



ISSMGE TC209 Workshop
on
Challenges of Offshore
Geotechnical Engineering
25 September 2019
Bodrum - Turkey

Phil WATSON

The University of Western Australia and Chair of TC 209

The Role of Physical Modelling in Offshore Geotechnics

Agenda

1. What are we trying to achieve?
2. Types of physical modelling
3. There's a community out there!
4. Centrifuge modelling
5. Examples
6. Closing comments

What are we trying to achieve with physical modelling?

The Role of Physical Modelling in Geotechnics (Phil Watson)

Are we ...

- Prototyping new concepts?
- Studying mechanisms / behaviours?
- Assessing performance?
- Validating design?
- Calibrating of numerical models?
- Understanding risk?

... all of the above!

Other examples of physical modelling

Wind tunnel

Aerodynamics



Tank testing

Hydrodynamics



Physical modelling for geotechnical problems

The Role of Physical Modelling in Geotechnics (Phil Watson)



<http://www2.eng.ox.ac.uk/geotech/research/PISA/FieldTests>



Andersen, K.H. Bearing capacity under cyclic loading — offshore, along the coast, and on land. The 21st Bjerrum Lecture presented in Oslo, 23 November 2007. © Canadian Science Publishing or its licensors

Field scale testing

Investigate behavior at ‘real’ scale

Challenges:

- Large loads
- Matching ground conditions
- Cost (and schedule)

Small scale testing

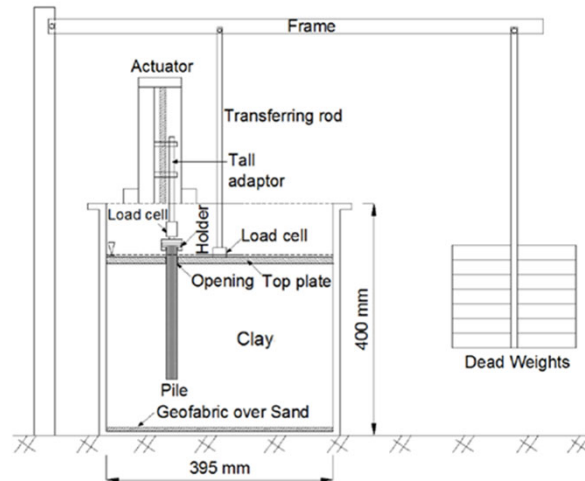
Explore foundation systems

Challenges:

- Idealised model
- Soil conditions
- Stress conditions

Physical modelling for geotechnical problems

The Role of Physical Modelling in Geotechnics (Phil Watson)



Calibration chamber testing

Testing in uniform soil conditions

Challenges:

- Axial loading only
- Element response



Centrifuge testing

Explore foundation systems

Challenges:

- Idealised model
- Idealised soil




Focus for remainder
of presentation

There's a community out there!

The Role of Physical Modelling in Geotechnics (Phil Watson)

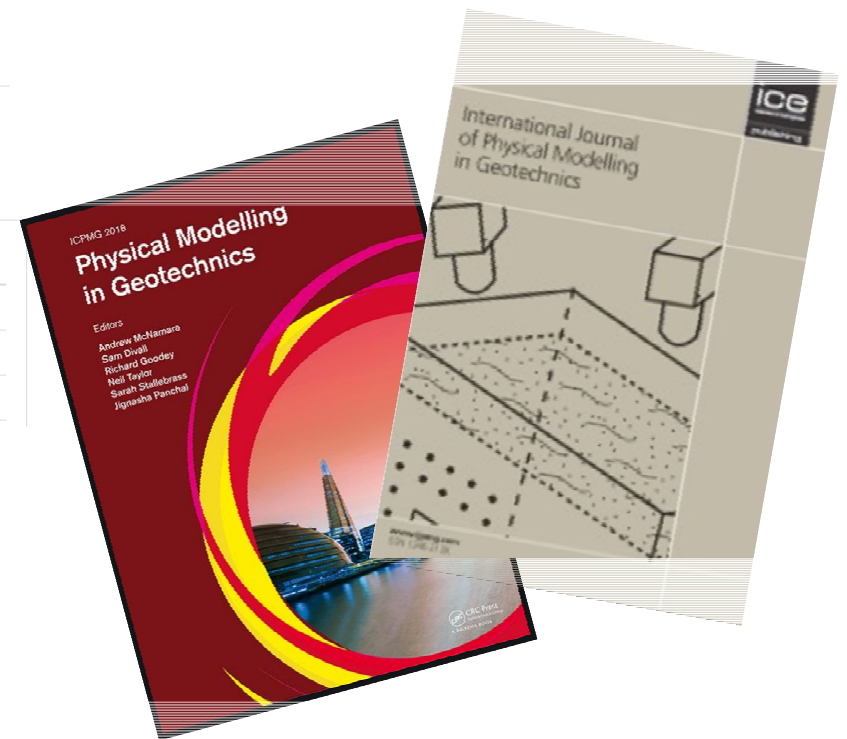
ISSMGE TC104 'Physical Modelling in Geotechnics'

Physical Modelling in Geotechnics

 Sign-up to receive committee news

Terms of Reference **Membership List** News Additional Information Contact

#	Type	Full Name	Country
1	Chair	Dong-Soo Kim	South Korea
2	Vice Chair	David White	United Kingdom
3	Secretary	Nam-Ryong Kim	South Korea



Honour lecture: Schofield Lecture

International journal and conference series

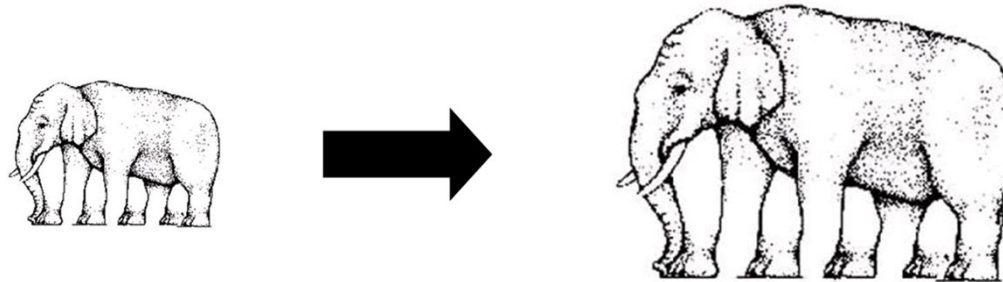
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Some background to centrifuge modelling

The Role of Physical Modelling in Geotechnics (Phil Watson)

Start by looking at scale modelling, and think about an elephant ...

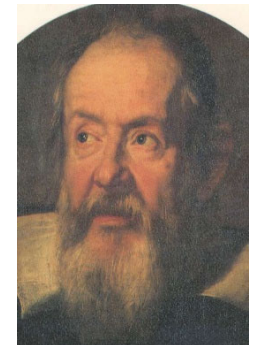
By how much can I multiply the size of an elephant before it collapses, unable to support it's own weight?



If the size is multiplied by n ...

