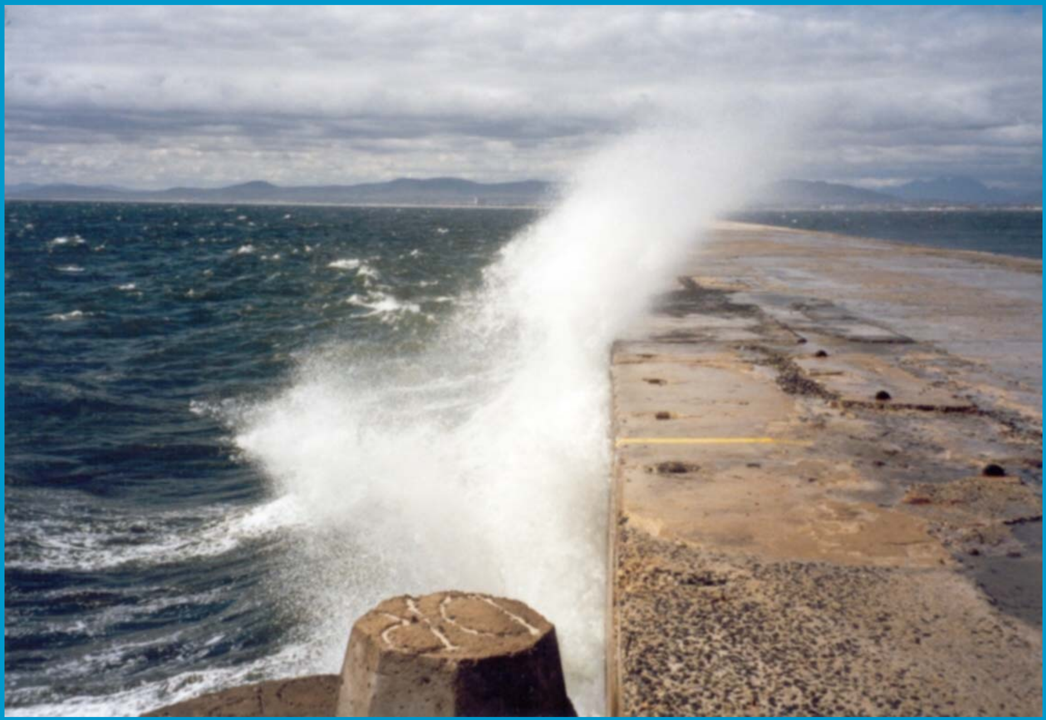
Chapter 10: Wave-structure interaction



ct5308 Breakwaters and Closure Dams

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March 29, 2012

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Section Hydraulic Engineering

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overview of interactions

- Wave (pressure) penetration
- Wave reflection
- Wave run-up
- Wave overtopping
- Wave transmission

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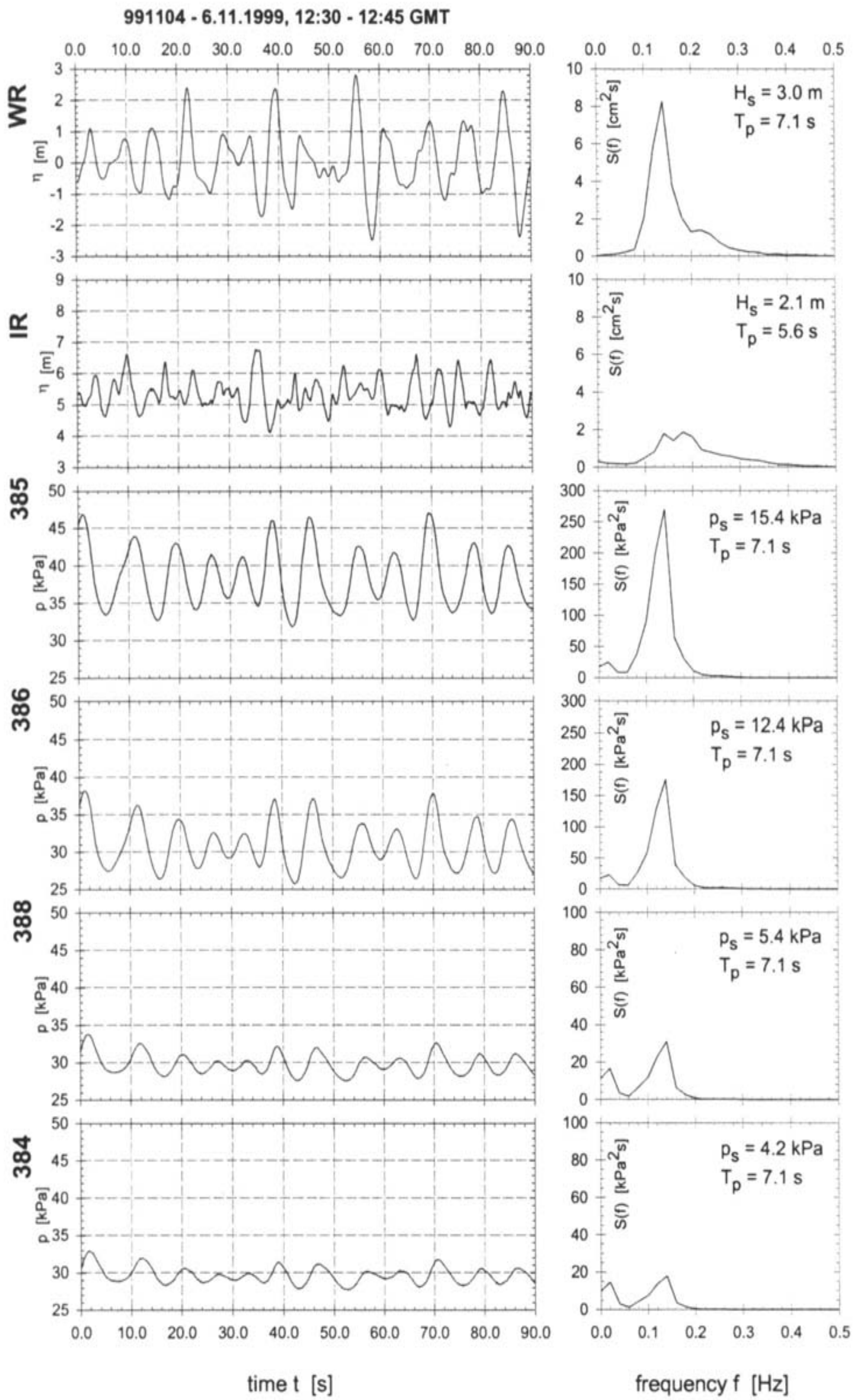

waves and pressures (1)

measurements at the Zeebrugge breakwater

storm of 4 November 1999

15 min wave record
WR = waverider, 150 m away
LR = laser at toe
385,386, 388, 384 = pressure sensors on one level

