GEOTEXTILE TUBES AS ECONOMICAL AND ENVIRONMENTAL REPLACEMENT OF ROCKFILL FOR CONSTRUCTION OF POLDER DIKE IN SAEMANGEUM PROJECT, KOREA

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TENCATE materials that make a difference

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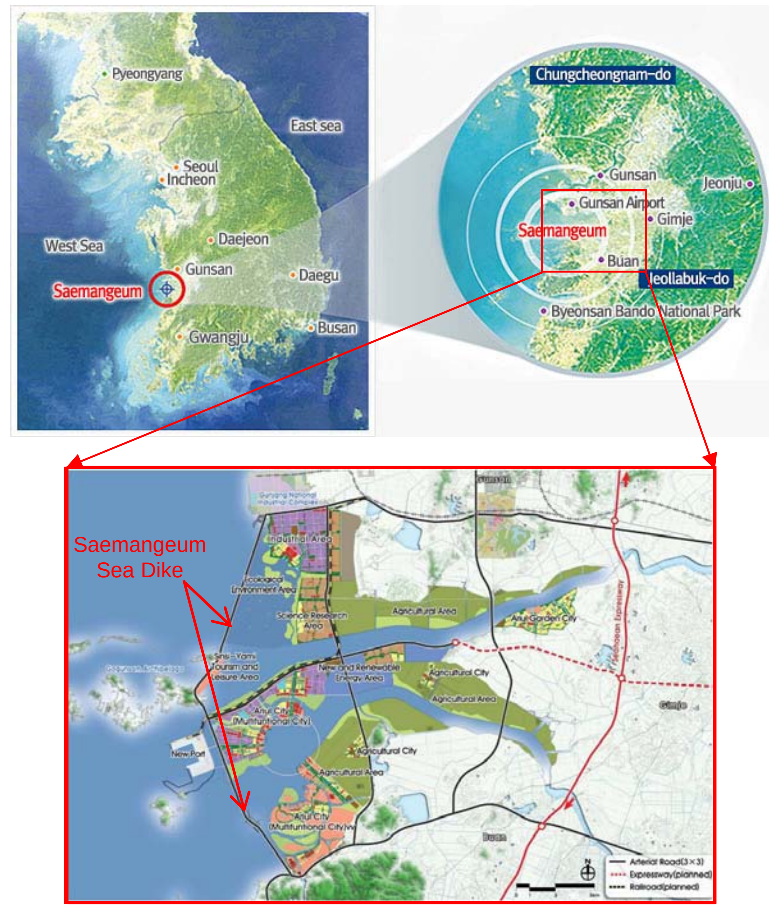
Introduction – Saemangeum Development Project

- The Saemangeum Development Project
  - Construction of 33.9 km long Saemangeum Sea Dike
  - Creation of 400 km^2 of combined reclaimed land and freshwater reservoir behind the Saemangeum Sea Dike
  - Mooted decades ago when South Korea had to import rice due to droughts and cold weather extremes during the 1960s to 1980s



Reservoir and reclaimed land behind Saemangeum Sea Dike

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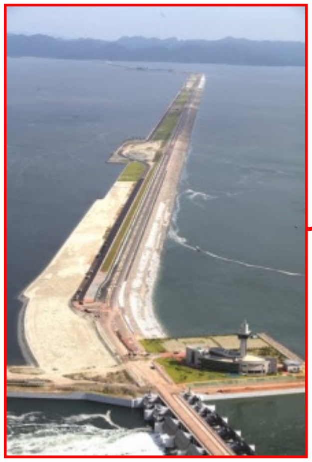
Introduction – Saemangeum Sea Dike

- The area was the tidal estuary of 2 rivers (max daily tidal difference of about 5 m)
- Dike construction began in 1991 and immediately met with resistance from environmental groups
- Court challenges resulted in construction stoppages
- Dike largely completed by 2006 and officially opened in 2010
- At 33.9 km long, the Saemangeum Sea Dike is the longest sea dike in the world

