Coastal protection based on Pressure Equalization Modules (PEM)

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ABSTRACT

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Land-based activities and natural physical processes have resulted in significant modifications of the shorelines in many countries, with drastic effects on the coastal geomorphology as well as on the coastal infrastructures. There is an urgent need to introduce new and cost-effective measures that can reduce and mitigate the impacts on the shorelines.

SIC Skagen Innovation Centre has invented an environmentally friendly coastal protection system. The SIC system is based on pressure equalisation modules. A long-term and comprehensive test of the efficiency has been carried out on the west coast of Denmark. Furthermore, a three years scientific research programme was performed in 2005. The obtained result shows that the system is far more efficient than conventional methods such as groins, breakwaters and sand nourishment. Due to the well-known lee side erosion effect, groins and breakwaters create even greater erosion in adjacent coastal areas. Sand nourishment by dredging is in general terms a very expensive approach (about 130,000 USD / km / year in Denmark), but unfortunately it is an inefficient solution since usually the sand will disappear during the first spring tide.

The result is significant already after the first year. The coastal erosion is stopped and a buffer of 476.000 cubic meter sand is built up in the fore shore and the dune front in the drained areas. 139.000 cubic meters is leeside accumulation.

ADITIONAL INDEX WORDS: *Beach dewatering, SIC, PEM.*

INTRODUCTION

A field test over 11,0 km with the SIC vertical drain system was carried out in January 2005 and placed by Skodbjerge at the Danish west coast(fig 1)

Figure 1

The location for the field test is 5 km south of Hvide Sande harbour on the west coast of Jutland fig. 1.

In relation to the channel into the harbour, was placed a groin 450 meters long in the beginning of the sixties fig. 2

The background for this long groin out in the sea was to stop the sand drift to the channel.

The groin has only an effect in about two years.

Afterwards the harbour authorities buy a dredger to pick up the sand from the channel and bypass the sand to the beach south of Hvide Sande harbour .The amount of sand is apx. 200.000 cubic meters per year. As we see in fig. 2 the 450 meter long groin generates big leeside erosion south for the harbour.

Figure 2

The yearly erosion rate in the field test area is 4 meter per year in the north and 1,5 meter per year in the south.

In our evaluation we calculate with a average erosion rate in the test area at 2,0 meters per year

The dune system is 15 meter's high and the yearly erosion at 11 km is 330.000 cubic meter's average per year

Erosion budget Danish west coast

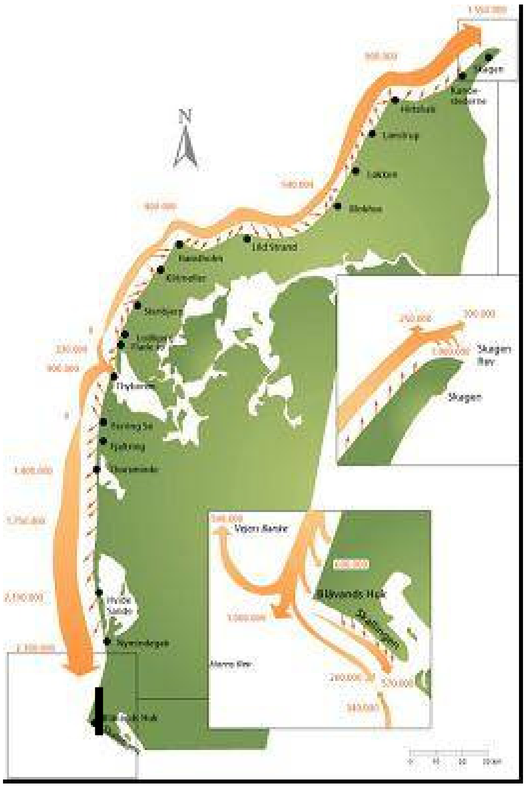

Figure 3

The central part of the Danish west coast 100 km is a high erosion area with a yearly erosion on 4,17 mill. cubic meter per year.

