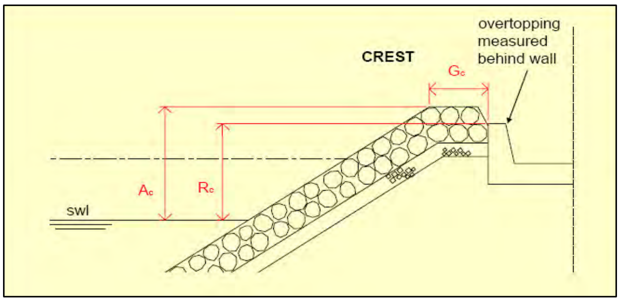
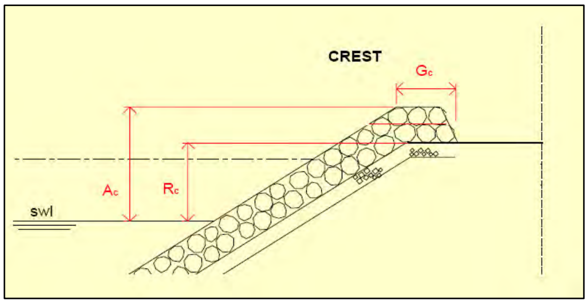
Simple Armoured Slope Overtopping Calculation

ROYAL HASKONING

Project No and Title	9V4473 Poole FRMS
Subject	Calculations of overtopping using EurOtop
Section	
Prepared By	XS
Date	03/09/2009
Design Condition (i.e RP)	
Checked By	

REFERENCES: EurOtop Manual - Chapter 6;
Wave Overtopping of Sea Defences and Related Structures: Assessment Manual (August 2007)





Assumptions
1.Crest width assumed at 3m
2.incident wave angle assumed at 0°

3. type of armour layer assumed as rocks (2 layers,permeable core)

Input Data

Incident Significant Wave Height	H_{mo}	=	0.7	m	
Freeboard, (SWL to Crest Level)	R_c	=	0.25	m	Measured from Crest to SWL
Incident Wave Angle	β	=	0	deg	0 degree is when wave normal to structure
Crest Width	G_c	=	0	m	Crest width >=0.75Hmo, No reduction for <0.75Hmo
Roughness Factor for Armour layer	γ_f	=	0.4		See Table 6.2 Page 115

Output Result

Effect of Oblique Wave Angle	γ_β	=	1	EQN 6.8	Calculated reduction factor for oblique wave attack
Effect of Crest Width	C_r	=	1.00	EQN 6.7	No reduction factor to be applied if G_c<0.75H_{mo}

Deterministic design or design & safety assessment

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 0.2 \cdot \exp\left(-2.3 \frac{R_C}{H_{m0} \cdot \gamma_f \cdot \gamma_\beta}\right)$$

EQN 6.5 Page 114

Mean Wave Overtopping Discharge	**q**	**=**	**0.04706**	**m^3/s/m**
New Mean Overtopping Discharge	**q_r**	**=**	**0.04706**	**m^3/s/m**
			47.061	**l/s/m**

No Reduction Applied

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Note

HASKONING UK LTD.
COASTAL & RIVERS

To	:	Poole FRMS Team
From	:	Benjamin Rostaing; Xiaolei Sun
Date	:	25August 2009
Copy	:	
Our reference	:	9V4473/NBR002/303377/PBor
Subject	**:**	**Freeboard calculations**

This note is to propose an approach to determine the appropriate freeboard in a coastal environment.

The total freeboard should allow for:

- Uncertainty on the design water level;
- Wave-overtopping;
- Settlement;
- Degradation (for soft defences only);

Uncertainty on the design water level

The uncertainty on the design water level depends on a range of parameters which include the length of tide record available, the accuracy of the tide gauge itself and also the spatial distribution of tide gauges in the vicinity of the area of interest.

The published extreme tide levels for Poole have been derived in a study lead by Royal Haskoning. The degree of confidence in the results was discussed in the report and confidence bounds provided. For Poole, the degree of confidence in the data was deemed good and the suggested confidence bound in all extreme tide levels was +/- 0.2m.

