Revisions to the EurOtop manual – version 2

Contents
1. Admissible overtopping
2. Summary of the changes
3. Calculation tools
4. Smooth slopes: dikes to vertical walls; zero freeboard, very steep slopes, promenades and storm walls
5. Armoured slopes
6. Vertical structures: new formulae on impulsive and pulsating waves
7. Closure

Life at the seaside: the “sunny” view

The developer or architect’s view

The coastal engineer’s view, including overtopping

Coastal vulnerability – transport

Writing EurOtop 2 – why?

Users and purpose of the manual

Who is the Overtopping Manual for?
- Design engineers responsible for assessment and/or of new/existing structures, or management of existing structures;
- Well-informed clients and managers responsible for management/assessment of existing structures.

What will the Overtopping Manual be used for?
- Understand wave overtopping processes;
- Predict wave overtopping for existing and/or new structures;
- Guide optimisation and/or adaptation in response to changing requirements and/or climate change.

Example reclamations, processing of LNG and related products => Low-crest defences, but demand for low overtopping discharges.
How do we describe overtopping?

Mean overtopping rate or discharge $q$ (m$^3$/s per m or l/s per m)

Distribution of overtopping wave volumes, $V$ (l/m)

Individual volumes, recent HYDRALAB+ tests

EurOtop 2 – the changes

Structure of the manual unchanged, improved formulae, some new data, better explanations.

Chapter 1: Introduction
Chapter 2: Wave and Water Levels – improved discussion on uncertainty
Chapter 3: Tolerable Discharges – effects of wave height
Chapter 4: Prediction of Overtopping – more on numerical modelling
Chapter 5: Dikes and Embankments – revised formulae, especially for small freeboards, gentle and shallow beach slopes
New material from Ghent on use of wave walls
Chapter 6: Armoured Structures – new formulae for berm breakwaters
Chapter 7: Vertical and Steep Structures – rationalise formulae, effects of impulsive vs. pulsating breaking
Chapter 8: Case studies

Previously

Update of EurOtop Manual (2016)

Prof Kortenhaus, Prof Bruce, Prof Allopp, Prof Delbrouck; Prof Troch, Prof Van der Meer and Prof Schüttrumpf

Missing: Dr Pullen and Prof Zanuttigh

16/05/2017
Wave run-up simulator generating overtopping rates over a dike crest, by individual volumes.

Videos on: www.overtopping-manual.com

Mean discharge and peak volumes

Discharge, peak volumes and wave height

Structural design of breakwaters, seawalls, dikes and dams

People and vehicles

Property behind the defence

Wave height classes:

- $H_{m0} \leq 1$ m
  - Rivers, wide canals and small lakes. Grass embankments.

- $1 < H_{m0} < 3$ m
  - Sheltered seashores and large lakes. Embankment seawalls with wave zone protected by rock, concrete units or block revetments. Grass crest, protected promenades.

- $H_{m0} \geq 3$ m
  - High waves and large water depths (> 10 m) near the structure. Breakwaters, reclamation seawalls.

Limits for structural damage

<table>
<thead>
<tr>
<th>Hazard type and reason</th>
<th>Mean discharge q (l/s per m)</th>
<th>Max volume $V_{max}$ (l per m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rubble mound breakwaters; $H_{m0} &gt; 5$ m; no damage</td>
<td>1</td>
<td>2,000–3,000</td>
</tr>
<tr>
<td>Rubble mound breakwaters; $H_{m0} &gt; 5$ m; rear side designed for wave overtopping</td>
<td>5–10</td>
<td>10,000–20,000</td>
</tr>
<tr>
<td>Grass covered crest and landward slope; maintained and closed grass cover; $H_{m0} = 1 – 3$ m</td>
<td>5</td>
<td>2,000–3,000</td>
</tr>
<tr>
<td>Grass covered crest and landward slope; non-maintained grass cover, open slopes, mines, base patches; $H_{m0} = 0.3 – 3$ m</td>
<td>0.1</td>
<td>500</td>
</tr>
<tr>
<td>Grass covered crest and landward slope; $H_{m0} &lt; 1$ m</td>
<td>5–10</td>
<td>900</td>
</tr>
<tr>
<td>Grass covered crest and landward slope; $H_{m0} = 0.3$ m</td>
<td>No limit</td>
<td>No limit</td>
</tr>
</tbody>
</table>

