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Enabling Delta Life

Testing and modelling for Offshore Geotechnics

Dynamic Spudcan-Seabed Interaction for JIP WindJack
or
Integrated Models for Soil-Structure Interaction

Dirk Luger

Outline of this presentation

- Problem areas
- Common characteristics
- Modelling approaches
- Examples: from wires and piles to anchors and spudcans
- Some “free findings”
- Ongoing developments and future plans

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Problem areas

All soil-structure or soil-water-structure interaction problems where a rigorous numerical analysis or true scaling of the prototype behaviour is not feasible.

Well known example from the recent past:

The P-Y curve for a laterally loaded pile. The curve captures local interaction between soil and pile that would require quite hard numerical effort to analyze “on the fly” during a pile load calculation.

(Recent past, since now 3D analysis of laterally loaded piles is feasible, but certainly not yet a “standard engineering approach”.)

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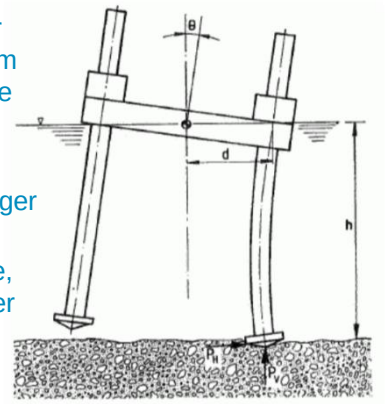
Common characteristics

A “rigid” element that represents a structure or is part of a larger structure, where the elements’ complex interaction with the surrounding soil and water can be captured in a simple model.

A “linear element” that together with other linear elements forms the complete system (a rope, pipeline or pile interacting with the soil).

A “point element”, that is attached to a larger system.

(e.g. an anchor attached to a mooring line, a suction-can as foundation element under a platform or a spudcan under a jack-up.)



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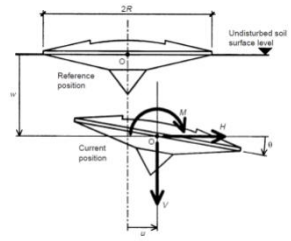
Approach

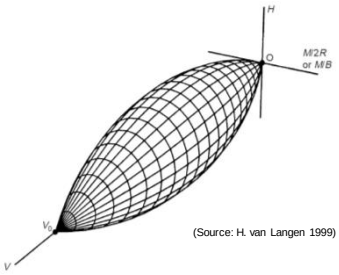
Consists of elements like:

- Analytical modelling
- Rigorous numerical analysis
- Scaled testing in the GeoCentrifuge
- Large and or small scale testing at 1 g



All leading to a formulation of behaviour in the force (–displacement) space.

Many similarities with constitutive modelling of soil where one deals with the stress (–strain) space.



(Source: H. van Langen 1999)

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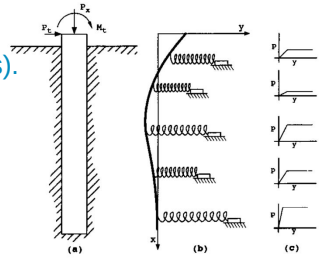
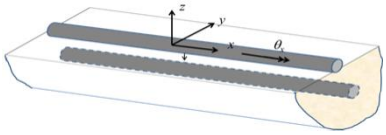
Increasing complexity – large potential

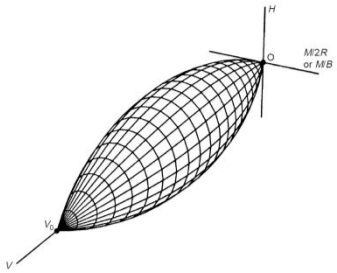
Apart from non-linear effects the difficulty lies in the number of degrees of freedom (dof's).



P-Y curve: 1 dof
P-Y and T-Z combined: 2 dof's
Spudcan, with V,H and M: 3 dof's

Wire rope or pipeline modelling:
Fx, Fy, Fz and Mx ➔ 4 DOF's





Imagine an anchors' 6 dimensional yield surface in Fx, Fy, Fz, Mx, My, Mz space!!!