Data from Peter Troch, Ghent University, PIANC bull 108, sept 2001

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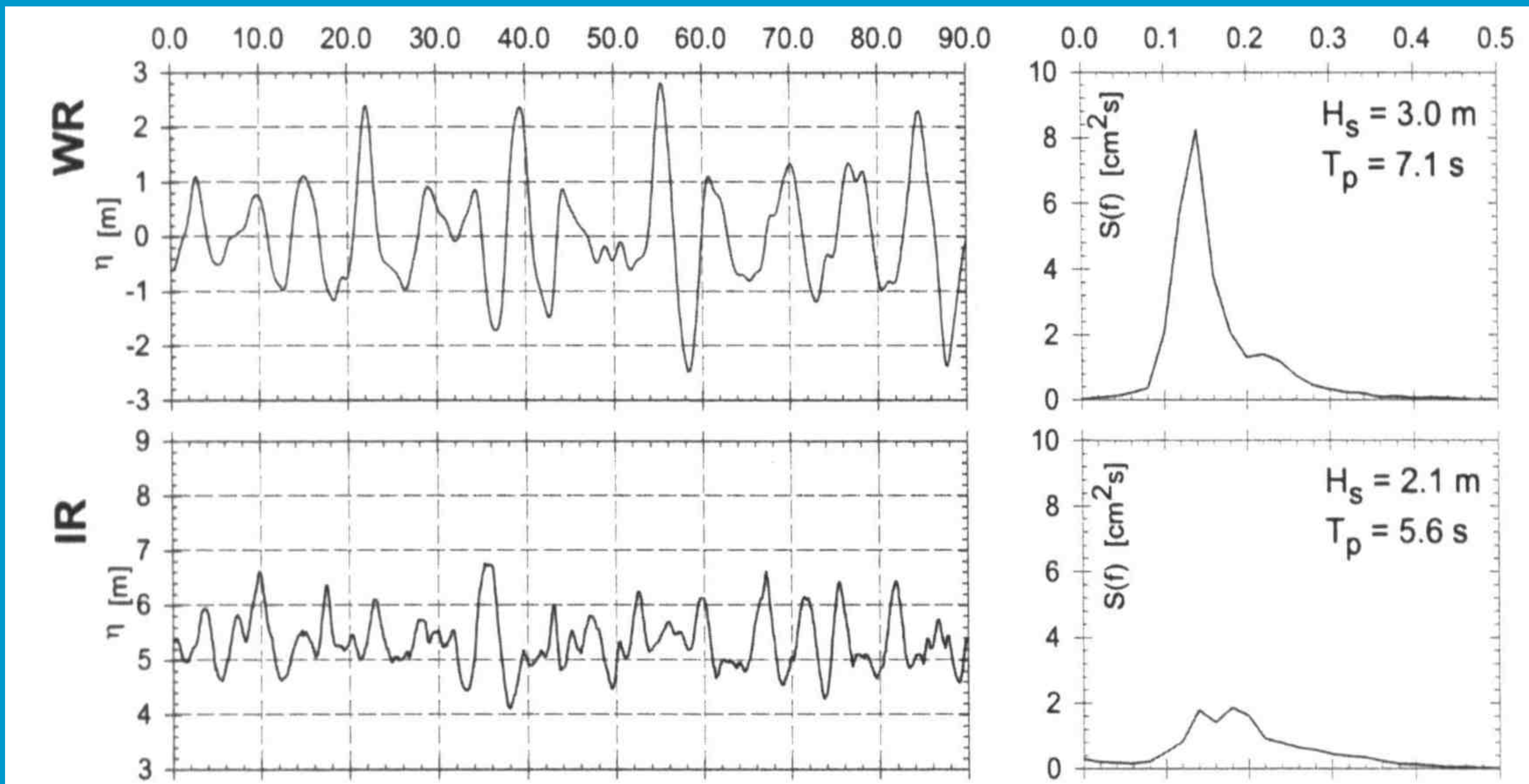
Zeebrugge

waves and pressures (2)



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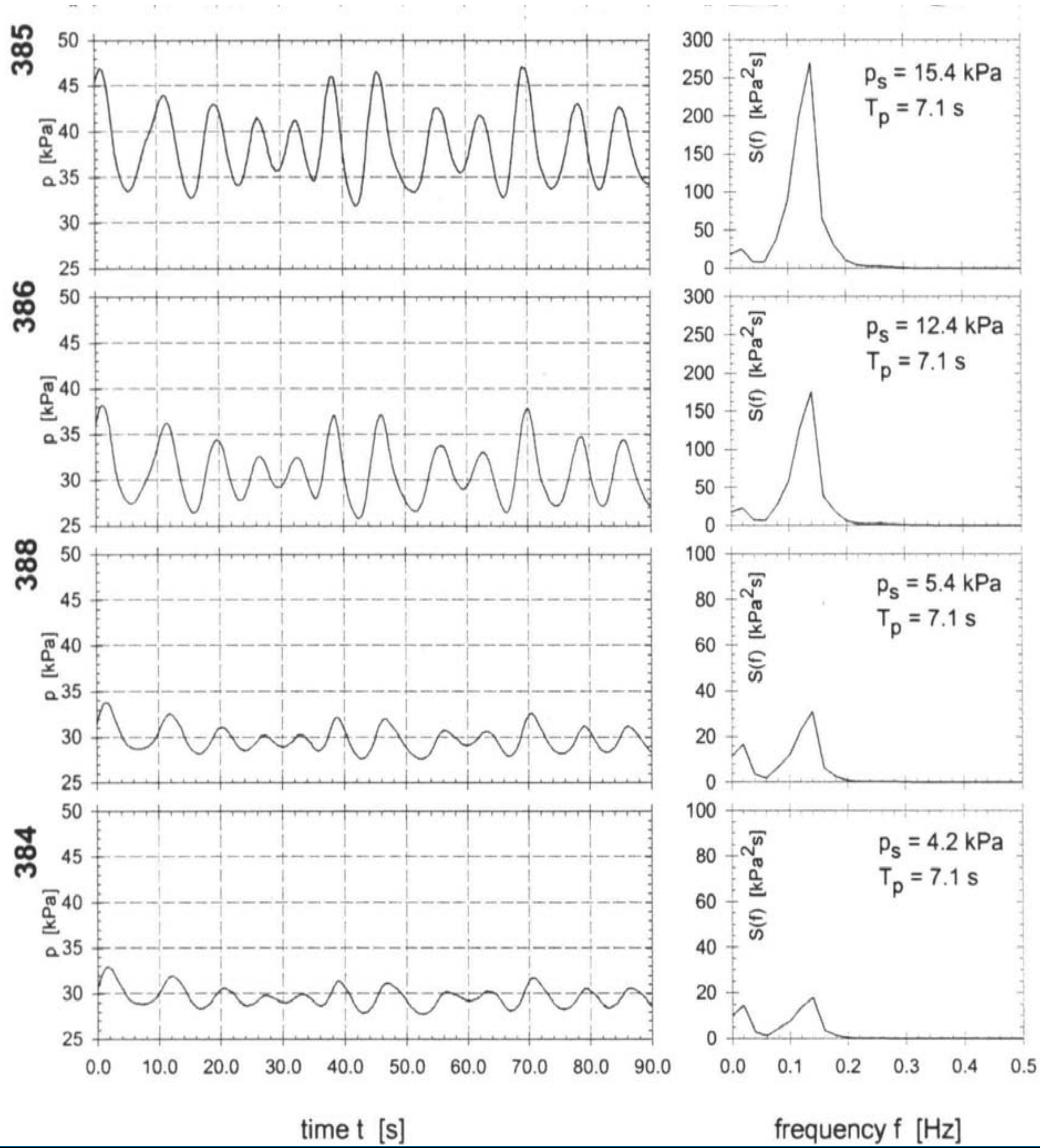
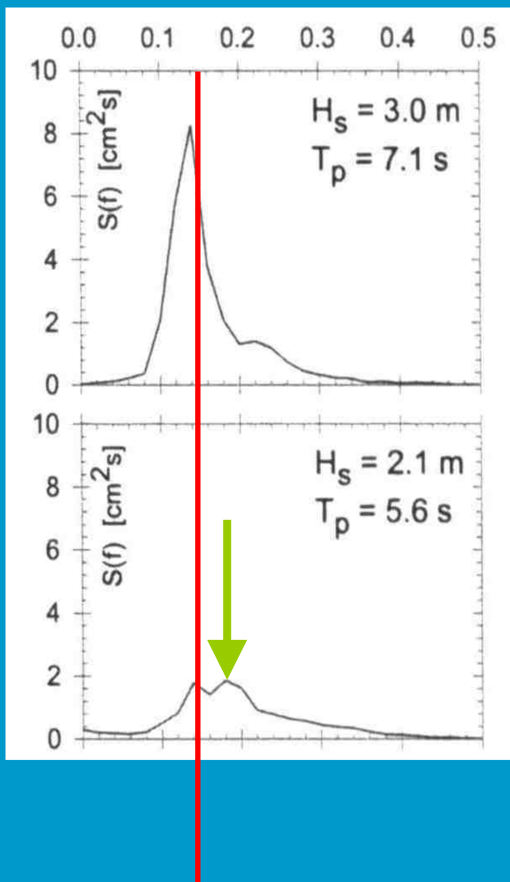
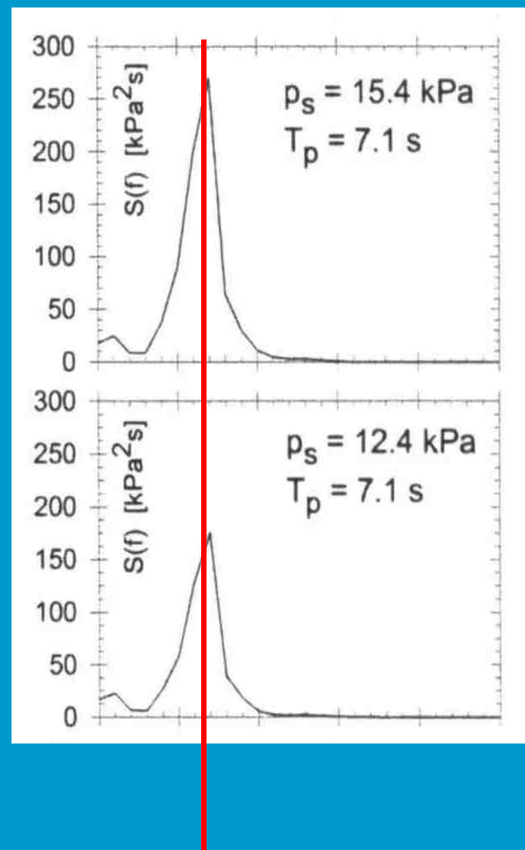
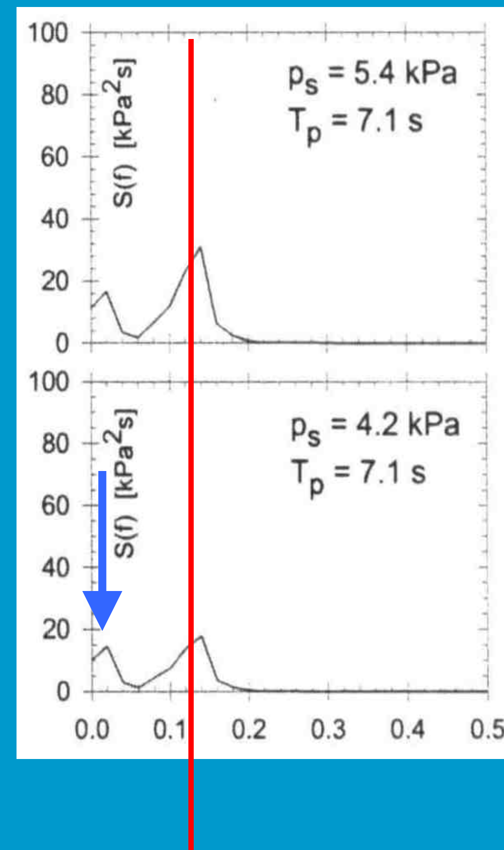


