MODELLING OF GRAIN SORTING MECHANISMS IN THE NEARSHORE AREA FOR NATURAL AND NOURISHED BEACHES

by

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In partial fulfilment of the requirements for the degree of

Master of Science
In the field of Civil Engineering

At the Delft University of Technology and the National University of Singapore

January 2015, Delft, The Netherlands

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Abstract

The nearshore area is a highly complex and dynamic region, confined by the point from where waves start interacting with the bottom until the point of the highest run-up in the swash zone. A good understanding of physical processes in the nearshore area is essential for the development and use of high-end process based hydro-morphodynamic models, like Delft3D. The aim of this study was to set up a modelling approach to understand and assess the effect of grain sorting on the nearshore morphodynamics. This was done for both natural and nourished beaches.

The literature review carried out for this thesis showed that sediment sorting is dependent on sediment characteristics as well as hydrodynamic conditions and that it is a combination of both that determines transport and sorting in the profile. Although the information found in literature is diverse, some general trends are found by several researchers: finer sediments are found more offshore and coarser sediments are found more onshore. Besides these general trends also a strong seasonal character is observed for grain size patterns.

Physical experiments were performed in Hannover in 2013, investigating not only hydro-morphodynamics but also sorting processes for a beach-profile. The data showed that the sorting processes were highly dependent on the hydrodynamics. Sorting processes were observed in the experiment very clearly. For erosive wave conditions a strong offshore fining was found explained by different transport and settling velocities of the finer sand grains, leading to settling of the finer grains further offshore than the coarser grains. Furthermore, coarsening around the bar area was observed. Milder wave conditions show a slight coarsening higher in the profile, around the part where erosion is observed, explained by different entrainment thresholds of the finer and coarser sand.

To obtain insight in the sorting processes observed in the flume experiment, a modelling study was carried out with the Delft3D modelling suite. Four different modelling approaches were set up and tested. Approach one used a single sediment fraction and did not incorporate the effect of short-wave grouping on bound long waves. Approach number two used a single sediment fraction and did incorporate the effect of short-wave grouping on bound long waves. Approaches three and four were the same as approach one and two, but now instead of a single sediment fraction, multiple fractions were used to model the sediment. Besides including multiple fractions, also a layered bed stratigraphy was used to keep track of the sediment sorting.

It was shown that a modelling approach that takes into account the (bound) long waves yields significantly better results than a modelling approach that does not take this into account. Including long waves into the computation leads to a better prediction of the bar position and height. Simulating with multiple fractions does not lead to significantly better results, although some improvement is observed: there is slightly less upper-shoreface erosion, but the bar is smoothed out a little. The model was able to simulate sorting processes as found by the experiment, predicting the correct patterns. Again significant improvement was found when long waves were taken into account by the model.

After confirming the models capabilities in simulating the correct hydro-morphodynamics and sorting processes in the flume, one model approach was applied to a case study involving nourishments. Based on the results of simulating the morphodynamic evolution as found in the wave flume in Hannover, the modelling approach including long waves and multiple sediment fractions was chosen. Three different nourishment designs were investigated: a beach nourishment and two shoreface nourishments. For the shoreface nourishments two designs were investigated: one located high in the profile (on top of the breaker bar) and one
located low in the profile (seaward of the breaker bar). The morphodynamic evolution of the nearshore area for all nourishment designs was compared to available data. A direct comparison was made for the beach nourishment with data from Vousdoukas et al. (2014) and a qualitative comparison was made for the shoreface nourishments with data from Walstra et al. (2010).

For the beach nourishment, the model was reasonably able to simulate the development of the profile under different wave conditions. However, the erosion rate of the nourishment itself was underestimated for accretive waves and overestimated for erosive waves. The shoreface nourishments qualitatively showed a similar behaviour to observations of Walstra et al. (2010). Even though accretive processes were not found by the model computations, a clear difference in behaviour was found for high energetic wave conditions and milder waves. The functioning of the nourishments was assessed using the model computations. The beach nourishment was redistributed in the upper part of the profile, not influencing the bar dynamics lower in the profile. A coarsening just offshore of the nourishment was observed. This trend was stronger when the nourishment consisted of coarser grains than the native beach, and a coarse upper layer was formed in the upper part of the profile. Both shoreface nourishment designs reduced erosion by reducing the wave height. No onshore movement of nourished sand was observed for both nourishment designs. The high nourishment design was more effective in reducing erosion than the low design. The high design reduced wave height throughout the entire surfzone, while the low design showed a more localized reduction of wave height. For both shoreface nourishment designs a coarsening around the nourished area was observed. Due to the reduced wave action compared to a situation where there is no nourishment in the profile, the coarser fractions settle around the nourishment. For all nourishment designs it was found that nourishing with a coarser grain than the native beach does not yield significant differences. This was attributed to the fact that the sediment size used for the nourishment (400 μm) was rather similar to the native sand (300 μm).

Based on the results found in this thesis, the best simulation results are obtained by using a modelling approach that takes into account long waves and multiple sediment fractions. However, it is not strictly necessary to use multiple sediment fractions in the computation to get a correct representation of the morphodynamic evolution of a beach profile. It was shown that Delft3D is capable of simulating the correct sorting processes for both natural and nourished beaches, so if it is desired to get information on the sorting of the sediment, then multiple fractions can be incorporated into the model computations.