The background for this big erosion is man made constructions with two harbours, Thorsminde and Hvide Sande.

On the top we have apx. 100 groins 100 - 150 meter's long, as increase the erosion on the west coast.

The costal protection is normally based on beach and bar nourishment with 2,4 mill. cubic meter per year.

The cost for the yearly bar and beach nourishment is apx. 10 mill €.

The result is negative with 1,70 mill. cubic meter yearly after an investment of 10 mill. € per year.

The result will be negative with 85 mill. cubic meters over the next 50 years with an investment at 500 mill. €

This is the background for test of new technologies.

The area is marked with a dashed line in fig. 3 and the test area is marked with a solid line 11 km.

Field test area 11 km.

Figure 4

The test area at 11 km is split up in two areas drained with the pressure equalization modules PEM, and three reference area's at 1,8 km each without drain system.

PEM 1 is 4700 meters.

PEM 2 is 900 meters

The configuration is shown in fig 4.

Ref. 1 - 1,8 km is placed in the north

Ref. 2 - 1,8 km is placed in the middle

Ref. 3 - 1,8 km is placed in the south.

Installation

Figure 5

The PEM modules are placed from the dune foot to the shoreline with a distance at 10 meters in the cross and 100 metes between the rows along the coastline.

One line is shown in fig. 5

Installation with drill.

Figure 6.

The PEM modules are 1,0 meter long filter tubes combined with 0,75 meter steel tube on the top.

The bottom is closed with a cap, and a cap with at ventilating filter is placed on the top of the PEM module.

The PEM modules are drilled down in the beach fig. 6.

The top of the PEM module is place 25 cm below the surface of the beach, so the modules not are visible at normal conditions.

The initial setup was 7 modules in each line and, afterwards max. 11 modules in each line.

Survey on the Beach and Dunes

Figure 7

The survey on the beach and the dunes are based on GPS, with a tolerance below 2 cm in the height.
The survey is done of a independent engineering company Carl Bro A/S Denmark figure 7.
There is 100 meter's between the survey lines along the coast line.
The survey is quarterly.

Survey off Shore 600 Metre

Figure. 8

The survey outside in the sea is made of The Danish Coastal Authority from the shoreline and 600 meters out in the sea.

The distance between the survey lines is 200 meters along the coast line.

In the first year the survey is quarterly, and afterwards half yearly.

The tolerance in the height is apx. 10 cm.

There is no reference platforms outside in the sea in the test area.

Water levels.

At the coast the difference between the mean high water level and the mean low water level is 0,7 – 0,8 m.

By heavy storms the mean water level can rise up to 3.1 m.
Low water levels can occur down to – 2,0 m by easterly winds.

Weather Conditions.

The wind speed in the area can rise up to 35 m/sec by heavy storm
The wind direction is primary from westerly directions.

There are not registered storms in the area in the first year, but only heavy winds with wind speed up to 20 m/sec at spring time 2005 and in the autumn 2005.

