Direct on-seabed sliding foundations

(A.K.A. “slippery foundations”)

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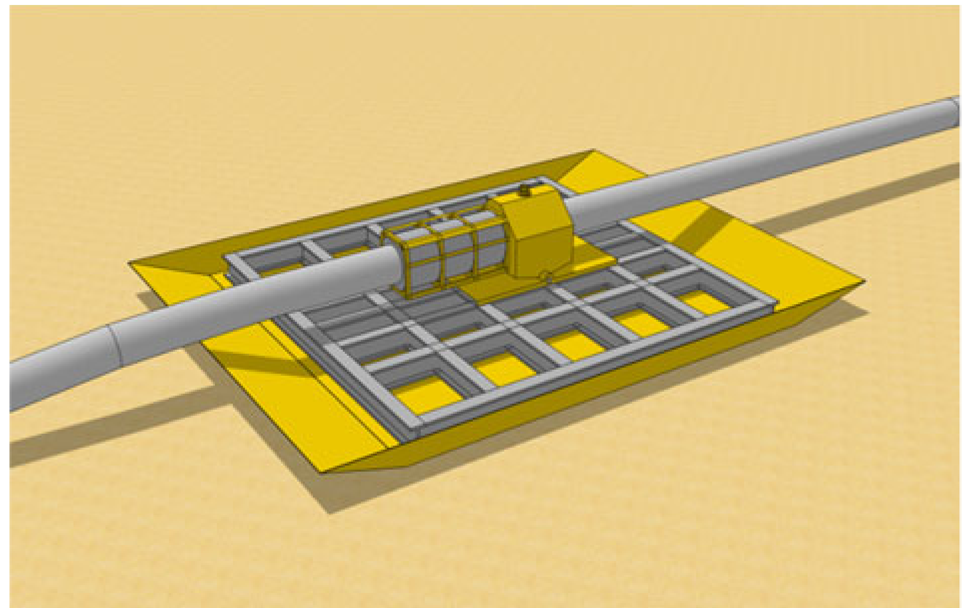

SUT-Perth geotechnical evening, 26/2/2014

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Presentation Overview

- What are they?
- Motivation (why?)
- Design (how?)
  - Key aspects
  - Reliable geotechnical engineering
  - System integration
- Summary

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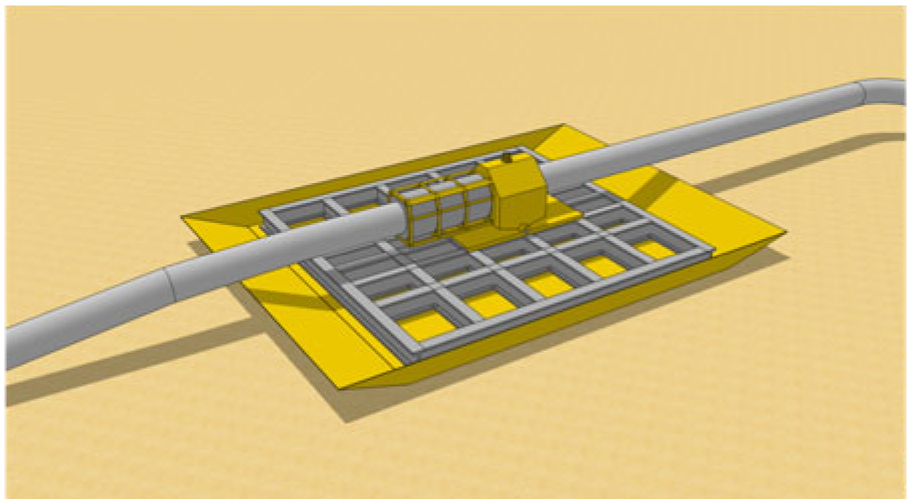
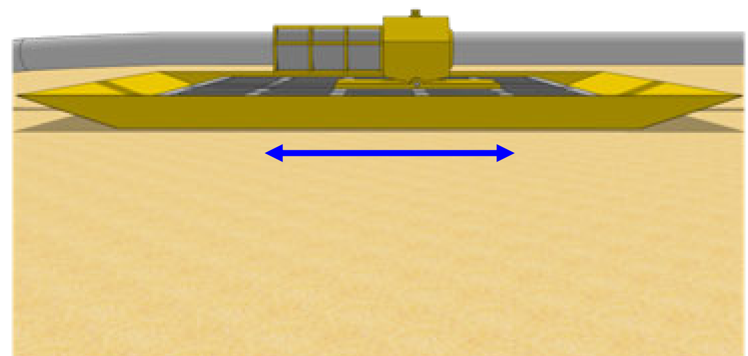
A direct on-seabed sliding foundation



A sliding foundation



Repeated sliding over the seabed

Initial literature
Cathie et al. (2008)
Bretelle & Wallerand (2013)