waves and pressures (3)

waves and pressures (4)







wave reflection

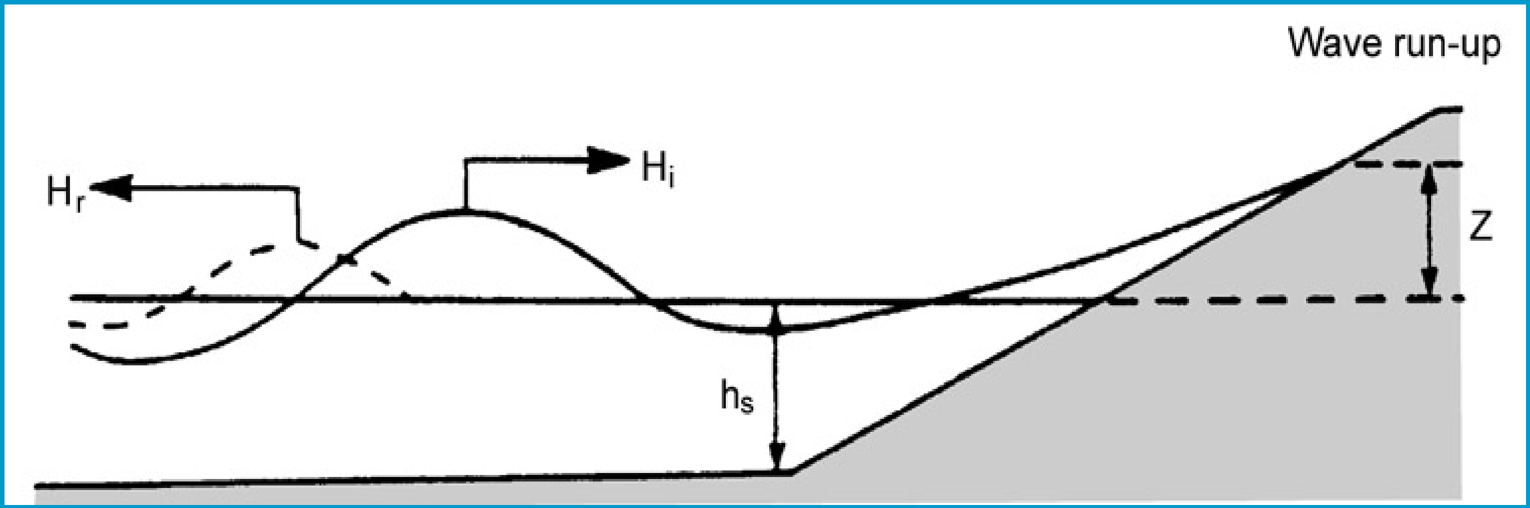
- The problem is the determination of the reflection coefficient
- Two proposals made by Postma

$$K_r = 0.140\,\xi_{0p}^{0.73}$$

$$K_r = 0.081 P^{-0.14} \left(\cot\alpha\right)^{-0.78} s_{0p}^{-0.44}$$

- In this equation P is the Notional Permeability as defined by Van der Meer
- This equation has a very strict validity

definition of wave run-up



correction factors for run-up

Structure	γ
Smooth, impermeable (like asphalt or closely pitched concrete blocks)	1.0
Open stone asphalt etc.	0.95
Grass	0.9 – 1.0
Concrete blocks	0.9
Quarry stone blocks (granite, basalt)	0.85 – 0.9
Rough concrete	0.85

Structure	γ
One layer of stone on an impermeable base	0.55 – 0.6
Gravel, Gabion mattresses	0.7
Rip-rap rock, layer thickness n > 2	0.5 – 0.55

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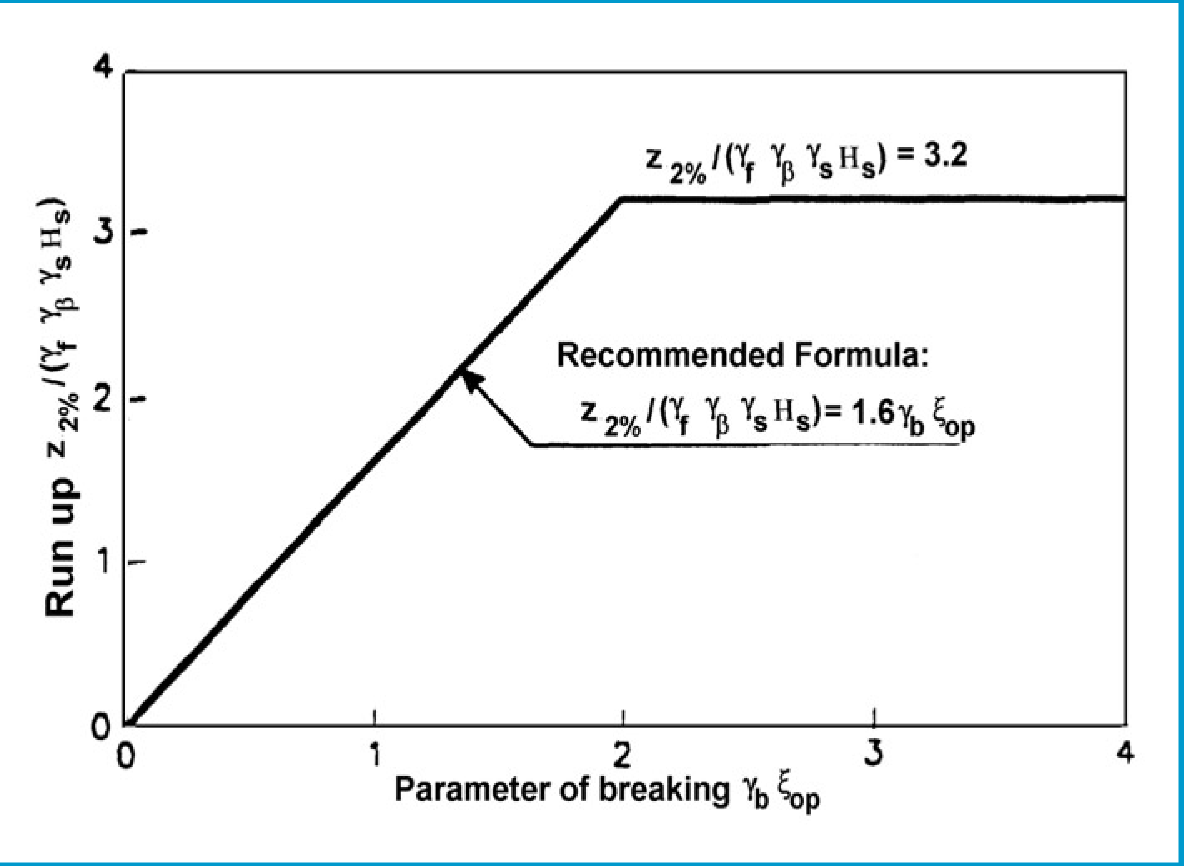
wave run-up on a smooth permeable slope