Evaluation Matrix

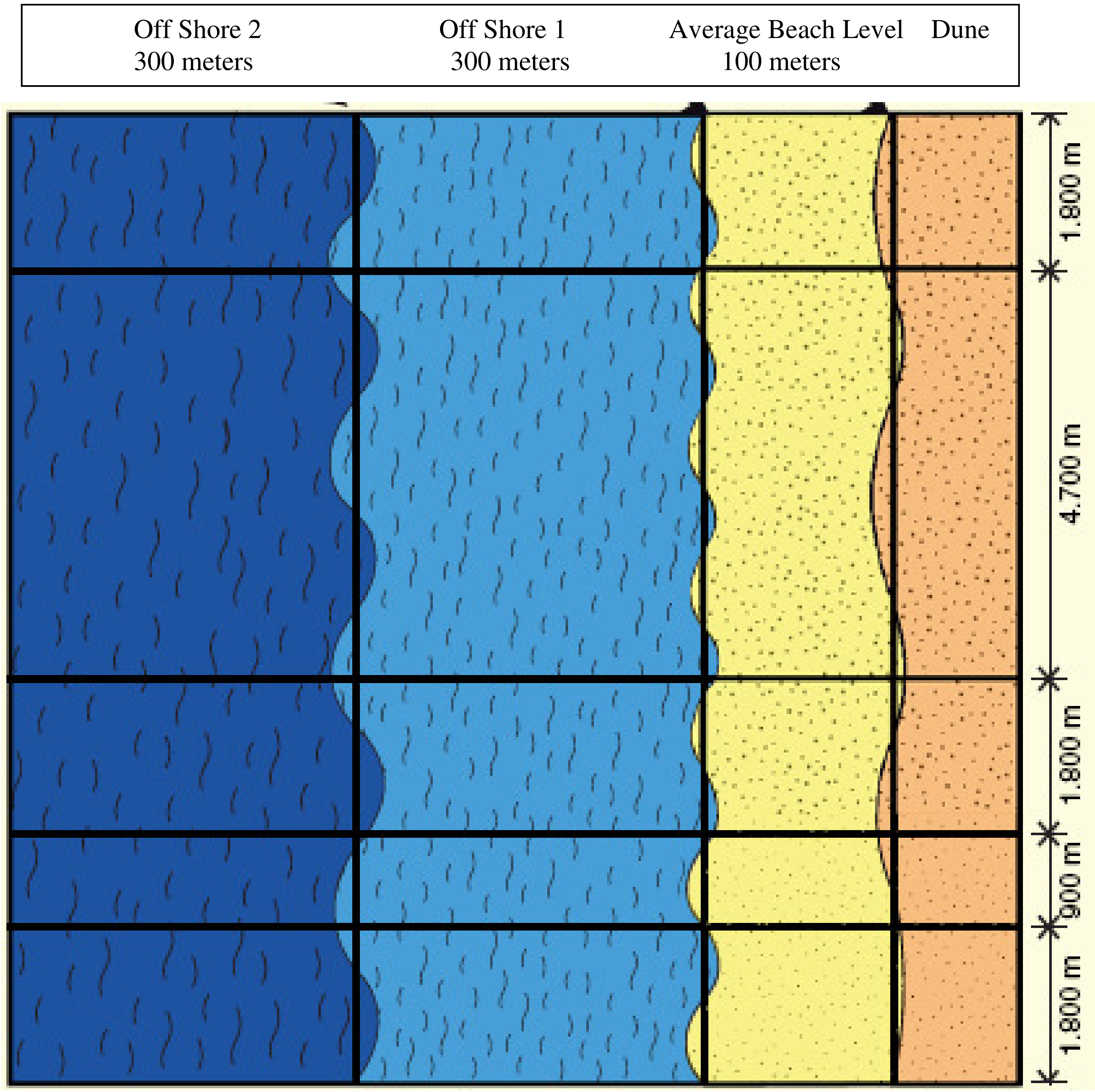

Figure 9

Off Shore

Off shore 1 is locked to the 100 meter line for Average Beach Level and is 300 meters wide.

Off Sore 2 is locked to off shore 1 and 300 meters wide.

Dune and Beach.

The dune foot is level 4.0 meters in relation to DVR 90
The reference line in this field test is the dune foot January 2005.

The average beach level in this project is calculated from the dune foot and 100 meters against the sea.

