Use of Geotextiles in Land Reclamation

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- Nonwoven, woven and composite geotextiles
- Conventional reclamation boundary protection on firm foundations
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- Reclamation fills
- Offshore underwater containment facilities
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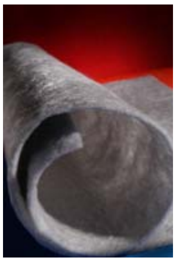
Land reclamation works


- Land reclamation works are constructed for a variety of reasons and uses
- Key issues are:
  - Hydraulic conditions
  - Foundation conditions
  - Containment dyke and seawall structures
  - Reclamation fill
- Focus of presentation will be on how geotextiles can be used to satisfy these issues
- Earliest land reclamation works using geotextiles in HK in 1972



Nonwoven geotextiles




- Fibres in random arrays
- Robust geotextiles with high elongations (40% to 70%)
  - High water flow rates
- Able to deform easily
- Excellent filters in marine applications
  - Revetment filters
  - Containment dyke filters

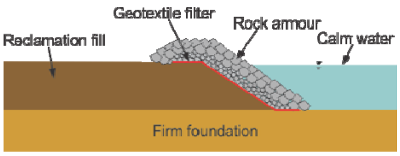
Woven geotextiles

- Fibres in orthogonal array
- Robust geotextiles with low elongations (≤ 15%)
- Able to restrict deformations
- Able to provide structural resistance
  - Installation at water depth
  - Marine structural units

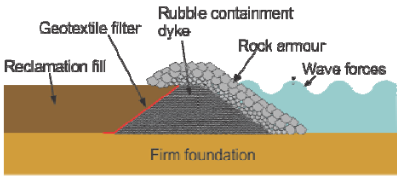
Composite geotextiles

- Composite nonwoven+nonwoven or woven+nonwoven geotextiles
  - Utilise the best attributes of each component
- Excellent durability and abrasion resistance
- Used in beach protection works

Reclamation boundary depending on hydraulic conditions



a) Conventional revetment to protect reclamation fill placement



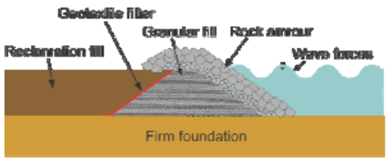
b) Rubble containment dyke to protect reclamation fill placement

- Land reclamation is performed in a wide variety of hydraulic conditions
- Where hydraulic conditions are benign then the reclamation fill can be placed with a revetment layer added for the final boundary protection
- Where hydraulic conditions are variable and severe a containment dyke is first constructed in order to retain the reclamation fill
- Other issues, such as water depth, etc. also impact the reclamation design
- Here, the geotextile is used as a filter – designed accordingly

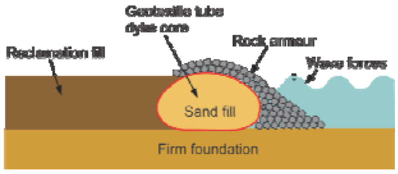
Geotextile filter design and selection approach

- Geotextile mechanical property requirements
  - Ensures the geotextile is not damaged and ruptured during construction
  - Standard procedures exist
- Geotextile hydraulic property requirements
  - Ensures the geotextile retains the reclamation fill but allows water to pass
  - Standard procedures exist
- Geotextile durability requirements
  - Ensures the geotextile lasts for required design life
  - Standard procedures exist

Alternative containment dyke structures



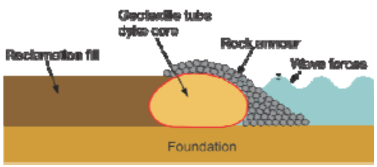
a) Rubble seawall to protect reclamation fill placement



a) Geotextile tube to protect reclamation fill placement

- Commonly, containment dykes consist of granular fill with a geotextile filter on the inside surface
- However, more use is being made of geotextile tube containment dykes as the amount of granular materials required is significantly reduced
  - More use of local sand
  - Can stack the tube units for different heights
  - Can easily change geometry to handle soft foundation conditions
  - Application of rock armour for final protection

