Climate Change Impacts in a Large-Scale Erosion Coast of Hai Hau District, Vietnam

Do Minh Duc¹ & Kazuya Yasuhara ² & Nguyen Manh Hieu¹ & Nguyen Chau Lan ³

¹ Department of Geotechnics, Faculty of Geology, VNU University of Science, Vietnam National University
² Institute for Global Change Adaptation Science, Ibaraki University
³ Geotechnical Engineering Laboratory, Civil Engineering Faculty, University of Transport and Communications, Vietnam
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The Intergovernmental Panel on Climate Change (IPCC 2007) reported that during the 21st century, the sea level will rise another 18 to 59 cm due to global warming.

Global mean sea level rise for 2081–2100 relative to 1986–2005 will likely be in the ranges of 0.26 to 0.55 m for representative carbon pathway (RCP) 2.6, 0.32 to 0.63 m for RCP4.5, 0.33 to 0.63 m for RCP6.0, and 0.45 to 0.82 m for RCP8.5 (Church et al. 2013)
Introduction Haihau coast

• An average rate of SLR is in the range of 1.75 to 2.56 mm/year in Vietnam (Hanh and Furukawa 2007).
• Hai Hau has suffered from severe erosion. The retreat rate could reach up to 15 to 20 m/year (Martin 2000).
• Serious damage to the local infrastructure and even loss of lives (Duc et al. 2007).
Recent state of erosion in Haihau coast
Recent state of erosion in Haihau coast


b) Hai Trieu commune in 2001 (L.G.Vu, 2003)

d) Hai Ly commune in September 2011

c) Hai Ly commune in July 2010
Impacts of climate change on the Hai hau coast

Number of tropical cyclones landed on Vietnamese coast (1961-2013) (Data source: Website of Vietnam National Center for Meteorology and Hydrology)
Impacts of sea level rise

• To estimate the future increase of coastal erosion, the formula from Bruun (1962) was used.

\[ R_x = S \frac{L_x}{h_x + B} \]

where \( S \) is SLR, \( R_x \) is the accelerated rate of erosion due to SLR, and \( L_x \) and \( (h_x + B) \) are the width and vertical extent of the active cross-shore profile, \( B \) is the height of the berm, \( h_x \) is the depth of closure.

Accumulative amounts of erosion by 2020 are 6.4, 6.8 and 9.4 m in Giao Phong, Hai Dong and Thinh Long, respectively. By 2100, amounts of erosion reach to 34-50 m for low scenario and 56-83 m for high scenario.
Impacts of sea level rise

• To estimate the future increase of coastal erosion, the formula from Bruun (1962) was used.

\[ R_e = S \frac{L_e}{h_e + B} \]

where S is SLR, \( R_e \) is the accelerated rate of erosion due to SLR, and \( L_e \) and \((h_e + B)\) are the width and vertical extent of the active cross-shore profile, B is the height of the berm, \( h_e \) is the depth of closure.

Accumulative amounts of erosion by 2020 are 6.4, 6.8 and 9.4 m in Giao Phong, Hai Dong and Thinh Long, respectively. By 2100, amounts of erosion reach to 34-50 m for low scenario and 56-83 m for high scenario.
Impacts of extreme weather events

• Typhoon-induced erosion

Hai Hau coast experienced an erosion rate of approximately 100 m in a severe typhoon in 1999 on the Nghia Phuc coast (Duc et al. 2007).

The retreat distance caused by extreme wave heights (Kriebel and Dean 1993):

\[ R(t) = R_\infty (1 - e^{-t/T}) \]

<table>
<thead>
<tr>
<th>Section</th>
<th>S (m)</th>
<th>( h_b ) (m)</th>
<th>( H_b ) (m)</th>
<th>B (m)</th>
<th>( m_0 )</th>
<th>( D_{50} ) (mm)</th>
<th>A ((\text{m}^{1/3}))</th>
<th>t (h)</th>
<th>R(t) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Giao Phong</td>
<td>4.25</td>
<td>6.96</td>
<td>3.15</td>
<td>2.00</td>
<td>0.0040</td>
<td>0.143</td>
<td>0.0798</td>
<td>2.4</td>
<td>3.9</td>
</tr>
<tr>
<td>Hai Hoa</td>
<td>4.25</td>
<td>9.23</td>
<td>4.10</td>
<td>2.00</td>
<td>0.0150</td>
<td>0.143</td>
<td>0.0798</td>
<td>2.4</td>
<td>7.1</td>
</tr>
<tr>
<td>Thinh Long</td>
<td>4.25</td>
<td>8.18</td>
<td>3.78</td>
<td>2.00</td>
<td>0.0100</td>
<td>0.147</td>
<td>0.0840</td>
<td>2.4</td>
<td>3.1</td>
</tr>
<tr>
<td>Lach mouth</td>
<td>4.25</td>
<td>8.83</td>
<td>3.23</td>
<td>2.00</td>
<td>0.0045</td>
<td>0.157</td>
<td>0.0872</td>
<td>2.4</td>
<td>2.2</td>
</tr>
</tbody>
</table>
Impacts of extreme weather events

