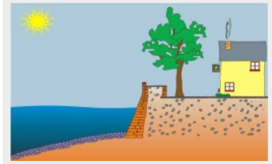
Updating the EurOtop manual on wave overtopping

William Allsop (Technical Director, HR Wallingford)

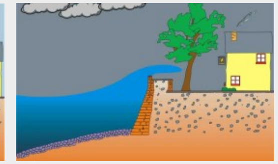
Revisions to the EurOtop manual – version 2

Contents

Life at the seaside: the "sunny" view



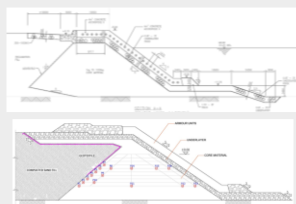
The developer or architect's view



The coastal engineer's view, including overtopping

Coastal vulnerability – transport

Writing EurOtop 2 – why?



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

Users and purpose of the manual

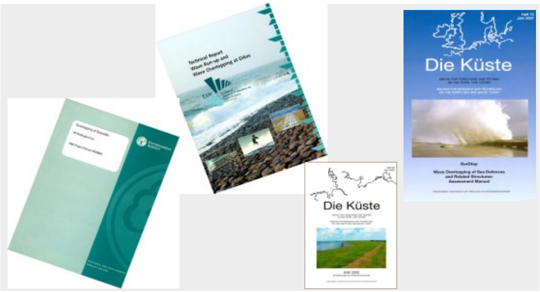
Who is the Overtopping Manual for?

- 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

Previously



Update of EurOtop Manual (2016)

Prof Kortenhaus, Prof Bruce, Prof Allsop, Prof DeRouck;
Prof Troch, Prof Van der Meer and Prof Schüttrumpf
Missing: Dr Pullen and Prof Zanuttigh

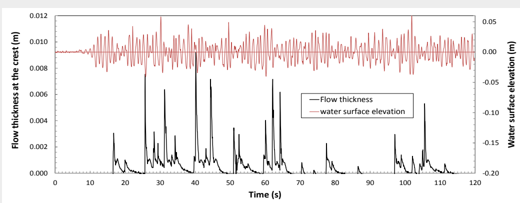
EurOtop 2 – the changes

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

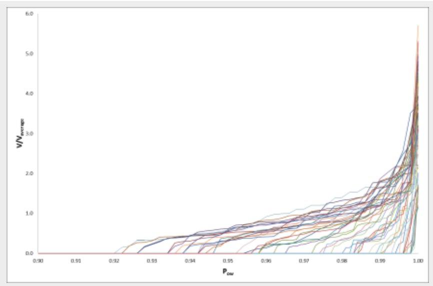
Chapter 1:	Introduction
Chapter 2:	Wave and Water Levels – improved discussion on uncertainty
Chapter 3:	Tolerable Discharges – effects of wave height
Chapter 4:	Prediction of Overtopping – more on numerical modelling
Chapter 5:	Dikes and Embankments – revised formulae, especially for small freeboards, 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

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



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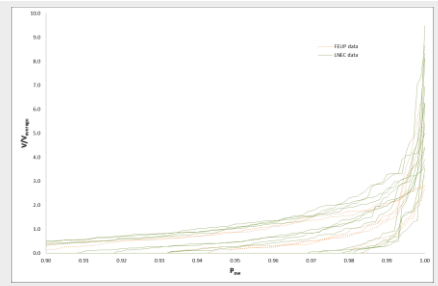
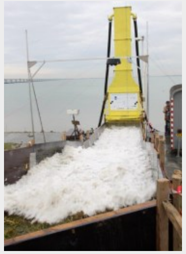


Mean discharge and peak volumes

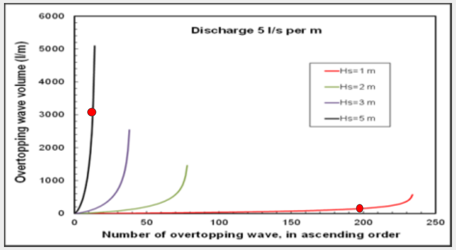


Wave run-up simulator generating overtopping rates over a dike crest, by individual volumes.