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run-up specific for breakwaters

For non-permeable breakwaters (P=0.1)

$$\frac{z_{u\%}}{H_s} = a\xi_m \qquad for\ \xi_m < 1.5$$

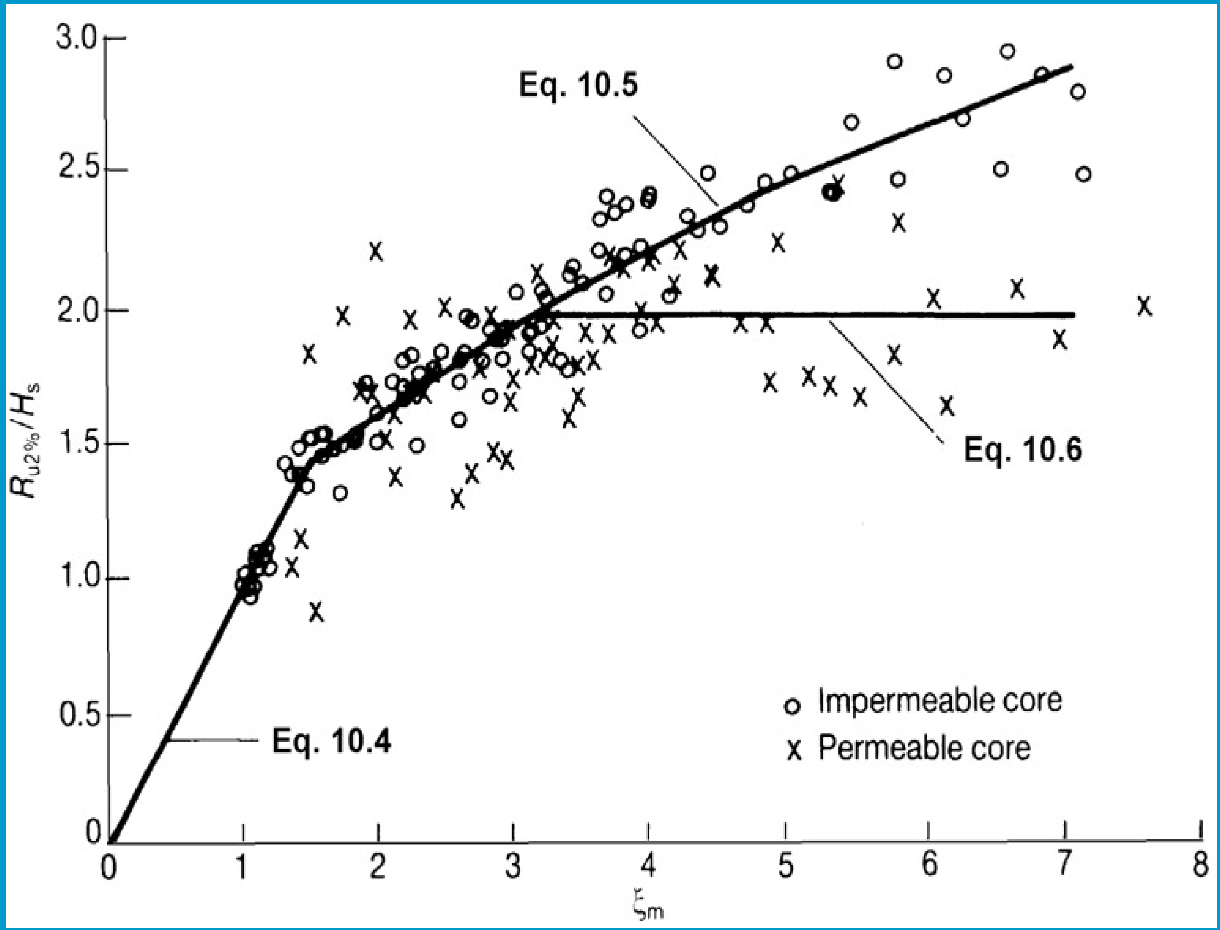
$$\frac{z_{u\%}}{H_s} = b\xi_m^c \qquad for\ \xi_m > 1.5$$

For permeable breakwaters (P=0.4)

$$\frac{z_{u\%}}{H_s} = d$$

run-up level *u* (%)	*a*	*b*	*c*	*d*
0.1	1.12	1.34	0.55	2.58
1	1.01	1.24	0.48	2.15
2	0.96	1.17	0.46	1.97
5	0.86	1.05	0.44	1.68
10	0.77	0.94	0.42	1.45
Sign.	0.72	0.88	0.41	1.35
Mean	0.47	0.6	0.34	0.82

Relative 2% run-up on rock slopes



Example

n1,2 = 1.5
B=0
gamma =0.5

p (5,95), z

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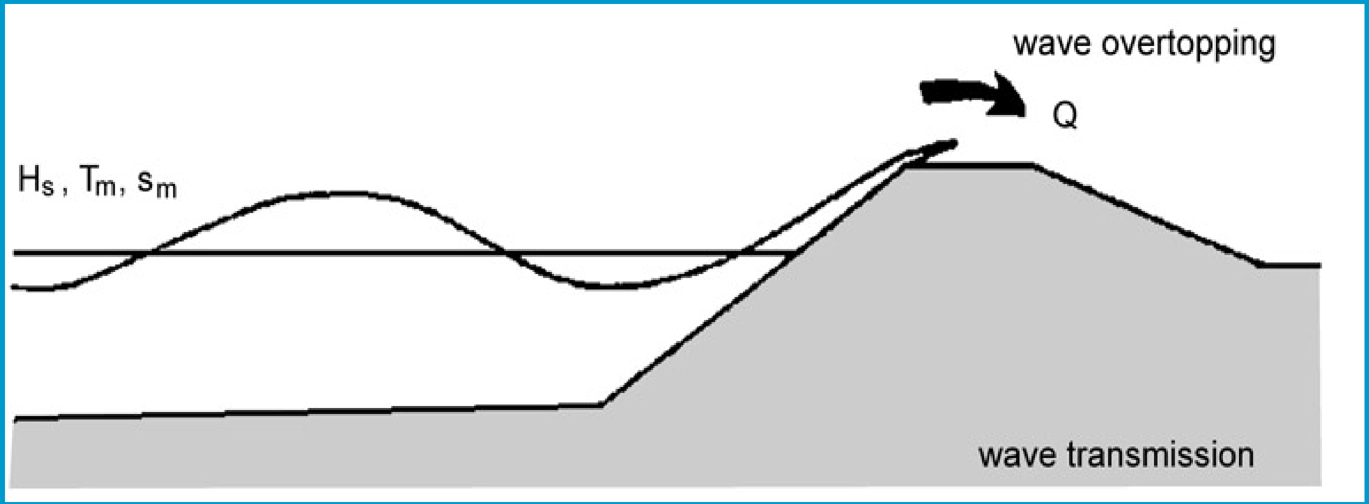
typical wave overtopping



Models available from Bradbury (textbook), Van der Meer and Besley.

Bradbury is only valid for “normal” slopes (1:1.5)

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Equations of Bradbury

$$Q^* = a(R^*)^{-b}$$

$$Q^* = \frac{Q}{\sqrt{g H_s^3}} \sqrt{\frac{s_{om}}{2\pi}}$$

$$R^* = \left(\frac{R_c}{H_s}\right)^2 \sqrt{\frac{s_{om}}{2\pi}}$$

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Overtopping (1)

