Offshore Wind Energy Foundations
Geotextile Sand-Filled Containers as Effective Scour Protection System

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2. Scour Protection & Materials Methods, geotextile Containers GSC
3. Design Fundamentals Efficiency, hydraulic stability
4. Practical experiences GSC as scour stabilization
5. Conclusion
Motivation: Offshore Wind Turbine Foundations

Concrete
$d \approx 30 \text{ m}$

Steel
$d \approx 25 \text{ m}$
mostly used (67%)

Heavy steel
$d \approx 35 \text{ m}$

Laterace steel
$d \approx 45 \text{ m}$

Challenging Renewable Energy
EWEE target for offshore wind energy until 2020: 8,000 to 11,000 foundations
(until 2030: 45,000 OWTs)
Motivation: Scour protection

Unprotected pile
(1978: Model tests by Zanke)

Scour protection prior to Offshore Monopile installation is recommended:

- Mainly marine sandy bottom: Avoiding scouring
- Offshore maintenance and repair works are expensive

\[ S = 1.3 \times D_{\text{pile}} \]

(± 0.7 standard deviation)
Fredsøe & Sumer, 2002
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Protected pile with **Geotextile Sand-filled Containers**
(Offshore Met Mast scour protection since 7 years in service, \(d = 20\) m)
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Side-Scan-Sonar Offshore Met Mast „Amrumbank West“ / North Sea:

- Protected pile ($\varnothing = 3.50$ m)
- 450 pcs. Geotextile Sand-filled Containers (GSC) made from Nonwoven
- random pattern around the pile at the bottom

Protected pile with Geotextile Sand-filled Containers
(Offshore Met Mast scour protection since 7 years in service, $d = 20$ m)
Why Scour protection?  —  Scour Protection  —  Design  —  Practice  —  Conclusion

Scour Countermeasure Elements

Two essential elements:

**Armour layer**: confining stress against depression and protection against movement of granular filter layer

**Filter layer**: smaller grained material for bottom stabilization (avoiding sediment movement)

Movable bed/bottom (sandy or silt type soil is encountered and in water depths of approx. 10-25 m)

Source: Ramboll, 2010
Geotextile scour protection with GSC

1. **GSC combines filter and armour in one element**
2. High performance thick needle-punched nonwovens for filtration, robustness and abrasion resistance
3. Straightened and simplified construction process (pre-installed)
4. Soft system: No risk of damages for cable devices
5. Flexible system: high adaptability to bottom / bed movement actions
6. Best replication of natural bottom

No additional granular layer required!
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Main load case: filling and installation phase!
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Requirement: Deformation capability

➔ reached by NP NW (needle-punched nonwovens)
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Source: Ingenieurbüro Mohn
Basic Design Rules

- Required GSC fill volume ➔ sufficient weight of GSC

Rule of thumb for OWT scour protection:
„As large as necessary, as small as possible“
Basic Design Rules

- **Required GSC fill volume ➔ sufficient weight of GSC**
- Model scale: 1:17 - $H_S = 10.8\text{m}$, $T_P = 13.8\text{s}$, $d = 37.5\text{ m}$, Regular waves and JONSWAP spectra - No tidal currents

Experimental results – GSC as scour protection (I/II)

- Required fill volume ➞ sufficient weight of GSC

- Location: 34 km NW of Sylt / North Sea
- Water depth: \( d = 21 \) m
- Pile diameter: \( D = 5.5 \) m
- Design wave: \( H = 12.5 \) m; \( T = 14 \) s
- Protection with NWSC
- Scope: Verification in model scale 1:10

Source: Sparboom et al. (2007ff)
Large-scale investigations on scour protection for monopile foundations
For offshore wind foundations

Coastal Research Center (FZK)
Large Wave Flume (GWK)
Hannover
Experimental results – GSC as scour protection (I/II)

- Required fill volume → sufficient weight of GSC

Results:
1. High fill rate (against internal sediment movement) provides higher hydraulic stability against displacement
2. Randomly placed GSC provide higher stability than regularly placed GSC
3. Fill rate ≥ 85%, weight ~ 3.5 tonnes
Experimental results – GSC as scour protection (II/II)

• Required fill volume $\Rightarrow$ sufficient weight of GSC

Experimental results – GSC as scour protection (II/II)

- Required fill volume ➞ sufficient weight of GSC

Experiences by practice – GSC as scour stabilization (I/II)

- Germany’s most severe scour problems / North Sea storm flood barrage (1993)

Scour stabilization: 45° scour slope up to 30 m water depth

Source: contractor group (ARGE) Eidersperrwerk
Experiences by practice – GSC as scour stabilization (I/II)

- Germany’s most severe scour problems / North Sea storm flood barrage (1993)

**Question:** How to install a granular filter layer 2/150 mm in 30 m depth without segregation?

**Solution:** Encapsulation into 48,000 nonwoven GSC / dumped from water surface.
Experiences by practice – GSC as scour stabilization (I/II)

- Germany’s most severe scour problems / North Sea storm flood barrage (1993)

Filling (movable twin fill device)

Sources: Boskalis Hirdes & NAUE
Experiences by practice – GSC as scour stabilization (I/II)

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Transport and Installation

Installation with stone dumping vessel - daily rate = 700 NWSC

Sources: Boskalis Hirdes & NAUE
Experiences by practice – GSC as scour stabilization (I/II)

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Total amount nonwoven NWSC: 48,000
Installation period: April – August 1993
Less then a number of 10 GSC were damaged!!

Dumping depth = 30 m

Sources: Boskalis Hirdes & NAUE
Experiences by practice – GSC as scour stabilization (II/II)

- Quay wall island Sylt / North Sea / Germany (1994) – 23,000 GSC

- Nonwoven GSC as scour stabilization
- Not covered
- Since 1995 still in practice successfully
Experiences by practice – GSC as scour stabilization (II/II)

- Quay wall island Sylt / North Sea / Germany (1994) – 23,000 GSC

*Source: NAUE GmbH & Co. KG*
Conclusion

• Geotextile sand-filled containers (GSC) made of
  
  … needle-punched filter nonwoven (NWSC),
  … filled with soil (sand) with a volume \( V \geq 1 \text{ m}^3 \),
  … installed randomly,
  … in a minimum two-layer-system prior to
  … pile driving

provide an effective scour protection system for offshore wind turbine foundations without any additional granular filter or armour layers.
Thank you for your kind attention!

For more information, please visit our booth!

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