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

EERA DEEPWIND January 2018

Skau, K.S., Senior engineer, NGI and PhD candidate, NTNU
Kaynia, A.M., Technical Expert and Professor II, NTNU
Page, A.M., PhD Candidate, NTNU
Løvholt, F., Senior Specialist, NGI
Norén-Cosgriff, K., Head of Section CGM, NGI
Sturm, H., Discipline leader Offshore renewables, NGI
Jostad, H.P., Technical director offshore energy NGI and Professor II, NTNU
Nygard, T.A., Senior researcher IFE and Professor, NMBU
Andersen, H.S., Structural Engineer, Dr. Tech Olav Olsen
Eiksund, G., Professor, NTNU
Havmøller, O., Senior researcher, Statoil ASA
Strøm, P., Lead Geotechnical Engineering, Statoil ASA
Eichler, D., Senior Lead Structural Engineer, Vattenfall

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

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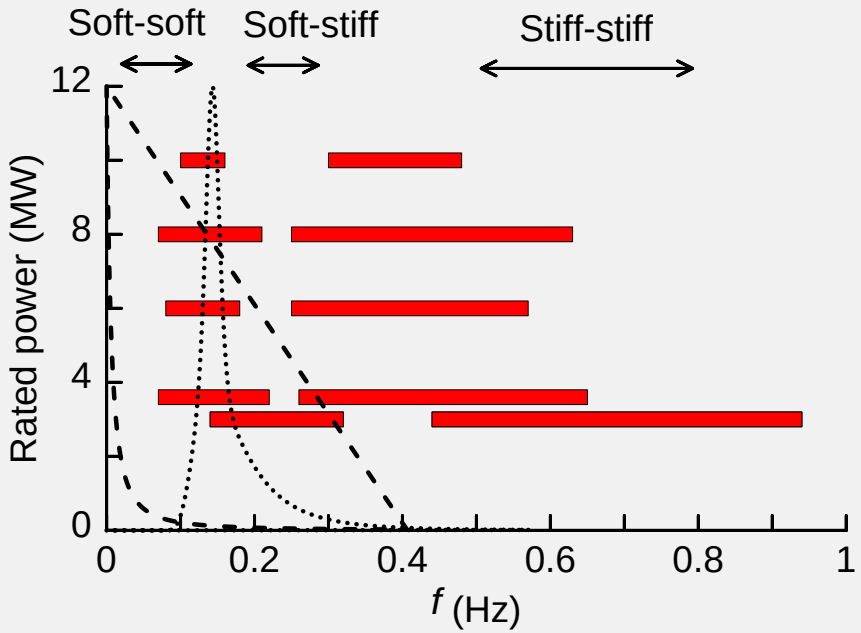
Load frequencies and eigen frequncy



Blade load frequencies (1P and 3P)

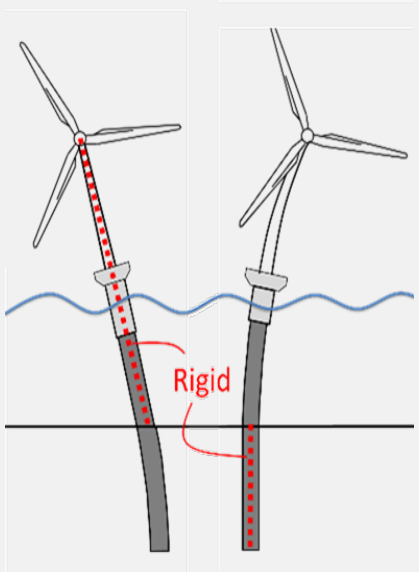
Wind spectrum (Kaimal)

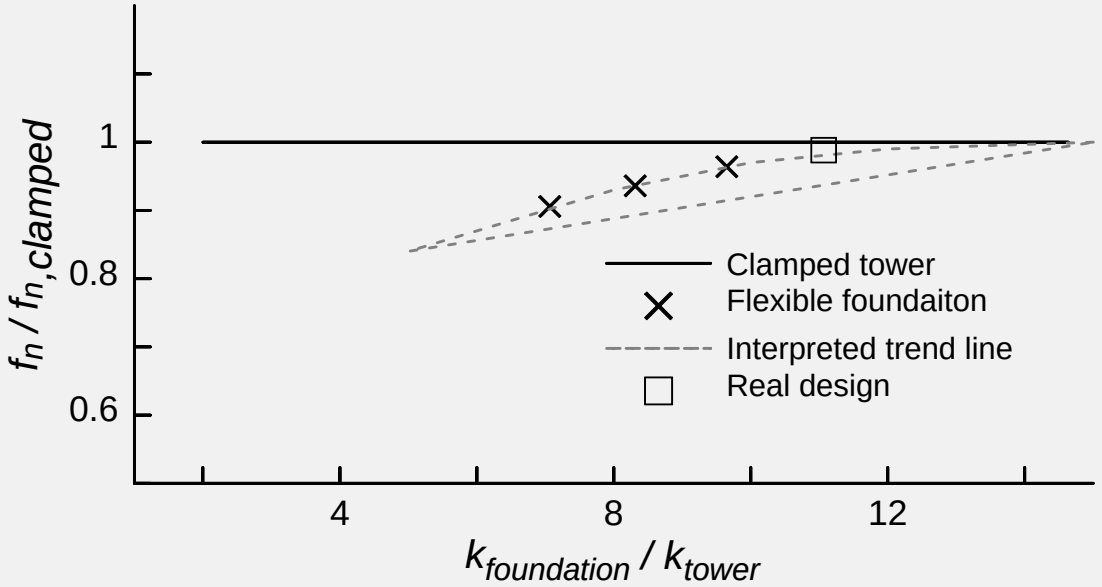
Wave spectrum (JONSWAP, H^s = 2.4 m)

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)

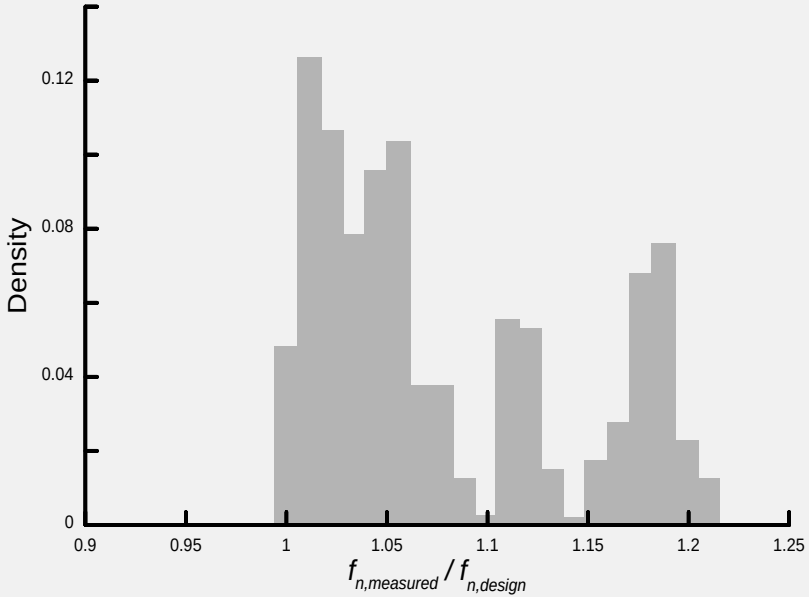
Source: Arany, L., Bhattacharya, S., Macdonald, J. H. G. and Hogan, S. J. (2016)

