Linear stability of planar beaches

focus on sediment transport formulation

Mark Klein[1] and Henk Schuttelaars[2]

Shoreface nourishments and rhythmicity in the surf zone

Recent observations of a combined shoreface and beach nourishment near Egmond, the Netherlands, showed that shoreface nourishments do not always 'simply' diffuse in long- and cross-shore direction, as was the common idea. In this case the nourishment became part of the bar system, see Figure 1. Furthermore, one and a half years after the nourishment, the rhythmic pattern in the surf zone has changed both in wavelength and orientation of the bar features. Whether this change in behaviour is caused by the nourishment or that this behaviour was already present in the coastal system before the nourishment was executed, is the question that this study finally wants to answer. This poster focuses on the influence of geometrical parameters and model formulations on the linear stability of planar sloping beaches.

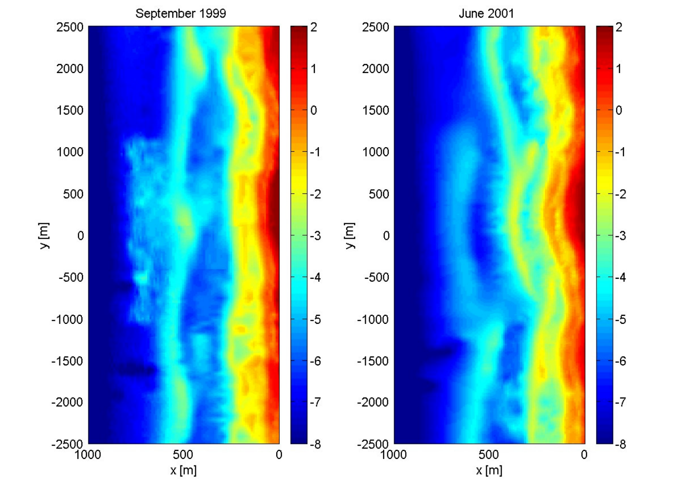

Figure 1. Rhythmicity in the surf zone: just after the execution of the shoreface nourishment (left panel) and one and a half years after the execution (right panel). Source: RIKZ

Linear stability analysis

In order to discern the influence of shoreface nourishments on the surf zone rhythmicity, the rhythmicity that was already present in the system, the so-called free-behaviour, needs to be known. In this study the linear free-behaviour of planar sloping beaches and its sensitivities to the angle of wave incidence θ_b, the bed slope β, the drag coefficient c_d and the complexity of the model formulations is studied.

A linear stability analysis (LSA) is used to identify this free-behaviour. A LSA starts with an alongshore-uniform coast (see left panel of Figure 2), which, in this case, is forced by obliquely incident waves. A LSA studies the initial, linear growth of a bed perturbation from this equilibrium bed. It results in an alongshore-periodic (with wavelength λ) bed perturbation with a cross-shore structure and corresponding growth (ω_i) and migration rates (c). If the growth rate is positive the bed perturbation will grow. If it is negative the bed perturbation will damp and the system will return to its equilibrium.

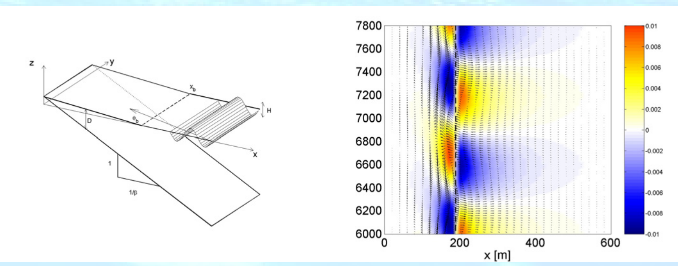

Figure 2. Alongshore-uniform, planar coast forced by obliquely incident waves (left panel) and bed and flow perturbation resulting from a LSA with $\theta_b = 5°$, $\beta = 0.01$ and $c_d = 0.0045$ (right panel).

This linear stability analysis is performed using a numerical model that computes the perturbed velocity field and associated sediment transport rates and bed changes. The model is based on the depth-averaged shallow water equations. Two different sets of model formulations have been used (see Table 1), viz. a set with many simplifications and a set that yields a state-of-the-art numerical model.