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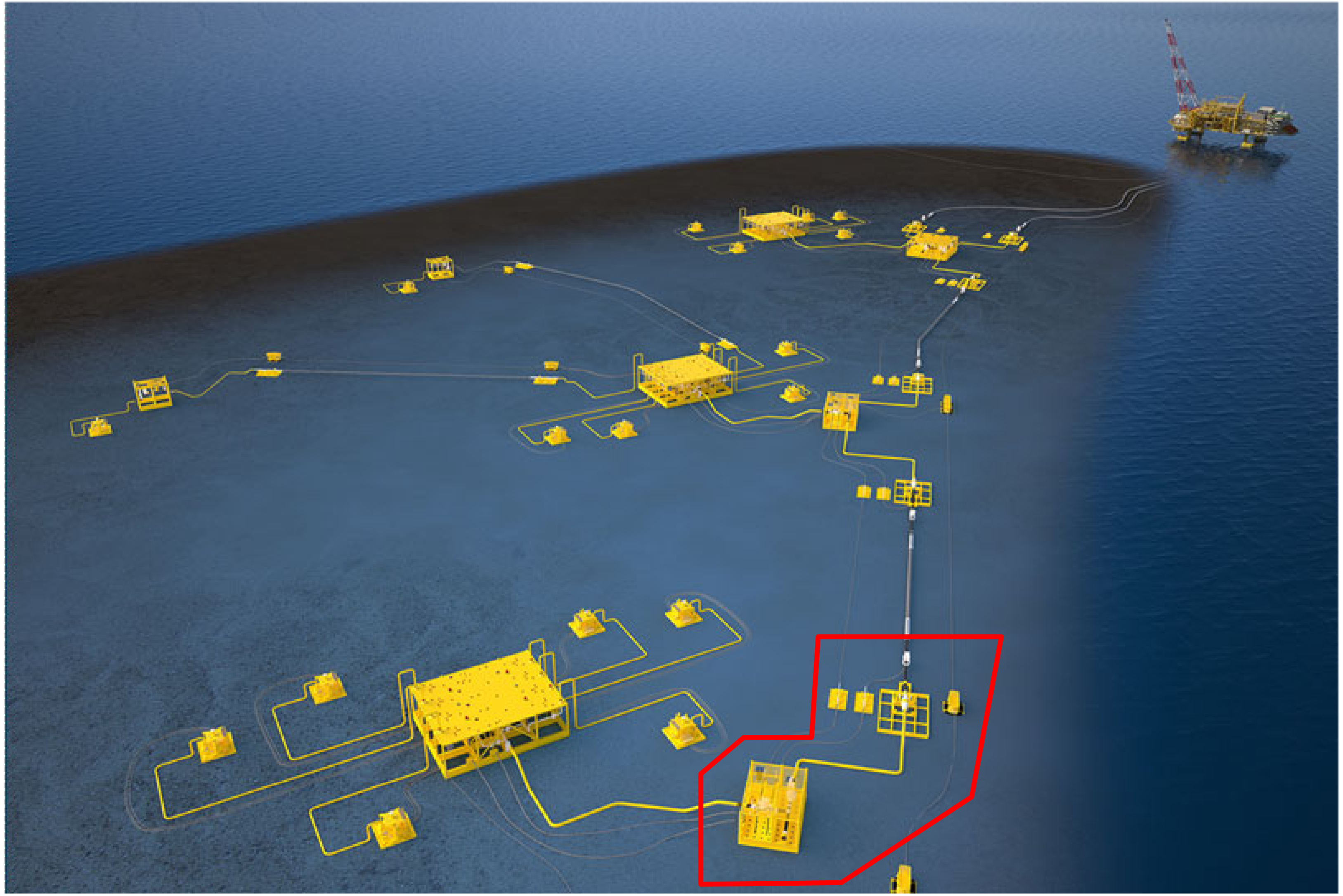
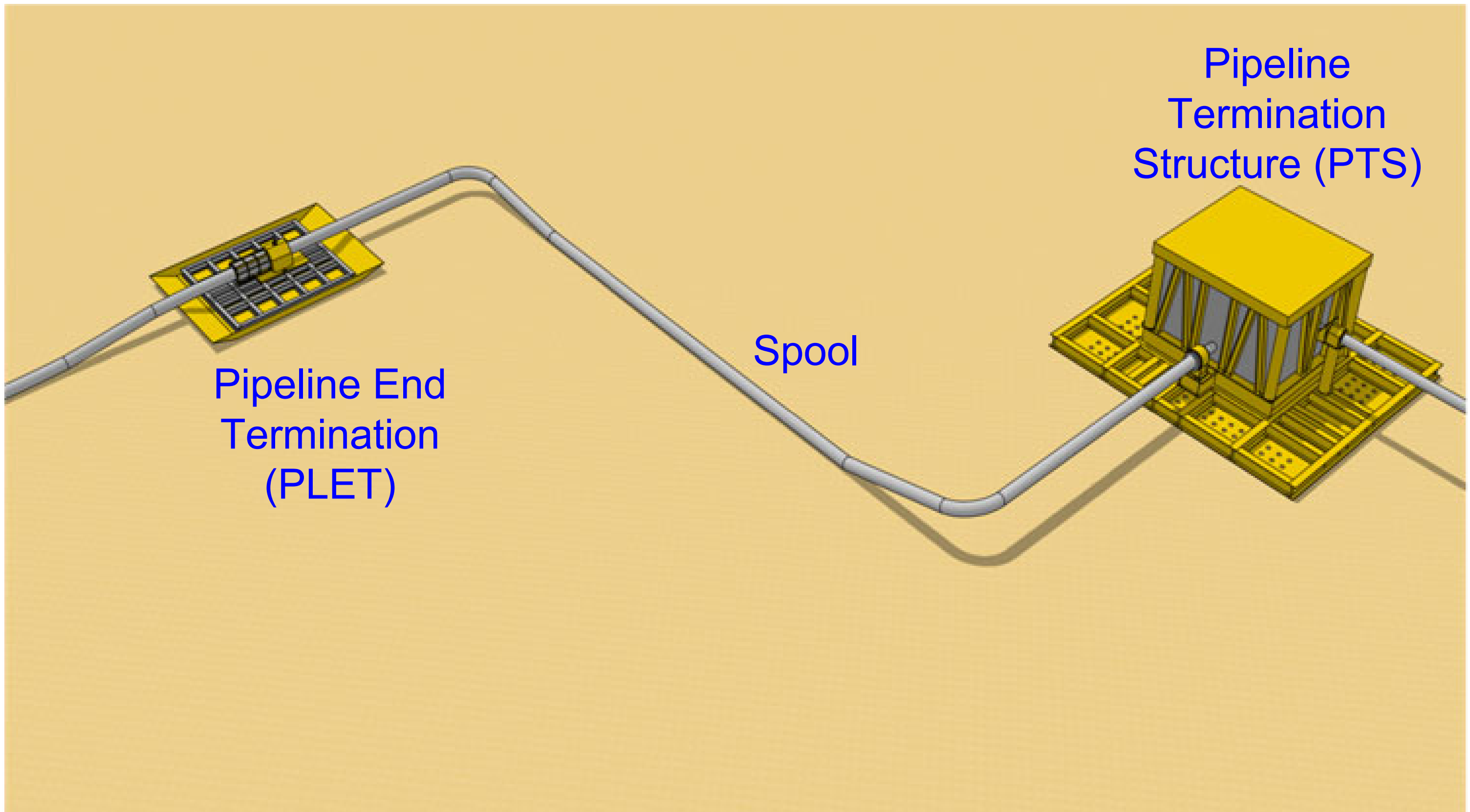