- The cross section of bone's leg is multiply by n^2
- The weight is multiply by n^3

“The geometrical similitude (simple reduction in size) is an obstacle to mechanical similitude” (Galilée, 1638)



Some background to centrifuge modelling

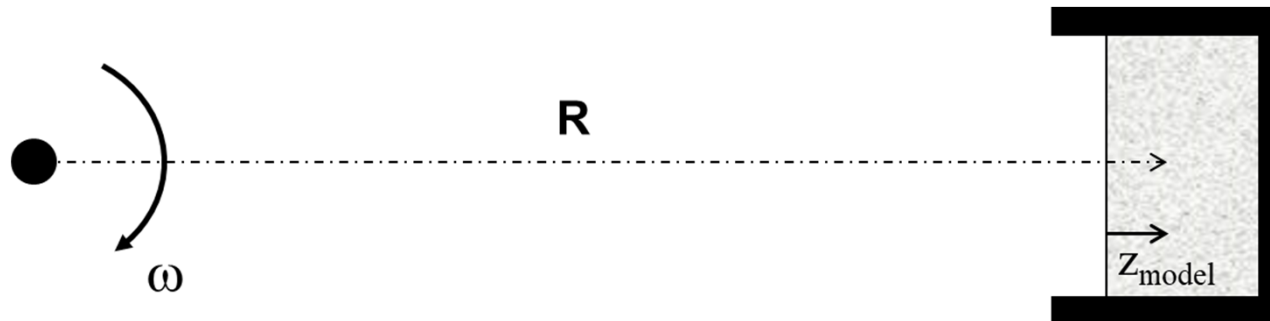
The Role of Physical Modelling in Geotechnics (Phil Watson)

So if we want to scale our model, how do we address the issue raised by Galilée?

We can either ...

- Modify the mechanical properties of the materials; or
- Modify the values of the body forces

Centrifuge modelling achieves the latter



$$\text{Acceleration} = \omega^2 R = ng$$

$$z_{\text{model}}/z_{\text{prototype}} = 1/n$$

$$\sigma_{\text{model}}/\sigma_{\text{prototype}} = 1$$

(stress similitude)

Some background to centrifuge modelling

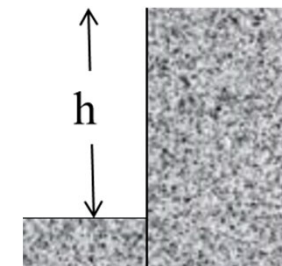
The Role of Physical Modelling in Geotechnics (Phil Watson)

Why is stress similitude important for geotechnical engineers?

Stress governs both the applied forces and the behavior of the soil

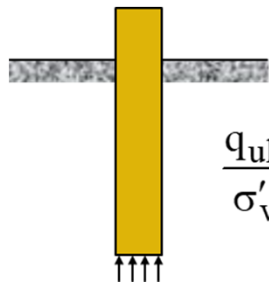
If not matched, then results will not be realistic

Clays (e.g. stability of vertical cut)



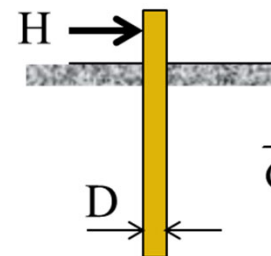
$$\frac{\gamma h}{s_u} = \frac{\sigma_v}{s_u} = N_s$$

Sands (e.g. end-bearing resistance)



$$\frac{q_{ult}}{\sigma'_v} = N_q = f\left(I_D, \frac{\sigma'_v}{\sigma_{crushing}}\right)$$

Soil-structure interaction (e.g. lateral pile response)



$$\frac{H}{G_{soil} u D} = f\left(\frac{EI_{pile}}{GD^4}, \frac{G}{\sigma'_v}\right)$$

Some background to centrifuge modelling

The Role of Physical Modelling in Geotechnics (Phil Watson)



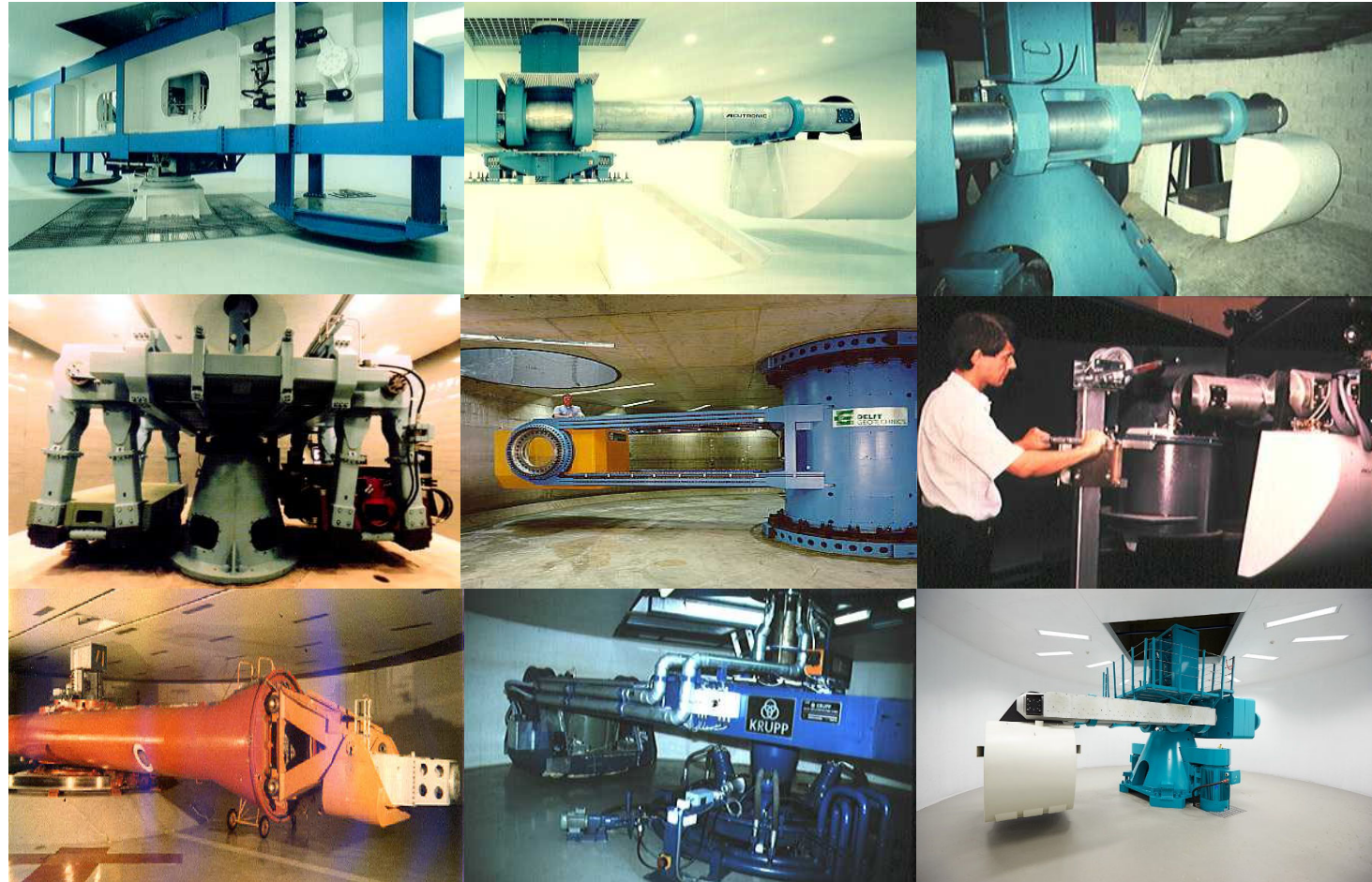
Common scaling factors for centrifuge modelling

PHYSICAL PARAMETER	SCALE FACTOR
Stress	1
Density	1
Acceleration	n
Length	1/n
Displacement	1/n
Strain	1
Velocity	1
Force	1/n ²
Time, dynamic problems	1/n
Time, diffusion problems	1/n ²