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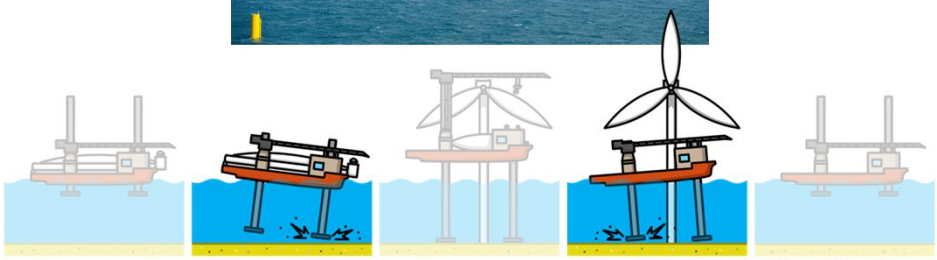
The WindJack JIP



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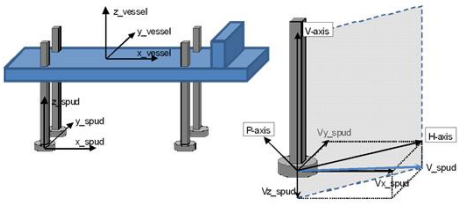
The WindJack JIP



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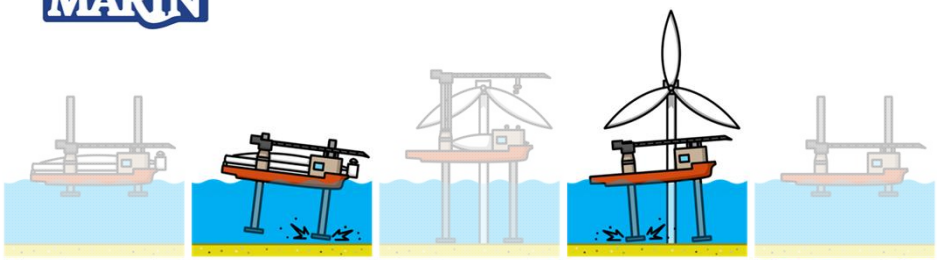