Saemangeum
Sea Dike



Google photo of Saemangeum
Sea Dike and Estuary

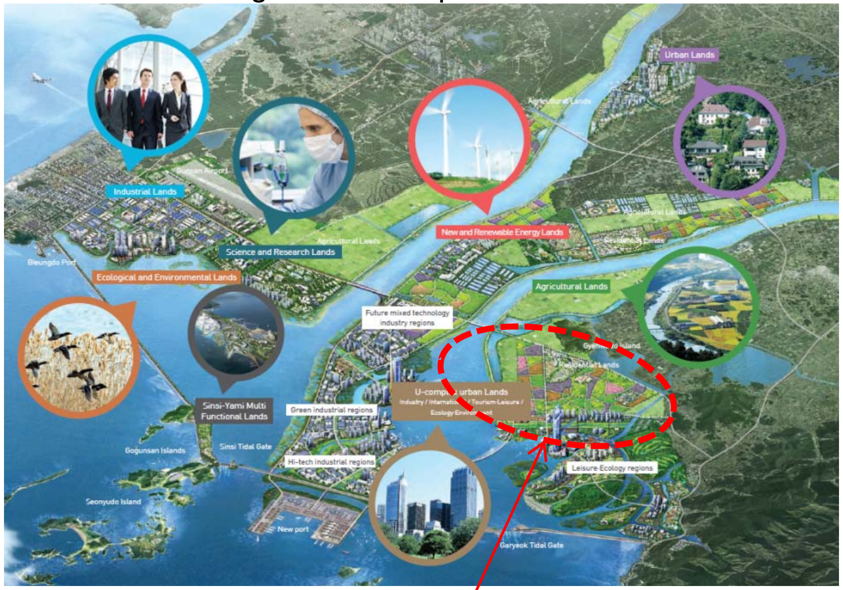
Introduction – Saemangeum Sea Dike

Construction progress of Saemangeum Sea Dike

Introduction – Reclamation and Land Use

- 283 km^2 of reclaimed land:
  - 30% for agricultural purposes
  - 29% for commercial, residential and eco-tourism development
  - 15% for ecological and environmental purposes
  - 8% for scientific research purposes
  - 7% for new and renewable energy purposes
  - 11% others
- Paper concerns primarily the construction of the Polder Dike of Dongjin 1 Package

Saemangeum Development Master Plan



Dongjin 1 Package

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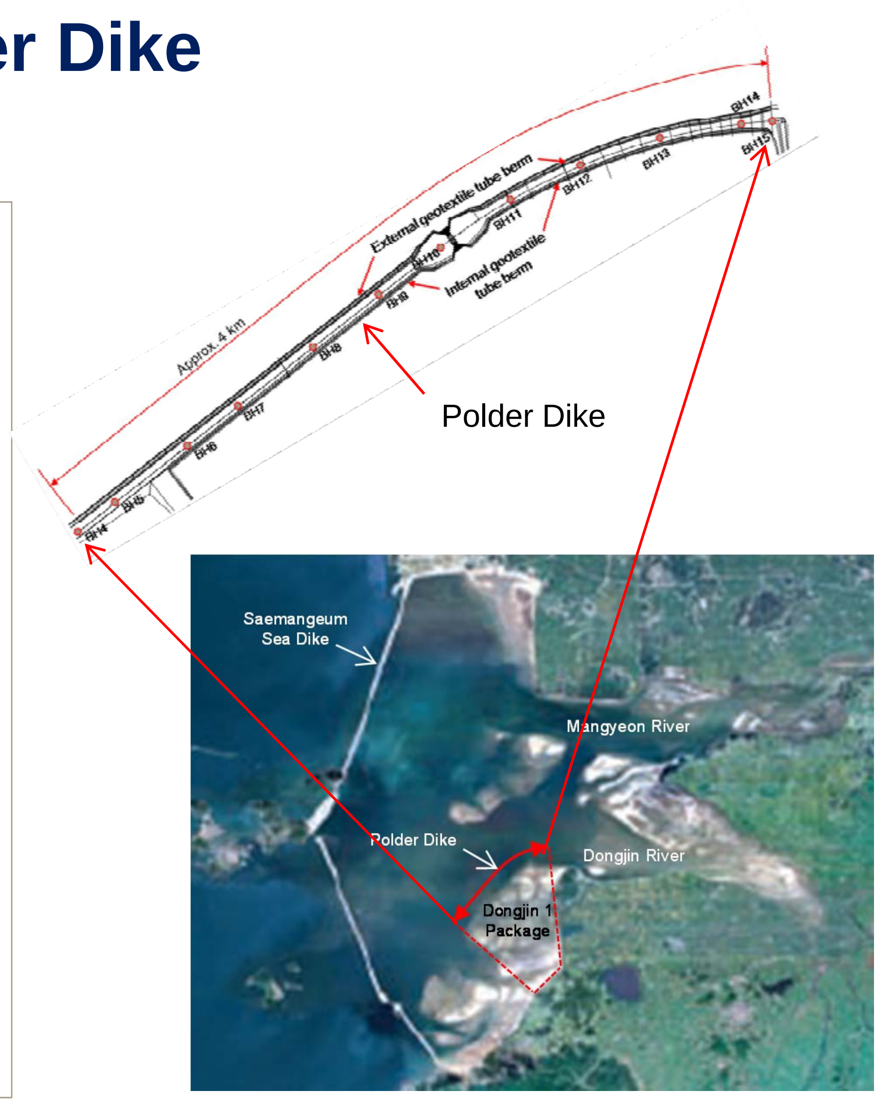
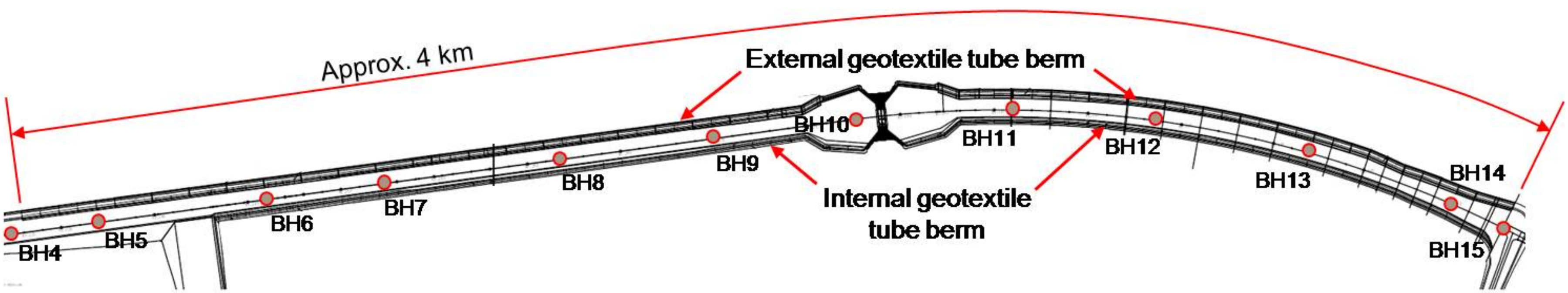
Introduction – The Polder Dike

