Offshore Wind Energy Foundations

Geotextile Sand-Filled Containers as Effective Scour Protection System

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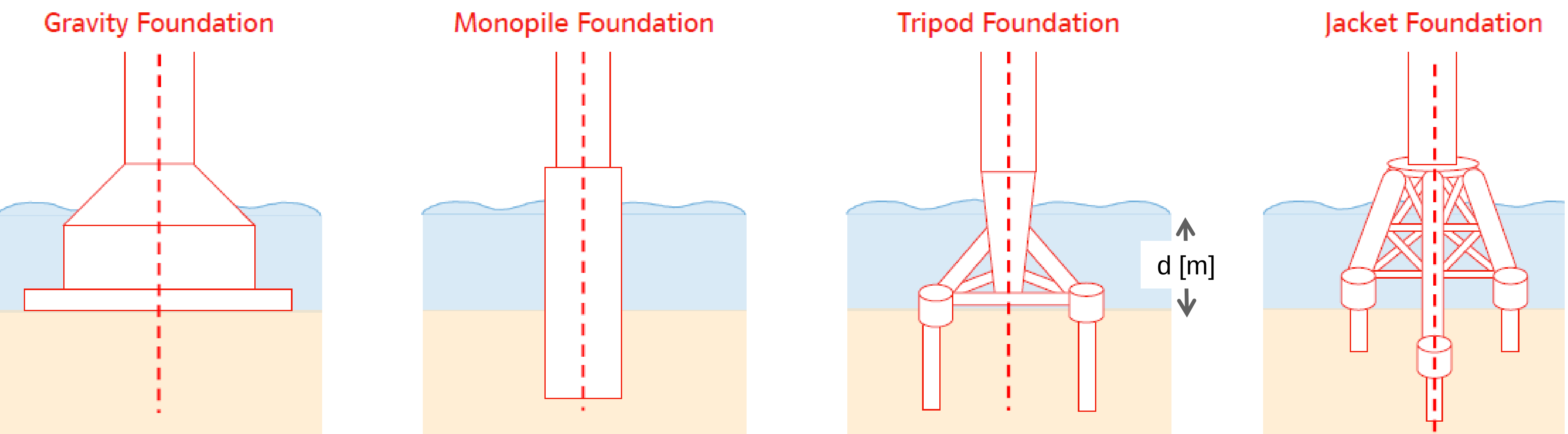
1. Motivation. Why Scour Protection? Processes and Terms of definitions
2. Scour Protection & Materials Methods, geotextile Containers GSC
3. Design Fundamentals Efficiency, hydraulic stability
4. Practical experiences GSC as scour stabilization
5. Conclusion

Motivation: Offshore Wind Turbine Foundations



Concrete
d ≈ 30 m

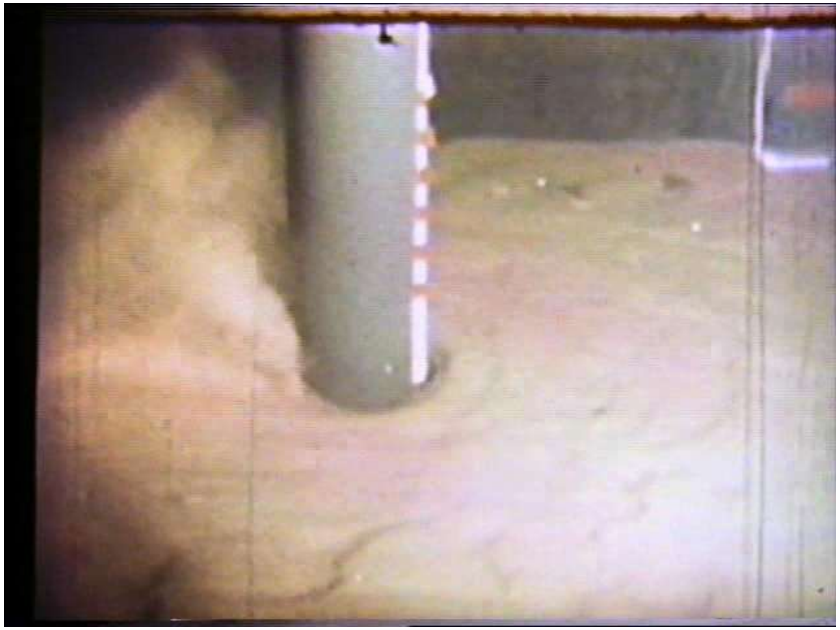
Steel
d ≈ 25 m
mostly used (67%)

Heavy steel
d ≈ 35 m

Laterace steel
d ≈ 45 m

Challenging Renewable Energy
EWEA 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)

$$S = 1.3 \times D_{pile}$$

(± 0.7 standard deviation)
Fredsøe & Sumer, 2002

Scour protection prior to Offshore Monopile installation is recommended:

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

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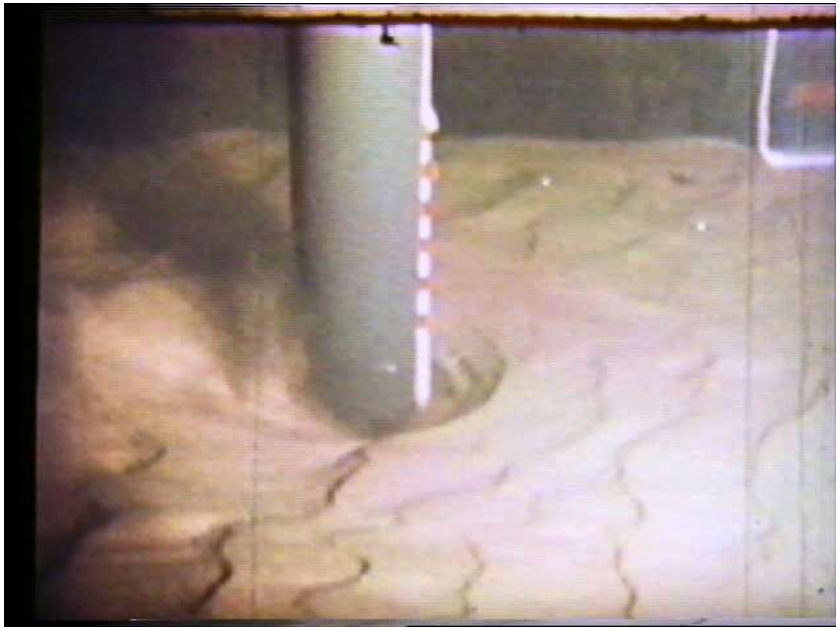

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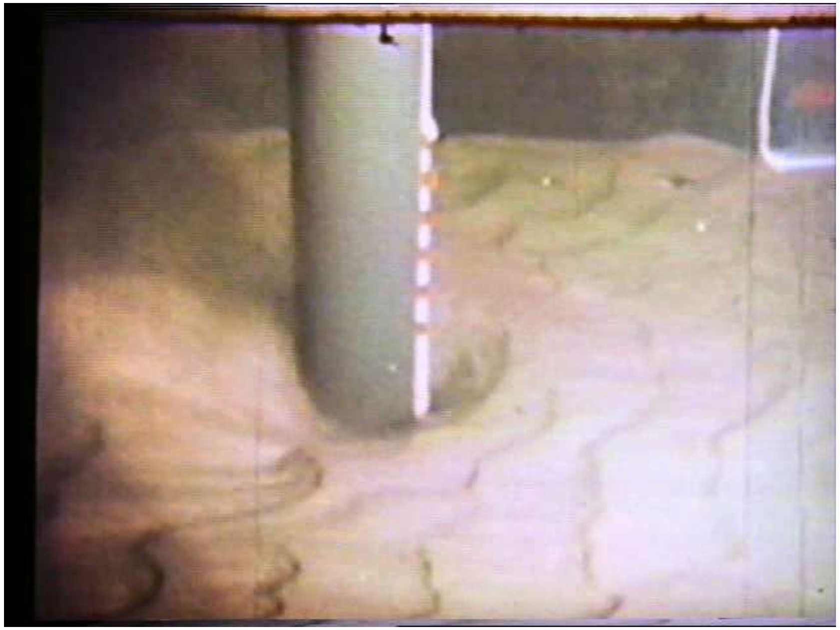

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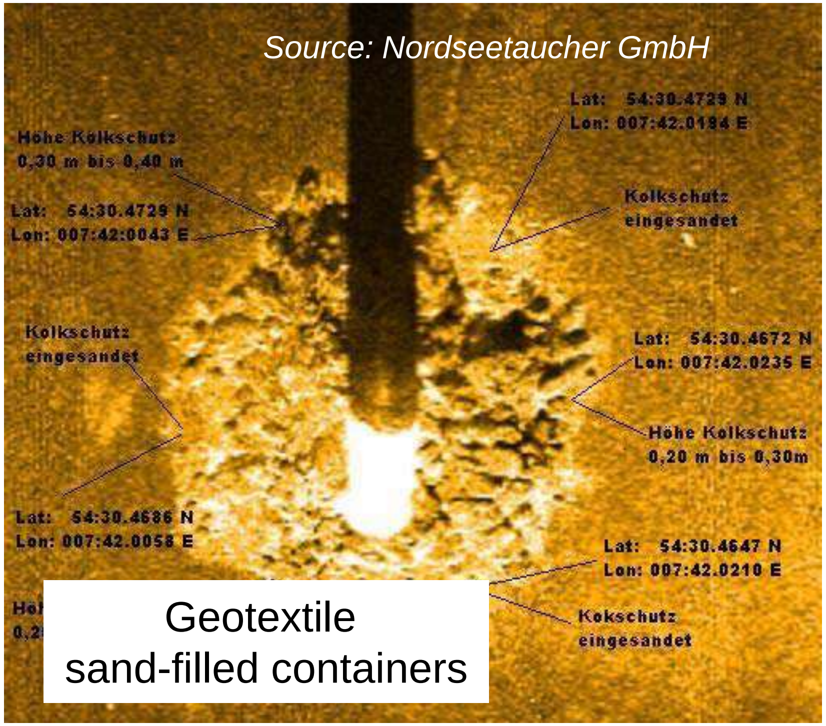

Protected pile with Geotextile Sand-filled Containers

(Offshore Met Mast scour protection since 7 years in service, d = 20 m)