• Wave overtopping and soil erosion

Destruction of outer slope by wave attacks, Thinh Long 22 Feb 2012

Destruction of inner slope by overtopping, Thinh Long 4 Dec 2013
Impacts of extreme weather events

Geotechnical properties of soils in coastal dykes in Hai Hau coast

<table>
<thead>
<tr>
<th>Properties</th>
<th>North Hai Dong</th>
<th>South Hai Dong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain sizes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand</td>
<td></td>
<td>61.7</td>
</tr>
<tr>
<td>Silt</td>
<td></td>
<td>12.0</td>
</tr>
<tr>
<td>Clay</td>
<td></td>
<td>26.3</td>
</tr>
<tr>
<td>Natural water content (%)</td>
<td>29.8</td>
<td>30.1</td>
</tr>
<tr>
<td>Unit weight (g/cm³)</td>
<td>1.81</td>
<td>1.81</td>
</tr>
<tr>
<td>Dry unit weight (g/cm³)</td>
<td>1.47</td>
<td>1.45</td>
</tr>
<tr>
<td>Specific gravity (g/cm³)</td>
<td>2.70</td>
<td>2.72</td>
</tr>
<tr>
<td>Void ratio</td>
<td>0.832</td>
<td>0.821</td>
</tr>
<tr>
<td>Porosity (%)</td>
<td>45.4</td>
<td>45.2</td>
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<tr>
<td>Degree of saturation (%)</td>
<td>74.0</td>
<td>73.7</td>
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<tr>
<td>Liquid limit (%)</td>
<td>44.5</td>
<td>42.7</td>
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<tr>
<td>Plastic limit (%)</td>
<td>31.9</td>
<td>30.6</td>
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<tr>
<td>Plasticity index (%)</td>
<td>12.6</td>
<td>12.1</td>
</tr>
<tr>
<td>Effective cohesion (kPa)</td>
<td>13.0</td>
<td>12.5</td>
</tr>
<tr>
<td>Effective internal friction angle (degree)</td>
<td>24.5</td>
<td>23.0</td>
</tr>
<tr>
<td>Soil type (after ASTM 2001 - D2487)</td>
<td>SC</td>
<td>SC</td>
</tr>
</tbody>
</table>
Erosion rates at dyke inner slopes of Thinh Long town in RCP2.6 and RCP8.6 scenarios

Estimation of soil erosion rates at inner slopes of the coastal dykes in Hai Hau coast
• inner Erosion rates at dyke of Thinh Long town in RCP2.6 and RCP8.6 scenarios
Pore water pressure monitoring
Pore water pressure monitoring
Stability

Saturated condition:
Geotechnical engineering measures for climate change adaptation

a) Adequate compaction

Natural and/or artificial fiber

b) Combining locally available natural fiber

Granular material Cohesive soil

c) Sandwich - structure using granular materials

Well-graded granular materials

Geosynthetics Concrete berm Soil bags including construction waste granular and soil

Expected SWL Present SWL

Previous dike

Base ground Concrete tubes filled with stones Beach

Additional dike (possible use of wastes)
Multiple protection mechanisms and adaptations to climate change of Hai Hau coast with different severities of erosion

a) Combination with mangrove - Weak erosion, erosion rate < 2m/year

b) Combination with mangrove and geotube - Medium erosion, 2 < erosion rate < 5m/year

c) Combination with concrete tubes and geotube - Strong erosion, erosion rate > 5m/year
Conclusion

• Coastal erosion has been a serious threat to the coast of the Hai Hau district.

• Accumulative amounts of erosion by 2020 are 6.4, 6.8 and 9.4 m in Giao Phong, Hai Dong and Thinh Long, respectively.

• By 2100, amounts of erosion reach to 34-50 m for low scenario and 56-83 m for high scenario.

• Multiple protective measures are good solution against climate change-induced severe erosion.