Geosynthetics Types, Functions & Applications

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Geosynthetics Course, Griffith University,
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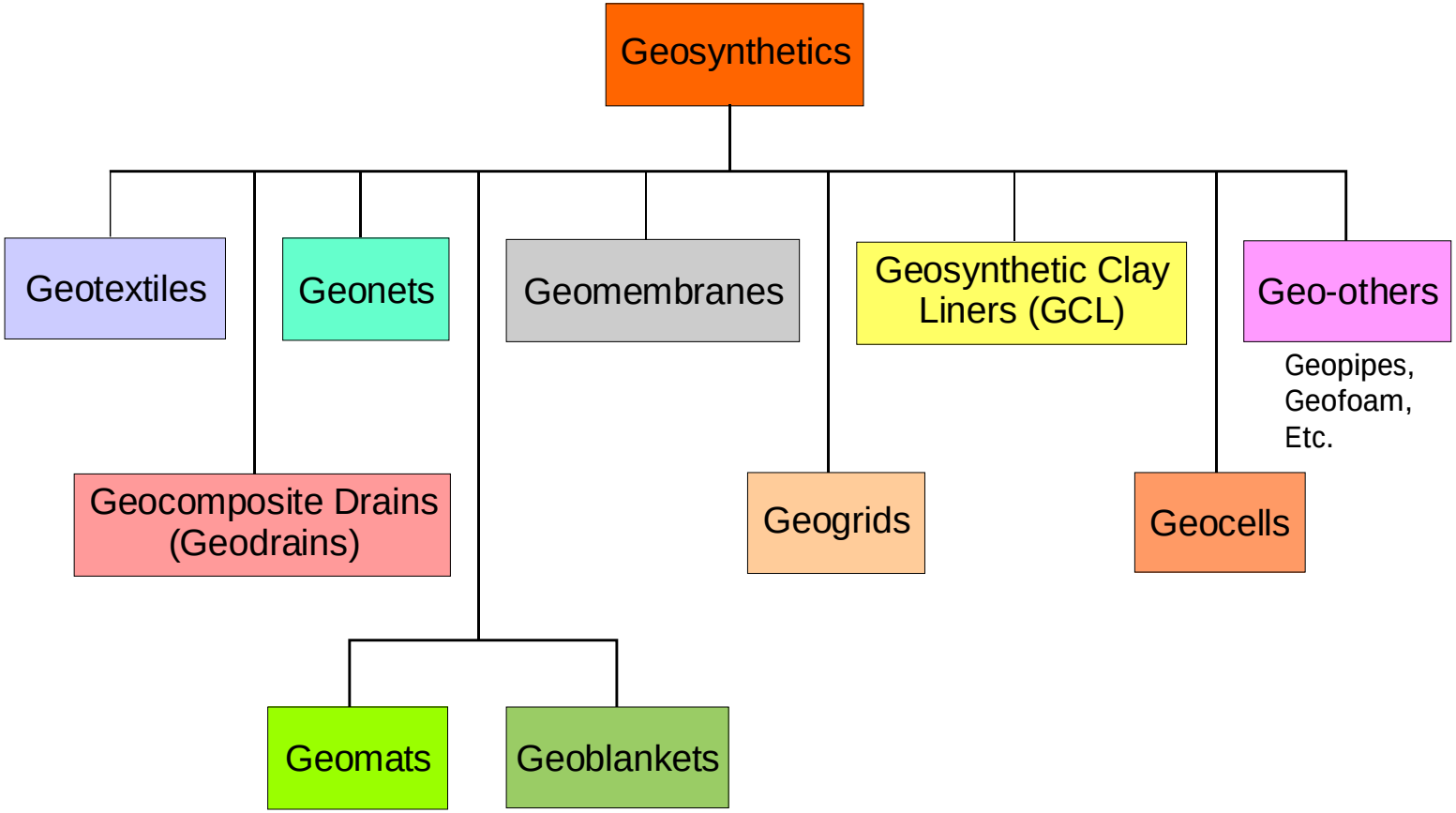
References

- Koerner, R.M. (2005). “Designing with geosynthetics”, Fifth Edition, Prentice Hall, USA.

Geosynthetics

- ***Definition:*** Synthetic materials (man-made and natural) used in a soil (geo) environment



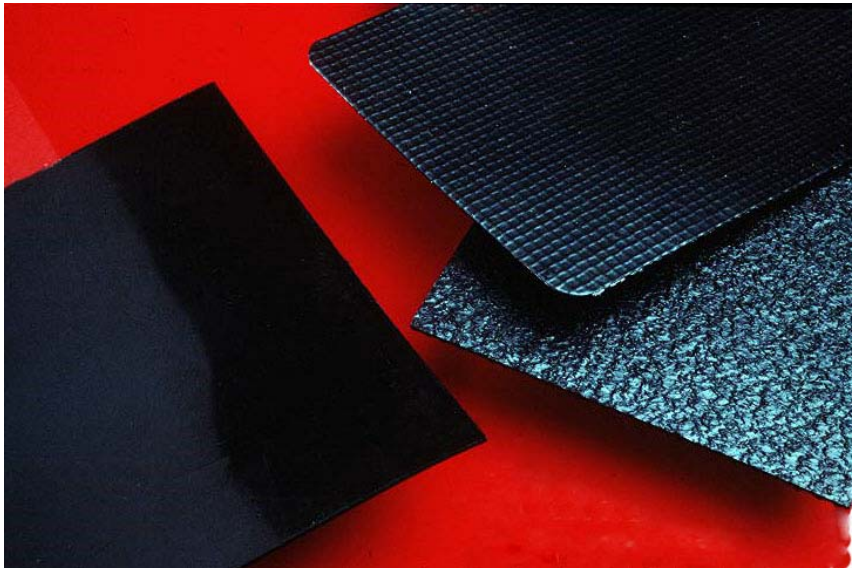
Geosynthetics milestones

- **1960's & 1970's:**
  - Development of geotextiles
  - Geomembranes for water containment
  - Geomats for erosion control
- **1980's:**
  - Geogrids for soil reinforcement
  - PVD's for foundation consolidation
  - Geomembranes for environmental applications
  - GCL's for environmental applications
  - Geotextile containment for hydraulic applications
  - Geonets for drainage
  - Geoblankets for erosion control
- **1990's:**
  - Geofoam for light weight fill
  - Geocells
- **2000's:**
  - Geotextile containment for environmental applications
- Geosynthetics is a maturing industry

Geotextiles

- Geotextiles are planar, permeable materials
- Around 60% of geosynthetics used (by volume) are geotextiles
- Two types:
  - Nonwoven geotextiles (~65%)
  - Woven geotextiles (~35%)
- Nonwovens:
  - Random arrays of circular fibres
  - Short (staple) fibres or continuous filaments
  - Bonding by needle-punching (~90%) or heat bonding (~10%)
- Wovens:
  - Two-directional array of fibres
  - Fibres can be flat tapes, fibrillated tapes, monofilaments or multifilaments
- Around 90% of geotextiles made from polypropylene (PP)

Geomembranes

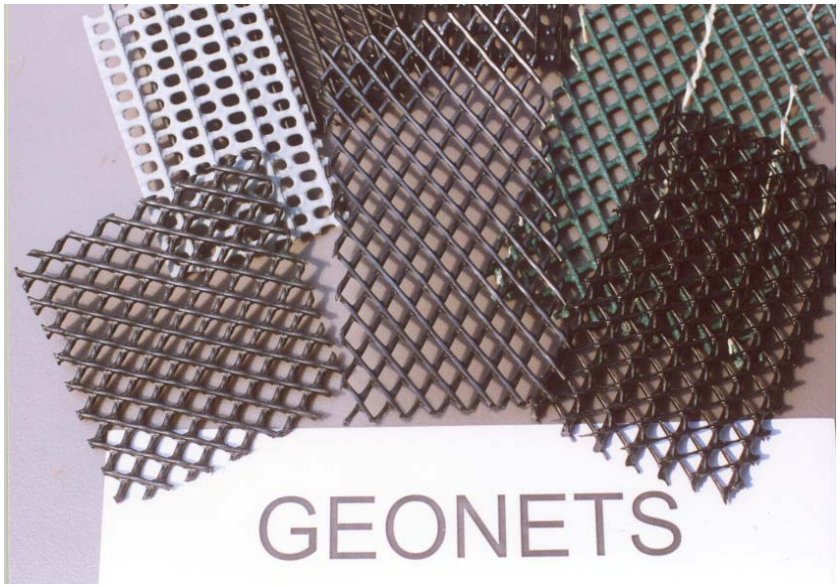


- Geomembranes have very low hydraulic conductivities
  - Provided there are no flaws in the geomembrane
  - Specifically developed as a barrier material
- Around 20% of geosynthetics used (by volume) are geomembranes
- Geomembranes are characterised by:
  - Different polymer types – HDPE, LDPE, PVC, etc
  - Different thicknesses
  - Smooth or rough surfaces
  - Reinforced or unreinforced