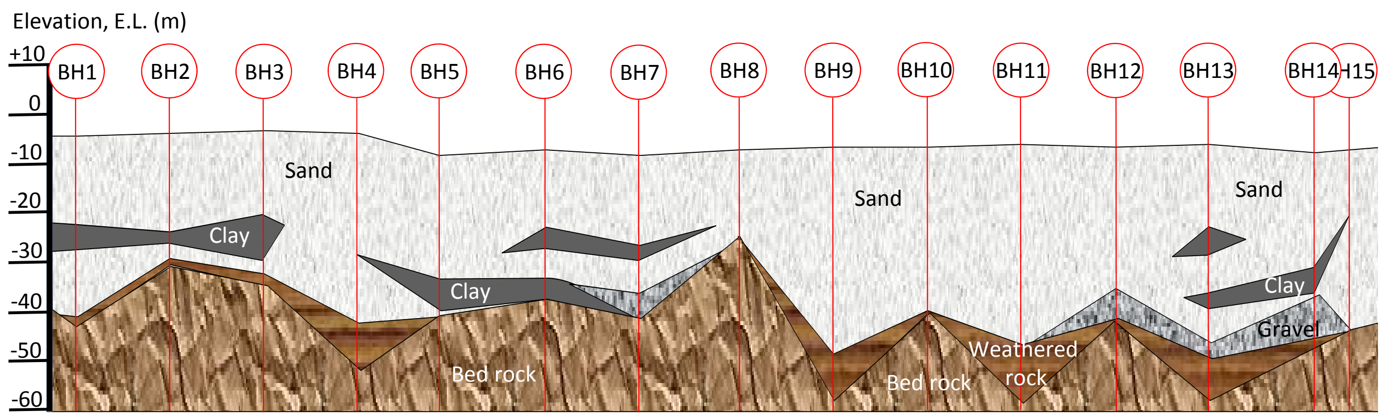
- Reclamation works implemented by the Korea Rural Community Corporation under the Ministry for Food, Agriculture, Forestry and Fisheries under multiple packages
- Dongjin 1 Package involves the construction of polder dike and formation of agricultural land and wetland area behind the polder dike
- Geotextile tube used for construction of polder dike



