Numerical Simulation of Wave Transmission at Submerged Breakwaters compared to Physical Modeling

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1 Introduction

The design of sea dikes requires knowledge about the wave parameter right in front. Especially the wave propagation along the foreland with structures like summer dikes or submerged breakwaters, determines the wave characteristics at the toe of the dike. Shoaling, refraction, wave breaking and bottom friction are the predominant processes for the wave transmission at foreland structures.

Besides of the change of total wave energy along the foreland also a change in the wave spectrum occurs. Both effects are analysed using physical models in the wave flume GWK and the wave basin WBM as well as numerical simulations with the model SWAN (see *Ris et al.*, 1994).

2 Physical and Numerical Model Test

The following physical model test were carried out:

Wave flume GWK:

- Dimensions of flume: 324 m x 5 m x 7 m
- Model tests at prototype scale
- Instrumentation: 26 resistance wave gauges
- Characteristics of the foreland:
  Height: 1.4 m, width: 40 m
- Characteristics of the summer dike:
  Crest height: 3 m, crest width: 3 m, slope: 1:7
- Characteristics of the polder:
  Height: 1.4 m, width: 160 m
- Boundary conditions:
  Water level: 3.0 m - 4.5 m
  Significant wave height: 0.6 m - 1.2 m
  Peak wave period: 3.5 s - 8.0 s
  Spectral shape: TMA
- Detailed description: See *Mai et al.* (1999a)

Figure 1: Experimental set-up in GWK

Wave Basin WBM:

- Dimensions of wave basin: 40 m x 24 m x 1.1 m
- Dimensions of side canal: 30 m x 1.7 m x 1.1 m
- Model tests at a scale of 1:5
- Instrumentation: 6 resistance wave gauges
- Characteristics of the foreland:
  Height: 0 m, width: 8 m
- Characteristics of the submerged breakwater:
  Crest height: 0.5 m, crest width: 0.2 m,
  slope: 1:2
- Characteristics of the polder:
  Height: 0 m, width: 21.8 m
- Boundary conditions:
  Water level: 0.45 m - 0.7 m
  Significant wave height: 0.025 m - 0.175 m
  Peak wave period: 1.00 s - 1.75 s
  Spectral shape: TMA
- Detailed description: See *Daemrich et al.* (2001)

The numerical simulations were carried out with identical bathymetries and boundary conditions in order to allow a direct comparision of the results. The following options of the model SWAN (Ver. 40.11) were used (see *Ris*, 1997):

- Horizontal resolution: 1 m (1D mode)
- Frequency resolution: 100 bins (0.1 Hz - 10 Hz)
- Directional resolution: 15°
- Including wave breaking, bottom friction, triad and quadruplet interactions
- Detailed description: See *Mai et al.* (1999b)

Figure 2: Experimental set-up in WBM

3 Results

Physical as well as numerical simulations revealed the following:

- Significant wave height decreases whenpropagating over the summer dike (see Figure 3)
- Mean wave period decreases as well
- Numerical modelling represents the change in characteristic wave parameter well (see Figure 3)
- Incoming TMA spectrum is changed into double peak wave spectrum due to wave transmission at the summer dike (see Figure 4)
- Second peak relates to the second higher harmonic
- Develepoment of a double peak spectrum is the cause for the reduction of the mean wave period
- Spectral peak remain nearly constant (see *van der Meer et al.*, 2000)
- Change in spectral shape is also reproduced by the numerical model SWAN
- Triad and quadruplet interactions are the causes for the redistribution of spectral energy (see *Isobe et al.*, 1996)

The energy transfer within the spectrum maybe described by:

- Seperating the spectrum into the spectral peak ($0.5\,f_p$ to $1.5\,f_p$) and the second higher harmonic ($1.5\,f_p$ to $2.5\,f_p$)
- Calculation of the energy E_{1H} resp. E_{2H} of the spectral peak (1H) resp. of the second harmonic (2H)
- Introducing the ratio E_{2H}/E_{1H}

This leads to the following results:

- Ratio E_{2H}/E_{1H} changes most at both toes of the summer dike (see Figure 5)
- In front of the summer dike typical ratios of E_{2H}/E_{1H} are 0.4, behind the summer dike they equal 0.8
- Change in ratio E_{2H}/E_{1H} decreases with increasing water level and decreasing sig. wave height (see Figure 6)