Geogrids

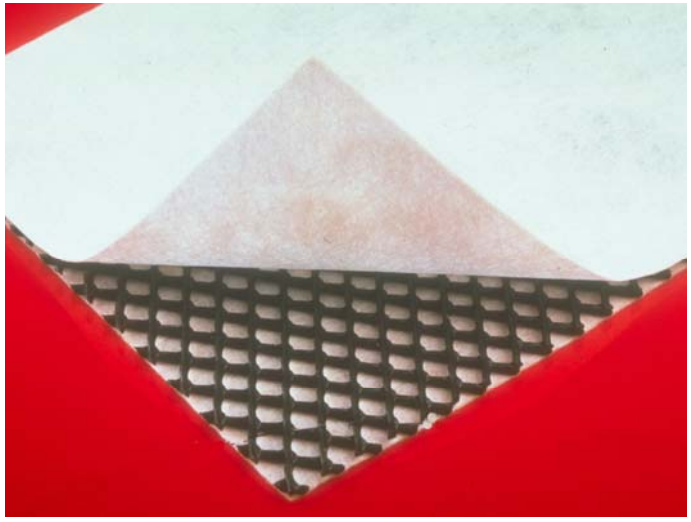
- Geogrids are very open structures
  - Specifically developed for soil reinforcement applications
- Around 10% of geosynthetics used (by volume) are geogrids
- Three types of geogrid:
  - Punched and drawn polymer sheets
  - Textile-based (woven or knitted)
  - Bonded polymer strips
- Medium to high strength, low extension
  - Uniaxial – major strength in length direction
  - Biaxial – similar strength in length and cross directions

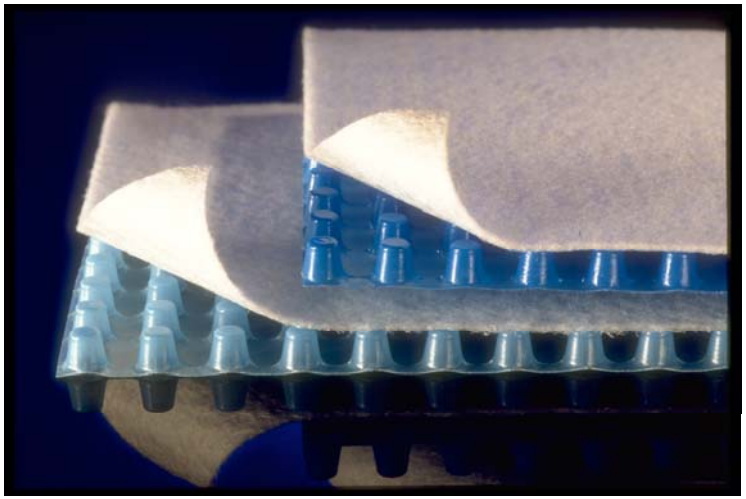
Geonets



- Used for fluid drainage where conventional granular materials are expensive or difficult to place
- Geonets consist of multi-layered polymer strands bonded together
- Two different structures:
  - Bi-planar – two layers of polymer strands
  - Tri-planar – three layers of polymer strands

Geocomposite drains





- Geocomposite drains consist of a polymer spacer (drainage) layer bonded to a geotextile filter
- Used where conventional drainage materials are expensive and difficult to place
- Geotextile filter consists of:
  - Nonwoven geotextile
  - Monofilament woven geotextile
- Drainage core consists of:
  - Geonet, or
  - Cuspated sheet, or
  - Fibrous sheet

Geoblankets

- Permeable, biodegradable structure placed over the soil for temporary erosion control applications while vegetation is being established
- Types:
  - Open weave meshes:
    - Open woven structures of jute, coir or polypropylene
    - Sometimes used to temporarily hold mulch in place
  - Erosion control blanket (ECB):
    - Polyolefin mesh with coir, straw, bark or polypropylene fibre infill

Geoblankets: coir and jute fibres

Geomats

- 3-D permeable, polymeric structure used to reinforce roots of grass and small plants for permanent erosion control applications
- Types
  - Turf Reinforcement Mat (TRM):
    - 3-D structures that reinforce the root zone of light vegetation thereby providing greater erosion resistance
    - Require good bending flexibility for intimate contact with soil
  - Erosion Control and Revegetation Mat (ECRM):
    - 3-D structures that reinforce the root zone and provide ground coverage to prevent erosion
    - Maybe thinner than TRM

Geomats: 3-D TRM's and ECRM's

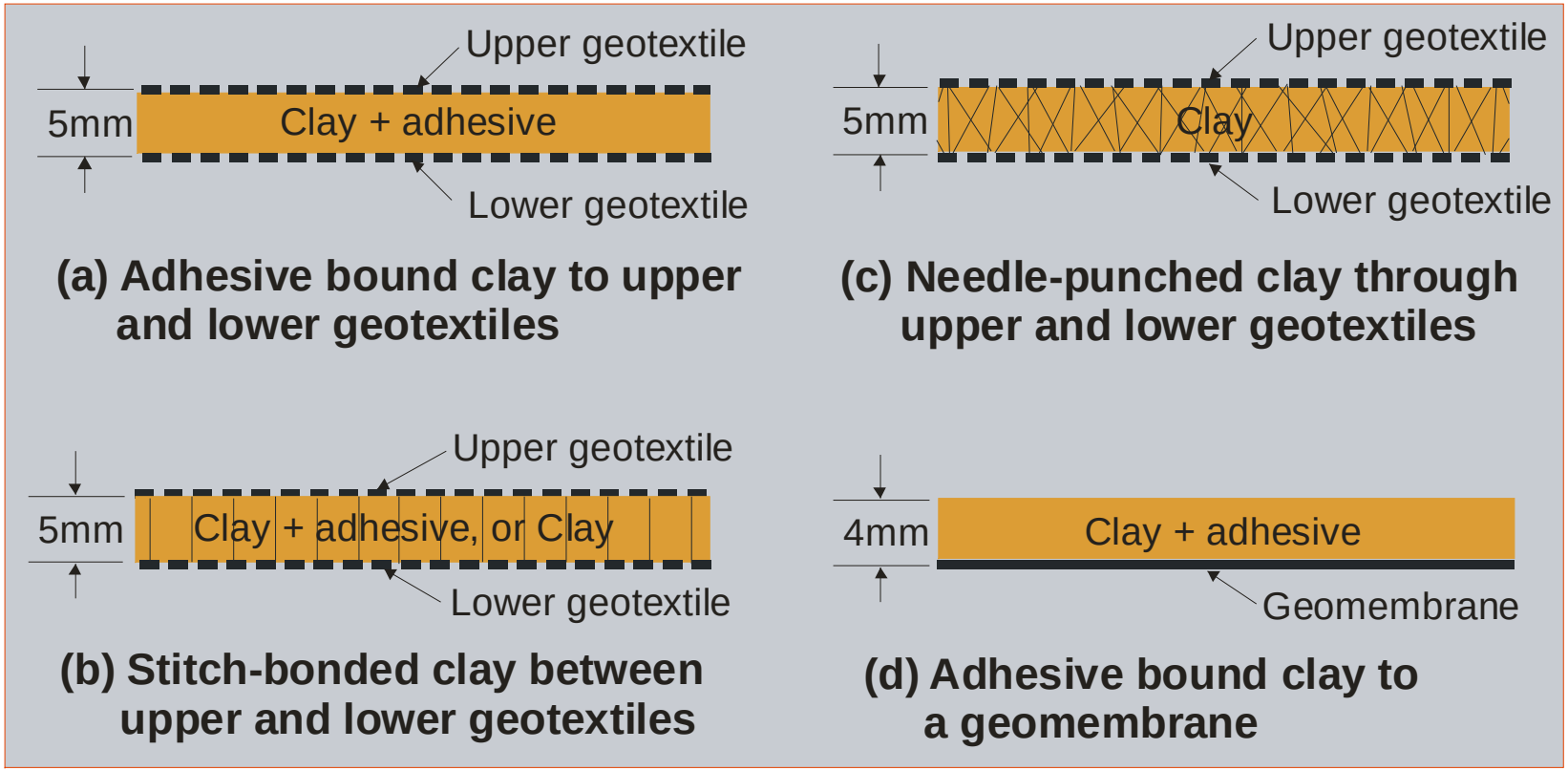
Turf reinforcement mats (TRM's): Top soil and seed placed after geomat installation

