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Hydrodynamica en sedimenttransport.
Fundamentele aspecten bij een duurzaam beheer van zandige kusten

HYDRODYNAMICS AND SEDIMENT TRANSPORT

FUNDAMENTAL ASPECTS RELATED TO SUSTAINABLE MANAGEMENT OF SANDY COASTS

AIM AND SCOPE OF THE RESEARCH PROJECT

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Aim of the research project

To protect the hinterland against the attacks from storm surges and waves, an explicit coastal defence is necessary. The associated measures can basically be split-up in so-called 'hard' and 'soft' methods, referring respectively to dikes, groynes, breakwaters,… and dynamic systems such as sand suppletion and floating geotextiles. More and more coastal authorities, also in Belgium, seem to prefer the soft coastal defence systems. The current success of beach renourishment techniques as a coastal defence alternative can be attributed both to the added ecological value and to the recreational beach potential.

Ideally sandy beaches form a system where erosion and accretion are in a dynamic equilibrium. Unfortunately, this dynamic equilibrium is not absolute and structural erosion is a threat to the coastal area. As a result beach maintenance is mandatory. Depending on the rate of maintenance, both in terms of volume and in terms of frequency, the socio-economic and the ecological impact can be considerable. Therefore, to develop a sustainable beach management of a sandy coast it is crucial to know and understand the different factors which play a role as well as their mutual interaction, see e.g. (De Vriend et al., 1993). Only fundamental knowledge of the physical processes will lead to a better insight. The dynamic coastal processes are not yet well understood. It is not so clear why certain areas are dynamically stable and others are not. A critical zone is the near-shore, a region where wave impact and tidal flows are equally important for the resulting sediment mobility. The processes in the near-shore zone form the subject of this study. The best route for fundamental research is to find a way to combine process theories, numerical simulation, physical experiments in laboratory conditions, and field campaigns. In most studies, synergy of these four components does not exist or is at least very incomplete.

The present study first of all wants to combine the theoretical study of physical processes, numerical modelling and laboratory experiments. Each of the partners in this project has considerable experience in at least one of the above aspects. Mutual collaboration will confront, combine and supplement the available knowledge. A detailed comparison with a field campaign as a last step in the synergy of the four components, does not form part of this project. However, the existence of field registrations on a macro-scale provides us with an opportunity to make a qualitative interpretation. For a dedicated field campaign of high quality, extensive preparation, and incorporation in an interdisciplinary and international framework is needed. The work proposed in this research project gives us excellent preparation tools.

Scope of the research project

Theoretical study

A basic understanding of the relevant physical processes starts with a detailed survey and study of the available literature. Starting from a general overview of coastal sediment dynamics, a detailed analysis of the hydrodynamics associated with the combination of currents and waves and the resulting sediment transport will be worked out. Standard references, e.g. (Soulsby, 1997), together with recent European and other international research work (COAST3D, SEDMOC, INDIA, SandyDuck, S.T.O.R.M.,…) will lead to a better understanding and problem identification in near-shore sediment processes. Also numerical work, e.g. (Trouw et al., 2000), and physical experiments, e.g. in the framework of the European TMR-LSF (Training and Mobility of Researchers – Access to Large-Scale Facilities Programme), will need to be studied.

Experimental modelling

Basically, physical experiments validate and analyse detailed sediment transport characteristics under controlled hydrodynamic conditions. Indeed, the complex interaction between waves, tidal flow and mobile sediments in the near-shore zone, forces the researcher to use idealized situations where the hydrodynamics may not be 100 percent realistic, but where they are controllable on the one side and reproducable on the other. Therefore, it is proposed to use the laboratory facilities of Flanders Hydraulics in Borgerhout. Their infrastructure is equipped with a wave basin. The wave generator is capable of producing the theoretical JONSWAP and Pierson-Moskowitz spectra and with the double pumping system it is possible to generate lateral flow (currents) and vertical water level variations (tide). The combination of these three components in the hydrodynamic load scheme makes the experiments quite unique - in comparison with e.g. the experiments in the framework of the SAFE-project, LIW-Braunschweig, Prof. H. Oumeraci and Prof. H.H. Dette (Dette et al., 1999). An explicit extension of the wave generation system to be able to generate more complex spectral forms of random waves is considered part of this project. The global target of this experimental part of the study is to record both in detail the wave field and the flow distribution together with the resulting sediment concentration (by using e.g. the ADV-velocity probe and OPCON-turbidity sensor) and the global cross-section evolution. Registration of the time evolution of the global cross-section is performed with a computer controlled scanning system, ensuring an accurate and detailed topographic survey of the resulting sea bottom. A so-called scale series of experiments will be executed on the same prototype but with different hydrodynamic and morphological scales in order to validate and understand the basic physical processes. A qualitative verification of this global cross-sectional evolution will be done by comparing the results of these laboratory experiments with available field registrations for a representative suppletion profile for the Belgian East coast. This qualitative validation on macro-scale should help to interprete the physical processes on micro-scale in the corresponding physical experiments.