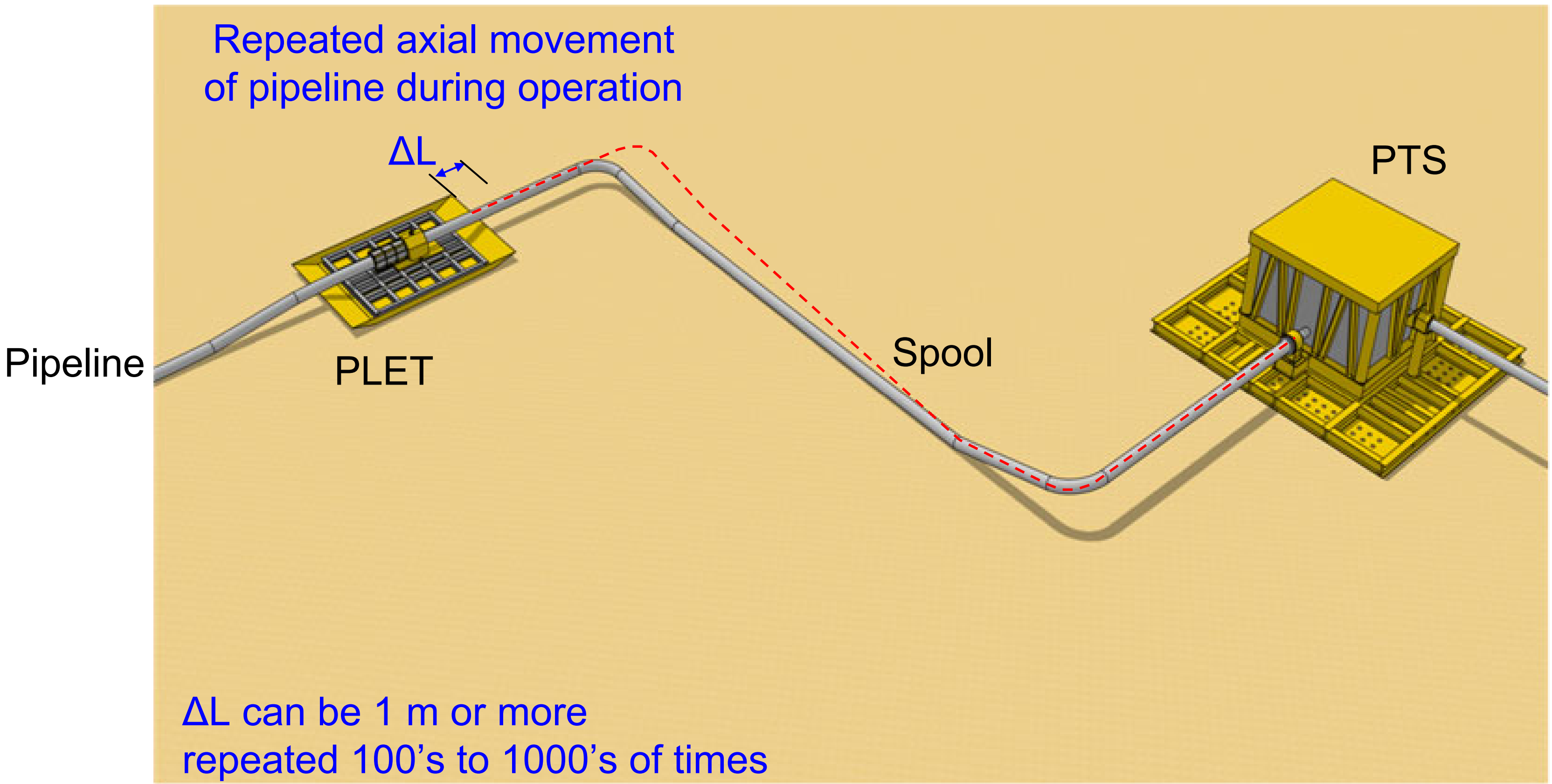
Julimar field*, Apache. www.apachecorp.com

* Just a freely available field layout – no sliding foundations as far as I'm aware.

Motivation – System Example



Motivation – System Example



ΔL a function of:
- Product (e.g. temperature and pressure)
- Pipeline properties (e.g. heat transfer)
- Pipeline design (e.g. buckle design strategy)
- Geotechnics (axial & lateral pipe 'friction factors')