Erosion control and revegetation mats (ECRM's): Soil and seed placed before geomat installation

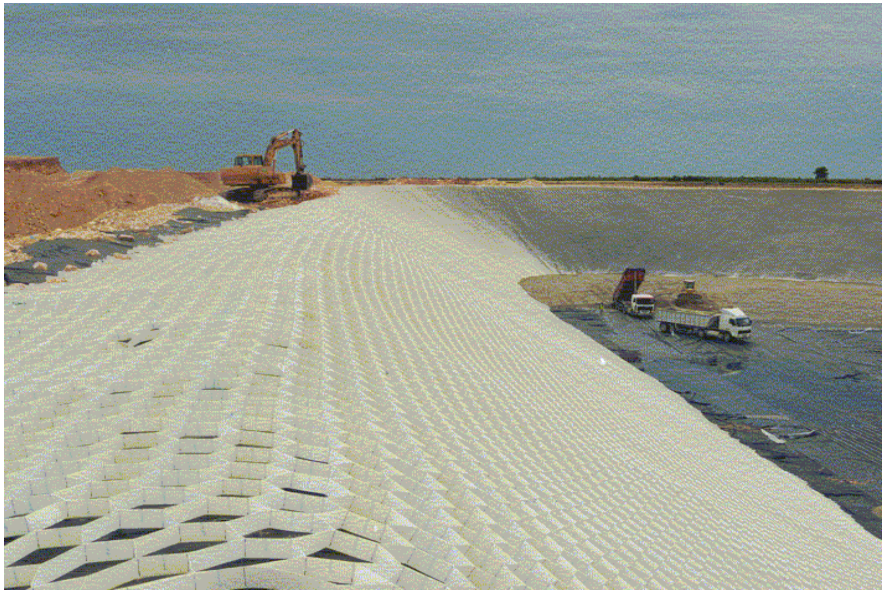
Geocomposite clay liners (GCL's)

- GCL's are relatively thin (5 mm when dry) bentonite clay layers sandwiched between two geotextile layers or against a geomembrane layer
  - When installed the bentonite absorbs moisture and expands to a gel-like consistency – highly water repellent
  - Hydraulic conductivity 10^{-10} to 10^{-12} m/sec
- Moisture needs to have access to the GCL for hydration
- GCL's should be subject to confining pressure during hydration for best barrier properties
- Issue of equivalency with thicker barrier materials, e.g. compacted clay

GCL's: types


Upper geotextile
5mm
Clay + adhesive
Lower geotextile
(a) Adhesive bound clay to upper and lower geotextiles
Upper geotextile
5mm
Clay
Lower geotextile
(c) Needle-punched clay through upper and lower geotextiles
Upper geotextile
5mm
Clay + adhesive, or Clay
Lower geotextile
(b) Stitch-bonded clay between upper and lower geotextiles
4mm
Clay + adhesive
Geomembrane
(d) Adhesive bound clay to a geomembrane

Geocells



- 3-D permeable, polymeric, honeycomb or web structure, used to confine soil or concrete
- Most commonly manufactured from bonded polymer sheets, but maybe nonwoven textile based
- Geocells are characterised by:
  - Strength of polymer sheet used for the cells
  - Size of cells
  - Height
  - Type of cell walls – smooth, rough, perforated

Geopipe

GEOPIPE

Geofoam

GEOFOAM

- Expanded polystyrene blocks
- Light weight fill & insulating material
  - Bulk density 0.1 to 0.4 kN/m^3
- Uses:
  - Light weight fill over soft, and frost susceptible, soils
  - Compressible fill behind retaining walls
  - Thermal insulation to avoid frost pressures

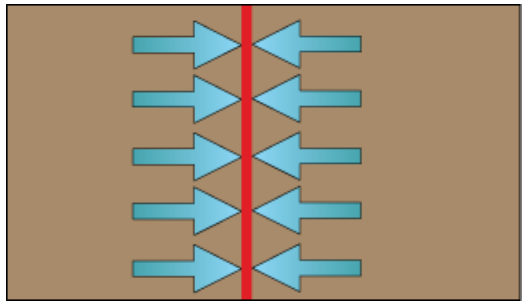
These geosynthetic materials can perform a number of important functions when incorporated in transportation, hydraulic & marine, and environmental structures

Geosynthetics functions

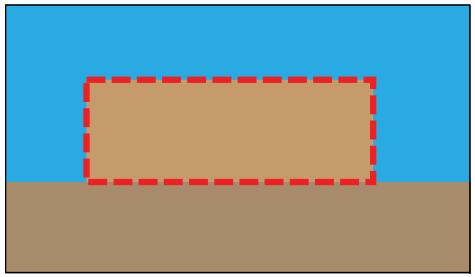
- Barrier – prevents migration of fluids
- Containment – contains soil & sediments to specific shape
- Drainage – collects & transports fluids
- Filtration – allows passage of fluids from a soil
- Protection – localised stress reduction layer
- Reinforcement – resists stresses and strains
- Separation – maintains distinct layer boundaries between two dissimilar materials
- Surficial erosion control – prevents surface erosion of soil particles

Some geosynthetics satisfy a single function, while others satisfy a range of functions

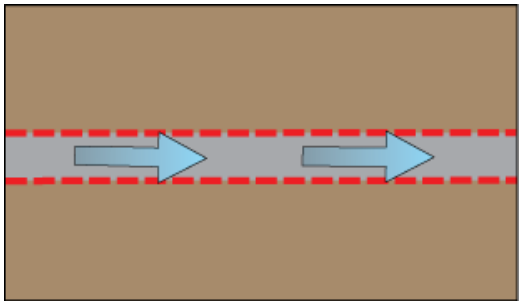
Geosynthetics function: barrier



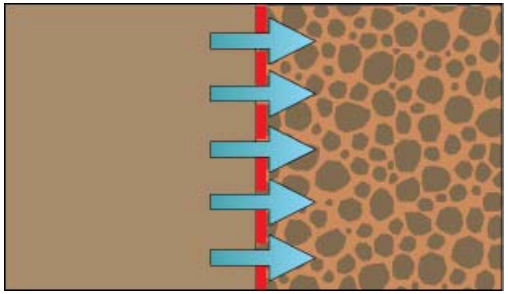
Geosynthetics function: containment



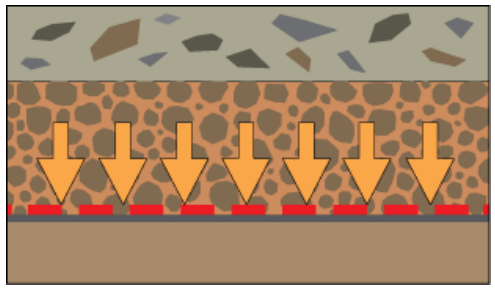
Geosynthetics function: drainage



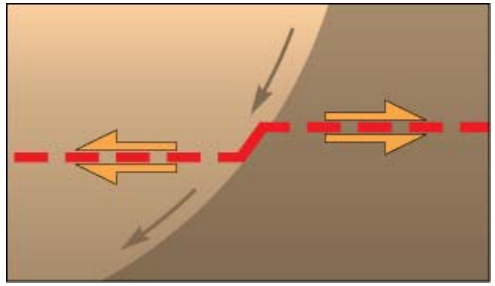
Geosynthetics function: filtration



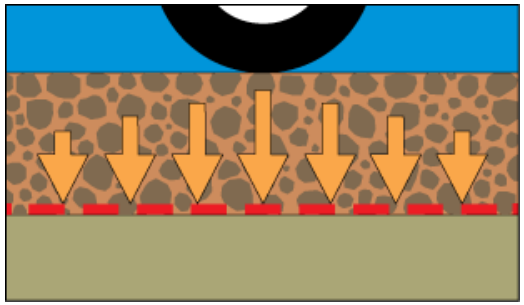
Geosynthetics function: protection



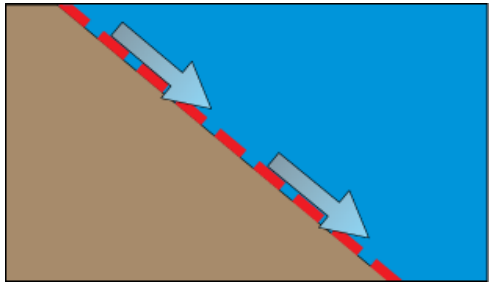
Geosynthetics function: reinforcement



Geosynthetics function: separation



Geosynthetics function: surficial erosion control



Geosynthetics: applications

- Transportation applications
  - Roads, highways & airfields, railways, fills
- Reinforced soil applications
  - Embankments, walls, slopes
- Hydraulic & marine applications
  - Water reservoirs, dams & ponds, rivers & canals, coastal & marine
- Environmental applications
  - Solid & liquid waste containment, remediation, waste processing
- Mining applications
  - Heap leaching of ore
- Agriculture & food production

