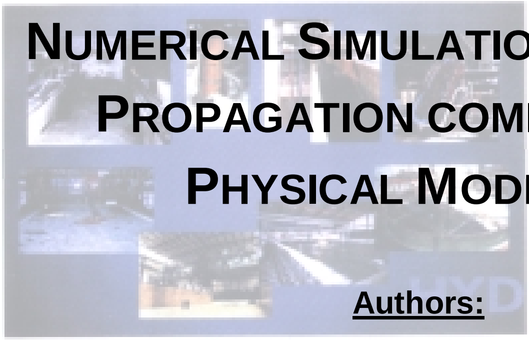

NUMERICAL SIMULATIONS OF WAVE PROPAGATION COMPARED TO PHYSICAL MODELING

Authors:

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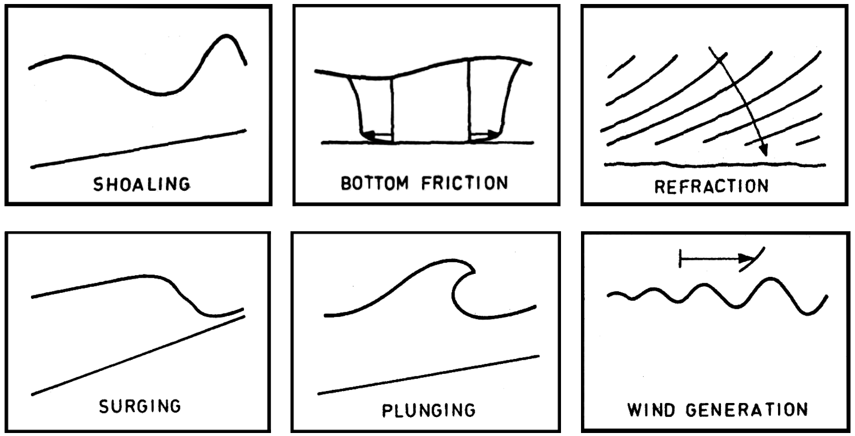
1. Introduction

Wave propagation within coastal zones is strongly influenced by coastal morphology

<u>Predominant processes in the coastal zone are:</u>



<u>Investigations:</u>

- Measurements of the wave propagation along a foreland with and without a submerged dike (summer dike) in the large wave tank of the FZK
- Numerical simulation of some of the above processes with standard wave models
- Test of the models by comparing the simulation results with the physical model - Adjustment of the parameters bottom friction and wave breaking
- Calculation of the transmission coefficients

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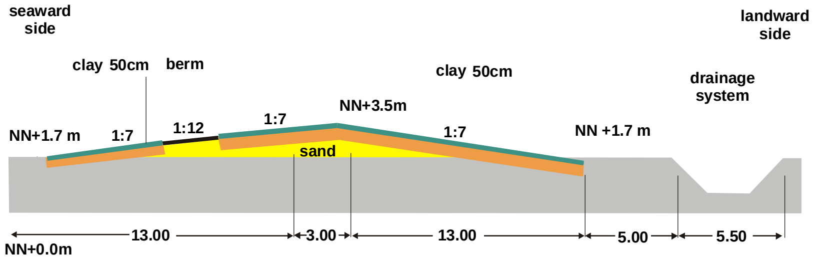
2. Physical Modeling

Location and topographical map of a summer dike:

Cross-section of a summer dike:



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Summer dike in nature and as model

Summer dike in nature

Due to the grass sods and the flat slope the dike is difficult to be seen.

Summer dike in model

Concrete coverage replaces clay and grass sods

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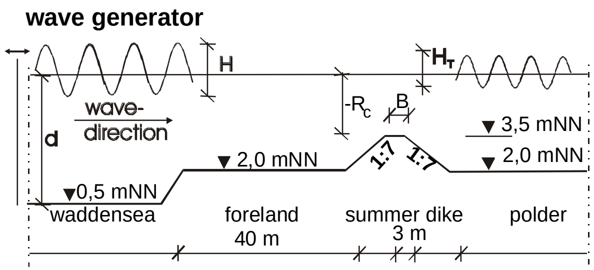
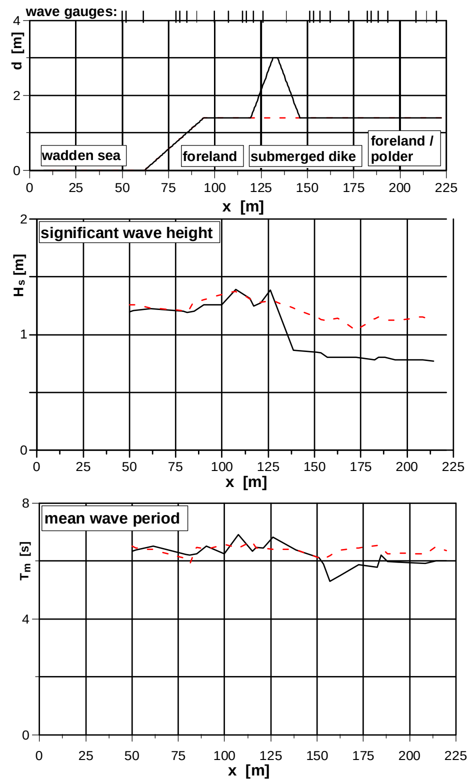
Experiment set-up and measurements in the large wave tank



