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Violent wave overtopping at the sea dikes

- Reduction of Wave Overtopping by Vetiver grass -
Wave overtopping at the sea dikes

- Reduction of Wave Overtopping by Vetiver grass -
Design Sea Dike

Reduce wave overtopping

Traditional method:
“Hard” revetments like concrete blocks, big rocks, glacial stones
“Hard” Revetments

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- Reduction of Wave Overtopping by Vetiver grass -
Design Sea Dike

Reduce wave overtopping height

Traditional method:
"Hard" revetments like concrete blocks, big rock, glacial stone

Methods which are low-cost and readily available

Combination between "Hard" revetments with Vegetations or Bioengineering methods.
"Soft" Solutions

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- Reduction of Wave Overtopping by Vetiver grass -
Vetiver grass

In a number of tropical countries Vetiver grass is well-known bioengineering.

Vertiver grasses grow naturally in clump with thin, long, and erect leaves.
Vetiver grass

Vetiver grasses as sea dike revetments

- Lack of basic understanding for processes and properties
- Lack of quantitative and qualitative knowledge of the protection on the outer slope of the sea dike by Vetiver

Addressing previous information: reduce wave overtopping by Vetiver grasses
Objectives

- The hydraulics of flow with Vetiver grass
- The interaction between flow velocity and flow depth in cases of Vetiver hedge in relation to the reduction of wave overtopping
- Improving the guidelines in designing sea dike dimensions
Model set-up

Full scale

- Vetiver grass
- Wave parameters in front of Vetiver hedge.
Model set-up

Overview of experimental set-up

- Flume
- Vetiver hedge
- Gate
- Reservoir
- Slope
- Root
- Leaves

- Reduction of Wave Overtopping by Vetiver grass -
Model set-up

Locations and instruments

- Wave Gauge Height Meter - GHM
- Electromagnetic Flow Velocity Meter - EMS

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- Reduction of Wave Overtopping by Vetiver grass -
## Model set-up

<table>
<thead>
<tr>
<th>Case</th>
<th>Density of grass (Stem/m²)</th>
<th>Water level inside reservoir $h_r$ (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case 1</td>
<td>Without grass</td>
<td>50, 45, 40, 35</td>
</tr>
<tr>
<td>Case 2</td>
<td>530</td>
<td>50, 45, 40, 35</td>
</tr>
<tr>
<td>Case 3</td>
<td>265</td>
<td>50, 45, 40, 35</td>
</tr>
<tr>
<td>Case 4</td>
<td>160</td>
<td>50, 45, 40, 35</td>
</tr>
</tbody>
</table>

*The experiment scenarios*
Results
The interactions

Energy losses

$h_r$ $u_i$ $h_i$ $u_b$ $h_b$

In front of the Vetiver hedges

Behind the Vetiver hedges

Stem density
Individual stem strength
Stem moment of inertia
Modules of elasticity
Results

- Flow through Vetiver hedges: Manning factor
- Overtopping discharge

Practical application: Nam Dinh-Vietnam

- Reduction of wave run-up
- Guideline for designing dams and reduction of the cost for upgrading of the present sea dike
Observations

Overview (film)

- Reduction of Wave Overtopping by Vetiver grass -
Observations

Wave Flow though the Vetiver hedge

- Reduction of Wave Overtopping by Vetiver grass -
Results (1)
Flow through Vetiver hedge

Water level in front of Vetiver hedge and Grass density

- Reduction of Wave Overtopping by Vetiver grass -
Results (1)
Flow through Vetiver hedge

Variation of roughness coefficient with flow depth through Vetiver hedge

\[ n = \frac{1}{u_1} \cdot \sqrt{S_f} \cdot h^3 \]

- Reduction of Wave Overtopping by Vetiver grass -
Results (2)

Overtopping Discharge

Reduction of overtopping discharge ~ Density

- Reduction of Wave Overtopping by Vetiver grass -
Practical Application
The reduction of wave run-up

- Calculate wave run-up on the outer slope.
- Re-calculate wave run-up in case of Vetiver grass are planted on the outer slope.
- Find the reduction of wave run-up.
- Define the influence factor for roughness of Vetiver grasses.
Practical Application - Results (4)
The reduction of wave run-up