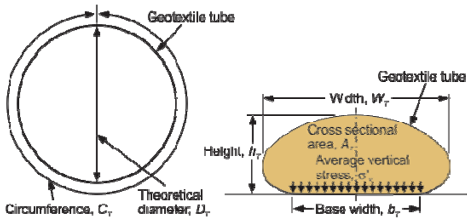
Geotextile tube containment dykes



- **Tubular containment formed insitu** on land or in water
- Diameters 2 to 5 m
- Hydraulically filled with sand, silty sand for hydraulic & marine applications
- Normally filled to maximum density and volume for stability and shape
- Mass-gravity structures for hydraulic & marine applications
- Good geometrical tolerances can be obtained

Geotextile tubes: filling

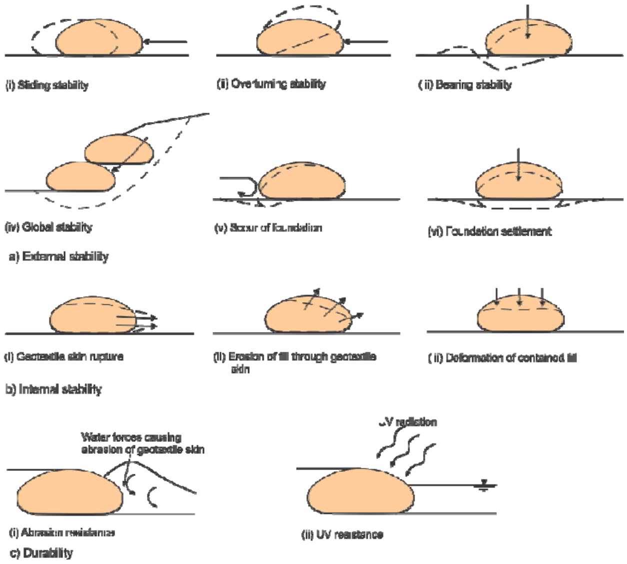
Geotextile tubes: important parameters



a) Empty geotextile tube parameters b) Filled geotextile tube parameters

Parameter	In terms of theoretical diameter, D_T	In terms of circumference, C_T
Maximum fill height, h_T	$h_T \approx 0.5\ D_T$	$h_T \approx 0.16\ C_T$
Filled width, W_T	$W_T \approx 1.6\ D_T$	$W_T \approx 0.5\ C_T$
Base contact width, b_T	$b_T \approx 1.1\ D_T$	$b_T \approx 0.35\ C_T$
Cross sectional area, A_T	$A_T \approx 0.57\ D_T^2$	$A_T \approx 0.06\ C_T^2$
Average vertical stress at base, σ_v'	$\sigma_v' \approx 0.6\ \gamma\ D_T$	$\sigma_v' \approx 0.19\ \gamma\ C_T$

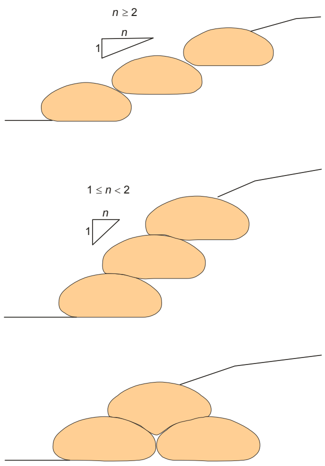
Geotextile tubes: design limit states



Use of armour protection on geotextile tubes

- The most common long term protection for geotextile tube containment dykes in land reclamation works is rock armour
- The armour layers should be designed as a conventional revetment
  - This may require more than one armour layer over the geotextile tube
- Consideration needs to be given as to the maximum rock size that can be placed directly against the geotextile tube
  - Maybe an additional geotextile protection layer will be required

Geotextile tubes: stacking

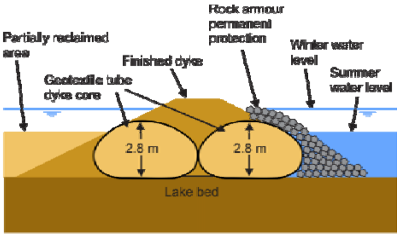


- For additional protection heights stacking of tubes may be required
- For gentle slopes the weight of the above tubes do not impact the stresses on the lower tubes
- For steep slopes the stresses imposed by upper tubes impact the stresses of the lower tubes
- For triangular shaped stacked tubes, the upper tube impacts the stresses on the lower tubes, and also additional stresses are imposed at the base of the upper tube
- Stacking geometry also governed by foundation soil strength

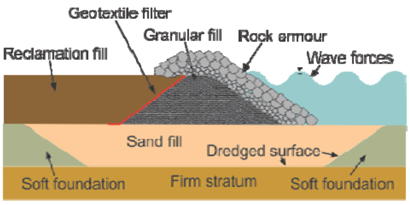
Wetland creation at Lake Marken, The Netherlands

- The Naviduct project involved the dredging of sediments to construct a new ship lock through the existing main dyke
- The dredged material, which consisted of a combination of sand and silt, had to be disposed of in an environmentally acceptable manner.
- It was decided to use the dredged sediment for the creation of a wetland area within Lake Marken.