Transportation applications

- Subgrade separation/stabilisation
- Subbase/base course stabilisation
- Asphalt overlays
- Moisture barriers
- Subsurface drainage
- Structure drainage
- Prefabricated Vertical Drains (PVD's) to accelerate foundation consolidation
- Tunnel linings
- Erosion control – streams & gullies
- Surface erosion control

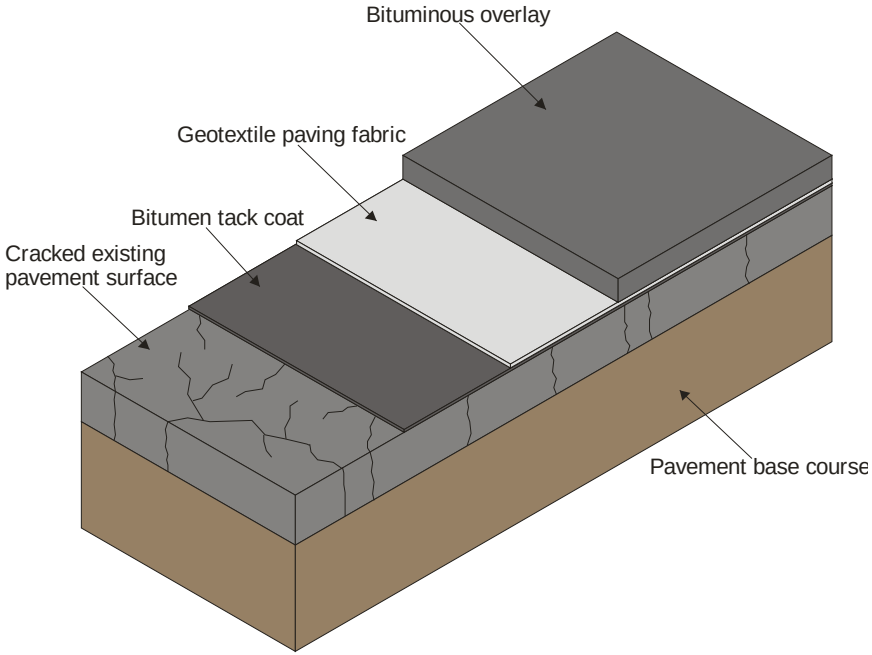
Subgrade stabilisation: geotextile at subgrade/base course interface

- Nonwoven geotextiles
- Woven geotextiles
- Geogrids + nonwoven geotextiles

Subbase/base course stabilisation

- Geogrids
- Woven geotextiles
- Geocells

Asphalt overlays: geotextile as stress absorbing interlayer



- Nonwoven geotextiles
- Geogrids + nonwoven geotextiles

Moisture barriers: expansive clay stabilisation

- Geomembranes

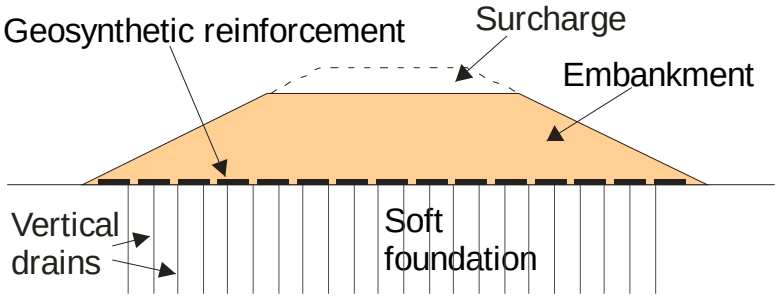
Subsurface drainage: geotextile as a filter

- Nonwoven geotextiles
- Monofilament woven geotextiles

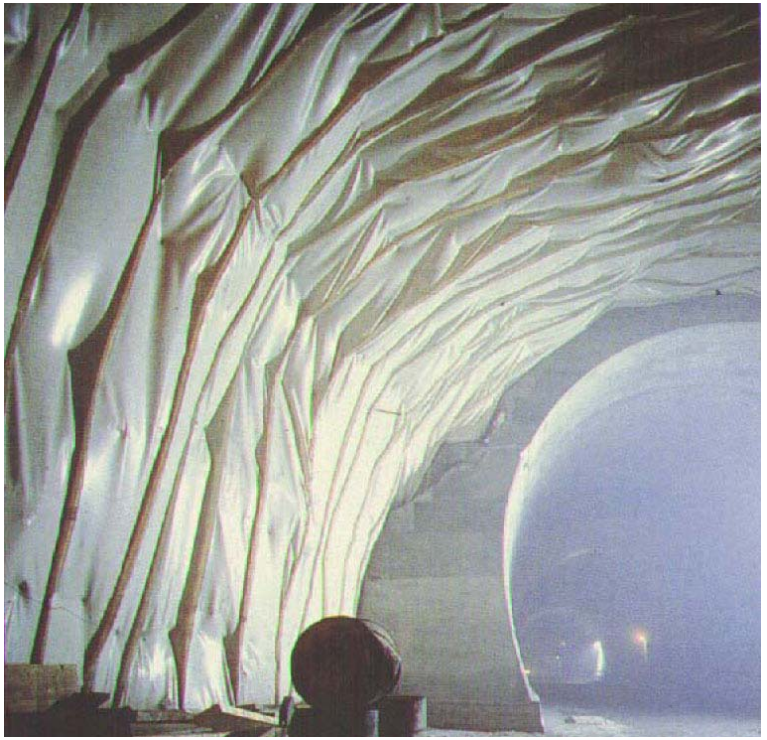
Structure drainage

- Geocomposite drains

PVD's – geocomposite drains to accelerate foundation consolidation



Tunnel linings



- Geomembranes, GCL's
- Nonwoven geotextiles
- Drainage composites

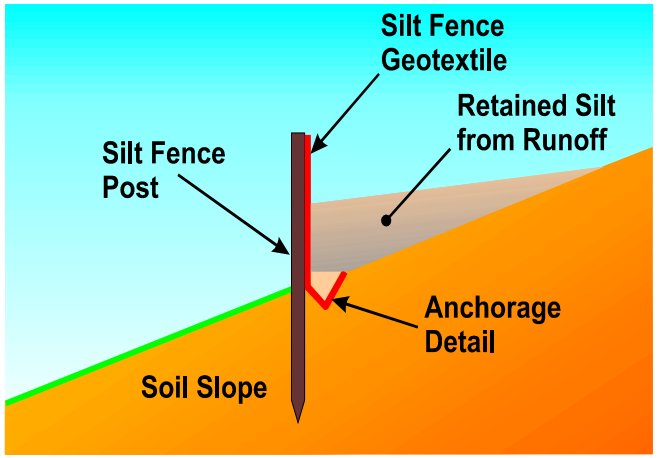
Erosion control: streams & gullies

- Nonwoven geotextiles
- Geomats
- Geotextile mattresses

Surface erosion control: protecting soil surfaces from rainfall run-off

- Geoblankets
- Geomats

Surface erosion control: protecting soil surfaces from rainfall run-off (“silt fence”)

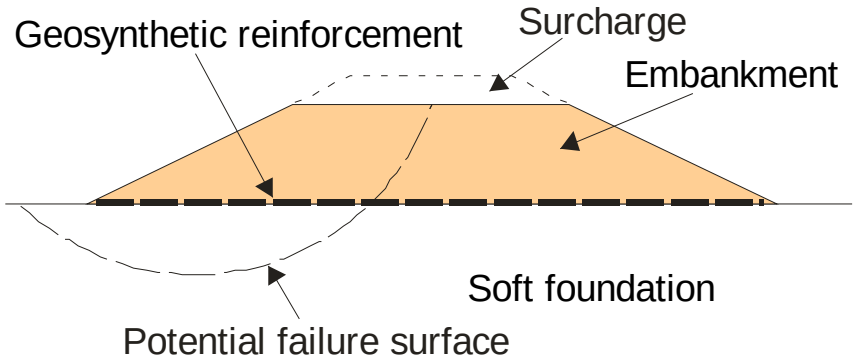


- Woven geotextiles

Reinforced soil applications

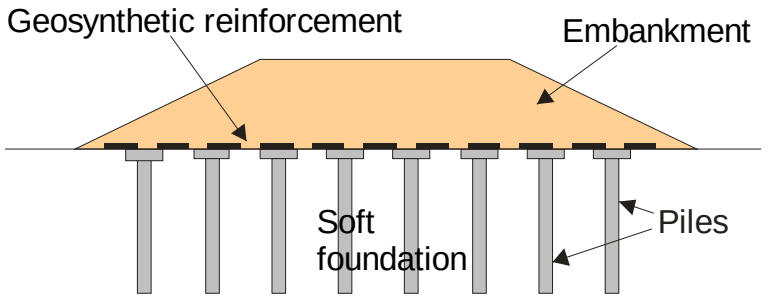
- Basal reinforced embankments on soft foundation soils
- Basal reinforced piled embankments
- Confined stone & sand columns
- Basal reinforced embankments spanning voids
- Reinforced fill slopes
- Reinforced soil retaining walls

