Lecture II

Example Applications of Geotextile Sand Containers (GSC) for Shore Protection

3.1 Important Remarks and Overview of Coastal Engineering Applications

3.2 Seawall/Revetment, incl. Dune and Beach Reinforcement

3.3 Sea Groins

3.4 Artificial Reefs

3.5 Perched Beaches

3.6 Core of Rubble Mound Structures

3.1 Important Remarks and Overview of Coastal Engineering Applications

Geotextile Sand Containers (GSCs): Definition & Types

- **Definition**:

Containment of sand encapsulated in geotextile to build flexible and erosion-resistant gravity structures used in hydraulic and ocean/coastal engineering.

- **Type of Geotextile Sand Containers used in Coastal Engineering**:

Type	Volume [m³]	Sand Fill	Shape	Applications
1. Geo-Tubes	Generally > 700 m³		cylindrical (D=1-55m)	• Groins • Containment dikes • Non-permanent structures
2. Geo-Containers	Generally 100 - 700 m³		cylindrical/pillow (D<5m)	• Reef structures (surf zone) • defence structure against tsunami
3. Geo-Bags	0.05 - 5 m³		pillow, box, mattress	As soft rock units to build any type of coastal structures. Also for scour protection and dune reinforcement.

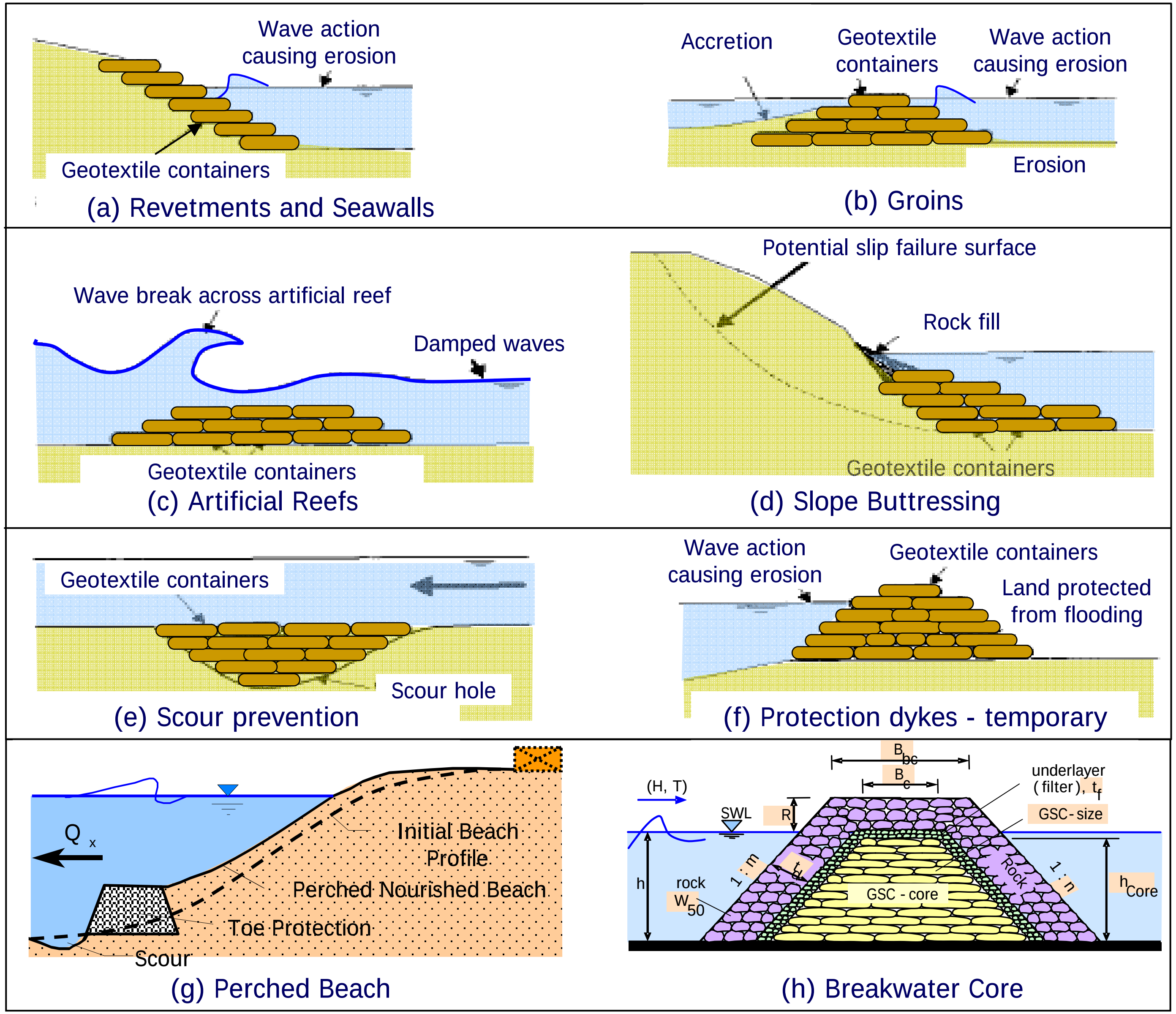
→ Essentially addressed in this course, but we call these smaller volume units „Geotextile Sand Containers" (GSCs).

Smaller volume GSCs are preferable for longer term permanent structures.

Advantage of Smaller Volume GSCs

- High density of sand fill can be achieved and better controlled.
- Less risk of liquefaction of sand fill and GSC-deformation.
- More adaptive to any requirements with respect to structure slope and geometry (better tolerance).
- Less tensile strength and thus less change of shape and higher durability.
- Maintenance and remedial work (replacement) much easier in case of vandalisms or degradation.
- More versatile in applications: any type of coastal structures, incl. coastal structure, dune and beach reinforcement.

Coastal Engineering Applications of Geotextile Sand Containers



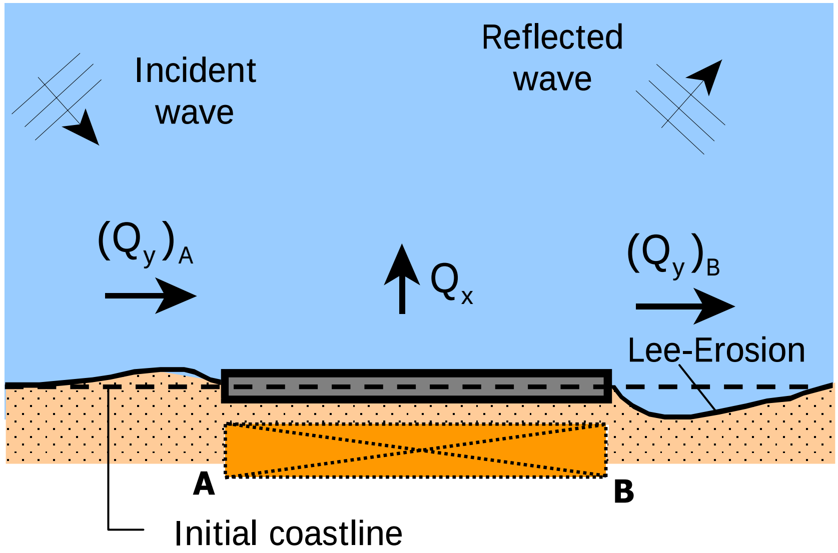
(Adapted & Modified from LAWSON, 2006)

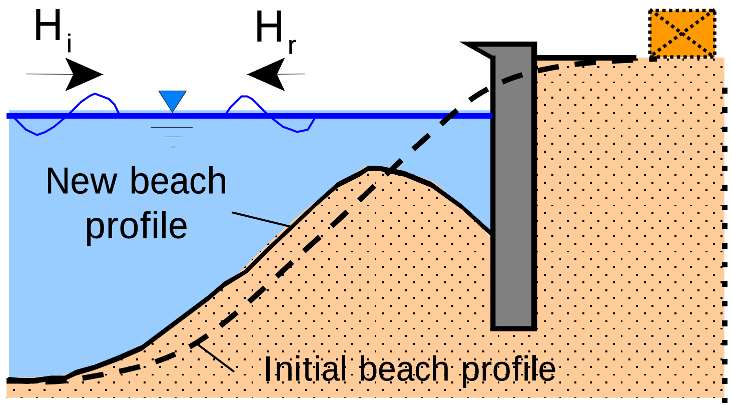
Geotextile Sand Containers: Range of Size Applied

3.2 Seawall/Revetment, incl. Dune and Beach Reinforcement

3.2.1 Example Applications

Seawall and Revetment

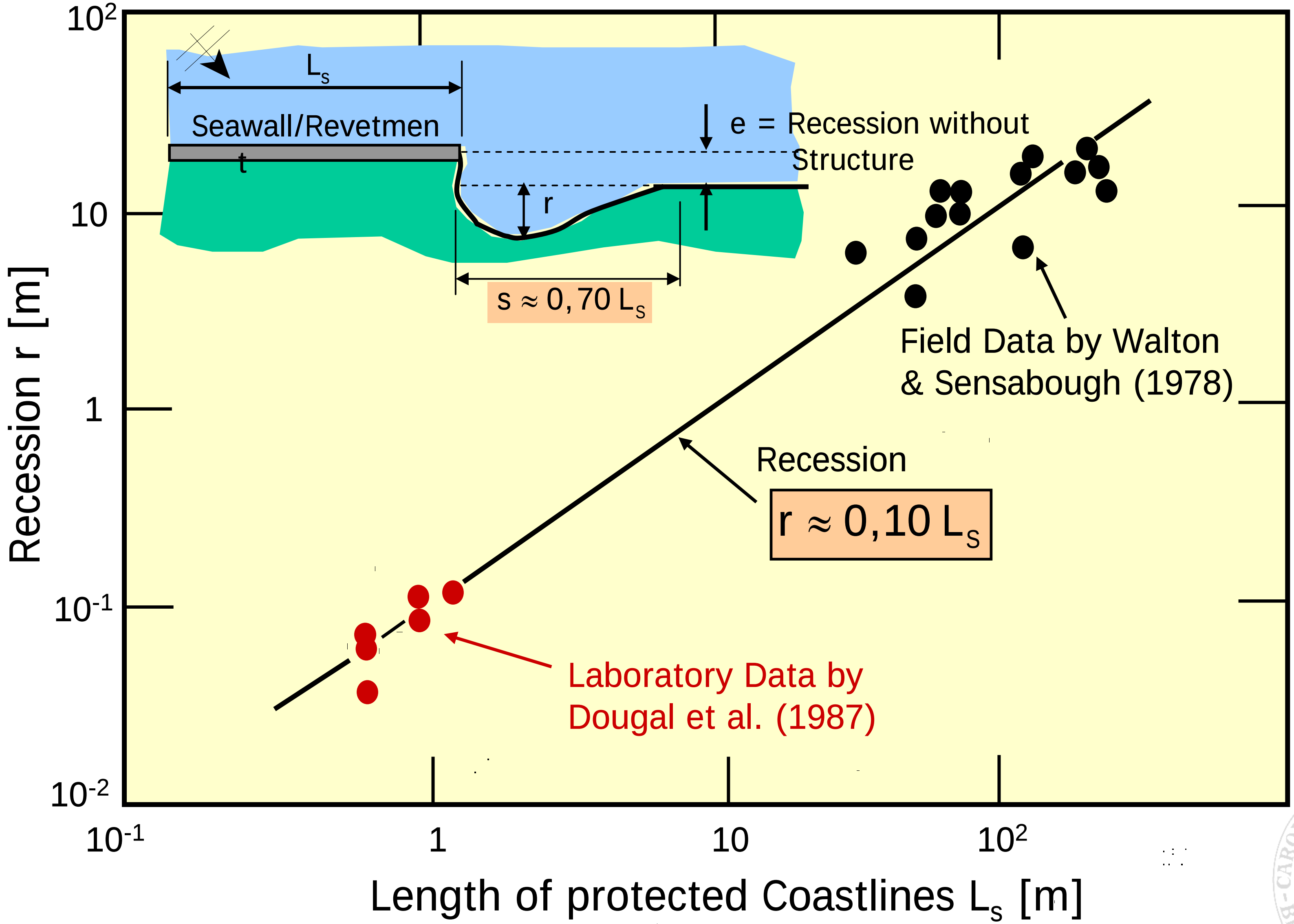




Seawall in Japan (before storm)

Seawall in Japan (after storm)

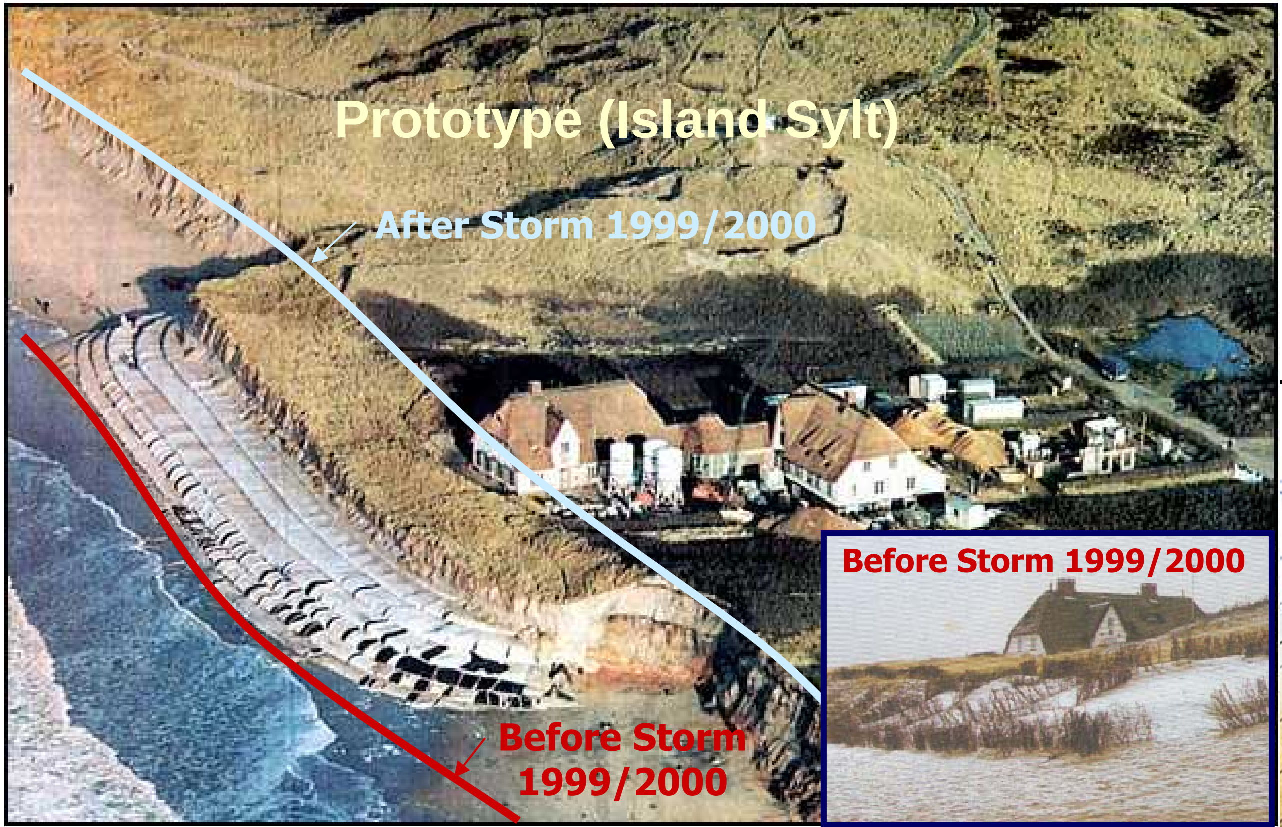
Extent of Down Stream-Erosion and Coastal Recession



