Expansion of Port of Hanstholm
New Western Breakwater

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COWI A/S
The Project

Design and build contract signed November 2017

The winning team:

Client: Port of Hanstholm
Client consultant: Rambøll A/S
Project cost: ~ 500 mio. DKK
  Outer breakwaters ~ 300 mio. DKK

COWI’s role

1) Tender design of new outer breakwaters
2) Detailed design of:
   - New western breakwater (incl. physical model test)
   - Caisson for new breakwater head
   - New eastern breakwater
   - Spur breakwater (incl. physical model tests)
3) Assistance regarding various marine engineering issues during construction
4) Construction supervision
Exposed project location

Expansion of Port of Hanstholm
Design Conditions

Offshore:

- Water depths from 9m to 13.5m
- Waves: $H_s = 7.5-8.5\text{m}$, $T_p = 14-16\text{s}$
- Water levels: -0.5m to +1.7m

At the breakwater:

- Water depths from 9m to 13.5m
- Waves: $H_s = 7.5-8.5\text{m}$, $T_p = 14-16\text{s}$
- Water levels: -0.5m to +1.7m
Western breakwater with Cubipods

Outer cross-section

North Sea

Harbour

~ 90 m

~ 21 m
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Why concrete elements?

› Design wave heights:
  \( H_s = 8.5 \text{ m} ; H_{\text{max,offshore}} \sim 15 \text{ m} \)

› Breaking wave conditions

› Typical rock solution would require 40-50 t rocks!

› 30 t granite (max. size) not sufficient

› Special concrete elements are necessary
Other alternatives

Caissons
- Critical with respect to weather windows
- Construction logistics locally

X-bloc / Accropode
- 14m$^3$ (34t)
- 2-5 t filter rock
- Slope, 1:1.5

Rectangular Blocks
- High density
- 14m$^3$ (38t)
- 6-14t filter rock
- Slope, 1:1.75
Other alternatives

- Caissons
  - Limited weather windows for installation
- Other monolayer concrete units:
  - All units have strict placement tolerances
  - Require steep slope and small filter rock (interlocking units)
  - High risk of severe damage during construction
  - Less robust. If units are damaged or extracted, the breakwater becomes very vulnerable
  - Damages are difficult to repair
There are examples of similar type of damage
  › Broken units
  › Large settlements in armour layer
  › Exposed filter rock
  › Significantly reduced stability
Remember the history...

Arzew El Djedid Breakwater, Algeria, 1981

- *Tetrapods 48 t, Slope 1:1.3*
- *Broken armour units*
Remember the history...

Sines Breakwater, Portugal, 1978

› *Dolos 42t, Slope 1:1.5*

› *Broken armour units*

Sines breakwater failure, 1978/9
Cubipods

- Robust solution - for the Port as well as for the Contractor
- 3-8 t filter rock withstands summer storms up to $H_s \sim 4m$
- High density concrete used to keep weight down
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Cubipods

- Developed in University of Valencia, Spain (Prof. J.R. Medina) in 2005
- Patented by SATO (part of OHL group)
- About 6 projects completed in the Mediterranean
- Hanstholm Breakwater is the first project outside the Mediterranean
Cubipods

Concept:

- Cubes: High porosity --> High Stability
- Cubes obtain a low porosity and tends to create a smooth surface
- ‘Pods’ on the Cubes (‘Cubipods’) ensures a high porosity, $p = 40\text{-}43\%$. 
Cubipod

Advantages:
› More stable than cubes (higher $K_D$)
› Less steep slope than other monolayer units
› Robust bulky shape – no broken units
› Larger filter rock up to $W_{50f} = W/3$
› Filter layer at a flatter slope – less risk during construction
› Simple production and placement compared to other monolayer units
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Expected wave conditions during construction

- Construction from April – September
- Wave hindcast data, 1981-2015 (DHI)
- $H_s > 2\text{m}$ almost every week
- Storms with $H_s > 3.5\text{m}$ every year
Stability of filter rock during summer storm

Van der Meer, $S_d=2$ ('Start of damage') (1:1.75)

Van der Meer, $S_d=8$ ('Failure') (1:1.75)
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Friday, 21st Sept. 2018: The storm ‘Knud’
Design verification by 3D Model tests

<table>
<thead>
<tr>
<th>Horizontal</th>
<th>Wavepaddle, mean position</th>
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<tbody>
<tr>
<td>Slope 1:10</td>
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<td>Array 1</td>
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NORDPIANC 2019
13 SEPTEMBER 2019
Expansion of Port of Hanstholm

Upgrading front amour layer

Before tests

After 100 year wave conditions

Significant damage detected in 15 t CP with extraction of units and large settlements
Testing with 15-22 t rocks on rear side

Before testing

After 100 wave conditions

15-22 t rocks

Significant damage and failure of crest and rear protection
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Testing with 15 t Cubipods rear side

Before testing

After 100 wave conditions

Some settlements are observed but no units extracted
Breakwater head – concrete caisson (40 x 22 x 16 m)

Weight: 7000 t

Departure from Poland, 18 June 2019
Float off operation offshore Frederikshavn, 23 June 2019
Expansion of Port of Hanstholm

Installation in Hanstholm, 25 June 2019
Ballasting with water, 25 June 2019
Thank you for your attention