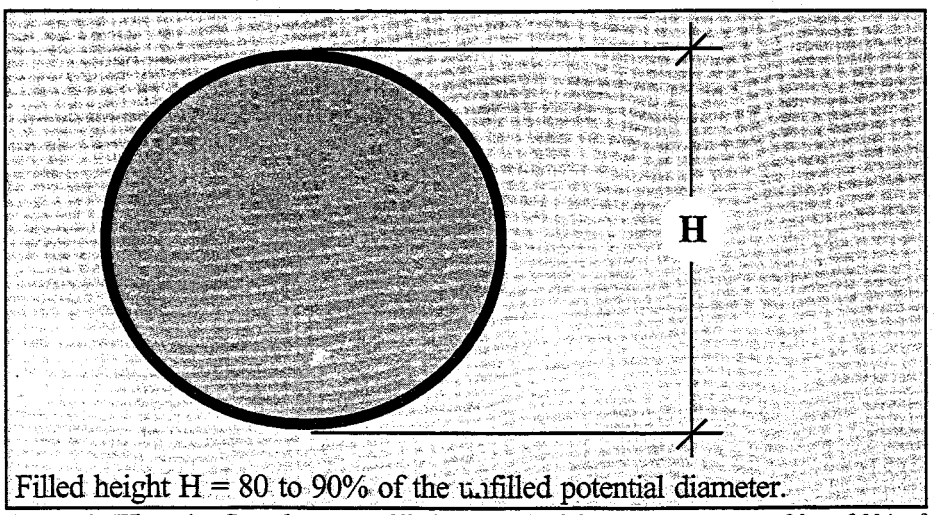
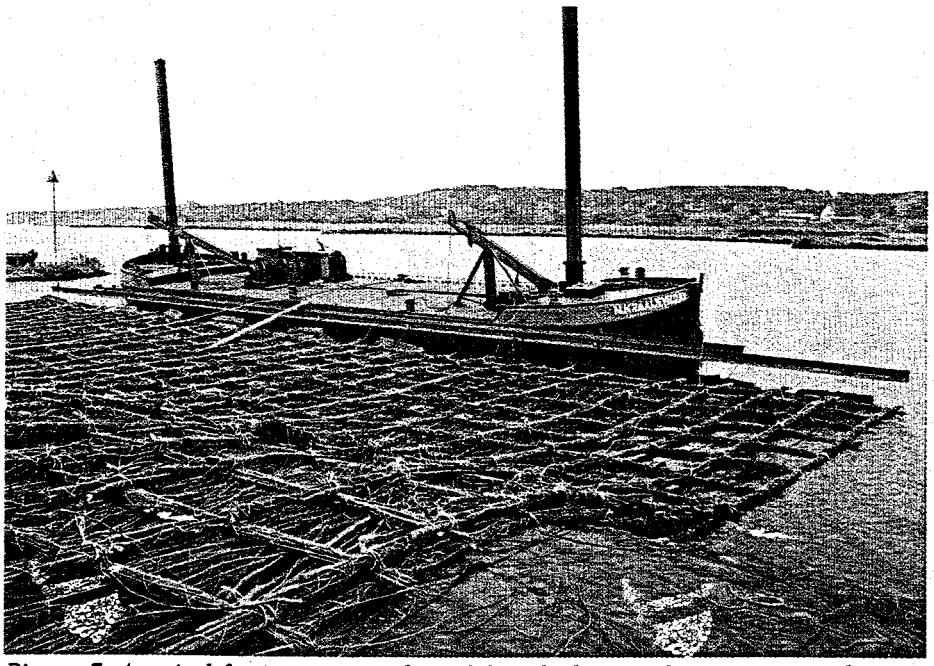
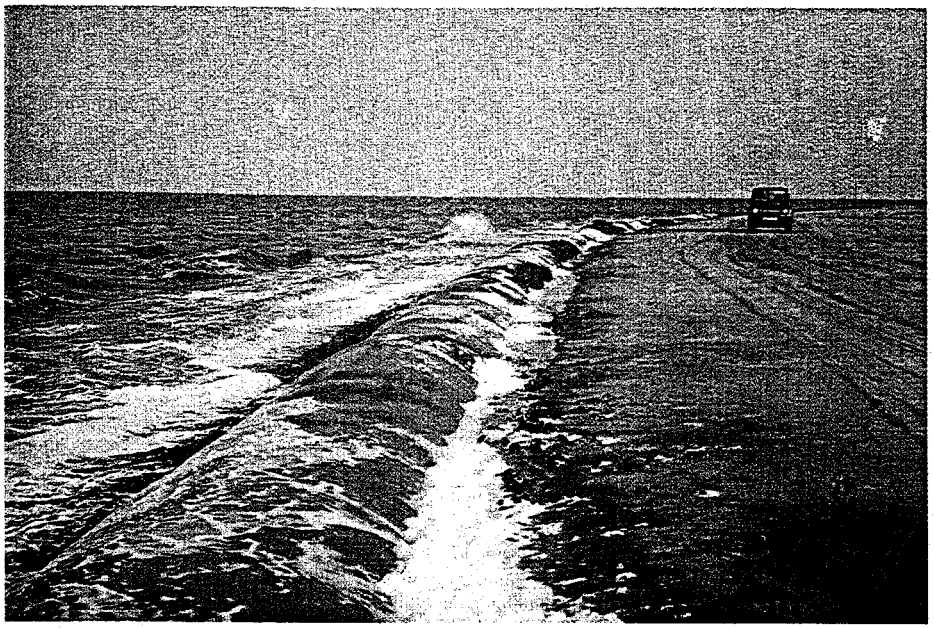
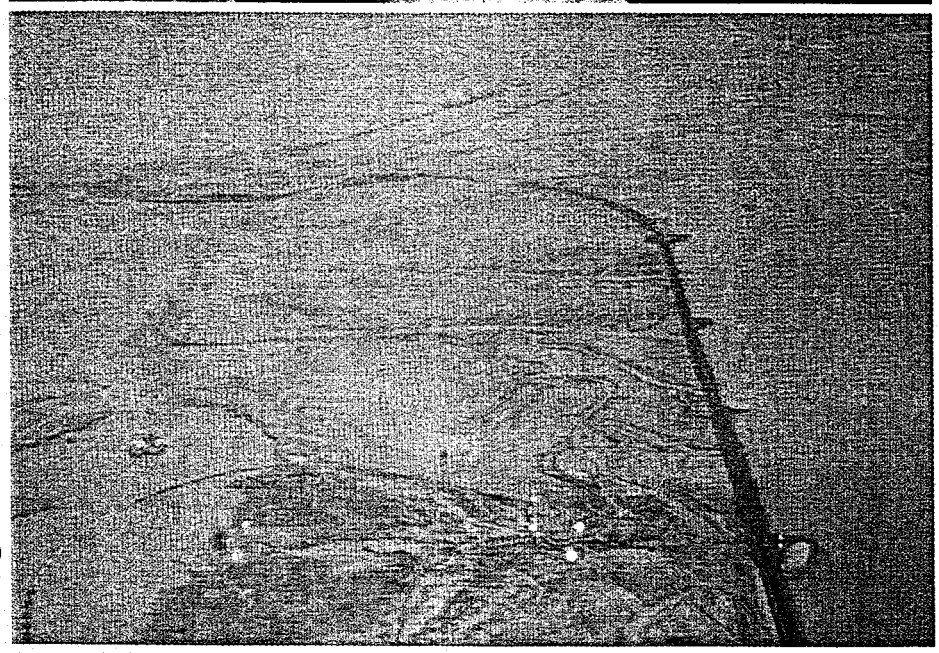