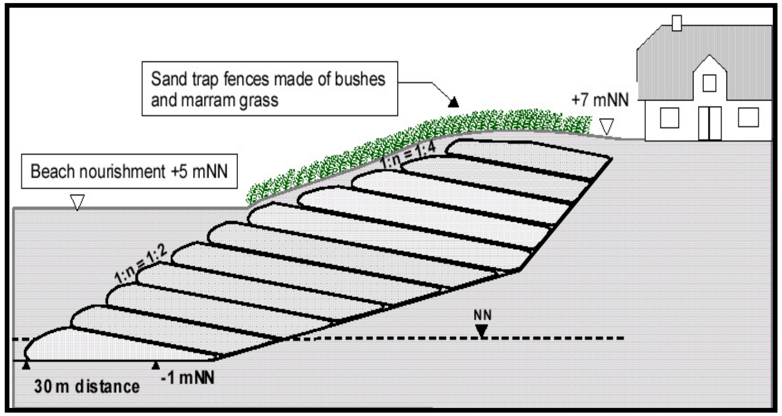
Geotextile Sand Containers as Beach Reinforcement

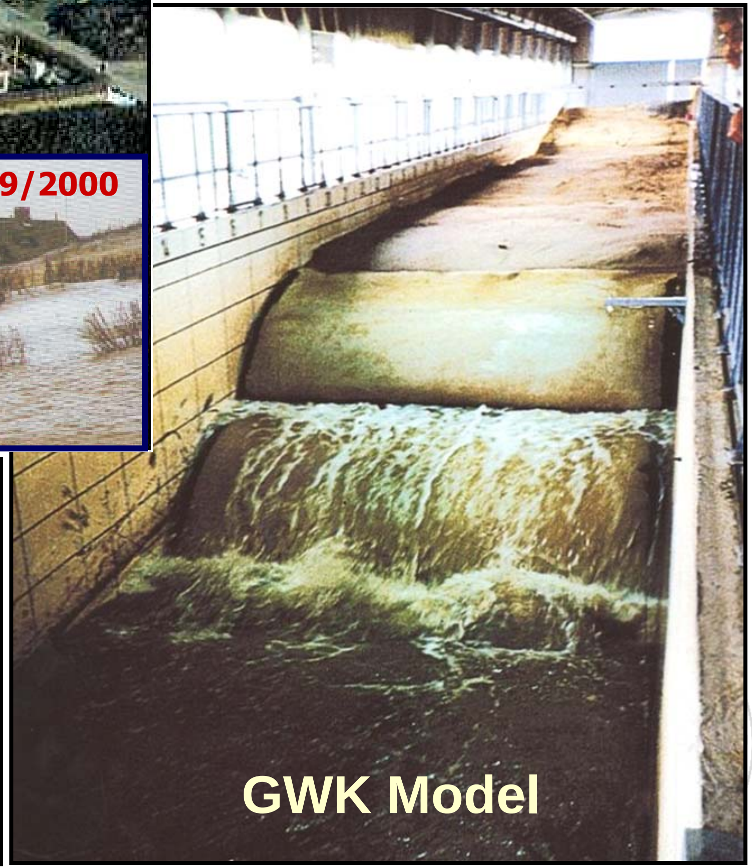
Stockton Beach Reinforcement, Australia

Dune Reinforcement Sylt Island, Germany



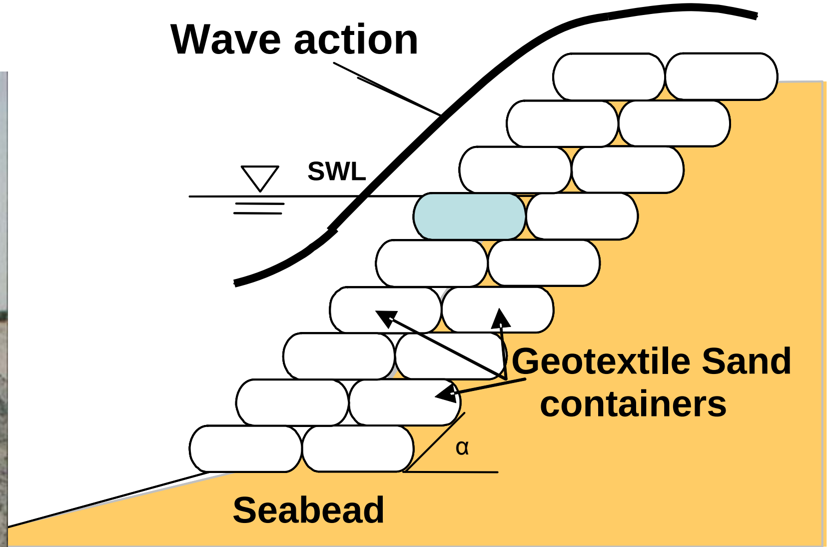
[Picture: Sylt Picture 2000]





Dune and Beach Reinforcement

Dune reinforcement in Baltic Sea, (Courtesy Naue GmbH & co. KG)



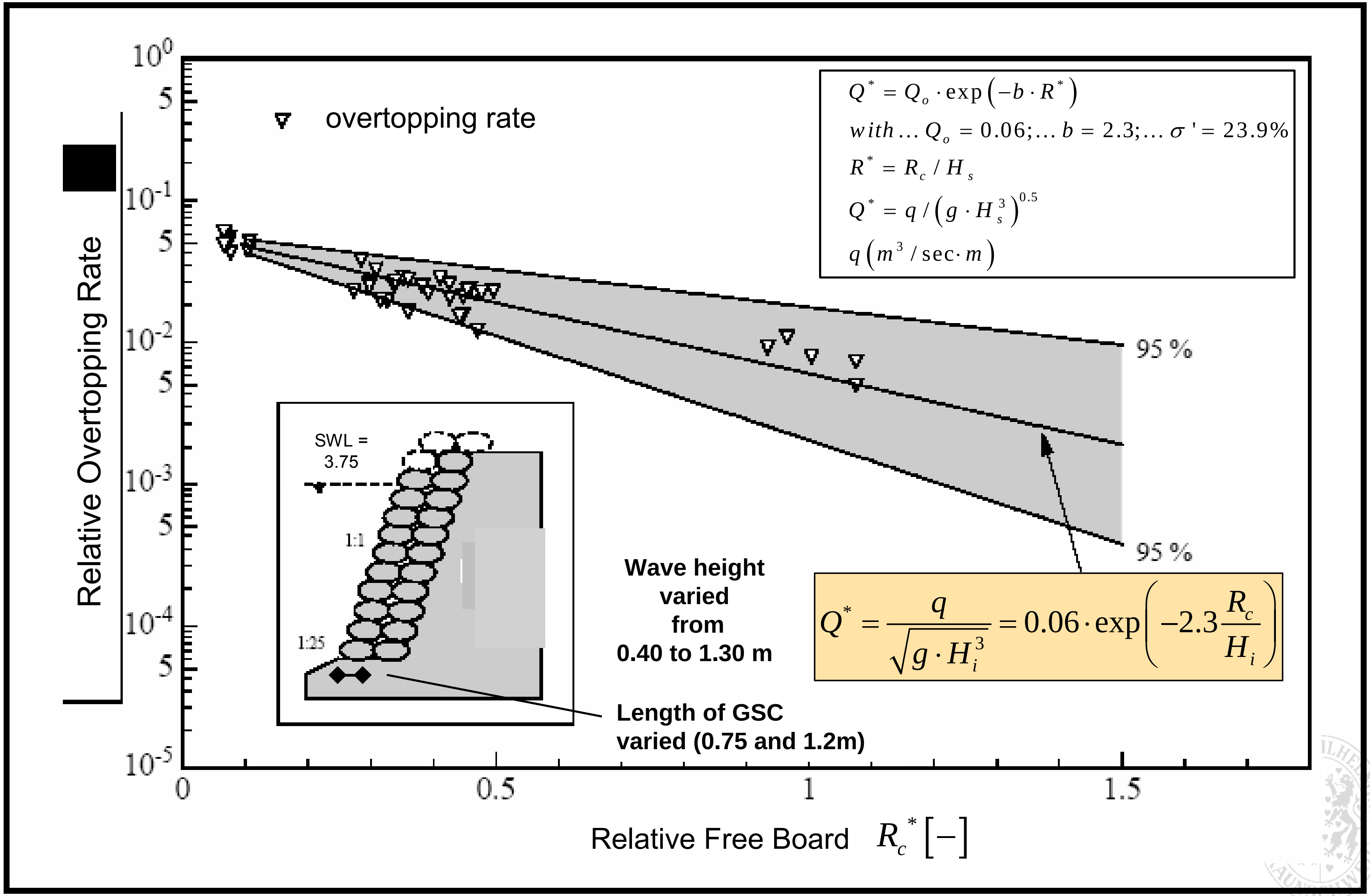
Beach Reinforcement in Australia, (Courtesy Naue GmbH & co. KG)

Caledon Shore Protection, USA (1)

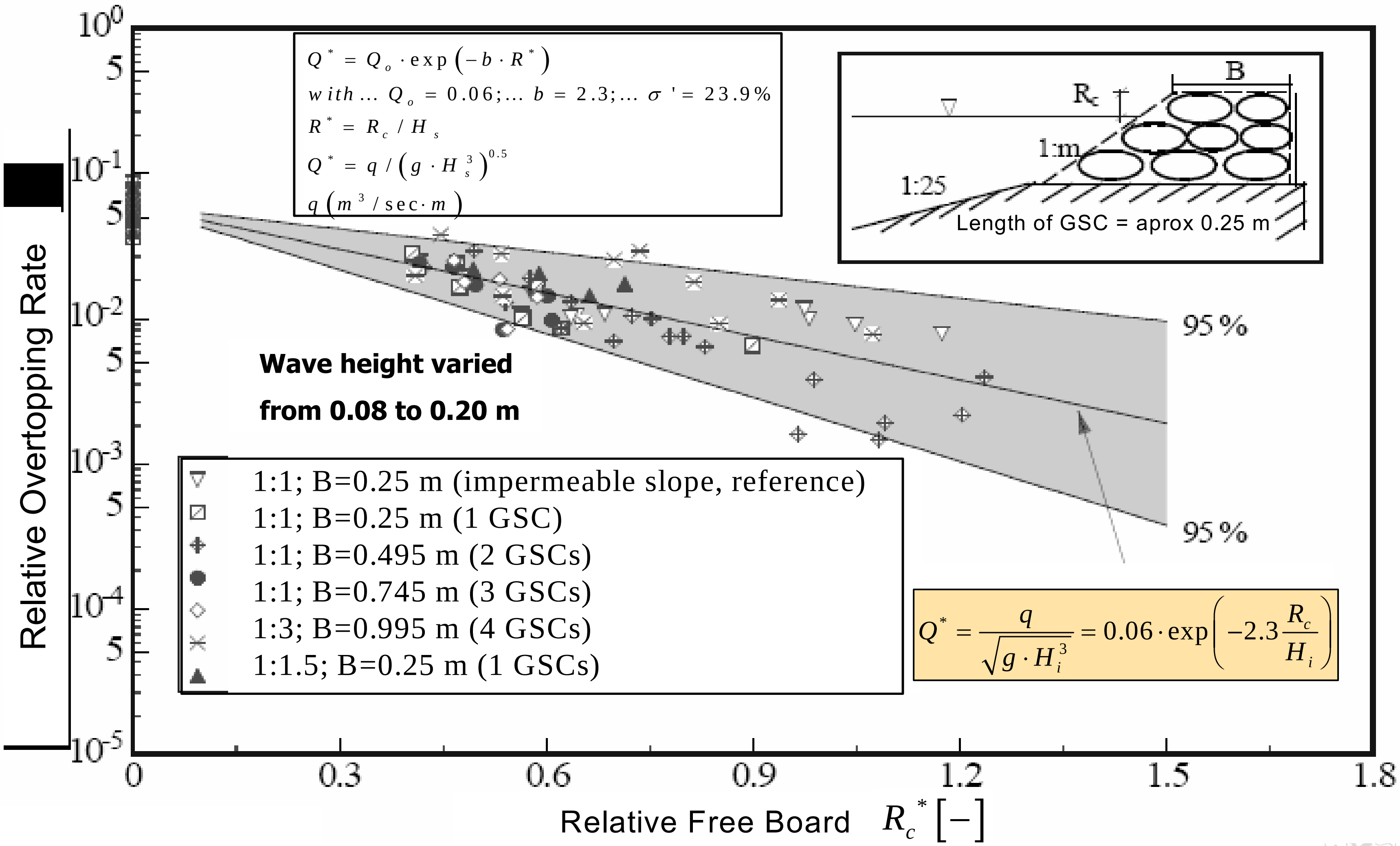
Caledon Shore Protection, USA (2)