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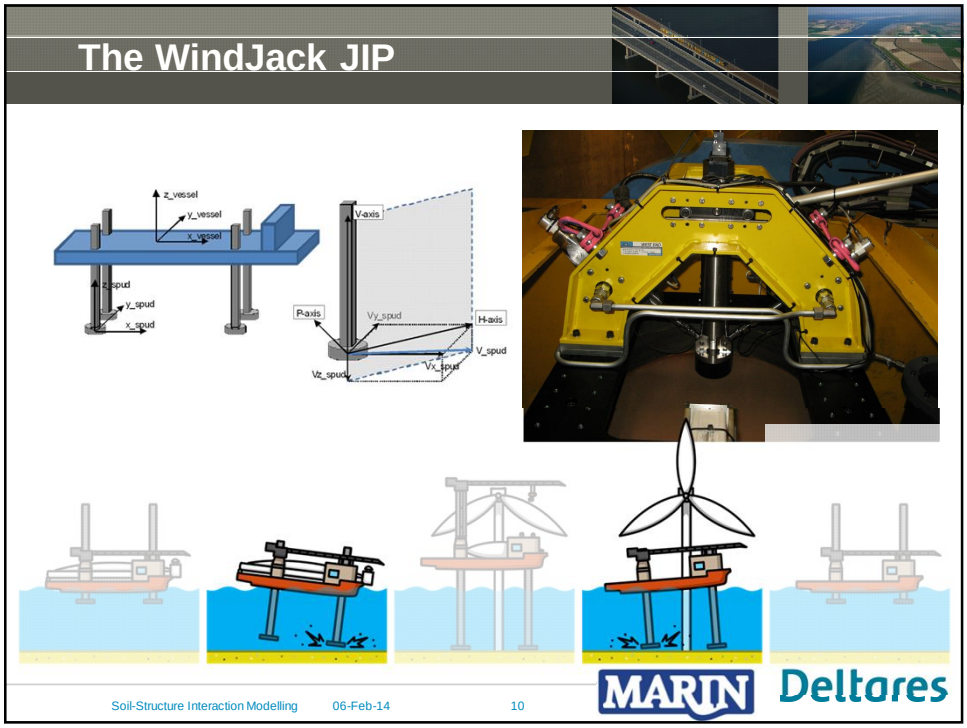
The WindJack JIP
z_vessel
y_vessel
x_vessel
z_spud
y_spud
x_spud
V-axis
P-axis
H-axis
Vy_spud
V_spud
Vz_spud
Vx_spud
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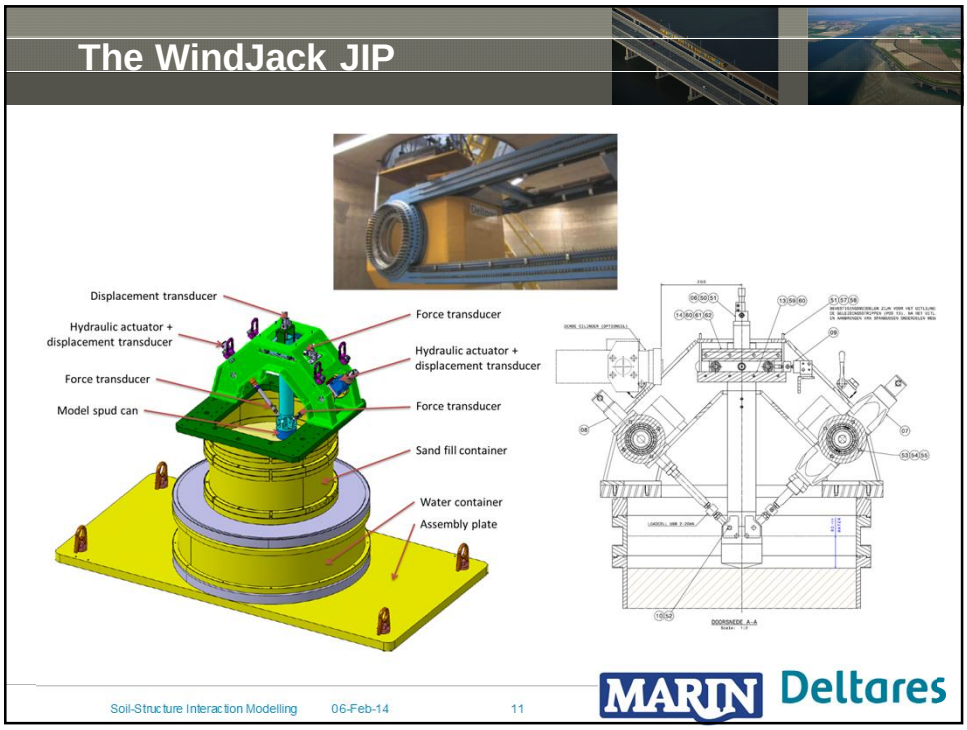
The WindJack JIP
Displacement transducer
Hydraulic actuator + displacement transducer
Force transducer
Model spud can
Force transducer
Hydraulic actuator + displacement transducer
Force transducer
Sand fill container
Water container
Assembly plate
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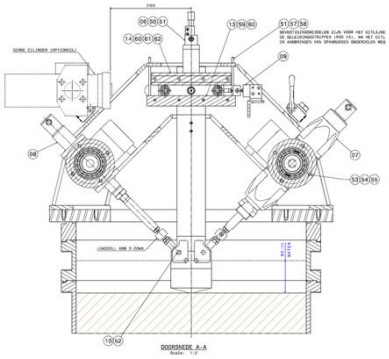
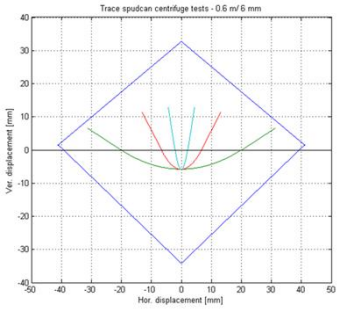
The WindJack JIP





