TC209 Offshore Geotechnics

Geotechnics for Offshore Wind

Setting the scene – Phil Watson

A developer's perspective of geotechnics for offshore wind – Elisabeth Palix

An overview of ‘new’ challenges facing offshore wind – Zack Westgate

Geotechnical research to support offshore wind – Christelle Abadie

Close – Phil Watson
New challenges facing offshore wind

- **US west coast (floating):** seismic loading, bedrock, unconsolidated sediments, debris flows
- **US east coast (fixed):** boulders, glauconite, carbonates
- **NW Europe (fixed):** chalks, calcarenite
- **Southeast Asia (fixed):** soft, compressible, liquefiable, layered silts and sands
- **Australia (fixed):** carbonate and calcareous sediments, calcarenite
New challenges facing offshore wind

“Site” characterization: a global challenge

Massive areas (>> 100 km²), lots of spatial variability, increasing sense of urgency (2-3 years of SI)

- Gullies, paleochannels
- Thin weak layers, cementation
- Over 40 soil units identified
- Many with both undrained and drained parameters

Some island area context:
- Manhattan (NYC): 60 km²
- Martha's Vineyard: 227 km²
- Islay, Scotland: 620 km²
- Oahu, Hawaii: 1500 km²

DeGroot et al. 2023
New challenges facing offshore wind

Glacial geology and changing sea levels

- Changing sea level: US East Coast low sea level stand ~ 120m below present-day
- Glacial retreat: glacial outwash, terminal moraines, recessional moraines, lodgment till, etc.

Oakley (2016)
Pendleton et al. (2019)
New challenges facing offshore wind

**Boulders**

- Deposited at terminal moraines
- Shallow and/or deep deposits
- Generally 1 to 6 m diameter, up to 15 m
- Risks: Pile buckling, cable trenching
- Mitigations: micrositing, removal

Credit: Mark Harrington

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Boulder mapping

Credit: Fugro 2018
New challenges facing offshore wind

Glauconite sand – what is it?

- iron rich potassium mica of illite clay family
- glaucony (morphological) vs glauconite and glauconitic (mineralogical)
- magnetic with high specific gravity (~ 3)
- authigenic (in situ) vs allogenic (reworked)

Westgate et al. (2023); after Obasi et al. (2011); López-Quirós et al. (2019)
New challenges facing offshore wind

Glauconite sand – how can we identify it?

CPT Identification:
- high $q_t$
- high $F_r$
- cavitation $u_2$
- or high positive $u_2$
- rod ‘smears’

Laboratory Identification:
- authigenic typically
  higher % glauconite
- magnetic separation
- XRD and XRF
- image analysis
- maturity based on K and Fe content

Westgate et al. 2024
New challenges facing offshore wind

Glauconite sand – SBT: misleading CPTs?

Robertson (2016) SBTn chart

Schneider (2008) chart
New challenges facing offshore wind

Glauconite sand – pile driving effects

NGI-led JIP at test site in New Jersey (UMass Amherst, Rutgers, U Arkansas, UMass Dartmouth)

Westgate et al. 2024

DeGroot et al. 2023

Westgate et al. 2024

Crushed glauconite from pile wall

Far-field glauconite

Percent passing (%)

Increasing dispersion cup mix time

Particle diameter (mm)
New challenges facing offshore wind

**Carbonate sediments**

![Map of USGS (1979) and Mid-Atlantic Planning Area](image1)

### T-bar resistance (MPa)

- **Non-carbonate**
  - $S_t > 10$
  - Depth (m)
  - $S_{u-cyc}/S_{u-mono}$

- **Carbonate**
  - $S_{u-cyc}/S'_{v}$

- Watson et al. 2019

![SEM Image of Calcium Carbonate Micrite](image2)

**Sharma and Joer 2015**

**Watson et al. 2019**
New challenges facing offshore wind

Chalk

- Soft, high porosity chalks of low-medium density
- Highly sensitive paste-like material along shaft (Zone A)
- Fractures, loss of lateral stiffness (Zones B, C)
- Pile runs, long term axial and lateral capacity challenges
- JIPs: Innovate-UK JIP (axial), ALPACA JIP (lateral field), ALPHA (lateral 3DFE)
New challenges facing offshore wind

Free falling piles

- Multiple incidents over past few years
  - Thrice on one project
- Soft, compressible soil?
  - check
- Weak layers?
  - check
- Potential liquefaction?
  - check
- Long, heavy monopiles?
  - check
- Poor site characterization?
  - Depends on who you ask!
New challenges facing offshore wind

Deep water geohazards: high seismicity

Morro Bay, Diablo Canyon Call Areas:
- San Andreas Fault

Humboldt Call Area:
- Cascadia Subduction Zone
New challenges facing offshore wind

Deep water geohazards: seabed conditions

Morro Bay, Diablo Canyon Call Areas:
- bedrock, unconsolidated sediments

Humboldt Call Area:
- bedrock, unconsolidated sediments
New challenges facing offshore wind

Deep water geohazards: landslide evidence

Many issues to consider for floating wind anchor selection and design