3.2.2 Hydraulic Performance of Seawalls Made of Geotextile Sand Containers

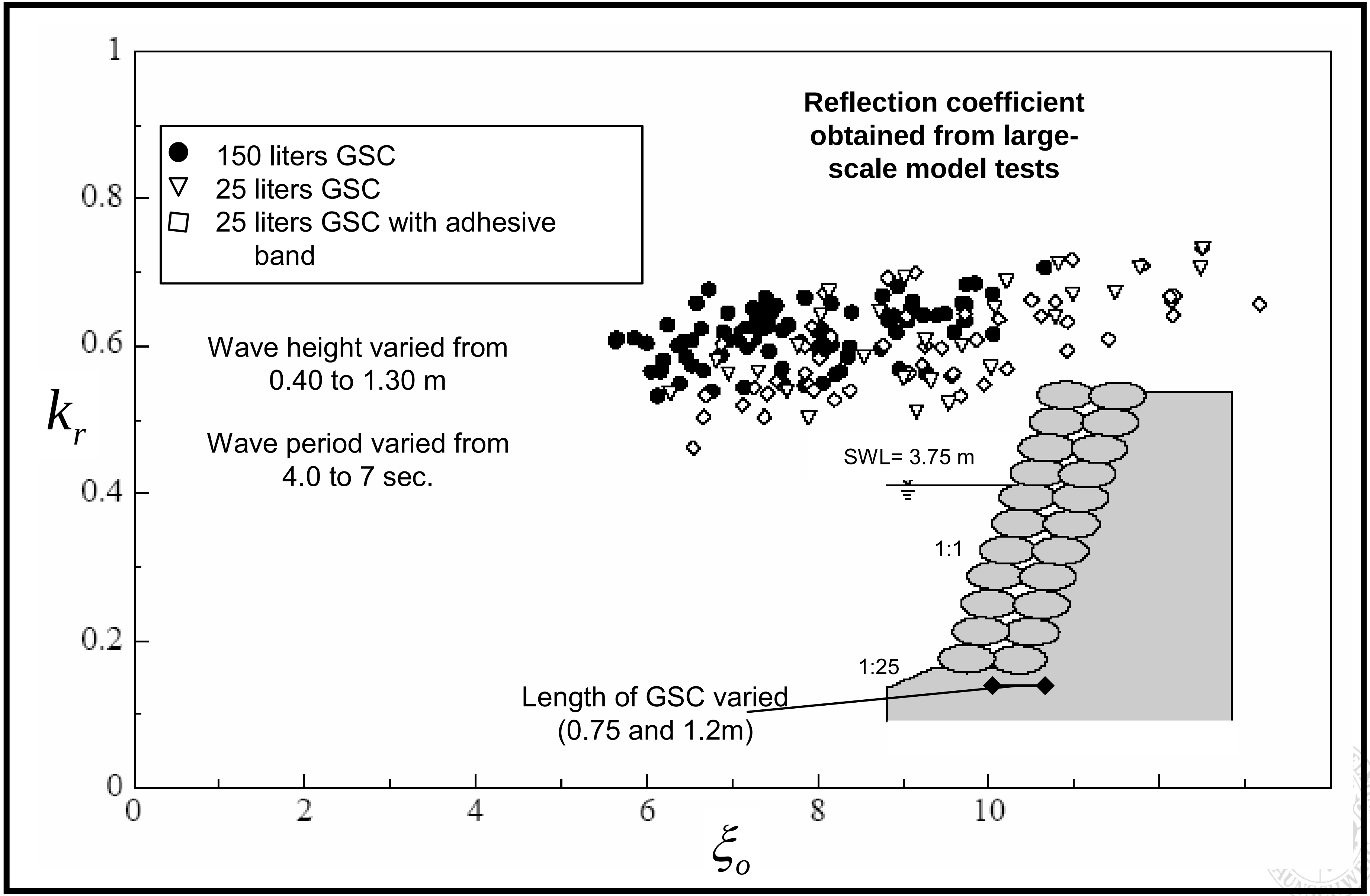
Wave Overtopping Formulae (large-scale model tests)



Wave Overtopping Formulae (small-scale model tests)

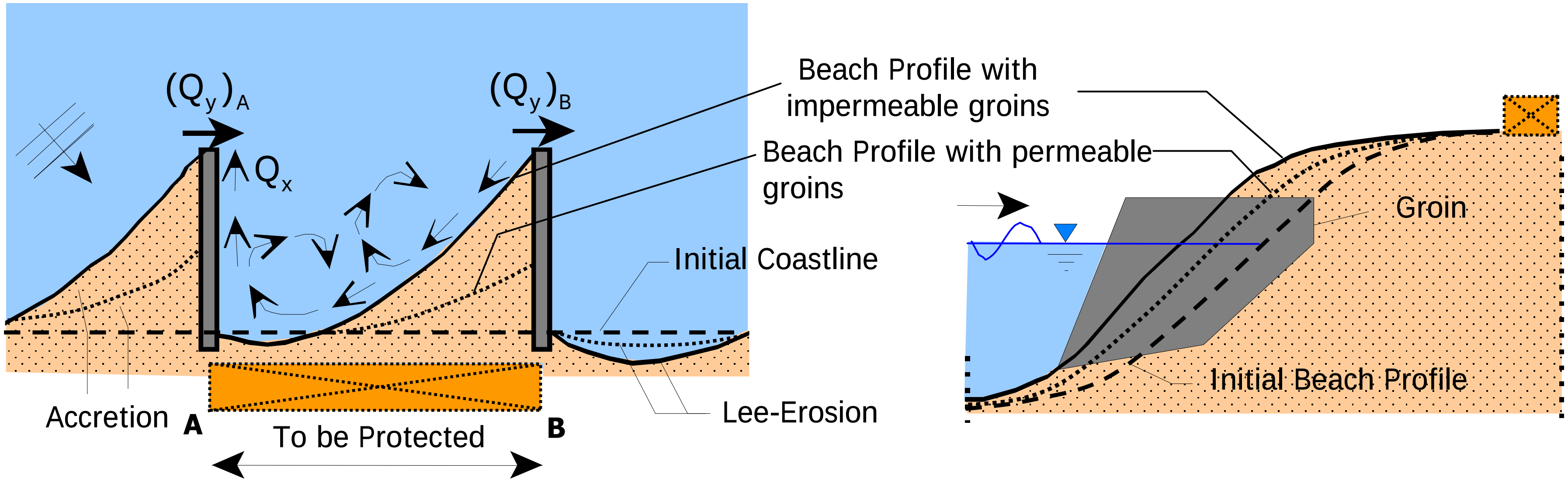


Reflection Performance from Large-Scale Model Tests



3.3 Sea Groins

Sea Groins

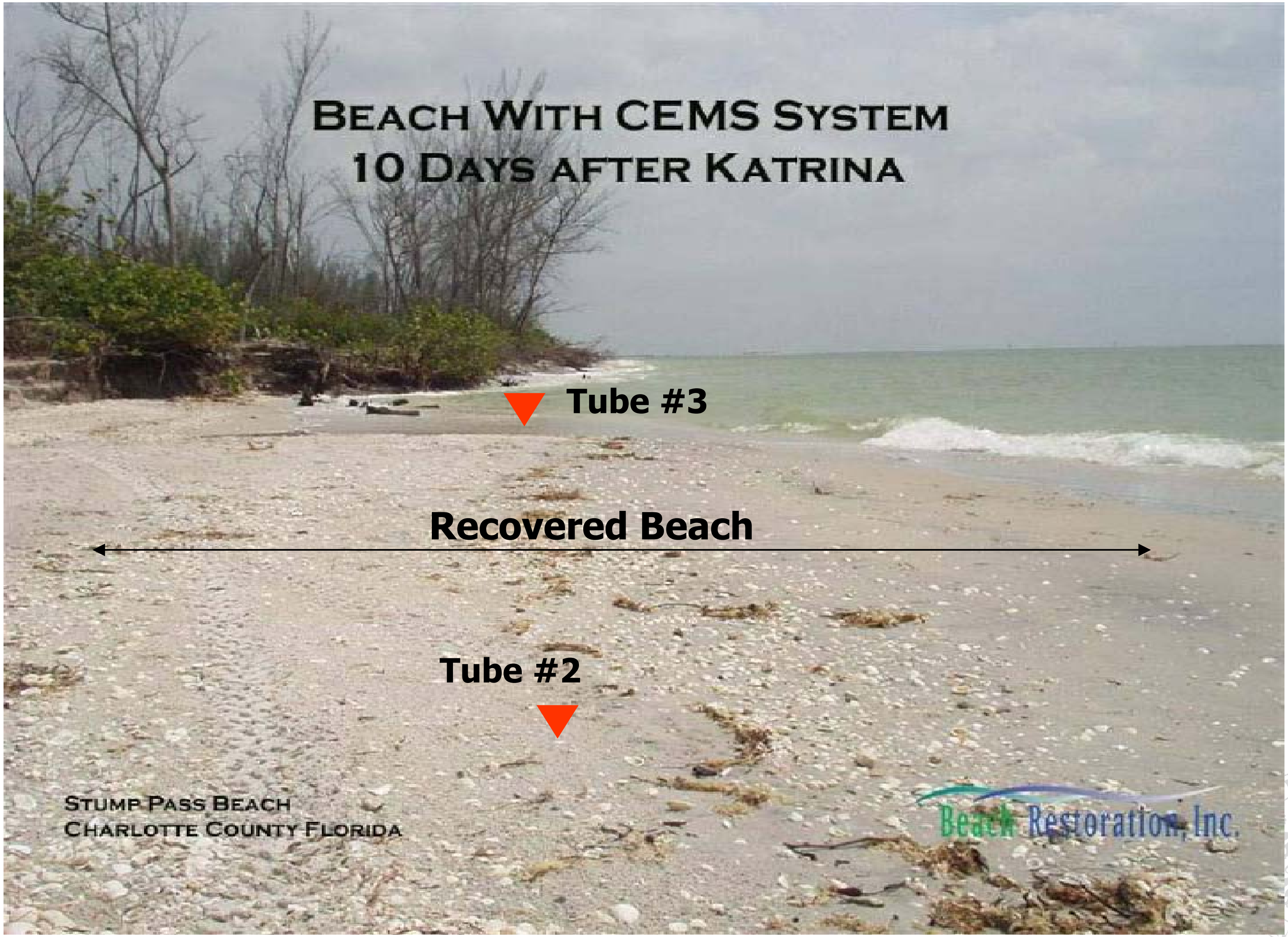


New-Jersey in Deal, Allenhurst and Asbury Park

Submerged groins made of geotextile Tubes, Greece

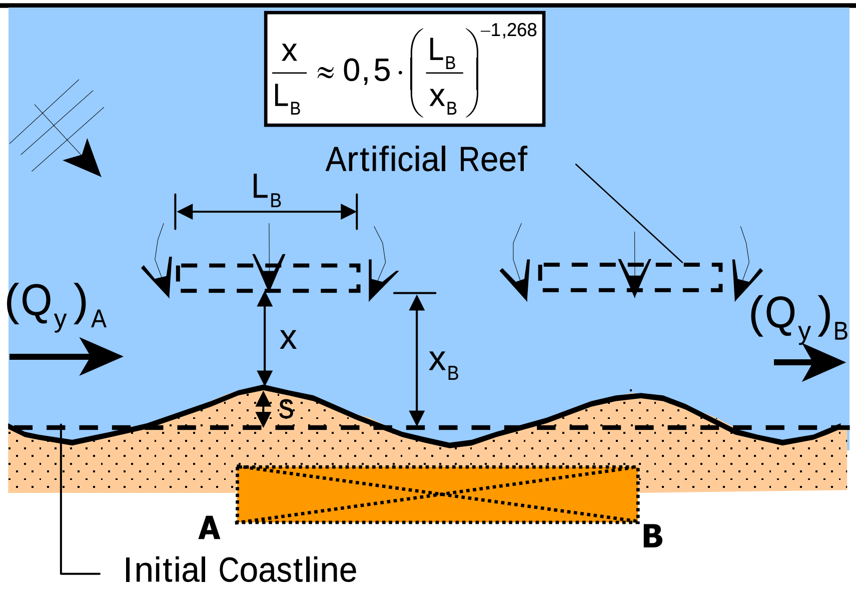
Submerged Groins Made of Geotextile Tubes (1)

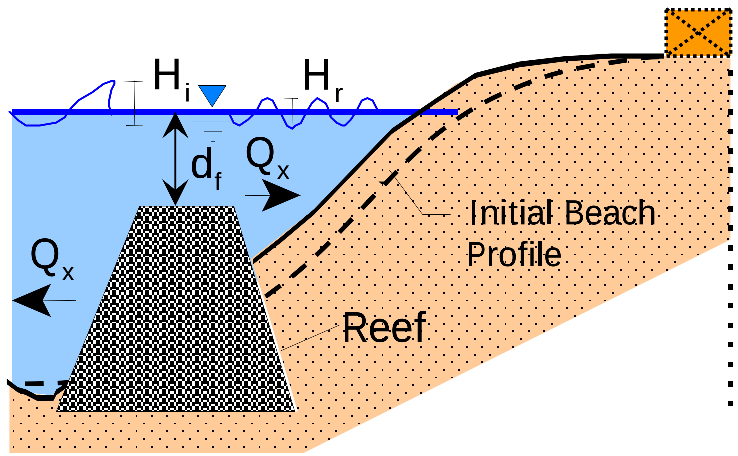
Submerged Groins Made of Geotextile Tubes (2)



3.4 Artificial Reefs

Artificial Reefs



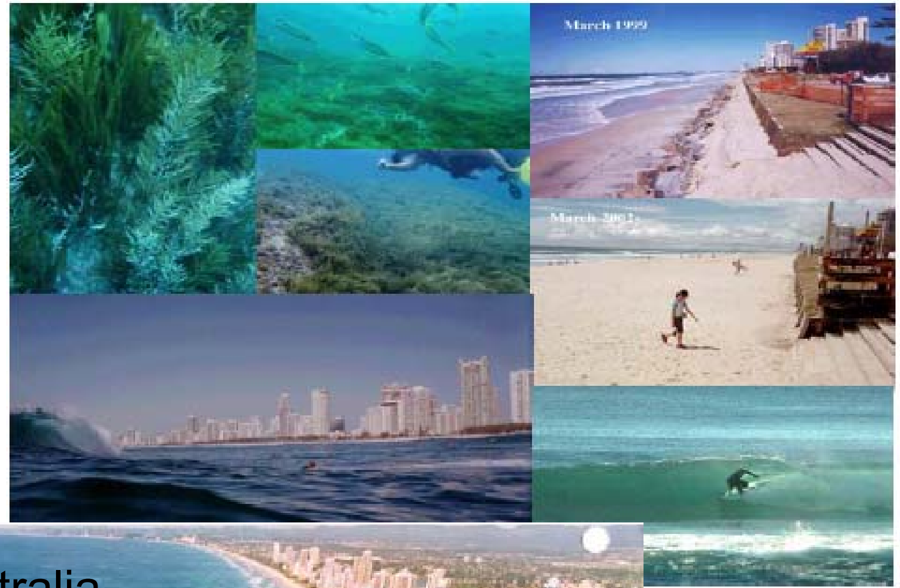


Reef, Moraville / Australia (Black, 2003)

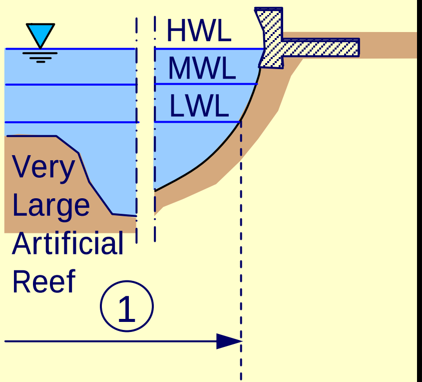
Narrowneck-Reef, Australia

Narrowneck Reef, Australia (Mega Sand Container 250 m³)