Average beach level

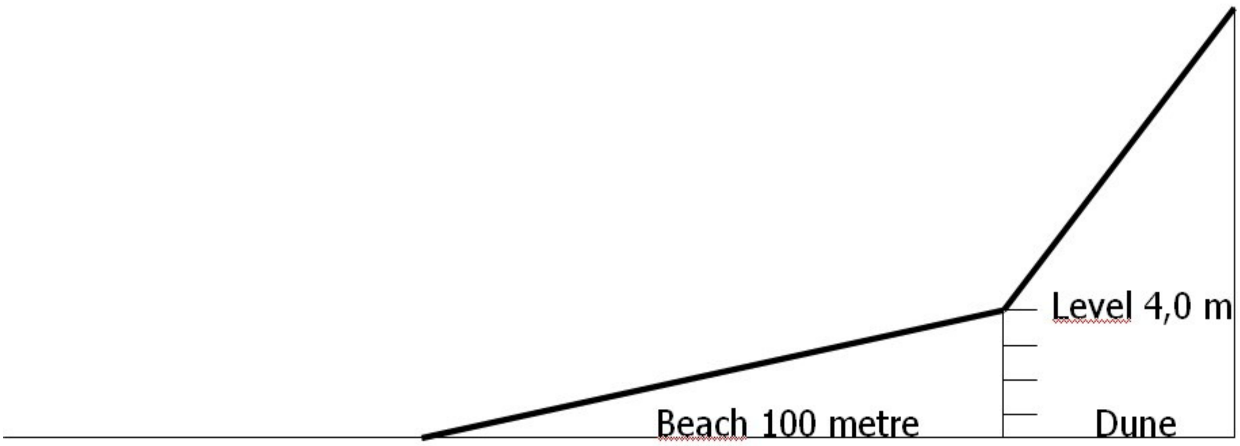

Figure 10

In relation to the "Global Sea Level Rise" .The average beach level is a very important parameter.

All scientific research projects about the SIC System shows the PEM modules rise the average beach level to a higher average beach level.

The width of the beach on a location is related to the difference between the high mean sea level and the low mean sea level.

At the southern part of the Danish west coast is the difference apx. 80 cm.
The beaches in the drained areas with the SIC system are apx. 100 meter wide and the background for the evaluation parameter.