Basal reinforced embankments on soft foundation soils



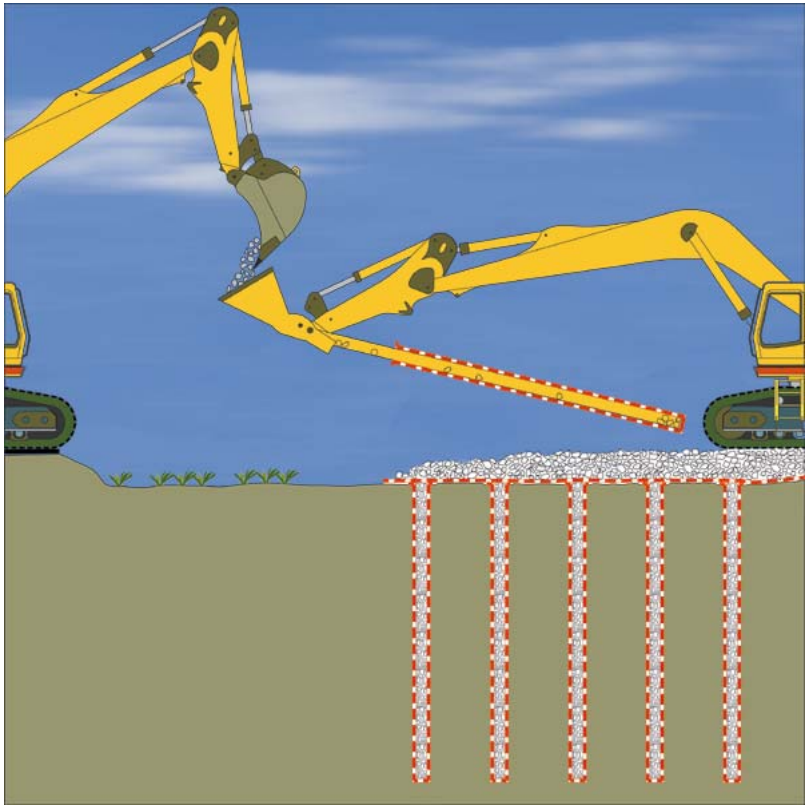
- Woven geotextiles
- Geogrids

Basal reinforced piled embankments



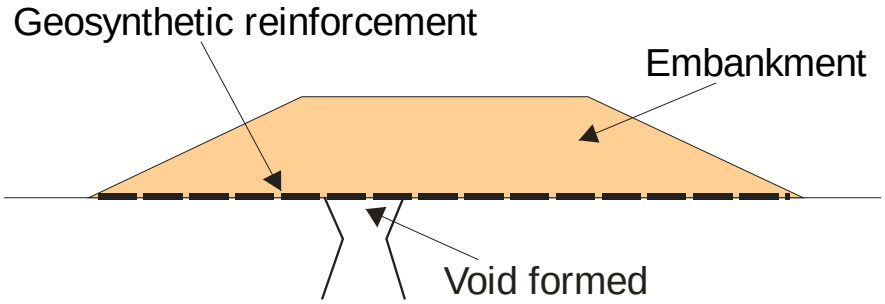
- Woven geotextiles
- Geogrids

Confined stone & sand columns



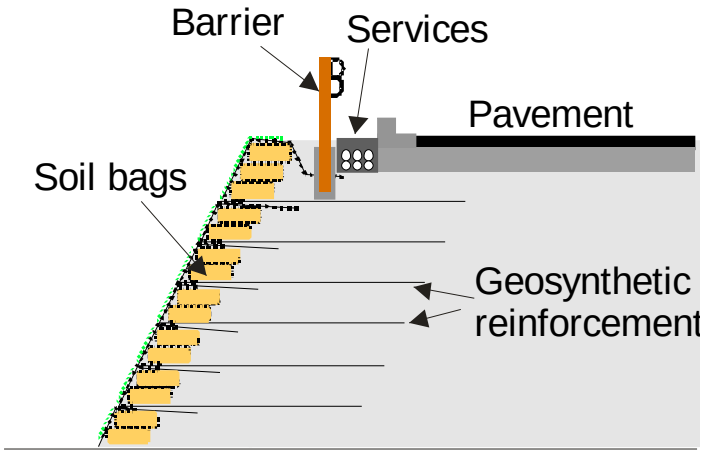
- Woven geotextiles
- Geogrids

Basal reinforced embankments spanning voids



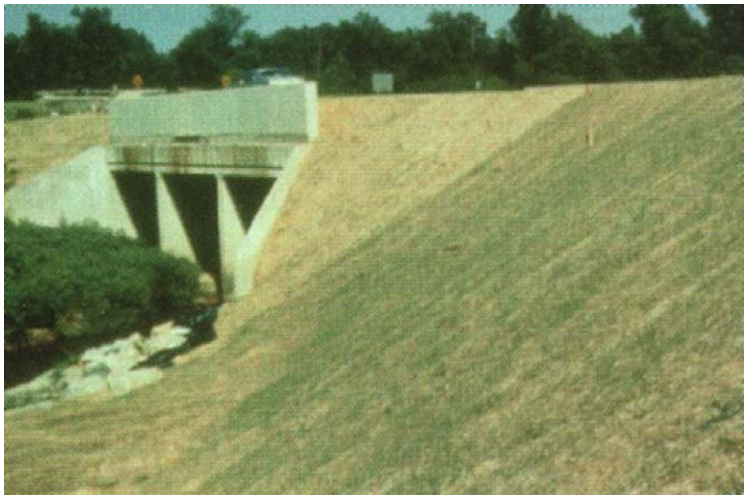
- Woven geotextiles
- Geogrids

Reinforced slopes

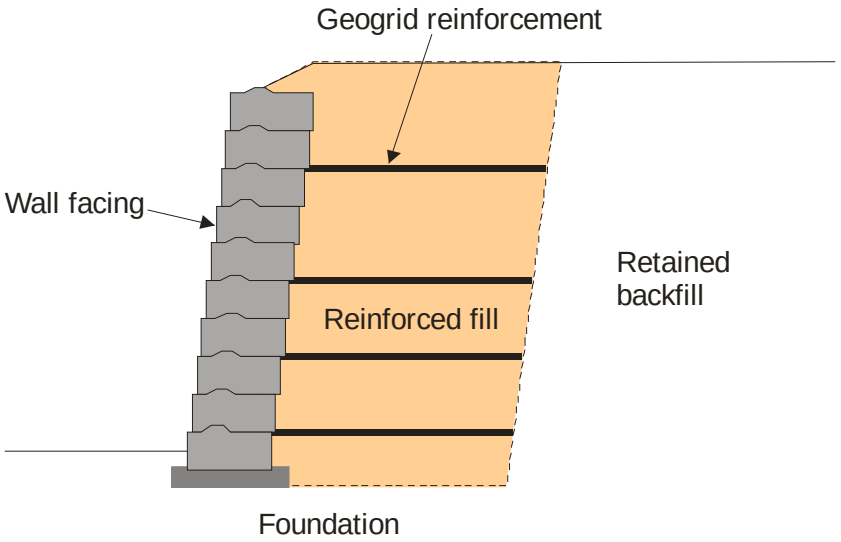


- Geogrids
- Woven geotextiles

Reinforced slopes

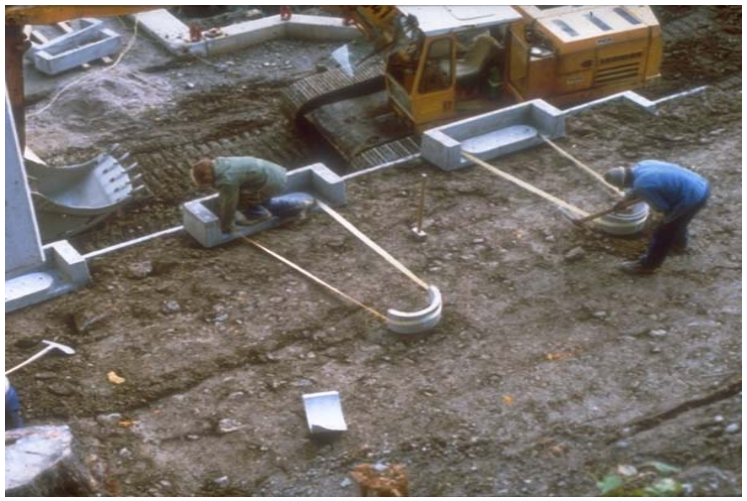


Reinforced soil retaining walls



- Geogrids
- Woven geotextiles
- Composite strips

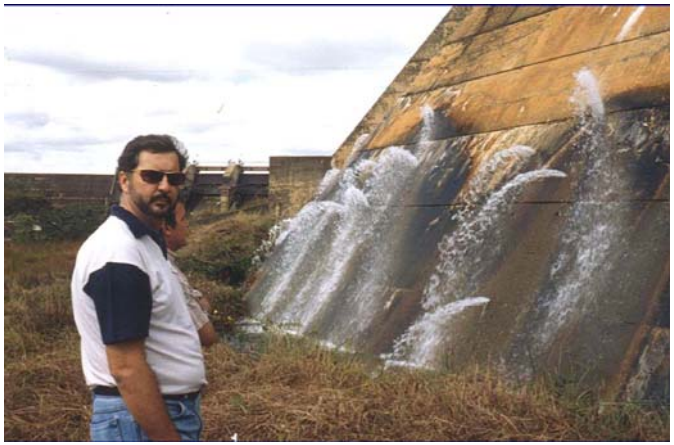
Reinforced soil retaining walls