mNN= meter above German datum



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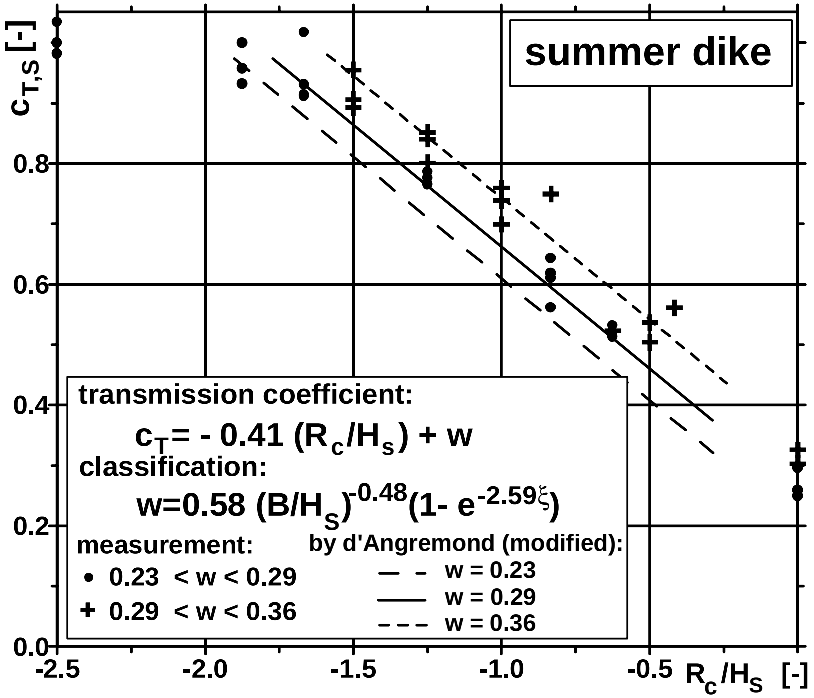
Calculation of the transmission coefficient



Calculation of the transmission coefficient:

- $c_T = \frac{H_T}{H}$ — c_T: transmission coefficient
  H_T: transmitted wave height
  H: incoming wave height

- **d'Angremond (1996):** $0{,}075 < c_T < 0{,}80$ - slopes: $\tan\alpha > (1:4)$

$$c_T = -\beta_1 \cdot \frac{R_C}{H_S} + \beta_2 \left(\frac{B}{H_S}\right)^{-\beta_3}\left(1 - e^{-\beta_4 \cdot \xi}\right)$$

R_C: freebord
H_S: significant wave height
B: crest widht
H/L: steepness

- ξ: Iribarren-Number, $\xi = \frac{\tan(\alpha)}{\left(\frac{H}{L}\right)^{0,5}}$