Artificial GSC-reef in Australia (Narrowneck, Australia)



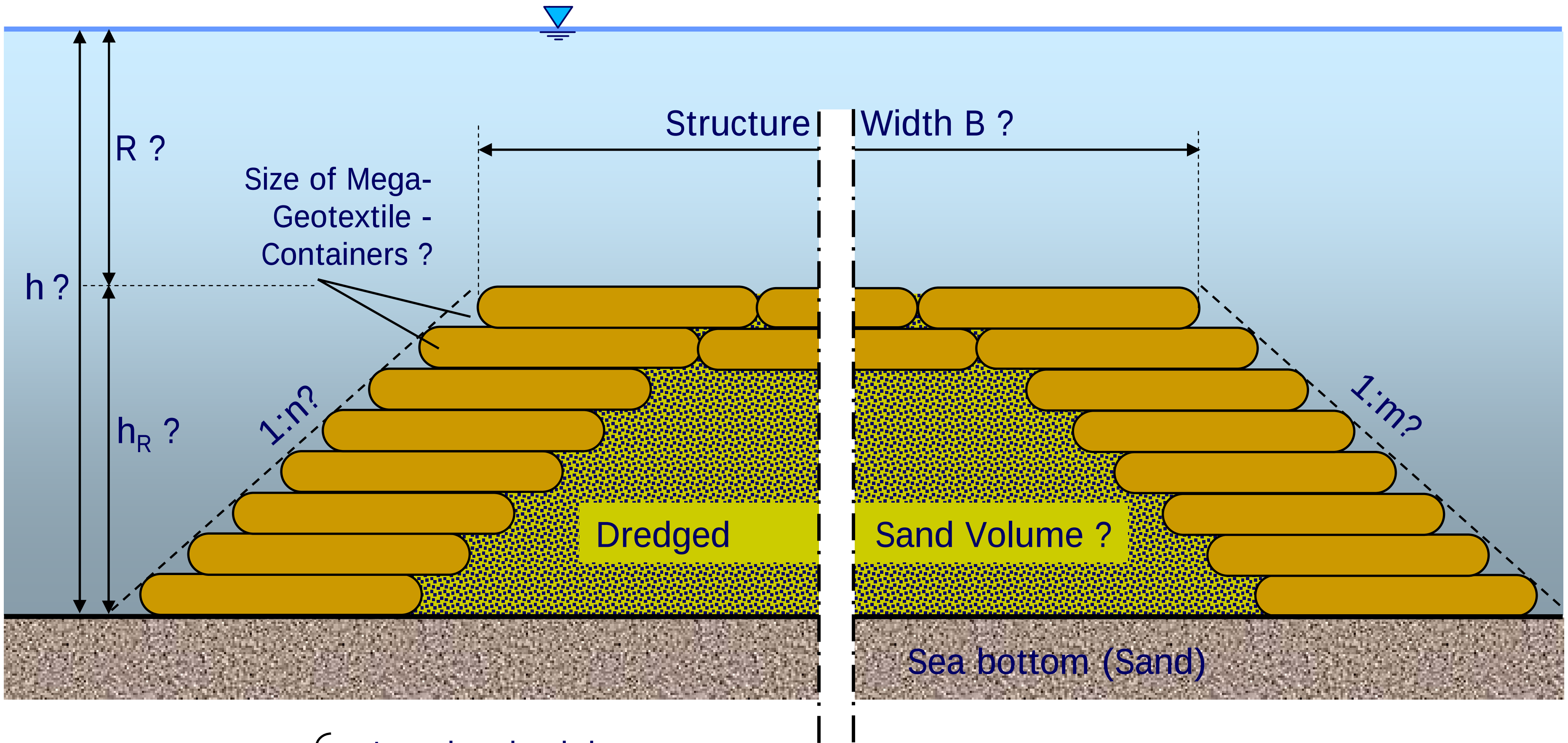
GSC-reef in Australia,
(Courtesy Naue GmbH & co. KG)



(1b) Mega-Geo-containers

Feasibility for the full range of wave periods (5 - 60 minutes) of tsunamis has first to be first checked.

Possible Application for Tsunami (Feasibility Study in Progress)

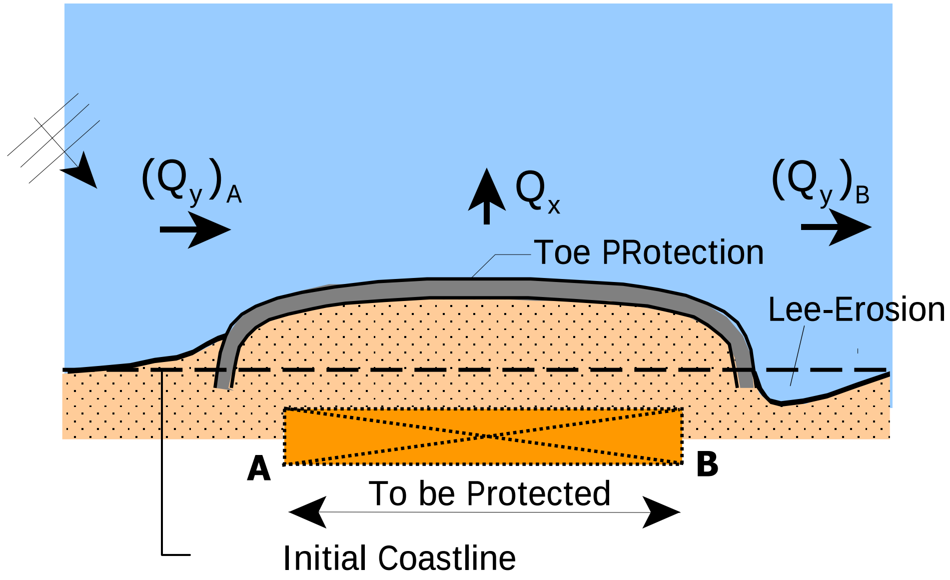


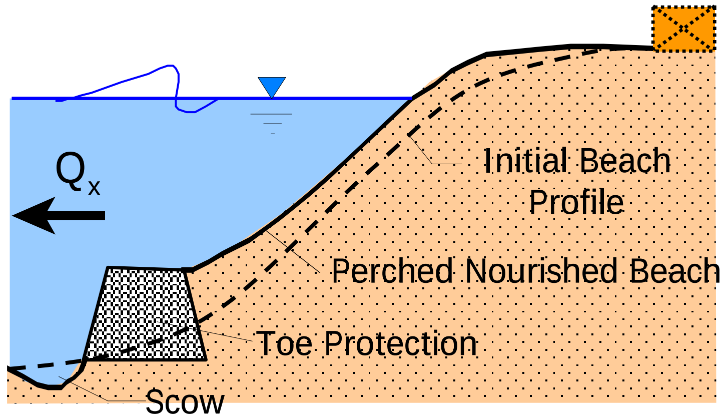
Reef Parameters
- Location depth h
- Structure width B and slope steepness 1:n and 1:m
- Reef height h_R and submergence depth R
- Size (volume, weight) of geotextile containers

must be determined as a function of target incident Tsunami wave parameters and target level of tsunami attenuation (transmitted wave parameters). The latter will depend on the nature of the next defence line(s) and the vulnerability of the flood prone area.

3.5 Perched Beaches

Perched Beach





Perched Beach, USA

Beach Nourishment combined with Supporting Structures:

- Groins
- Offshore breakwater
- Artificial reefs
- Headlands

3.6 Core of Rubble Mound Structure

Motivation and Objectives

Sand Core instead of Quarry Run Core: Benefits & Drawbacks

LWI

Motivations & Benefits

① Non-availability of rock material in sufficient quality and at affordable costs

↓

Improve feasibilities of RM-Solution

② Too much sediment infiltration through conventional rubble mound breakwater

↓

Reduce shoaling of harbours/navigation channels, and thus maintenance dredging costs

③ Too much wave transmission through conventional rubble mound breakwater

↓

Reduce transmission which particularly might be crucial for long waves

Possible Drawbacks

① Increase of wave run-up and over-topping

↓

Stability of rear slope

② Increase of wave reflection

↓

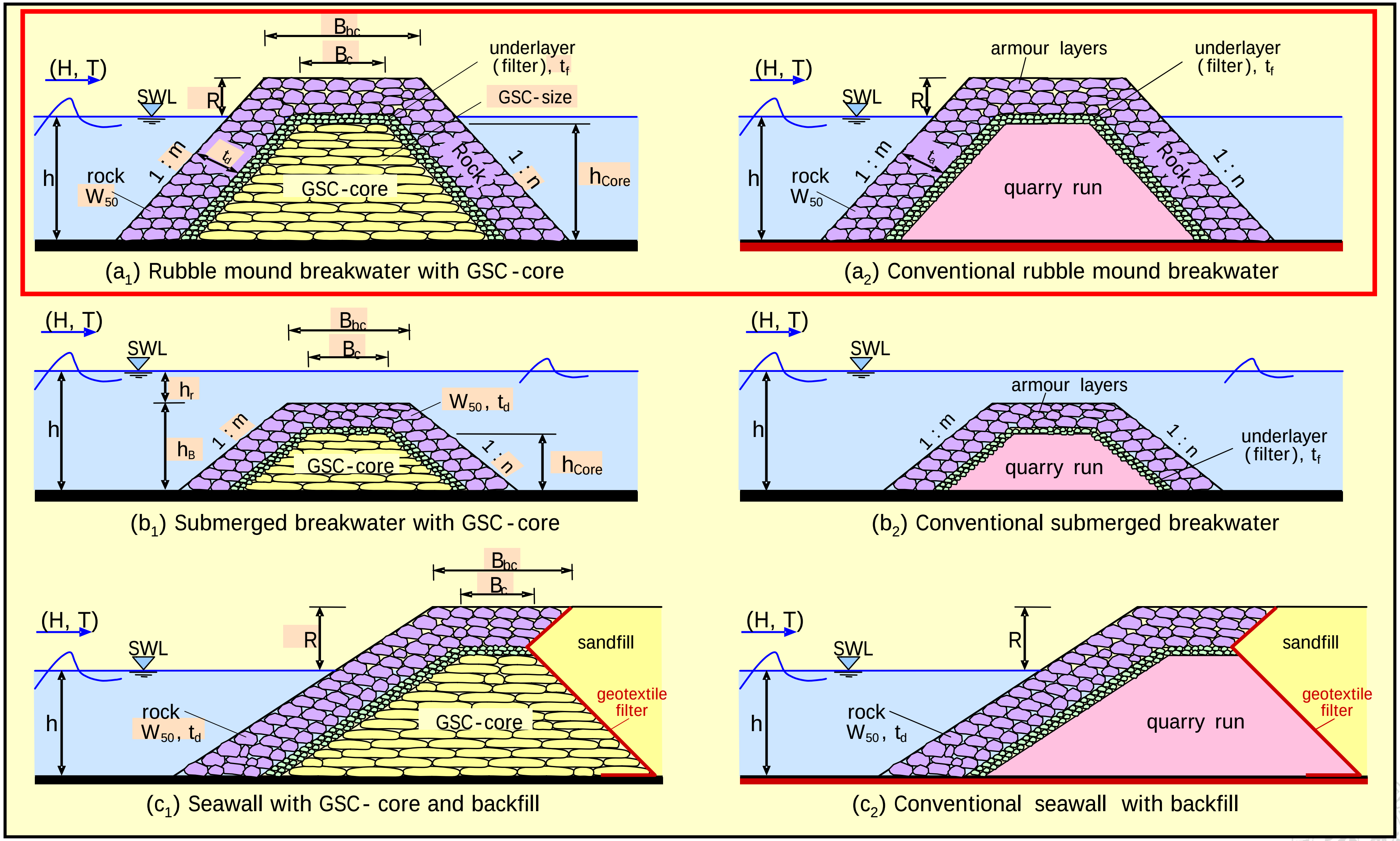
Toe stability (scour)

③ Less energy dissipation in the core

↓

Stability of seaward slope

Rubble Mound Structures with Core Made of Geocontainers



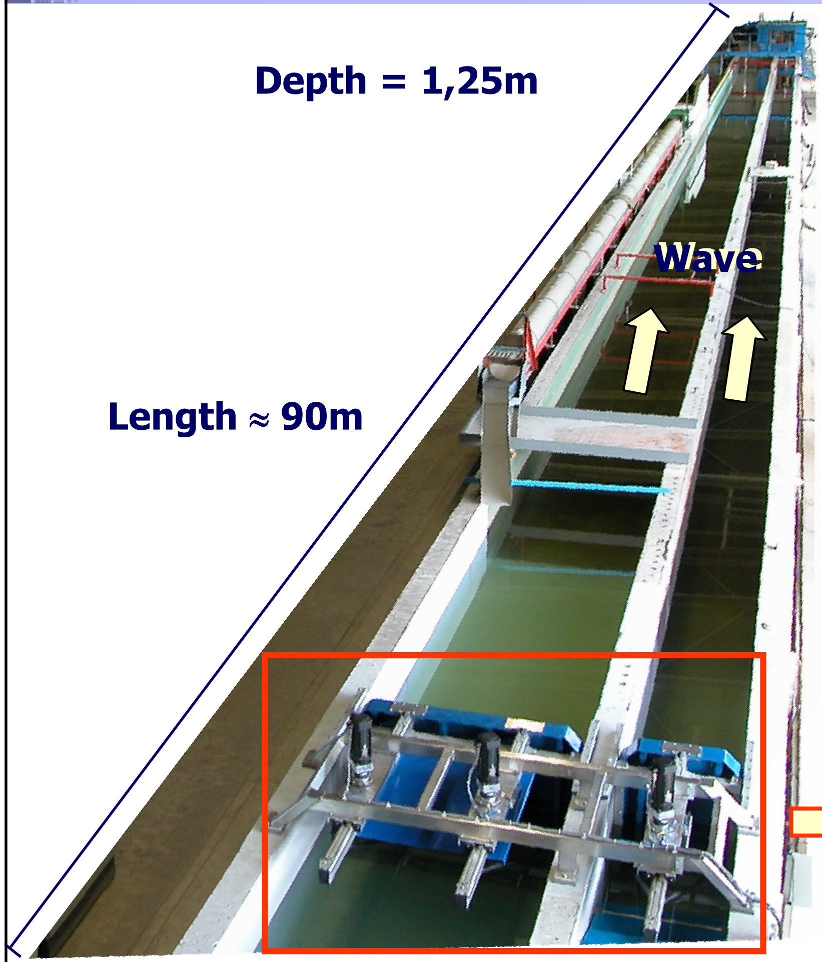
Comparative Experimental Study of Hydraulic Performance and Armour Stability in Twin Wave Flume of LWI