Dongjin 1 Package

The Polder Dike – Subsoil Profile



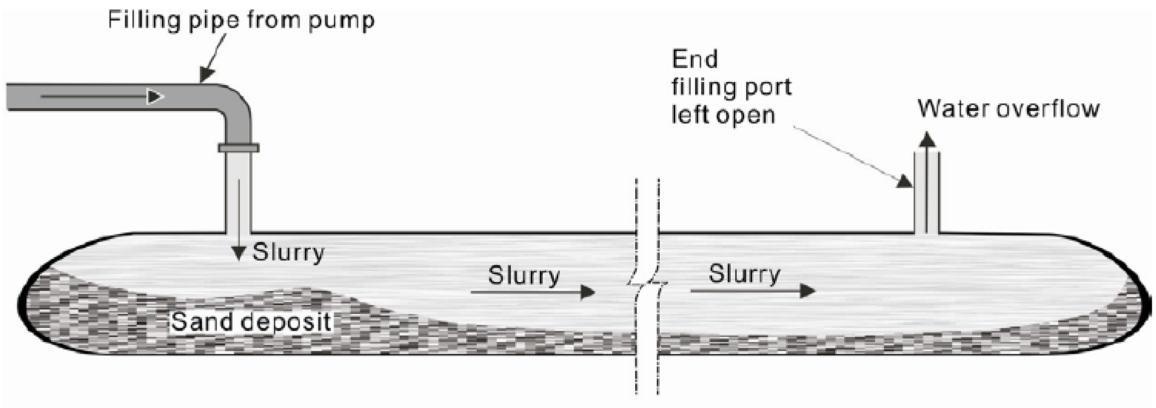


The Polder Dike – Original Design, Rockfill Berm

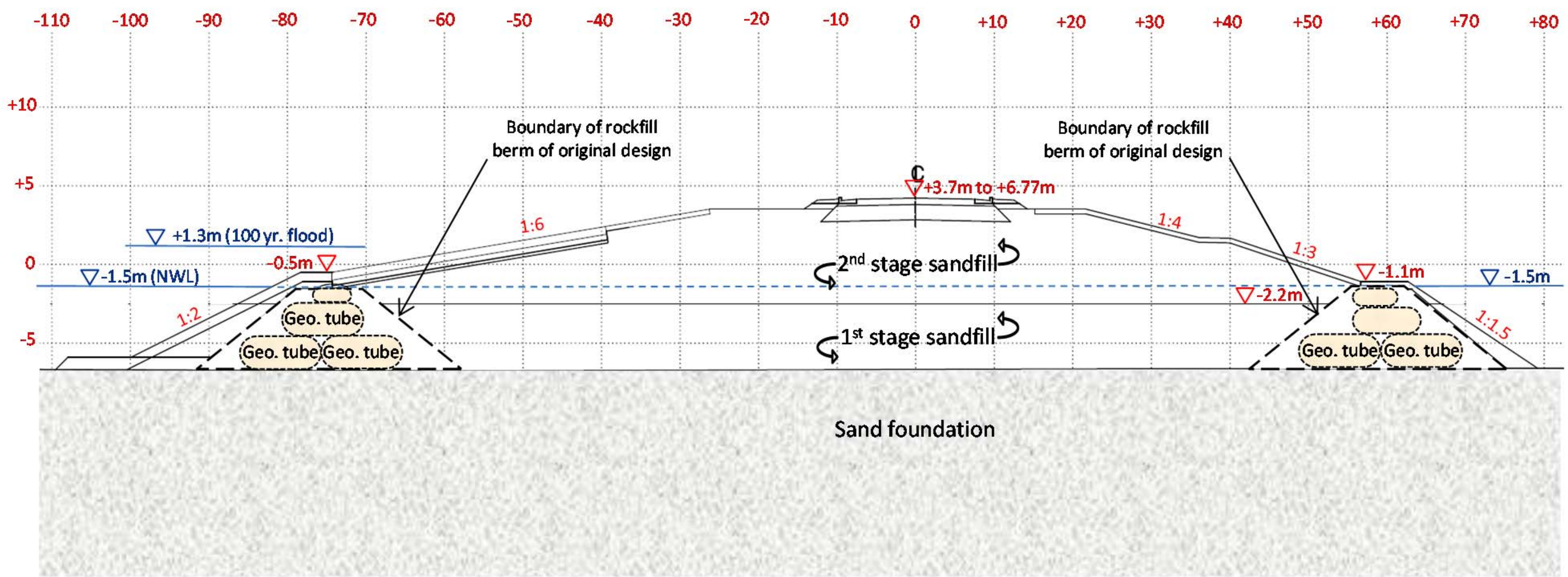
- NWL (Normal Water Level) of the reservoir is at EL. -1.5 m
- The Polder Dike is a wide based embankment with road pavement on top (E.L. +3.7 m to E.L. +6.77 m), and consists of a sandfill core with rock revetment on both sides
- Sand is available in abundance at site, thus is used as core fill material for construction Polder Dike
- For the original design of the Polder Dike rockfill berms (built to above the NWL) are used to retain the sandfill core during construction

The Polder Dike – Alternative Design, Geotextile Tube Berm

- Geotextile tube filled hydraulically with sand may be used to form berm structures
- Consequently, the use of geotextile tube as replacement of rockfill for the construction of berm becomes an attractive option here



The Polder Dike – Cross Section

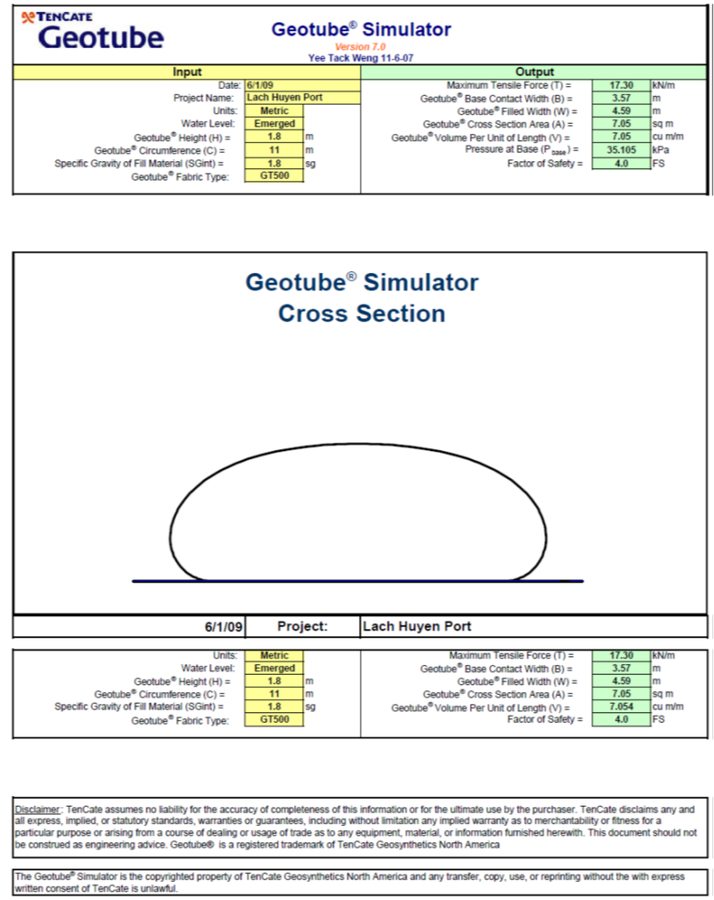


Geotextile Tube Design – Overview

- CUR 217: Dutch version in 2006, English version in 2012
- Geometrical design
- Internal design
  - Stress analysis
  - Sand-tightness
- External design
  - Hydraulic stability
  - Geotechnically stability
- Durability considerations
  - Assess risk of UV attack, abrasion, impacting debris, vandalism, etc. during exposure

