GUIDELINES FOR DESIGNING SAND NOURISHMENTS ON LOW TO HIGH EXPOSURE COASTS

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MOTIVATION

Danish law establishes a common right of passage on foot along the Danish shoreline, even though beaches are often privately owned. The law also states that coastal protection must not hinder this. Therefore, sand nourishment should be part of every coastal protection scheme against erosion. Sand nourishments can be designed in numerous ways depending on their objectives. As part of the European Interreg project, Building With Nature (BWN), guidelines will be developed by the Danish Coastal Authority (DCA) in end-2020. This abstract presents these guidelines with special focus on the coasts of Denmark.

METHODOLOGY

Special emphasis will be on insight into the natural variation of the coasts, as this is vital both when designing effective coastal protection schemes and when evaluating the impact of the nourishment. In this project, the pathway along which sediment is being transported spans from offshore at the outer bar to the coastal cliff.

10 beach nourishments in Denmark and Sweden, and 8 shoreface nourishments in Denmark were analyzed during the project. The nourishment volumes ranged from 4,000 to 2,000,000m^3. Results from the co-analysis in BWN on nourishments in Belgium, The Netherlands and Germany will also be included.

The aim is to be able to determine the along- and cross-shore paths, along which the nourishment sand is transported, the diffusion velocity of the nourishment and the impact on the surrounding coasts. Based on the results of the multiple analysis, the primary objective is to produce guidelines on how to use sand nourishment to counteract erosion in a sustainable and socioeconomic way.

ANALYSIS

In this abstract, the ongoing work and analysis of a shoreface nourishment at southern Holmsland barrier, a beach nourishment at Nørlev and a beach nourishment at Fredericia will be presented, as they are located on highly different coastal stretches. Furthermore, they represent highly different nourishment designs, monitoring programs and results of the various analyses.

At Southern Holmlands Tange, a shoreface nourishment of 310,000m^3 sediment was placed along a 775m coastal stretch in 2011. Multiple surveys have been conducted prior to the nourishment and Fig. 1 shows the variation in the active profile over a period of 10 years. Especially the bars are highly dynamic. Analyses showed relatively significant patterns in the long-, and cross-shore breaker bar variations and positions. The benefits of adapting the shoreface nourishments to the native morphology and breaker bar variations could potentially increase the benefits from the nourishments. The high frequency in profile measurements showed a large variation, which had not been evident from the yearly measurements.

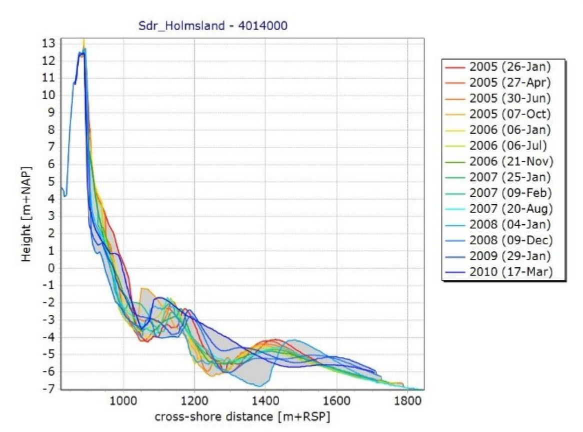

Figure 1 – Natural variations in the active profile 2005-2010, 14 surveys.

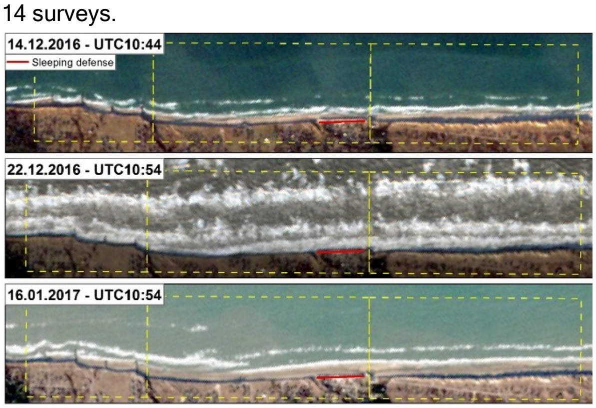

Figure 2 – Satellite images of breaker bar system.

