Chapter 8: Dynamic Stability

ct5308 Breakwaters and Closure Dams

H.J. Verhagen

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Faculty of Civil Engineering and Geosciences
Section Hydraulic Engineering

Delft University of Technology

What is dynamic stability ?

- Do not design on “damage”
- Try to make the breakwater in such a way that it gets a “stable” form
- Extra material is needed
- “Natural” dynamically stable breakwaters seem to exist on Iceland
- However, these breakwaters are <u>not</u> permeable

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Types of berm breakwaters

- **Statically stable non-reshaping structures**
  In this condition only some few stones are allowed to move similar to a conventional rubble mound breakwater
- **Statically stable reshaped structures**
  In this condition the profile is allowed to reshape into a profile, which is stable and where the individual stones are also stable
- **Dynamically stable reshaped structures**
  In this condition the profile is reshaped into a stable profile, but the individual stones may move up and down the slope

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Selection process for rubble mounds

- Is it economical to design an conventional rubble mound ? Can all quarried material be used ?
- If not all material can be used, and H_s < 2, use stable non-reshaping berm breakwater.
  If 2 < H_s < 3 m this might be a good option in case of dedicated quarry.
- If the stones are too small, use statically reshaped type
- If this also is not possible, use more stone and make dynamically stable berm breakwater

Types of berm breakwaters

Dynamically stable reshaped BB

- Two stone classes
- Homogeneous berm
- Wide stone gradation
- Low permeability
- Reshaping structures
- Allowed erosion < berm width
- More voluminous
- No interlocking

Statically stable non-reshaping BB

- Several stone classes
- Berm of size-graded layers
- Narrow stone gradation
- High permeability
- Non-reshaping structures
- Allowed recession $< 2*D_{n50}$
- Less voluminous
- Interlocking prescribed

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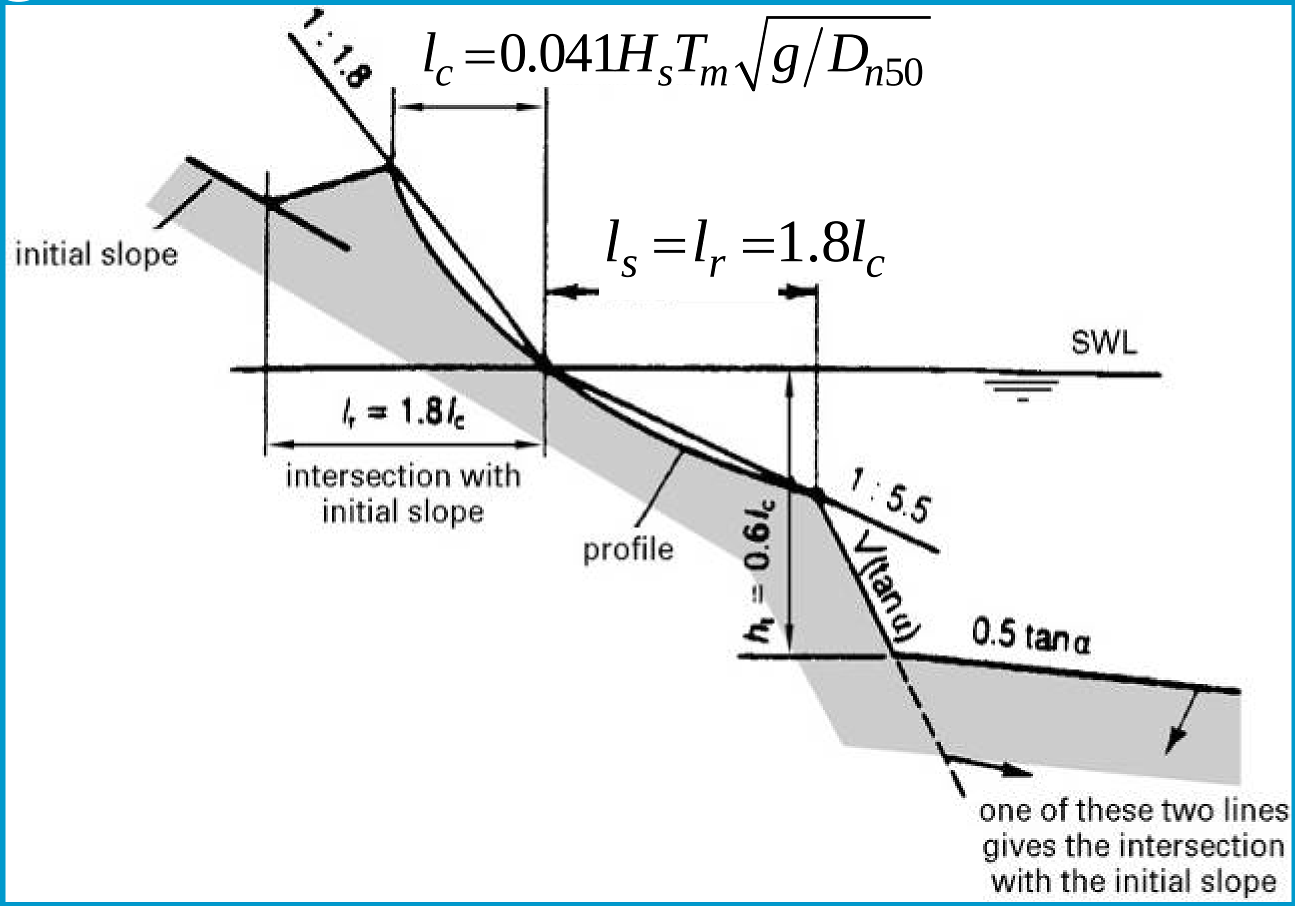
Berm breakwaters in the world

