Beach Nourishment on the West Coast of Jutland
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ABSTRACT


This paper deals with the maintenance of the Danish North Sea coast, which is highly exposed for erosion. The actual efforts to reduce the erosion are construction of groins and breakwaters combined with beach nourishment. Different methods of beach nourishment are described and discussed.

ADDITIONAL INDEX WORDS: Coastal protection, beachfill, sandtransport, coastal barriers, engineering, hopper dredge.

INTRODUCTION

The Danish Coast Authority is situated in a small town named Lemvig which lies a short distance from the North Sea coast (Figure 1). The authority is a department under the Ministry of Public Works. It deals with all kinds of construction works on the sea and shore, and it has as a special task to maintain and improve the coast protection works along the North Sea coast established by the Danish Government. These older constructions, some of which were established more than 100 years ago, consist of a group of groins combined with dikes to protect the Thyborøn barriers, a group of groins at Bovbjerg, and dikes at the Thorsminde barriers (Figure 2).

The main problem on the west coast of Jutland is the heavy erosion which has taken place during hundreds of years along its sandy parts.

Within the last few years strong gales and storm surges have caused extra-heavy erosion and damage along the whole coastline. A single storm surge on 24 November 1981 eroded 10 m in many places and as much as 30 m at exposed localities. The existence of fixed harbour constructions at Hvide Sande, Thorsminde and Thyborøn and recreational areas just behind the beaches and dunes have caused severe problems and the need for coastal protection works is increasing.

In 1983 the Government decided, after political pressure from county councils and local communities, to take 50% part in financing of further development of protection works on some locations on the North Sea coast. The Coast Authority performs the preliminary investigations, planning and design, and the projects themselves are carried out by contractors or by the Authority.

BACKGROUND INFORMATION

For many years the Coast Authority has made soundings and levellings along the sandy
coast, for example, in the Thyborøn area since 1874. The soundings are conducted along lines spaced 600 m and 1,000 m apart and to a water depth of approximately 15 m. Water levels are recorded at the harbour sites, and wave recordings are made at various locations. Also, a series of test dredgings and vibrocore drillings have been performed along the coast to map the sand resources available for beach nourishment.

On basis of analysis of soundings and levellings, the future average erosion along the coastline has been estimated, not taking into account any new constructions (Figure 3). It is seen that the heavy erosion at some locations in general can be explained as leeside effects from fixed constructions (harbours and groups of groins). The actual efforts to reduce the erosion of the coast are construction of groins or breakwaters combined with beach nourishment. Furthermore, the foot of the cliffs or dunes is protected by construction of revetments and reinforcement of the dunes.

### CHOICE OF CONSTRUCTION

The experience with groups of groins from the barriers at Thyborøn shows that it is possible to reduce the erosion. Before construction of the groins, the profile eroded at a rate of about 10 m/year. The erosion is now reduced to 1-2 m/year. It is also seen from the curves that the depth contours need about 50 years to adapt to the new situation and form a new steeper equilibrium profile (Figure 4).

Normally, the placement of groins will cause severe erosion on the leeside; therefore, nearly 10 years ago we decided mainly to construct detached breakwaters. They are normally placed at a water depth of 1 m and are built of imported stones. The purpose of the construction of detached breakwaters is to reduce the wave energy behind the breakwaters so that suspended sand settles and a high beach in front of the cliff or dune is built up. The adverse leeside effect of breakwaters is diminished in comparison to groins because the structures...
Figure 2. Part of the North Sea coastline showing locations mentioned in the text.

Figure 3. Estimated future average erosion.
allow a certain amount of sand to pass behind them under storm conditions. It is estimated that the rate of erosion behind the breakwaters is reduced to 50%. To maintain an equilibrium situation it is necessary to nourish the beach or coast artificially.

**MASTER PLANS**

Within the last few years the Coast Authority has made master plans for construction and beach nourishment for the forthcoming 10 years at several locations. These master plans encompass the following projects.

**The Thyborøn Barriers**

Fixed constructions are nearly finished. On the northern barrier we plan to nourish the beach with 50,000 m³/year. On the southern barrier we expect to nourish with 100,000 m³/year partly, where necessary area is available, as a reinforcement on the inner slope of the dike, partly as beach nourishment.

**Vrist**

At the coast south of the Thyborøn barriers it is planed to build 2.7 km of revetment, 6 breakwaters, and 6 short groins. Before carrying out these constructions, it has been necessary to nourish with 300,000 m³ of sand in order to strengthen the profile. After completion of the construction works we plan to nourish the coast with approximately 120,000 m³/year, equally distributed on the bar and on the beach.

**Bovbjerg**

The groins in this area have shown their
effectiveness and the erosion has for the last 50 years been nearly zero. During the last two years we have experienced an erosion north of the groins, and it will be necessary to strengthen the cliff by construction of a revetment.

**Fjaltring-Mærsk (Thorsminde N)**

In this area we have the greatest erosion. In the course of the following years we have planned to execute 4.3 km of revetment and 13 breakwaters. The coast has a nourishment requirement of nearly 400,000 m$^3$ of sand every year.