Limits for property / equipment

<table>
<thead>
<tr>
<th>Hazard type and reason</th>
<th>Mean discharge q (l/s per m)</th>
<th>Max volume $V_{max}$ (l per m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Significant damage or sinking of larger yachts; $H_{m0} &gt; 3$ m</td>
<td>$&lt;1$</td>
<td>$&lt;1,000$</td>
</tr>
<tr>
<td>Significant damage or sinking of smaller yachts; $H_{m0} = 3$ m</td>
<td>$&lt;1$</td>
<td>$&lt;1,000$</td>
</tr>
<tr>
<td>Damage to larger yachts; $H_{m0} = 3$ m</td>
<td>$&lt;1$</td>
<td>$&lt;10$</td>
</tr>
<tr>
<td>Damage to smaller yachts set back 5–10 m from wall; $H_{m0} = 3$ m</td>
<td>$&lt;1$</td>
<td>$&lt;10$</td>
</tr>
<tr>
<td>Building structure elements; $H_{m0} = 1$ m</td>
<td>$&lt;1$</td>
<td>$&lt;1,000$</td>
</tr>
<tr>
<td>Damage to equipment set back 5–10 m; $H_{m0} = 3$ m</td>
<td>$&lt;1$</td>
<td>$&lt;1,000$</td>
</tr>
</tbody>
</table>
### Limits for people and vehicles

<table>
<thead>
<tr>
<th>Hazard type and reason</th>
<th>Mean discharge q (l/s per m)</th>
<th>Max volume Vmax (l per m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>People at structures with possible violent overtopping, mostly vertical structures</td>
<td>0.3</td>
<td>400 – 600</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>400 – 600</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>400 – 600</td>
</tr>
<tr>
<td></td>
<td>&gt;0.5</td>
<td>No limit</td>
</tr>
<tr>
<td>Cars on crest of a dike for dike inspection</td>
<td>&lt;5</td>
<td>1000 – 2000</td>
</tr>
<tr>
<td></td>
<td>&gt;5</td>
<td>1000 – 2000</td>
</tr>
<tr>
<td></td>
<td>&gt;10</td>
<td>1000 – 2000</td>
</tr>
<tr>
<td>Highways and roads, fast traffic</td>
<td>Close before debris in spray becomes dangerous</td>
<td></td>
</tr>
<tr>
<td>Railway tracks, slowing moving train</td>
<td>See cars on crest of a dike</td>
<td>See cars on crest of a dike</td>
</tr>
</tbody>
</table>

### Chapter 4: Overtopping tools in perspective

**Overview**

- Revised empirical equations
- Empirical calculator
- PC-Overtopping
- EurOtop database
- EurOtop Artificial Neural Network
- Gaussian Process Emulator
- Numerical modelling
- Physical modelling

### Refined approaches to the formulae

- **Mean value approach.** Use formula as given with mean value of stochastic parameter(s) to predict or compare with test data. Model factor m is given with σ(m). This is the probabilistic design approach in EurOtop (2007);
- **Design or safety assessment approach.** This is an easy semi-probabilistic approach (partial safety factor); as the mean value approach above, but including uncertainty of the prediction: m = μ(m) + σ(m). This was the deterministic design approach in EurOtop (2007);
- **Probabilistic approach.** Consider the stochastic parameter(s) with their given standard deviation and assuming a normal or log-normal distribution.
- The 5%-exceedance lines, or 90%-confidence band, can be calculated by using μ(m) ± 1.64σ(m) for the stochastic parameter(s).
Online prediction tool that was developed for dike type structures

- It can account for different roughness / permeability along a structure – an advancement of the empirical calculator which can only resolve for idealised structure geometries with a single roughness.

- NB. This tool will continue to use the original formulae of EurOtop (2007) and not be updated for EurOtop (2016).

Output remains fairly close to the new prediction tools for cases where; $R_c/H_{m0} > 0.5m$.

Input:
- wave height, wave period, wave angle, water level, storm duration, mean period

Unlimited number of sections, uses $x$-$y$ co-ordinates, own roughness for each section.

No existing numerical model is capable of including all of these processes.

Require 500 – 1000 waves to be statistically reliable which is computationally demanding.