Hydraulic & marine applications

- Dam &reservoir linings
- Pond linings
- Floating covers
- Canal & channel protection
- Aqueduct linings
- Dam & reservoir filters
- Revetments
- Breakwaters
- Land reclamation
- Groynes
- Artificial reefs
- Offshore containment dykes

Dam & reservoir linings



- Geomembranes + nonwoven geotextiles
- GCL's

Pond linings

- Geomembranes
- GCL’s

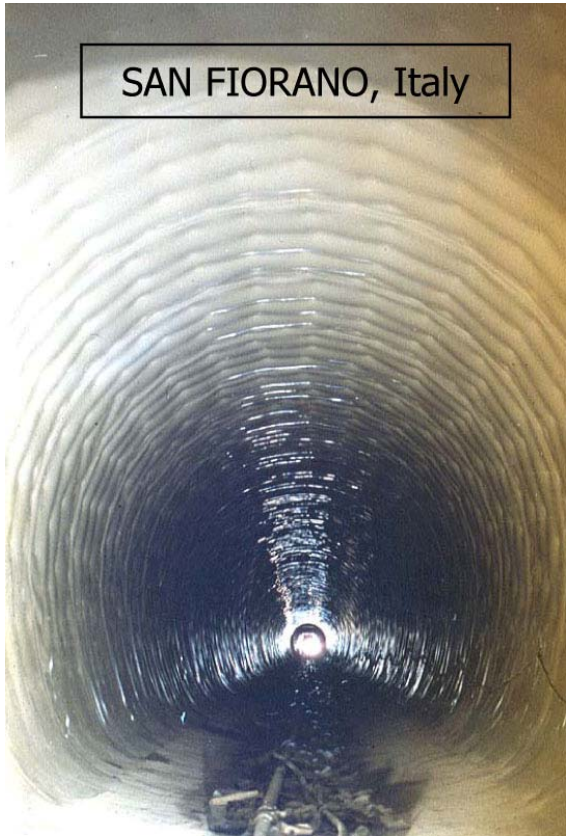
Floating covers

- Geomembranes

Canal & channel protection

- Geotextiles
- Geocomposite drains
- Geomembranes, GCL's
- Geomats

Aqueduct linings

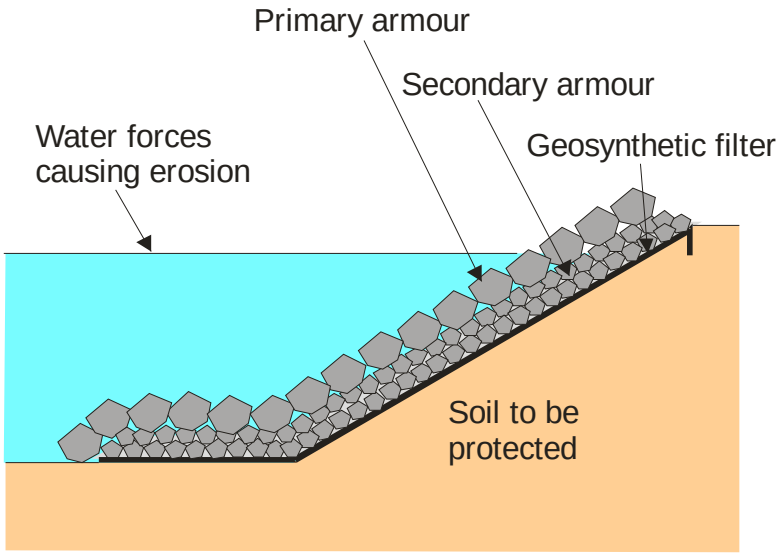


- Geomembranes + nonwoven geotextiles

Dam & reservoir filters

- Nonwoven geotextiles
- Woven geotextiles

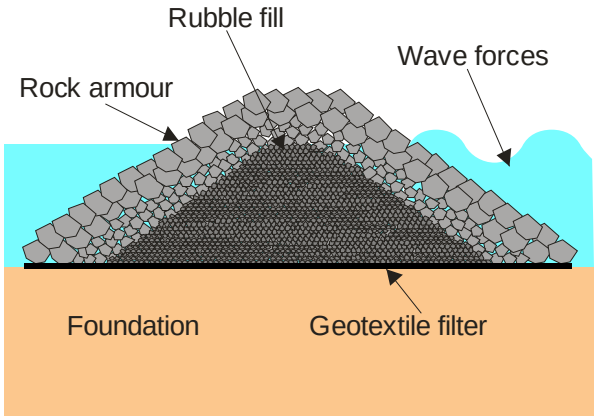
Revetments: filter beneath armour protection