Figure 2. When the Geotubes were filled to 100% of their capacity some 80 to 90% of their theoretical diameter was achieved. This slightly oval cross section provides the best possible bedding for the tube.



Picture 7. A typical fascine mattress formed from high strength woven geotextiles attached to transverse reinforcement struts. After it has been pulled into position by the barge, it can be submerged under the weight of a layer of dumped rock rubble and will function as a bed protection in the inlet - outlet channel.





Acknowledgements

Design and actual construction supervision:

Staatliches Amt für Wasser und Abfall, Aurich/Niedersachsen, BRD.

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Editor's notes.

1. Further information about the application of Geotubes, Geocontainers and other types of hydraulic engineering geoproducts could be obtained by contacting either of the authors:

Mr. Peter de Bruin or Mr. Chris Loos,
Nicolon B.V.
Sluiskade NZ 14,
P.O. Box 236,
7600 AE Almelo,
The Netherlands.
Tel. + 31-546-544453.
Fax. + 31-546-544490.

2. Geotube, Geolon and Geocontainer are registered trademarks and belong to Nicolon B.V.

Picture 8. After a night of a severe storm, with gale force 10 - 11 winds, it was found that rocks had been driven onto and over a partially exposed section of Geotube, however damage and sand loss was so minimal that repair was unnecessary. Further, the actual positioning of the tube had not been disturbed.