Some background to centrifuge modelling

The Role of Physical Modelling in Geotechnics (Phil Watson)

There are many
facilities around
the world



Some background to centrifuge modelling

The Role of Physical Modelling in Geotechnics (Phil Watson)

National Geotechnical Centrifuge Facility at The University of Western Australia



1.2 m diameter drum centrifuge



3.6 m diameter fixed beam centrifuge

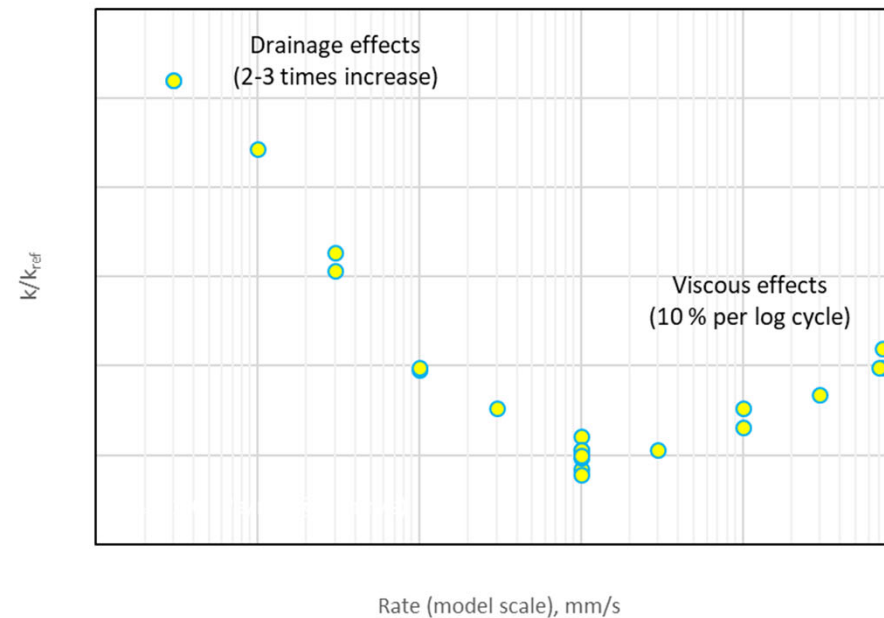
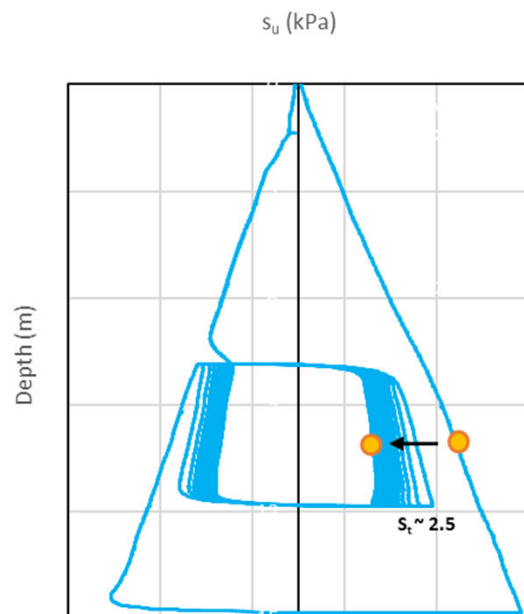


10 m diameter fixed beam centrifuge

Examples – Soil characterisation

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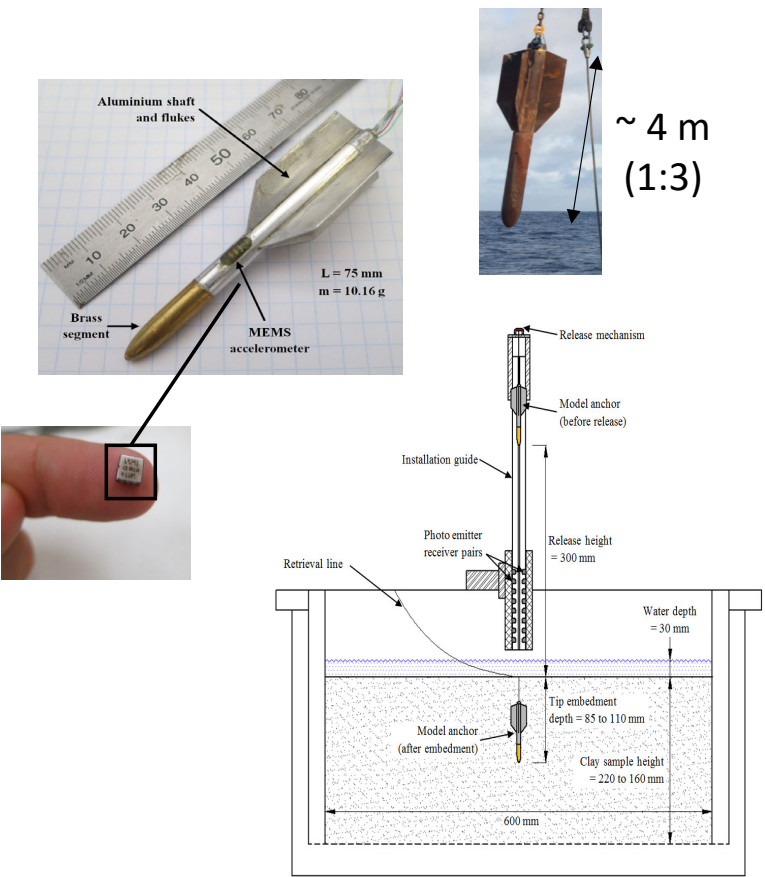
Development of new tools (e.g. T-bar)
Investigation of soil behaviour (e.g. rate effects)



Examples – Prototyping

The Role of Physical Modelling in Geotechnics (Phil Watson)