Table 1. Characteristics of the two applied models

Simple model	Complex model
Saturated surf zone	2nd generation wave model
Linear bed shear stress	Non-linear bed shear stress
$\mathbf{q} \propto \mathbf{u}^5 \sim H^2\mathbf{u_c} = \alpha(x)\mathbf{u_c}$	Bailard's total load formulation

The free-behaviour of planar beaches: simple model

The sensitivity of the wavelength λ_p and the growth rate ω_i (characterizing the free-behaviour) for the angle of wave incidence, the bed slope and the drag coefficient, applying the simple model, are presented in Figure 3.

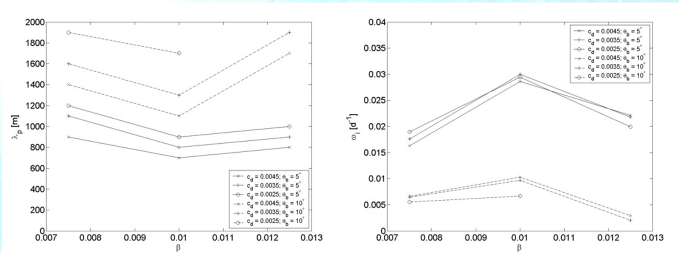

Figure 3. Preferred wavelength λ_p (left panel) and growth rate ω_i (right panel) as a function of the angle of wave incidence, the bed slope and the drag coefficient.

The sensitivities of the wavelength to the angle of wave incidence and drag coefficient are in correspondence with intuition. The larger the angle of wave incidence and the smaller the drag coefficient, the larger the preferred wavelength. Its sensitivity with respect to the bed slope parameter is less obvious. One can clearly see that a minimum in wavelength occurs for a bed slope of 1%.

The influence of the angle of wave incidence on the growth rate is clear. The larger the angle, the smaller the growth rate. The influence of friction on the growth rate depends on the bed slope as well. A maximum in the growth rate is present for a bed slope of 1%.

The spatial structure of the bed perturbation is hardly influenced by the angle of wave incidence, the bed slope and the drag coefficient. A typical bed and flow perturbation is displayed in the right panel of Figure 2. The bed perturbation can be characterized as a crescentic bar pattern around the breaker line (dashed line).

The free-behaviour of planar beaches: complex model

The results of the LSA change dramatically when the complex model is applied. An experiment with the same parameter settings as mentioned in Figure 2 is performed. It yields a preferred wavelength that is smaller than 300 m. Also the bed perturbation changes considerably, see Figure 4. Applying both suspended and bed load (left panel), or bed load transport only (right panel), result in similar spatial structures. Suspended sediment transport only affects the growth and migration rates.

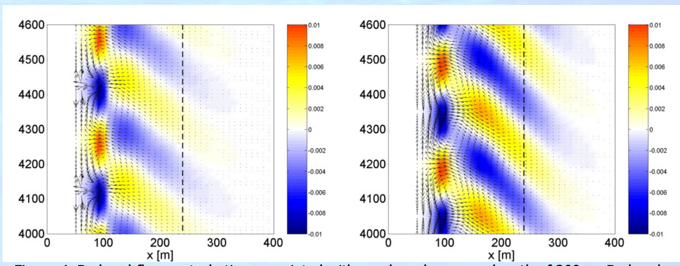

Figure 4. Bed and flow perturbation associated with an alongshore wavelength of 300 m. Bed and suspended sediment transport (left panel) and bed load transport only (right panel).

Conclusions

The main conclusion is that the results of a LSA of planar sloping beaches are highly depended on model formulations, and especially on the sediment transport formulation, although either bed load or bed and suspended load only affects the growth rate.

[1])Faculty of Civil Engineering and Geosciences
Delft University of Technology
P.O. Box 5048, 2600 GA, Delft, The Netherlands
Phone: (+31 15) 278 1541
E-mail: m.d.klein@ct.tudelft.nl
URL: www.waterbouw.tudelft.nl/public/klein

[2])Institute for Marine and Atmospheric Science
Utrecht University
Princetonplein 5, 3584 CC Utrecht, The Netherlands
Phone: (+31 30) 253 3070
E-mail: h.m.schuttelaars@phys.uu.nl
URL: www.phys.uu.nl\~schuttel

TU Delft