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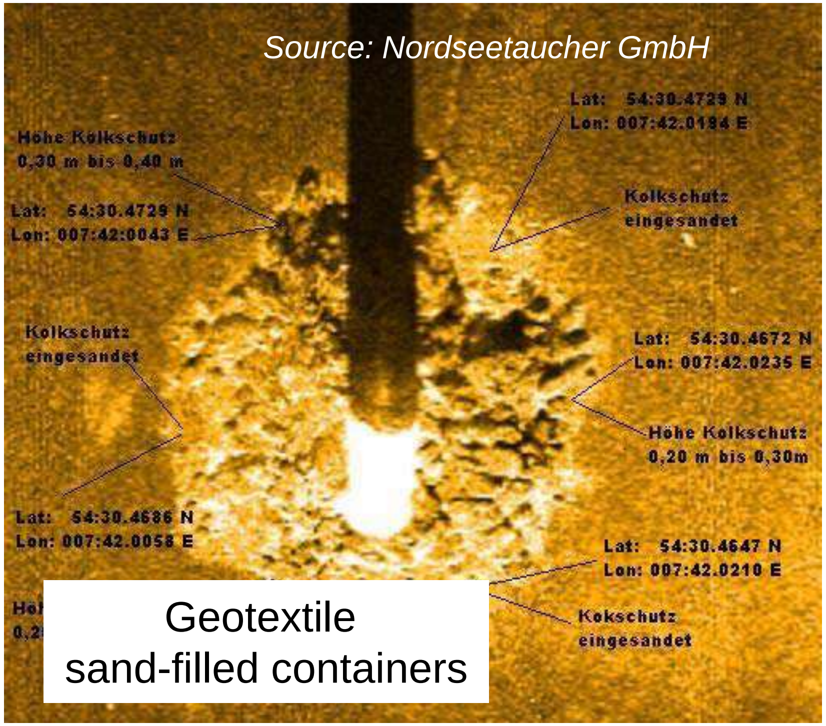


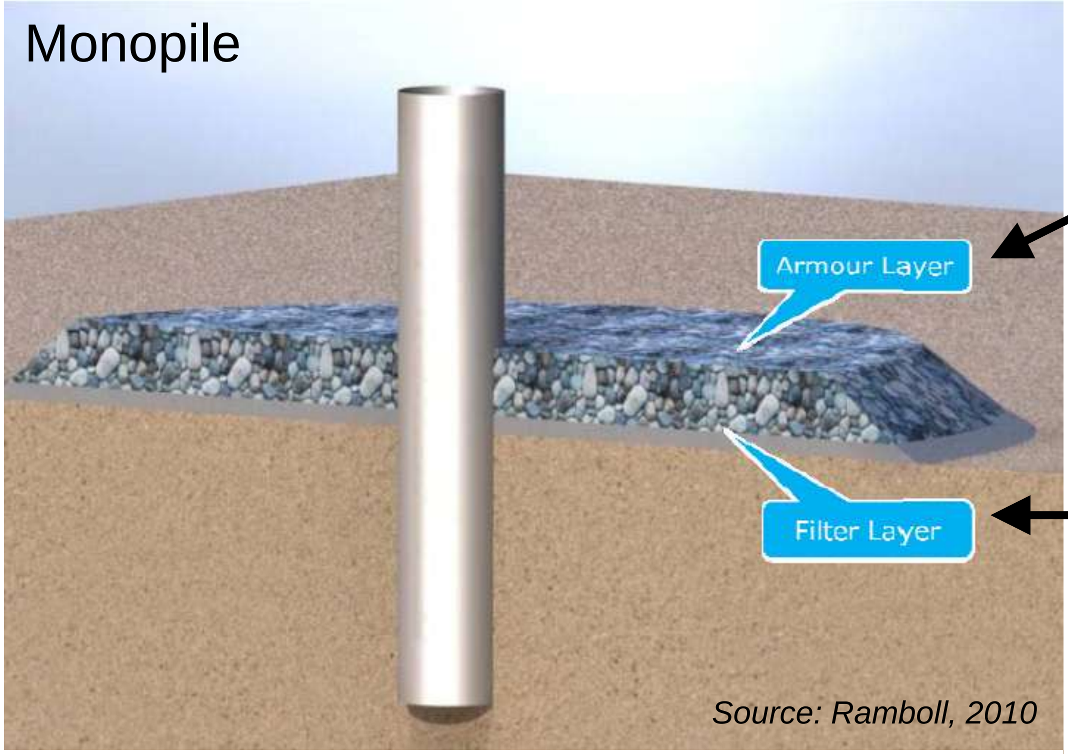
Side-Scan-Sonar
Offshore Met Mast „Amrumbank West“ / North Sea:

- Protected pile (**∅ = 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)

Scour Countermeasure Elements



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

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)