Experimental Set-up and Procedure

Twin Wave Flume at Leichtweiß Institute

Depth = 1,25m

Length ≈ 90m

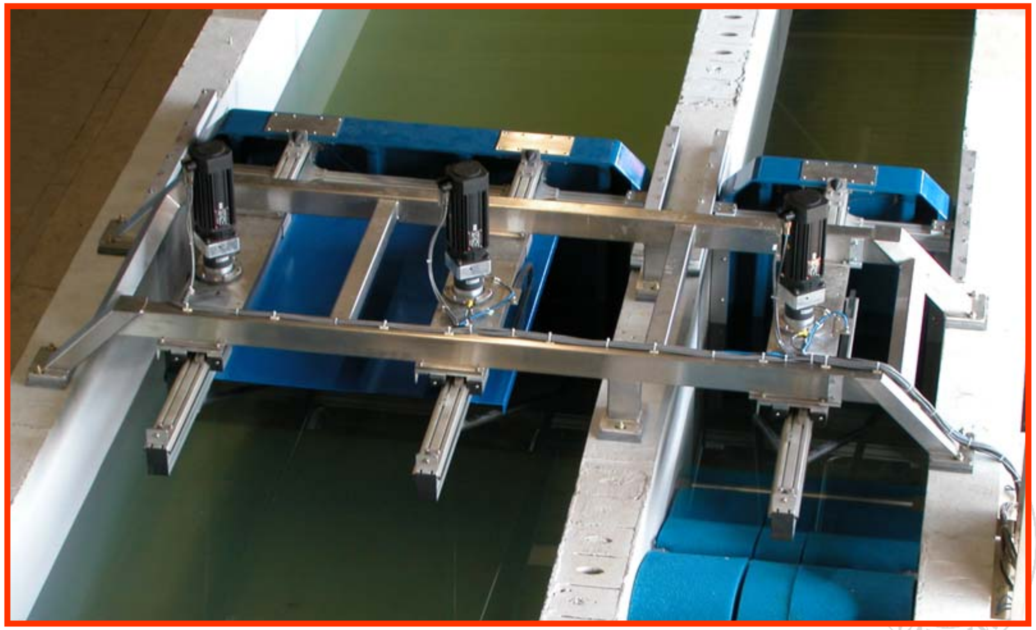


2m 1m

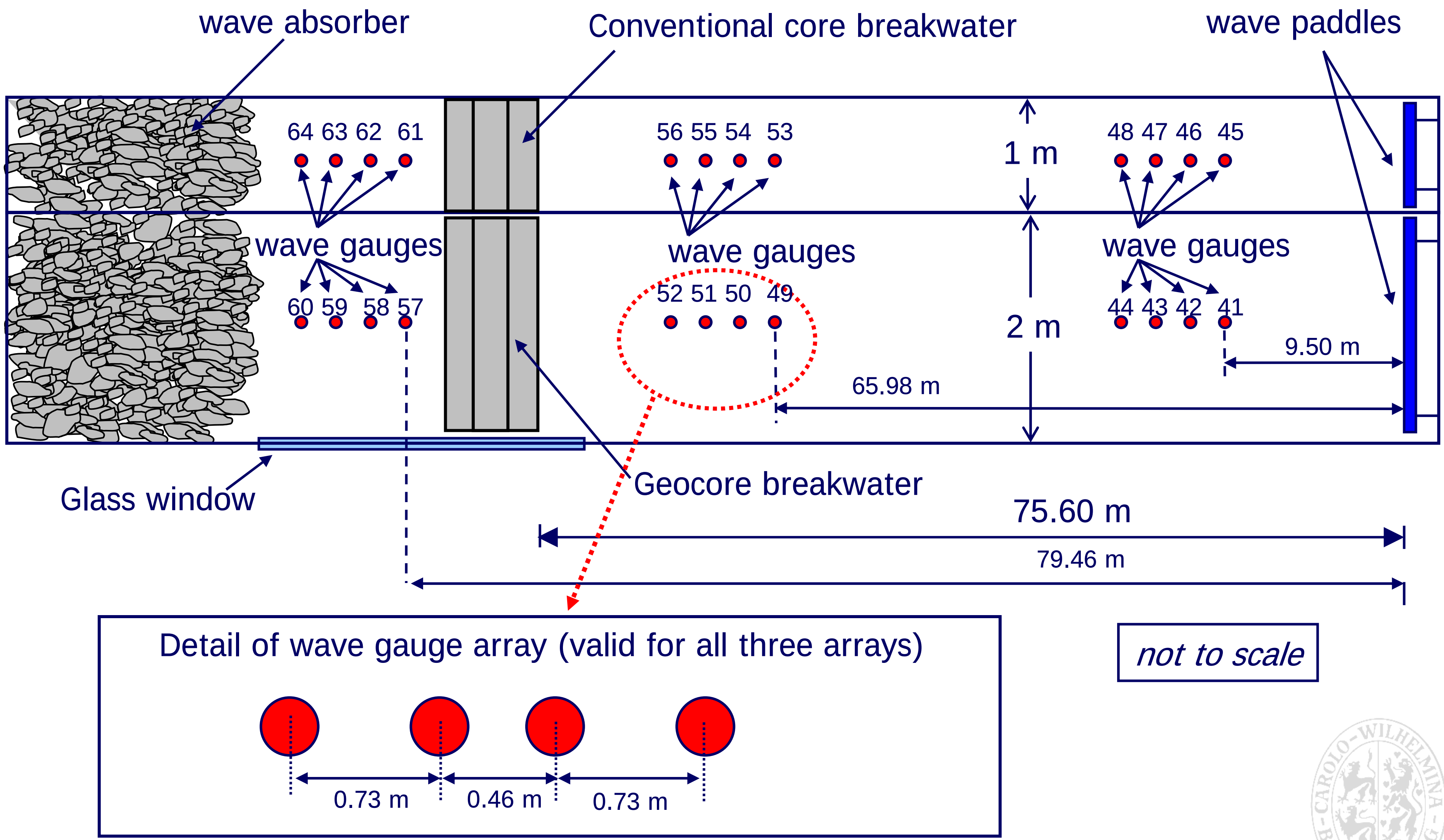
(a) General view of twin wave flumes

- Regular waves: up to H= 30cm
- Random wave: up to H_S= 20cm
- Solitary waves: up to H= 30cm
- "Freak waves": up to H= 30cm

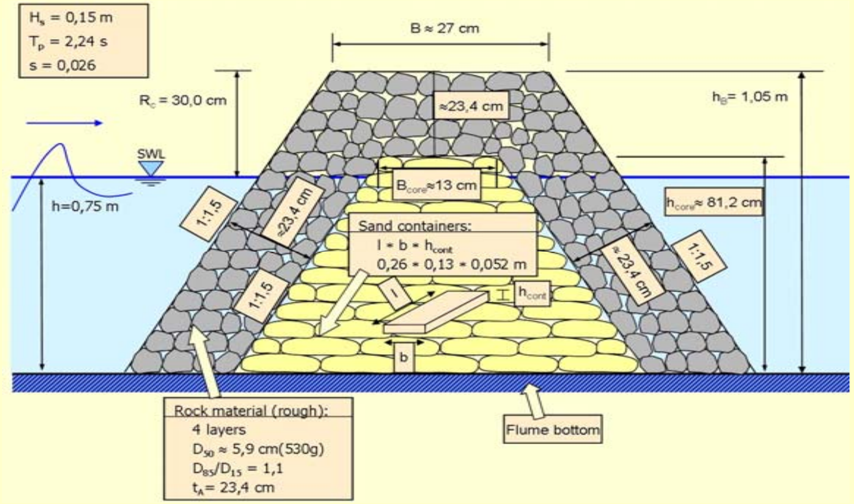
(b) Twin-Wave Paddle (Synchron or independent)

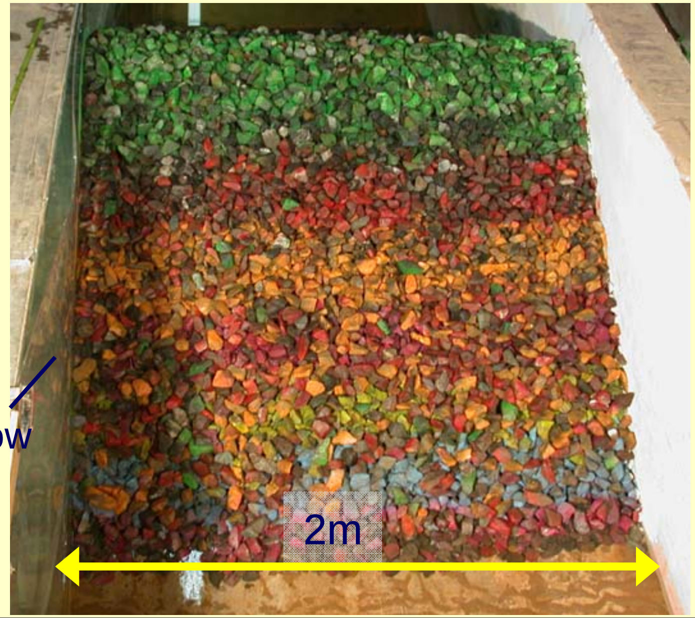


Breakwater Models in the Twin Wave Flumes (Plan View)



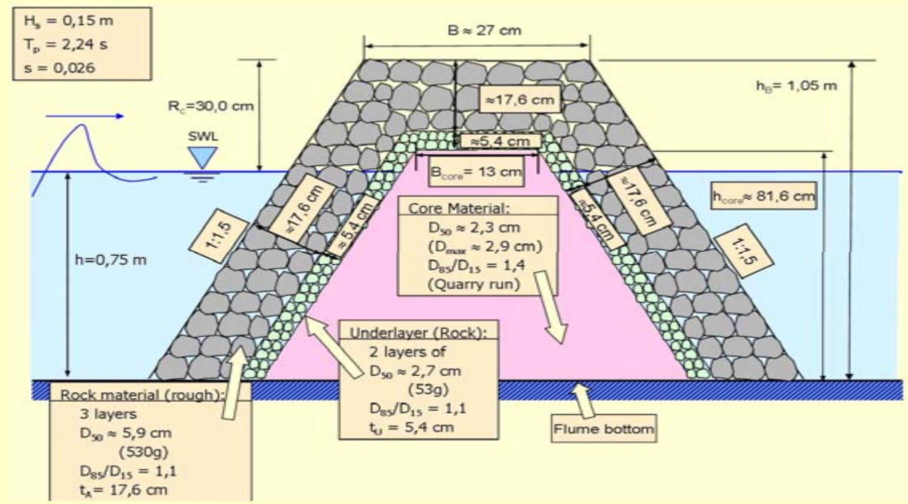
(a) Geocore Breakwater in first flume





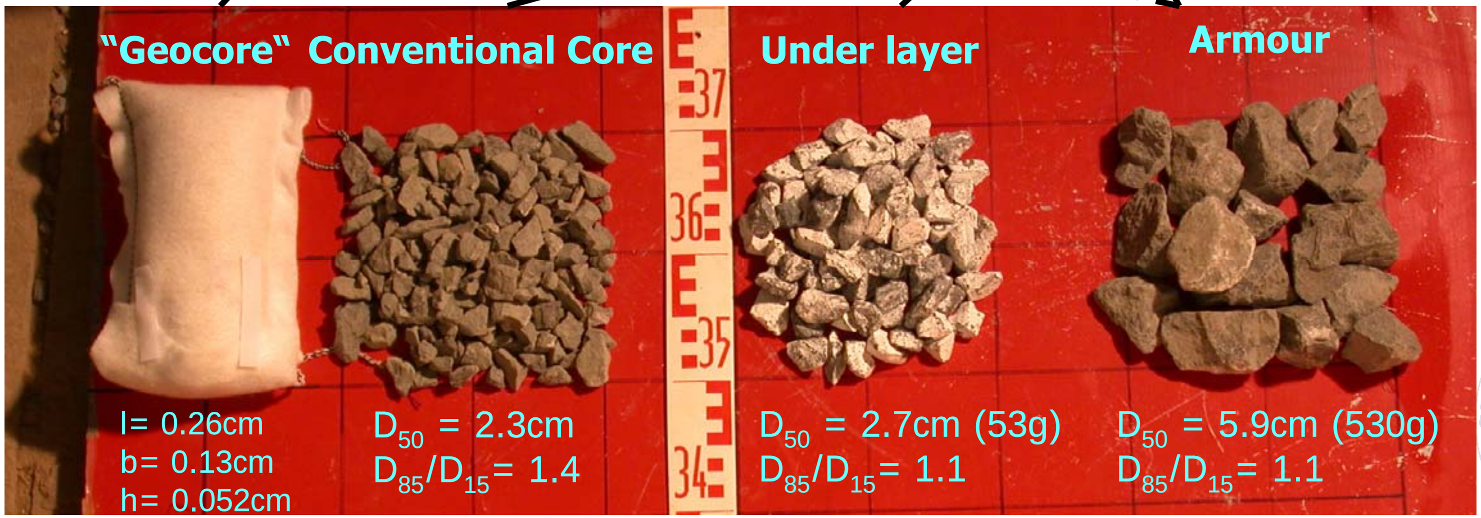
Glass window

(b) Conventional Breakwater in 2nd flume



Materials for Geocore and Conventional Breakwater Model

Glass window



Core Type	Description	Darcy´s permeability coefficient k value [m/s]
	GSC-structure made of geotextile sand containers placed **randomly** $^{(*)}$ (0.26x0.13x0.052cm)	**2.4×10^{-2} (*)**
	Structure made of gravel D_{50} = 2.3cm; D_{max} = 2.9cm D_{85}/D_{15} = 1.4	**3.9×10^{-1}**