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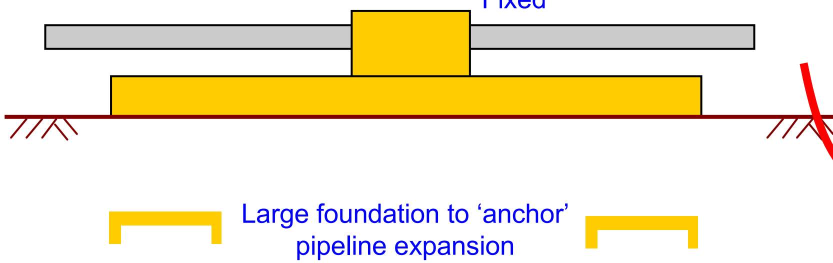
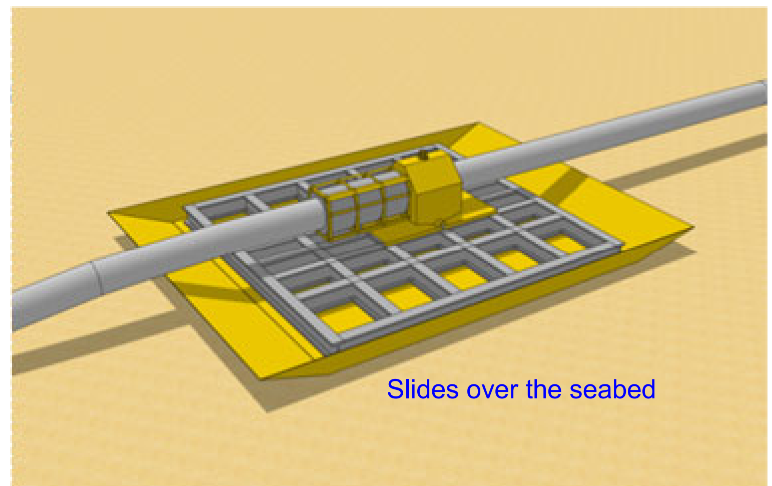
PLET Options

Fixed PLET



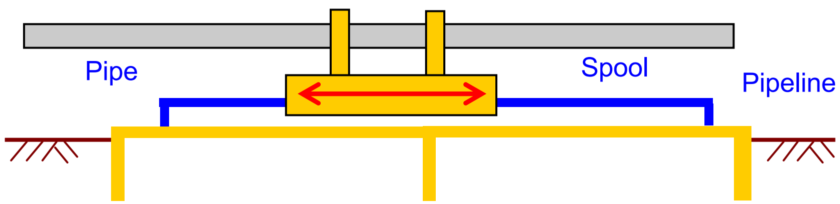
Direct on-seabed sliding



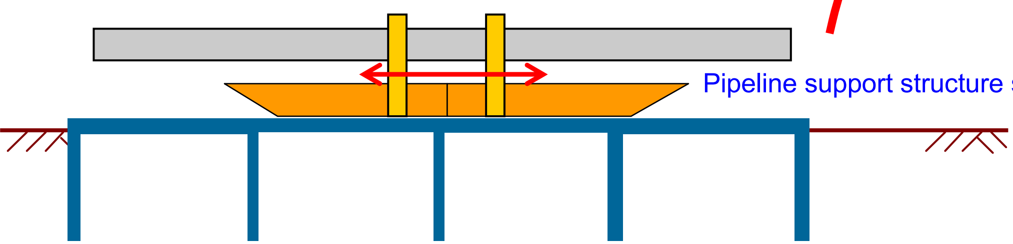
Maybe in-line installable

Smaller foundation

Fixed foundation - sliding PLET



Pipeline support slides on rails



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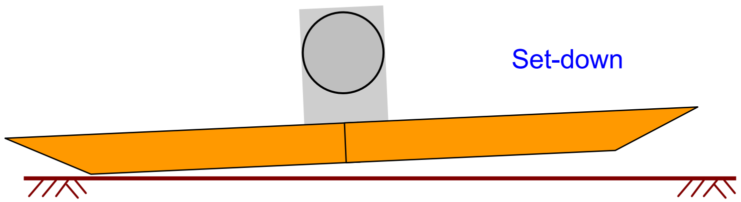
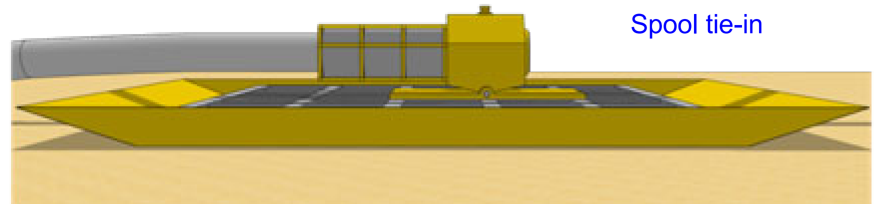
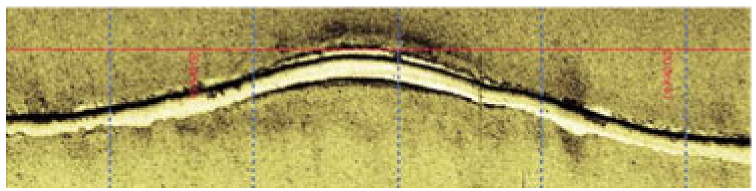
Key design aspects

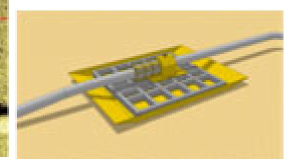
- Capacity and Stiffness — Sufficient for set-down, tie-in and external loading (e.g. cyclonic)