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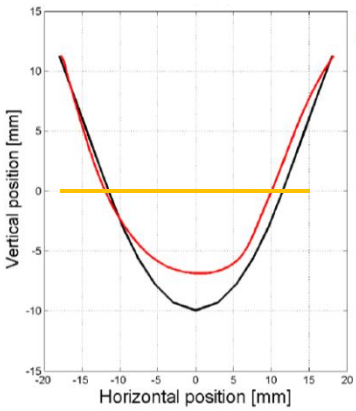
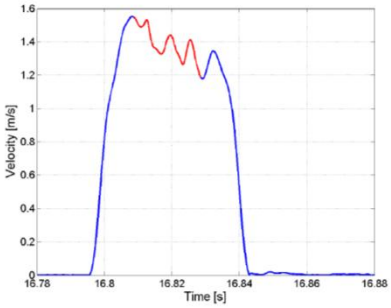
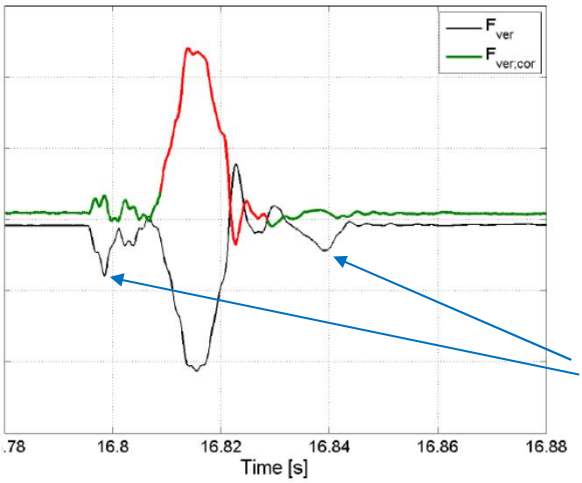




One of the major challenges in the centrifuge test:
Test velocities must be equal to Prototype velocities ➔
Here spudcan-sand contact is ca 20 milliseconds!!

The WindJack JIP



Forces have to be corrected for inertia effects.

Note the force to set the spudcan in motion and the force to stop it again.

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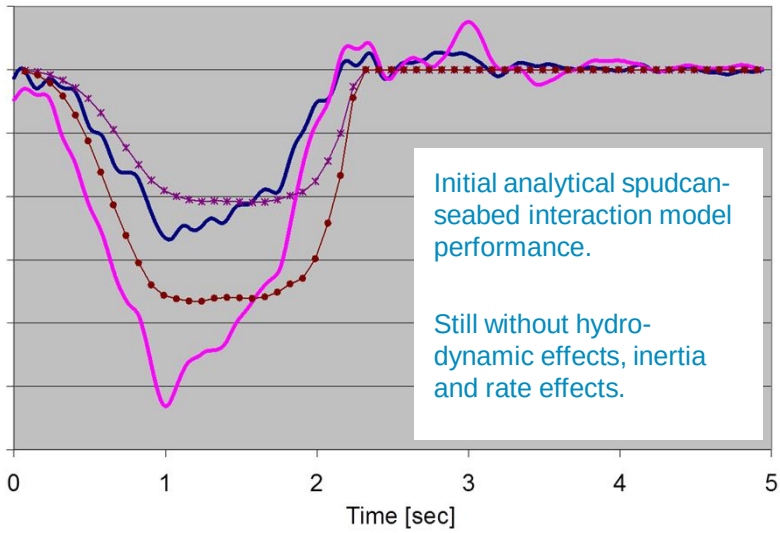

Initial analytical spudcan-seabed interaction model performance.

Still without hydro-dynamic effects, inertia and rate effects.