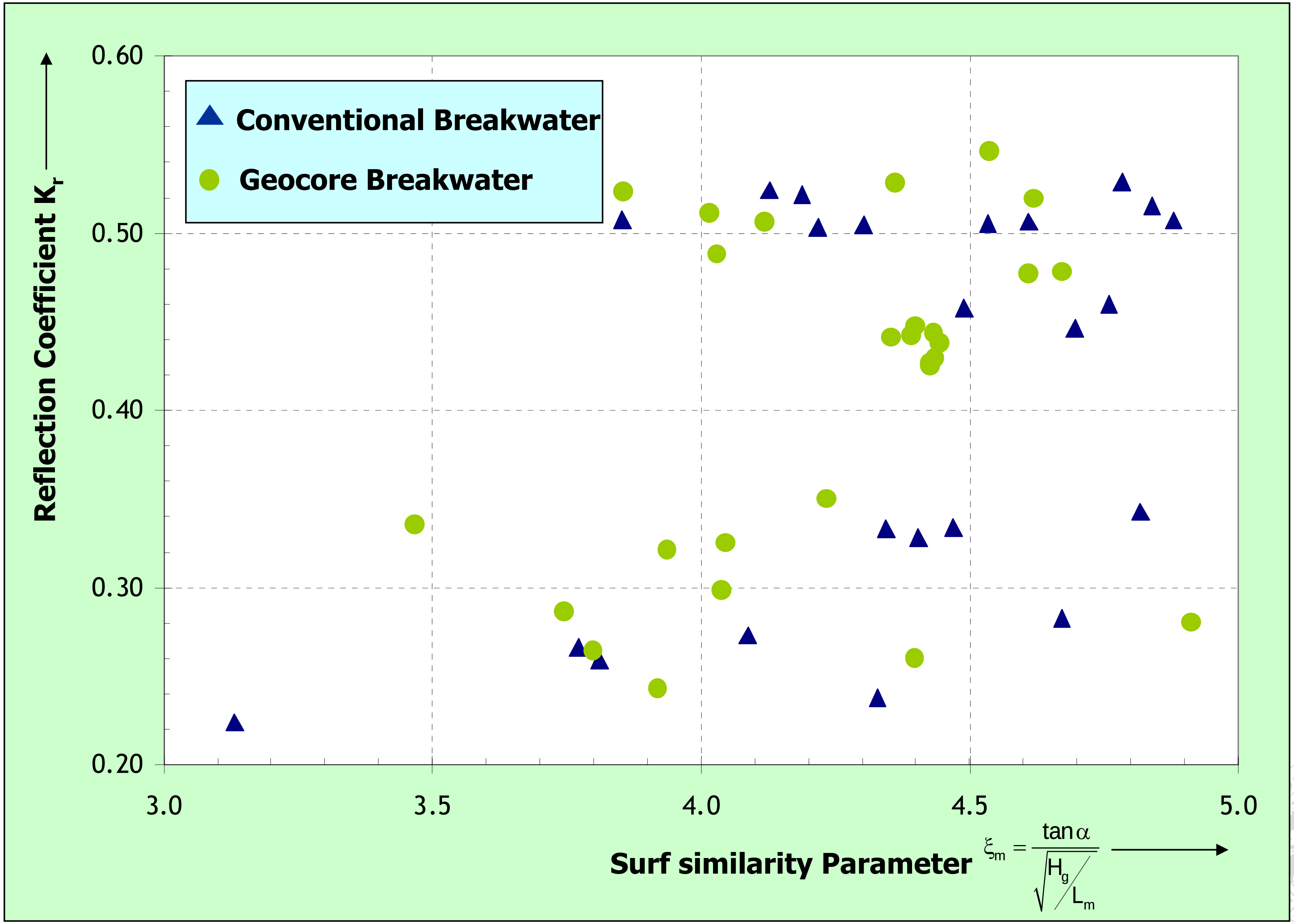
(*) longitudinally placed: k= $2.3 \cdot 10^{-2}$ m/s; longitudinally/transversally placed: k= $1.2 \cdot 10^{-2}$ m/s

- **Type of waves:** Wave spectra (JONSWAP)
- **Water depth:** d = 0.25 – 0.85m (Δh = 25cm)
- **Wave Height:** H_S = 0.08 – 0.20m (ΔH = 2 – 3cm)
- **Wave Period:** T_p = 1.15 – 3.00s (ΔT = 0.25 – 0.5s)
- **Number of waves:** N_0= 1000/test (with wave absorption)

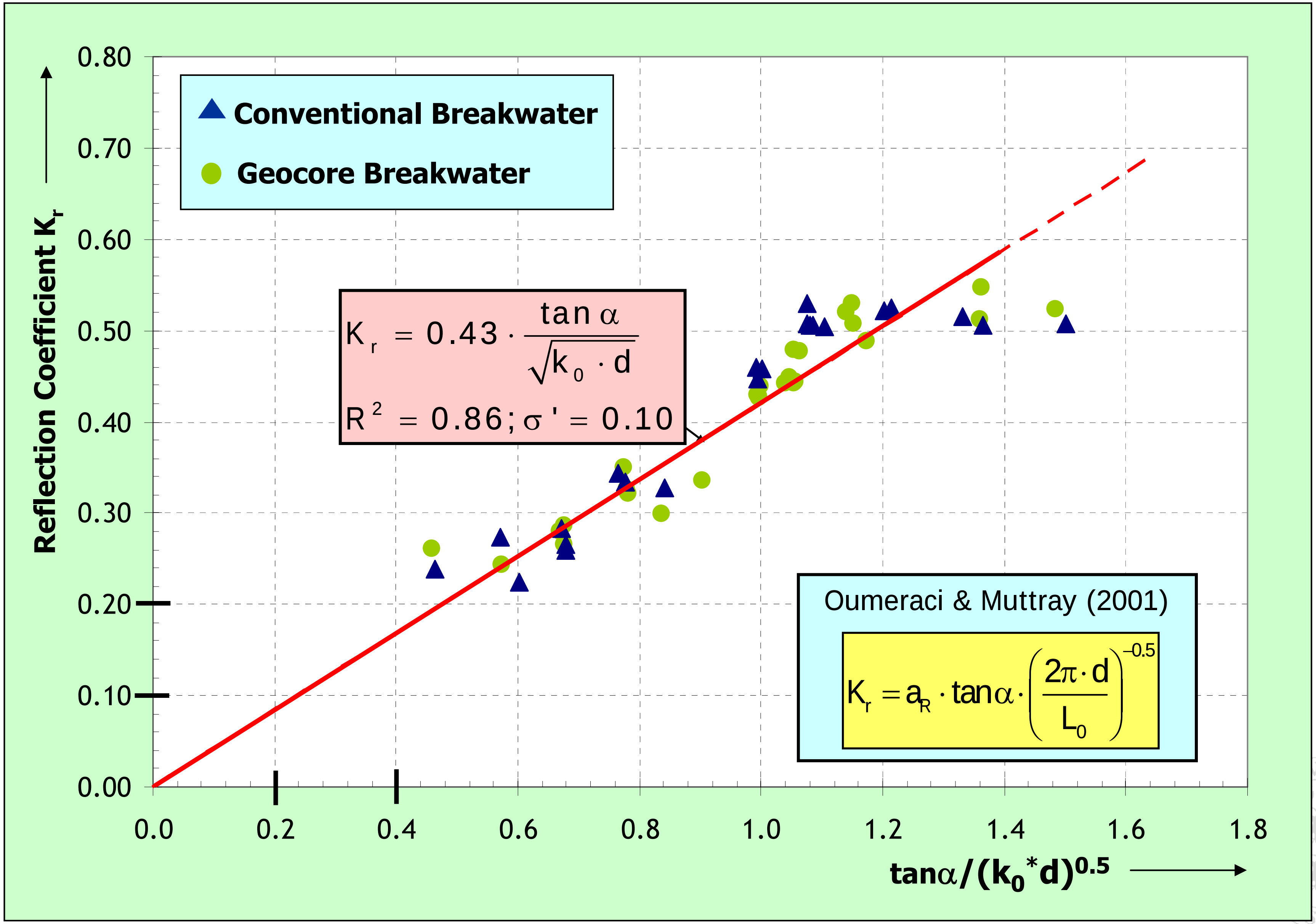
Hydraulic Performance

- Comparative Analysis of Conventional Core and Geocore Alternatives -

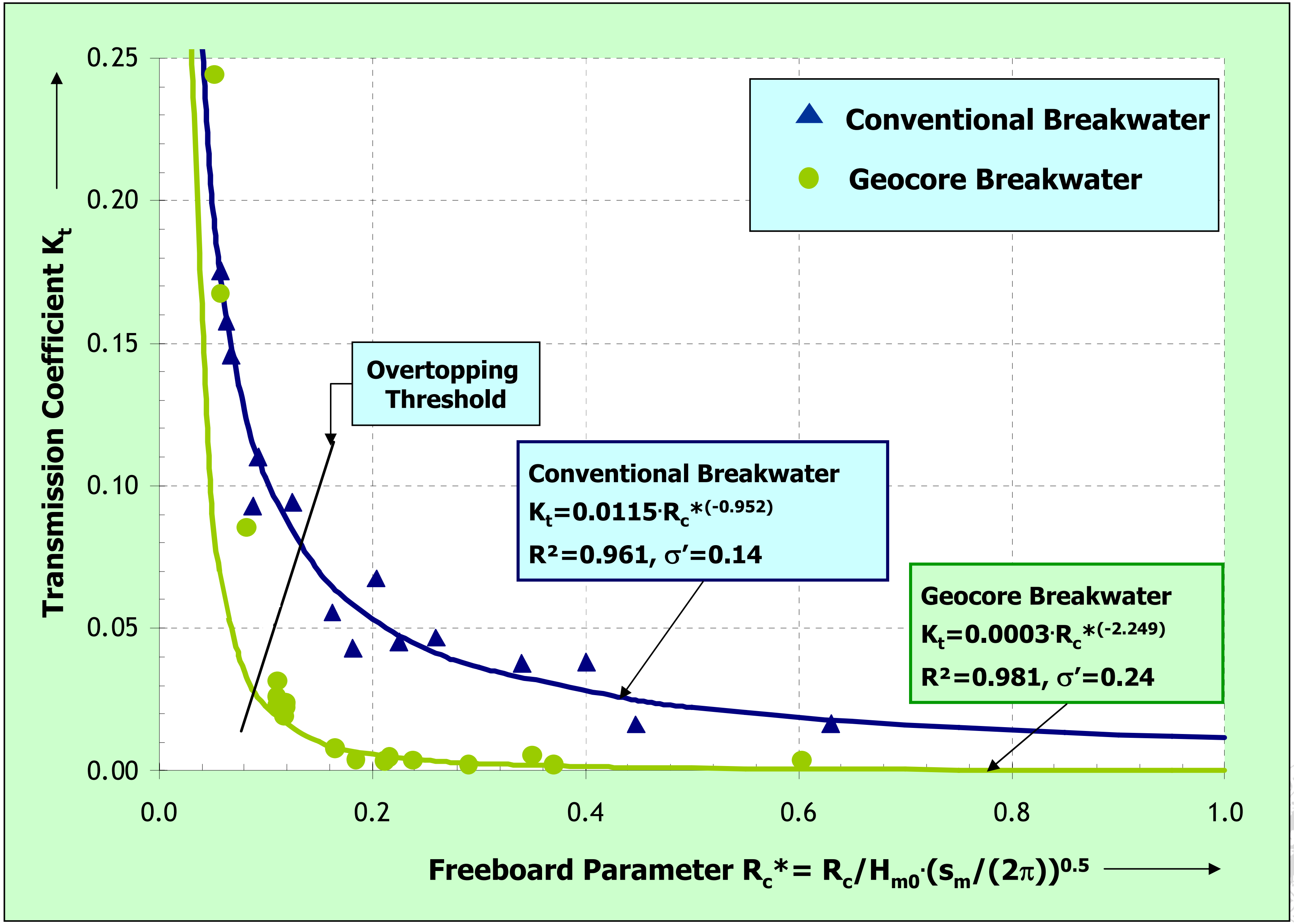
Wave Reflection Performance (1)



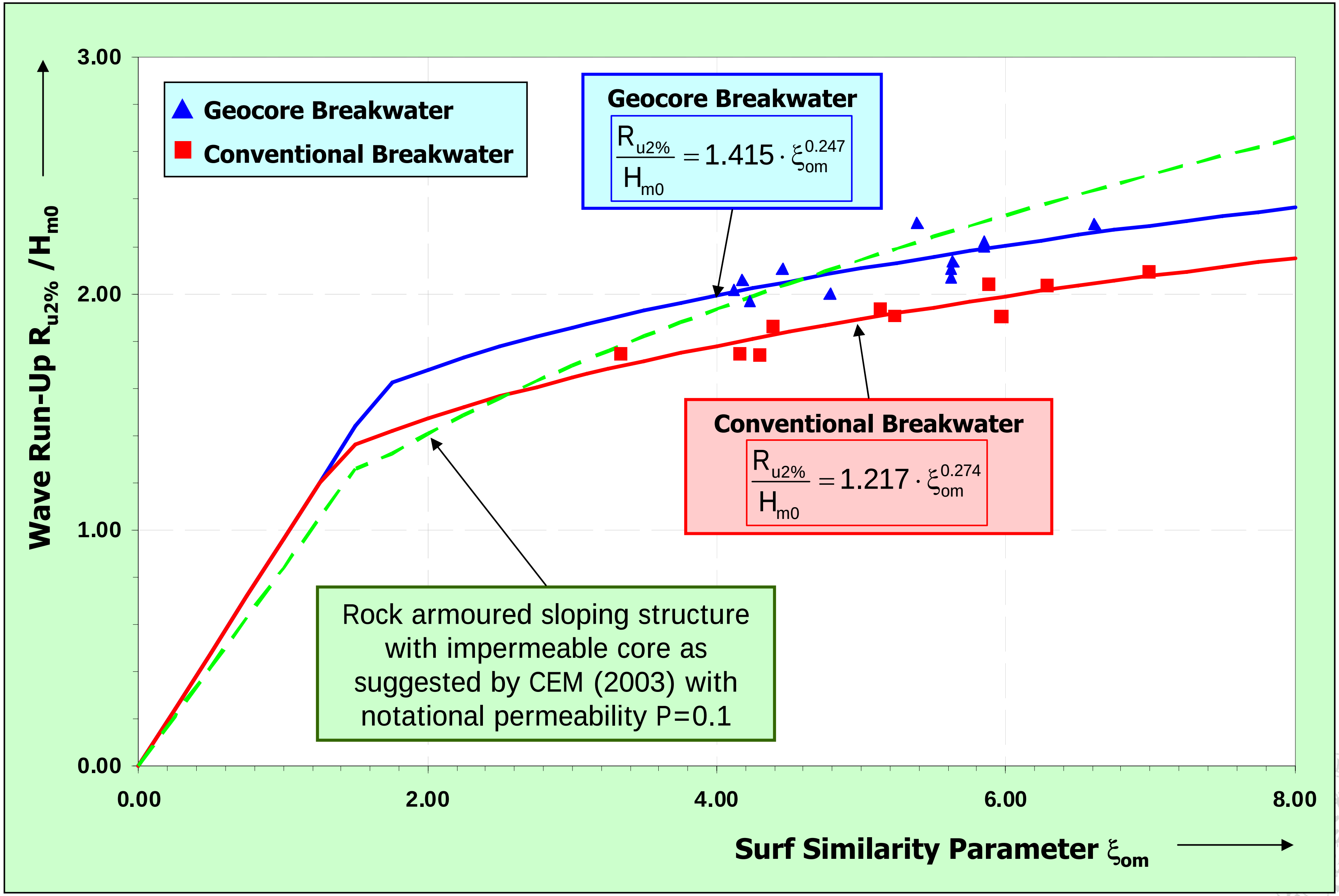
Wave Reflection Performance (2)