At Nørlev, a beach nourishment of 18,000m^3 sediment was placed along a 340m stretch as a 10m wide rectangular buffer in the duneface. The nourishment volume diffused into the profile and was redistributed along- and cross-shore after the first winter storm. Long-term and natural variations on the stretch were analyzed from orthophotos and profile measurements. Satellite images from Sentinel 2 were used to determine the variation of the bars over seasons, but also for before, during and after storm analysis of the beach nourishment

development.
Fig. 2 shows three RBG-images with a resolution of 10x10 m from the Sentinel-2 satellite. From these images it was possible to determine the variation of the bar system and identify a depression in the outer bar just outside the location of a significant dune erosion. Regular drone footage has contributed to document these natural variations in the active coastal zone, and to the analysis of temporal diffusion of nourishment sediment.

At Fredericia, a beach nourishment of 18,000m^3 sediment was placed along an 800m stretch, mostly by nourishment by pipe from a ship. The goal of the nourishment was to extend the shoreline to the position it had in 1954. The stretch was monitored regularly by drone by the DCA but otherwise no monitoring program was planned. Nourishment analysis was mainly based on imagery from the drone captured at comparable positions as seen in Figures 3 and 4. Additionally modeled wave data, modeled and measured water levels and two national digital elevation models were included. Decreases in planform and volume were not unexpected and did not exceed the potential transport rates. After 1.5 year, the beach volume and width had still increased compared to the state prior to nourishment.

Figure 3: Southern part of nourishment stretch at Fredericia before nourishment.

Figure 4: Southern part of nourishment stretch at Fredericia after nourishment.

NOURISHMENT DESIGN AND MONITORING

The degree of exposure, morphology, natural variation, protective measures, stretch length, nourishment method, etc. are all different for the three examples above. What the stretches have in common is their general sedimentary deficit. This is handled by adding sediment. However, there are key elements which can be addressed in design and planning of future nourishments. Firstly, the actual problem at the stretch must be addressed. In general, on eroding coasts, the sediment deficit is the main issue. In Fredericia this was handled by increasing the beach width and volume, the goal being to extend the shoreline to the position it had in 1954. However, the lifetime of the nourishment was not considered in the planning process and the intended goal of the nourishment was achieved on the day the nourishment was completed. The general sediment deficit and natural beach width for such a coastline was not considered in the original plans. The diffusion of sediment and reduction in planform was to be excepted, considering the natural behavior of such a system, but an outside viewer might consider this development unexpected and see the nourishment as unsuccessful.

To improve future designs and effects of nourishments it is a general recommendation to analyze the natural development of the coast and the local migration of sediment. Nourishment sediment does not “disappear”, the position of the sand grains are though shifted. Coastal protection schemes should therefor include evaluations or analysis of nourishment development and effects, as this contributes to increase the knowledge, essential for both stakeholders and planners. This will undoubtedly benefit planning of future protection. A questions in this respect could be: “What natural development would have taken place without the nourishment?”

To analyze nourishment development and effects, a pre-planned monitoring program is essential for gathering information and data. When planning such a program the natural morphology and knowledge of the variation of the system comes into play. Planning could benefit from gathering and reviewing data already available on the stretch in question. Profile measurements, orthophotos, DTMs, imagery, etc. might be available, and monitoring methods should try to emphasis the present data so that analysis of nourishment development can be based on data comparable to those used for analysis of the natural behavior of the stretch. Low-budget data acquisition could be as simple as drone imagery captured from the same position once a month. This data can be utilized not only in analyzing the stretch but also for informative campaigns directed towards the stakeholders. Drone monitoring can also be extended to the acquisition of imagery for construction of both DTMs and orthophotos if there is a need for detail. However, this naturally comes at a slightly higher cost.

CONCLUSIONS

The use of frequent data (survey, satellite, orthophoto, drone images, etc.) to quantify the natural variation on erodible coasts has improved the ability to asses and quantify the effects of sand nourishments. The planned and ongoing further analyses are expected to result in statistically significant results, which will be used to make improved guidelines on the design on nourishments.

ACKNOWLEDGMENT

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