Picture 9. Aerial view showing a major part of the site during construction.

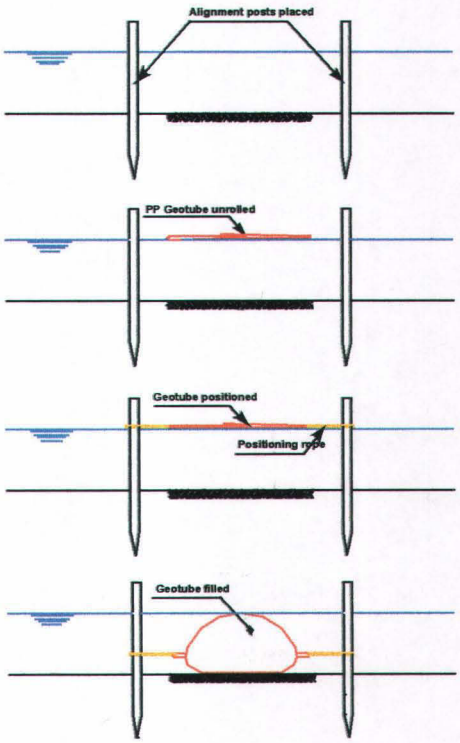
Top left, the platform for construction of the sluice gates, for passage of ships and the storm water weir gates. Middle left the dredger used, in part, to supply the sand used for hydraulic Geotube filling. Middle to bottom left, a section of filled Geotube. Running from the bottom right of the picture and leading towards the left near the top of the picture, the rock dike. Here the Geotube prevents washout of the sandy fill material through the rock rip-rap at the base of the embankment.

GW

METHOD STATEMENT GEOTUBE® FILLING

This method statement applies to the unfolding, unrolling, placing, alignment and filling of the Geotubes.

1) Place the alignment posts as indicated on the drawing 1 in 4.85 meter intervals along the length of the Geotube and at a 10.0 meter distance put in the same number of alignment-posts at 4.85 meter intervals. The distance of 10.0 meters is chosen because with this distance between the 2 rows of posts, a small craft can tow the Geotube in place and will have some space to operate into.

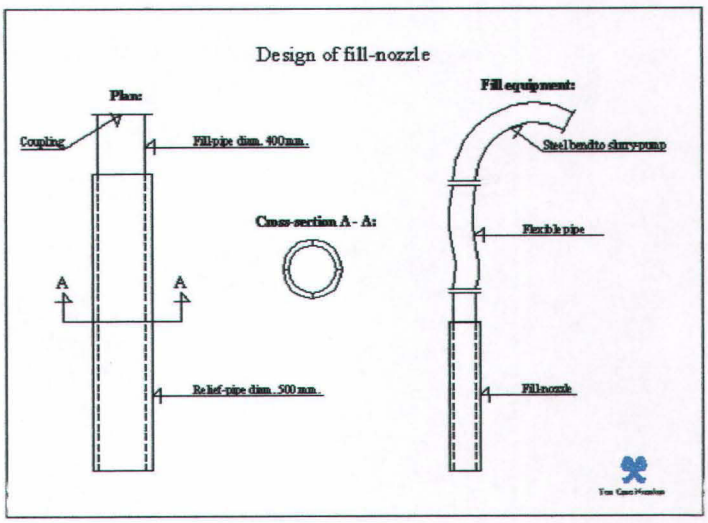


2) Remove the wrapping or other packaging materials from the roll carefully, without cutting into the geotextile of the Geotube.

3) Unroll the Geotube in such a way that the fill-nozzles (inlets/outlets) are situated on top of the Geotube, and unfold the Geotube completely till it is wide.

4) Attach the Geotube, using all of the provided loops of the Geotube, with PP ropes diam. 10 mm to the alignment-posts. This is such a way that the PP ropes have sufficient slack to allow the Geotube to become his designed wide after filling. Also note that the Geotube when being filled will become a little bit shorter, due to the pillow shaped beginning and end of the Geotube.

5) Close all outlets (in most cases 6) with a rope and attach the fill-nozzle to the first inlet-port, as shown in the photo's. For details on the fill-nozzle see drawing.



6) When the Geotube has to be filled in a water-depth > 2.60 meters, the fill operation should start at approx. 1 hour before high tide, with a mixture containing a maximum of 5 percent sand.

7) When the Geotube has to be filled in a water-depth < 2.60 meters, the fill operation should start at approx. 1 hour before low tide, with a mixture containing a maximum of 5 percent sand.