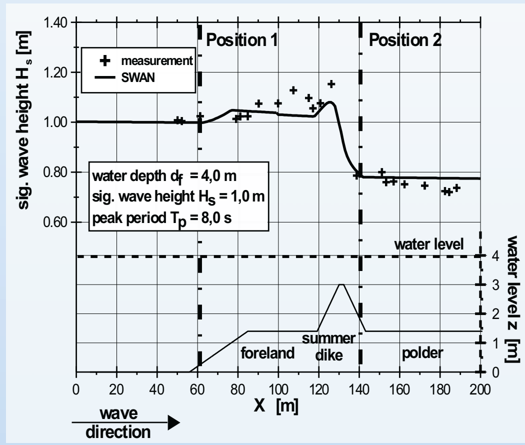

Figure 3: Change of the significant height of waves propagating over a foreland with summer dike - comparison of physical modelling (GWK) and numerical modelling (SWAN)

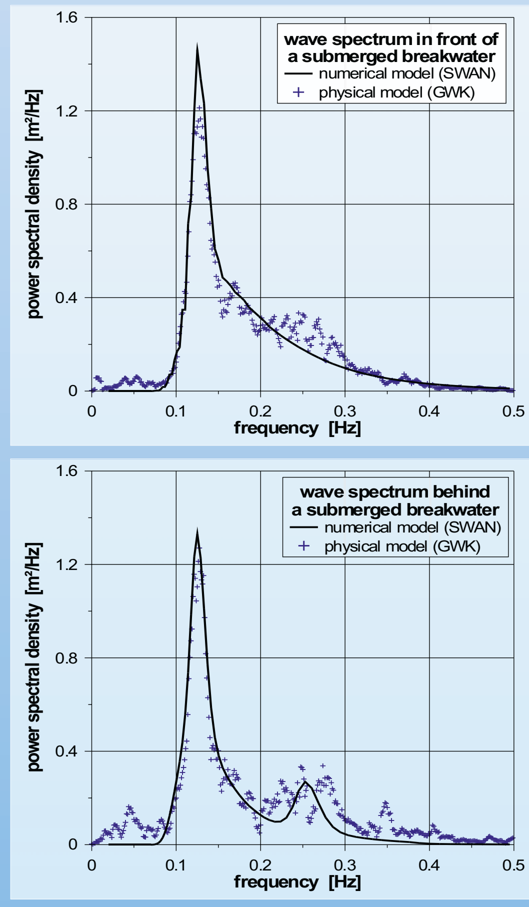

Figure 4: Spectrum of the incoming (top) and the transmitted (bottom) wave spectrum - comparison of physical modelling (GWK) and numerical modelling (SWAN)

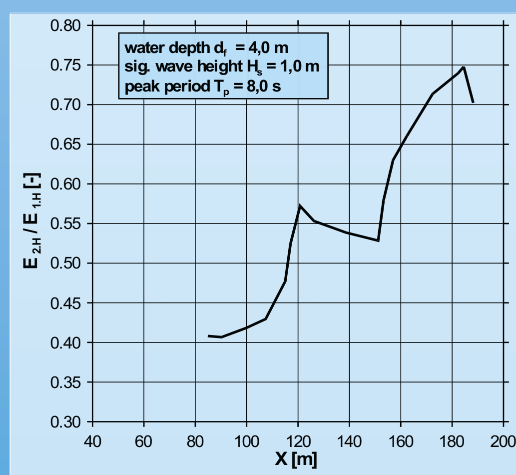

Figure 5: Ratio of the energy content of the first and second spectral peak

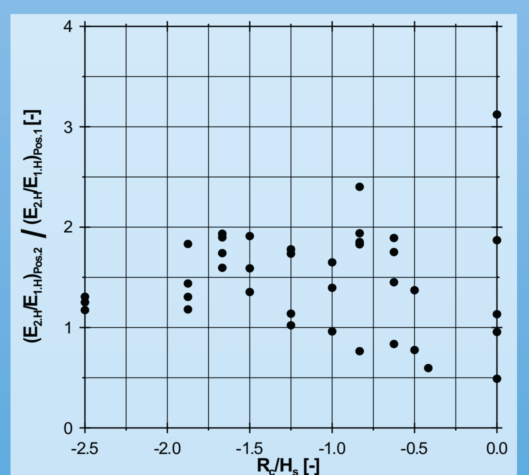

Figure 6: Normalised relative ratio of the energy content as a function of relative freeboard

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