- Basically same type of equations as for run-up
- Usually wave overtopping is expressed in a discharge q However, this is a <u>time-averaged</u> discharge

$$Q = a \exp\left(b \frac{R}{\gamma} \right)$$

$$for\, breaking\, (plunging) \quad a = 0.06,\ b = 5.2,\ \sigma_b = 0.55$$

$$for\ non-breaking \qquad a = 0.2,\ \ b = 2.6,\ \sigma_b = 0.35$$

Q is dimensionless overtopping
R is dimensionless freeboard

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Overtopping (2)

$$Q = \frac{q}{\sqrt{gH_s^3}} \sqrt{\frac{h/L_0}{\tan\alpha}}$$

$$R = \frac{h_k}{H_s}\frac{1}{\xi}$$

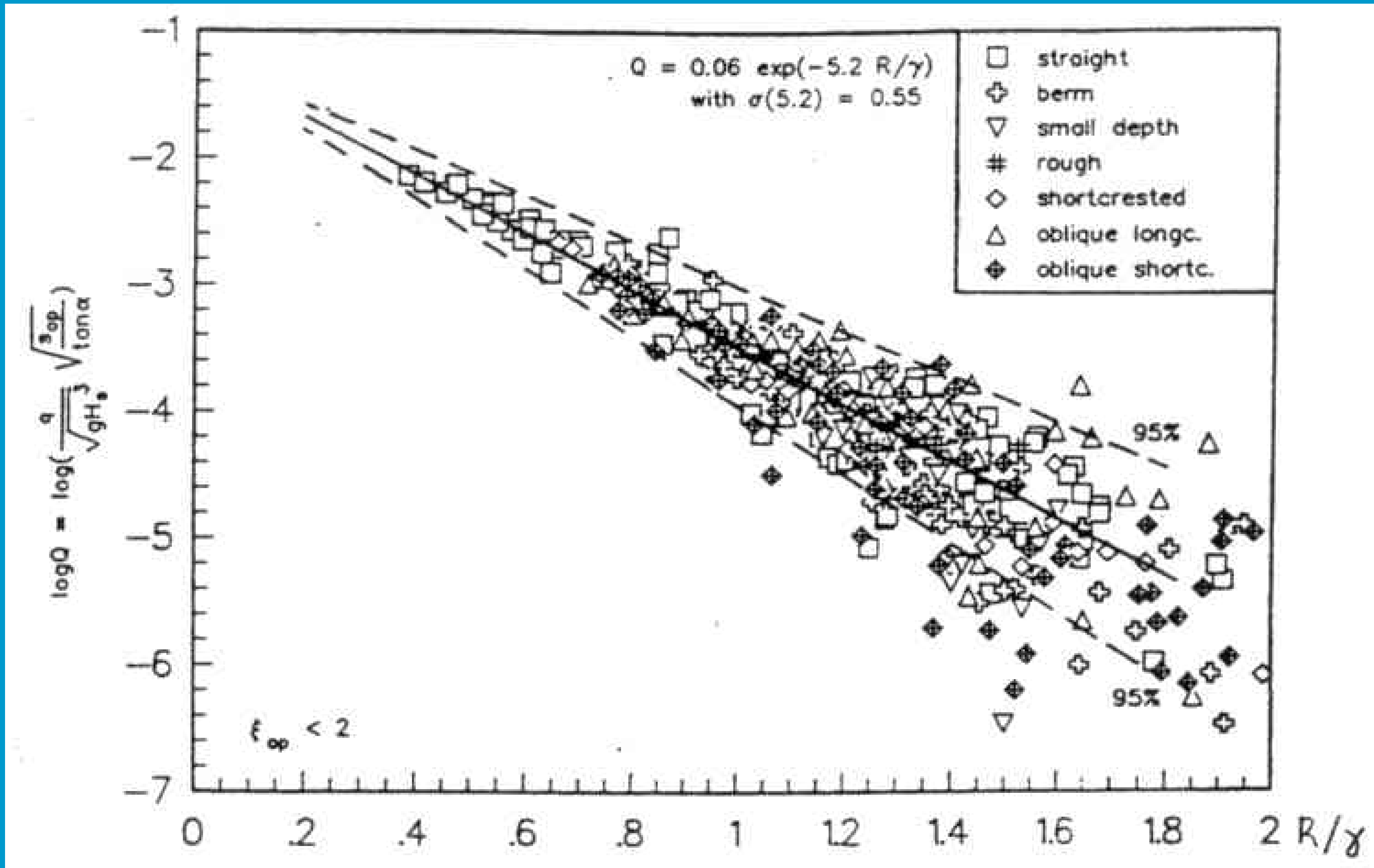
In case of non-breaking, this root should be 1

In which:

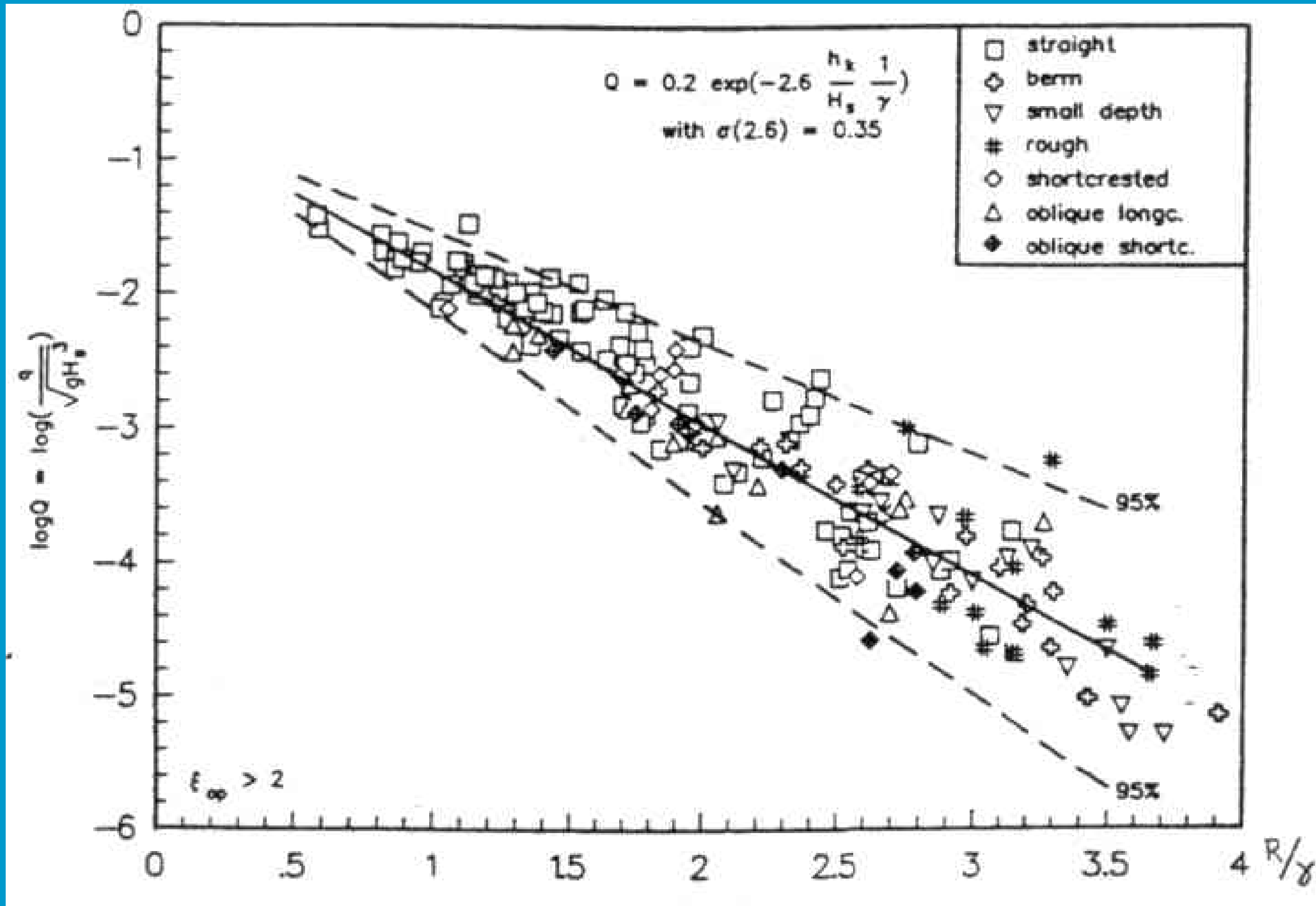
q = average overtopping (m^3/s per meter)

h_k = crest freeboard (m)

Measured overtopping (breaking)



Measured overtopping (non-breaking)



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Overtopping (3)

