Scour & scour protection
Recent research & innovative ideas

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CEDA / IRO clubavond, Wassenaar, 9 March 2010
Background

source: EWEA (2008)
UK Crowne Estate: Round 3 (9 areas)

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Nordsee: Offshore Windparks

source: BSH (2010)
Background

Plans until 2020

- UK 29 GW
- Germany 25 GW
- Netherlands 6 GW
- Denmark 5 GW
- Sweden 3 GW
- Finland 2 GW

- expected: 40 – 50 GW until 2020

- 2008: 373 MW installed
- 2009: 577 MW installed
- 2010: about 1,000 MW expected

source: EWEA (2009)
Outline of presentation

1. Scour at unprotected pile
2. Scour protection with rock
3. Scour protection with composite rubber mat
4. Scour protection with collar
5. Summary & conclusions
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What is scour?

- local scour = erosion of seabed material at a single foundation
- cause: complex vortex pattern
- takes time, dynamic process

- rule of thumb: $S_{\text{max}} = 1.5 \times D_{\text{pile}}$
Relevance of scour & scour protection

Open questions

design
  - scour protection necessary?
  - required volume and stone size
  - which system
    - statically stable or dynamically stable?
    - number of layers?
  - performance under design storm

installation
  - time (speed of scour development)
  - required accuracy
Scour around an unprotected monopile

Model test: transparent pile with camera and fisheye lens

before

after

view from inside the pile
Scour around an unprotected monopile

Scour (and backfilling) depending on conditions and time

Scour prediction formulae

Application of formulae to time series
Verification of scour formulae

Research project: verification of empirical formulae against field data:
Offshore windpark Prinses Amalia

- 60 monopiles ($D_{\text{pile}}=4\text{m}$)
- 20-25m water depth
- seabed consisting of fine sand
- monopiles temporarily unprotected

research: analysis of bathymetry surveys
Verification of scour formulae

Collection of metocean data between surveys: field measurements and numerical modelling

- wave heights
- peak periods
- tidal current velocities
- water depth
Verification of scour formulae

Hindcast of scour development for each pile, comparison with measurements
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Basic options for offshore scour protection

Known scour protection methods

Alternative ideas

rubber mat

collar
**Classic scour protection for monopiles**

**Offshore Windpark Egmond aan Zee – scour protection**
- design of scour protection on basis of laboratory tests (2005)
- since installation in 2006: analysis of field surveys
  - (long-term) performance of scour protection
  - development of edge scour outside protection
- until summer 2009 218 surveys (36 piles) analyzed
- scour protection deformation as expected, fit for purpose’

**CROSS-SECTION**

- **monopile**
  - armour layer (Dn50=0.4m), minimum extent 18m
  - filter layer (Dn50=0.05m), minimum extent 24m
- **edge scour**
- **dynamic zone**

**Graphs**

- Average difference between surveys SU05-SU01
  - 122 days after pile installation on average
- Average difference between surveys SU23-SU21
  - 1027 days after pile installation on average
Classic scour protection for monopiles

Offshore Windpark Egmond aan Zee – edge scour

- predicted edge scour (2005): 1-2m
- maximum edge scour (2009): 0.8-2.2m
- equilibrium almost reached
- characteristic timescale: approx. 1yr

\[ S_{\text{edge}} = S_{\text{eq, edge}} \cdot \left(1 - \exp\left(-\frac{t}{T_{\text{char}}}\right)\right) \]

in which

- \( S_{\text{eq, edge}} = 1.61 \text{ m} \)
- \( T_{\text{char}} = 386 \text{ days} \)

**Diagram:**

- **2006**
  - September-November 2006 (SU05)
  - June-July 2007 (SU06)
  - August 2007 (SU07)
  - May 2008 (SU08)
  - May 2009 (SU09)

- **2009**
  - Average difference between surveys SU05-SU01
    - 127 days after pile installation on average

**Legend:**

- Red squares: September-November 2006 (SU05)
- Blue triangles: June-July 2007 (SU06)
- Green circles: August 2007 (SU07)
- Purple stars: May 2008 (SU08)
- Black diamonds: May 2009 (SU09)
Scour protection with small stones

Model tests

before

waves current

after

model test: severe storm
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Scour protection with a composite rubber mat

Basic idea:
- low weight & low costs
- pre-fabrication on land
- easy to remove

Questions:
- What are the failure mechanisms?
- Which mat properties are required?
- Which additional weight is required?

client: Continental
Scour protection with a composite rubber mat

Model tests
- various configurations
- stepwise increase of wave load until failure
- camera inspection
Scour protection with a composite rubber mat

Example 1:
- 20 blocks
- regular waves

**test 304 – 20 blocks**  
**test 305 – 20 blocks**

Example 2:
- steel chain at outer edge
- regular waves

**test 307 – heavy steel chain**
Conclusions for components of most promising system

- a flexible, robust rubber sheet with a size of 3 times the pile diameter
- a continuous, flexible weight along the edges of the mat (e.g. steel chain)
- a sufficiently tight connection between rubber sheet and pile to avoid washing out of sediment

Future challenges

- installation
- pile connection
- design guidelines

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Basic idea:
- pre-fabrication
- keep strong vortices away from seabed
- significantly reduce scour
Scour protection with a collar

delayed scour development

publication in progress…
Conclusions on hydraulic behaviour

- efficient for current-dominated conditions and severe storms
- to be installed at the bed (no gap)
- a skirt would be beneficial

Future challenges

- investigate long-term behaviour
- pile-collar connection (fixed, flexible)
- installation
- cable connection
OSCAR =
Offshore Scour and Remedial Measures

PC program under development:
• Hydrodynamics
• Scour prediction
• Scour protection

Library:
• Monopile
• Spudcans (JIP OSCAR participants only)

Extension of library possible:
• Structures: GBS, jacket, tripod etc.
• Type of protection: gravel bags, mattresses etc.
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Summary & conclusions

1. Scour development around unprotected monopiles
   → Validated formulae available, including time effect

2. Potential for optimization of scour protection
   → required volume, stone size, distribution
   → one-layer system (wide gradation)
   → highly dynamic protection (small stones)
   → time for installation

3. Alternative ideas for scour protection
   → rubber mat with heavy chain
   → pre-fabricated collar

   Challenges: develop practical solutions and design guidelines
Thank you for your attention!