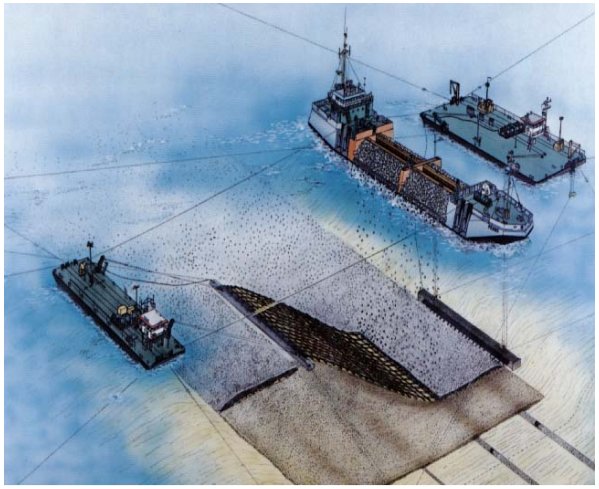


- Nonwoven geotextiles
- Woven geotextiles

Revetments: filter beneath armour protection

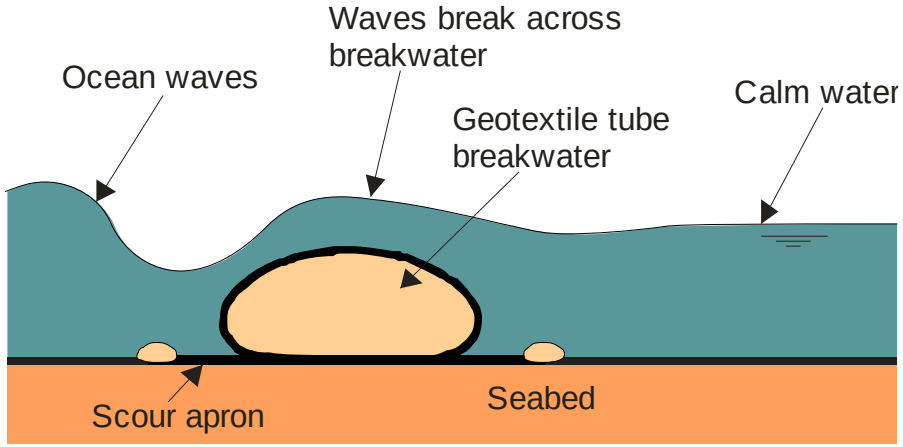
Breakwaters: base filter for breakwater





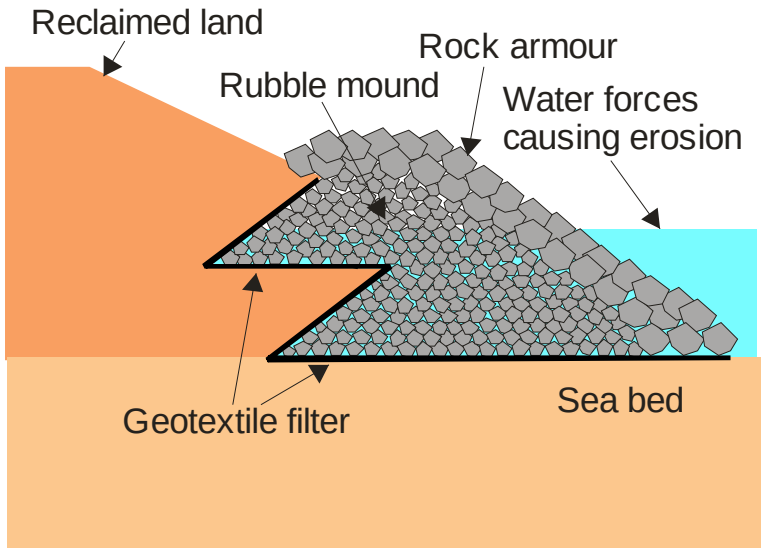
- Woven geotextiles

Breakwaters – geotextile tube offshore breakwaters



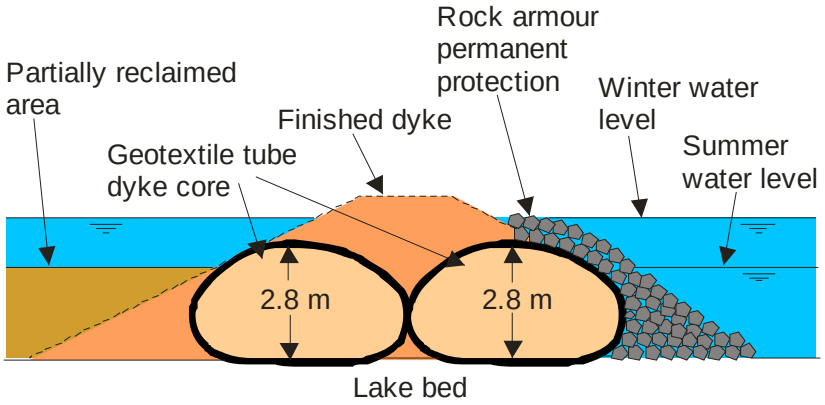
- Woven geotextiles
- Nonwoven geotextiles

Land reclamation: geotextile filter



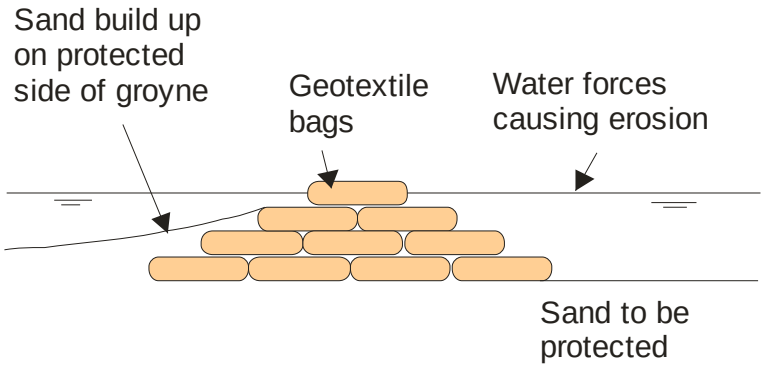
- Woven geotextiles
- Nonwoven geotextiles

Land reclamation: geotextile tube containment dykes



- Woven geotextiles
- Nonwoven geotextiles

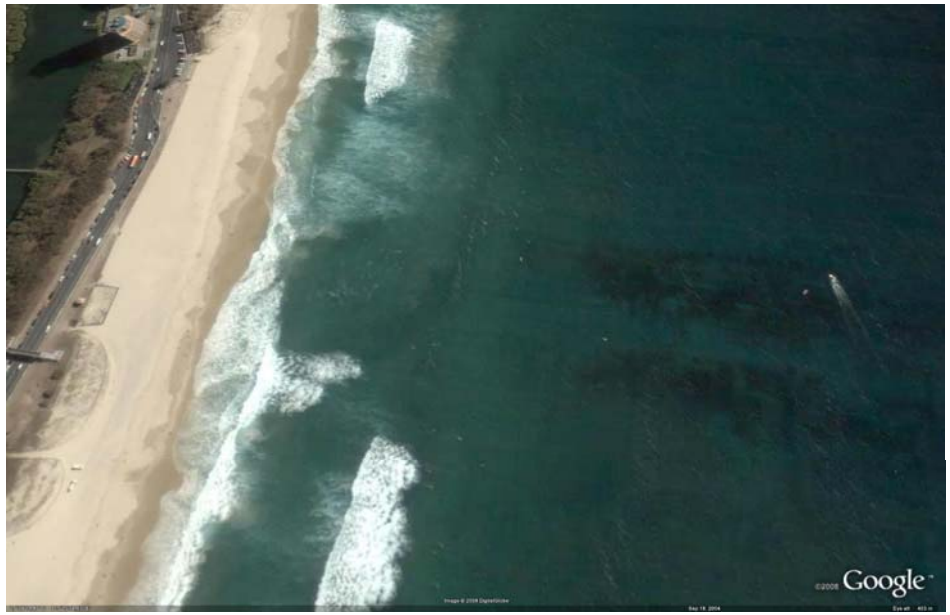
Groynes: geotextile bag units

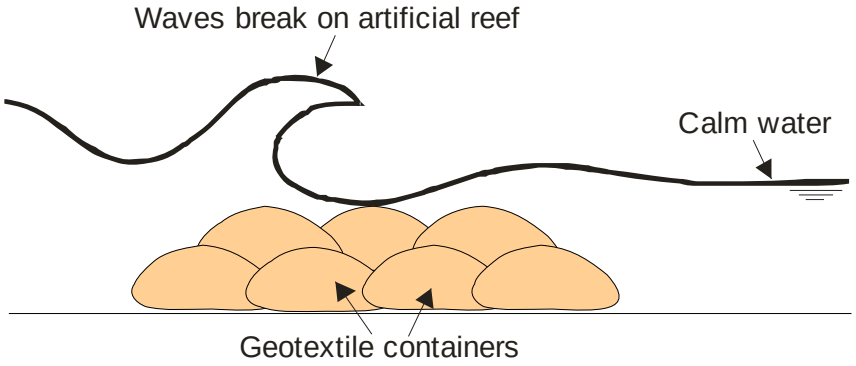


Groynes

- Nonwoven geotextiles
- Woven geotextiles

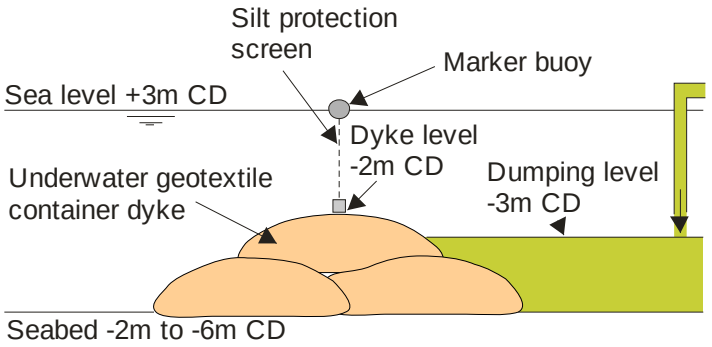
Artificial reefs: geotextile container units





- Woven geotextiles
- Nonwoven geotextiles

Offshore containment dykes: geotextile container units



Section through containment dyke

- Woven geotextiles
- Nonwoven geotextiles

Environmental applications

- Solid waste containment - landfills
- Liquid waste containment
- Vertical cut-off walls
- Protection layers
- Leachate collection layers
- Differential settlement protection
- Reinforced bunds to increase containment capacity
- Closure of waste ponds
- Dewatering of slurry waste & contaminated sediments

