Numerical Prediction of Wave Overtopping

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Aims

• Can we use a numerical tool to model overtopping?
• Wave by wave analysis with tides and surge
• Effect of beach profile
• EuroTop comparison
• Walcott and Blackpool case studies
• Input for flood inundation models
Prediction of Wave Overtopping

Options
- Physical Models
- Empirical Tools
- Numerical Models?

Nonlinear Shallow Water Equations

\[ c = \sqrt{gh} \]
\[ c = f(h,T) \]

NLSW equations
Shallow water only

Boussinesq – type equations
Intermediate depths
Wave Breaking

Where does breaking start?

What happens to breaking waves?

\[
\frac{\partial \eta}{\partial t} > 0.25 \sqrt{gh} \\
\frac{H}{h} > c_s
\]

Shallow Water Equations

Wave Input (Larsen and Dancy, 1983)

- Free surface level input (no paddle)
- Sponge layer at offshore boundary
- Incident Waves

hu = 0

Sponge Layer

Wave Input

Input elevation depends on group velocity
Spectral Wave Input

- Solitary Waves
- Regular Waves
- Random Waves
- Wave Runup
- Wave Overtopping
- Field Data
Model Validation – Wave Overtopping

Anchorsholme Seawall
Blackpool
• Field data (HR Wallingford / EA)
• Physical model tests at HR Wallingford
Model Validation – Wave Overtopping

Wave Overtopping Volumes - Prototype Scale
$H_m = 3.41\, \text{m}, \frac{H_m}{L_0} = 0.040$

- Without Wall Force
- Experimental Data
- Force from Recurve Wall
Model Validation – Wave Overtopping

Wave Overtopping Volumes - Prototype Scale

- Without Wall Force
- Experimental Data
- Field Data (from EA)
- Force from Recurve Wall

Cumulative Volume \( m^3/m \)

Time (s)

Wave Overtopping Volumes - Prototype Scale

- \( H_{m0} = 3.41m, H_{m0}/L_{D} = 0.040 \)

Walcott - Waves

Storm from November 2007

- \( H_{m0} = 2.43m \)
- \( T_p = 11.17s \)
- \( T_{m02} = 7.19s \)
- SWL at 3.2maOD

\( H_{m0} = 2.43m \)

\( T_p = 11.17s \)

\( T_{m02} = 7.19s \)

SWL at 3.2maOD
Walcott Seawall

Beach Profiles
Profiles for SWAB Model

Level (mOD)

x (m) – Wave Input at x = 200 m
Wave Input

- Random waves
- Eleven sets of random phases
- 200 waves per run

Overtopping and Beach Level

Effect of Beach Level on Mean Overtopping Rate

Effect of Beach Level on Maximum Overtopping Volume

Mean of all 11 Runs
Overtopping and Beach Level

2007 Storm – Modelled Conditions

Maximum Conditions

\( H_{m0} = 2.53 \text{m} \)
\( T_p = 11.2 \text{s} \)
\( h' = 3.08 \text{m} \)
2007 Storm – Overtopping and Inundation

Cumulative Overtopping Volume Throughout Storm

- 8.02 m³/m throughout storm
- Mean rate = 0.45 l/s/m over 5 hrs

Cumulative Volume (m³)

Time (hours)

Overtopping Rate (m³/m)

Time (hours)

2007 Storm – Overtopping Rates

Hourly Mean Overtopping Rates - SWAB Model vs Neural Network Tool

- SWAB Model
- Neural Network - No Setup
- Neural Network + Setup

Mean Overtopping Rate (l/s/m)

Water Level (m aOD)

Time (hours)

3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8

0 1 2 3 4 5 6

0 0.5 1 1.5

3 3.5 4 4.5 5 5.5 6 6.5 7 7.5 8

0 0.5 1 1.5 2

2.6 2.5 2.4 2.3

H_m (m)
Joint Probability Analysis

Smoothed Particle Hydrodynamics (SPH)

Very complex multi-phase multi-scale highly nonlinear problems

(Maurice McCabe – University of Manchester)

26/05/2011
LANDFORM – Coastal Flood risk – From storm surge and waves to inundation

Frame: 1661

Frame: 1671
LANDFORM – Coastal Flood risk – From storm surge and waves to inundation

Frame: 1681

Frame: 1684
LANDFORM – Coastal Flood risk – From storm surge and waves to inundation

Frame: 1685

Frame: 1686
In SPH, we know that overtopping is dependent on resolution, so with a much finer resolution this could well produce higher values.

An international collaboration between 4 universities:

- The Johns Hopkins University (USA)
- Universidade de Vigo (Spain)
- University of Manchester (UK)
- University of Rome, La Sapienza (Italy)

- Code has been released as free open-sourceware
  http://www.sphysics.org (4000+ downloads)
Conclusions

• Can we use a numerical tool to model overtopping? YES
• Wave by wave analysis with tides and surge
• Effect of beach profile
• EuroTop comparison Same order of magnitude
• Walcott and Blackpool case studies Good results
• Input for flood inundation models

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