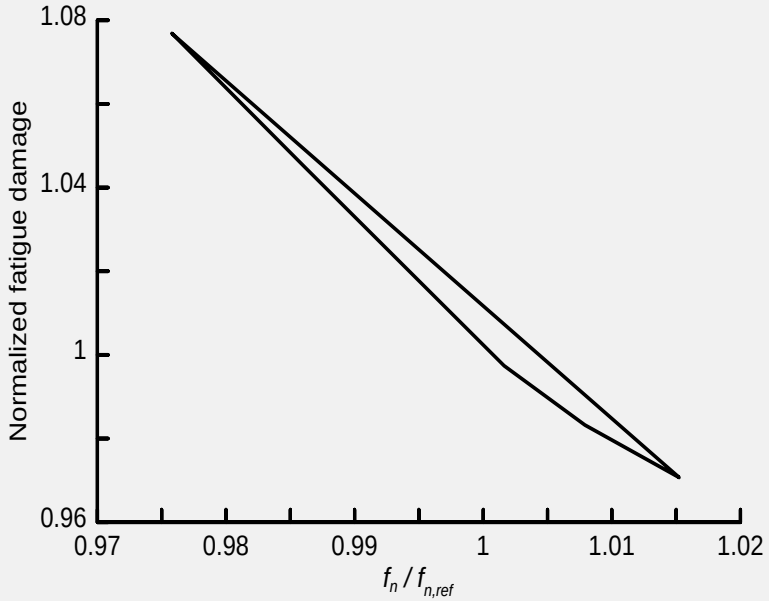
The importance of the foundation





The importance of the foundation



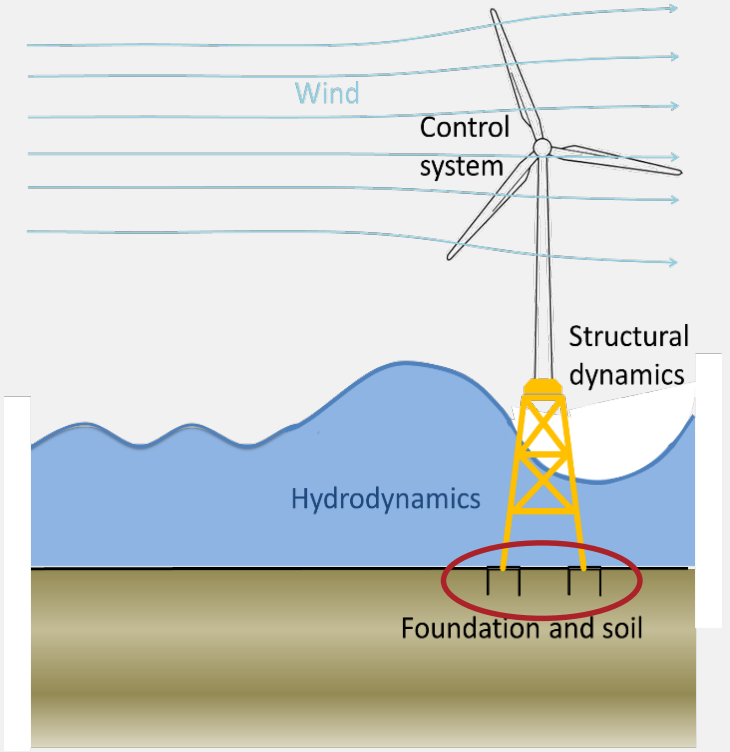


Source: Kallehave, D., Byrne, B. W., LeBlanc Thilsted, C. and Mikkelsen, K. K. (2015)

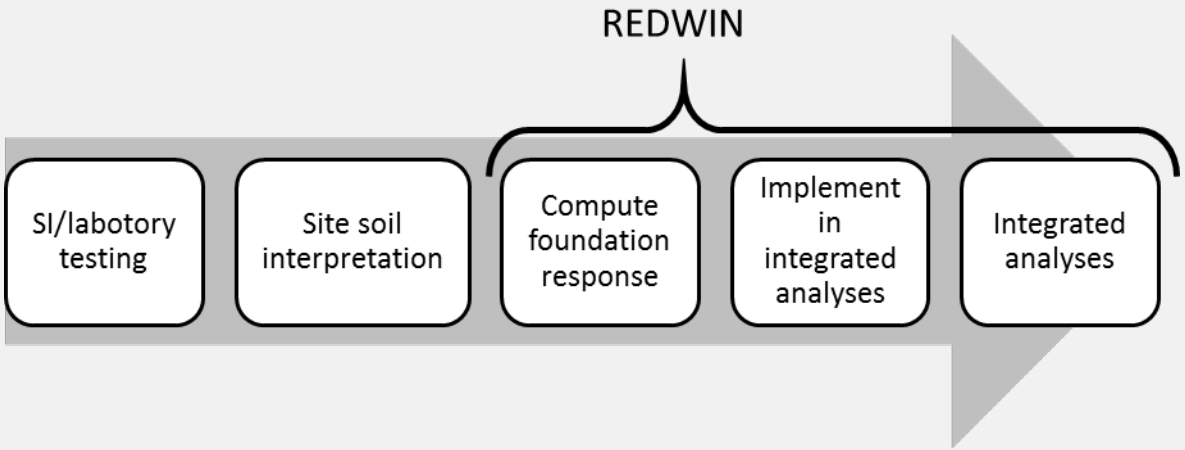
Adapted from: Schafhirt, S., Page, A., Eiksund, G. R. and Muskulus, M. (2016)

Integrated dynamic analyses

- Aero dynamics
- Hydro dynamics
- Struktural dynamic
- Turbine controller (pitch)
- Soil/foundation respons