Numerical modelling

When doing numerical modelling, one has modelling of the details of the individual processes and modelling of the global effects of these processes. Ideally one should be able to quantify the long-term global effects by integrating the detailed processes over time. In practice this is impossible both because of insufficient computing power and because of insufficient knowledge of the detailed processes. A better understanding of the detailed physics however, should allow improving the parametrisation of the global effects. For example, to incorporate the effect of waves on sediment transport one typically assumes that shear stresses due to waves and due to currents can be calculated separately and then superimposed. Moreover, for the estimation of the shear stresses under waves one assumes that the full wave spectrum can be represented by two numbers, the wave height and some characteristic period, for example the peak period, see e.g. (Monbaliu et al., 1999). This assumption is quite often inadequate, especially in near shore zones where wave spectra are frequently more complex. An improved parametrisation of the effect of the spectral distribution of wave energy on sediment transport, forms the first objective in the numerical modelling part of this study.

For the numerical modelling, a variety of models is needed:

- Hydrodynamic models (2D/3D
- Wave models
  - In the frequency domain (spectral wave models; adequate for fairly large areas)
  - In the time domain (shallow water models such as Boussinesq-models; only suited for relatively small areas)
- Sediment transport models

A second objective of the modelling exercise is therefore to create a framework to quantify sediment transport in the near-shore zone. The idea is to have a double action: how does one zoom in on a detail of a coastal zone and how does one zoom out. This framework will be tested in a realistic setting of a part of the Belgian coastal zone.

In this study we want to use commercially available software where possible, supplemented by public domain and own developments where needed.

Concerning commercial software, our first choice is the TELEMAC-system. This software package contains 2D- and 3D-hydrodynamic models, sediment transport models and a Boussinesq model. It is a powerful package and for research purposes it is available at very low cost. The spectral wave models WAM and SWAN will supplement this system. The K.U.Leuven research team has considerable experience with these last two models. The TELEMAC-system does not contain a package for beach profile modelling. Danish Hydraulic Institute and Delft Hydraulics offer such models. At this moment however, we do not consider these models essential for the tasks in this study.

Synergy of the theoretical basis and the physical and numerical modelling

It is well known that both physical and numerical models have limitations. More and more numerical models are seen as the tools to study applications in coastal areas. Nevertheless physical modelling is important and will remain to be. The physical phenomena are sometimes badly understood or too complicated to work them out numerically. Also the computing power needed for some problems is so large, that it is impossible to carry out calculations within a reasonable amount of time.

Synergy of the different aspects offers a good alternative (Schäffer, 1999). Synergy can play in two ways. Numerical models can be used efficiently to generate good boundary conditions for physical model studies (zooming in). Physical models can be studied in more detail and in controlled circumstances in the lab. These experiments can also be modelled numerically. The intercomparison provides better insight (important for zooming out). The laboratory experiments will therefore concentrate on providing understanding of the behaviour of non-cohesive sediments under currents and waves representative for a complex spectrum (cf. objective 1 in the numerical modelling part).

The planned confrontation with the available terrain measurements has considerable added value. In situ measurements at the Belgian coast (both bathymetric surveys and wave data) have been archived over a long period. The richness they contain can be used to trigger an interdisciplinary and international research project.

Summary

The main scientific objectives of this research proposal can be summarised in the question why certain sandy coasts are dynamically stable and others are not. The following tools will be used to search for the answer:

- Literature study
- Building of a framework to model sediment transport in the near shore zone
- Incorporation of the influence of complex spectra in the formulation of sediment transport influenced by currents and waves
- Synergy of understanding of the physical processes (theoretical basis), numerical and physical modelling
- Qualitative confrontation with available in situ measurements

Since we are convinced that the planned research activities are of international value, not only in terms of scientific merits but also from the point of view of sustainable coastal development, the following objectives form also part of this proposal:

- Collaboration with other research teams in Europe who deal with this topic, for example by participating in experiments in the framework of TMR-LSF
- Writing and submitting of a problem oriented and interdisciplinary research proposal to the E.U.
- Dissimination of the results through conferences and by publication in international journals

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