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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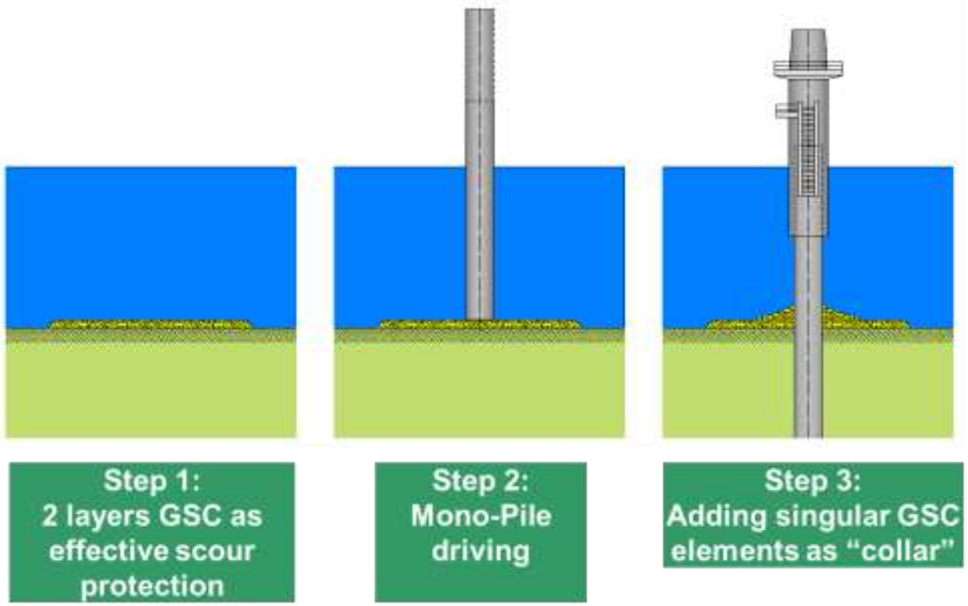

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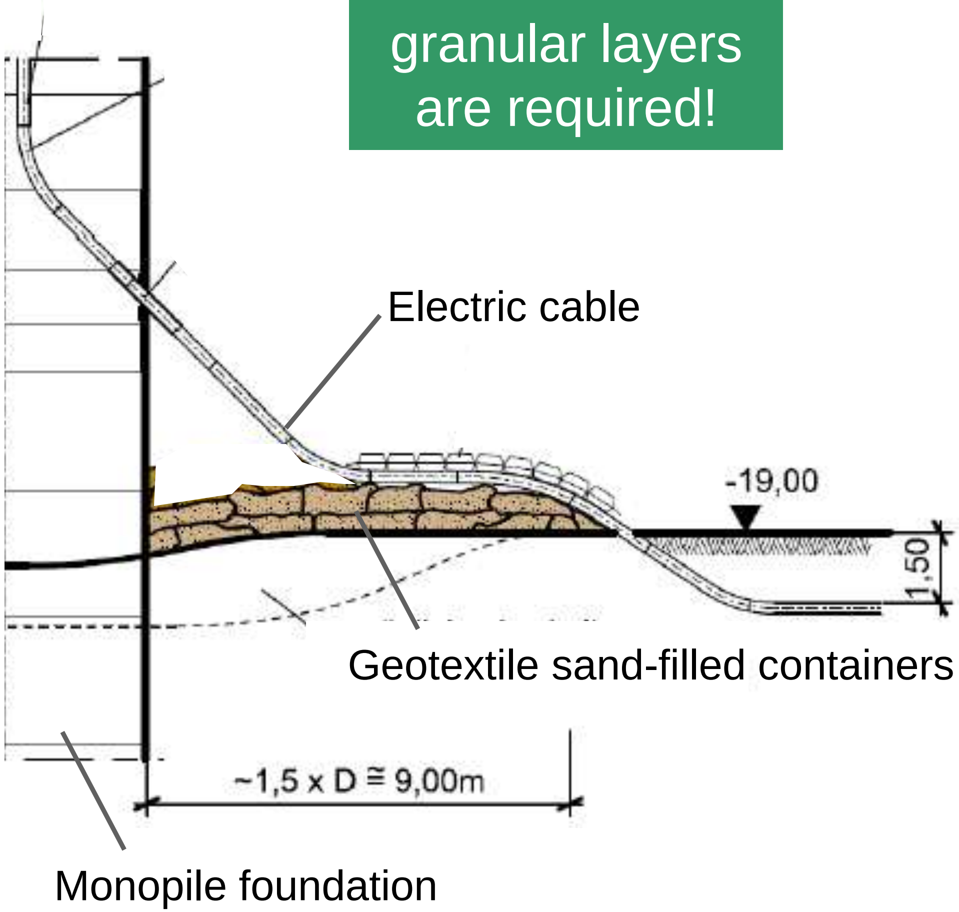
No additional granular layers are required!



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Requirement:
Deformation capability
➔ reached by NP NW (needle-punched nonwovens)

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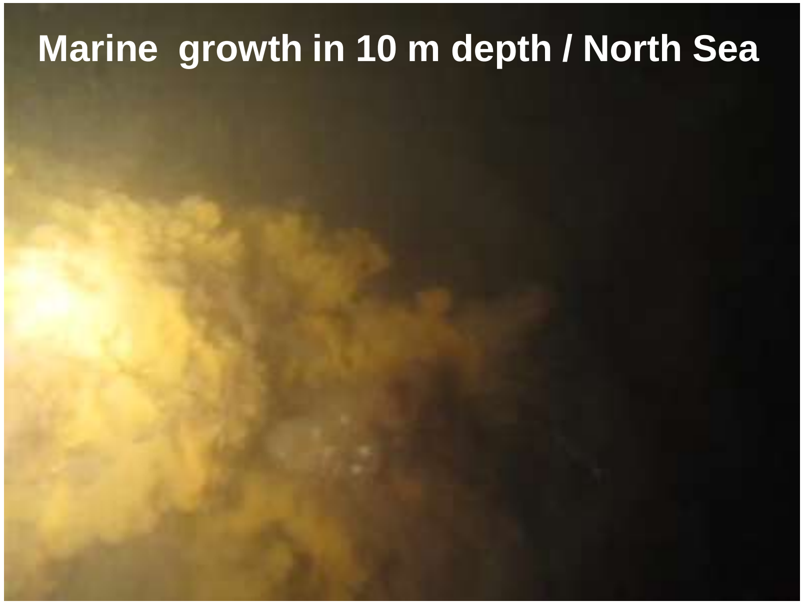