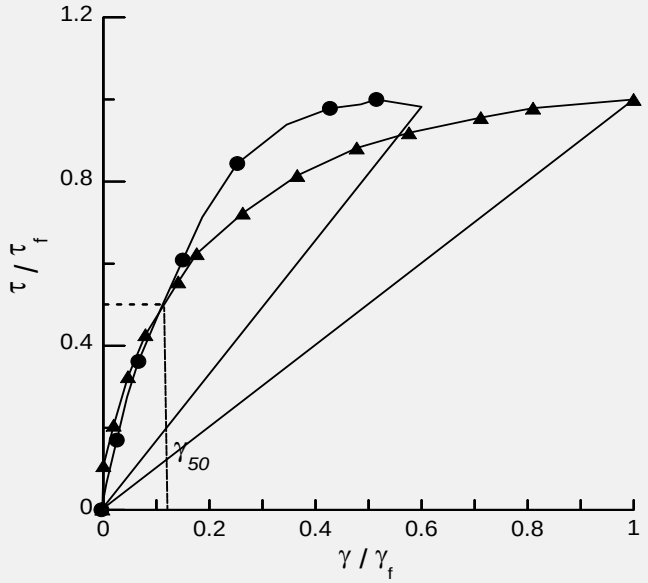


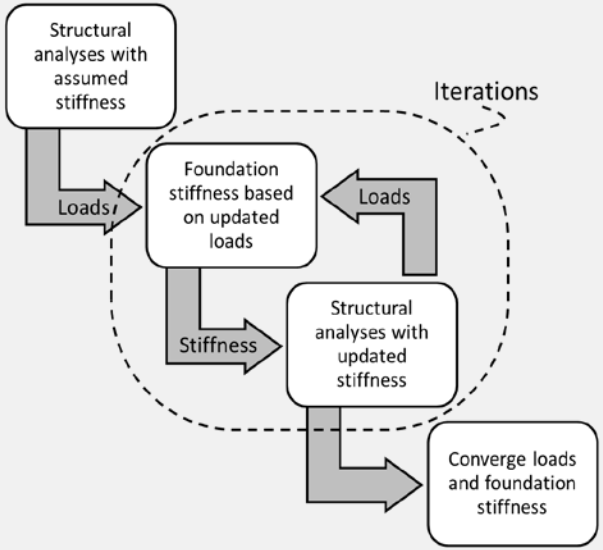
Geotechnical involvment



Current practise

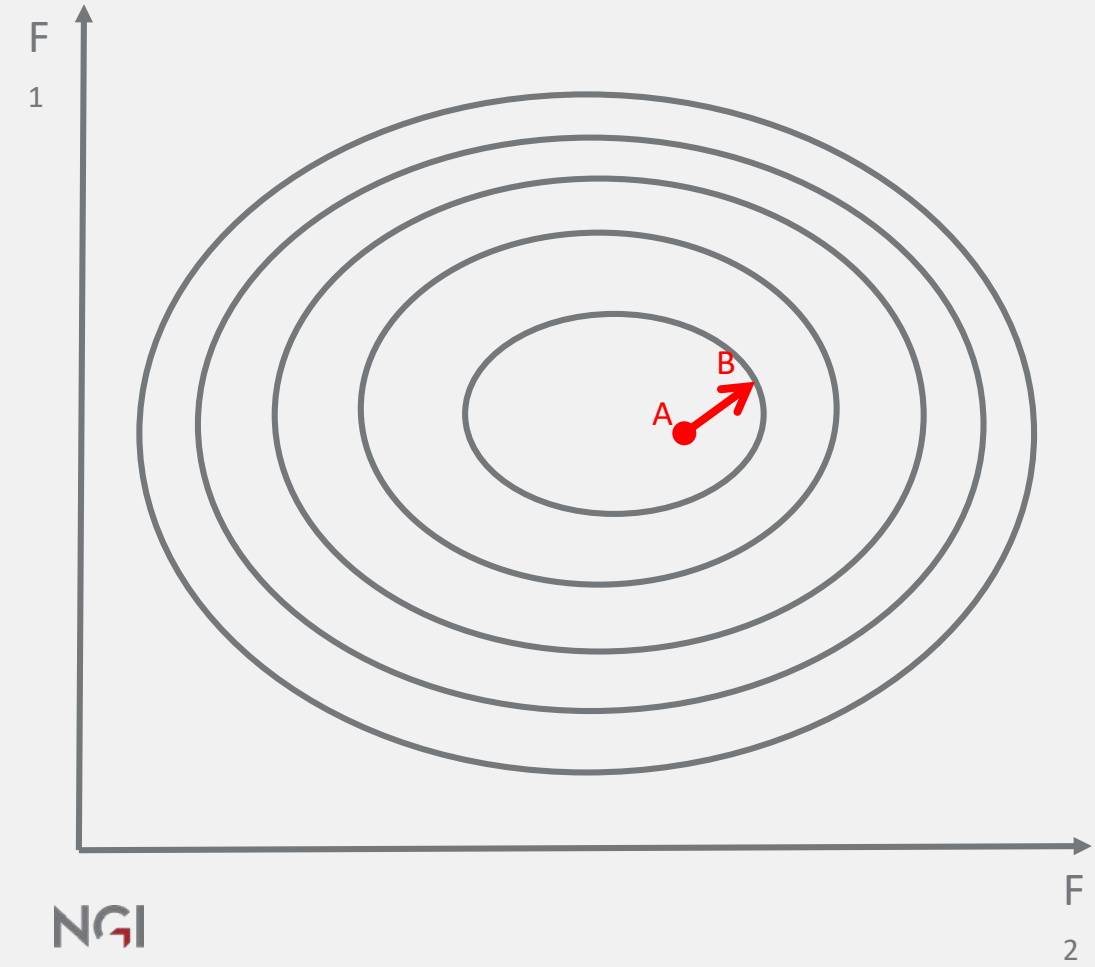
- *p-y* springs (API, PISA) for monopiles
- Linear elastic springs for shallow fundations