Therefore, the freeboard relative to the extreme tide levels in Poole is 200mm.

Wave-overtopping

<u>Principles</u>

The aim of the allowance is to limit wave-overtopping to an acceptable rate or volume. The acceptable quantity can be to avoid failure of the defence, limit the rate to acceptable levels for pedestrian safety or even limit the total volume of wave overtopping to prevent inland flooding. The allowable mean overtopping discharges for various types of defences and conditions can be derived from Table 5.4 “Critical overtopping discharges and volumes (Allsop et al., 2005)” taken from the Rock Manual[1].

Once the critical allowable overtopping rate has been determined, overtopping calculations can be undertaken to assess the overtopping rate at the peak tide level. The wave conditions must be determined appropriately. The overtopping rate can be calculated using the “W178 – Overtopping of seawalls” spreadsheet, AMAZON (in-house software developed by Keming Hu)

[1] The Rock Manual, The use of rock in hydraulic engineering, (2nd edition), CIRIA C683, 2007

or the Eurotop Manual. The crest level of the defence can be iteratively changed until the overtopping rate is acceptable.

It should also be noted that the total overtopping volume over a tidal cycle can also be calculated so as ascertain whether the overtopping volume can cause flooding. Typically, the overtopping rate varies exponentially with a decreasing freeboard such that the tide curve can be converted into an overtopping hydrograph once the overtopping rate has been calculated for a range of still water levels.

Table 6.4 *Critical overtopping discharges and volumes (Allsop et al, 2005)*

	q mean overtopping discharge (m^3 /s per m length)	V_{max} peak overtopping volume (m^3/per m length)
Pedestrians		
Unsafe for unaware pedestrians, no clear view of the sea, relatively easily upset or frightened, narrow walkway or proximity to edge	$q > q > 3 \cdot 10^{-5}$	$V_{max} > 2 \cdot 10^{-3} - 5 \cdot 10^{-3}$
Unsafe for aware pedestrians, clear view of the sea, not easily upset or frightened, able to tolerate getting wet, wider walkway	$q > 1 \cdot 10^{-4}$	$V_{max} > 0.02 - 0.05$
Unsafe for trained staff, well shod and protected, expected to get wet, overtopping flows at lower levels only, no falling jet, low danger of fall from walkway	$q > 1 \cdot 10^{-3} - 0.01$	$V_{max} > 0.5$
Vehicles		
Unsafe for driving at moderate or high speed, impulsive overtopping giving falling or high velocity jets	$q > 1.10^{-5} - 5.10^{-5}$	$V_{max} > 5 \cdot 10^{-3}$
Unsafe for driving at low speed, overtopping by pulsating flows at low levels only, no falling jets	$q > 0.01 - 0.05$	$V_{max} > 1 \cdot 10^{-2}$
Marinas		
Sinking of small boats set 5-10 m from wall, damage to larger yachts	$q > 0.01$	$V_{max} > 1 - 10$
Significant damage or sinking of larger yachts	$q > 0.05$	$V_{max} > 5 - 50$
Buildings		
No damage	$q < 1 \cdot 10^{-6}$	
Minor damage to fittings etc.	$1 \cdot 10^{-6} < q < 3 \cdot 10^{-5}$	
Structural damage	$q > 3 \cdot 10^{-5}$	
Embankment seawalls		
No damage	$q < 2 \cdot 10^{-3}$	
Damage if crest not protected	$2 \cdot 10^{-3} < q < 0.02$	
Damage if back slope not protected	$0.02 < q < 0.05$	
Damage even if fully protected	$q > 0.05$	
Revetment seawalls		
No damage	$q < 0.05$	
Damage if promenade not paved	$0.05 < q < 0.2$	
Damage even if promenade paved	$q < 0.2$	

Freeboard Calculation at Poole

The wave climate within the Poole Bay has been adopted from the Poole ABD study, which used a significant wave height (H_s) of 0.7m and a wave period of T_s=6s. This wave height value was itself extrapolated from data published in the Poole Bay and Harbour Strategy Study.

It was decided to calculate the freeboard required for three different typical types of defences for the Poole frontage: a plain vertical wall, a simple armour slope and an embankment. Wave overtopping has been calculated using Eurotop or W178 as appropriate.