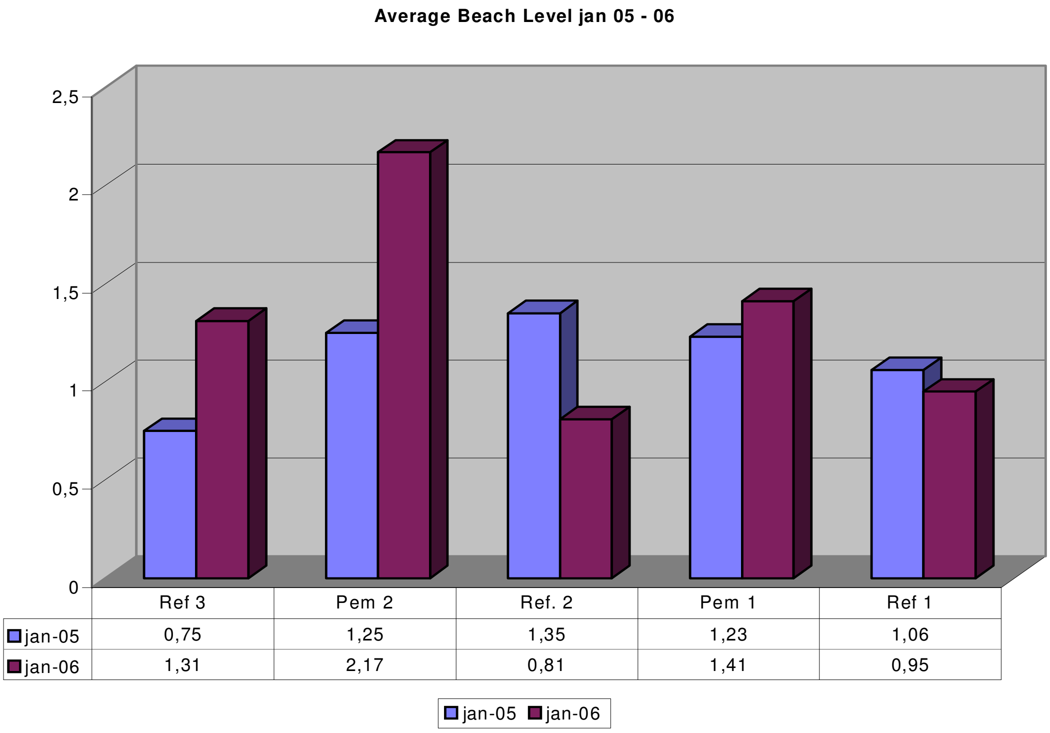

Fig 11

We see clearly the average beach level is raised in the PEM areas opposite ref. 1 and ref. 2 from January 2005 to January 2006

In ref. 3 we have lee side accumulation.

Analysis.

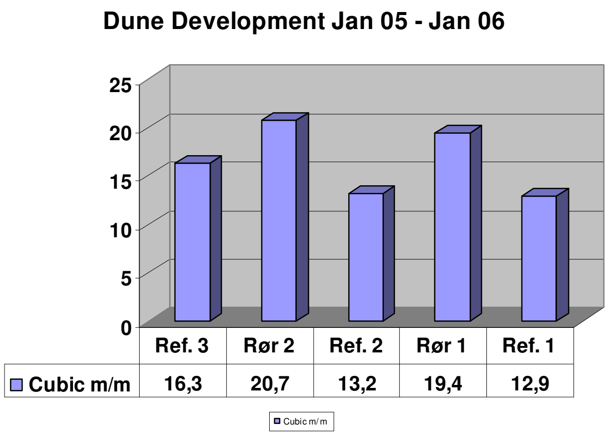

Figure 12

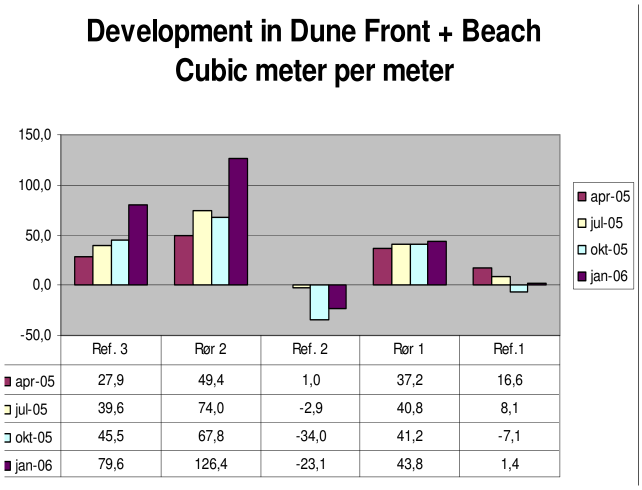

Figure 14

Dune front development.

The development in the front of the dunes in the first year, are significant in the drained PEM areas.
The accumulation of sand in front of the dunes is more than 50 % higher in PEM 1 and PEM 2 compared with ref 1 and ref 2.

We can't compare with ref. 3, because we have big leeside accumulation in the beach.

Wind erosion

We have an accumulation on 20 cubic meters in the dune front based on the western wind generally.

This sand comes from the beach in front of the dunes and the beaches are lowered with 20 cm in a 100 meter wide area over a year.

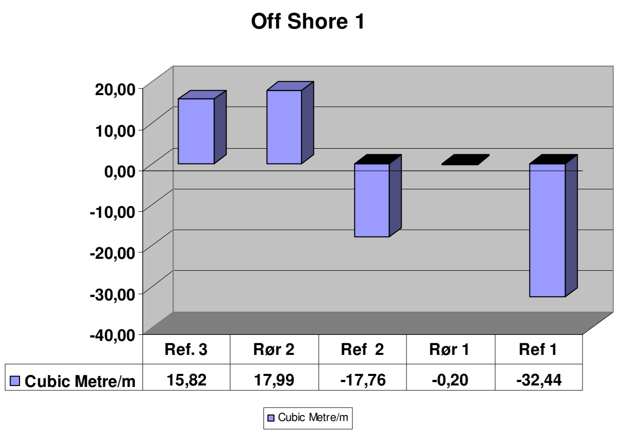

Figure 13

Figure 13 shows the development out site in off shore 1.
We don't see any steeping of the sea bed outside the drained areas PEM 1 and PEM 2.