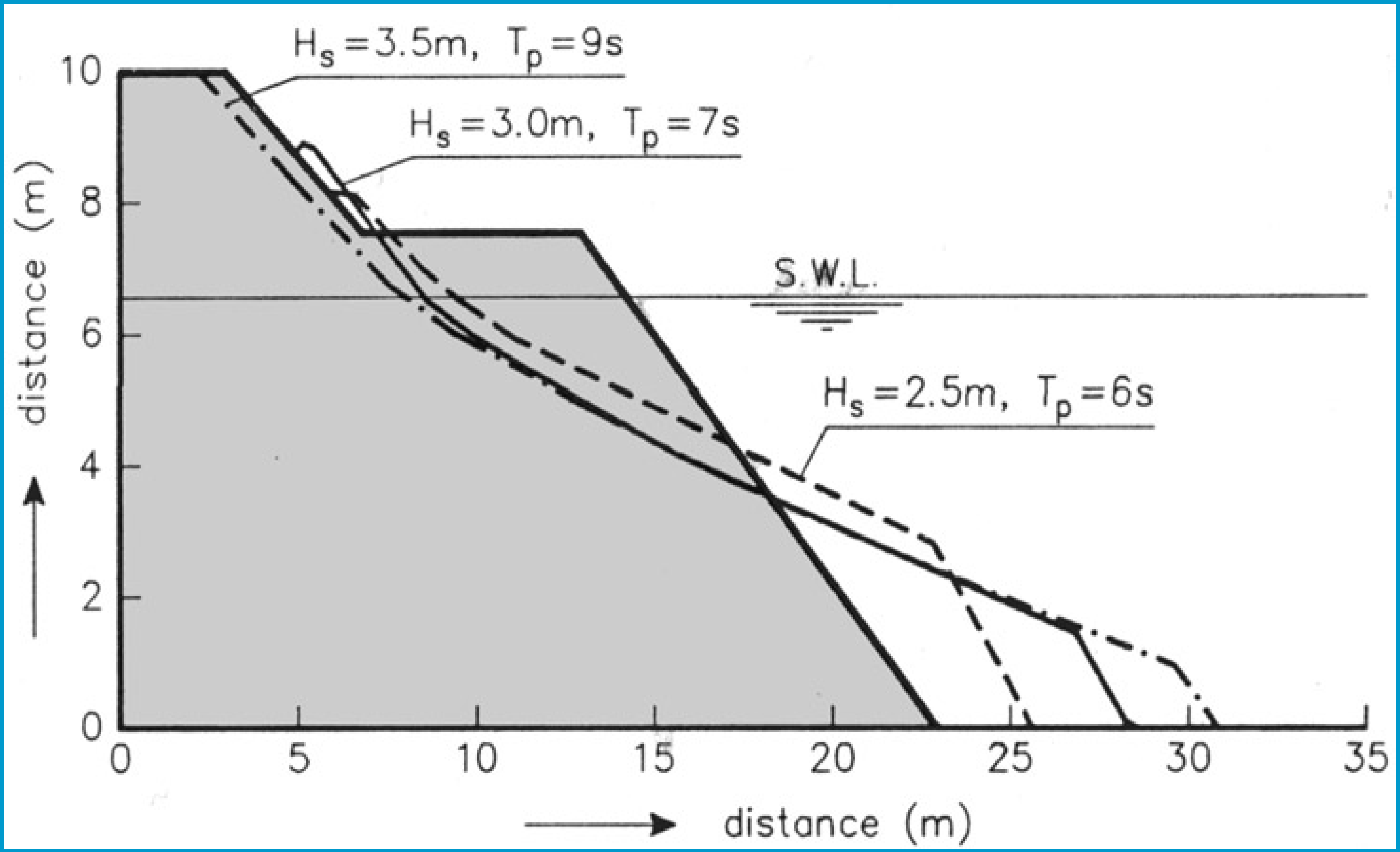
Country	Number of berm breakwaters	Year first breakwater was completed
Iceland	27	1984
Canada	5	1984
USA	4	1984
Australia	4	1986
Brazil	2	1990
Norway	4	1991
Denmark (Far Oer)	1	1992
Iran	8	1996
Portugal (Madeira)	1	1996
China (Hong Kong)	1	1999
Total	57	