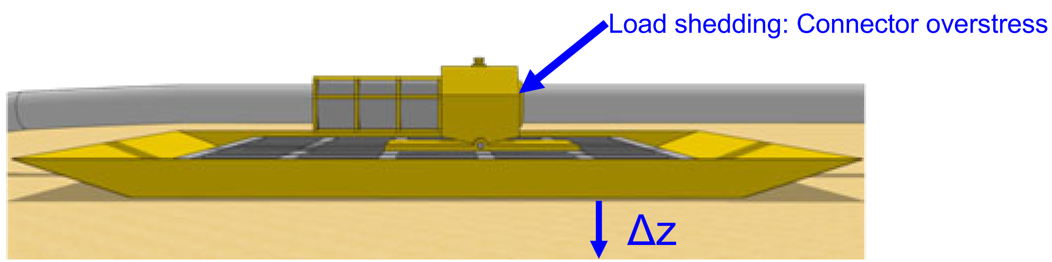


- Sliding resistance — Should be minimised



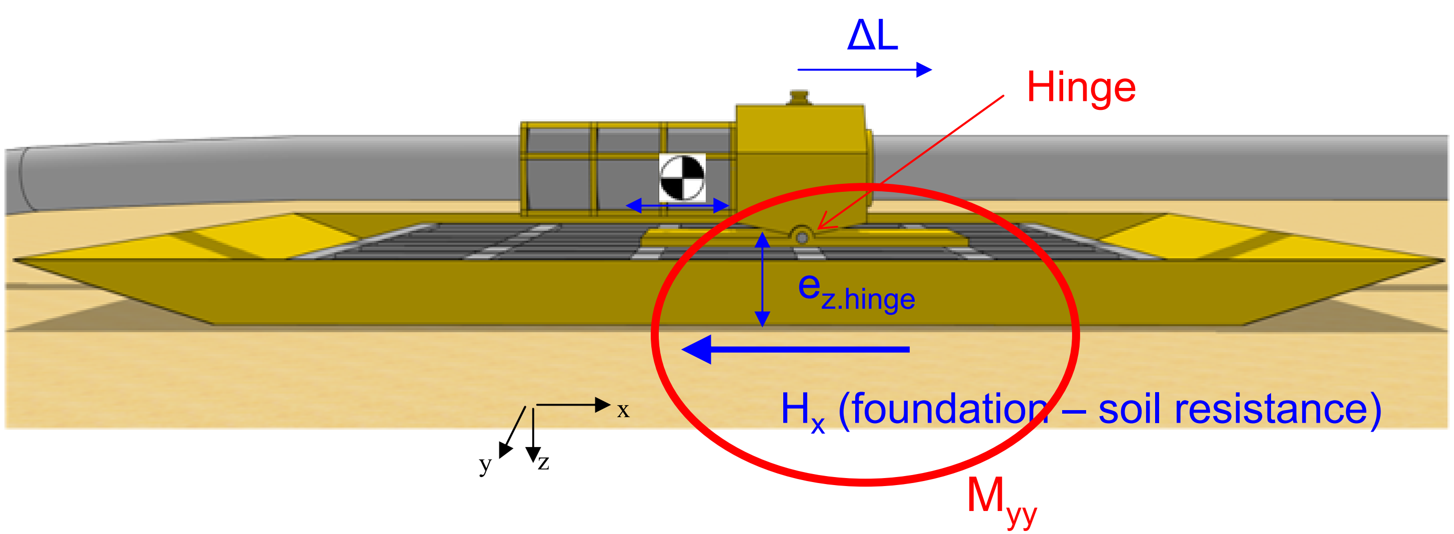


- Settlement — Should be minimised



Imposed forces

- Weight (V_z)
- Sliding resistance (H_x)
- Moment (M_{yy}, M_{xx})



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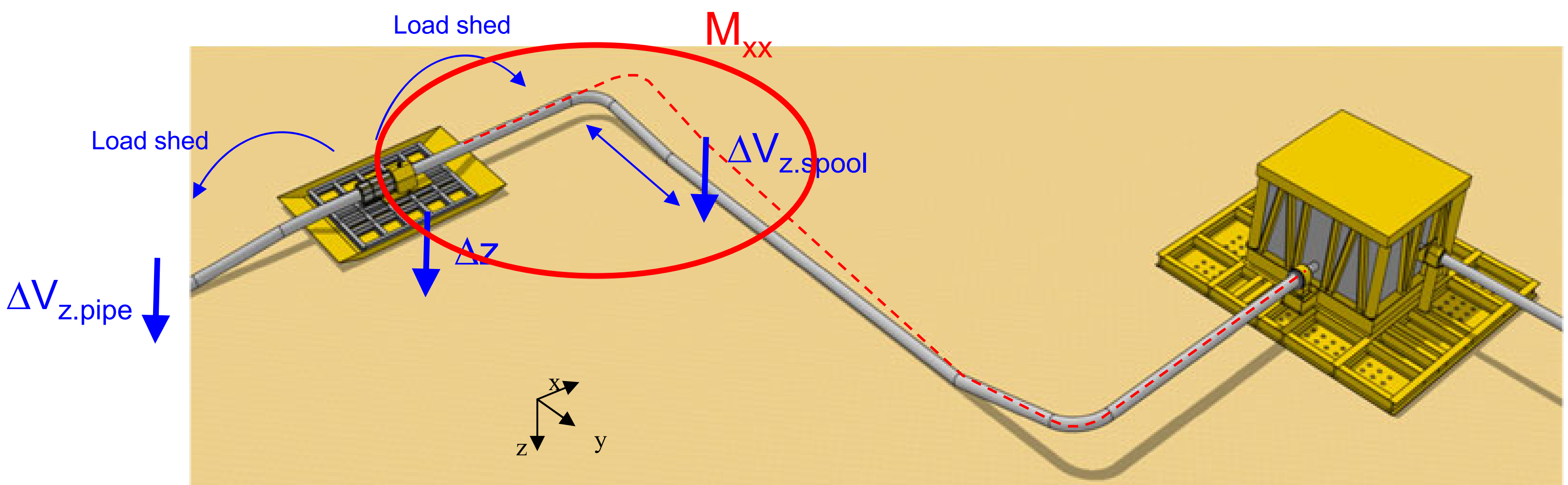
Imposed system forces

- Load shedding from PLET may cause overstress.
- System analysis and interaction with pipe engineering teams vital.