- Reduction coefficients are equal to Run-up
- However:
  correction for angle of incidence:
  $\gamma_b = 1 - 0.0033\,\beta$

run demo Cress

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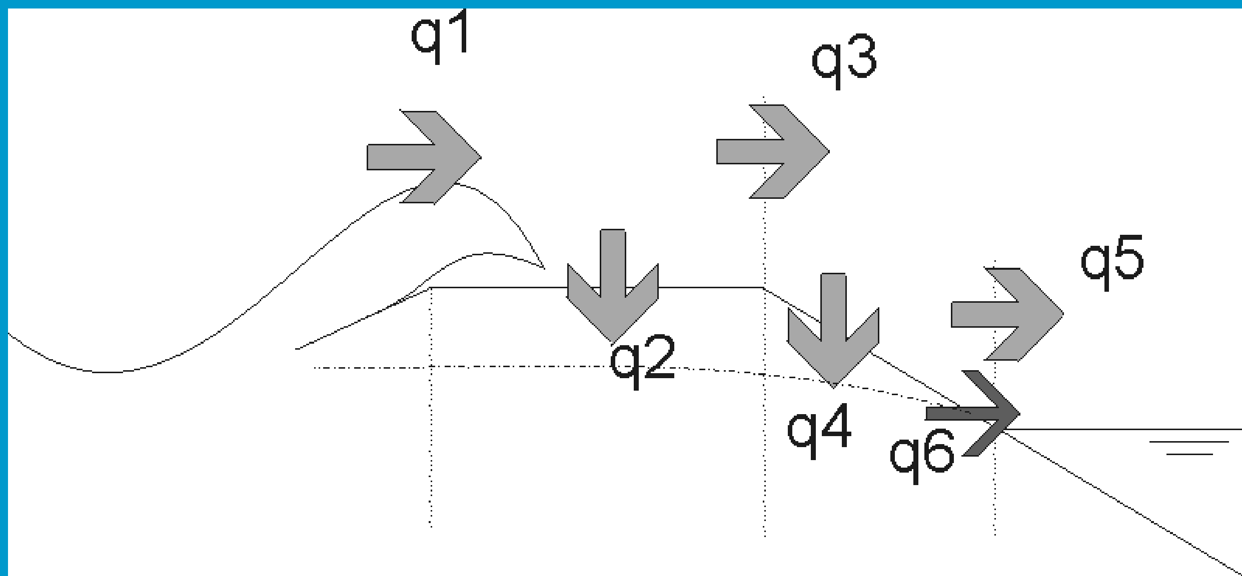
Elements in overtopping



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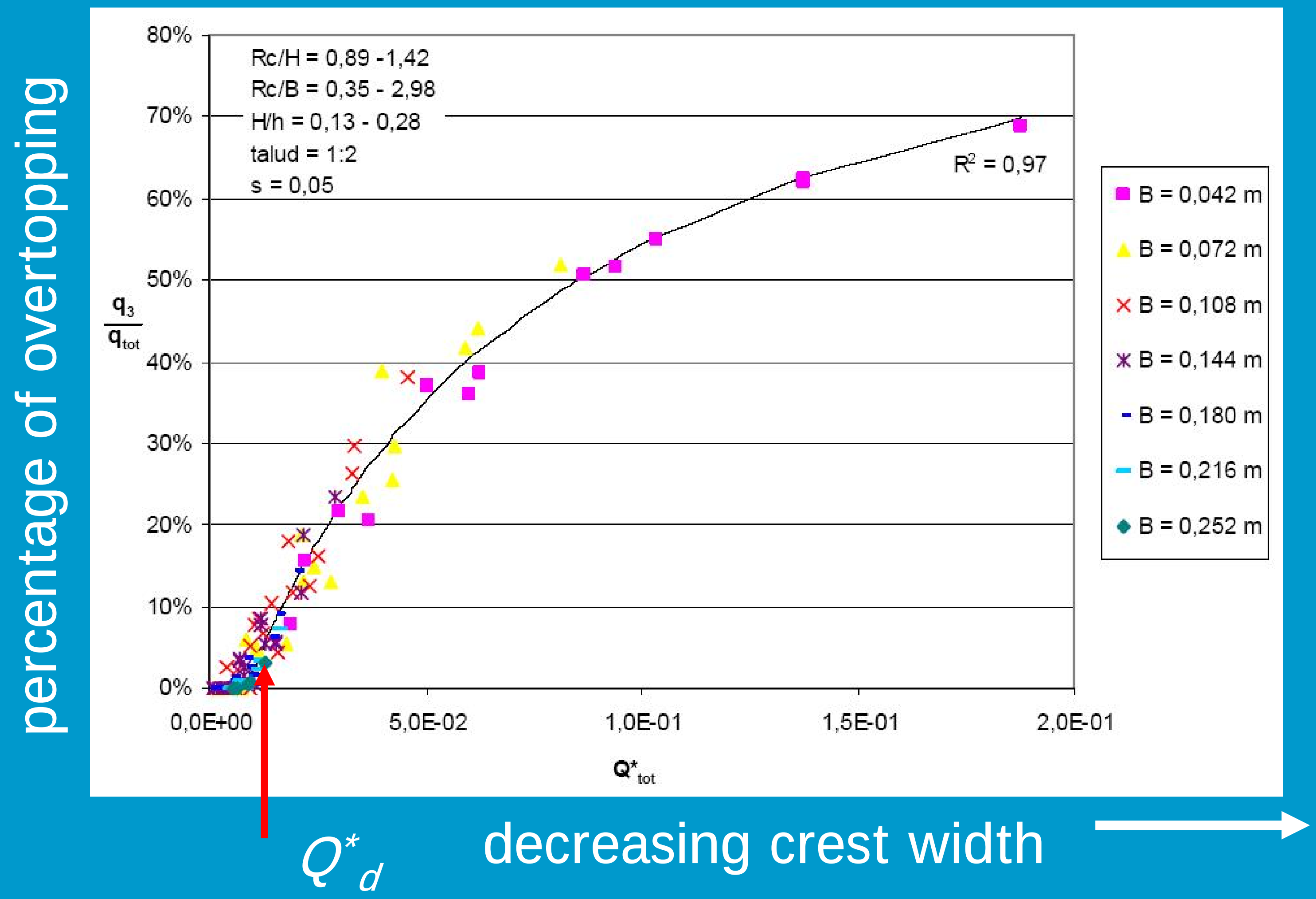
Top view of the model

