



DHI CASE STORY

HANSTHOLM PORT: FIGHTING NORTH SEA WAVES

MODELLING FOR A SAFE AND ECONOMICAL PORT EXPANSION

The Port of Hanstholm in Denmark is a major fishing and commercial port. As a busy port with a finite amount of space, increasing traffic required a concomitant increase in port size. However, the Port sits fully exposed to the large waves of the North Sea – the design significant wave height is close to 8m. In order to proceed with the expansion plans, a cost-effective and safe breakwater design was required. In addition, the port layout also needed to be optimised with respect to wave disturbances inside the port. We brought our expertise to the project by conducting comprehensive numerical and physical modelling to pave the way for a safe and cost-effective port expansion.

THE PORT EXPANSION – AN ENGINEERING CHALLENGE

Our history with Hanstholm goes back several decades. When Hanstholm Harbour was first being built on the northwest coast of Denmark, its construction was seen as infeasible. But two of our founders – Professor Helge Lundgren and Director Torben Sørensen – re-examined the technical aspects of the project. Based on their findings, a new report concluded that the project was sound, allowing for the construction of Hanstholm Harbour.

Nearly 50 years later, we helped with the planning of a major expansion of the Port of Hanstholm, now a major Danish fishing and commercial port. To cope with growing demand, plans were recently drawn up to increase the size of the port area.

Taking future navigation conditions into account, this expansion would include:

- Expanding the harbour to make it over three times larger than the existing one



Photo from the 2D breakwater stability tests carried out at DHI

SUMMARY

CLIENT

Grontmij A/S and Port of Hanstholm

CHALLENGE

- Major port expansion
- Direct exposure to North Sea waves
- Requirement of accurate design wave conditions
- Need to ensure cost-effective and safe breakwater designs for more than 2km of new breakwaters
- Need to establish acceptable wave conditions inside the new port

SOLUTION

- Numerical modelling of wave conditions
- Statistical analysis for provision of extreme and normal wave conditions
- Numerical modelling of wave disturbance in the port
- Comprehensive physical model tests for optimisation of breakwater design

VALUE

- Optimised port layout and breakwater structures
- Economical and safe port expansion

LOCATION / COUNTRY

North Sea Coast, Denmark

- Increasing the water depth at the entrance and approach to the harbour to 12.5m, an increase of 3-4m
- Constructing a new port entrance northeast of the present one
- Building more than 2km of new breakwaters at a water depth of up to 14m

OVERCOMING THE WAVES OF THE NORTH SEA

The location of the port provides little protection from the winds and strong waves of the North Sea. This means that more than 2km of new breakwater structures would be exposed. In order to carry out the port expansion economically and safely, it was necessary to ensure optimal breakwater designs and port layout.

We conducted comprehensive numerical modelling to achieve accurate design wave conditions, as well as to study the wave conditions inside the new port. In parallel, we conducted physical model tests to optimise the breakwater design.

EXAMINING THE PAST TO MODEL THE FUTURE

We established the wave conditions at the port through numerical wave hindcast modelling for a period of 30 years. Applying a two-step approach, we modelled wave conditions:

- for the entire North Sea
 - at the Port of Hanstholm. A high-resolution local area model was used, applying boundaries from the North Sea model
- We calibrated and validated the modelling complex against:
- more than 12 years of wave measurements from a permanent buoy at the port
 - new directional wave measurements that we conducted for the project

For the wave transformation modelling, we applied our third generation spectral wind-wave model – MIKE 21 SW. We then statistically analysed the modelled long-term wave conditions along the planned breakwater structures. This provided the design wave as well as the normal wave conditions governing port operations.

PHYSICAL MODELLING OF BREAKWATER STABILITY

To optimise the breakwater design, we conducted 2D (flume) and 3D (basin) hydraulic model tests to evaluate the hydraulic stability and wave overtopping of the breakwaters. In the 2D model tests, we investigated trunk sections of the new breakwaters at different depths. We used this information to optimise the breakwaters with respect to geometry, armour types and sizes, as well as scour protection.

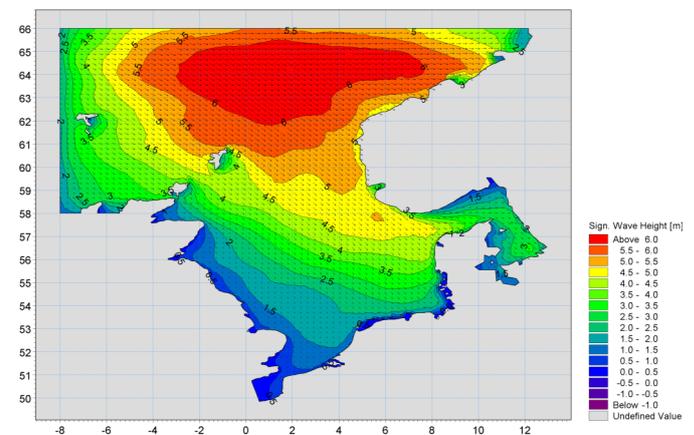
The design of the breakwater heads and adjacent trunk sections were especially challenging and required a comprehensive 3D wave basin model. In this model, we studied and optimised the stability at the breakwater heads.

We evaluated both traditional rubble mound heads and combined caissons-rubble mound designs. Special attention was required at the interface between:

- the caissons and armour layers
- the different armour types (Xblocc® and rock), which are often challenging design elements

WAVE DISTURBANCE MODELLING

The port entrance and the interior of the port determine the wave conditions at the berths. Navigational and sedimentation aspects mainly dictated the entrance configuration. We assisted in defining the right layout of the port interior, ensuring safe mooring conditions, by modelling the wave propagation into the port basins. We studied both the primary short period waves as well as long period waves to ensure that the risk of harbour resonance/seiching was negligible.



Snapshot from the North Sea wave model during a storm. Significant wave heights. MIKE 21 SW.

We used the MIKE 21 BW (Boussinesq wave model) for high resolution wave disturbance modelling for a series of wave conditions and port layouts.

THE SAND TRANSPORT CHALLENGE

A large harbour expansion like this also raises a number of questions related to the sand transport:

- What are the future conditions for bypass of sand past the harbour?
- How much dredging will be necessary to maintain the 12.5 m navigation depth?
- What are the conditions for deposition of sand along the new main northern breakwater west of the entrance?
- What is the impact on the surrounding coastlines if the conditions for bypass change?

We addressed these sedimentation challenges in a separate study.

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