Data from Pianc report on berm breakwaters 2003

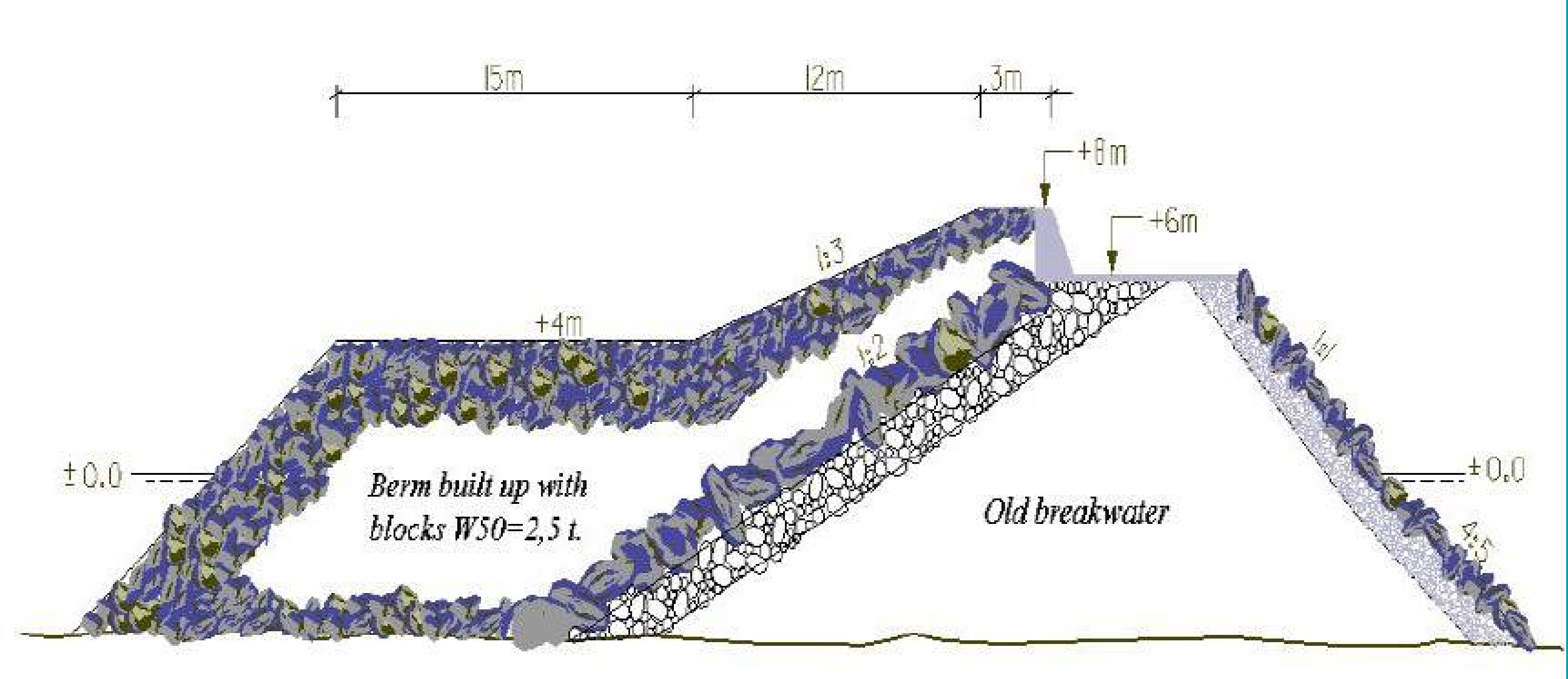
schematised profile for sand and gravel beaches