It was also decided to split the frontage between areas where wave overtopping is an issue (e.g. frontline defences) and those that will be more sheltered and for which a nominal freeboard can be adopted.

In the case of a plain vertical wall, the Eurotop tool was used to estimate the overtopping rate. The following assumptions on the overtopping conditions have been made:

- The incident significant wave height is 0.7m and its mean wave period (T_m)is 5s;
- The water depth at the toe of the structure is taken as 4m in year 2026 and 5.1m in year 2126; and
- The critical overtopping rate is adopted as 0.01m^3/s/m, which means resulting conditions would be unsafe for driving cars at low speed and for all pedestrians.

In the case of a simple armour slope, the Eurotop tool was used to estimate the overtopping rate. The following assumptions on the overtopping conditions have been made:

- The incident significant wave height is 0.7m and its mean wave period (T_m)is 5s;
- The incident wave attack angle is normal to structure to provide the worst case scenario;
- The crest width is 0m, i.e. the wall is built right at the end of the armour slope;
- The slope is assumed as 2 layers of rocks with a permeable core; and
- The critical overtopping rate is taken as 0.05m^3/s/m, at which point the revetment starts to be damaged.

In the case of an embankment, the W178 spreadsheet was used to estimate the overtopping rate. The following assumptions on the overtopping conditions have been made:

- The incident significant wave height is 0.7m and its mean wave period (T_m)is 5s;
- The embankment slope is taken as 1:2;
- The crest width is 4m;
- The incident wave attack angle is normal to structure to provide the worst case scenario;
- The embankment material is stone blocks, pitched or mortared and is therefore not permeable;
- The critical overtopping rate is taken as 0.05m^3/s/m, at which point the embankment starts to be damaged.

The calculation sheets for each of the 3 scenarios are provided in **Appendix A** to this note.

For the locations where wave-overtopping is not an issue, it was decided to adopt a freeboard equal to the wave height (0.7m) if the calculated freeboard is greater than 0.7m and to adopt a nil freeboard if the calculated freeboard is less than 0.7m (in the case of the simple rock armour).

The results from the analysis are summarised in **Table 1** overleaf.

			Minimum freeboard required (m)			
	Critical Overtopping rate	Meaning	Overtopping sensitive		Non-overtopping sensitive	
	$m^3/s/m$		Year 2026	Year 2126	Year 2026	Year 2126
Plain vertical wall	0.01	Unsafe for driving at low speed, unsafe for trained staff	0.8	0.8	0.7	0.7
Simple armour slope	0.05	Revetment seawalls start to get damage, unsafe for driving at low speed	0.3	0.3	0	0
Embankment	0.05	Embankment seawalls get damage even it fully protected	1.1	1.1	0.7	0.7

Table 1 – Wave overtopping freeboard summary

Settlement
Settlement is discussed in the Fluvial Freeboard Guidance Note[2]. In a coastal environment, the same principle can be followed. Specialist geotechnical input may be sought where required.

Degradation
Degradation is also discussed in the Fluvial Freeboard Guidance Note. This is to do with grazing animals and vehicular traffic which can cause wear or degradation of the crest of grassed flood embankments which will reduce the effective height of the defence.

Generally speaking since degradation is often localised, it will be preferable to treat it as a maintenance issue rather than a requirement for additional freeboard. If the degradation is likely to be more widespread, and it cannot be overcome, then a degradation allowance of 75 to 100mm may be appropriate.

[2] Fluvial Freeboard Guidance Note, R&D Technical Report W187, 2000

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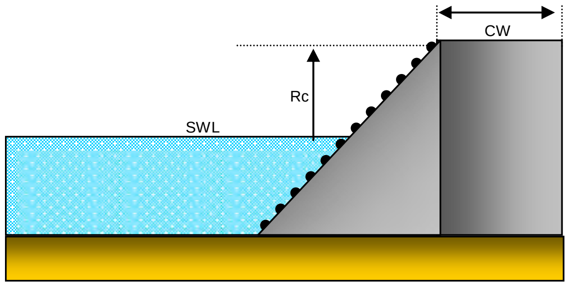
Appendix A
WAVE OVERTOPPING CALCULATIONS

TYPE 3 PERMEABLE SIMPLE SLOPE



Area	
OS 1-10k tiles	
Defence Code	
Cross Section No.	