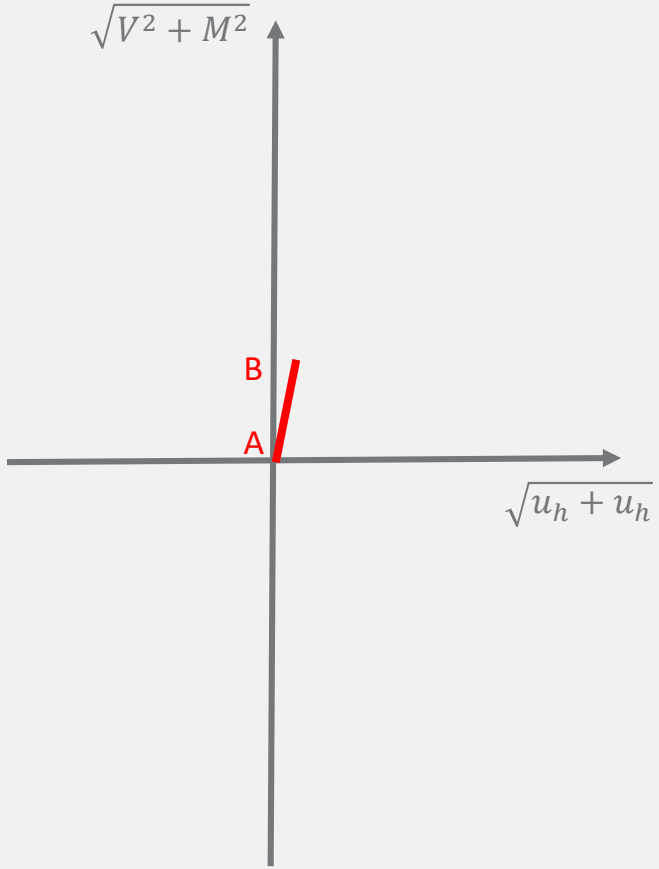


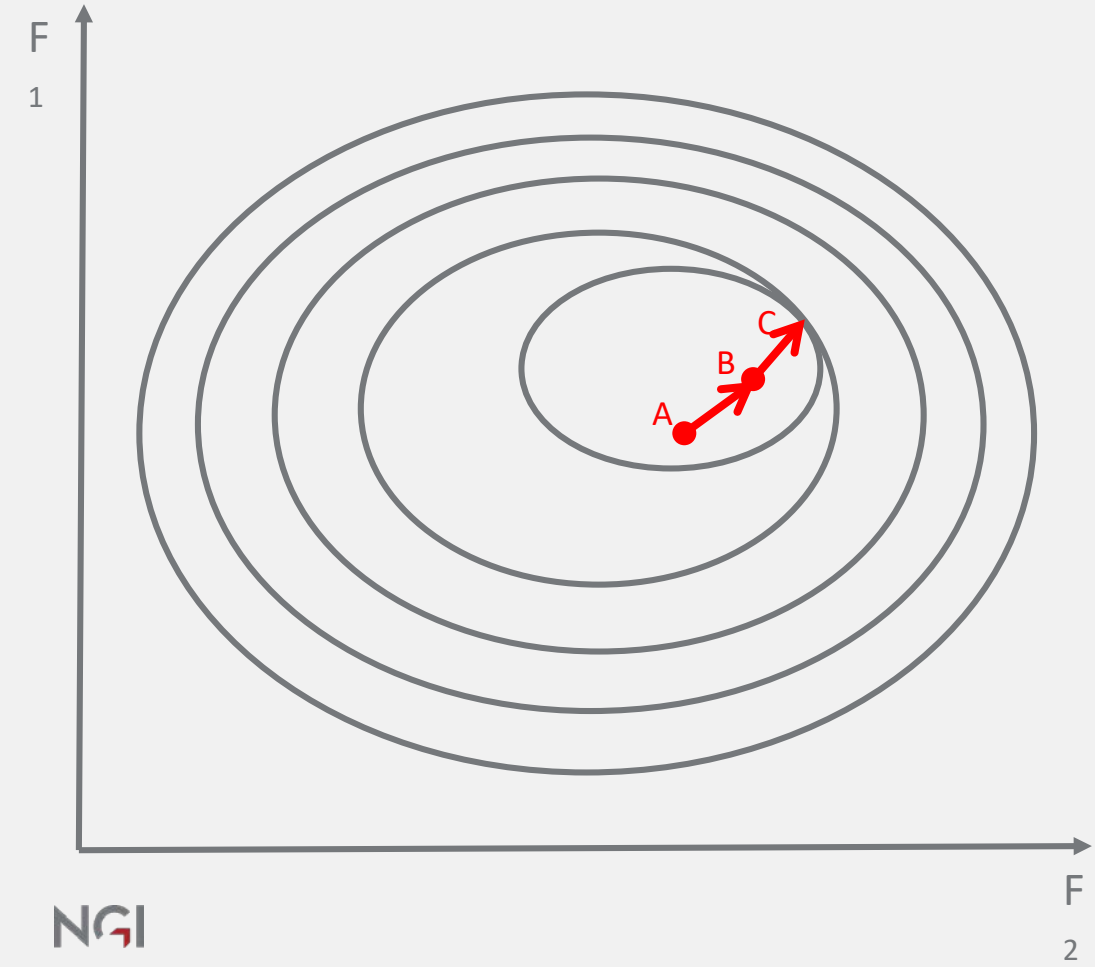


REDWIN model principles

- 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.


F
1
B
A
F
2


$\sqrt{V^2 + M^2}$
B
A
$\sqrt{u_h + u_h}$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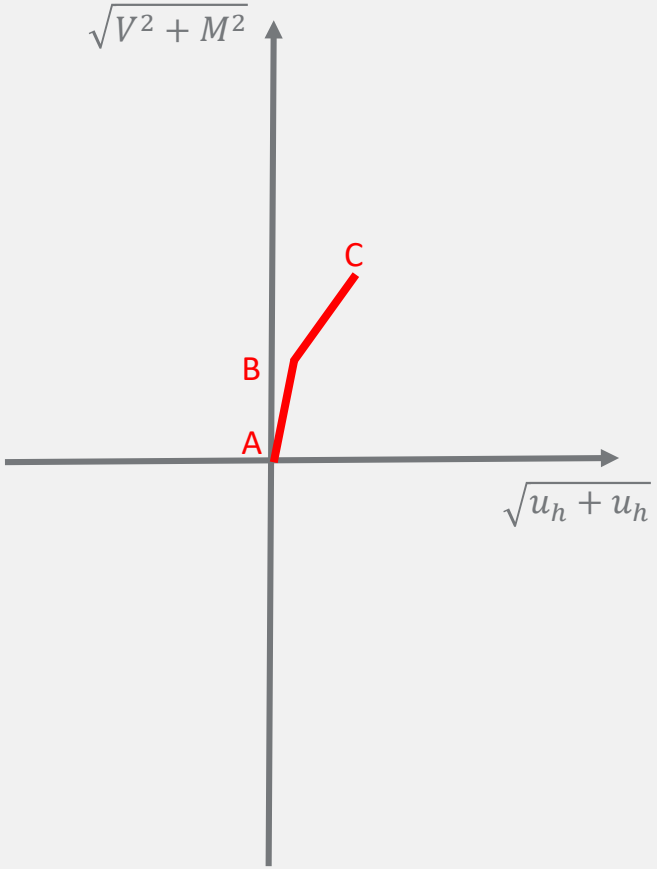
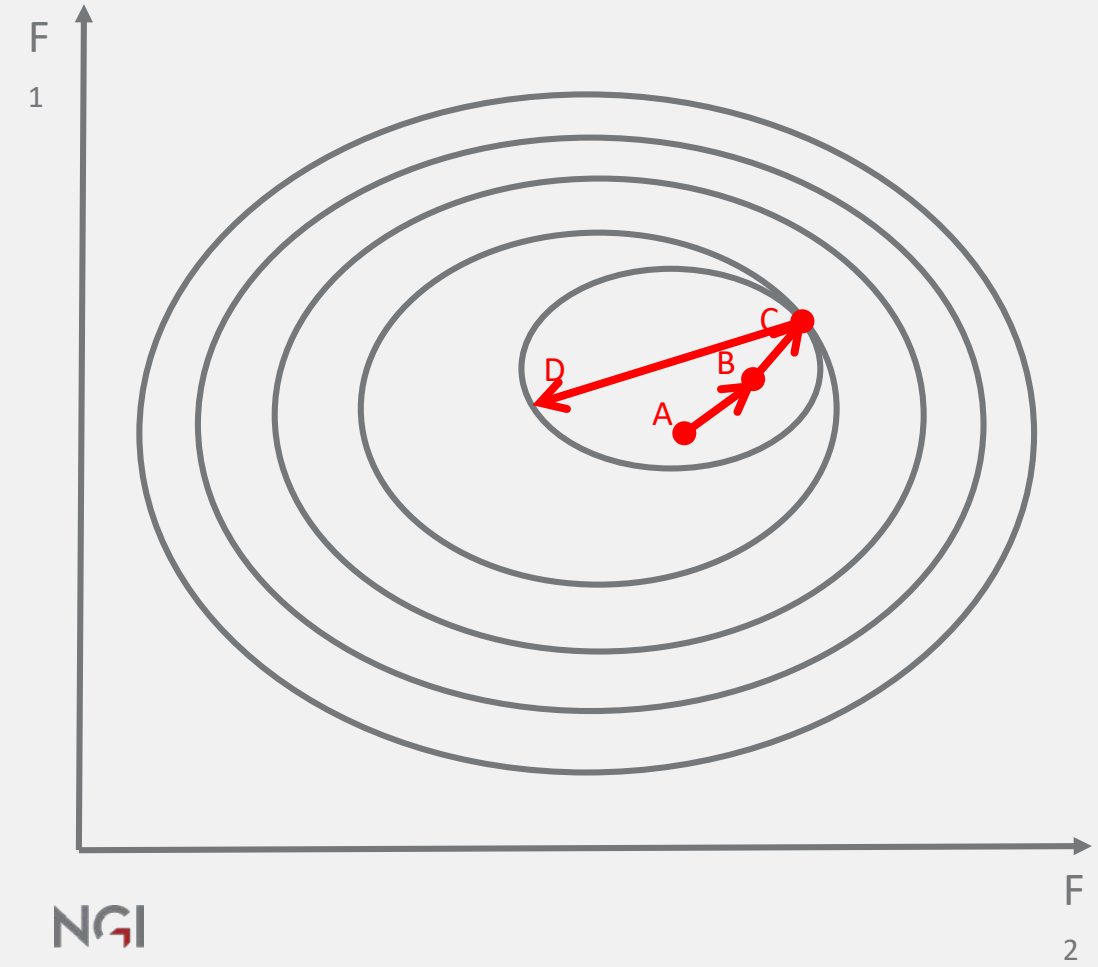