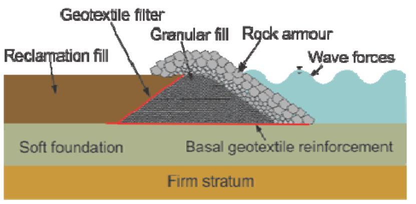
Wetland creation at Lake Marken, The Netherlands



Containment dykes on soft foundation soils



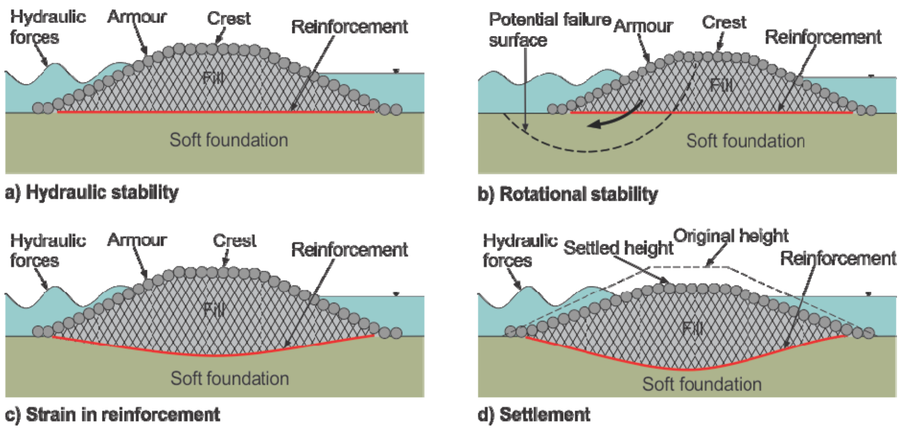
a) Conventional containment dyke on soft foundation



b) Basal reinforced containment dyke on soft foundation

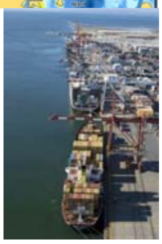
- Historically, common practice for large containment dykes and seawalls located on soft foundations is to dredge soft foundation and replace with sand fill before dyke is constructed
  - No settlement issues
  - However, expensive
- For smaller dykes and seawalls use basal reinforcement for stability
  - Use buoyant unit weight of fill
  - Need to account for settlements
- Standard Codes of Practice such as BS8006 used to design these basal reinforced dykes and seawalls
  - Today, standard practice (follows onshore practice)

Basal reinforced containment dykes and seawalls: design limit states



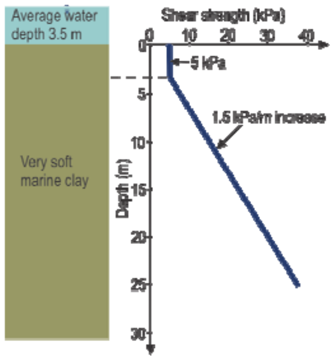
Seawall construction, Brisbane Port, Australia

Courtesy Ameratunga et. al.



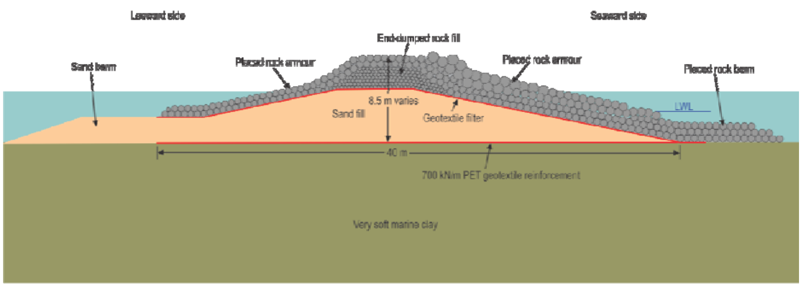
- **General**
  - Brisbane Port, located at mouth of Brisbane River, undergoing major expansion due to increased trade and concentration of Port activities into one location
  - Expansion:
    - Reclaimed 230 ha area to North East of existing port area
    - Plan to construct a 4.6 km seawall around the expansion area
    - Fill the expansion area with spoil from maintenance dredging operations to create the land bank
  - Environmentally sensitive area, near Moreton Bay Marine Park