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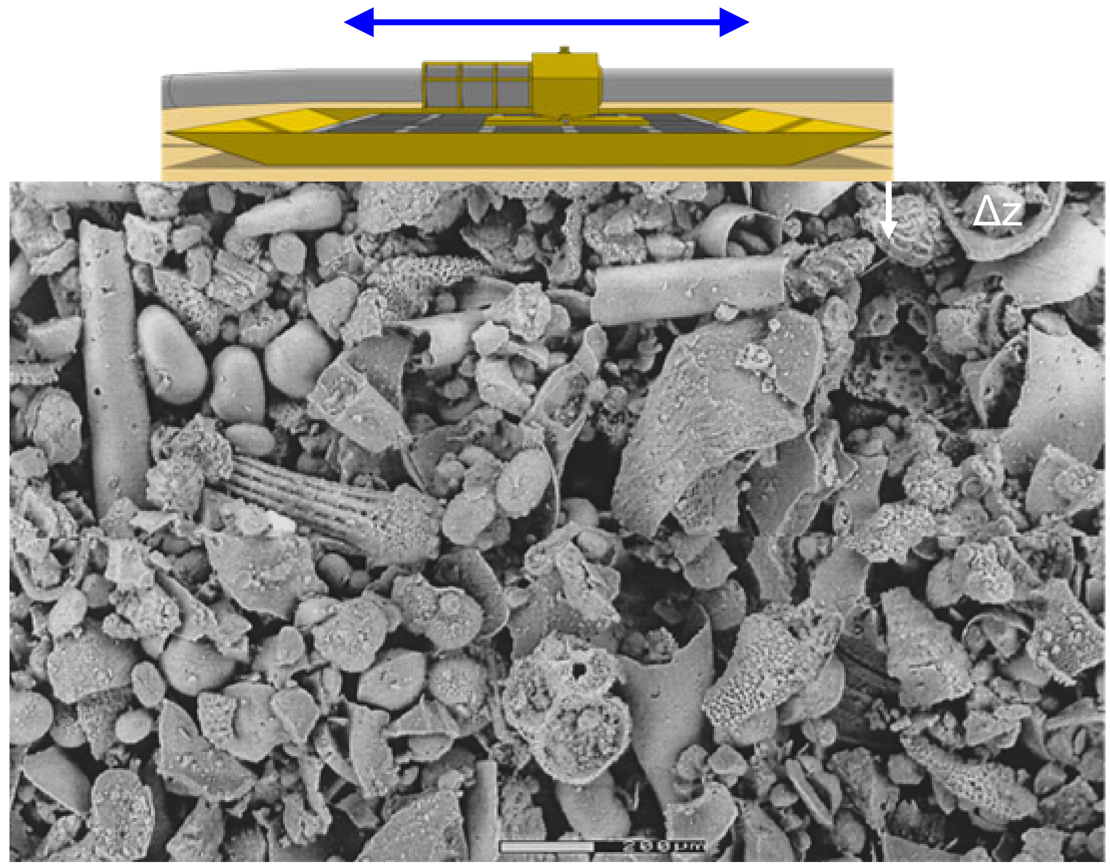
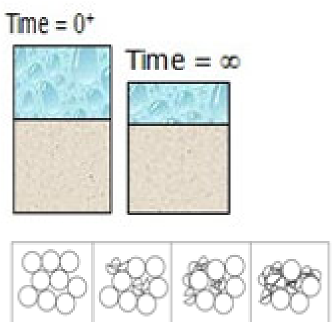
Long term settlement focus

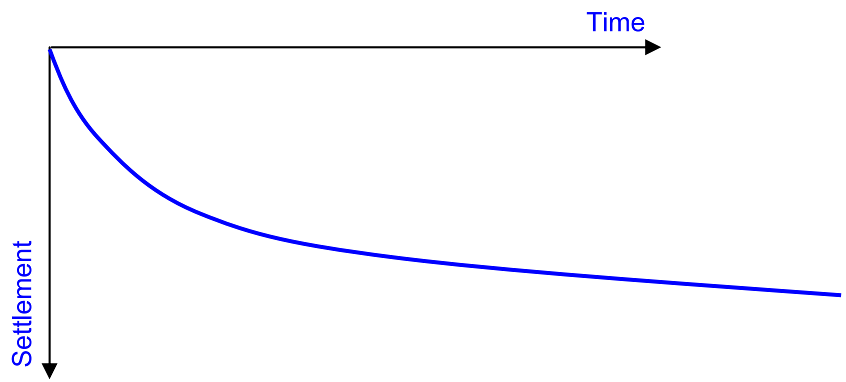
- Consolidation & creep
- Plastic sliding deformations
- Shakedown

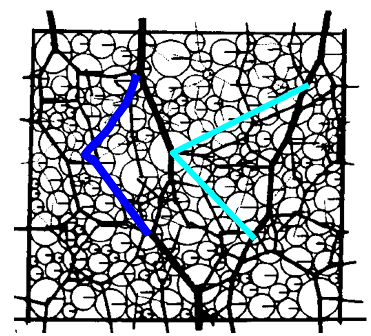


Soil consolidation & creep



Consolidation
(hours or months?)