Geotextile Tube Design – Stress Analysis

- TenCate Geotube® Simulator software used in design
- Design independently cross-checked using GeoCoPS software
- Tensile force in circumferential and axial directions provided
- Tube inflated geometry provided



TENCATE Geotube

Geotube® Simulator

Version 7.0

Yee Tack Weng 11-6-07

Input			Output		
Date:	6/1/09		Maximum Tensile Force (T) =	17.30	kN/m
Project Name:	Lach Huyen Port		Geotube® Base Contact Width (B) =	3.57	m
Units:	Metric		Geotube® Filled Width (W) =	4.59	m
Water Level:	Emerged		Geotube® Cross Section Area (A) =	7.05	sq m
Geotube® Height (H) =	1.8	m	Geotube® Volume Per Unit of Length (V) =	7.05	cu m/m
Geotube® Circumference (C) =	11	m	Pressure at Base (P_{base}) =	35.105	kPa
Specific Gravity of Fill Material (SGint) =	1.8	sg	Factor of Safety =	4.0	FS
Geotube® Fabric Type:	GT500				

Geotube® Simulator
Cross Section

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Specific Gravity of Fill Material (SGint) =	1.8	sg	Geotube® Volume Per Unit of Length (V) =	7.054	cu m/m
Geotube® Fabric Type:	GT500		Factor of Safety =	4.0	FS

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Geotextile Tube Design – Tube Standardization

- 5 standard tube sizes using 2 different fabric type adopted

Table 2. Fabric type, circumferential and longitudinal tensions for various tube sizes and conditions.

Standard tube size	Theoretical diameter (m)	Filled tube height (m)	External water level (m)	Circum-ferential tension (kN/m)	Longi-tudinal tension (kN/m)	Tube fabric type	Fabric ultimate tensile strength (kN/m)
A	2	1.1	0.6	39	31	I	120
			1.1	21	14		
B	2.5	1.4	0.9	70	55	I	120
			1.4	35	24		
C	3	1.7	1.2	110	86	I	120
			1.7	53	36		
D	3.5	2.0	1.5	169	129	II	200
			1.0	79	53		
E	4	2.2	1.7	197	155	II	200
			2.2	92	63		

Geotextile Tube Design – Geometry and Stresses

- Geotextile tube stacking matched against berm height requirement

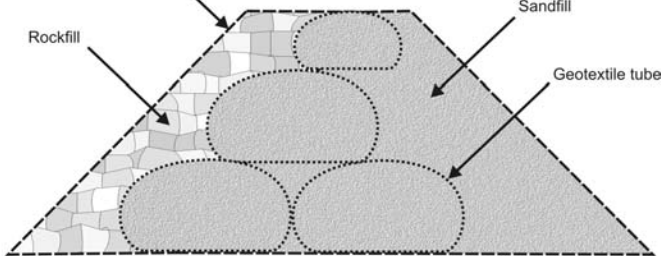


Table 3. Geotextile tube stacking format.

Stacking format	Bottom layer tube size class	2nd layer tube size class	3rd layer tube size class	Stacked height (m)
1a	2 x E	E	D	6.4
1b	2 x E	E	C	6.1
1c	2 x E	E	B	5.8
1d	2 x E	E	A	5.5
1e	2 x E	E	-	4.4
2a	2 x E	D	D	6.2
2b	2 x E	D	A	5.3
2c	2 x E	D	-	4.2
3a	2 x E	C	B	5.3
3b	2 x E	C	A	5.0
3c	2 x E	C	-	3.9
4a	2 x D	D	A	5.1
4b	2 x D	D	-	4.0
5a	2 x D	C	B	5.1
5b	2 x D	C	A	4.8
5c	2 x D	C	-	3.7
6a	2 x C	C	B	4.8
6b	2 x C	C	A	4.5

Geotextile Tube Design – Sand tightness

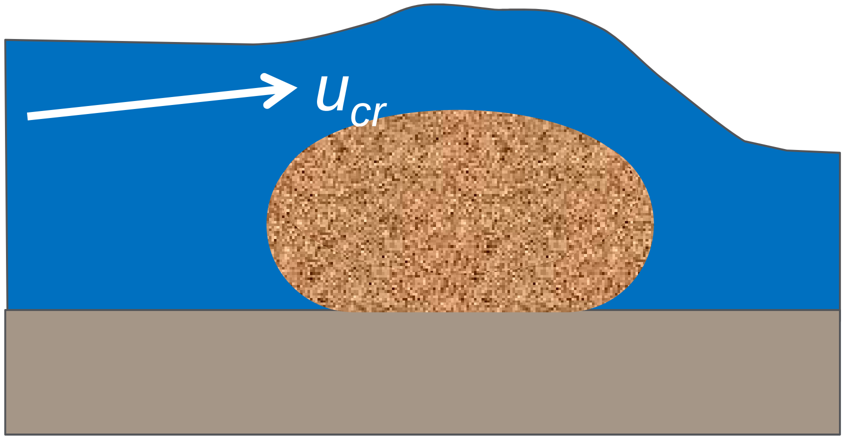
Geotextile Tube Design – Sand tightness

Hydraulic load	Requirement 1	Requirement 2
Stationary load (current)	$O_{90} < 5D_{10}\sqrt{C_u}$	$O_{90} < 2D_{90}$
Dynamic load (wave)	$O_{90} < 1.5D_{10}\sqrt{C_u}$	$O_{90} < D_{90}$