Dynamically embedded anchors



Extreme strain rate effects
Water entrainment
Drag resistance in soil

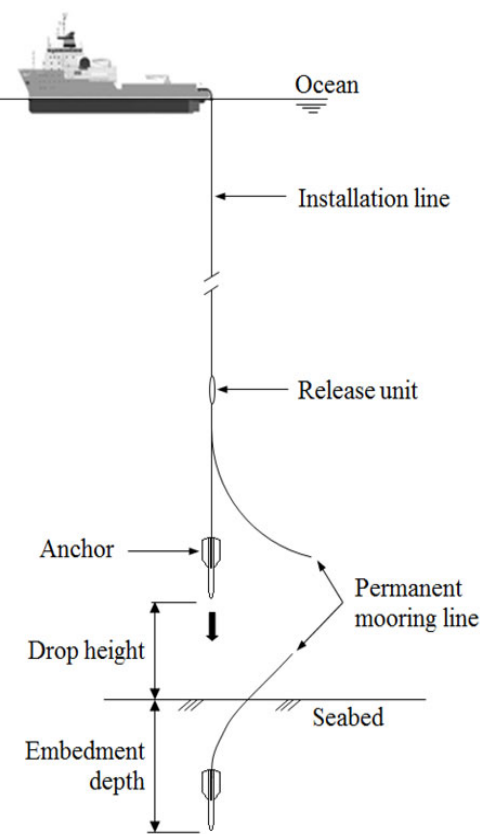
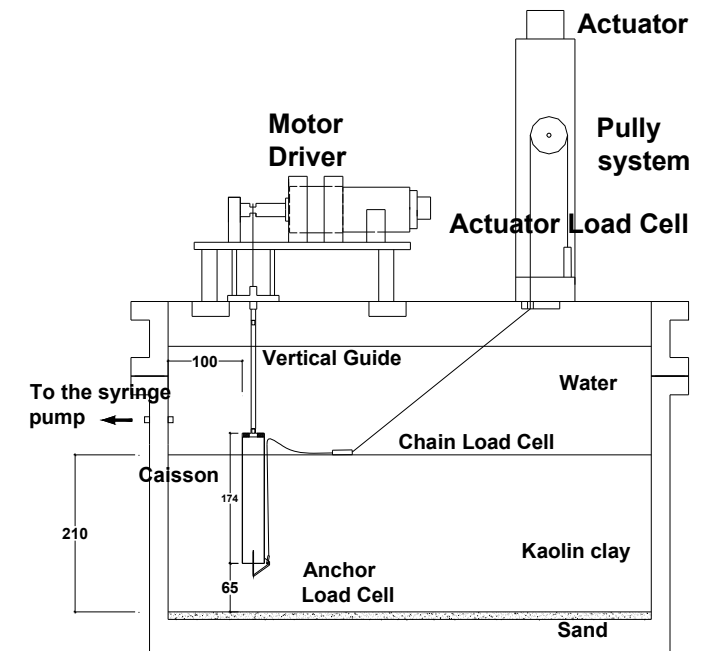
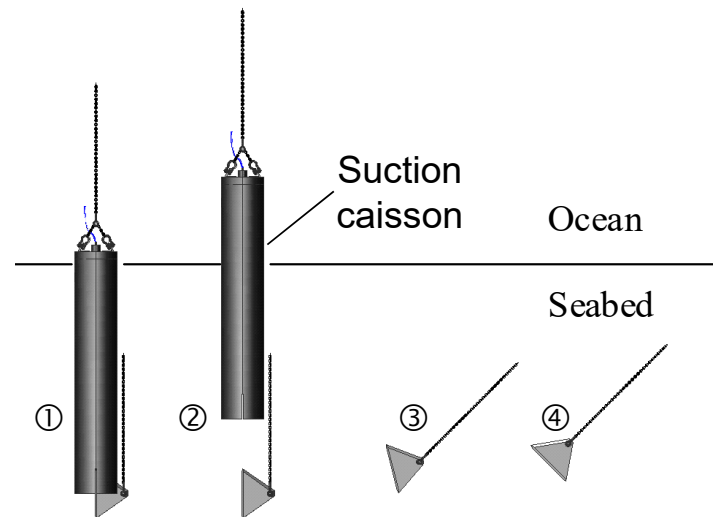


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Examples – Enabling design

The Role of Physical Modelling in Geotechnics (Phil Watson)

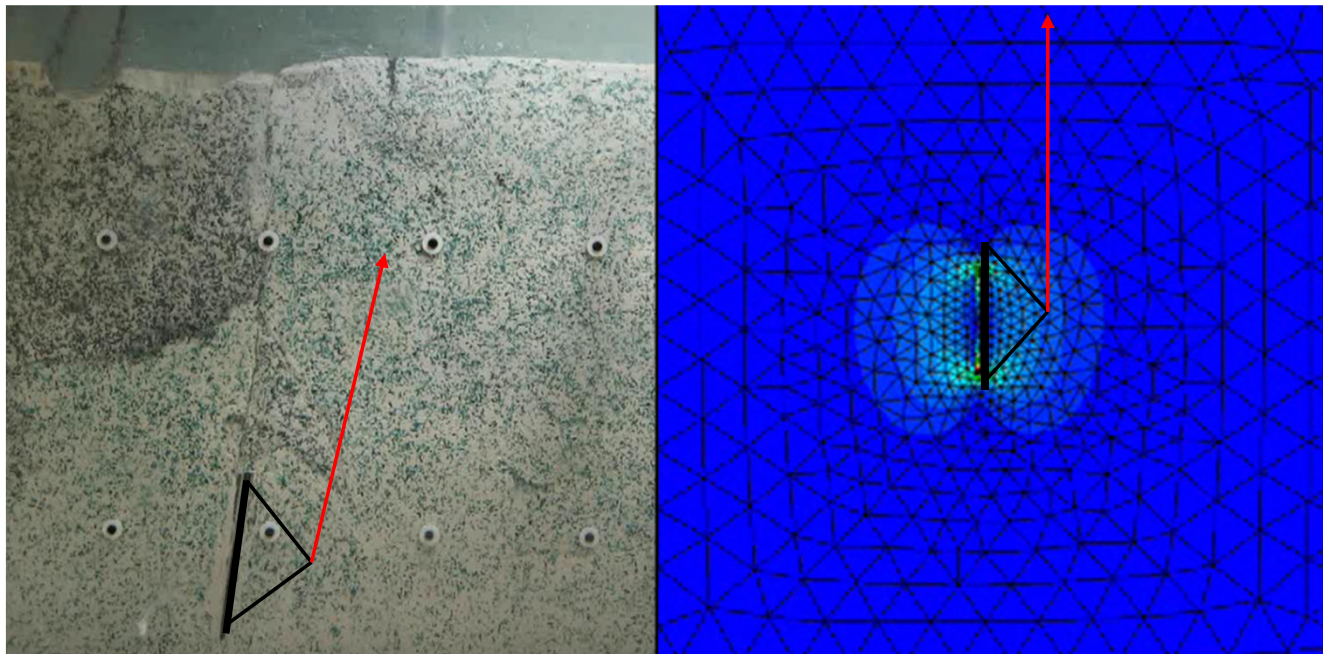
Suction embedded plate anchors



Examples – Enabling design

The Role of Physical Modelling in Geotechnics (Phil Watson)

Suction embedded plate anchors



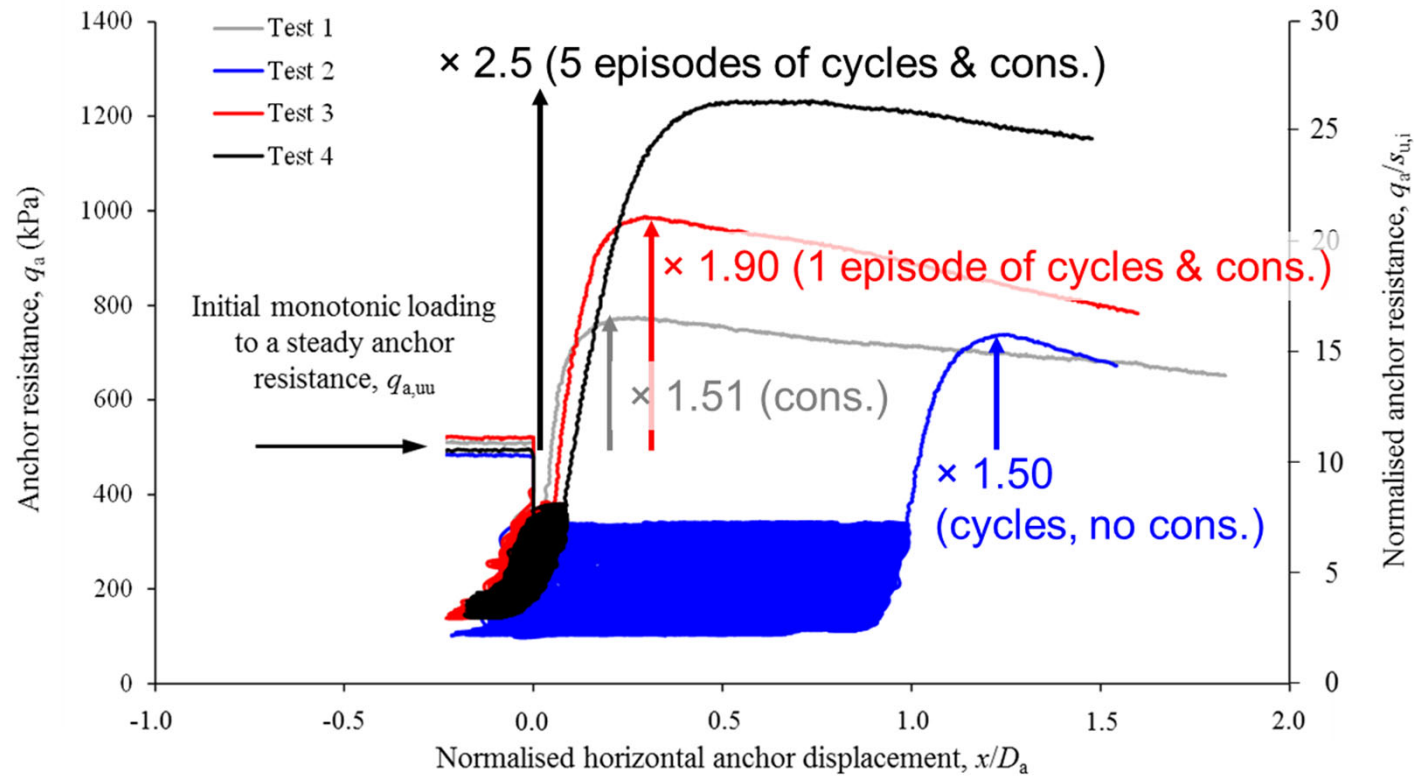
Also highlights how physical modelling can be used to 'calibrate' numerical models