Nam Dinh province
- Location
- 72km length of coastal line

- Reduction of Wave Overtopping by Vetiver grass -
Practical Application - Results (4)
The reduction of wave run-up

- Reduction of Wave Overtopping by Vetiver grass -
## Practical Application
The reduction of wave run-up

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Real value</th>
<th>Case 1</th>
<th>Case 4</th>
<th>Case 3</th>
<th>Case 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass density</td>
<td>stem/m²</td>
<td>-</td>
<td>0</td>
<td>160</td>
<td>256</td>
<td>530</td>
</tr>
<tr>
<td>Ration of wave height</td>
<td>-</td>
<td>-</td>
<td>0.886</td>
<td>0.501</td>
<td>0.422</td>
<td>0.406</td>
</tr>
<tr>
<td>$R_{u2%}$</td>
<td>m</td>
<td>3.26</td>
<td>2.49</td>
<td>1.41</td>
<td>1.19</td>
<td>1.14</td>
</tr>
<tr>
<td>Reduction of wave run-up</td>
<td>%</td>
<td>-</td>
<td>23.73</td>
<td>56.85</td>
<td>63.64</td>
<td>65.1</td>
</tr>
<tr>
<td>$\gamma_f$</td>
<td>-</td>
<td>0.95</td>
<td>0.75</td>
<td>0.410</td>
<td>0.345</td>
<td>0.332</td>
</tr>
</tbody>
</table>
Practical Application

The reduction of wave run-up

Relationship between grass density and wave run-up

- Reduction of Wave Overtopping by Vetiver grass -
Practical Application - Case Study

- Use the previous influence factor for roughness of Vetiver grasses (Result 4)
- Allowed discharge of overtopping \( q = 0.0001 \text{m}^2/\text{s} \)
  (Dutch Guideline for the design dam)

- Use Van der Meer formula (2001)

\[
\frac{Q}{\sqrt{g \cdot H_{m0}^3}} = \frac{0.06}{\sqrt{\tan \alpha}} \cdot \gamma_b \cdot \xi_0 \cdot \exp \left( -4.7 \cdot \frac{R_c}{H_{m0}} \cdot \frac{1}{\xi_0 \cdot \gamma_b \cdot \gamma_f \cdot \gamma_\beta} \right)
\]

- Calculation the total cost for upgrading the present sea dike
Case Study

Crest height of sea dike

<table>
<thead>
<tr>
<th>No Hedge</th>
<th>One Hedge</th>
<th>Two Hedges</th>
<th>Three Hedges</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.60</td>
<td>6.70</td>
<td>6.80</td>
<td>6.90</td>
</tr>
<tr>
<td>7.00</td>
<td>7.10</td>
<td>7.20</td>
<td>7.30</td>
</tr>
<tr>
<td>7.40</td>
<td>7.50</td>
<td>7.60</td>
<td>7.70</td>
</tr>
</tbody>
</table>

Introduction Objectives Model Set-up Result Case study Conclusions

- Reduction of Wave Overtopping by Vetiver grass -
Case Study
Total cost for one meter length

- Without Vetiver grass: $147.5
- Two Vetiver hedges: $128.96
- Reduction 12.6% total costs

- Reduction of Wave Overtopping by Vetiver grass -
Conclusions

- The resistance of the slope with Vetiver grass is 2.5 times larger in comparison with the slope without grass.

- The Vetiver hedges have ability to withstand flow which reaches depths up to 40cm.
Conclusions

- The wave overtopping reduces with 45% in case of 200 stem/m².

- The influence factor for roughness of Vetiver grass varies from 0.33 to 0.41.

- For upgrading sea dikes, the crest level would reduce 0.49m, and the total costs 12.6% if two Vetiver hedges are planted.
Recommendations

- The influence factor of berm and angle of wave attack
  → Further research which includes these factors.

- The accurate velocities in the middle of grass need more studies and investigations.

- The living condition of Vetiver on the outer slope under saline condition.

- A problem could appear because of grass’s roots.
Thanks for your attention

- Reduction of Wave Overtopping by Vetiver grass -