O_{90} = pore size of the geotextile tube;
D_{10} = sieve size through which 10% fraction of the sand material passes;
D_{60} = sieve size through which 60% fraction of the sand material passes;
D_{90} = sieve size through which 90% fraction of the sand material passes;
C_u = uniformity coefficient (= D_{60}/D_{10})

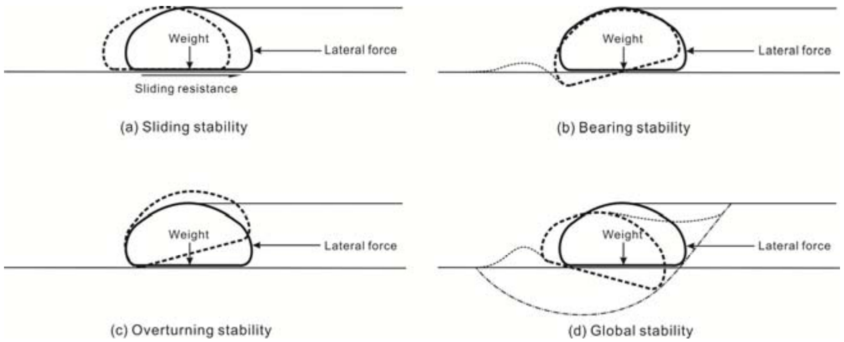
Geotextile Tube Design – Hydraulic Design

- 100 years return period for hydraulic stability:
  - Wave attack checked using significant wave height of 1.6 m with wave period of 4.1 s.
  - Flow attack was checked using a critical velocity of 0.4 m/s.



Geotextile Tube Design – Geotechnical design

- Geotechnical stability checks included:
  - Sliding (FS $\geq$ 1.4)
  - Overturning (FS $\geq$ 2)
  - Bearing capacity (FS $\geq$ 2)
  - Global stability (FS $\geq$ 1.4)



Geotextile Tube vs Rockfill Berms – Cost Comparison

- Cost comparison made between original rockfill berm and geotextile tube berm designs
- The cost saving of the geotextile berm alternative design over the rockfill berm original design was USD 6.2 million, based on actual tender prices

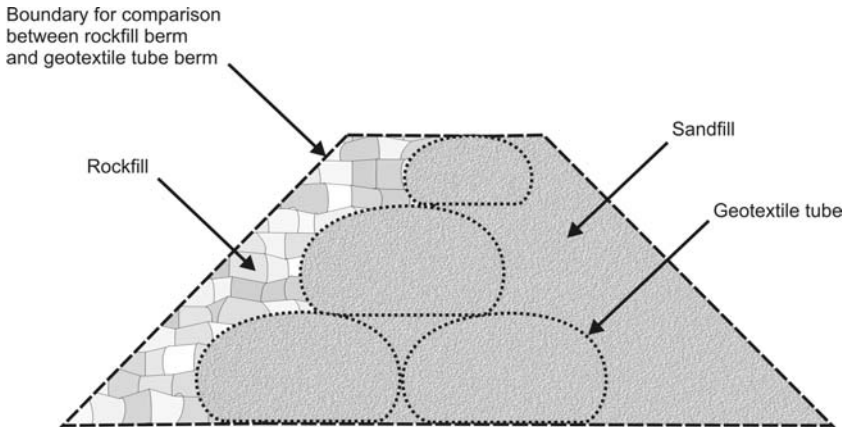
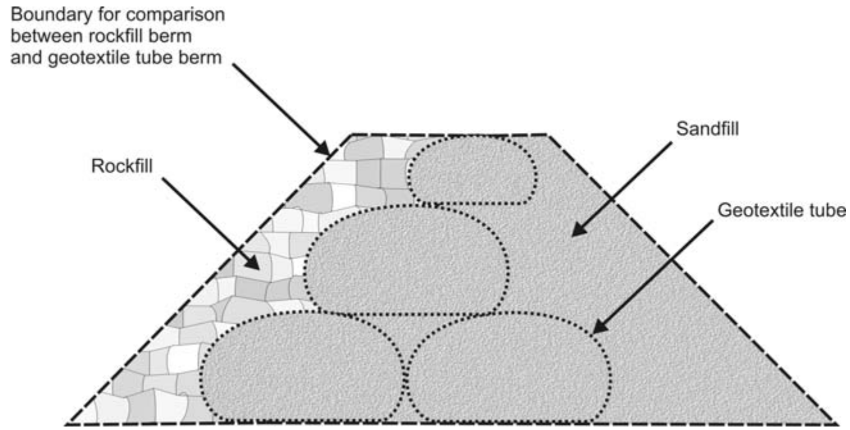