$\sqrt{V^2 + M^2}$
A
B
C
$\sqrt{u_h + u_h}$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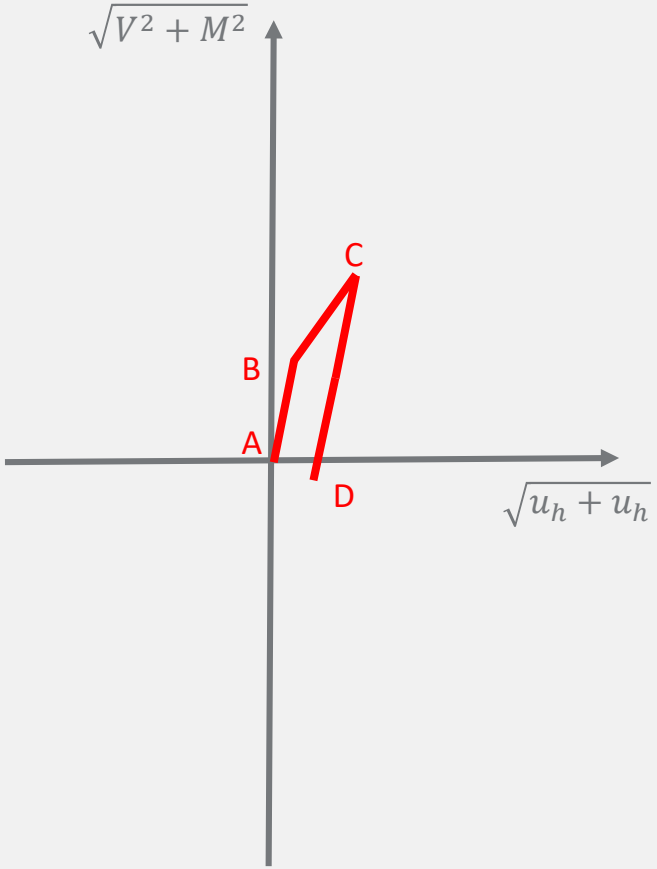
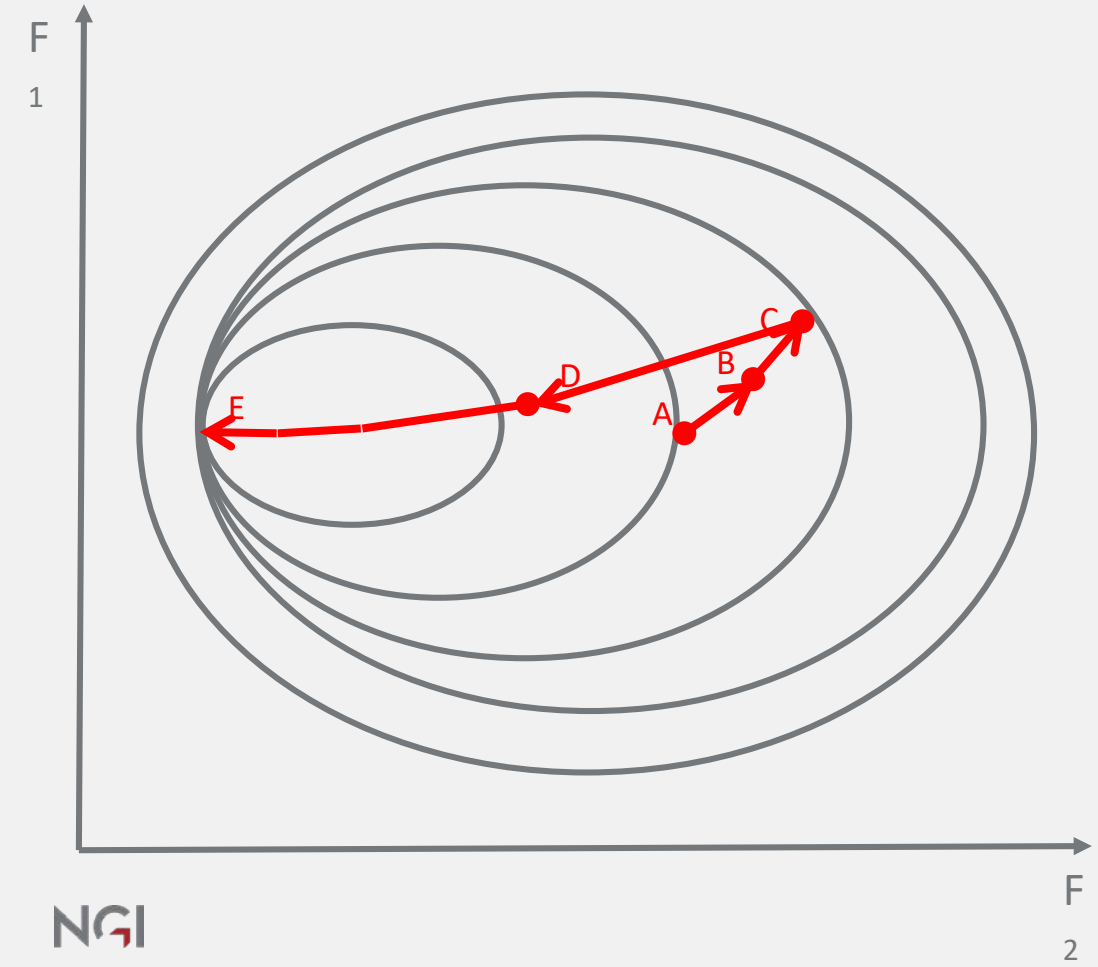