Dimensionless results



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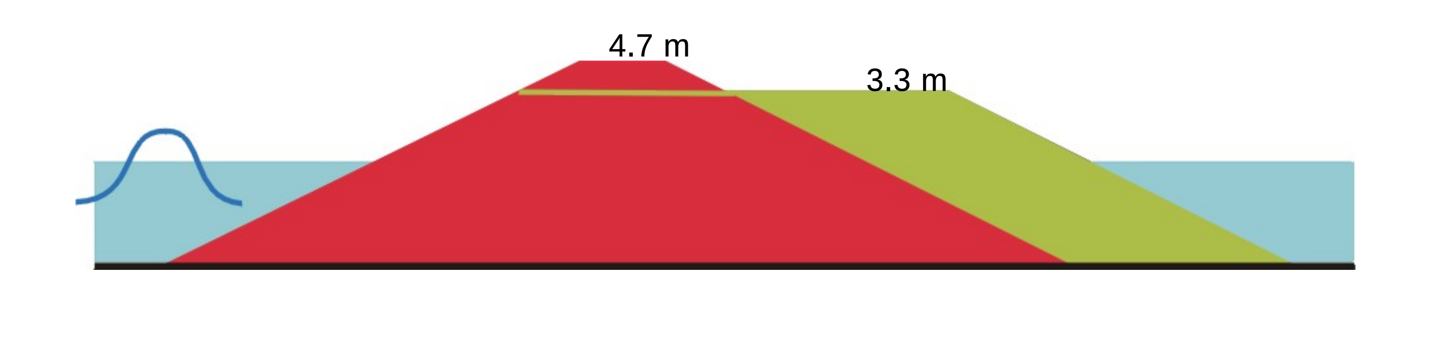
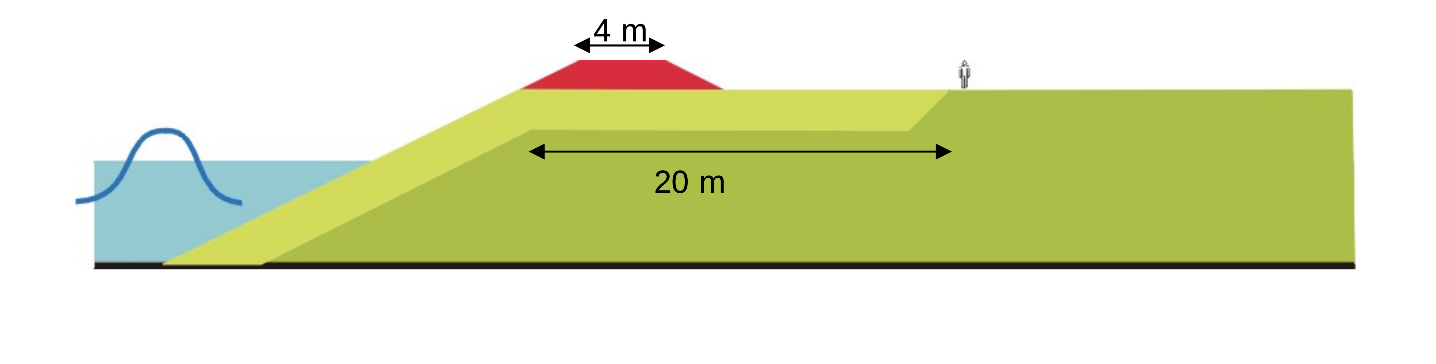
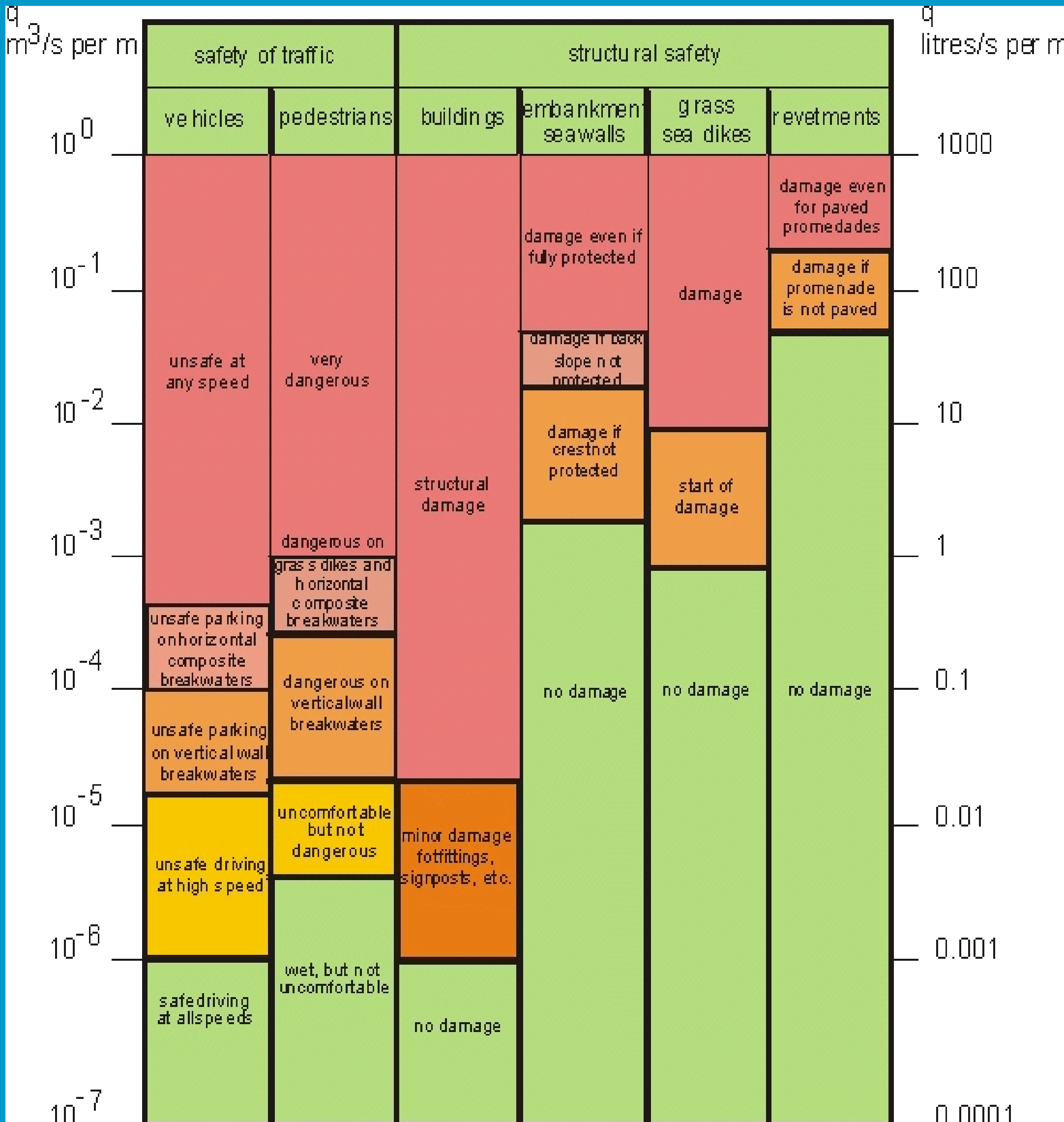
A real case (H= 3 m, T=7 sec, 1 l/s per m)





Overtopping vs. Run-up

- For design inner slope overtopping is more relevant than run-up
- In the past overtopping could not be computed
- In modern design, apply overtopping rules

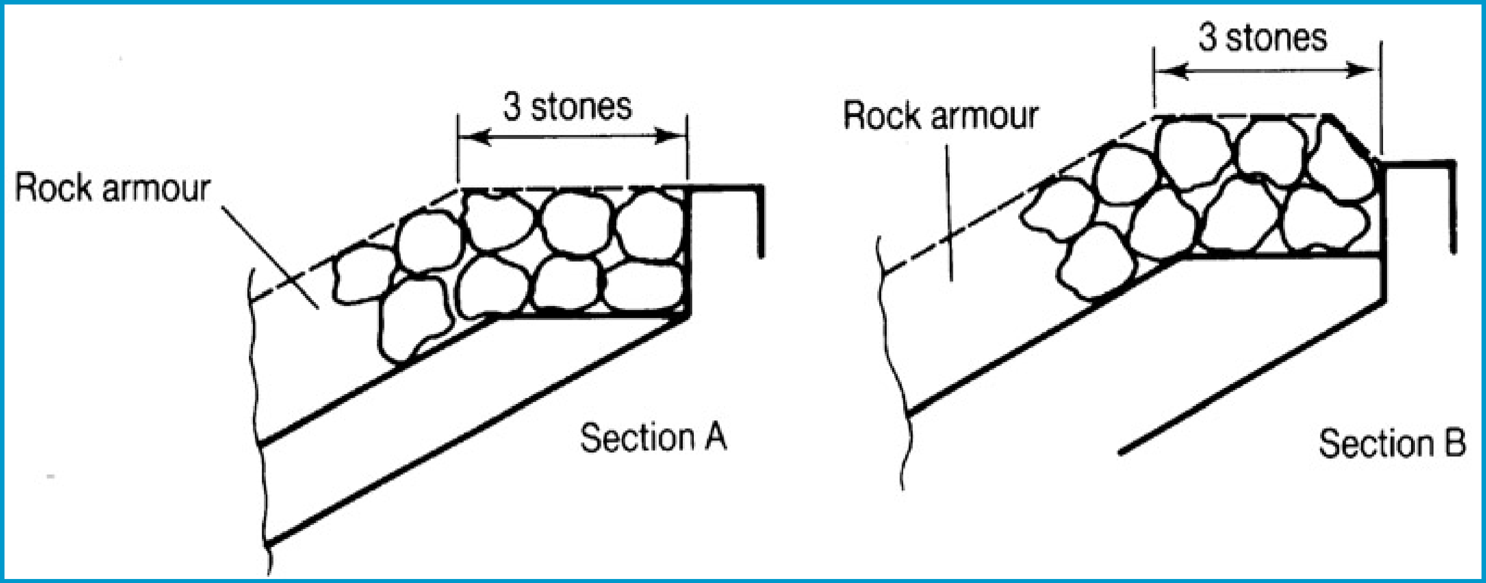


overtopping discharges and their effects

Allowable overtopping

- Dutch dikes:
  - any slope $q < 0.1$ l/s
  - normal slope $q < 1.0$ l/s
  - high quality slope $q < 10$ l/s
- For breakwaters much higher values can be applied
- For safe passages of cars $q < 0.001$ l/s
- For safe passage of pedestrians $q < .005$ l/s
- For no damage to buildings $q < .001$ l/s
- For acceptable damage to buildings $q < .02$ l/s