New EurOtop database

- Builds on the CLASH database ~10,000 tests, now >17,000 tests.
- Covers a wide range of structures; dikes, rubble mound breakwaters, berm breakwaters, caissons and combinations of these structures.
- Reliability (RF) and complexity factor (CF) assigned; 1 = most reliable, 4 = least and not used.
- The new database includes wave transmission ($K_t$) and wave reflection ($K_r$) datasets as well as overtopping ($q$).
- The database can be searched to find corresponding examples to the one being examined.

EurOtop Artificial Neural Network

Advantages:
- It works for wider ranges of structure configuration – an advancement on PC-Overtopping and Empirical calculator
- It is easy to calculate trends instead of just one calculation with one answer

Disadvantages:
- How well your structure fits the database is not shown and does not yield the dataset of closest comparison

Bayonet Gaussian Process Emulator

- Another new online prediction tool under development which will also go live on website
- Developed by HR Wallingford and Environment Agency
- Trained on the same EurOtop database
- Not a neural network. Uses Gaussian processes to take median path rather than line of best fit

Advantages
- If the case being examined matches an entry within the database it will yield the original result
- Gives a score based on closeness to known data and validity of the input
- Prevents you from calculating outside the known dataset – green, orange, red

Physical modelling

- Mean discharge & individual overtopping volumes can be measured – important for defining tolerable discharge
- Frequently occurring and extreme storm events can be modelled over the entire storm duration – statistically more reliable

Improvements for very low crests

- New formula, Eq. 4.3
- EurOtop (2007) formula, Eq. 4.2
- EurOtop (2007) formula not valid anymore

From slope to steeply battered

cota = 10; 6; 4; 3; 2; 1.5; 1.0; 0.5; 0.33; 0.25

Slopes: up to zero freeboard

Relative freeboard \( R_c/H_{m0} \)


**From slope to steeply battered**

\[ \cot \alpha = 10; 6; 4; 3; 2; 1.5; 1.0; 0.5; 0.33; 0.25 \]

Relative overtopping rate \[ \frac{q}{(gH_{m0}^3)^{0.5}} \]

Relative freeboard \[ \frac{R_c}{H_{m0}} \]

Smooth slope non-breaking

Vertical cota=0

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**Armoured slope**

\[ \cot \alpha = 10; 6; 4; 3; 2; 1.5; 1.0; 0.5; 0.33; 0.25 \]

Seawall with low freeboard – Ostend, Belgium

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**Coastal seawalls with wave walls**

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**Wave overtopping on inland reservoirs**

Very steep waves, steep slopes, deep water.

Many dams with toe of wave wall close to or at the design water level.
Coastal seawalls with wave walls

Seawall with stilling basin, ICCE 2006
Effect of parapet walls, ICCE 2010
Promenade and recure influence factors defined in section 5.4.7.

Vertical walls, three cases

Vertical wall with influencing foreshore, non-impulsive conditions (no breaking)

Franco et al., 1998

Relative freeboard $R/H_{m0}$

Equation:

$$q = \frac{1}{gH_{m0}}$$

Influencing foreshore, impulsive:

$$q = 0.01 \left( \frac{H_{m0}}{h_{m0}} \right)^{0.15} \exp \left( -2.2 \frac{R_c}{H_{m0}} \right)$$
valid for $0 < R_c/H_{m0} < 1.35$

$$q = 0.004 \left( \frac{H_{m0}}{h_{m0}} \right)^{0.5} \left( \frac{R_c}{H_{m0}} \right)^{1.5}$$
valid for $R_c/H_{m0} \geq 1.35$

Vertical structures

No influencing foreshore:

$$q = 0.047 \exp \left( -2.78 \frac{R_c}{H_{m0}} \right)$$

Influencing foreshore, non-impulsive:

$$q = 0.01 \exp \left( -2.78 \frac{R_c}{H_{m0}} \right)$$

EurOtop 2 – the changes

Revised EurOtop 2 manual is downloadable as a .pdf document from the web: www.overtopping-manual.com

Supported by:
• Calculation Tool to calculate overtopping discharge using empirical formulae
• Neural Network
• PC-Overtopping
• Videos of overtopping processes

Note: Some problems are complicated – we prefer to give you guidance where we can, but there will be some aspects left to the user!

EurOtop 2 – Acknowledgements

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• Hadewych Verhaeghe, Flanders Community,
• Corrado Altomare, Flanders Hydraulics,

EurOtop 2 – pre-release version

Pre-release version of EurOtop Manual (2016) available
www.overtopping-manual.com