$\sqrt{V^2 + M^2}$
A
B
C
D
$\sqrt{u_h + u_h}$


F
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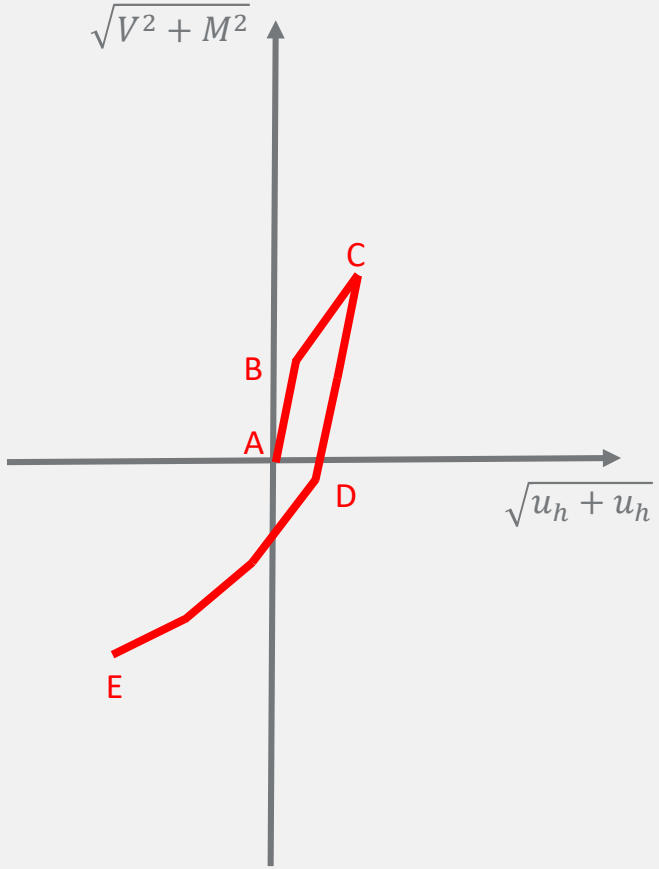
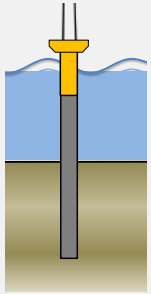
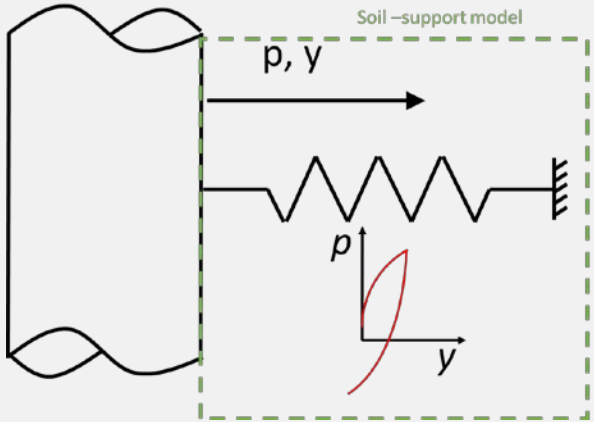
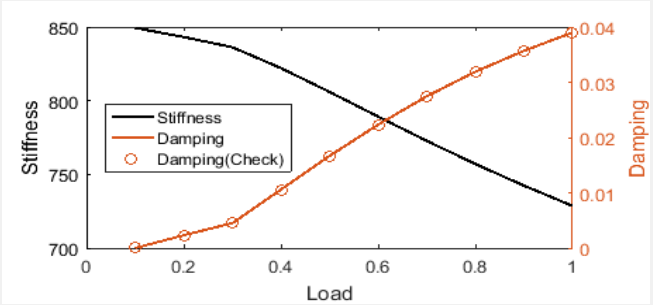

$\sqrt{V^2 + M^2}$
A
B
C
D
E
$\sqrt{u_h + u_h}$

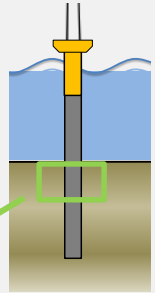
Monopiles

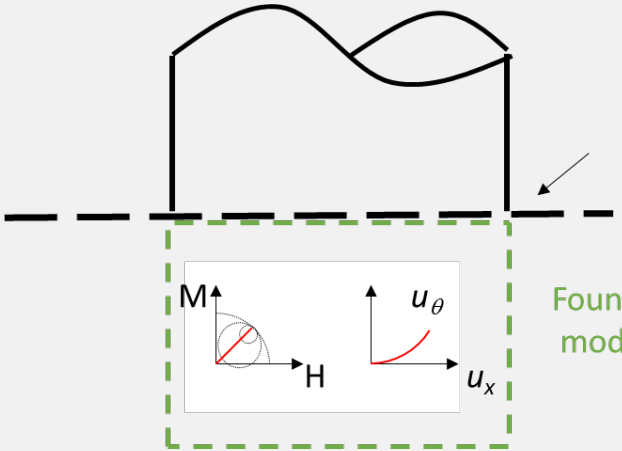
Foundation and substructre	Model applicable	Loading regime
		





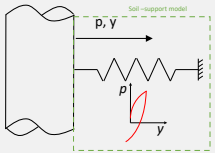
Monopiles



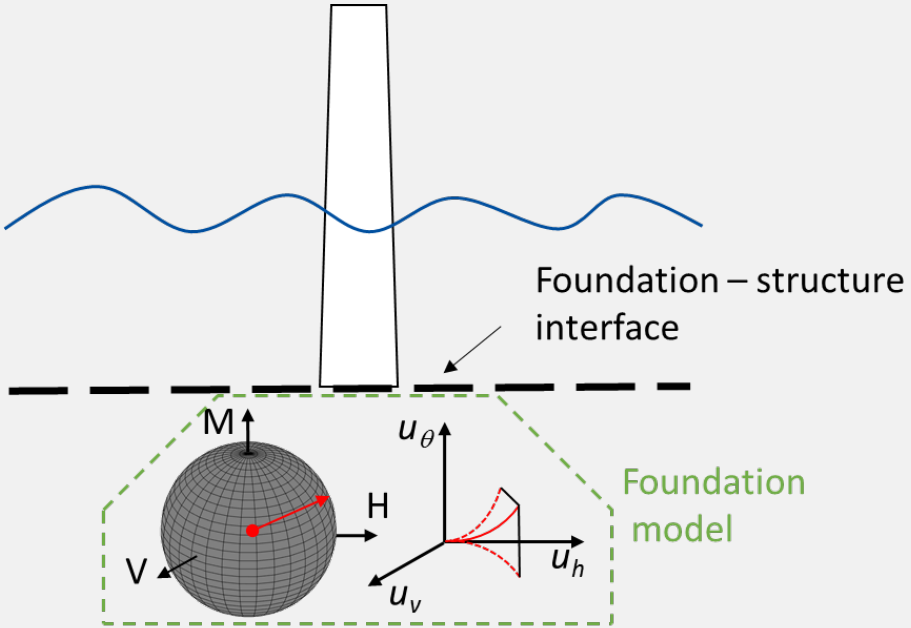


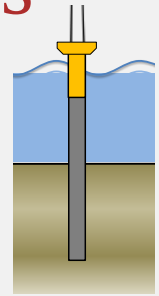
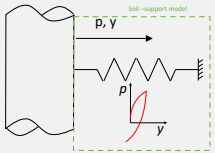
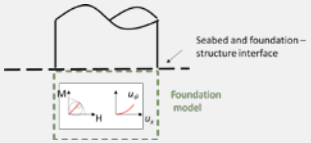
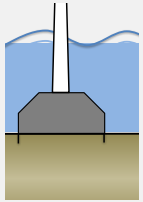
Seabed and foundation – structure interface