Videos on:

www.overtopping-manual.com

Mean discharge and peak volumes



Mean discharge and peak volumes

Three-minute videos looking up-slope and downwards, with the distribution of overtopping wave volumes

For conditions: H_{m0} = 1 m; 2 m and 3 m
and: q = 1; 5; 10; 30; 50 and 75 l/s per m

Individual overtopping wave volumes of:

100; 150; 200; 250; 300; 400; 500; 600; 700; 800; 1000; 1200; 1400; 1600; 1800; 2000; 2250; 2500; 2750 and 3000 l per m.

Use the videos to make your own judgement of tolerable overtopping

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} ≤ 1 m — Rivers, wide canals and small lakes. Grass embankments.

H_{m0} = 1 - 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} ≥ 3 - 5 m — High waves and large water depths (> 10 m) near the structure. Breakwaters, reclamation seawalls.

Limits for structural damage

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
Rubble mound breakwaters; H_{m0} > 5 m; no damage	1	2,000-3,000
Rubble mound breakwaters; H_{m0} > 5 m; rear side designed for wave overtopping	5-10	10,000-20,000
Grass covered crest and landward slope; maintained and closed grass cover; H_{m0} = 1 – 3 m	5	2,000-3,000
Grass covered crest and landward slope; not maintained grass cover, open spots, moss, bare patches; H_{m0} = 0.5 – 3 m	0.1	500
Grass covered crest and landward slope; H_{m0} < 1 m	5-10	500
Grass covered crest and landward slope; H_{m0} < 0.3 m	No limit	No limit

Limits for property / equipment

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
Significant damage or sinking of larger yachts; H_{m0} > 5 m	>10	>5,000 – 30,000
Significant damage or sinking of larger yachts; H_{m0} = 3-5 m	>20	>5,000 – 30,000
Sinking small boats set 5-10 m from wall; H_{m0} = 3-5 m Damage to larger yachts	>5	>3,000-5,000
Safe for larger yachts; H_{m0} > 5 m	<5	<5,000
Safe for smaller boats set 5-10 m from wall; H_{m0} = 3-5 m	<1	<2,000
Building structure elements; H_{m0} = 1-3 m	≤1	<1,000
Damage to equipment set back 5-10m	≤1	<1,000

Limits for people and vehicles

Hazard type and reason	Mean discharge q (l/s per m)	Max volume V_{max} (l per m)
People at structures with possible violent overtopping, mostly vertical structures	No acces for any predicted overtopping	No acces for any predicted overtopping
People at rubble mound breakwater crest and at dike crest. Clear view on the sea. H_{m0} = 3 m H_{m0} = 2 m H_{m0} = 1 m H_{m0} < 0.5 m	0.3 1 10-20 No limit	400 – 600 400 – 600 400 – 600 No limit
Cars on crest of a dike for dike inspection. H_{m0} = 3 m H_{m0} = 2 m H_{m0} = 1 m	<5 10-20 <75	1000-2000 1000-2000 1000-2000
Highways and roads, fast traffic	Close before debris in spray becomes dangerous	Close before debris in spray becomes dangerous
Railway tracks, slowly moving train	See cars on crest of a dike	See cars on crest of a dike

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

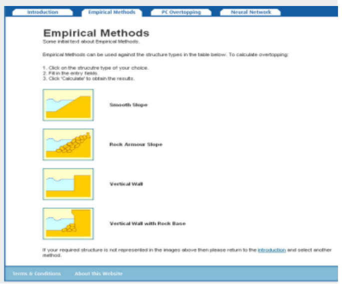
Refined approaches to the formulae

- **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).