8) As soon as the submerged Geotube has reached the design height or the semi-submerged Geotube reaches a reasonable height and shape, the sand-water mixture may be increased to a maximum of 20 percent solids.

9) Constant monitoring of the sand contents in the mixture must be done in order to prevent blocking of the fill-nozzle or of the Geotube.

10) The height of the Geotube during the fill operation must not exceed the design height, this must be checked continuously, for instance by means of a measuring device spanning two opposite alignment-posts, or other acceptable means of control. The height of the Geotube during filling can be controlled by opening one or more outlets, starting with the outlet farthest away from the inlet-port used by the fill-nozzle.

11) During the fill-operation constant checking of the sand-level inside the Geotube should be maintained. When it is obvious that the sand near the fill-nozzle is going to block further flow to the rest of the Geotube, the fill-nozzle should be removed from the first inlet-port and placed inside the last inlet-port. It may be required to place the fill-nozzle also at the end of the fill-operation into the inlet-port in the middle of the Geotube (inlet-port number 4).

12) After the complete filling of the Geotube, the ropes connecting the Geotube to the alignment-post can be untied and the alignment-posts can be lifted and reused for the next Geotube.

13) The inlet-ports are either sewn shut or tied shut and pushed inside the Geotube.

14) If the speed of the current and/or the wave height are such that the empty Geotube or the Geotube during intial stages of filling, cannot be controlled with the rows of alignment-posts sitting at 10.0 meters distance, the alternative is to set the two rows of alignment-posts the design width of the geotube apart. In this way the Geotube rests directly against the alignment-posts during the fill-operation and is prevented from rolling, curving a.s.o. The removal of the alignment-posts after the filling of the Geotube should be done with extreme care, in order to avoid damage to the fabric of the Geotube. Also constant friction of Geotube against the wooden posts or the steel tubes should be prevented, as this could cause wear to the fabric.

GEOTUBES® AND GEOCONTAINERS®



Period	Country	Project	Description
2001/2003	Bahrein	Reclamation bund for constuction of Amwaj Island	30 km1 Geotube® diameter 4,13 m
2001/2002	The Netherlands	Closure of an artificial lake – Pannerdensch Kanaal	200 Geocontainers® of 280 m3 each 3150 m1 Geotube® diameter 3,20 m
2001	The Netherlands	Construction of a dam, Amsterdam	73 Geocontainers® of 280 m3 each 260 m1 of Geotube® diameter 3,25 m
2000/2001	Singapore	Reclamation Southern Islands	105 Geocontainer® of 590 m3 each
1999/2000	The Netherlands	Breakwater core for the construction of a naviduct near Enkhuizen	10.000 m1 Geotube® diameter 3,92 m
1998/1999	Germany	Krautsand, construction of underwater sill in the river Elbe	497 Ceocontainers® of 350 m3 each
1998	Germany	Twielenfleth, construction of underwater dams in the River Elbe	115 Geocontainers® of 315 m3 each
1997	Taiwan	Extension of artificial Island, Lukang Port	490 Geocontainers® of 190 m3 each
1993-1997	The Netherlands	Breakwater Cores in the Markermeer	9.000 m1 of Geotube®, diameter 3.0 m
1996	The Netherlands	Erosion fill, Zuidbroek	150 Geocontainers® of 180 m3 each
1996	Malaysia	Breakwater cores at Port Dickson	150 Geocontainers® of 600 m3 each 2.200 m1 Geotube® diameter 3,25 m
1995	USA	Hidden protection, Atlantic City Boardwalk	1800 m1 of Geotubes® diameter 3.0 m

INFORMATION AND SALES:

Ten Cate Nicolon bv
P.O. Box 236, 7600 AE Almelo, The Netherlands

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GEOTUBES® AND GEOCONTAINERS®



Period	Country	Project	Product / quantity
1994	USA	Red Eye Crossing, River groynes at the Mississippi River	700 Geocontainers® of 180 m3 and 525 m3 each
1994	USA	Contaminated Soil, Marina Del Rey, Oakland	44 Geocontainers® of 1000 m3 each
1993	Japan	Slope reclamation at Yokohama Port	12 Geocontainers® of 600 m3 each
1992	France	Off-shore breakwater, St. Maries-de-la-Mer	500 m1 of Geotube® diameter 1.6 m
1992	Martinique	Groynes, Gran Rivière	500 m1 of Geotube® diameter 2.2 m
1988-1990	Germany	Retaining bunds reclamation, Leybucht	15.000 m1 of Geotube®, diameter 1.6 m
1989	The Netherlands	Scour protection River Maas	12,000 m1 of Geotube® diamater 1.6 m

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