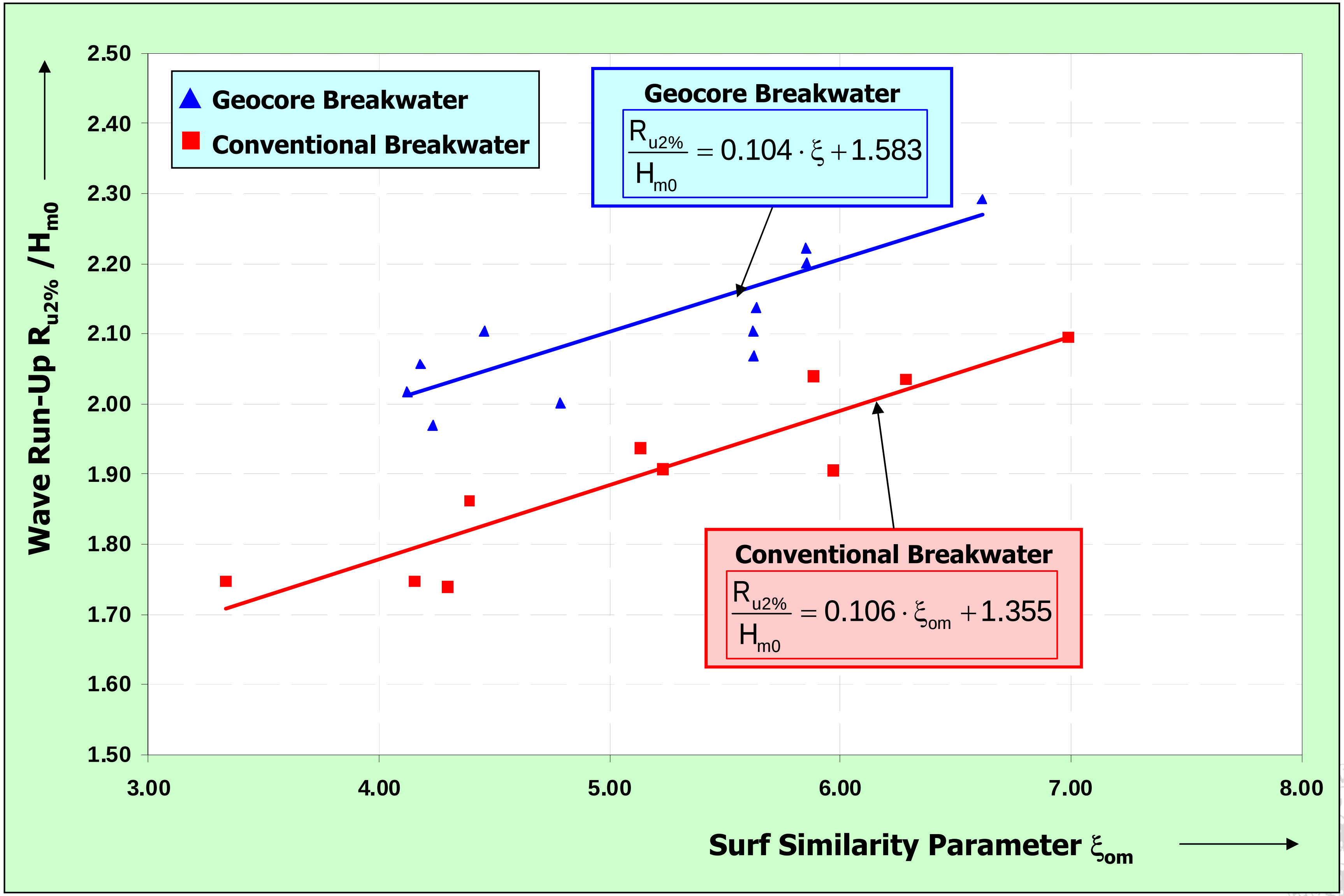
Wave Transmission Performance



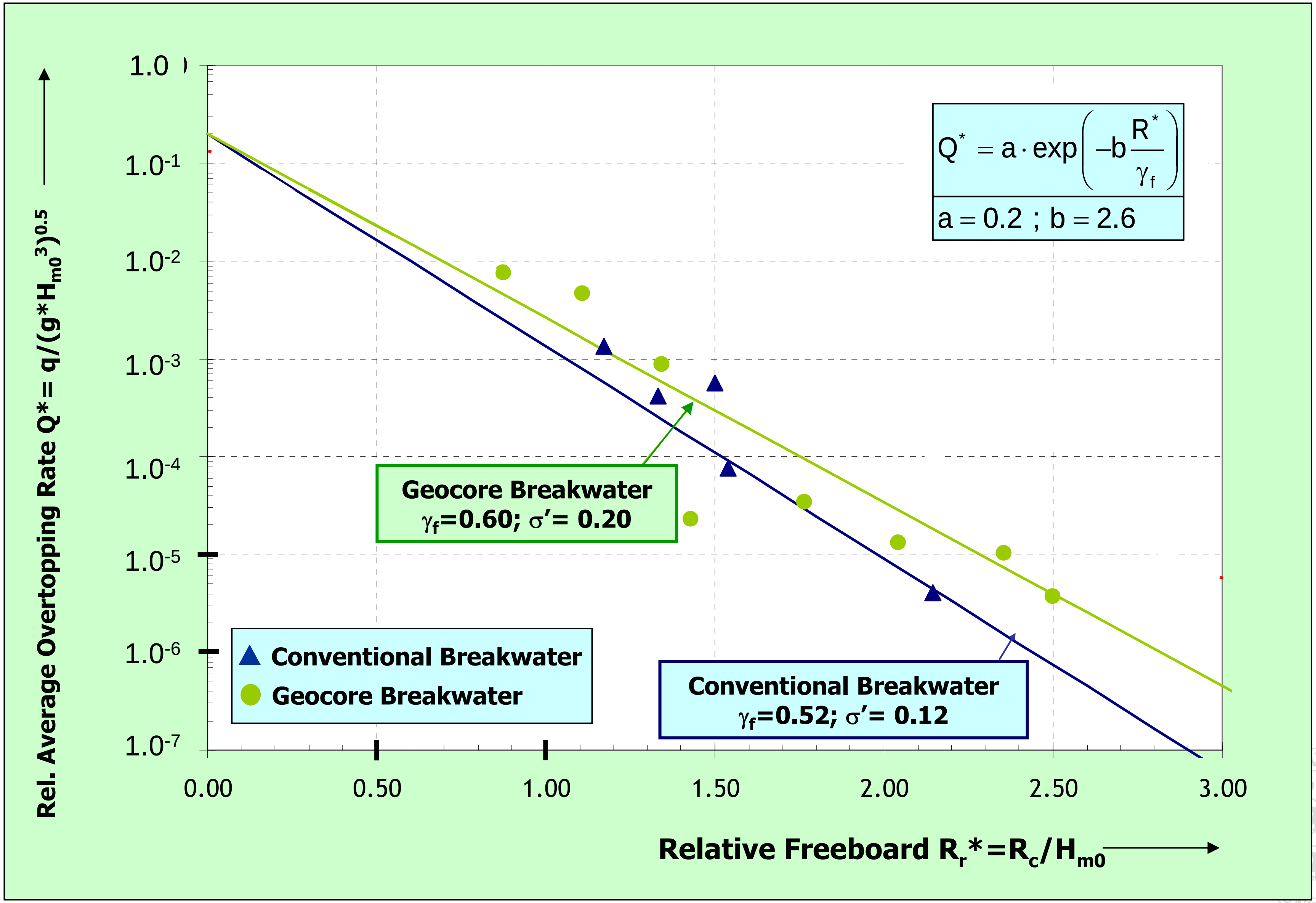
Wave Run-Up Described by CEM (2003) Model



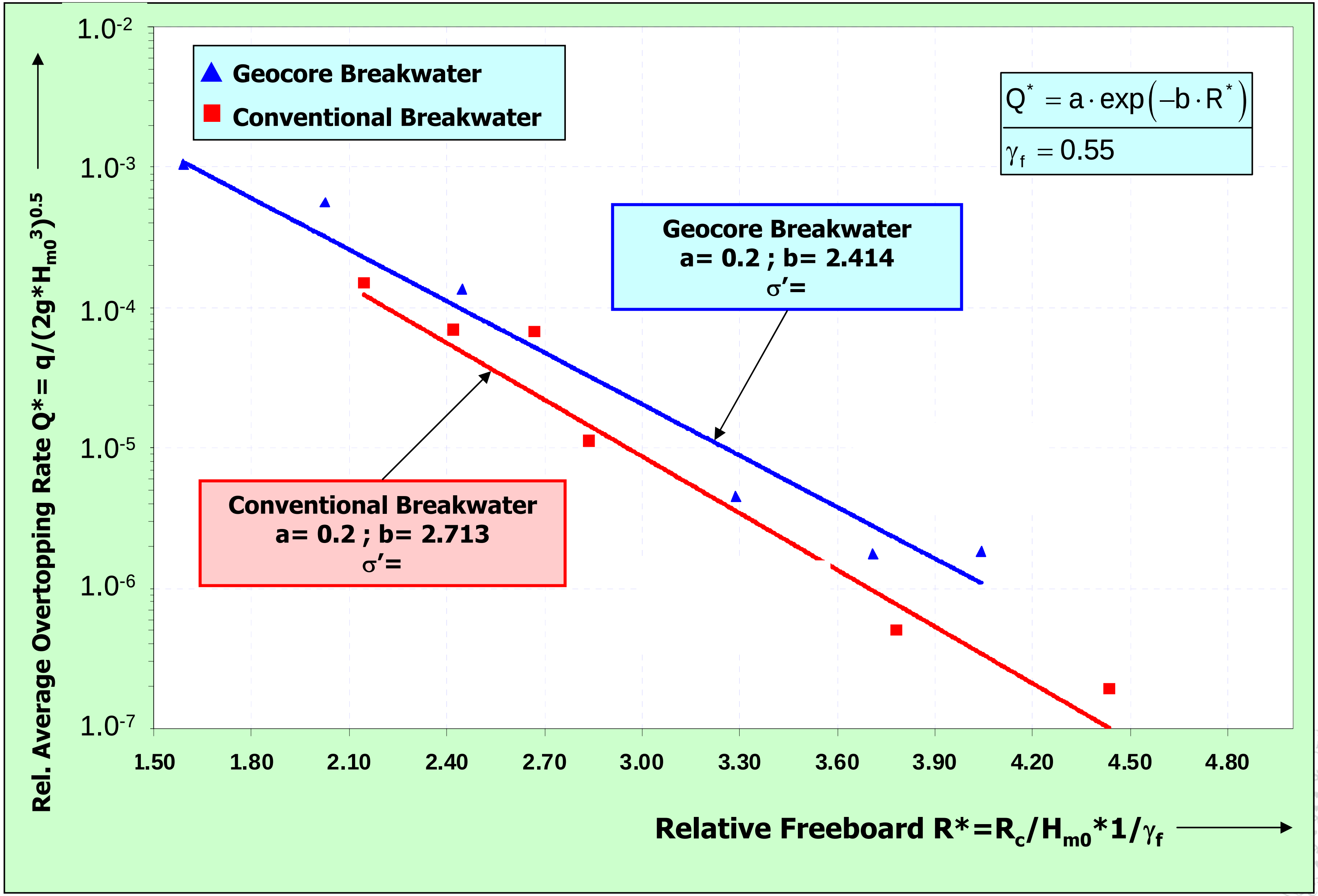
Wave Run-Up Described by Van de Walle (2003) Model



Wave Overtopping Performance (1)

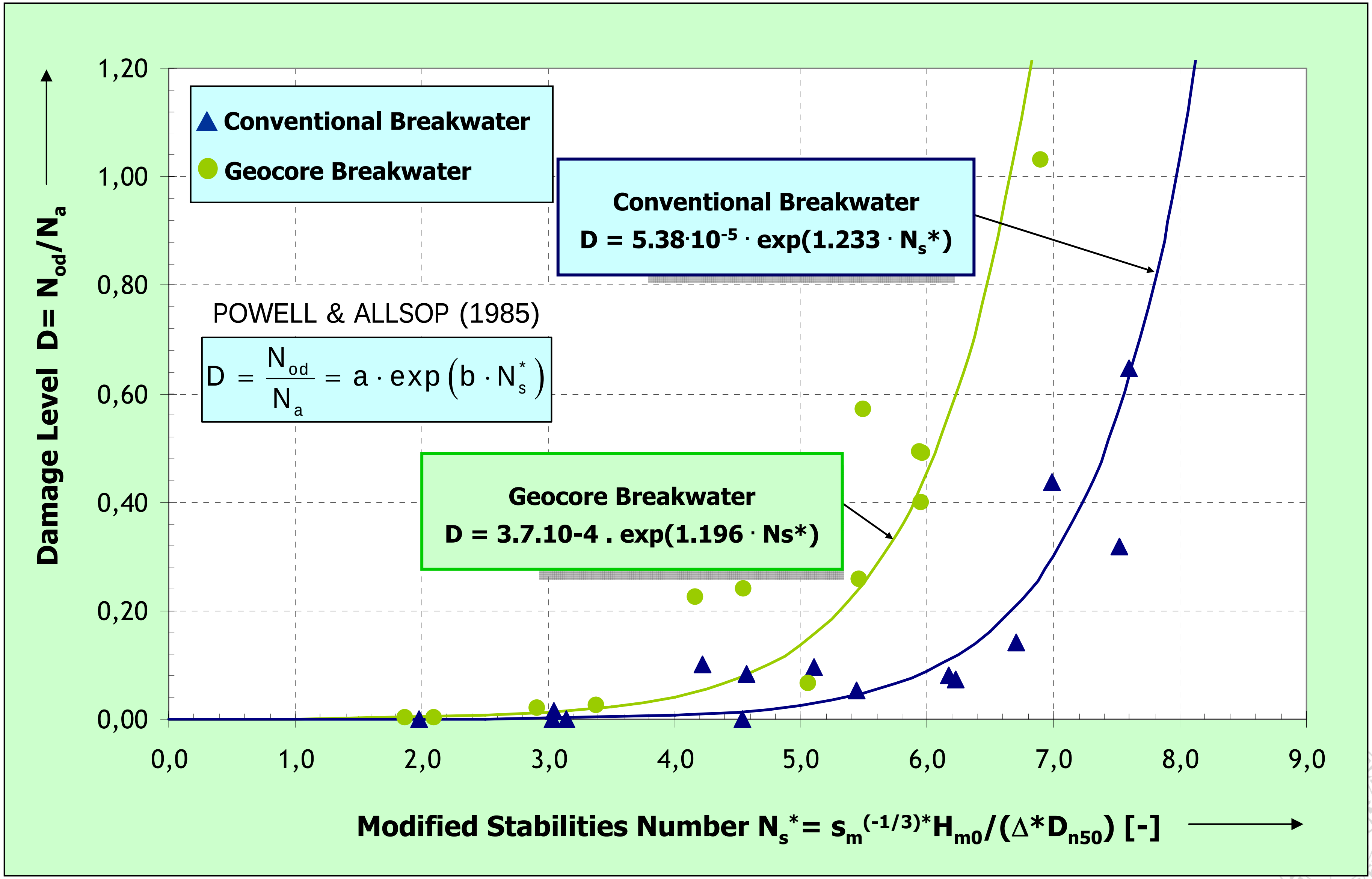


Wave Overtopping Performance (2)