Seawall construction, Brisbane Port, Australia



- **Foundation conditions**
  - Along North side up to 4 m sand overlying soft marine clay
  - Along East side up to 30 m very soft marine clay
    - Water depth averaged 3.5 m
    - Undrained shear strengths 5 kPa at surface, then strength increasing linearly with depth from 3 m down
    - For stability, basal reinforcement was used
    - Anticipated settlements during construction – 1 m

Seawall construction, Brisbane Port, Australia



- **East seawall**
  - Use of geotextile basal reinforcement to provide required stability for seawall
  - Placement of sand-fill to height and side slopes
  - Placement of geotextile filter over sand-fill prior to surface placement of rock-fill
  - Placed rock armour

Seawall construction, Brisbane Port, Australia

- **Geotextile reinforcement placement**
  - GR fabricated into 40 m lengths on land and then transferred to barge for installation
    - Seamed to existing GR on barge prior to installation
    - Steel reinforcing bars used to hold GR in position on seabed
  - Sand-fill spread hydraulically over GR in layers to height required
    - Side slopes graded to requirement
  - Installation carried out during times of calm weather
  - Careful to contain any water pollution

Seawall construction, Brisbane Port, Australia

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Seawall construction, Brisbane Port, Australia

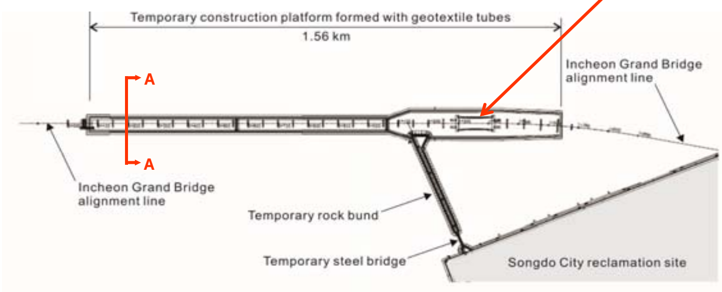
- Over time, the plan is to fill the reclamation area with spoil dredged from the shipping channel
  - Then carry out ground improvement works to prepare the platforms for development

Seawall construction, Brisbane Port, Australia

Artificial island for Incheon Bridge Project, Korea

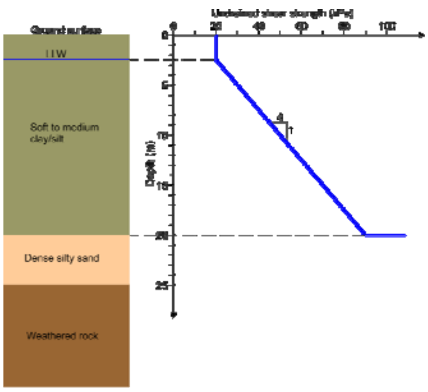
Artificial island for Incheon Bridge Project, Korea

Section A-A



Plan view of geotextile tube artificial island

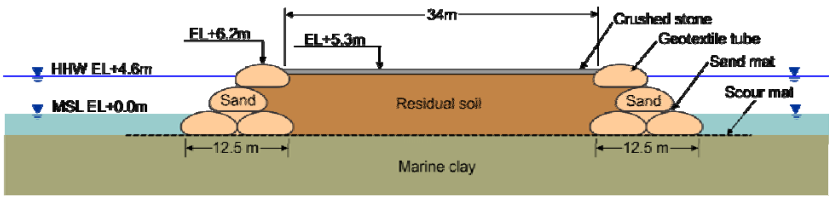
Artificial island for Incheon Bridge Project, Korea



- **Local conditions**
  - High tidal range – 9.2 m
  - Significant wave height 2.0 m at 10 secs
  - At low tide the area consists of mud flats
    - Fairly flat, 1.8 m change in surface level over 1.5 km distance
  - Foundation consists of 20 m of soft marine clay overlying sands and weathered soil and rock
  - Site investigation mainly concentrated on foundations for the viaduct piers
    - Some SPT, FV and CPT testing in the soft marine clay layer