**Thorsminde S.**

The construction works include 2.6 km of revetment and 26 breakwaters. We plan to nourish the coast with 250,000 m$^3$/year. Half of this amount of sand will be placed on the bar and half on the beach.

**Hvide Sande**

In this area we have planned to reinforce the dunes and to build 11 breakwaters. Coastal nourishment is estimated at 200,000 m$^3$/year.

When our master plans are completed our protection works will extend over nearly 100 km of coast and consist of 118 breakwaters, 89 groins, and 18.4 km of revetments. Also we will have a total need of sand supply of approximately 1.1 mill. m$^3$/year.

**METHODS OF NOURISHMENT**

The harbour administrations in Hvide Sande and Thorsminde have, free of charge, agreed to deliver sand dredged from the entrance channels. The sand will either be pumped to depots south of the harbour entrances or dumped on the bars. From the depots, we are trucking the sand to the actual localities, and we plan to obtain 125,000 m$^3$/year in this way. North of the harbours we are excavating sand from the accumulation areas and trucking it to the nourishment areas. The yearly amount is estimated to be another 125,000 m$^3$. We have by these methods in coorporation with the harbour administrations made a very simple and inexpensive sand bypassing system. The lacking amount of sand in these areas, approximately 150,000 m$^3$/year, is dredged from deep water by a hopper dredger and it is pumped over the bow on the shoreward end of the bar in a water depth of about 4.0 m (Figure 5).
The Thyborøn barriers are nourished with sand from the entrance channel. The sand is dredged from the channel and pumped into depots on the eastern side of the northern barrier and at our working harbour on the southern barrier. Each of the depots has a capacity of 100,000 m³. From the depots the sand is trucked to the beach. At Vrist the sand is dredged from deep water and pumped over the bow on the bar.

In 1986 we made experiments with split barges. After they were loaded from a hopper dredger they sailed to the delivery site where they grounded, opened and dumped the sand, and then sailed away (Figure 6). Preliminary results show that we can work under worse wave conditions than with hopper dredgers pumping over the stem. Records on beach nourishment in 1987 and 1988 show that costs are nearly equal for use of either hopper dredgers or split barges. The future choice of method will depend upon the actual offer for open competition.

At Mærsk/Thorsminde North, where there is the greatest demand for sand supply, we have tried different methods in recent years. In 1981, we placed a plastic pipe on the sea bottom fixed by anchors and tied to a loading buoy at a water depth of 7 m. Unfortunately this pipe could not stand the wave action under storm conditions and it was damaged under nearly every gale. As soon as it was repaired, a new gale struck. Quite a lot of money was expended, but we got only very little sand on the beach.

In 1983 we dumped 240,000 m³ sand, dredged from deep water, on the bar at 3 localities south of the groins at Fjaltring (Figure 7). After dumping the sand, we made a series of soundings and levellings. They showed that the sand remained in the littoral zone, that there was practically no onshore transport, and that it was necessary as a supplement to nourish the beach.

In 1984, we decided on the basis of these tests
Figure 7. Aerial view of nearshore nourishment, Fjaltring.
to place a plastic pipe, ballasted with concrete blocks and buried under the sea bottom, from the beach to a water depth of 7-8 m terminated by a concrete block, which can be connected to a loading buoy (Figure 8). The total cost of this pipe was about 1.4 million US dollars. In 1986 we started to nourish the beach through this pipe (Figure 9). The yearly amount has varied between 200,000 and 300,000 m$^3$. The sand was distributed along the beach with trucks in 1986 and 1987. In 1988 a large booster was tested for distribution of sand on the beach. The test is intended to be continued this year. Furthermore, it is intended, possibly at other working sites, to test smaller (transportable) boosters, both single and in series, for longer transport distances.

EXPENSES OF NOURISHMENT

The following prices on beach nourishment do not include supervision and administration. Furthermore, write off and maintenance on the buried sea pipe are not included.

(a) Excavating and loading of sand from the beach costs 0.75 US$/m$^3$.
(b) Dumping of sand on the bar costs approximately 2 US$/m$^3$.
(c) Pumping through the pipe on to the beach at a depot costs 3 US$/m$^3$.
(d) Transportation by trucks depends on the distance. With a transportation distance between 2 and 4 kilometers, the costs are calculated to be about 1.5 US$/m^3$.

CONCLUSIONS

Up till now the works on beach nourishment have shown that it is necessary to continue the nourishment, if we want to preserve the coast at the present level of security.

The works already completed indicate that we shall get the best economy by nourishing the beach and the nearshore section until a water depth of approximately 1.0 m. Based on an
analysis of soundings and levellings of selected nourished areas, we expect during this year to determine the methods of nourishment in the years to come.

The tests performed on longshore distribution of the sand showed an economic advantage by using a booster at Mærsk, where a relatively great amount of sand is distributed. New tests shall be done to show the economy by use of smaller movable boosters.

Figure 9. Sand depot on the beach, Mærsk.