Solid waste containment: base liners

- Geomembranes
- GCL's

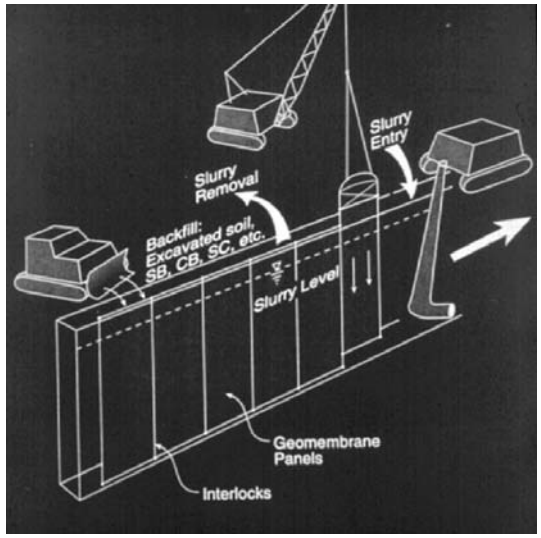
Solid waste containment: capping liners

- Geomembranes
- GCL's

Liquid waste containment: base liners

- Geomembranes
- GCL’s

Vertical cut-off walls – geomembrane panel



- HDPE Geomembrane

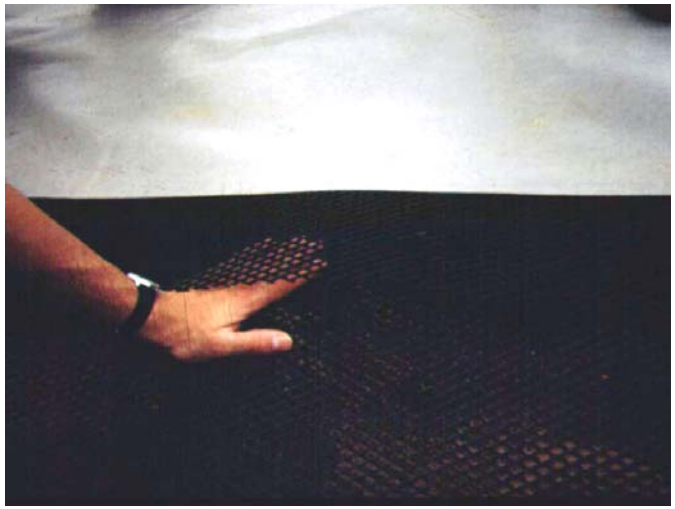
Geomembrane protection layers

- Needle-punched nonwoven geotextiles
- Sand mattresses

Leachate collection drains: geotextiles filters

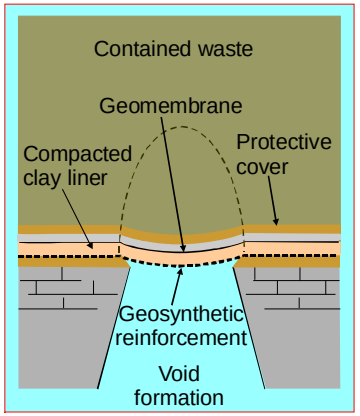
- Monofilament woven geotextiles

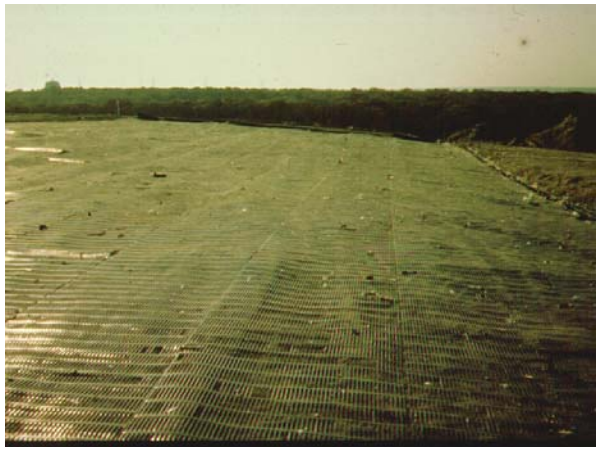
Leachate detection drains: geonet drains



- Geonets

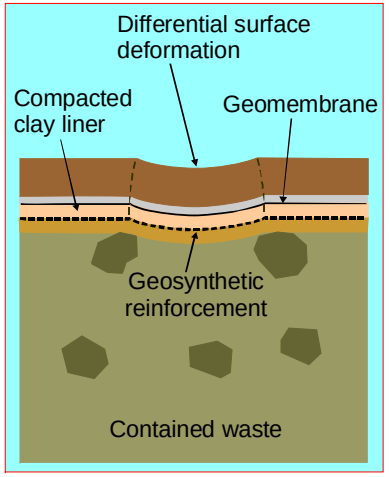
Differential settlement protection





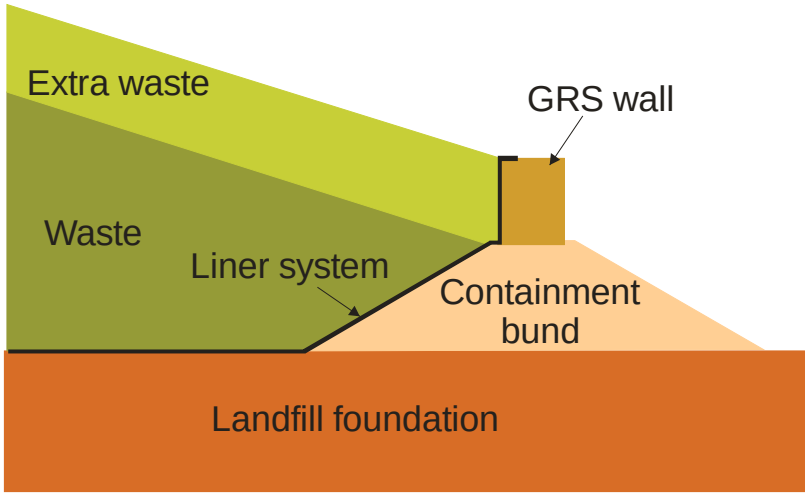
Base liner system

- Geogrids
- Woven geotextiles



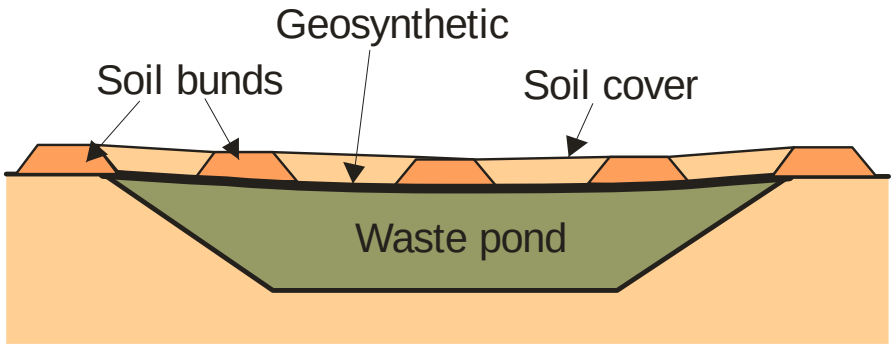
Cap liner system

Reinforced bunds to increase containment capacity



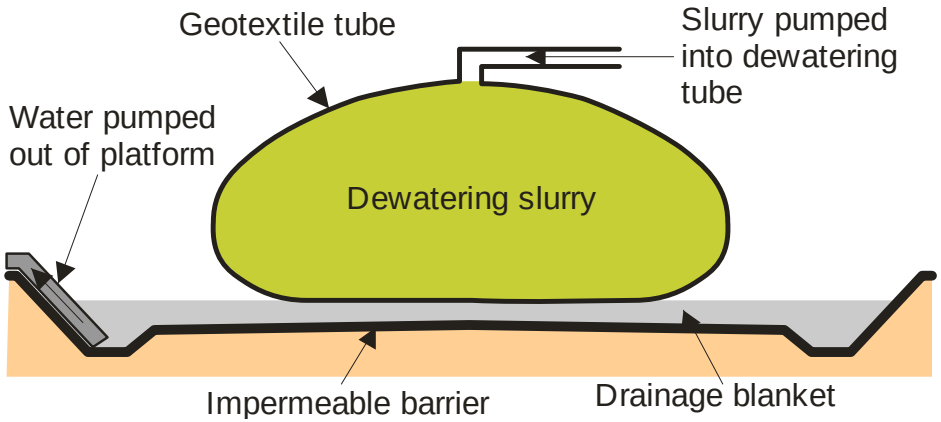
- Geogrids
- Woven geotextiles

Closure of waste ponds

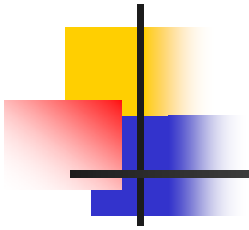


- Woven geotextiles

Dewatering of slurry waste – geotextile tube dewatering



- Woven geotextiles



Mining applications

- Mining uses a range of the previous applications already covered
- Heap leaching of ore

Heap leach pads

- Geomembranes
- GCL's

Conclusions

- The geosynthetics discipline has developed around a family of products – the types are growing
- These geosynthetic products can perform a number of important functions when incorporated in transportation, hydraulic & marine, environmental and mining structures
  - Several functions may be performed in the one application
- The range of applications where geosynthetics are used is diverse – new and more refined applications are developing all the time
- Today, it is almost impossible to practice geotechnical, highway, environmental and mining engineering without using geosynthetics