Foundation model

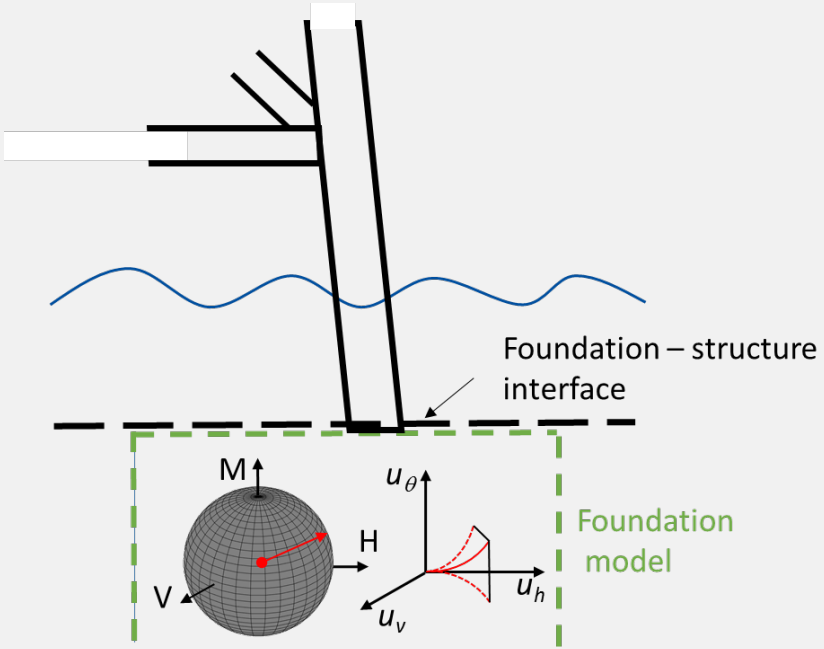
Foundation and substructre	Model applicable	Loading regime
	Redwin model 1 	Distributed 1D model to be applied to any DOF.

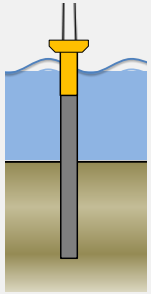
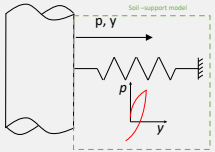
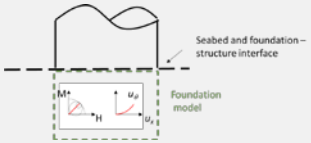
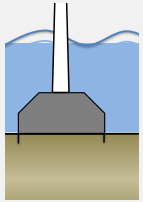
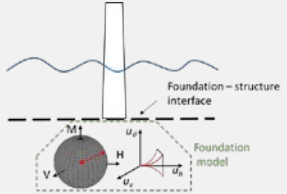
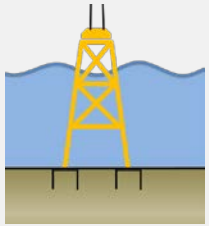
Gravity based foundations

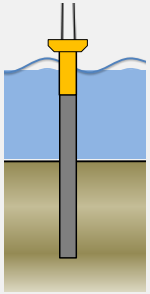
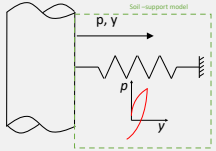
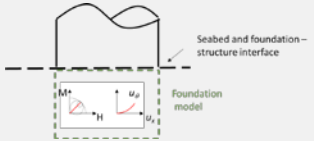
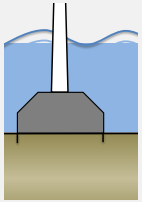
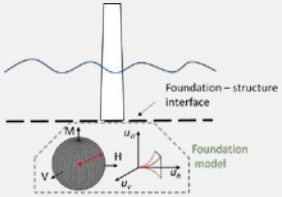
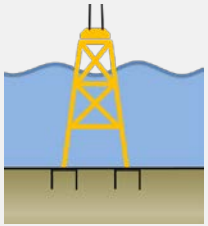
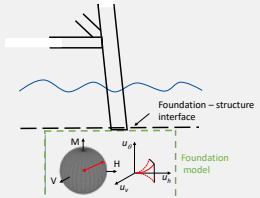


Foundation and substructre	Model applicable	Loading regime
	Redwin model 1 	Distributed 1D model to be applied to any DOF.
	Redwin model 2 	HM-loading
		

