REDWIN – REDucing cost in offshore WINd by integrated structural and geotechnical design

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REDWIN

- 4-year research project
- Sponsors: NFR, Statoil, Vattenfall, Statkraft
- Partners: NGI, NTNU, IFE, Dr. Tech. Olav Olsen
- 16 mill NOK
- Bottom fixed OWT
- 1 year left
Load frequencies and eigen frequency

Blade load frequencies (1P and 3P)
- - - - Wind spectrum (Kaimal)
- - - - - - Wave spectrum (JONSWAP, Hs = 2.4 m)

Turbines:
DTU 10 MW
Vestas V164 (8MW)
Siemens SWT-6.0-154 (6MW)
Siemens SWT-3.6-107 (3.6 MW)
Vestas V90 and V91 (3MW)

The importance of the foundation
The importance of the foundation


Integrated dynamic analyses

- Aero dynamics
- Hydro dynamics
- Struktural dynamic
- Turbine controller (pitch)
- Soil/foundation response
Geotechnical involvement

- SI/labotory testing
- Site soil interpretation
- Compute foundation response
- Implement in integrated analyses
- Integrated analyses

REDWIN
Current practise

- p-y springs (API, PISA) for monopiles
- Linear elastic springs for shallow fundations

![Graph showing the comparison between γ/γ_f ratios and τ/τ_f ratios with iterations for structural analyses and foundation stiffness updates.](image)
REDWIN model principles

- Application oriented models, such that the choice of model appear intuitive.
- User interface understandable for practitioners.
- General models, adaptable to different ground conditions.
- The models have to work in time domain analyses.
Monopiles

Soil–support model

\( p, y \)

\( \rho \)

\( y \)

Foundation–structure interface

Stiffness

Damping

Load

Foundation and substructure Model applicable Loading regime

Redwin model 1

Distributed 1D model to be applied to any DOF.

Redwin model 2

HM-loading

Redwin model 3

VHM-loading

Soil–support model

Foundation model
Monopiles

Foundation and substructure

Model applicable

Loading regime

Redwin model 1

Distributed 1D model to be applied to any DOF.

Redwin model 2

HM-loading

Redwin model 3

VHM-loading

Soil – support model

Foundation – structure interface

Seabed and foundation – structure interface

Foundation model
Gravity based foundations

Foundation – structure interface

Foundation model

Redwin model 1
Distributed 1D model to be applied to any DOF.

Redwin model 2
HM-loading

Redwin model 3
VHM-loading

Soil – support model

Foundation – structure interface

Foundation model
Bucket foundations

Foundation – structure interface

Foundation model

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<th>Foundation and substructure</th>
<th>Model applicable</th>
<th>Loading regime</th>
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Model demonstration

a)

b)

c)

\[ v, H, M \]

\[ U_{xx}, U_{yy}, U_{zz} \]

a)

\[ 2M/D (kN) \]

\[ 0 \]

\[ 1000 \]

\[ 0 \]

\[ -1000 \]

\[ -1000 \]

\[ -2000 \]

\[ 0 \]

\[ 100 \]

\[ 0 \]

\[ 500 \]

\[ 600 \]

Time (s)
Foundation damping

\[ D_{\text{found}} = \frac{\sum (V \cdot E_h)}{4\pi \sum (V \cdot E_p)} \]
Effect of foundation behaviour on fatigue

- Mode A: p-y elements
- Model B: Lumped linear elastic
- Model C: Lumped linear elastic with viscous damper
- Model D: Lumped nonlinear REDWIN model 1

Comparison of model and measured response

Normalized PSD

Revised analyses with Redwin model 2

Design prediction range
Summary and conclusions

- The models and tools developed in REDWIN seems to contribute to more accurate descriptions of foundations in design.
- They include damping, which is often neglected.
- The knowledge of soil and site can be better utilized in design.
- Improved accuracy reduce costs.
- Currently working on cost reduction effects in more detail.
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And thanks for your attention!