Source: Ingenieurbüro Mohn

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Basic Design Rules

- **Required GSC fill volume ➔ sufficient weight of GSC**

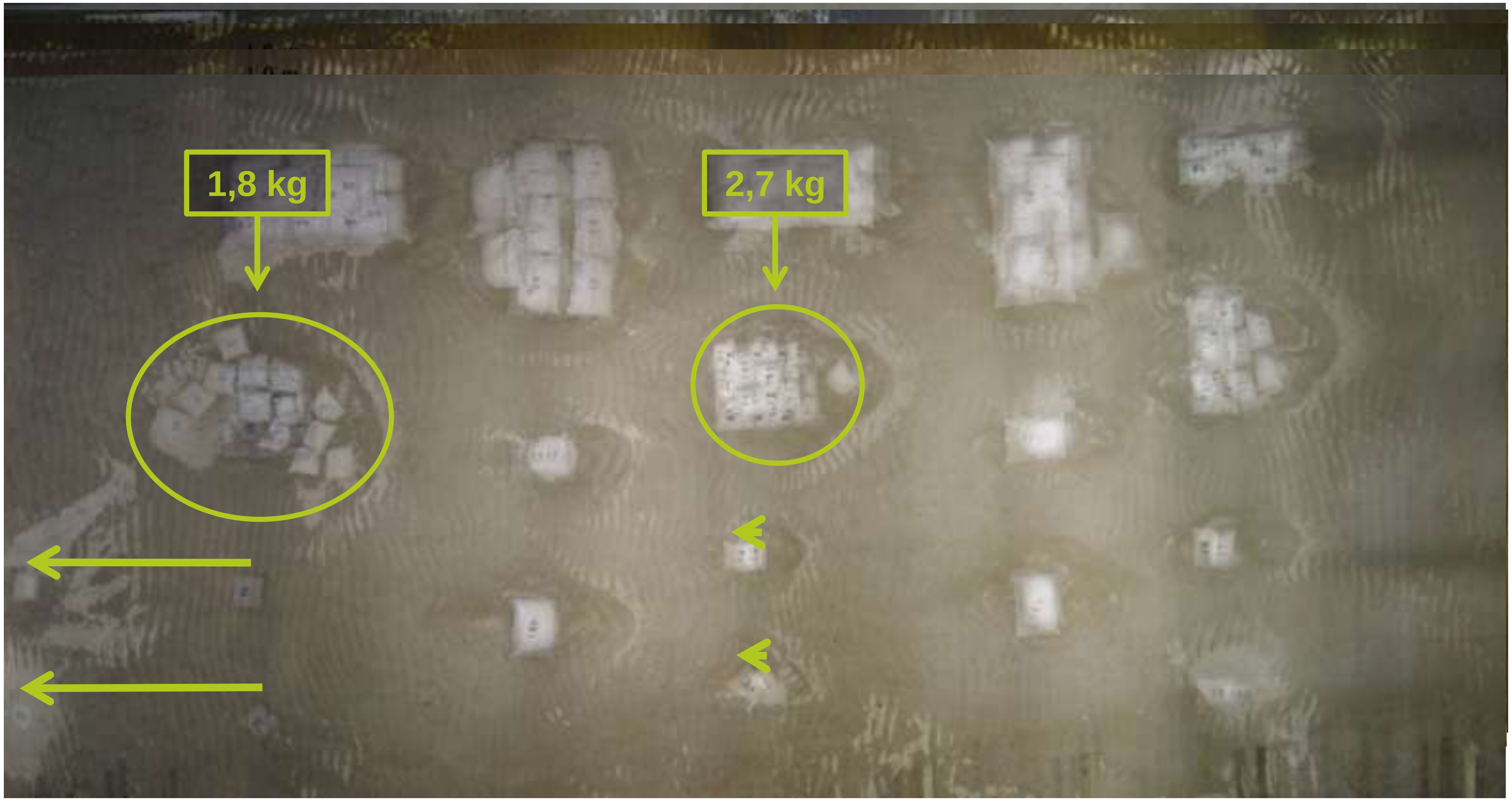
Natural scale 1:1

Model scale 1:17

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 = 10.8m, T_P = 13.8s, d = 37.5 m, Regular waves and JONSWAP spectra - No tidal currents



Source: Wilms, Wahrmund, Stahlmann, Heitz, Schlurmann (2011)

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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)