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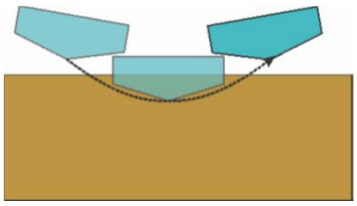

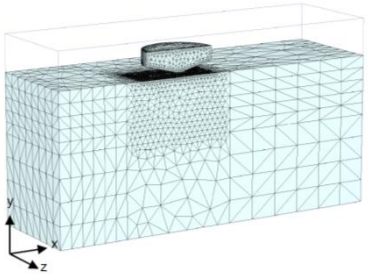

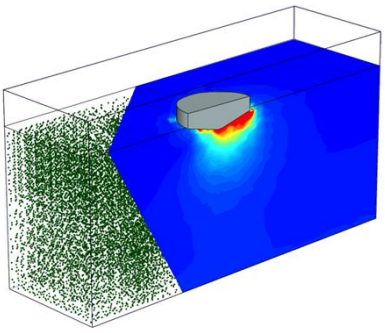

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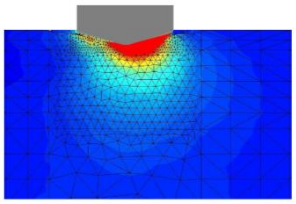
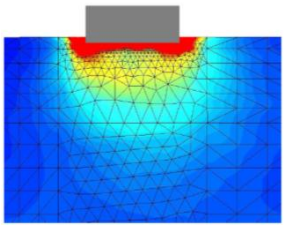
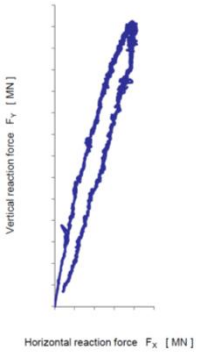
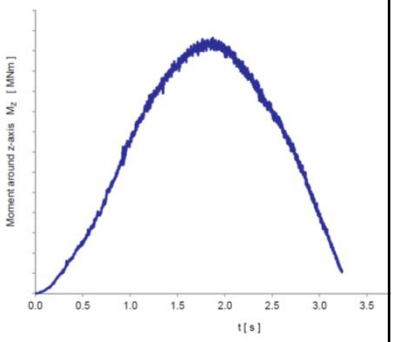
MPM calculation results









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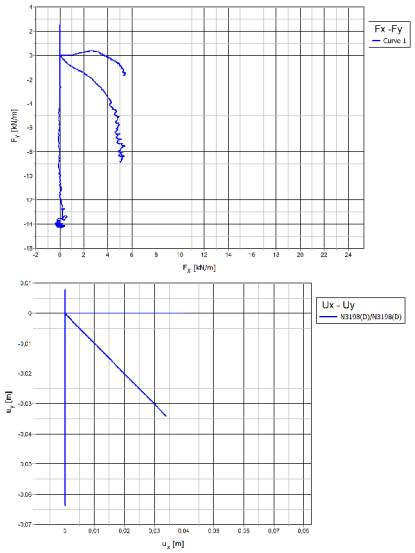
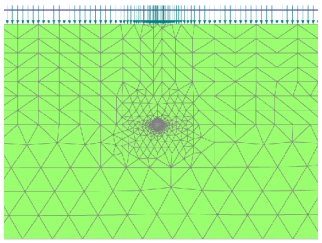
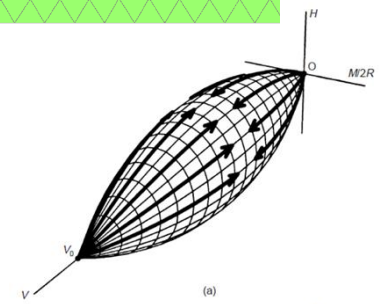
A yield/failure envelope sample – buried pipe