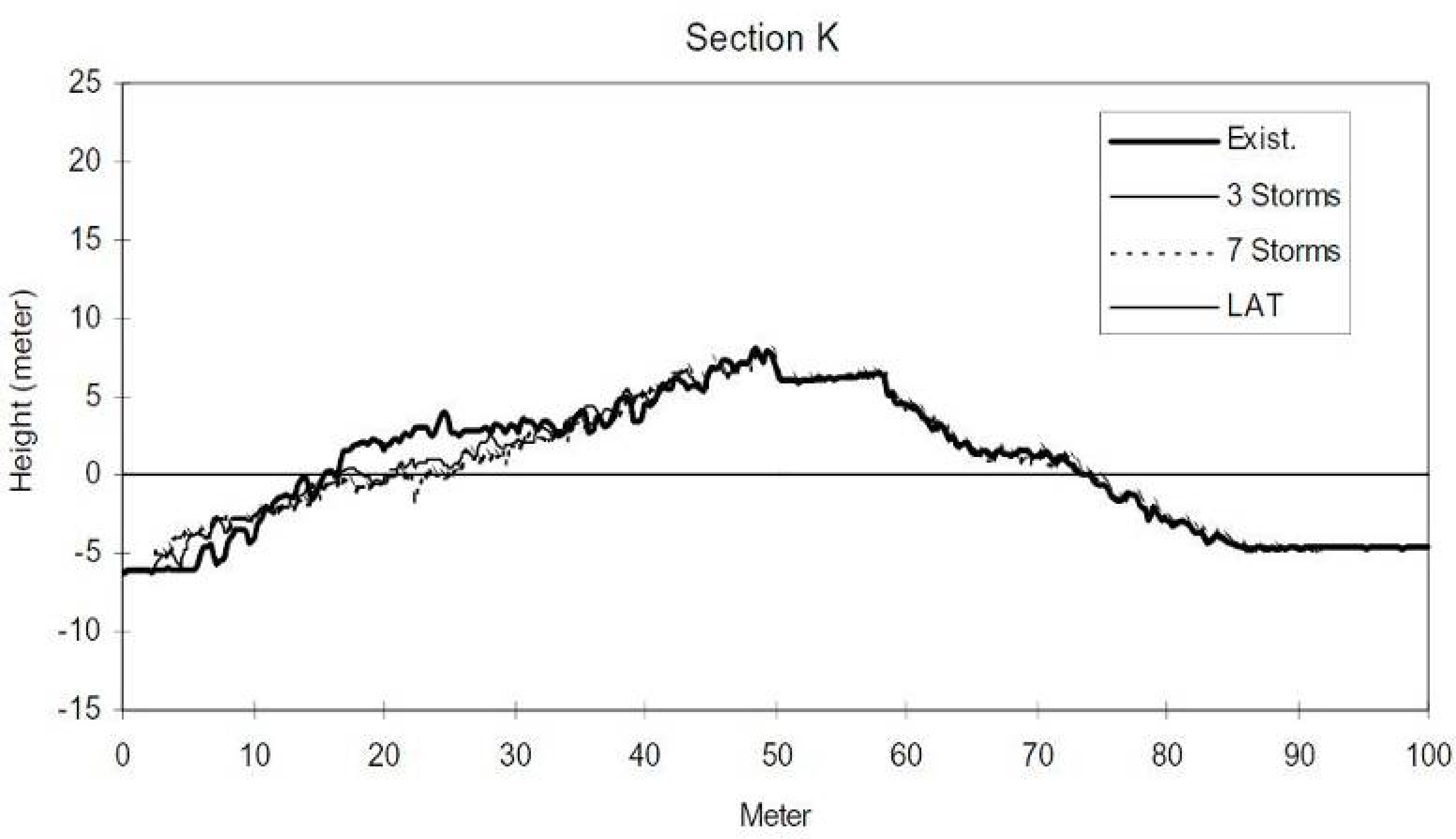
Influence of wave climate on a berm breakwater profile



Berm breakwater Berlevåg (Norway)



Reshaped profile of Berlevåg breakwater



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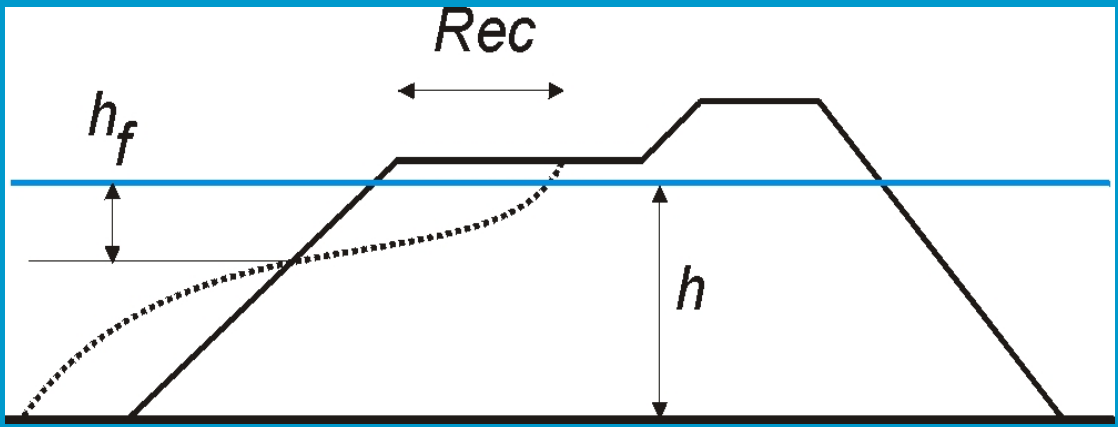
Reshaping calculations

- Van der Meer (1988 - 1990 Breakwat
- Van Gent (1995) Odiflocs
- Archetti and Lamberti (1996) (See Copedec Cape Town)

- new research by Tørum (1998, 2001)



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Recession according to Tørum (1)

Special parameter for recession: H_0T_0

$$H_o = \frac{H_s}{\Delta D_{n50}}$$

$$T_0 = T_z \sqrt{\frac{g}{D_{n50}}}$$

T_z is mean period

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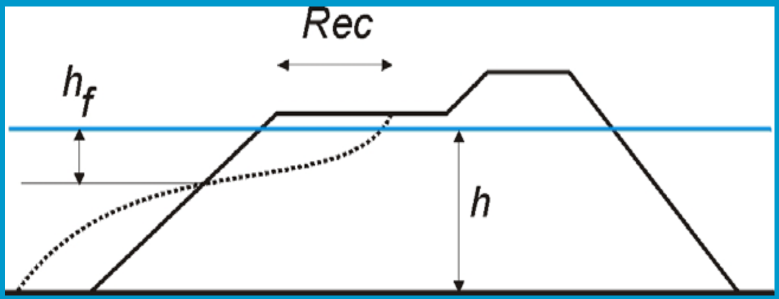
Recession according to Tørum (2)