- $\beta_1 = 0{,}41$ $\beta_2 = 0{,}58$ $\beta_3 = 0{,}48$ $\beta_4 = 2{,}59$

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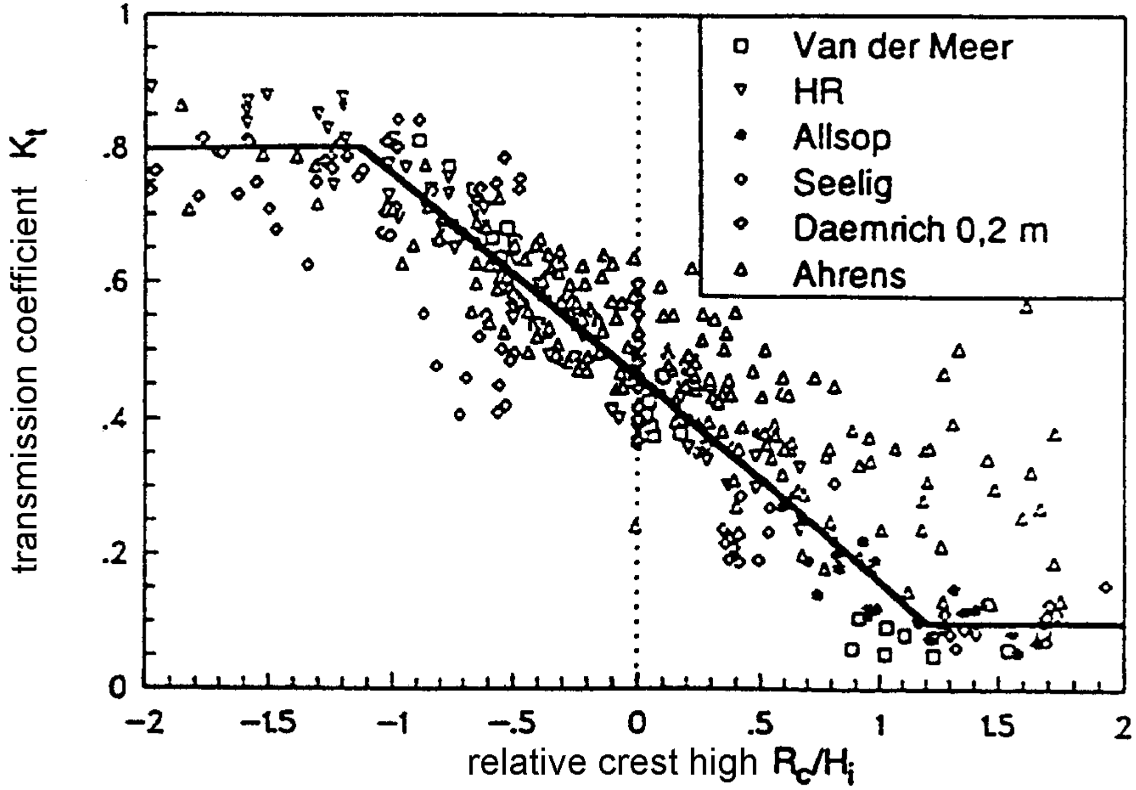
Transmission coefficient (measured by different authors)



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3. Numerical Modeling

Standard Wave Models (used):

- **HISWA**

  HIndcast Shallow Water WAves, TU Delft

- **SWAN**

  Simulation WAves Nearshore, TU Delft

- **MIKE 21 EMS**

  Mike 21 Elliptic Mild Slope, Danish Hydraulic Institute

Basic Model Equations:

- **HISWA and SWAN**

  Action Balance Equation

  ⇒ Wave Breaking by Battjes and Jansen (1978)

  ⇒ Bottom Friction by Collins (1972) and Madsen (1988)

- **MIKE 21 EMS**

  ⇒ Wave Breaking by Battjes and Jansen (1978)

  ⇒ Bottom Friction by Dingemans (1983)

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EXPERIMENTAL RESEARCH AND SYNERGY EFFECTS WITH MATHEMATICAL MODELS

Dissipation of wave energy due to wave breaking

Numerical formulation of wave breaking - Formula by Battjes and Jansen:

$$D_{br} = \frac{\alpha}{4} Q_{br} \, \bar{f} \, \rho \, g \, H_{max}^2 \quad , \quad \frac{1 - Q_{br}}{\ln Q_{br}} = -\left(\frac{H_{rms}}{H_{max}}\right)^2 \quad , \quad H_{max} = \frac{\gamma_1}{k} \tanh\left(\frac{\gamma_2}{\gamma_1} k \cdot d\right)$$

D_{br} : mean dissipation rate per area
Q_{br} : fraction of breaking waves
ρ : water density
H_{rms} : root mean square
H_{max} : maximum wave height
α, γ_1, γ_2 : adjustable coefficients

Dissipation of wave energy $S_{ds,\,br}$ due to wave breaking:

- HISWA: $S_{ds,br(x,y,\theta)} = -D_{br} \cdot \frac{E_{(x,y,\theta)}}{E_{tot(x,y)}}$, where $E_{tot(x,y)} = \int E_{(x,y,\theta)} d\theta$
- SWAN: $S_{ds,br(x,y,\sigma,\theta)} = -D_{br} \cdot \frac{E_{(x,y,\sigma,\theta)}}{E_{tot(x,y)}}$, where $E_{tot(x,y)} = \iint E_{(x,y,\sigma,\theta)} d\sigma d\theta$
- MIKE 21 EMS : $e_{br} \propto \frac{D_{br}}{E}$.