Examples – Enabling design

The Role of Physical Modelling in Geotechnics (Phil Watson)

Zhou, Z. O'Loughlin, C.D., White, D.J. Stanier, S. A. (2019) Improvements in plate anchor capacity due to cyclic and maintained loads combined with consolidation, *Géotechnique*, in press

Suction embedded plate anchors



Cycle back to
prototyping
(DEPLA)



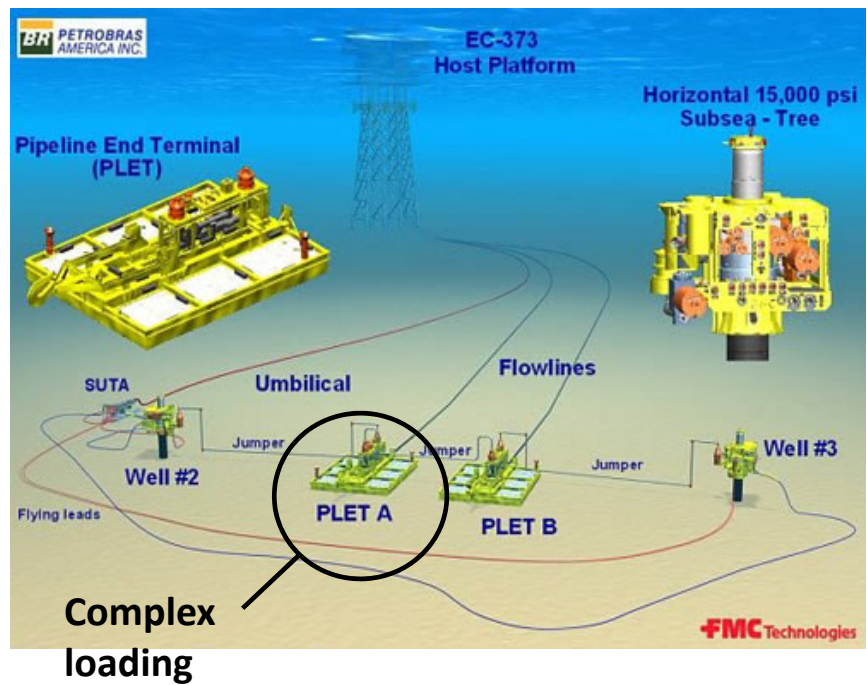
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Examples – Enabling design

The Role of Physical Modelling in Geotechnics (Phil Watson)

Hybrid foundations

Gaudin C., Randolph M.F., Clukey E., Dimmock P. (2012). Centrifuge modelling of a hybrid subsea foundation for subsea equipment. Proceedings of the 7th International Conference of Offshore Site Investigations and Geotechnics, London, England, 411-420.



Piles installed in flight
V, Hx, Hy, Mx, My and Mz load

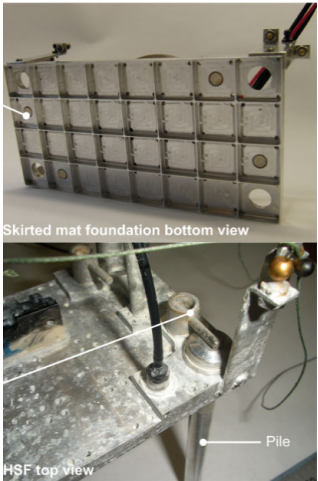


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VIDEO

Examples – Soil-structure interaction

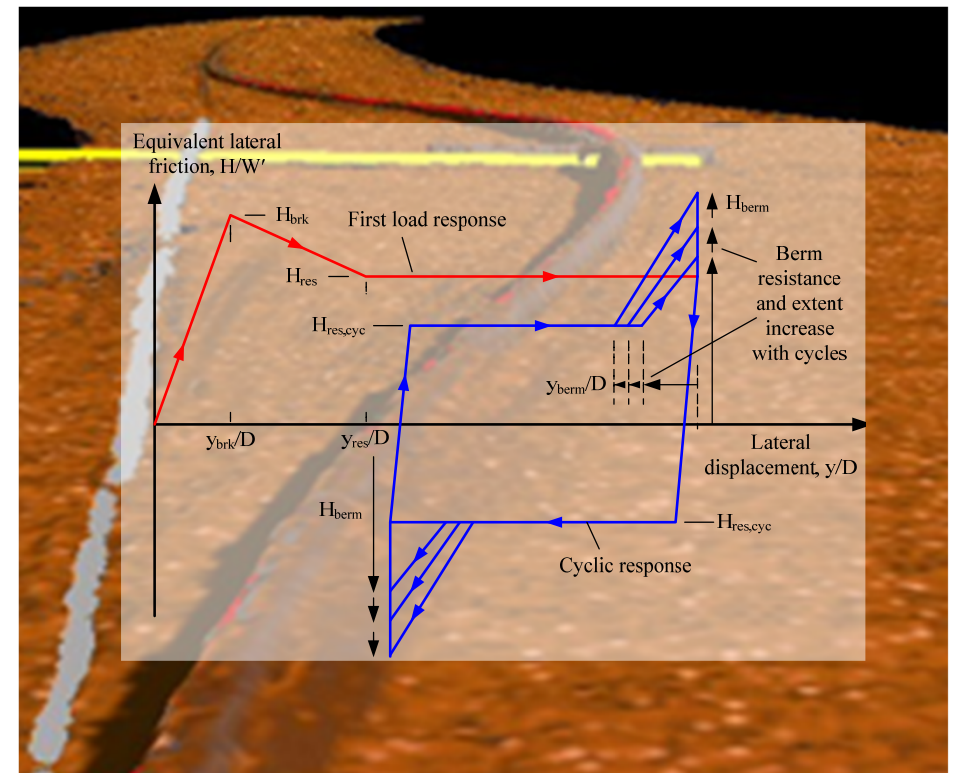
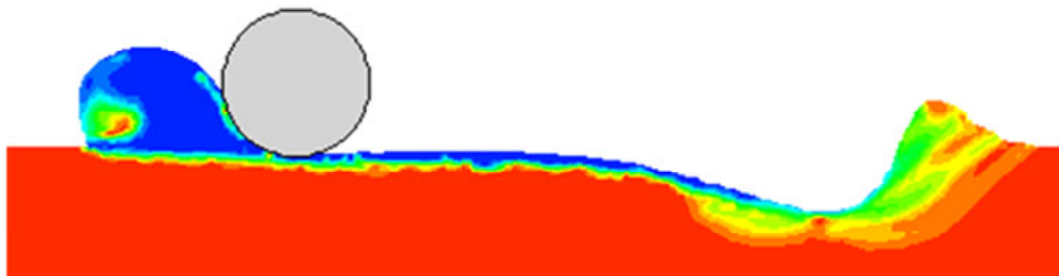
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Behaviour of subsea pipelines