$$\frac{Rec}{d_{n50}} = A(H_0T_0)^3 + B(H_0T_0)^2 + C(H_0T_0) - (-9.9 f_g^2 + 23.9 f_g - 10.5) - f_h$$

$$A = 2.7 \cdot 10^{-6}$$

$$B = 9 \cdot 10^{-6}$$

$$C = 0.11$$



gradation factor $f_g = d_{n85} / d_{n15}$ $\quad 1.3 < f_g < 1.8$

depth factor $f_h = -0.1\left(\frac{h}{d_{n50}}\right) + 3.2$

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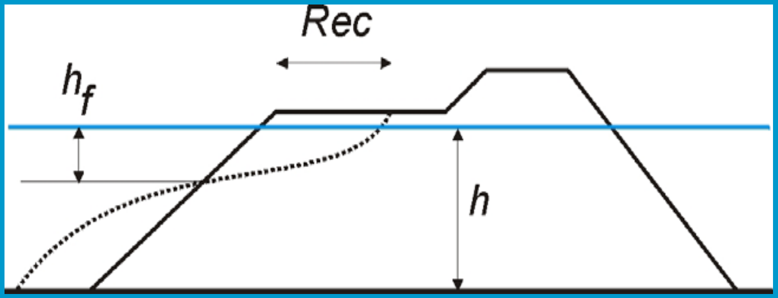
Recession according to Tørum (3)



Place of the intersection of profiles:

$$\frac{h_f}{d_{50}} = 0.2\frac{h}{d_{50}} + 0.5 \qquad \textit{for}\ 12.5 < \frac{h}{d_{n50}} < 25$$

Longshore transport of stone

- apply same type of formula as longshore sand transport
- to prevent excessive transport, apply

$$\frac{H_s}{\Delta D_{n50}} \leq 4.5$$

- for heads use a value of 3

- Curve fitted transport formula:

$$S(x) = 0.00005\left(\frac{H_s}{\Delta D_{n50}} T_p \sqrt{\frac{g}{D_{n50}}} - 105\right)^2$$

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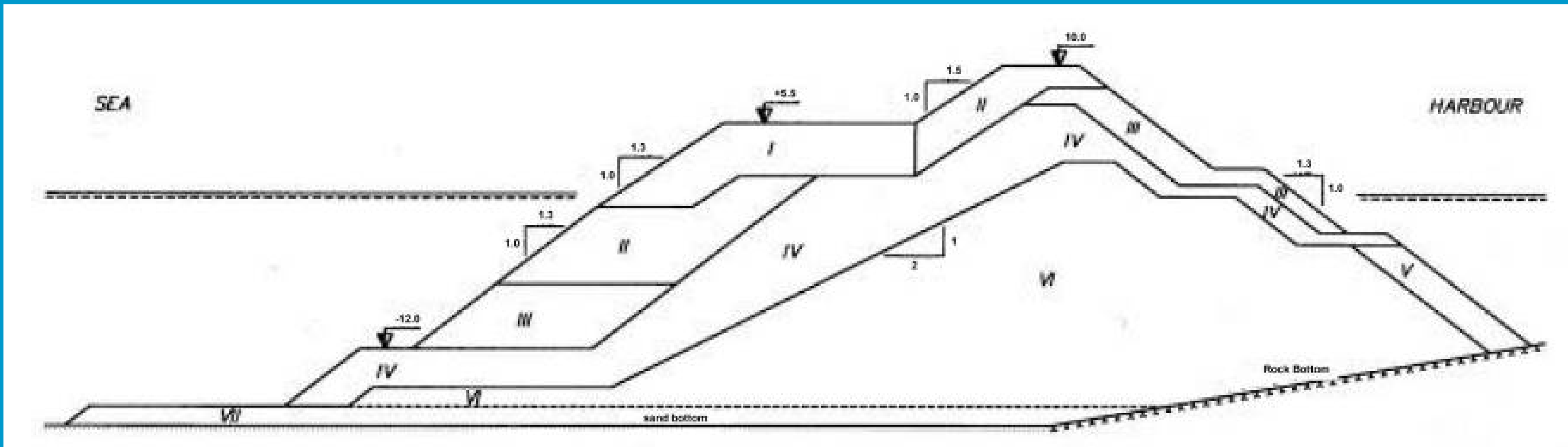
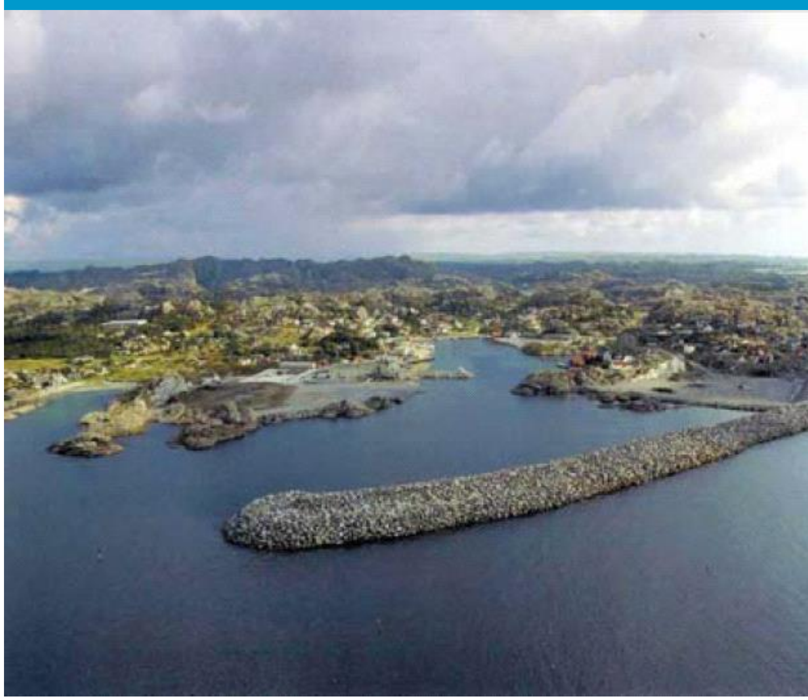
cross section of the Sirevåg breakwater