Location

ß	=	0	angle of wave attack to the normal (degrees)
Or	=	-	ratio of discharge under angled wave attack to that under normal wave attack
A	=	0.00939	empirically derived coefficients
B	=	21.6	empirically derived coefficients
Cr	=	-	reduction factor
Cw	=	4	crest berm width (m)
g	=	9.81	acceleration due to gravity (m/s^2)
Hs	=	0.7	the significiant wave height at the toe of the wall (m)
Q*	=	-	discharge parameter (dimensionless)
Q	=	-	the mean overtopping discharge rate per metre run of seawall ($m^3/s/m$)
Rc	=	1.1	freeboard (height of the crest of the wall above still water level) (m)
R*	=	-	dimensionless crest freeboard
r	=	0.95	roughness coefficient
Tm	=	5	the mean wave period at the toe of the structure (s)

Parameters

Or	=	$1 - 0.000152\ ß^2$	**valid for $0^o < ß < 60^o$**
R*	=	$Rc / (Tm\ (g\ Hs)^{0.5})$	
Q*	=	A EXP (-B R* / r)	**valid for 0.05 < R* < 0.30**
Qi (impermeable)	=	Q* (Tm g Hs)	
if crest berm is permeable also then			
Cr	=	3.06 exp (-1.5 Cw / Hs)	**when CW/Hs < 0.75 assume Cr = 1**
Qp (permeable)	=	Qi Cr	

Equations

Or	=	NORMAL WAVE ATTACK
R*	=	0.083953568
Q*	=	0.00139209
Qi	=	0.047797413
if crest berm is also permeable then enter 2, if not enter 1		1
Cw/Hs	=	5.714285714
Cr	=	0.000579692
Qp	=	SEE ABOVE

Calculations

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thinking in all dimensions

Q (l/s/m)	47.8

Result

Plain Vertical Walls Overtopping Calculation

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REFERENCES: EurOtop Manual - Chapter 7;
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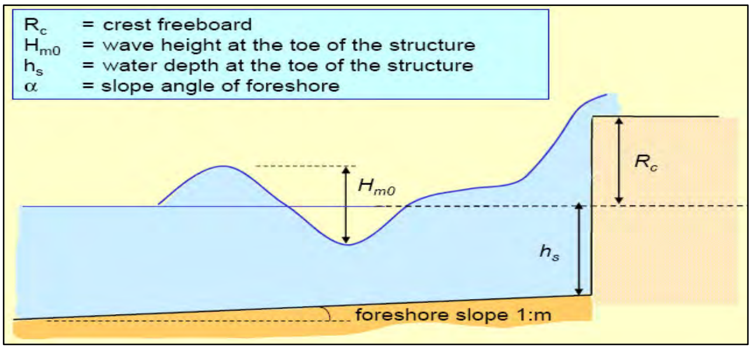

Calculation Assumptions:

1. Assessment of overtopping at plain vertical walls only
2. No effect of obliques waves is taken into account
3.Critical overtopping duscharge is 0.05m^3/s/m
4. Water depth at toe assumed at 4.0m

Input Data

Incident Significant Wave Height	H_{mo}	=	0.7	m
Spectral or Mean Wave Period	$T_{m-1,0}$, T_m	=	5	s
Water Depth at Toe	h_s	=	4.00	m
Freeboard (SWL to Crest Level)	R_c	=	0.8	m

Output Result

"Impulsiveness" Parameter	h_*	=	0.7905	
"Impulsiveness" Condition		=	non-Impulsive Condition - EQN 7.4	
(Impulsive) Dimensionless Freeboard	$h_* R_c/H_{m0}$	=	N/A	N/A
Dimensionless Freeboard (EQN 7.4)	R_c/H_{mo}	=	1.1	Valid

Deterministic design or design & safety assessment

non-impulsive conditions ($h_* > 0.3$):