EurOtop 2 – Calculation Tool

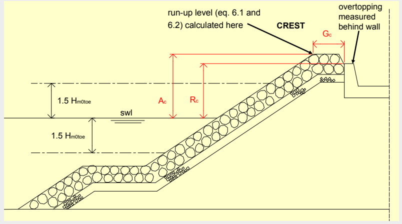
Calculation Tool to calculate overtopping discharge using empirical formulae

- To be extended and updated, but little change otherwise

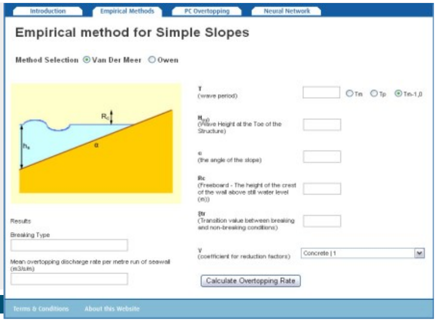


Empirical calculator

Armoured slopes



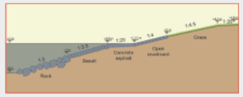
EurOtop 2 – Calculation Tool

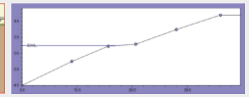


PC-Overtopping

- 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; Rc / Hm0 > 0.5m

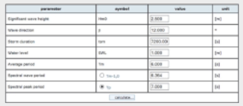
PC-Overtopping

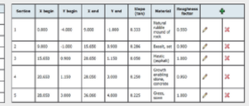




Input: wave height, wave period, wave angle, water level, storm duration, mean period

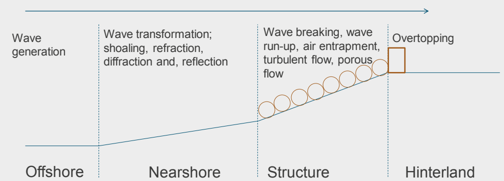
Unlimited number of sections, uses x-y co-ordinates, own roughness for each section

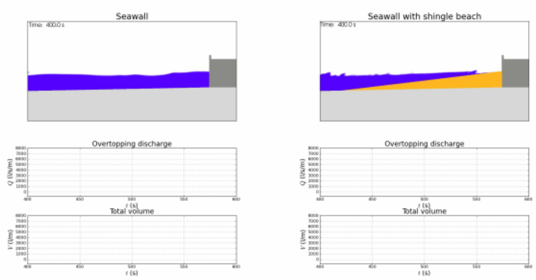




Numerical modelling

- No existing numerical model is capable of including all of these processes
- Require 500 - 1000 waves to be statistically reliable which is computationally demanding





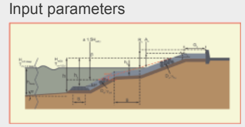
OpenFOAM model (*in development, Cuomo, Richardson & others*).

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 (Kt) and wave reflection (Kr) datasets as well as overtopping (q)
- The database can be searched to find corresponding examples to the one being examined
- Will be available on the webpage www.overtopping-manual.com

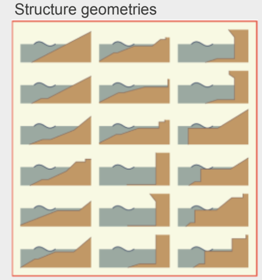
New EurOtop database

Input parameters



- 42 parameters per dataset entry covering hydraulic, structural, geometry, and general features to fully describe each entry in more detail than the CLASH database

Structure geometries



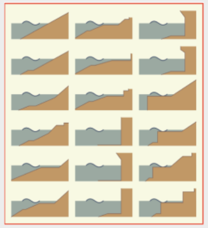
EurOtop Artificial Neural Network

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

- The number of parameters and complex wave-structure interaction make physical models the most reliable tool for measuring overtopping

Wave generation

↓

Wave transformation; shoaling, refraction, diffraction and, reflection

↓

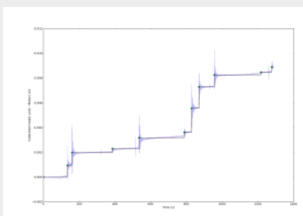
Wave breaking, wave run-up, air entrapment, turbulent flow, porous flow