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EXPERIMENTAL RESEARCH AND SYNERGY EFFECTS WITH MATHEMATICAL MODELS

Dissipation of wave energy due to bottom friction

Dissipation of wave energy $S_{ds,b}$ due to bottom friction:

- HISWA: $S_{ds,b(x,y,\theta)} = -C_{bot} \frac{\sigma_0^2}{g^2 \cdot \sinh^2(k_0 \cdot d)} E_{(x,y,\theta)}$
- SWAN: $S_{ds,b(x,y,\sigma,\theta)} = -C_{bot} \frac{\sigma^2}{g^2 \cdot \sinh^2(k \cdot d)} E_{(x,y,\sigma,\theta)}$

  k_0, σ_0 : mean wave number and mean wave frequency

  C_{bot} : friction coefficient.

- MIKE 21 EMS - Formula by Dingemans

$$D_b = \frac{f_e}{16 \cdot \pi \cdot g}\left(\frac{\omega \cdot H_{rms}}{\sinh(k \cdot d)}\right)^3, \quad f_e = \begin{cases} 0.24 & , \; a_b / K_N < 2 \\ \exp\left(-5.977 + 5.213 \cdot \left(\frac{a_b}{K_N}\right)^{-0.194}\right) & , \; a_b / K_N \geq 2) \end{cases}$$

and $e_f \propto D_b / E$

$E = \rho \cdot g \cdot H_{rms}^2 / 8$: energy density of the wave field

f_e : energy loss factor.

Bottom friction coefficient C_{bot}:

- Collins: $C_{bot} = C_{fw} \cdot g \cdot u_{rms}$ and $u_{rms} = \iint \frac{\sigma^2}{\sinh^2(k \cdot d)} E_{(x,y,\sigma,\theta)} d\sigma d\theta$
- Madsen: $C_{bot} = f_{wr} \cdot \frac{g}{\sqrt{2}} \cdot u_{rms}, \quad \frac{1}{4\sqrt{f_{wr}}} + \lg\left(\frac{1}{4\sqrt{f_{wr}}}\right) = m_f + \lg\left(\frac{a_b}{K_N}\right)$

$$a_b^2 = \iint \frac{1}{\sinh^2(k \cdot d)} E_{(x,y,\sigma,\theta)} d\sigma d\theta$$

u_{rms} : orbital velocity at the bottom

K_N : equivalent Nikuradse bottom roughness

a_b : representative near-bottom excursion amplitude

C_{fw}, f_{wr}, m_f : model parameter

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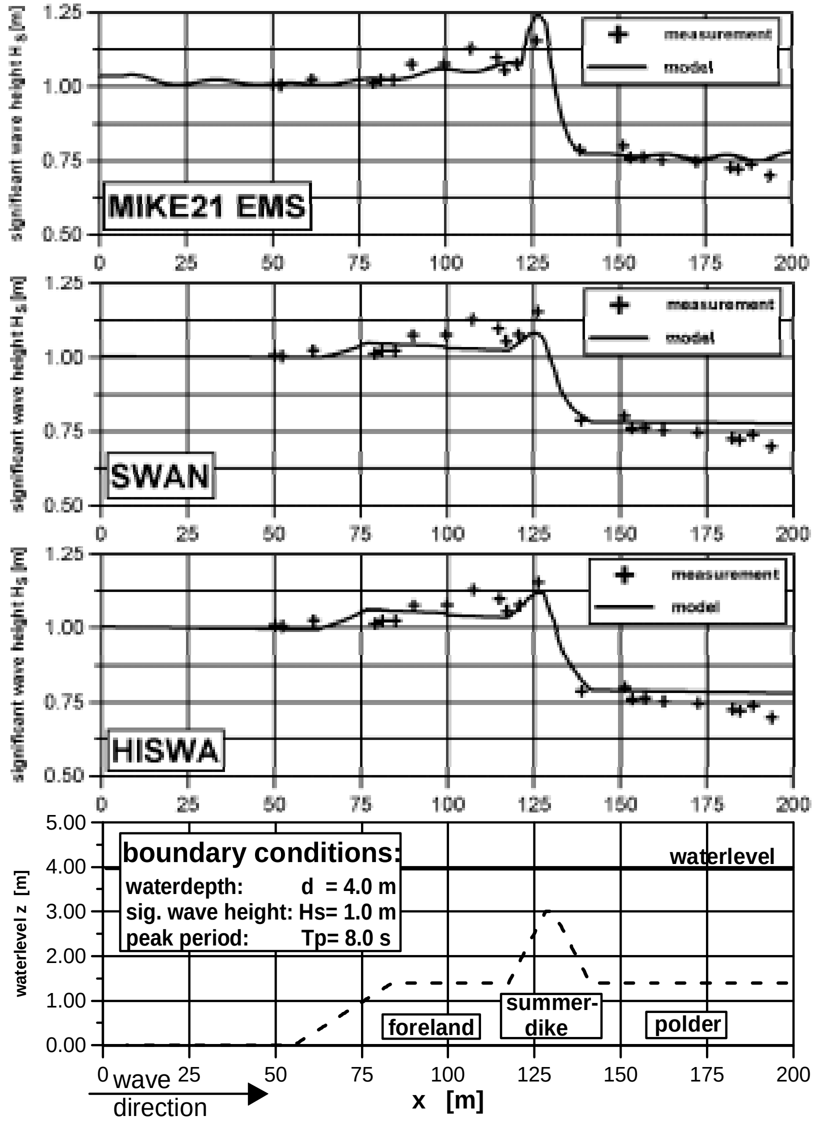
Simulation of the significant wave height by different wave models