Stone class	W_{min}-W_{max} (tonnes)
I	20-30
II	10-20
III	4-10
IV	1-4

€ 20.000/m (2000/2001)

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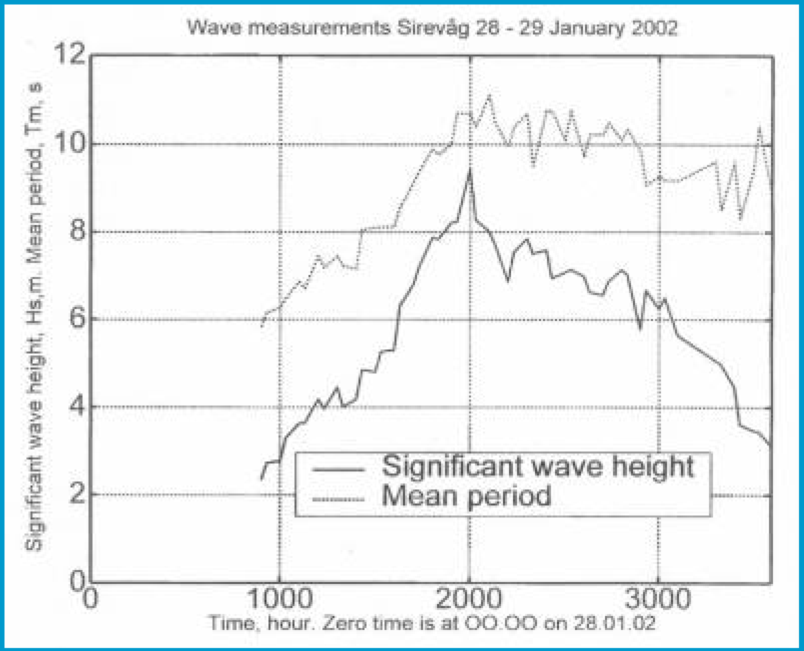
Design conditions

- 100 years return period H_s = 7.0 m, T_p=14.2 s (based on hindcast + refraction study)
- Storm of December 1998: H_s=7.0 m, T_p=14 s
- Storm of February 1999: H_s=6.7 m, T_p=15 s
- Storm of January 2002: H_s=9.3 m at deep water (450 m offshore) H_s=7.9, T_p=10 s