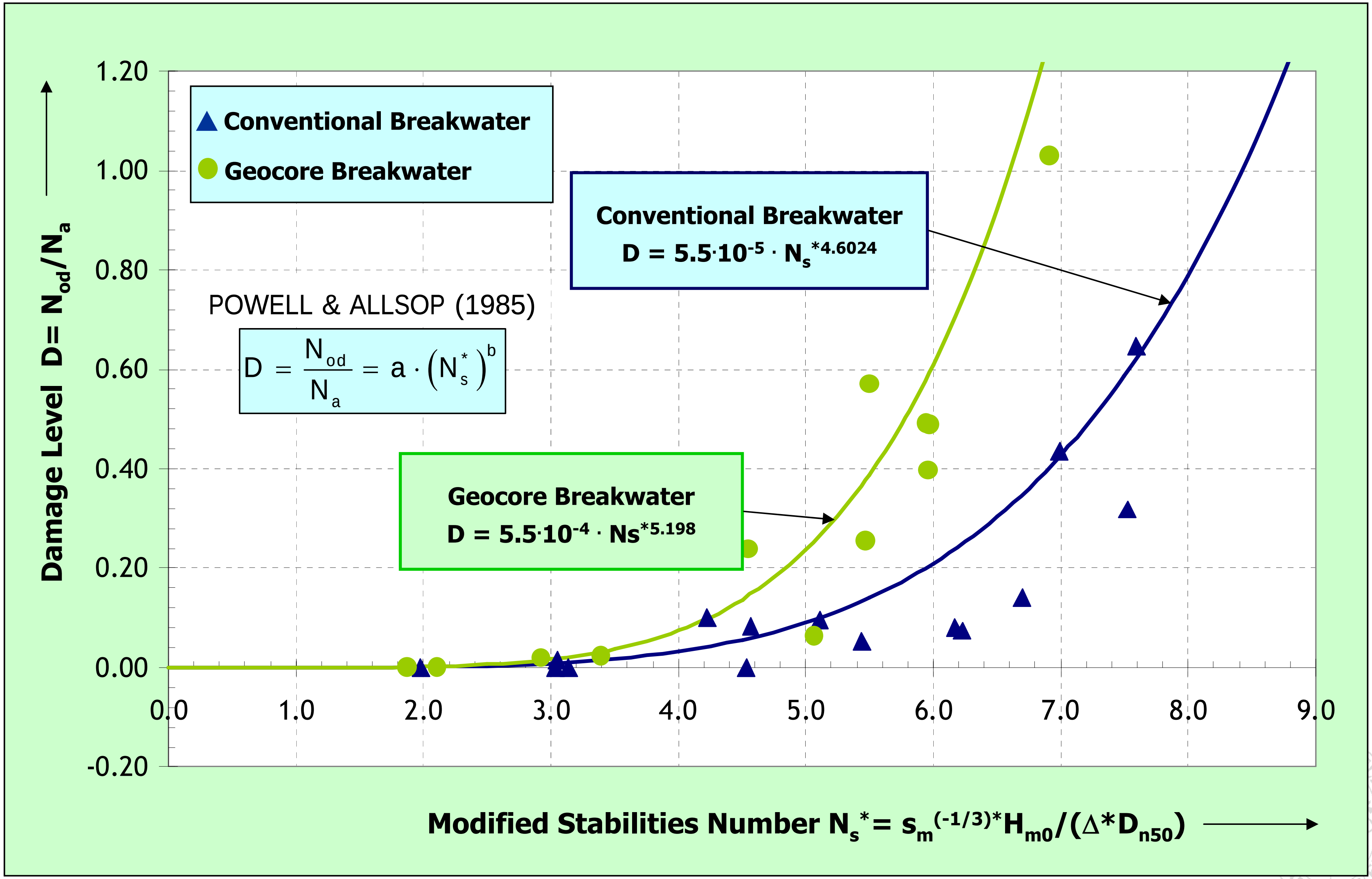


Armour Stability
of Front and Rear Breakwater Face

Damage Level D Described by POWELL & ALLSOP (1985)'s Model for Seaward Slope



Damage Level D Described by a Power Model for Seaward Slope



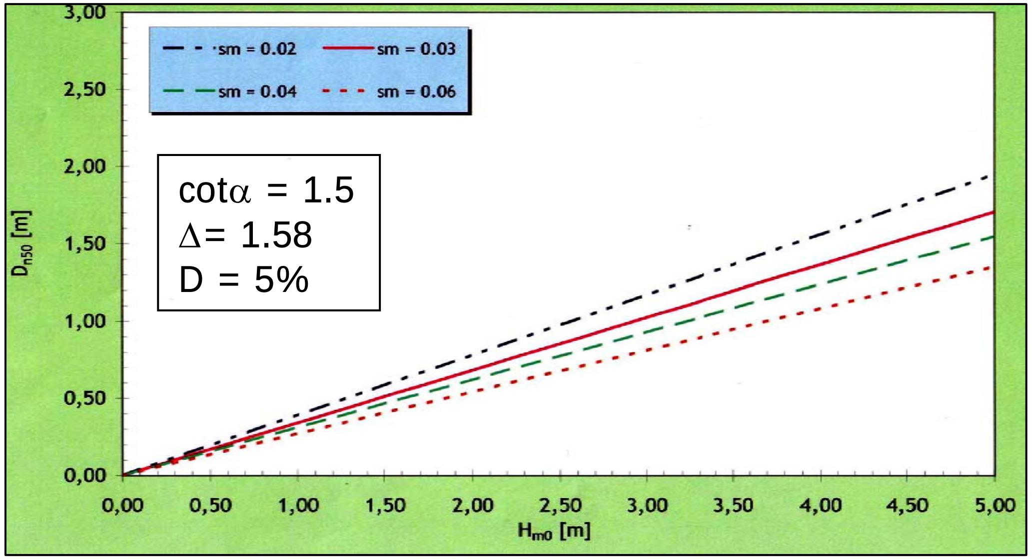
Example Application

- **Design Wave Parameter: H_S = 3.0m, T_p = 10s**
- **Slope Steepness: 1 : 1.5; $\Delta = (\rho_s/\rho_w)-1 = 1.58$**
- **Allowable Damage Level: D ≤ 5%**

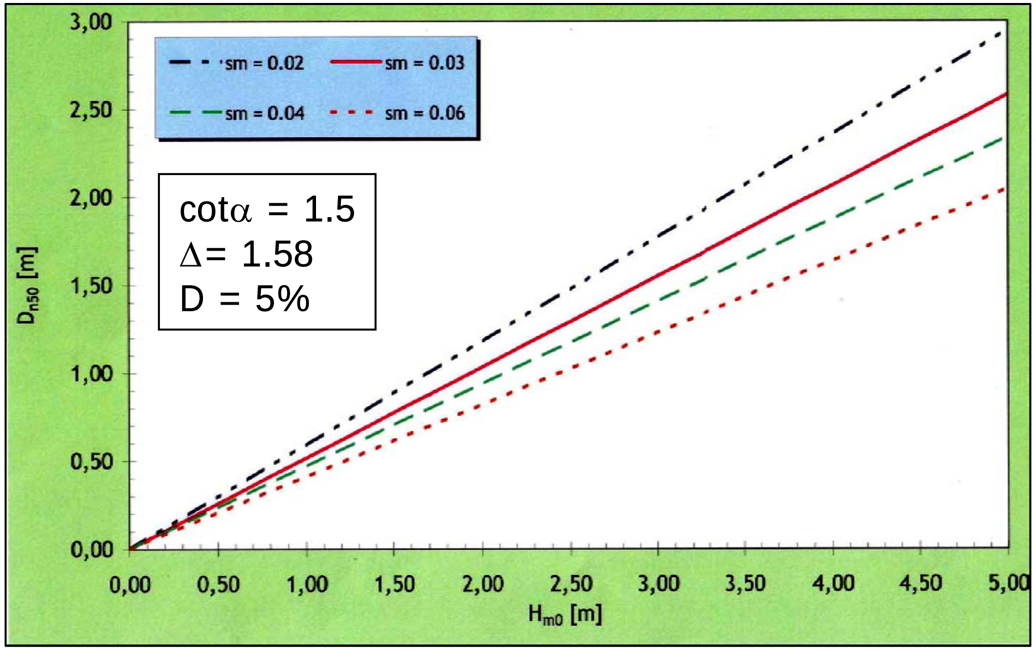
	Conventional	**Geocore**
$K_D = \frac{s_m}{\cot\alpha}\cdot\left(\frac{D}{a'}\cdot(\cot\alpha)^c\right)^{3/b}$ [–] $= s_m\cdot(\cot\alpha)^{\left(\frac{3c}{b}-1\right)}\cdot\left(\frac{D}{a'}\right)^{3/b}$	K_D= 1.90 with a'= 3.67×10^{-5} b= 4.653 c= 1.0 D= 5%	K_D= 1.24 with a'= 3.67×10^{-5} b= 5.127 c= 1.2 D= 5%
Required nominal diameter [m] $D_{n50} = \left(\frac{M_{50}}{\rho_s}\right)^{1/3}$	**D_{n50}= 1.33m**	**D_{n50}= 1.54m**
Required unit mass [t] $M_{50} = \frac{\rho_s\cdot H_{m0}^3}{K_D\left(\frac{\rho_s}{\rho_w}-1\right)\cdot\cot\alpha}$	**M_{50}= 6.3t**	**M_{50}= 9.7t**

Required Armour Unit Size for Conventional and Geocore Breakwater

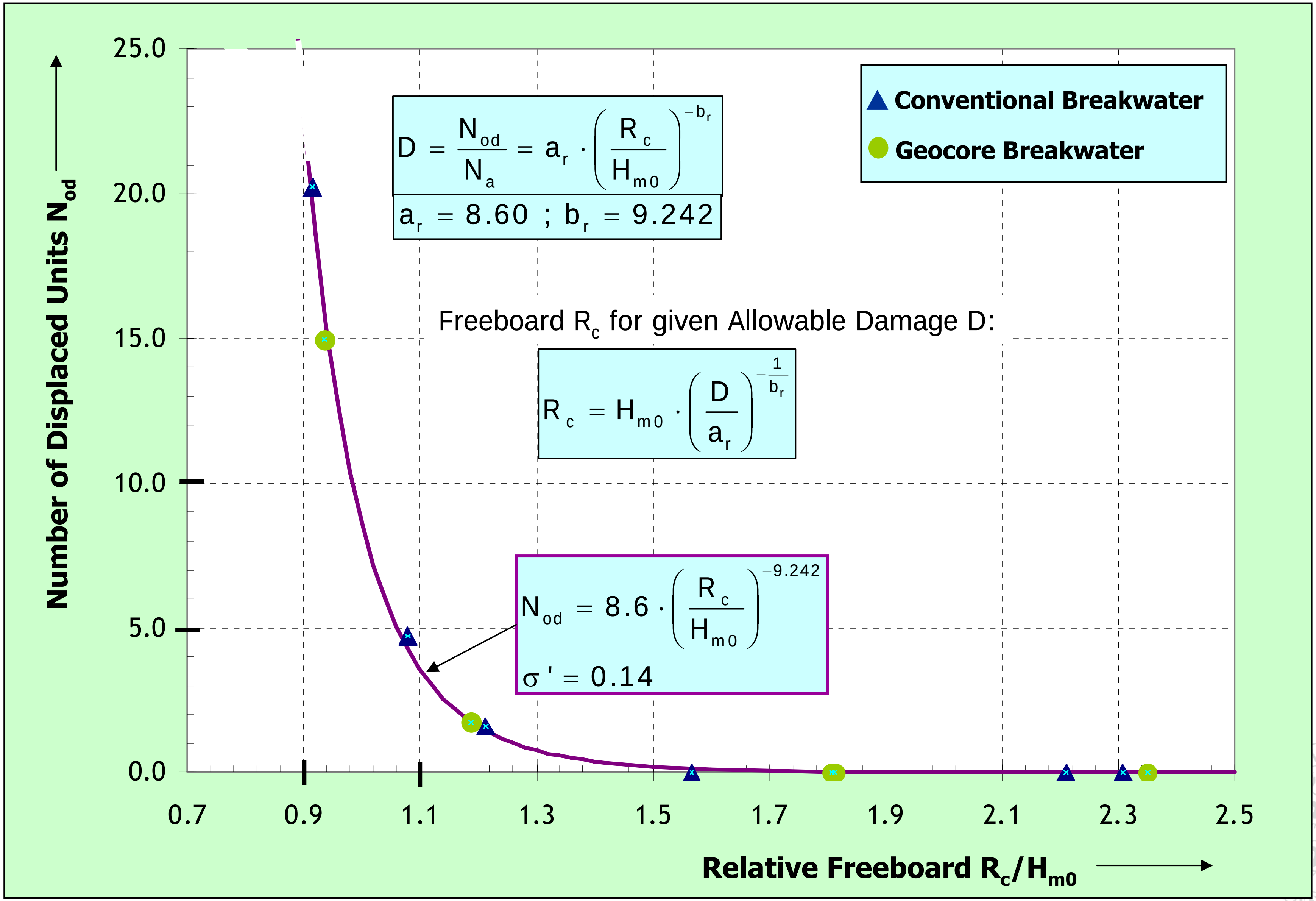
(a) Conventional Core Breakwater



(b) Geocore Breakwater



Stability Parameter N_{od} for Rear Slope Armour



Summary of Key Results and Outlook

➢ Core permeability:

- Geocore more than 10 times less permeable than conventional core (quarry run)

➢ Wave Reflection:

- Surprisingly no significant difference betw. Convent. and Geocore Breakwater
- Best fit achieved with Model of Oumeraci & Muttray (2001)

➢ Wave Transmission:

- Expectedly large difference, depending on wave steepness and relative freeboard
- Best fit achieved with a power model based on modified freeboard proposed by Allsop (1983)

➢ Wave Run-Up:

- For $\xi > 3$: 20% higher run-up for Geocore breakwater
- Run-Up Model by Van de Wall most appropriate

➢ Wave Overtopping:

- Smaller difference than expected for common design freeboard ($R_c/H_s < 1.5$)
- Best fit with TAW (2002)'s Model with a correction factor γ_f (γ_f=0.52 for conventional and γ_f=0.6 for GeoCore)

➢ Seaward Armour Stability:

- Expectedly large difference: More than 60% larger armour unit mass required

➢ Rear Armour Stability:

- Surprisingly no significant difference for common design freeboard
- Model proposed to calculate required freeboard for given damage level