Artificial island for Incheon Bridge Project, Korea

Planned cross section

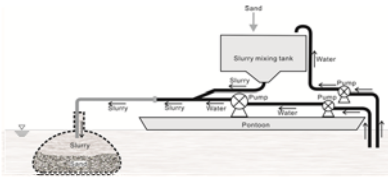


- Geotextile tube containment dyke slope approx. 45° with a maximum height of 8 m
  - Height to accommodate tides + design waves
- 5 m, 4 m and 3 m diameter tubes used for the containment dykes
  - 2,1,1 configuration

Artificial island for Incheon Bridge Project, Korea

Artificial island for Incheon Bridge Project, Korea


Placing sand into slurry mixing tank



Schematic of mixing and pumping setup

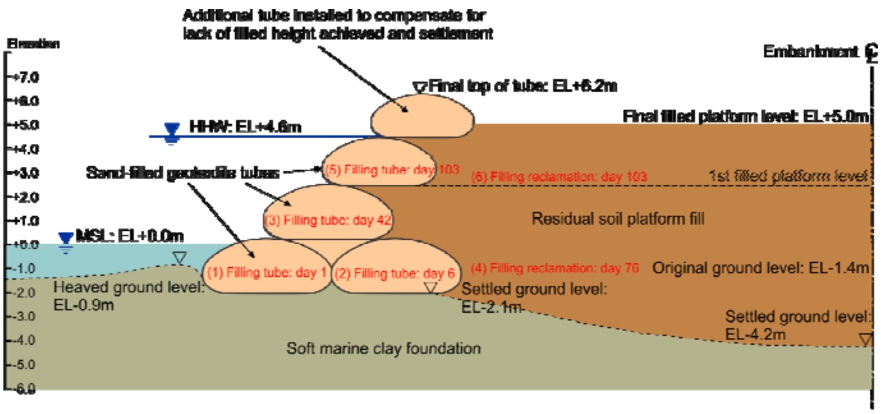
- **Sand / slurry details**
  - Sand sourced nearby and barged onto site
    - Medium – coarse sand, well-graded
  - Mixed with seawater on adjacent barge and pumped into geotextile tubes at ratio around 1:4
    - Slurry delivery around 150 m^3/hr
    - Tubes filled during high tide

Artificial island for Incheon Bridge Project, Korea

Artificial island for Incheon Bridge Project, Korea

Artificial island for Incheon Bridge Project, Korea - settlements

Settlements



Artificial island for Incheon Bridge Project, Korea

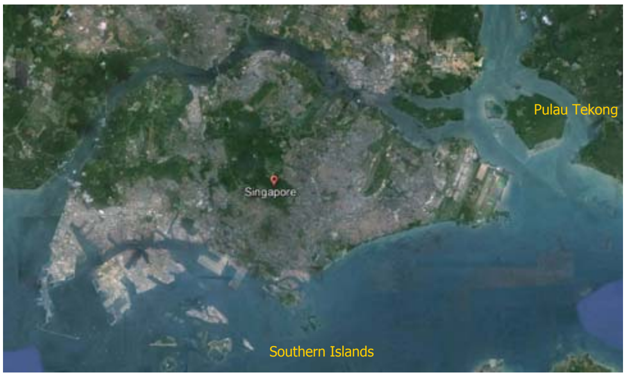
Artificial island for Incheon Bridge Project, Korea

Reclamation fills

- Reclamation fills are placed either by hydraulic or dry means
- Preferred fill type is sand or granular fill
  - However, these fill types are becoming expensive and in some cases impossible to obtain
- Fine grained fills are being utilized in an increasing number of reclamation projects
  - Because of cost and environmental reasons
  - This brings other issues that require solving
    - Bearing capacity/stability
    - Settlements/consolidation