overtopped rock structures with low crown walls



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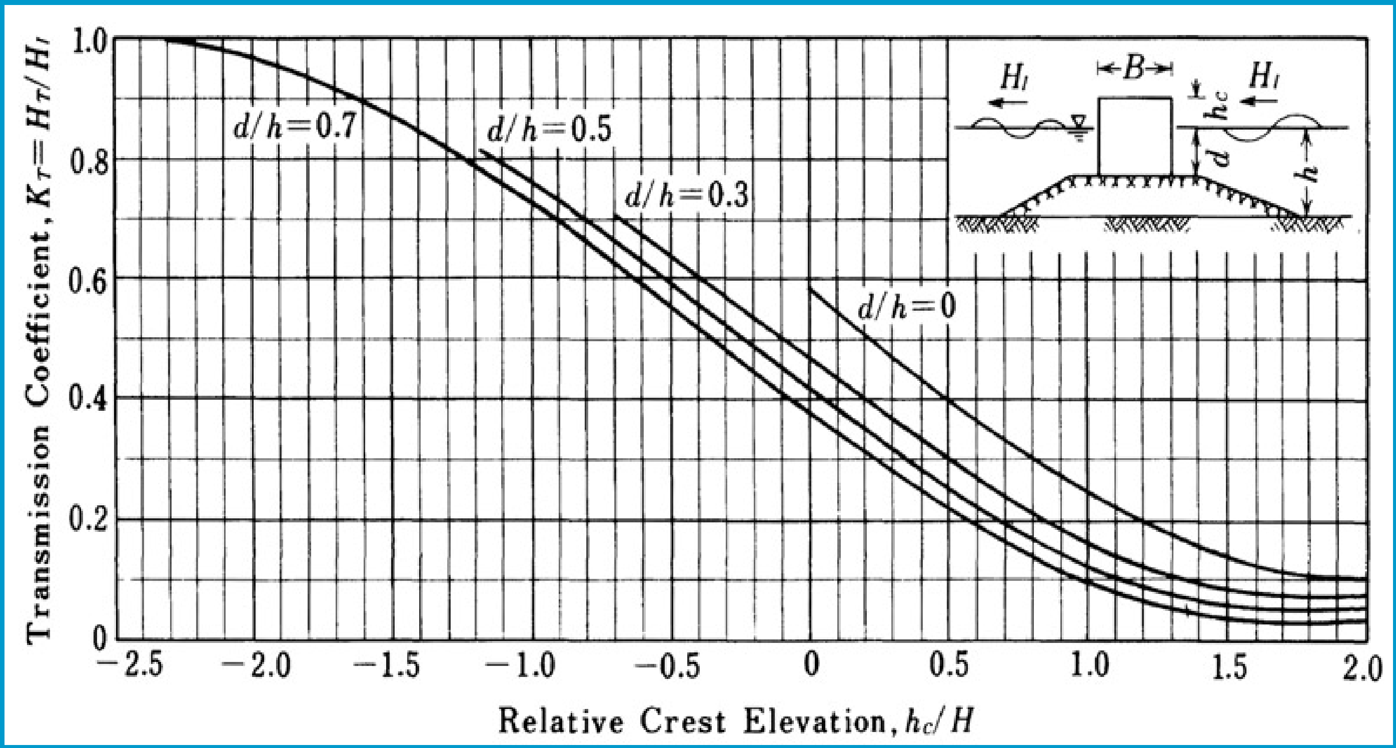
wave transmission for a vertical breakwater



$$\frac{q}{\sqrt{gH_s^3}} = a\exp\left(-b\frac{R_c}{\gamma H_s}\right)$$

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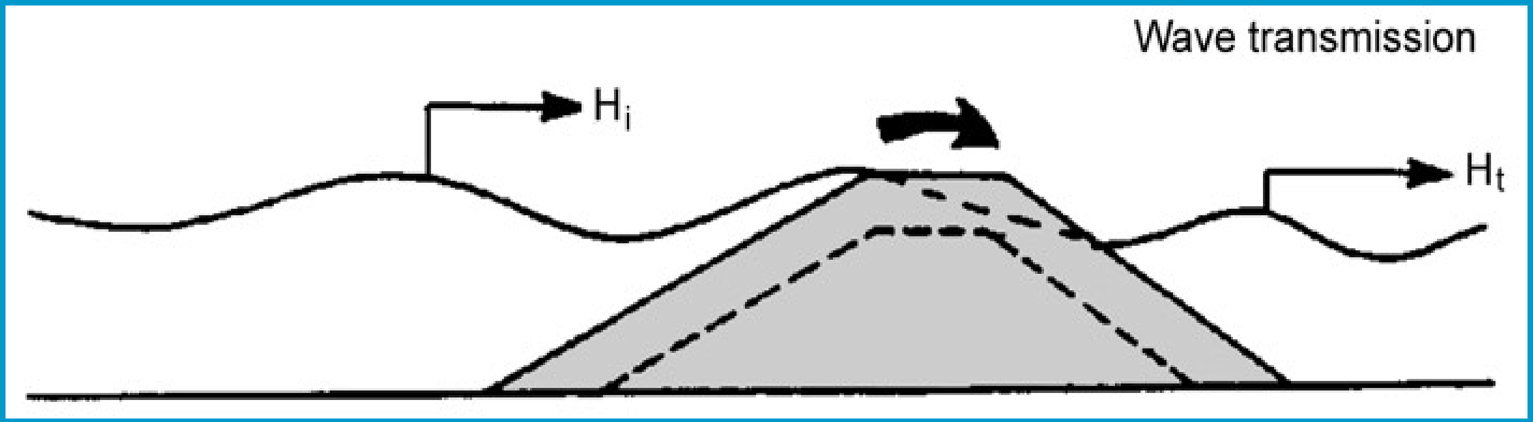
typical wave transmission

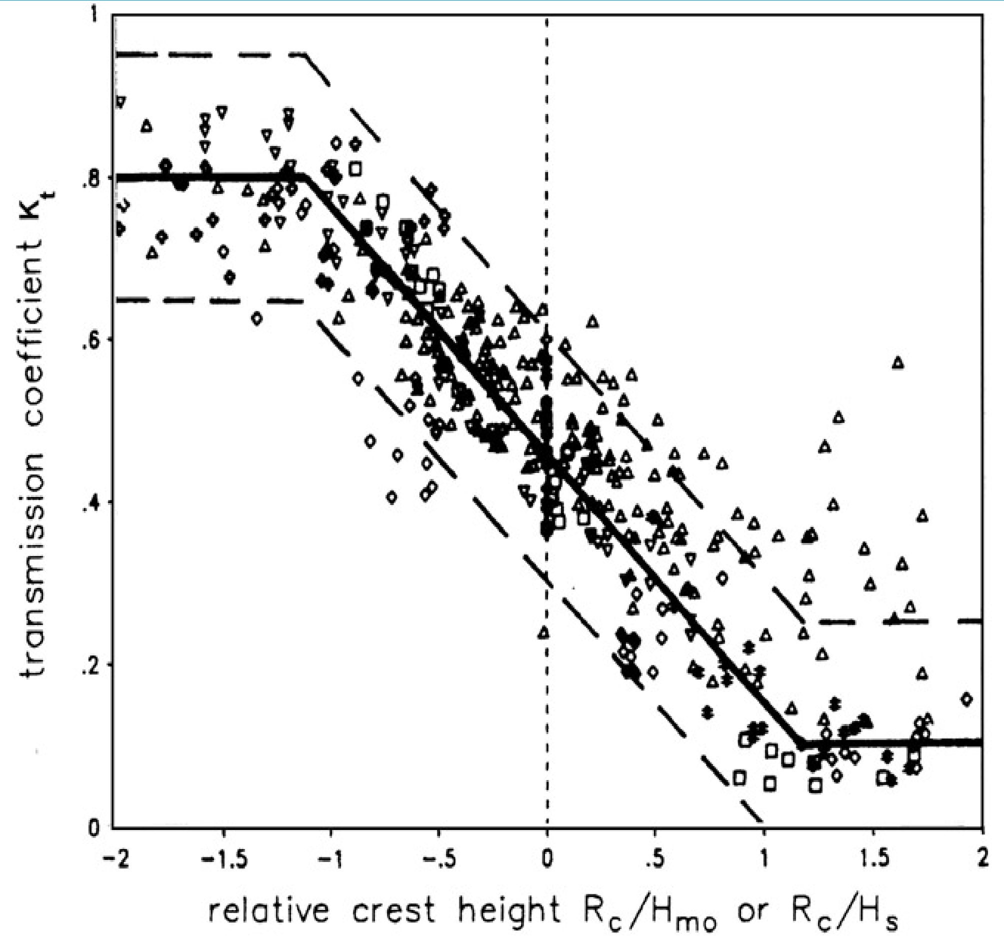


$$K_t = a\frac{R_c}{D_{n50}} + b$$

$$a = 0.031\frac{H_i}{D_{n50}} - 0.24$$

$$b = -5.42 s_{op} + 0.0323\frac{H_i}{D_{n50}} - 0.0017\left(\frac{B}{D_{n50}}\right)^{1.84} + 0.51$$

wave transmission for low crested structures



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