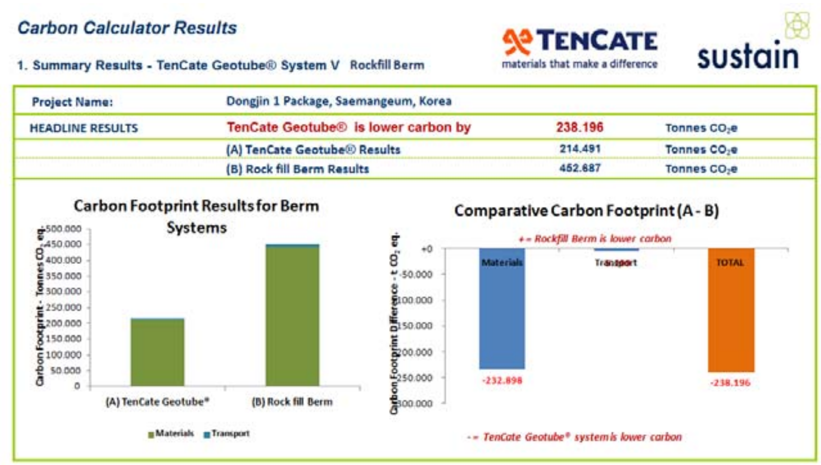
Table 4. Material quantity differences between original rockfill berm design and geotextile tube berm alternative design.

Item		Unit	(X) Rockfill berm	(Y) Geotextile tube berm	(X-Y) Difference
Rockfill		m^3	837,000	387,000	+450,000
Sandfill		m^3	-	450,000	-450,000
Geotextile tube	Type A	m	-	9,386	-9,386
	Type B	m	-	7,235	-7,235
	Type C	m	-	5,333	-5,333
	Type D	m	-	1,281	-1,281
	Type E	m	-	2,888	-2,888
	Total	m	-	26,123	-26,123
Cost saving		USD	-	-	+6,200,000

Geotextile Tube vs Rockfill Berms – Carbon Footprint Comparison

- Carbon footprint of rockfill berm includes energy consumption in:
  - the quarrying of rock
  - the transportation of the rockfill (50 km by road and 4 km by barge)
  - the mechanical transferring of rock from dumper trucks onto barges
  - the mechanical placement of rockfill at site
- Carbon footprint of geotextile tube berm includes:
  - carbon footprint of the geotextile tubes used (based on cradle to site life cycle)
  - transportation from plant to site (road journey of 500 km and a sea journey of 3,000 km)
  - energy consumption in dredging and delivery of sand for the filling of geotextile tube
  - energy consumption of equipment involved in installation of geotextile tube
- Geotextile tube option saved 230,000 tons of CO_2e (52% reduction in carbon footprint)





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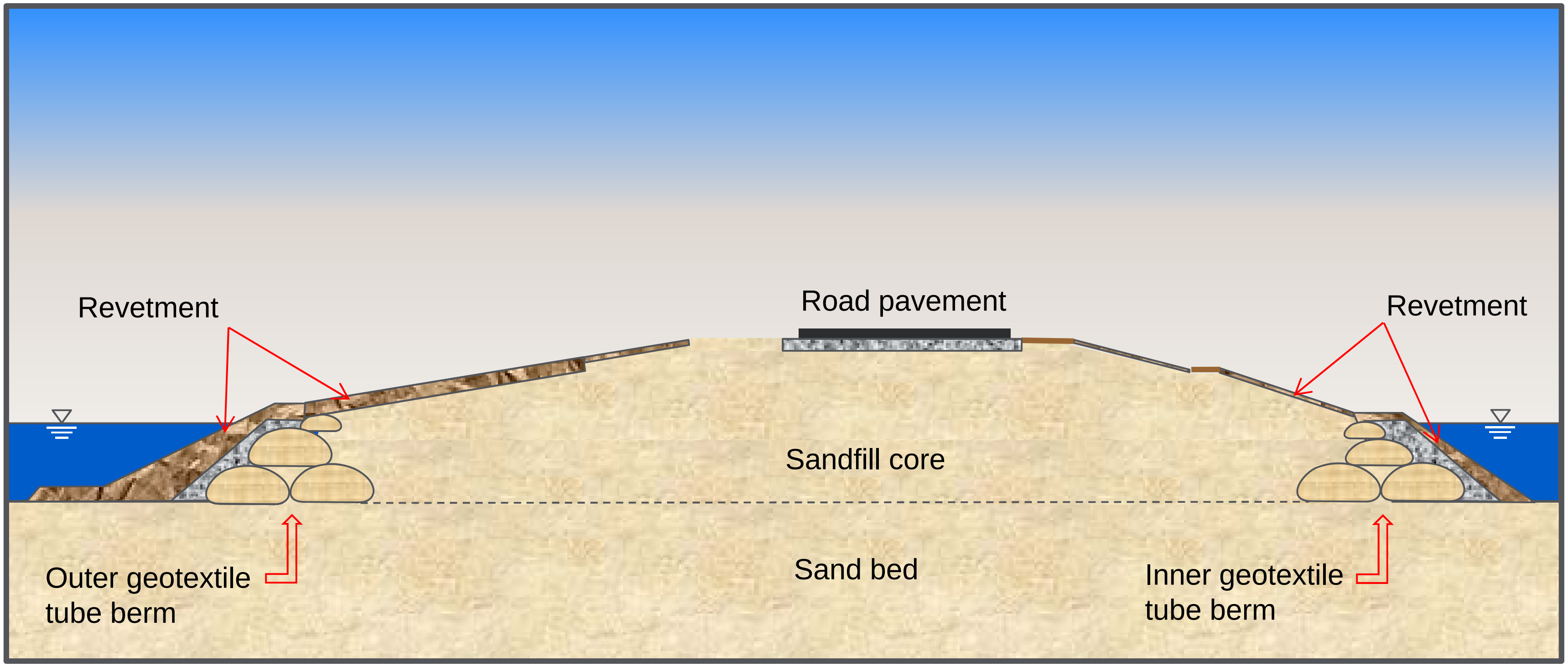
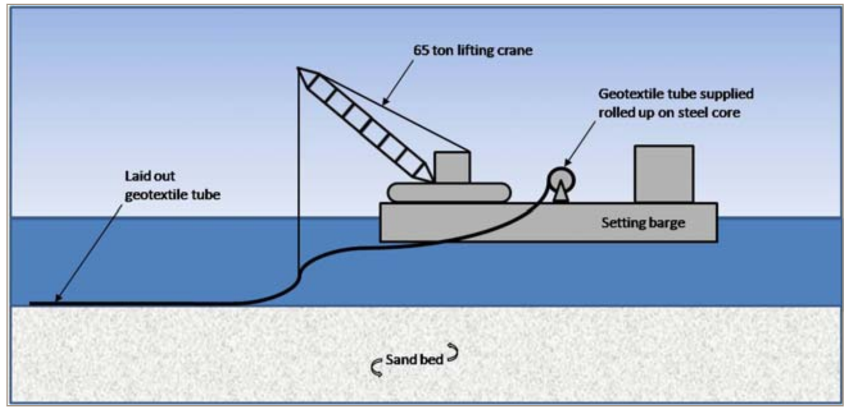
Construction – Overall Work Sequence