Soil response highly non-linear – needs to be captured for pipeline design (fatigue, stress)



Helen Dingle
Dave White
Christophe Gaudin
Centre for Offshore Foundation Systems, UWA
Pipe-soil interaction testing for the SAFESUCK JIP

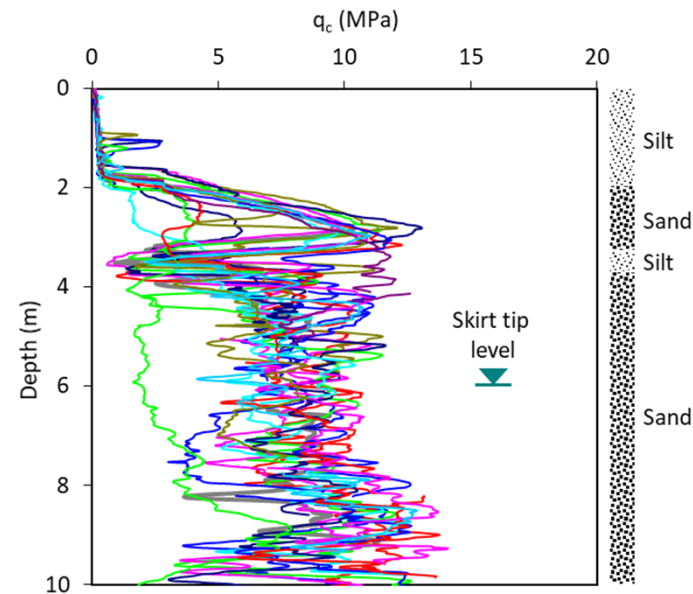
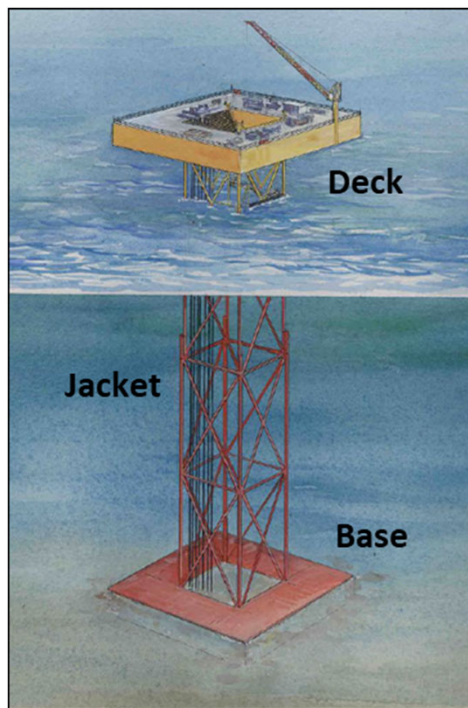


Examples – Planning for installation

The Role of Physical Modelling in Geotechnics (Phil Watson)

Watson, P.G., Jackson, G. & Humpheson, C. 2019. The Maari WHP foundation – Design, installation and performance, 13th Australia New Zealand Conference on Geomechanics, Perth, Australia

Suction installation in complex soils



Questions to be addressed:

- Would the silt layer lift during installation?
- Will seepage lower skirt resistance?

Examples – Planning for installation

The Role of Physical Modelling in Geotechnics (Phil Watson)

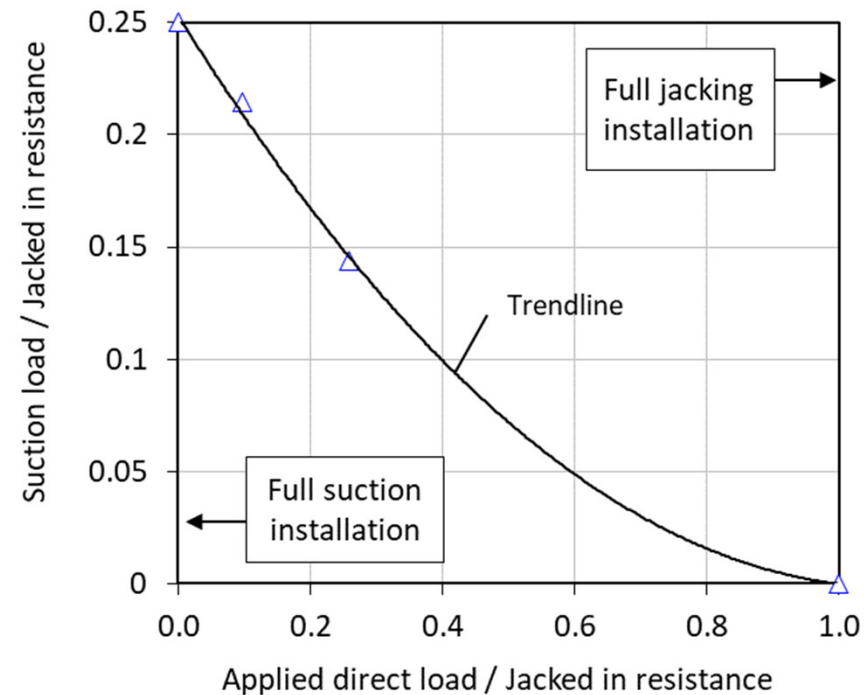
Watson, P.G., Jackson, G. & Humpheson, C. 2019. The Maari WHP foundation – Design, installation and performance, 13th Australia New Zealand Conference on Geomechanics, Perth, Australia

Suction installation in complex soils



Findings:

- Limited plug heave (full skirt installation)
- Suction reduces penetration resistance



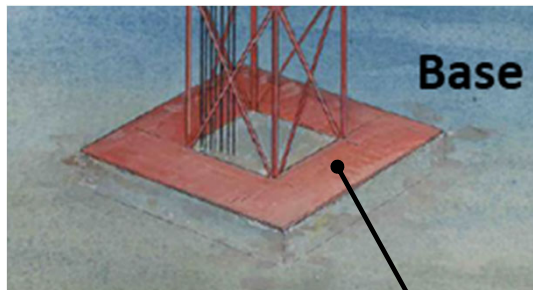
Examples – Managing risk

The Role of Physical Modelling in Geotechnics (Phil Watson)