The sand for the beach and dune development is picked up from the long shore sediment transport.

Fig. 14 shows the development in each area in the first year in the dune front and the beach in cubic meters per meter along the coast line.

Figure 15 shows the results in each area in dune front and the beach total for the first year.

Result.

PEM 1 + PEM 2	336.640 Cubic m.
Lee Side Accumulation in Ref. 3	139.300 Cubic m
Accumulation total	475.940 Cubic m

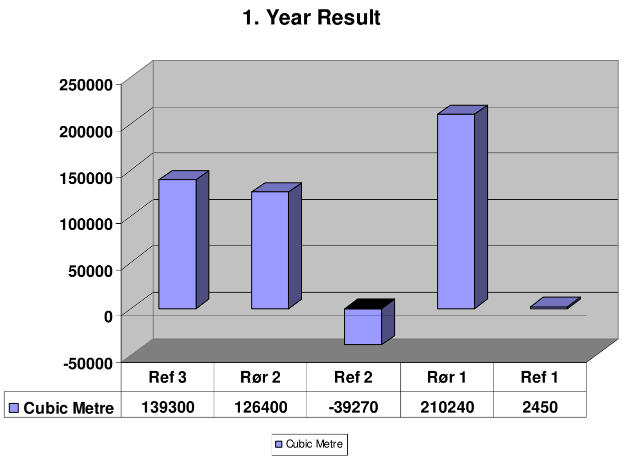

Figure 15

Final Result and Conclusion

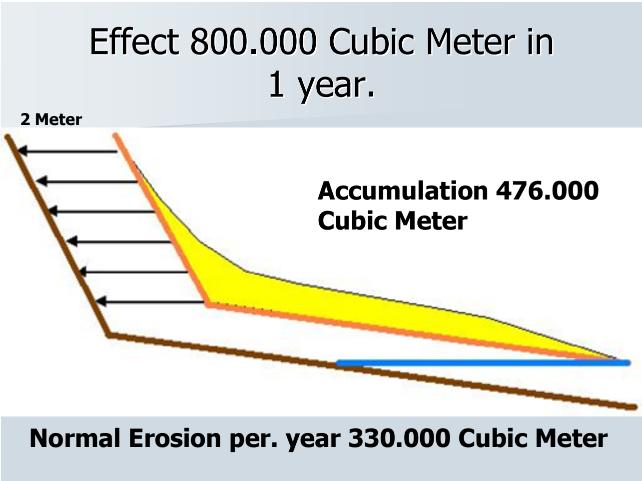

Figure 16

Final Result

The SIC system stopped the normal erosion 2 meter per year	330.000 cubic meter
Accumulation in PEM 1 and PEM 2	336.640 cubic meter
Lee side accumulation in ref 3	139.300 cubic meter
Total effect	805.940 cubic meter

The arrows in fig 16 illustrate the normal beach erosion yearly. The accumulation of sand is placed on the top of the beach as a buffer.

Conclusion

- The average beach level is raised in the PEM areas.
- The accumulation of sand in the dune front in year 1in the PEM Areas is more than 50% higher in relation to ref. 1 and ref. 2.
- There is no lee side erosion, but lee side accumulation
- There is no steeping of the sea bed outside the drained areas
- The Effect off the SIC system is more than 800.000 cubic meter in the first year.
- The Sand comes from the long shore sediment transport at the coastline.
- The SIC system is a solution in relation to the Global Sea Level Raise

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