↓

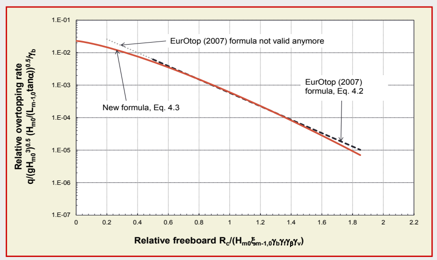
Overtopping

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



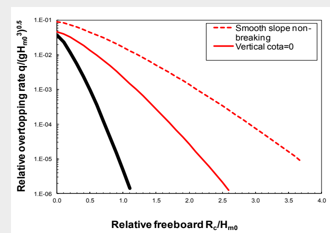
Improvements for very low crests



Slopes: up to zero freeboard

From slope to steeply battered

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



From slope to steeply battered

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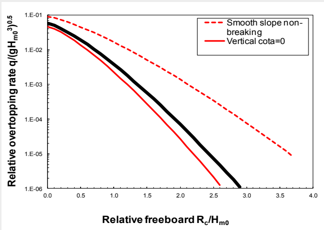

From slope to steeply battered

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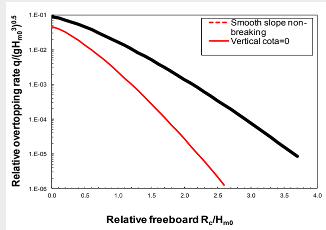

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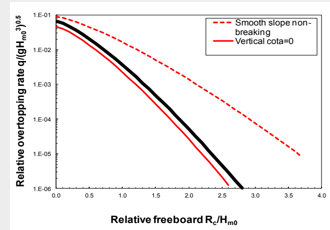
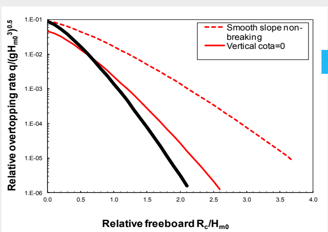


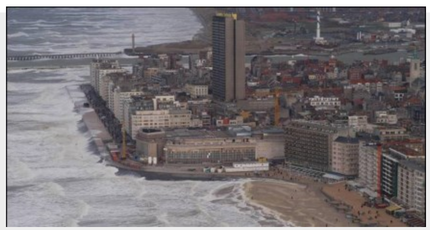
Armoured slope

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



γ_f=0.5

Coastal seawalls with wave walls



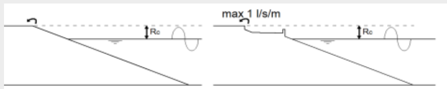
Seawall with low freeboard – Oostende, Belgiom

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

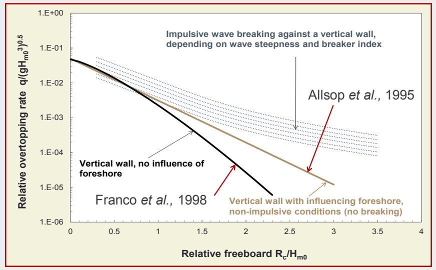


Seawall with stilling basin, ICCE 2006

Effect of parapet walls, ICCE 2010

Promenade and recurve influence factors defined in section 5.4.7.

Vertical walls, three cases



Vertical structures

No influencing foreshore:

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.047 \cdot \exp\left[-\left(2.35\frac{R_C}{H_{m0}}\right)^{1.3}\right]$$

Influencing foreshore, non-impulsive:

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.05\exp\left(-2.78\frac{R_c}{H_{m0}}\right)$$

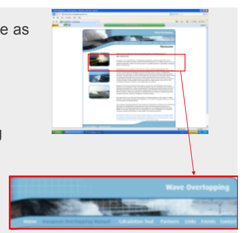
Influencing foreshore, impulsive:

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.011\left(\frac{H_{m0}}{hs_{m-1,0}}\right)^{0.5}\exp\left(-2.2\frac{R_c}{H_{m0}}\right)$$ valid for $0 < R_c/H_{m0} < 1.35$

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.0014\left(\frac{H_{m0}}{hs_{m-1,0}}\right)^{0.5}\left(\frac{R_c}{H_{m0}}\right)^{-3}$$ valid for $R_c/H_{m0} \geq 1.35$

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

This activity has partial funding, but relies strongly on good-will and informal support. The EurOtop 2 Team particularly thanks:

- Netherlands Rijkswaterstaat
- UK Environment Agency
- Ghent University; University of Edinburgh;

Steering Group:

- Bas Hofland, Deltares,
- Hans van der Sande, Dutch Water Boards,
- Leo Franco, Modimar & University of Rome 3,
- 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