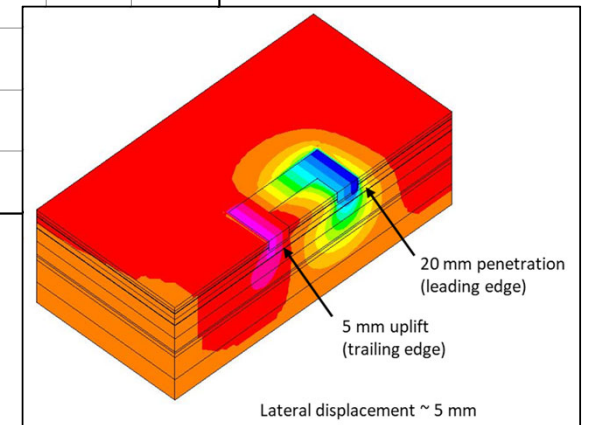
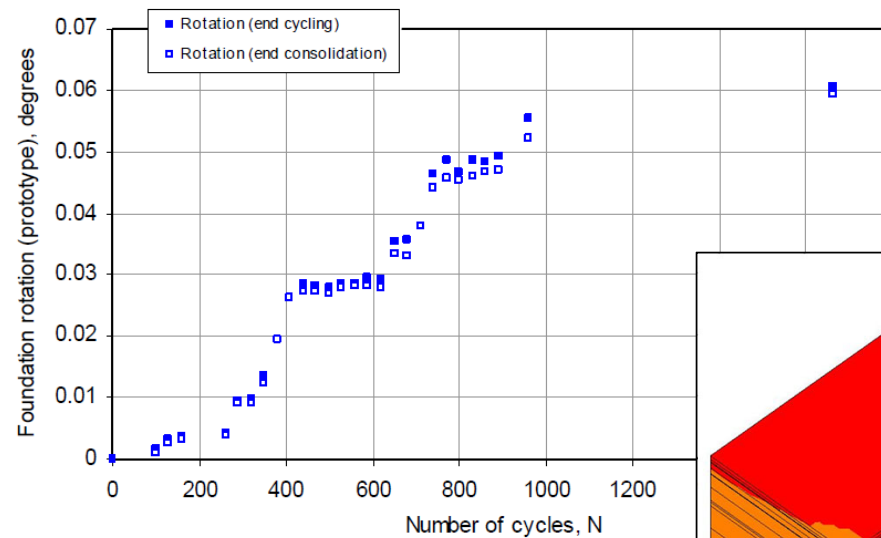
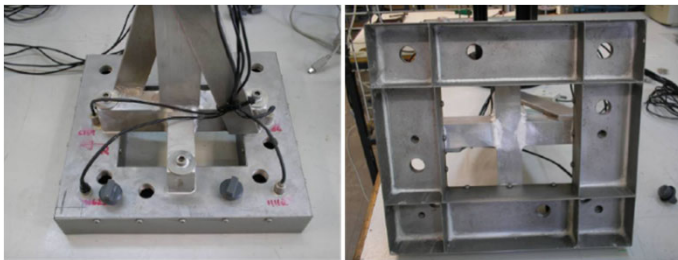
Watson, P.G., Jackson, G. & Humpheson, C. 2019. The Maari WHP foundation – Design, installation and performance, 13th Australia New Zealand Conference on Geomechanics, Perth, Australia

Foundation response under uplift loading

Large
moment



High uplift on
trailing 'strip'



Currently testing uplift of caissons
to support OWF jackets

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Examples – Managing risk

The Role of Physical Modelling in Geotechnics (Phil Watson)

Axial capacity of jetted conductors

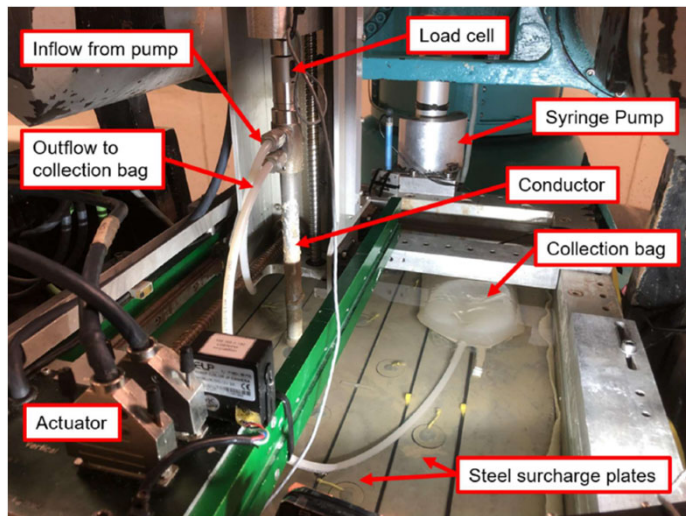
Jetting conductors

- Quick and cost effective
- Well suited to deep water



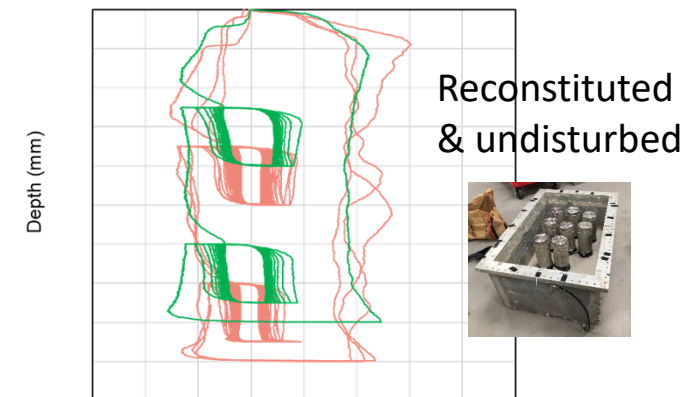
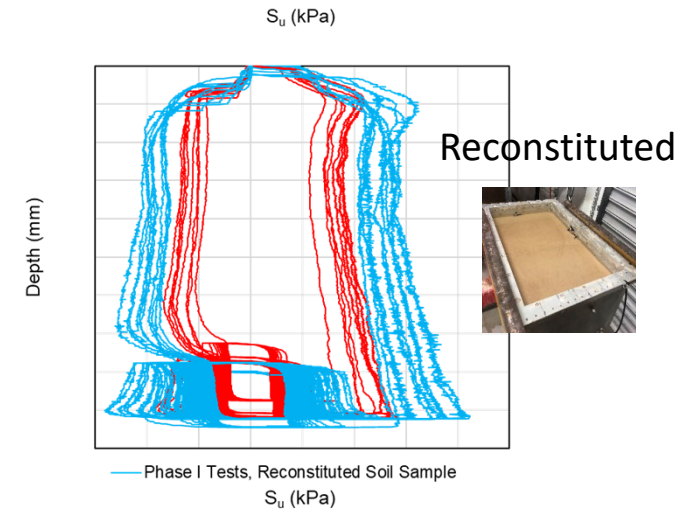
Issues

- Axial capacity uncertainty
- Subsidence (slumping) events



Testing explored:

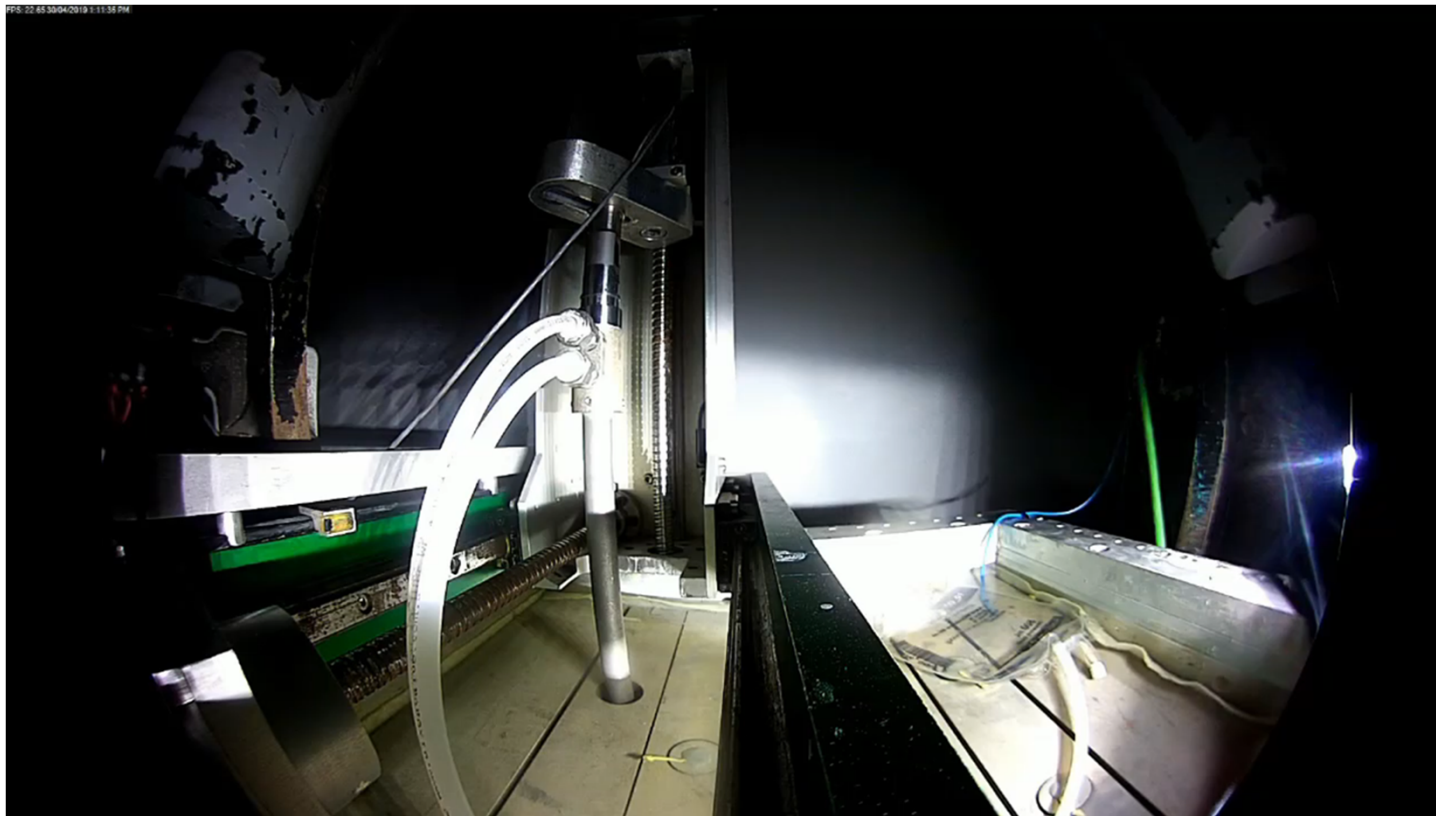
- Capacity changes with time
- Broaching, collars, reciprocation (etc)



Examples – Managing risk

The Role of Physical Modelling in Geotechnics (Phil Watson)

Axial capacity of jetted conductors

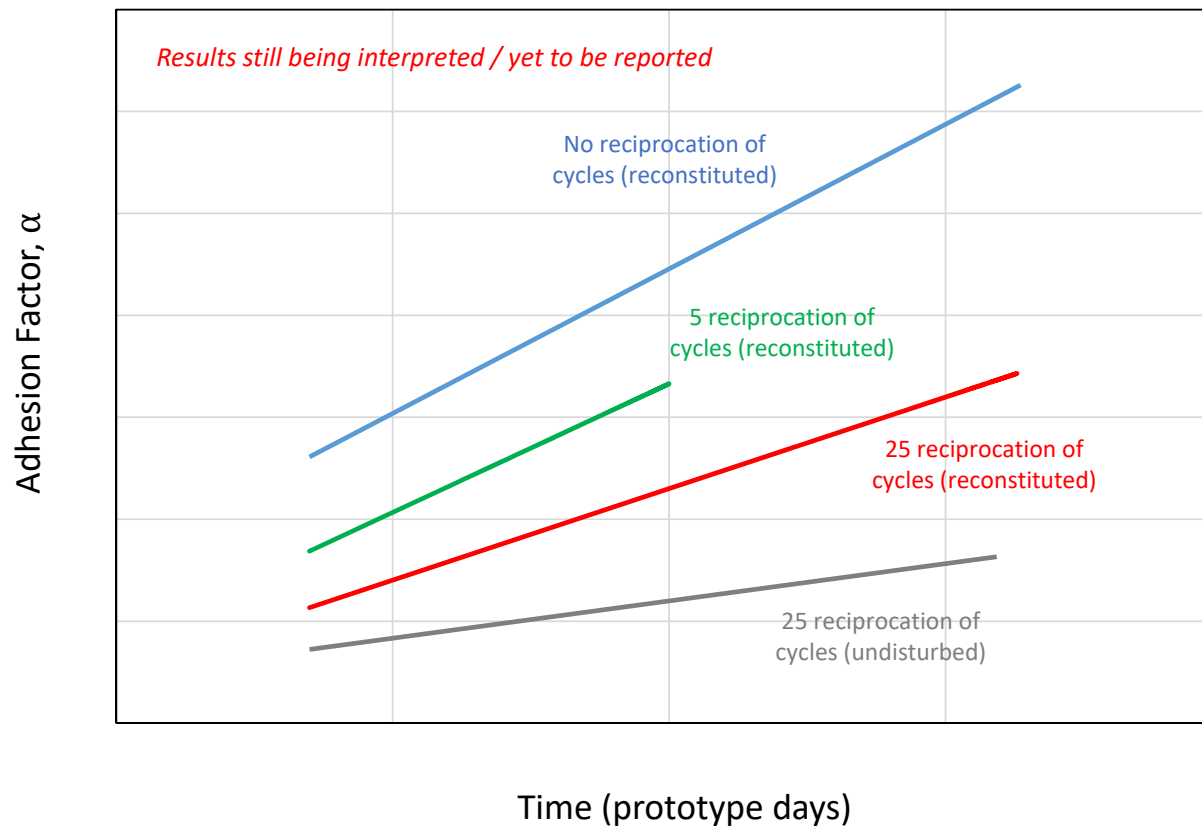


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Examples – Managing risk

The Role of Physical Modelling in Geotechnics (Phil Watson)

Axial capacity of jetted conductors



Capacity increases with time (setup)

Higher capacity for less 'damage' during installation

Undisturbed does not show same recovery with time

Results highlight an important consideration – capturing the behavior of soils with fabric (e.g. carbonate soils)

Closing comments

The Role of Physical Modelling in Geotechnics (Phil Watson)



Centrifuge modelling can be a valuable tool for an offshore engineer – I hope I have convinced you!

Like all tools – it needs careful consideration - and is (often) best used in combination with analytical/numerical tools, and good judgement!

ISFOG 2020 (an **ISSMGE TC209** supported event) will be held in Austin, Texas

- This will include a prediction event – participants asked to predict responses seen in the centrifuge
- Will also host the 5th McClelland Lecture – to be delivered by Ed Clukey on the topic of physical modelling in geotechnics

Finally, I'd like to acknowledge my colleagues from UWA and beyond (especially Christophe Gaudin, Conleth O'Loughlin, Dave White, Alex Osuchowski)