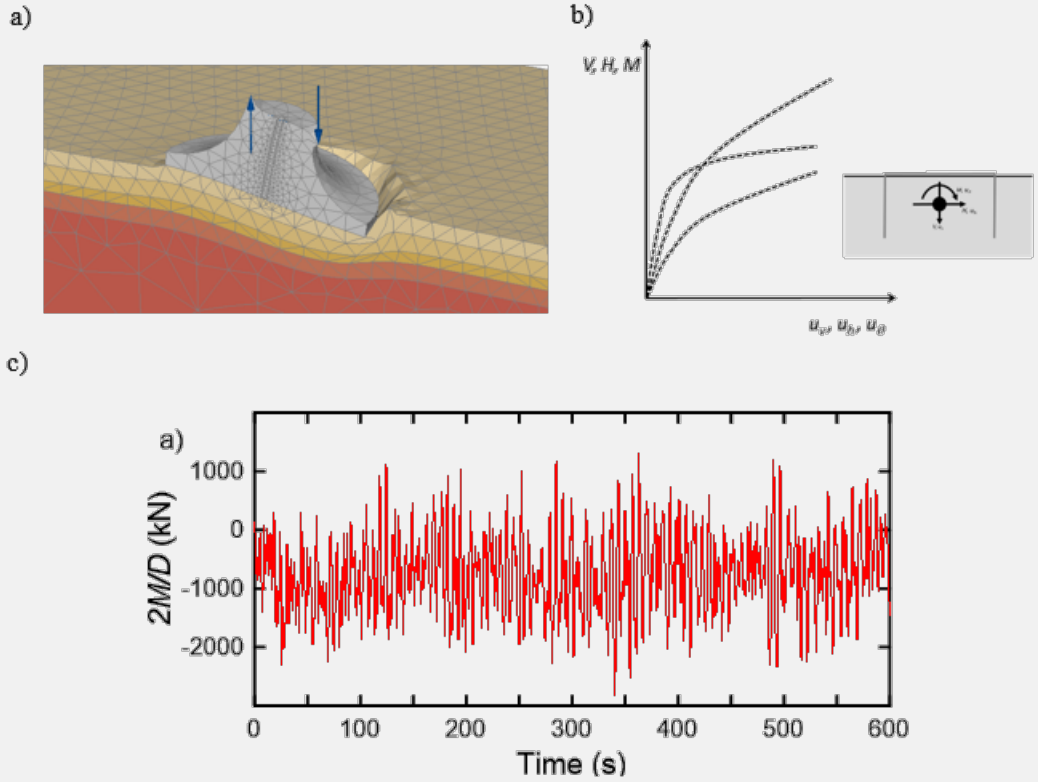
Bucket foundations



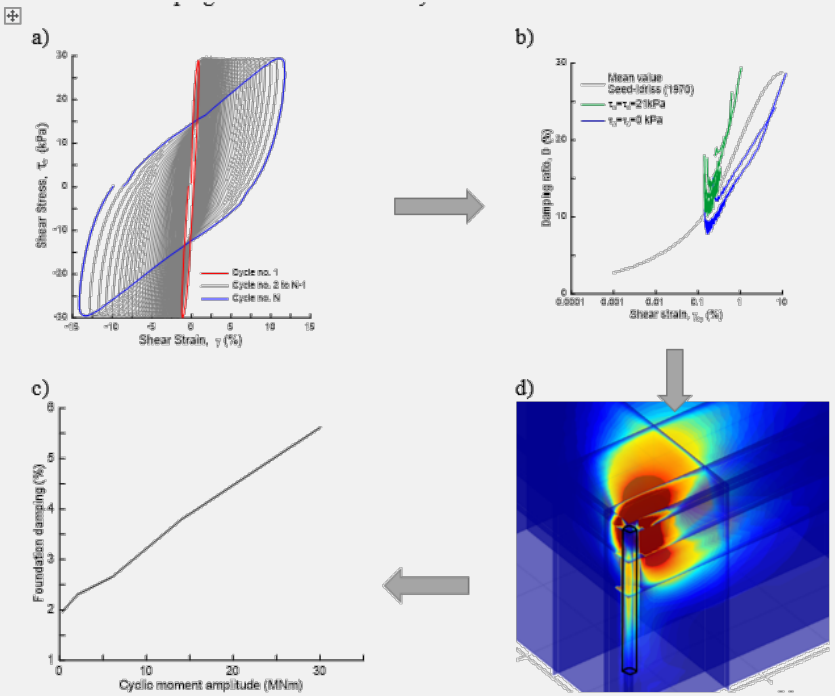
Foundation and substructre	Model applicable	Loading regime
	Redwin model 1 	Distributed 1D model to be applied to any DOF.
	Redwin model 2 	HM-loading
	Redwin model 3 	VHM-loading
		

Foundation and substructre	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
	Redwin model 3 	VHM-loading

Model demonstration

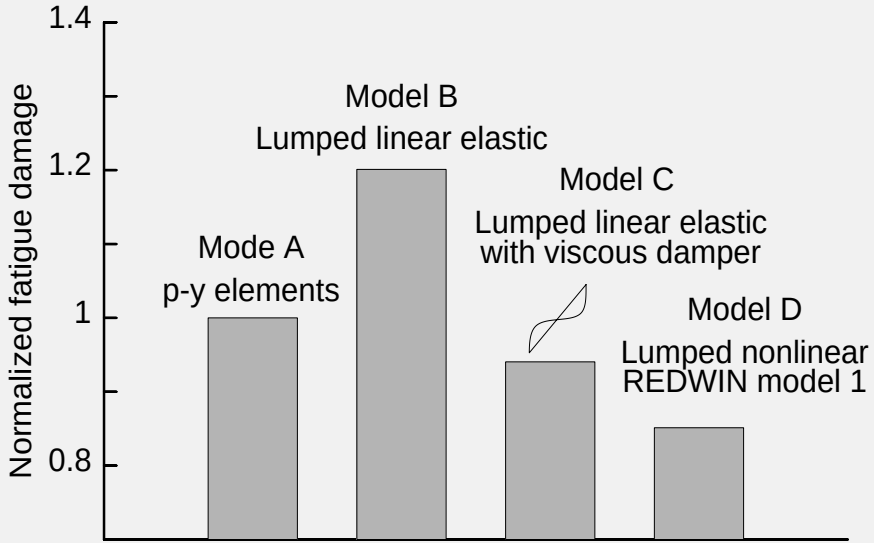


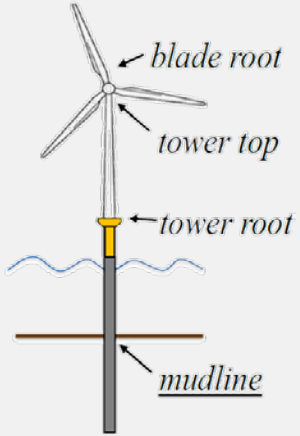
Foundation damping



$$D_{found} = \frac{\sum(V \cdot E_h)}{4\pi \sum(V \cdot E_p)}$$

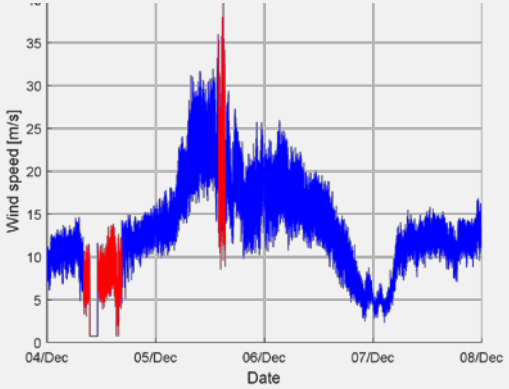
Effect of foundation behaviour on fatigue

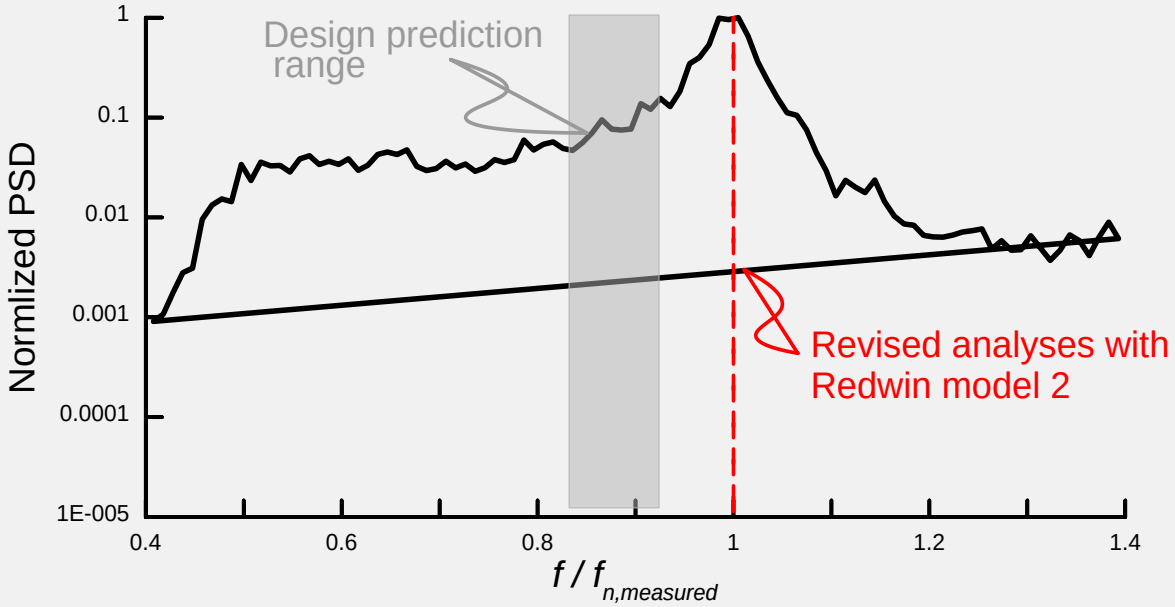




Aasen, S., Page, A. M., Skau, K. S. and Nygaard, T. A. (2017)

Comparison of model and measured response





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 om cost reduction effects in more detail.

NGI

Thanks to:

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..and co-authors and contributors !

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And thanks for your attention !

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