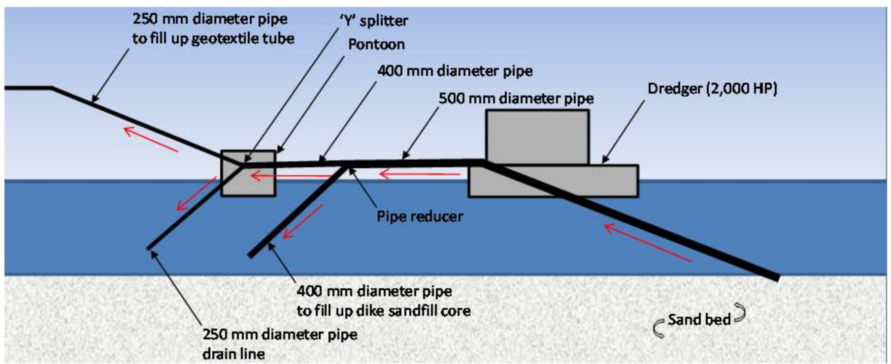


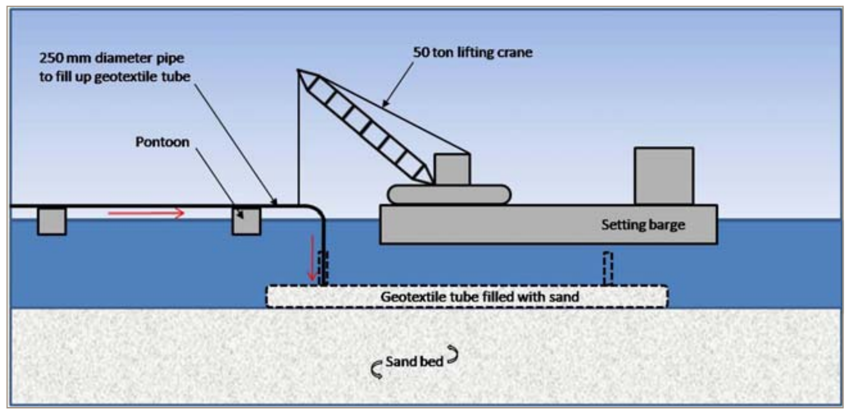
Construction – Equipment

Table 6. Equipment deployed for dredging, geotextile tube installation and construction of the sandfill core of the Polder Dike.

Equipment		For deployment	
		Capacity	Unit
Setting barge		1400HP	1
Flat barge		1900HP	1
Tug boat		650HP	1
Lifting crane		65 metric tons	1
Backhoe		0.6 m^3	1
Dredger			
Anchor boat			







Construction – Geotextile Tube Installation

Setting out using GPS

Construction – Geotextile Tube Installation

Start of geotextile tube filling

Construction – Geotextile Tube Installation

- Installation of the geotextile tubes commenced in July 2012
- On the average, the time required to install type A, B, C, D and E geotextile tubes of length 62 m each are 3.5, 4.6, 5.7, 6.8 and 9 hours respectively
- Installation interrupted for three months in Winter
- Installation of geotextile tube berm for the Polder Dike was completed in May 2013
- The geotextile tube alternative resulted in construction time saving of 7 months over the original solution using rockfill berm

Conclusions

- A case study involving the use of geotextile tubes as economical and environmental replacement of rock for the construction of polder dike of Dongjin 1 Package in Korea has been presented
- The geotextile tube berm alternative design resulted in cost saving of USD 6.2 million
- The geotextile tube berm alternative design resulted in carbon footprint saving of more than 230,000 metric tons of CO_2e (or 52%)
- The geotextile tube berm alternative design also helped shorten the overall project duration by 7 months

Thank you for your kind attention
Questions are most welcome!

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