•Damage to breakwater: 8 stones removed, 6 stones moved

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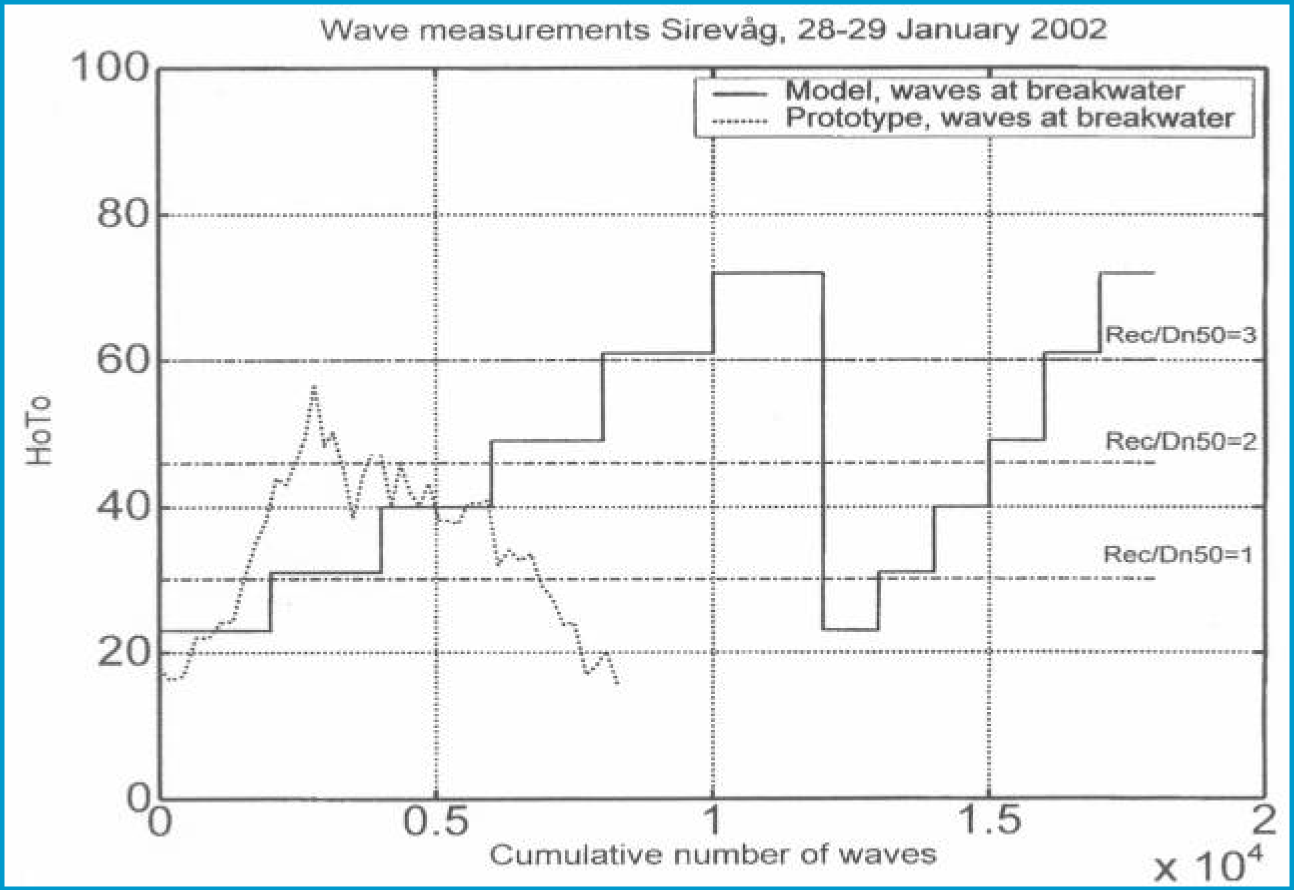
Prototype and model



