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

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Introduction – Saemangeum Development Project

• The Saemangeum Development Project
  • Construction of 33.9 km long Saemangeum Sea Dike
  • Creation of 400 km² 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
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
Introduction – Saemangeum Sea Dike

Construction progress of Saemangeum Sea Dike
Introduction – Reclamation and Land Use

- 283 km² 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
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
The Polder Dike – Subsoil Profile

Approx. 4 km

External geotextile tube berm

Internal geotextile tube berm

Elevation, E.L. (m)

BH1  BH2  BH3  BH4  BH5  BH6  BH7  BH8  BH9  BH10  BH11  BH12  BH13  BH14  BH15

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
### Geotextile Tube Design – Tube Standardization

- 5 standard tube sizes using 2 different fabric type adopted

<table>
<thead>
<tr>
<th>Standard tube size</th>
<th>Theoretical diameter (m)</th>
<th>Filled tube height (m)</th>
<th>External water level (m)</th>
<th>Circumferential tension (kN/m)</th>
<th>Longitudinal tension (kN/m)</th>
<th>Tube fabric type</th>
<th>Fabric ultimate tensile strength (kN/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>2</td>
<td>1.1</td>
<td>0.6</td>
<td>39</td>
<td>31</td>
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<td>120</td>
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<td>B</td>
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<td></td>
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<td>35</td>
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<td>I</td>
<td>120</td>
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<td>D</td>
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<td>II</td>
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<td>E</td>
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<td>2.2</td>
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<td>155</td>
<td>II</td>
<td>200</td>
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<td></td>
<td></td>
<td>2.2</td>
<td>92</td>
<td>63</td>
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</tbody>
</table>
Geotextile Tube Design – Geometry and Stresses

- Geotextile tube stacking matched against berm height requirement

Table 3. Geotextile tube stacking format.

<table>
<thead>
<tr>
<th>Stacking format</th>
<th>Bottom layer tube size class</th>
<th>2nd layer tube size class</th>
<th>3rd layer tube size class</th>
<th>Stacked height (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>2 x E</td>
<td>E</td>
<td>D</td>
<td>6.4</td>
</tr>
<tr>
<td>1b</td>
<td>2 x E</td>
<td>E</td>
<td>C</td>
<td>6.1</td>
</tr>
<tr>
<td>1c</td>
<td>2 x E</td>
<td>E</td>
<td>B</td>
<td>5.8</td>
</tr>
<tr>
<td>1d</td>
<td>2 x E</td>
<td>E</td>
<td>A</td>
<td>5.5</td>
</tr>
<tr>
<td>1e</td>
<td>2 x E</td>
<td>E</td>
<td>-</td>
<td>4.4</td>
</tr>
<tr>
<td>2a</td>
<td>2 x E</td>
<td>D</td>
<td>D</td>
<td>6.2</td>
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<td>2b</td>
<td>2 x E</td>
<td>D</td>
<td>A</td>
<td>5.3</td>
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<tr>
<td>2c</td>
<td>2 x E</td>
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<td>-</td>
<td>4.2</td>
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<td>3a</td>
<td>2 x E</td>
<td>C</td>
<td>B</td>
<td>5.3</td>
</tr>
<tr>
<td>3b</td>
<td>2 x E</td>
<td>C</td>
<td>A</td>
<td>5.0</td>
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<tr>
<td>3c</td>
<td>2 x E</td>
<td>C</td>
<td>-</td>
<td>3.9</td>
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<tr>
<td>4a</td>
<td>2 x D</td>
<td>D</td>
<td>A</td>
<td>5.1</td>
</tr>
<tr>
<td>4b</td>
<td>2 x D</td>
<td>D</td>
<td>-</td>
<td>4.0</td>
</tr>
<tr>
<td>5a</td>
<td>2 x D</td>
<td>C</td>
<td>B</td>
<td>5.1</td>
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<tr>
<td>5b</td>
<td>2 x D</td>
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<td>A</td>
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<tr>
<td>5c</td>
<td>2 x D</td>
<td>C</td>
<td>-</td>
<td>3.7</td>
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<tr>
<td>6a</td>
<td>2 x C</td>
<td>C</td>
<td>B</td>
<td>4.8</td>
</tr>
<tr>
<td>6b</td>
<td>2 x C</td>
<td>C</td>
<td>A</td>
<td>4.5</td>
</tr>
</tbody>
</table>
Geotextile Tube Design – Sand tightness
## Geotextile Tube Design – Sand tightness

<table>
<thead>
<tr>
<th>Hydraulic load</th>
<th>Requirement 1</th>
<th>Requirement 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stationary load (current)</td>
<td>$O_{90} &lt; 5D_{10}\sqrt{C_u}$</td>
<td>$O_{90} &lt; 2D_{90}$</td>
</tr>
<tr>
<td>Dynamic load (wave)</td>
<td>$O_{90} &lt; 1.5D_{10}\sqrt{C_u}$</td>
<td>$O_{90} &lt; D_{90}$</td>
</tr>
</tbody>
</table>

$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 ≥ 1.4)
  - Overturning (FS ≥ 2)
  - Bearing capacity (FS ≥ 2)
  - Global stability (FS ≥ 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
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 CO₂e (52% reduction in carbon footprint)
Construction – Overall Work Sequence

- Sand bed
- Outer geotextile tube berm
- Inner geotextile tube berm
- Sandfill core
- Road pavement
- Revetment

2013
Construction – Equipment

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

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Capacity</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting barge</td>
<td>1400HP</td>
<td>1</td>
</tr>
<tr>
<td>Flat barge</td>
<td>1900HP</td>
<td>1</td>
</tr>
<tr>
<td>Tag boat</td>
<td>650HP</td>
<td>1</td>
</tr>
<tr>
<td>Lifting crane</td>
<td>65 metric tons</td>
<td>1</td>
</tr>
<tr>
<td>Backhoe</td>
<td>0.6 m³</td>
<td>1</td>
</tr>
<tr>
<td>Dredger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anchor boat</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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$_2$e (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!

Speaker: T.W. Yee
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