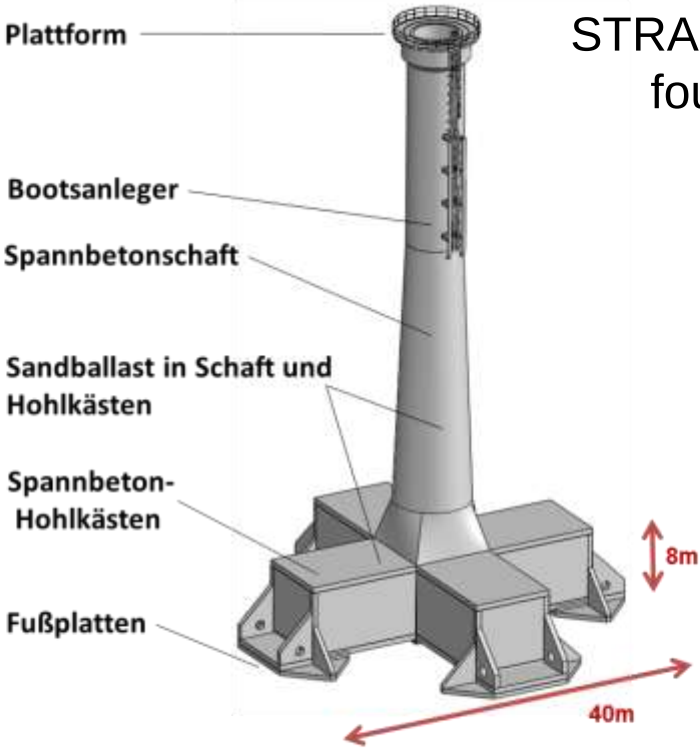
- **Required fill volume ➔ sufficient weight of GSC**

Results:

1. High fill rate (against internal sediment movement) provides higher hydraulic stability against displacement
2. Randomly placed GSC provide higher stability then regularly placed GSC
3. fill rate ≥ 85%, weight ~ 3.5 tonnes

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

- **Required fill volume → sufficient weight of GSC**



STRABAG gravity foundation

Source: Wilms, Wahrmund, Stahlmann, Heitz, Schlurmann (2011)

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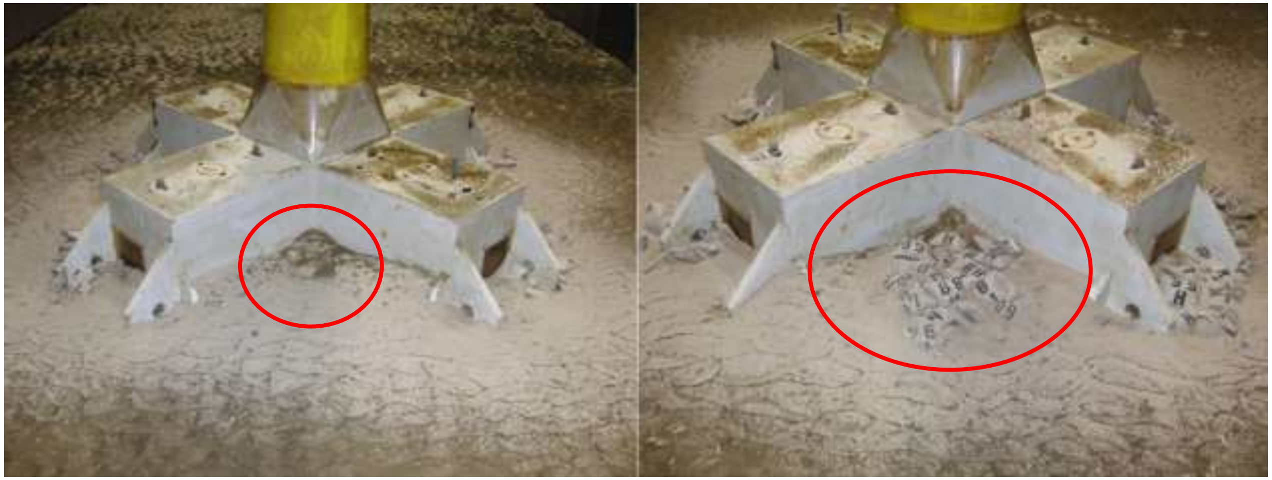
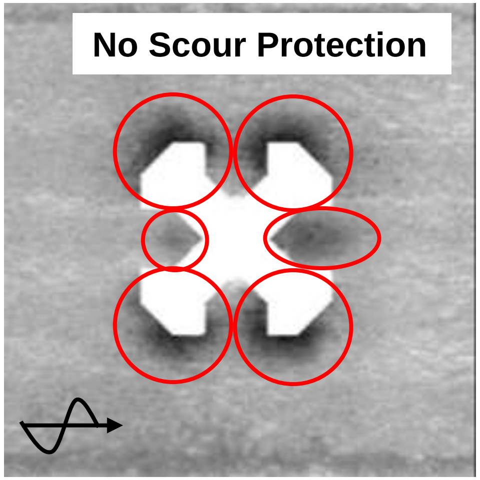
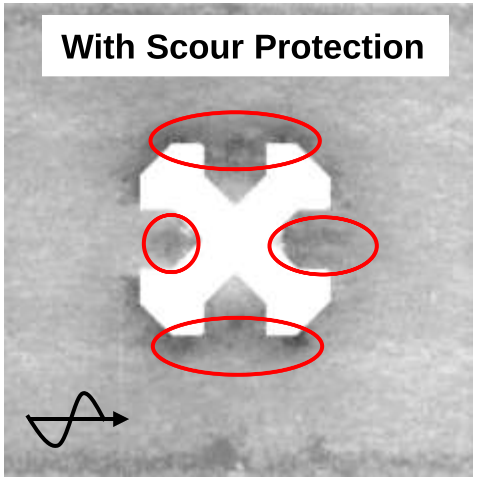