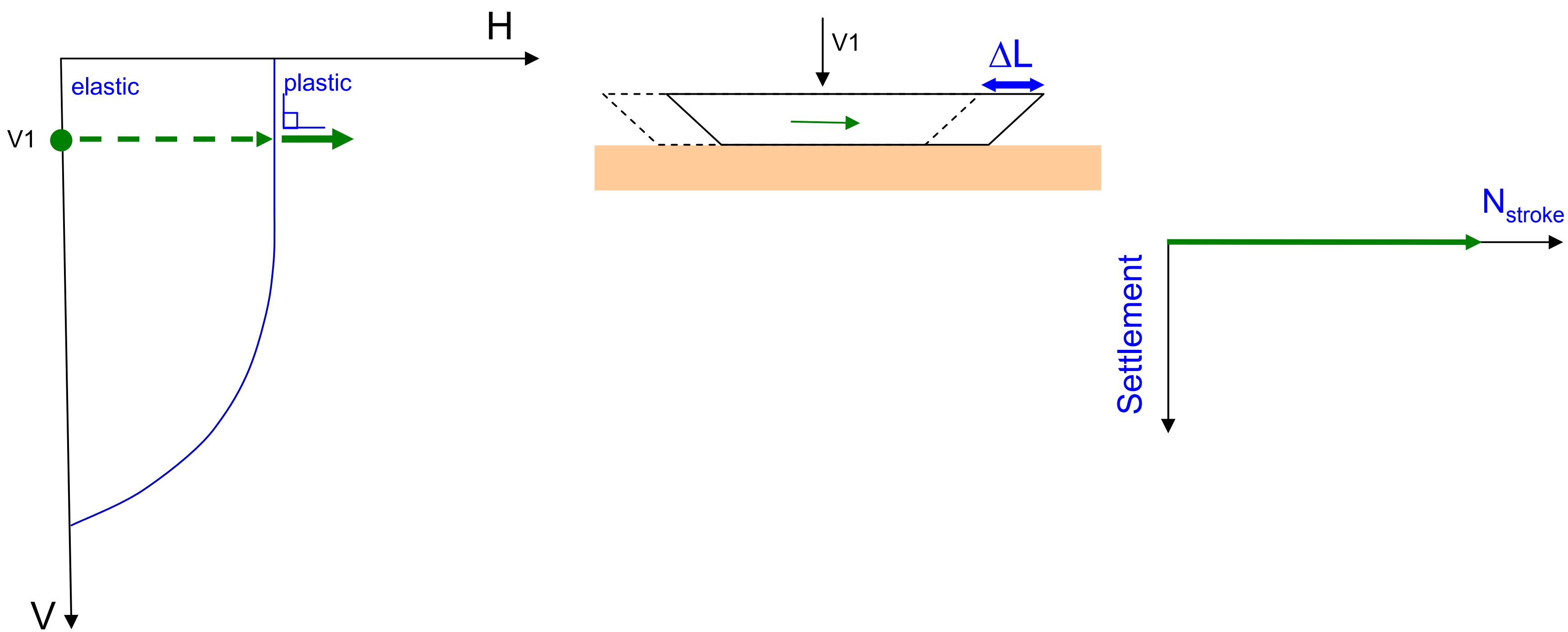




Creep
(years or decades?)

[Soil densification]

Plastic deformation while sliding



Soil interaction diagram

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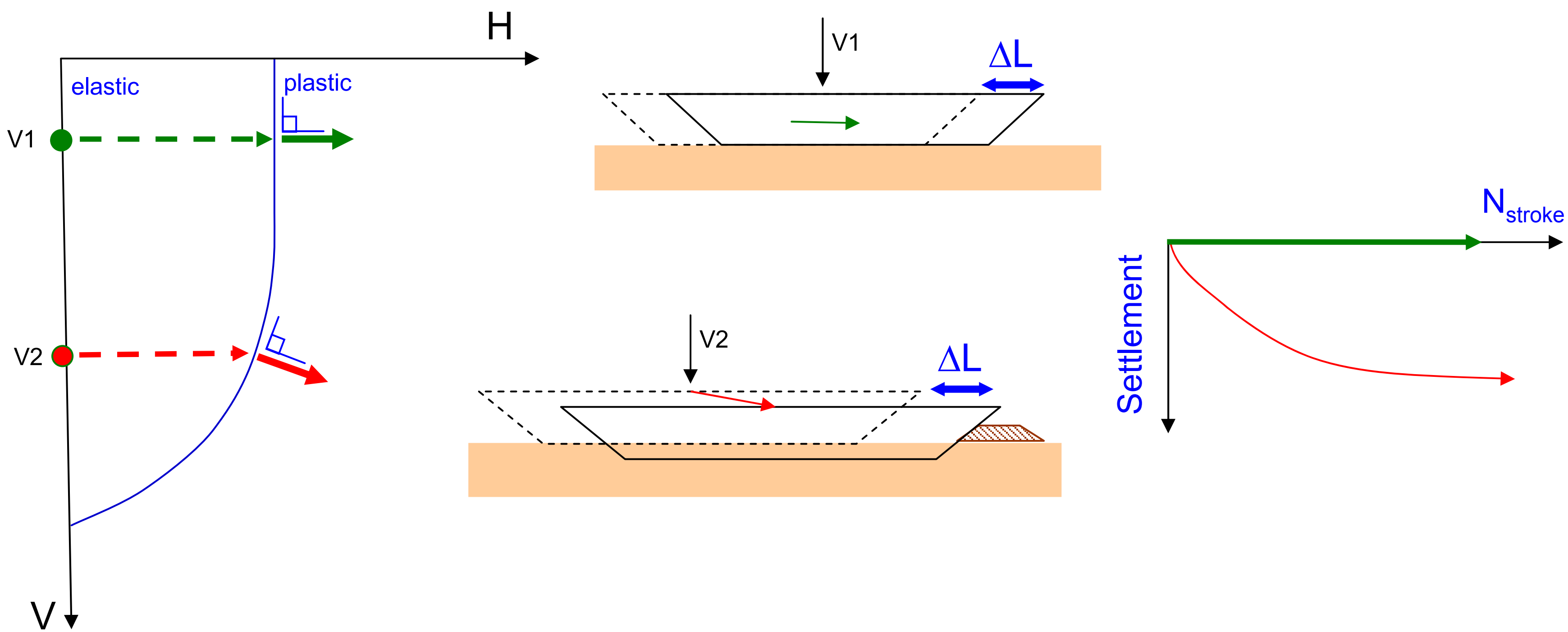
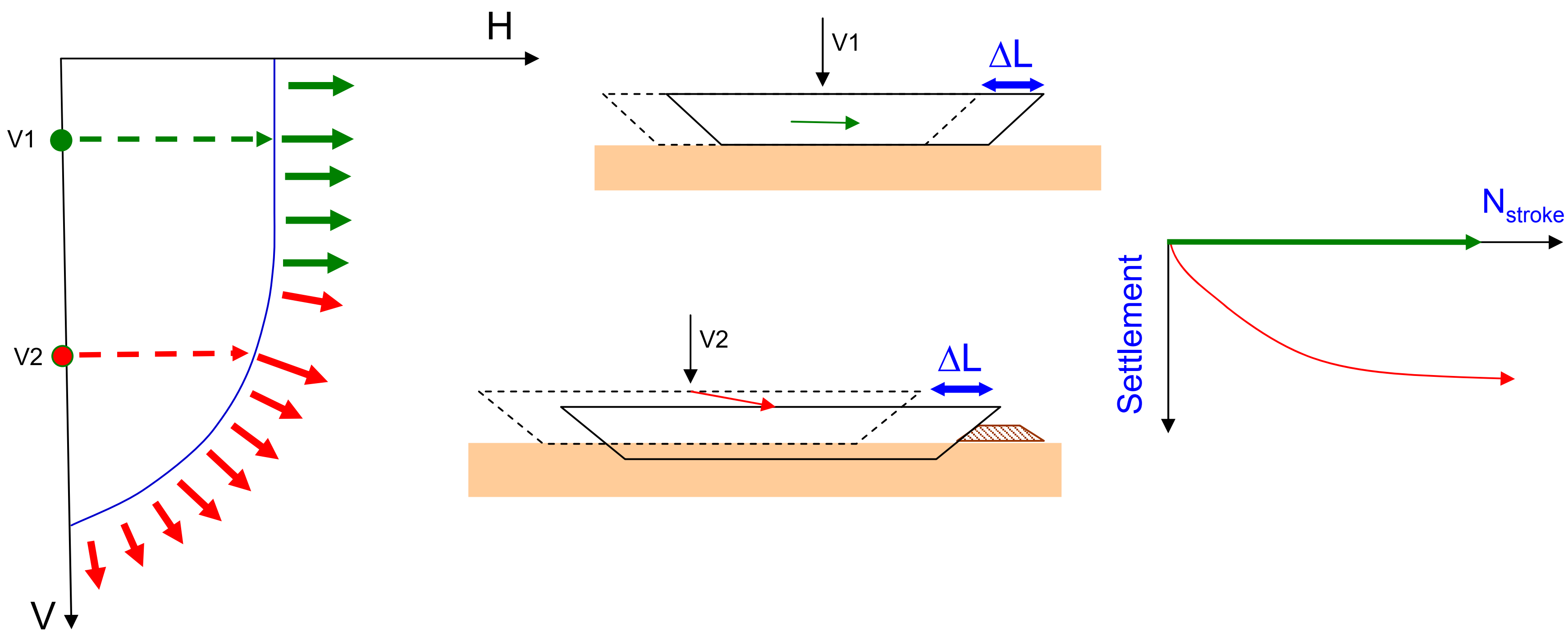
Plastic deformation while sliding