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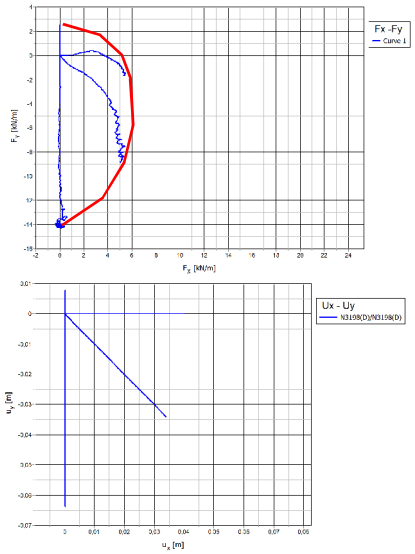
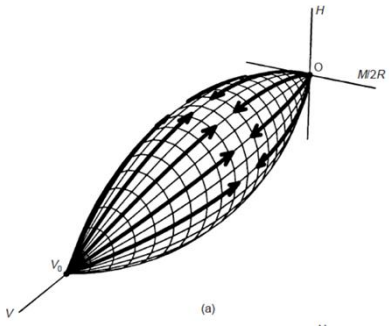
First outline of the envelope



Looks like the real thing.

Now simulate the sweep test numerically



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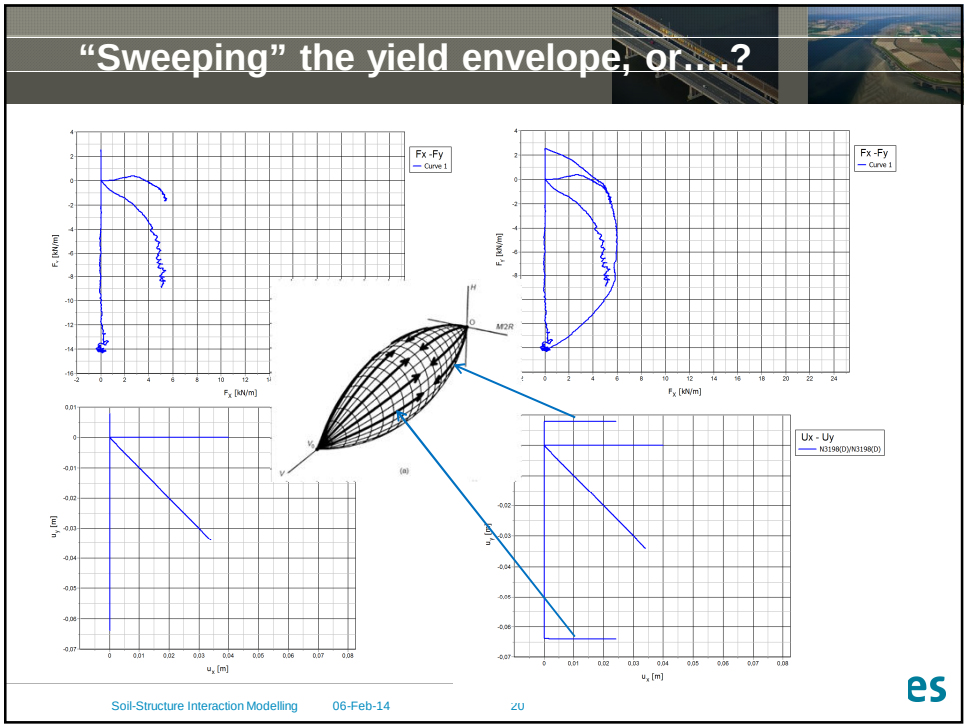
“Sweeping” the yield envelope, or….?
Fx -Fy
Curve 1
Ux - Uy
N3198(D)/N3198(D)
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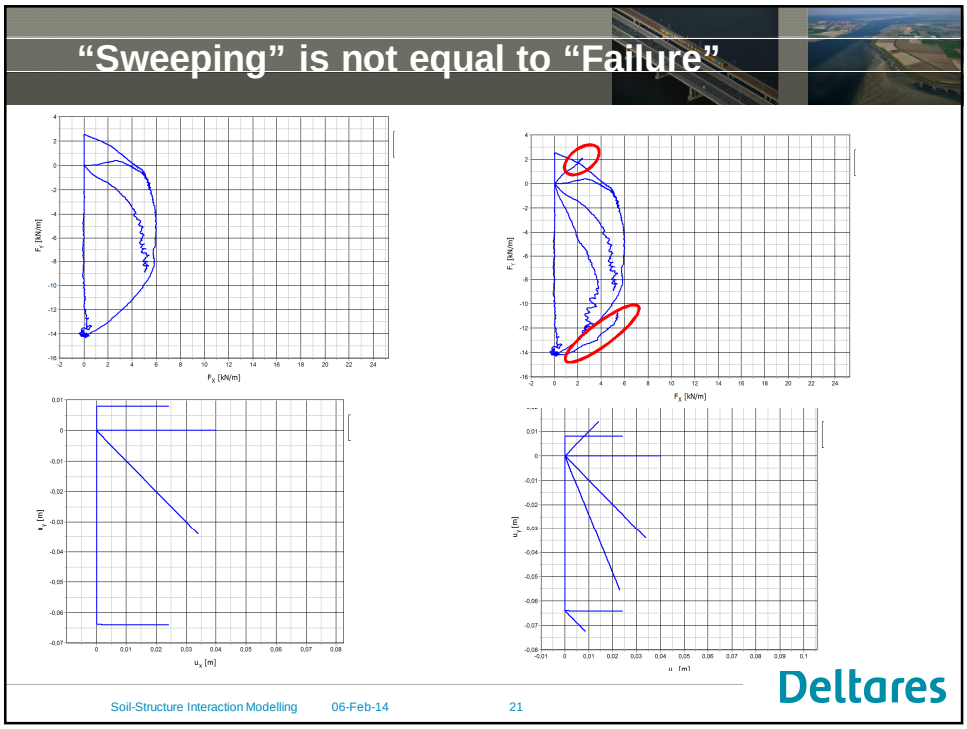
es