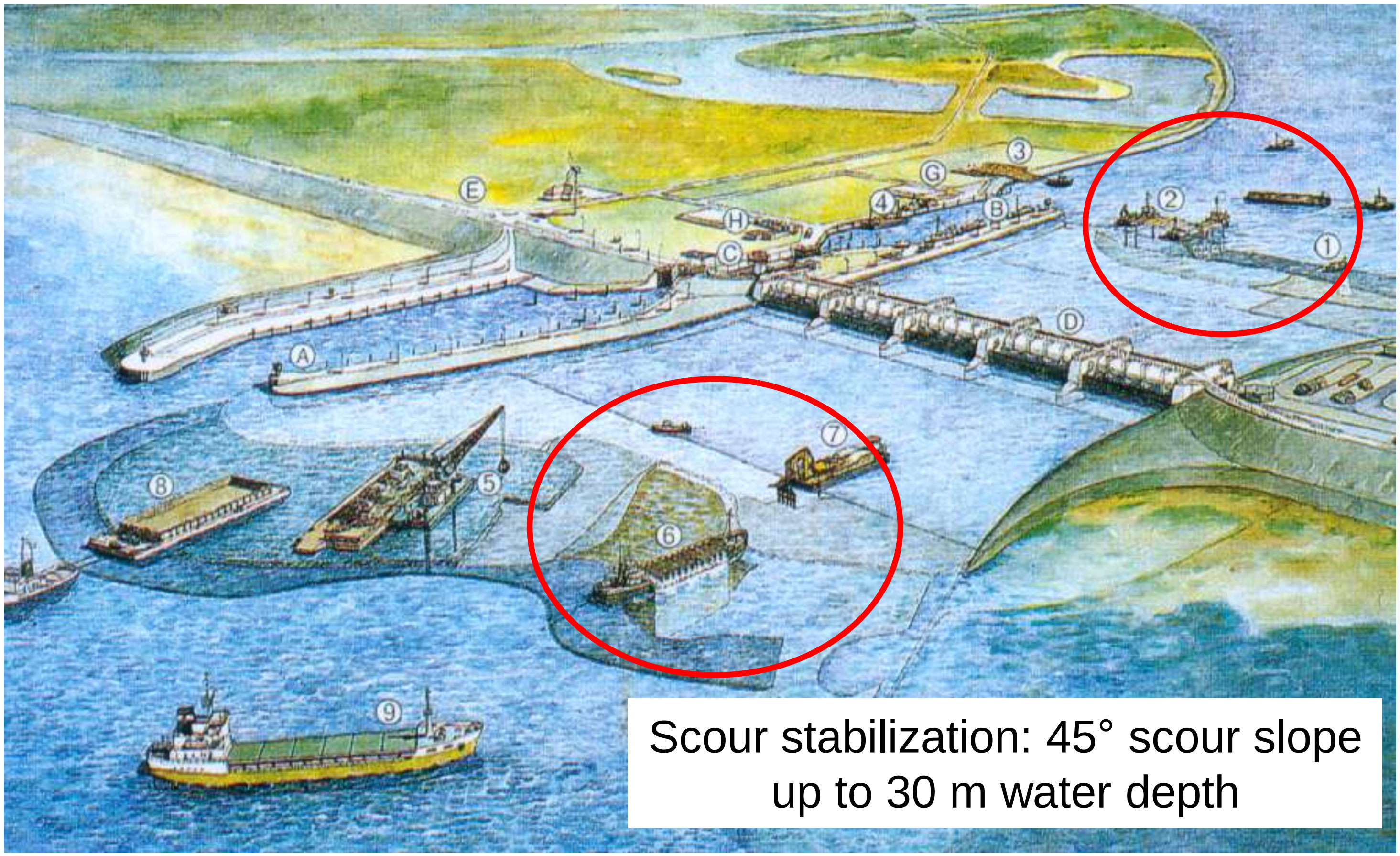




Source:
Wilms, Wahrmund, Stahlmann, Heitz, Schlurmann (2011)