Offshore underwater containment facilities

Southern Islands development, Singapore

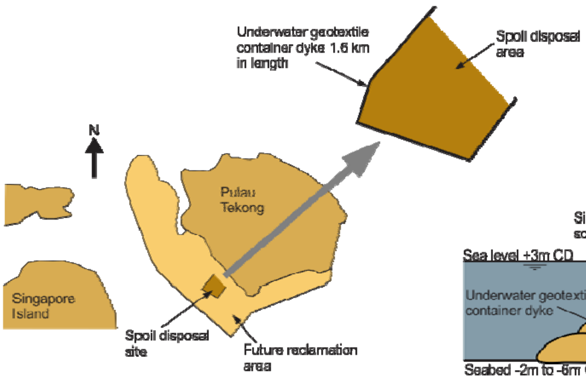


- Development of small islands to South of Singapore into recreation area
- Disposal of reclamation spoil to offshore underwater facility on Southern side of Pulau Tekong

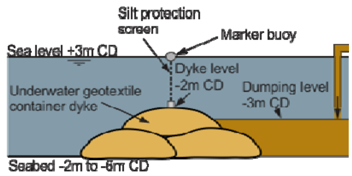
Southern Islands development, Singapore

- Plan to join series of small islands South of Singapore and develop into a recreation and aquatic park
- Need to dispose of existing dead coral and spoil from past shipping operations
- Need to import clean sand fill and then develop recreational and aquatic areas

Offshore disposal facility, Pulau Tekong, Singapore

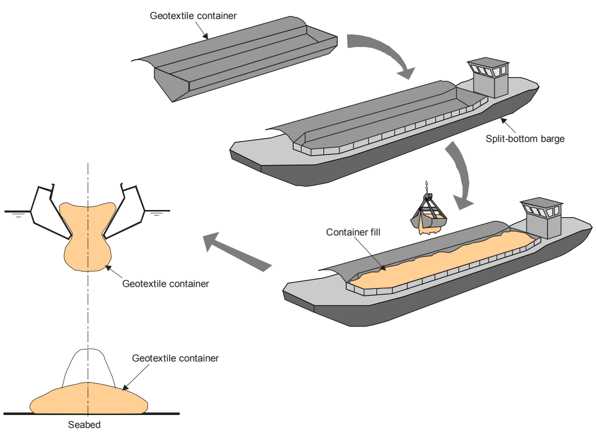


Location of Pulau Tekong disposal facility



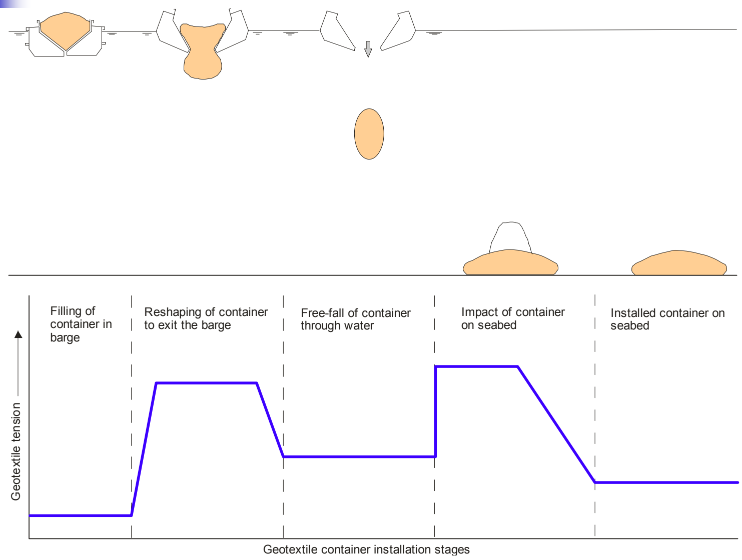
Section through containment dyke

Geotextile containers: features



- Geotextile containers installed by split-bottom barges
- For marine applications container volumes are in range 100 to 800 m^3
  - Smaller volumes give better installed tolerances and are more easily installed but are more costly
- For Pulau Tekong disposal facility geotextile containers were 650 m^3 in size

Geotextile containers: tensions generated in geotextile



Offshore containment dyke, Pulau Tekong, Singapore

Offshore containment dyke, Pulau Tekong, Singapore

Concluding remarks

- A wide range of geotextile solutions exist for land reclamation works
  - Different hydraulic conditions
  - Different foundation conditions
  - Different containment structures
- Geotextiles MUST be considered as engineering materials and designed and selected accordingly
- In the future it is expected that geotextile solutions will become even more important for land reclamation works because of:
  - Cost/benefit considerations
  - Differing conditions and requirements
  - Environmental sustainability considerations