“Sweeping” is not equal to “Failure”
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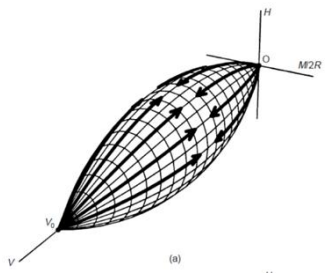
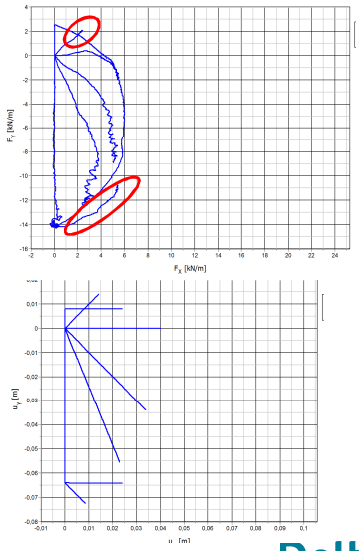
“Sweeping” is not equal to “Failure”

Yield envelope is not unique,
Sweeping envelope stays within the failure envelope.





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Ongoing and future developments

Now:

Research into a more robust, generalized, formulations for force-displacement models, with application to:

- Dynamic spudcan behaviour – linked with vessel motion models
  More precise loads on legs in different sea-states ➔Extending workability, less weather downtime and better project planning.
- Wire behaviour – 3D above and below seabed wire model for pulling operations
  Better prediction of pull-in forces ➔ Proper matching of rope, vessel and winches to a given project, optimalisation of marine operations.
- Anchor system behaviour – Anchor model linked with 3D catenary model
  Analysis of mooring systems and anchor penetration ➔ Prevention of cable breaks, analysis of anchor threat to cables and pipelines, economic design of protective measures.

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Ongoing and future developments

In the (near?) future, together with the industry:

- Extension of spudcan-, wire- and anchor-system models.
- Extension to bucket foundation models.
- Extension to pipeline and cable integrity models (JIP SAFETRENCH).

JIP SAFETRENCH

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Closure

Thank you for your attention!

Any Questions?

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