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

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



Source: contractor group (ARGE) Eidersperrwerk

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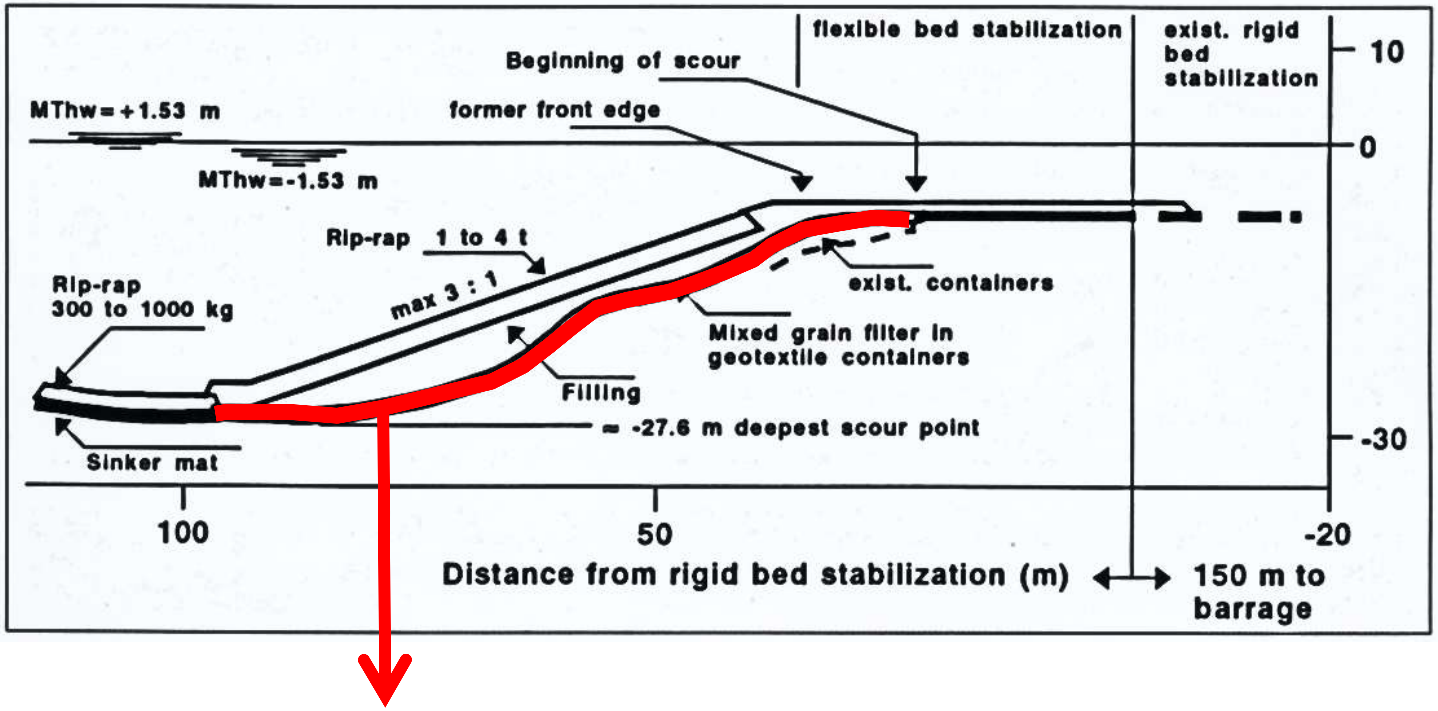

Unexpected success

- Question: How to install a granular filter layer 2/150 mm in 30 m depth without seggregation?
- 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)

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

Installation with stone dumping vessel - daily rate = 700 NWSC

Sources: Boskalis Hirdes & NAUE

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

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

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

Sources: Boskalis Hirdes & NAUE

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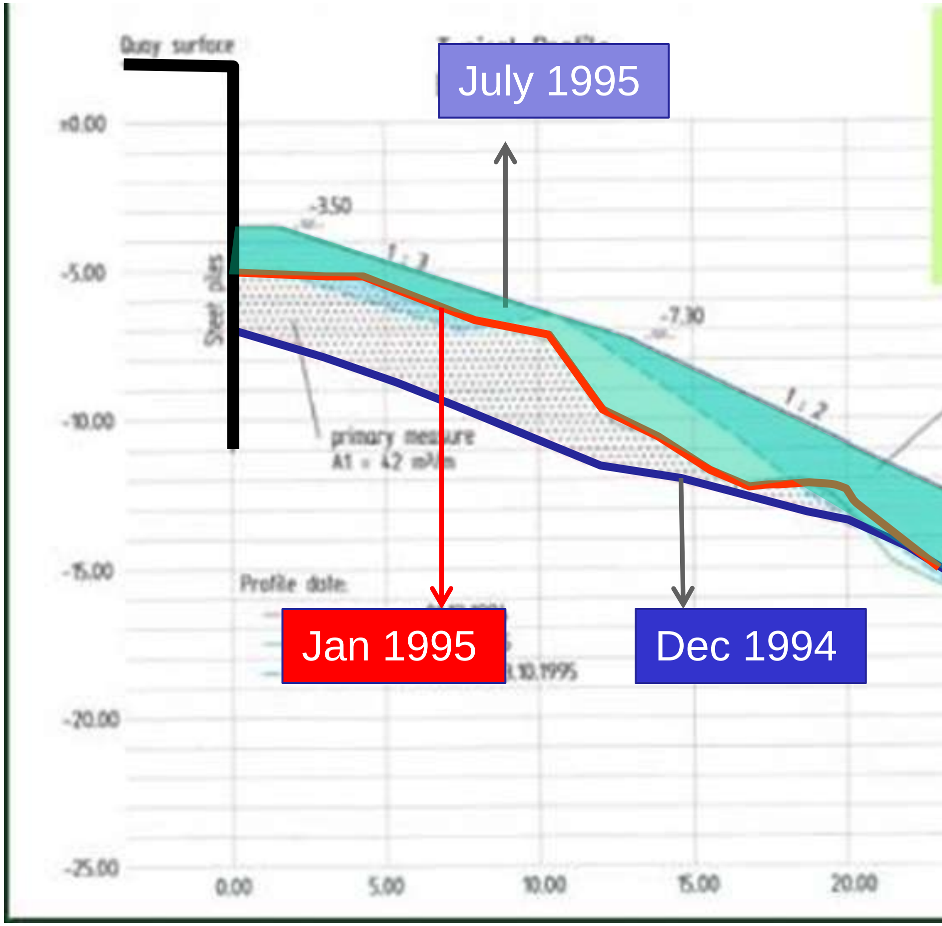
Experiences by practice – GSC as scour stabilization (II/II)

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



- Nonwoven GSC as scour stabilization
- Not covered
- Since 1995 still in practice succesfully

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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 $V \geq 1\ m^3$,

  … 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!

kwerth@bbgeo.com