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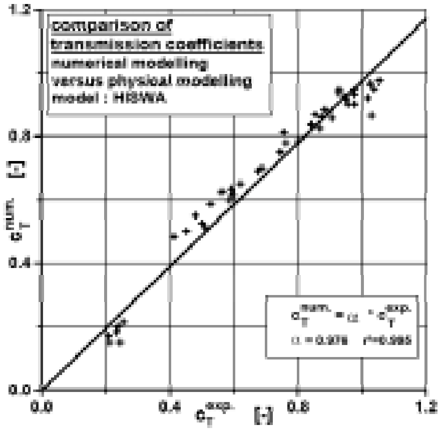
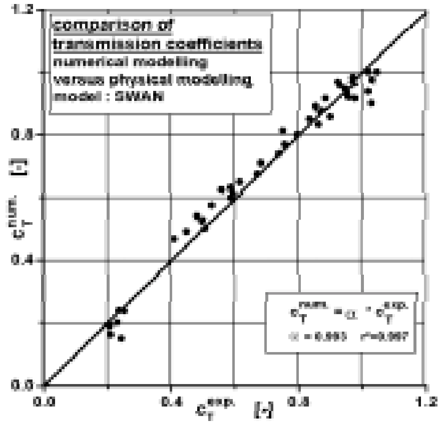
EXPERIMENTAL RESEARCH AND SYNERGY EFFECTS WITH MATHEMATICAL MODELS

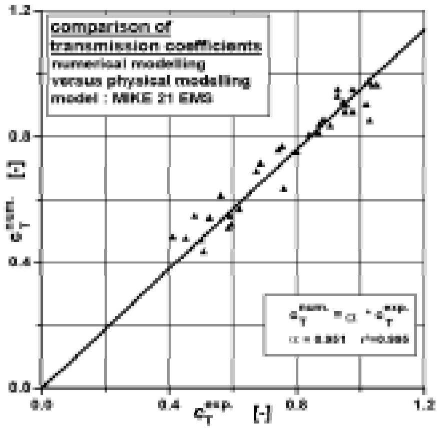
Comparison of the results (transmission coefficients)

4. Comparison of the Results

Comparison of the transmission coefficients :







Boundary conditions of the physical and numerical models
No. of test cases : 42 (36)
water level :   z = 3.5 m up to 4.5 m
incoming significant wave height : H_S= 0.6 m up to 1.2 m
incoming peak-period : T_P= 3.5 s up to 8.0 s

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5. Conclusion and Discussion

Adjustment of the parameters bottom friction and wave breaking:

DISSIPATION PROCESS	NUMERICAL MODEL		
	HISWA	**SWAN**	**MIKE 21 EMS**
Wave breaking	$\alpha = 0.95$ $\gamma_1 = 0.85$ $\gamma_2 = 0.95$	$\alpha = 1.45$ $\gamma = 0.75$	$\alpha = 1.0$ (not adjustable) $\gamma_1 = 1.05$ $\gamma_2 = 0.85$
Bottom friction	$C_{fw} = 0.01$	$K_N=0.02$	$K_N = 0.03$

Summary:

- All Standard numerical wave models worked well.
- Still it is necessary to calibrate the models.
- This can be done with physical models or field data.
- Advantage of physical models are the well defined boundary conditions.
- Difficulties of field measurements are costs, extreme and unreliable boundary conditions.

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