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.04\exp\left(-1.8\frac{R_c}{H_{m0}}\right) \quad \text{valid for } 0.1 < R_c/H_{m0} < 3.5$$ EQN 7.4

impulsive conditions ($h_* \leq 0.2$):

$$\frac{q}{h_*^2\sqrt{gh_s^3}} = 2.8\times10^{-4}\left(h_*\frac{R_c}{H_{m0}}\right)^{-3.1} \quad \text{valid over } 0.03 < h_*\frac{R_c}{H_{m0}} < 1.0$$ EQN 7.7

$$\frac{q}{h_*^2\sqrt{gh_s^3}} = 3.8\times10^{-4}\left(h_*\frac{R_c}{H_{m0}}\right)^{-2.7} \quad \text{valid for } h_*\frac{R_c}{H_{m0}} < 0.02\text{; broken waves}$$ EQN 7.9

Mean Overtopping Discharge	**q**	**=**	**0.00938**	**m^3/s/m**
			9.38	**l/s/m**

Plain Vertical Walls Overtopping Calculation

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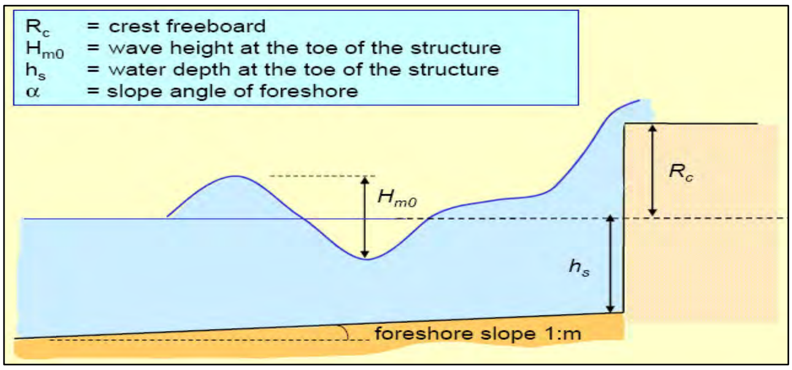

Calculation Assumptions:

1. Assessment of overtopping at plain vertical walls only
2. No effect of obliques waves is taken into account
3.Critical overtopping discharge is 0.05m^3/s/m
4. Water depth at toe assumed at 4.0m

Input Data				
Incident Significant Wave Height	H_{mo}	=	0.7	m
Spectral or Mean Wave Period	$T_{m-1,0}$,T_m	=	5	s
Water Depth at Toe	h_s	=	5.10	m
Freeboard (SWL to Crest Level)	R_c	=	0.8	m

Output Result				
"Impulsiveness" Parameter	h_*	=	1.2851	
"Impulsiveness" Condition		=	non-Impulsive Condition - EQN 7.4	
(Impulsive) Dimensionless Freeboard	$h_* R_c/H_{m0}$	=	N/A	N/A
Dimensionless Freeboard (EQN 7.4)	R_c/H_{mo}	=	1.1	Valid

<u>Deterministic design or design & safety assessment</u>

non-impulsive conditions ($h_* > 0.3$):

$$\frac{q}{\sqrt{gH_{m0}^3}} = 0.04\exp\left(-1.8\frac{R_c}{H_{m0}}\right) \quad \text{valid for } 0.1 < R_c/H_{m0} < 3.5$$

EQN 7.4

impulsive conditions ($h_* \leq 0.2$):

$$\frac{q}{h_*^2\sqrt{gh_s^3}} = 2.8\times10^{-4}\left(h_*\frac{R_c}{H_{m0}}\right)^{-3.1} \quad \text{valid over } 0.03 < h_*\frac{R_c}{H_{m0}} < 1.0$$

EQN 7.7

$$\frac{q}{h_*^2\sqrt{gh_s^3}} = 3.8\times10^{-4}\left(h_*\frac{R_c}{H_{m0}}\right)^{-2.7} \quad \text{valid for } h_*\frac{R_c}{H_{m0}} < 0.02\text{; broken waves}$$

EQN 7.9

Mean Overtopping Discharge	**q**	**=**	**0.00938**	**m^3/s/m**
			9.38	**l/s/m**