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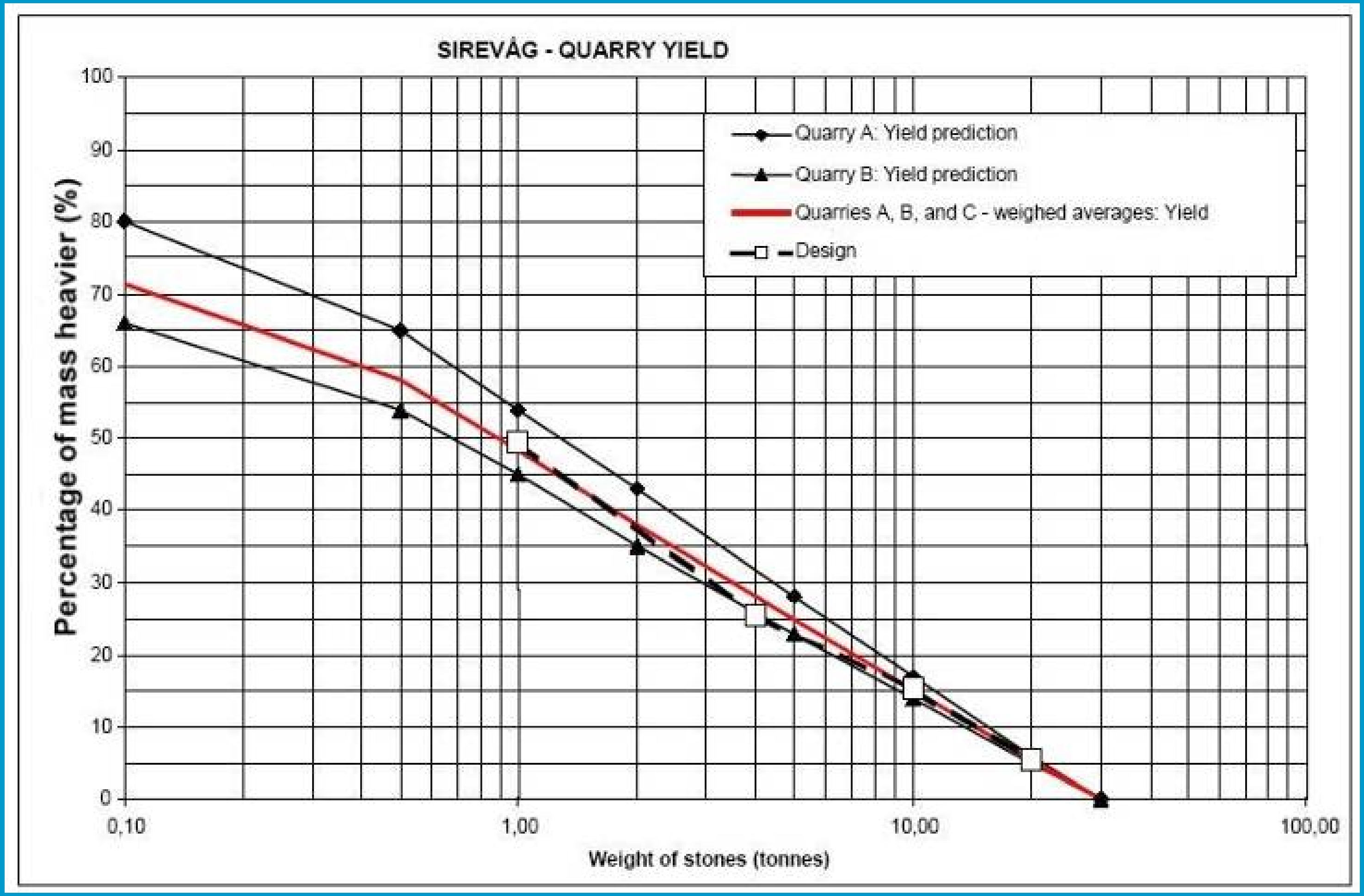
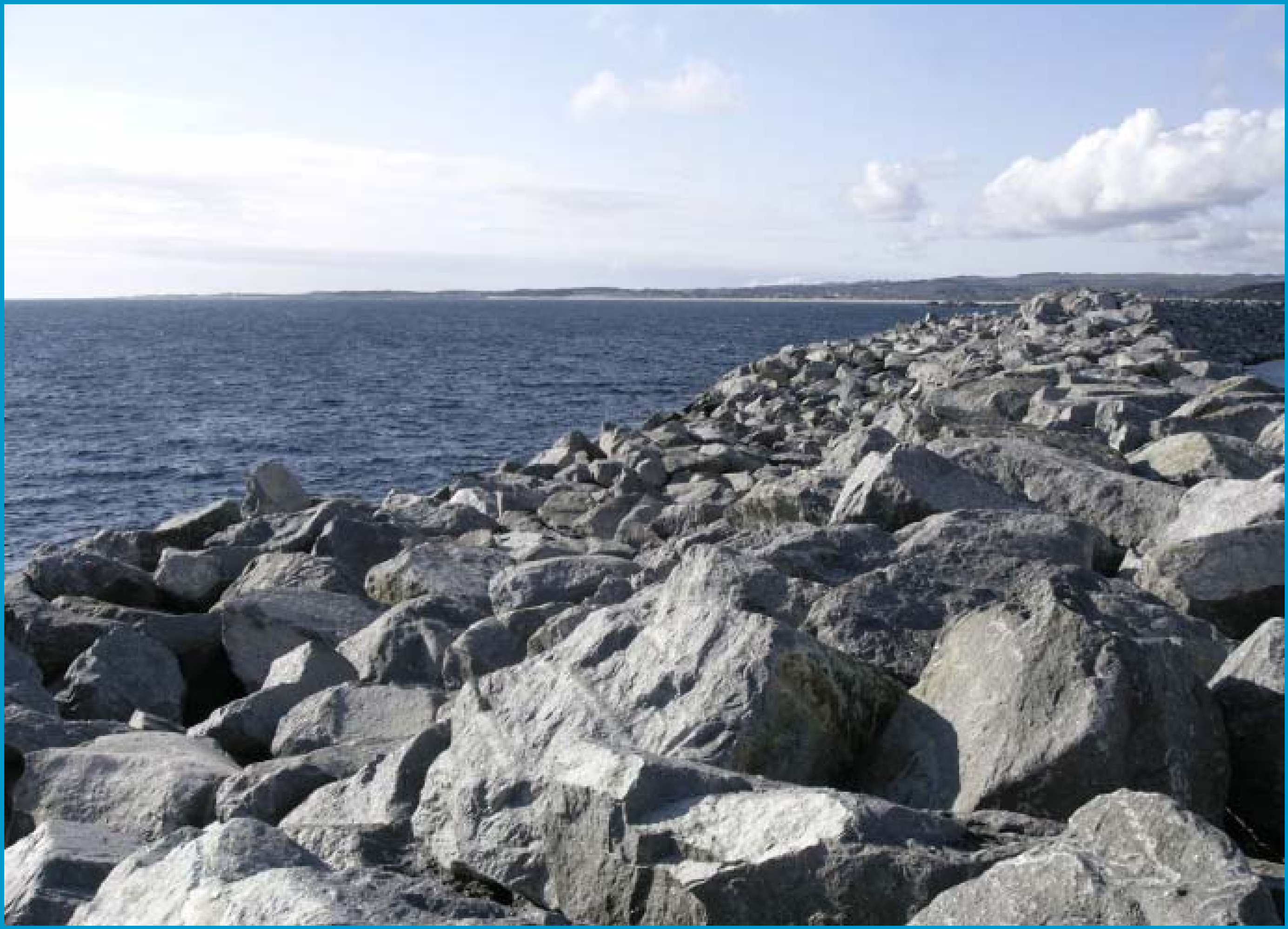
Stone classes and Quarry yield Sirevåg

Stone Class	W_{min}-W_{max}	W_{mean}	W_{max}/W_{min}	d_{mx}/d_{min}	Expected quarry yield
I	20-30	23.3	1.5	1.114	5.6%
II	10-20	13.3	2.0	1.26	9.9%
III	4-10	6.0	2.5	1.36	13.7%
IV	1-4	2.0	4.0	1.59	19.3%

Sirevåg yield cure



Sirevåg breakwater



Sirevåg breakwater

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Sirevåg breakwater

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