Soil interaction diagram

[Soil removal]

Plastic deformation while sliding



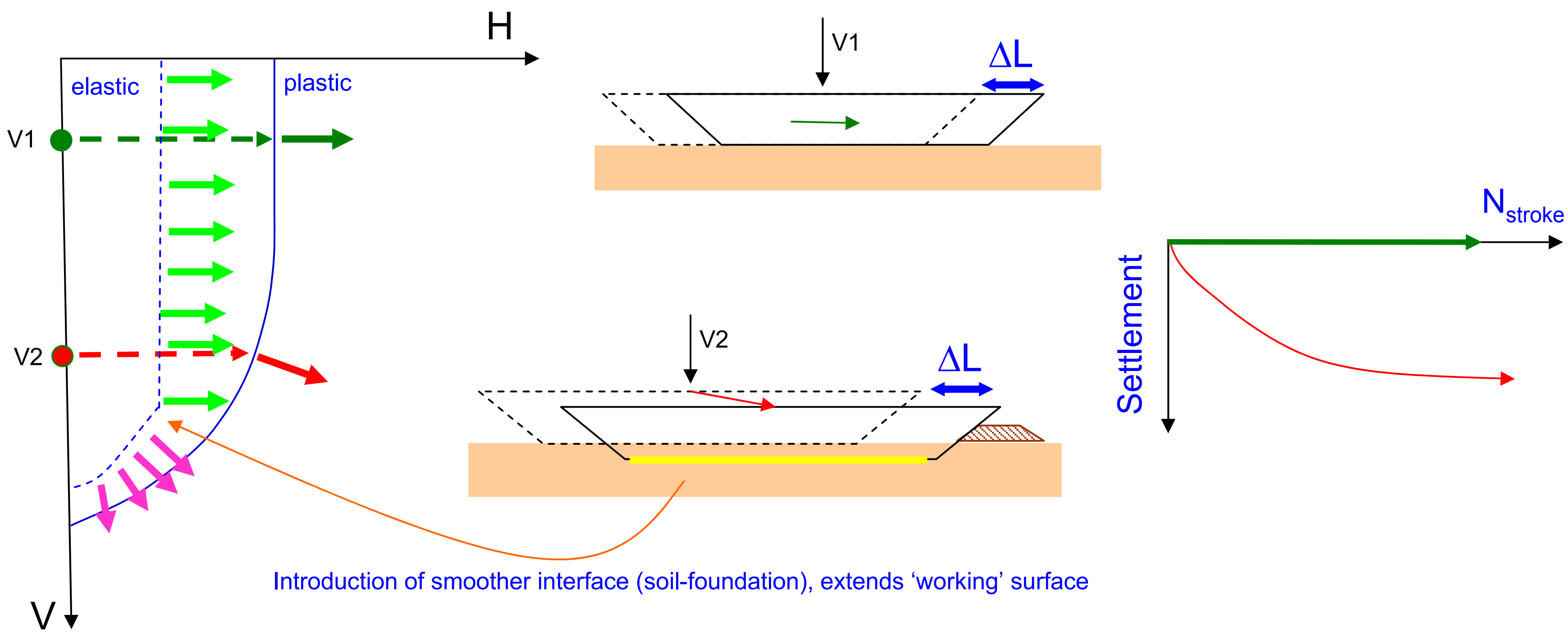
Soil interaction diagram

Prevented by design : minimised V/V_{ult} and soil-foundation interface strength

[analysis needs to consider VHM loading, Cyclic strength degradation, drainage, N_{eq} etc]

[Soil removal]

Plastic deformation while sliding



Soil interaction diagram

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[Soil removal]

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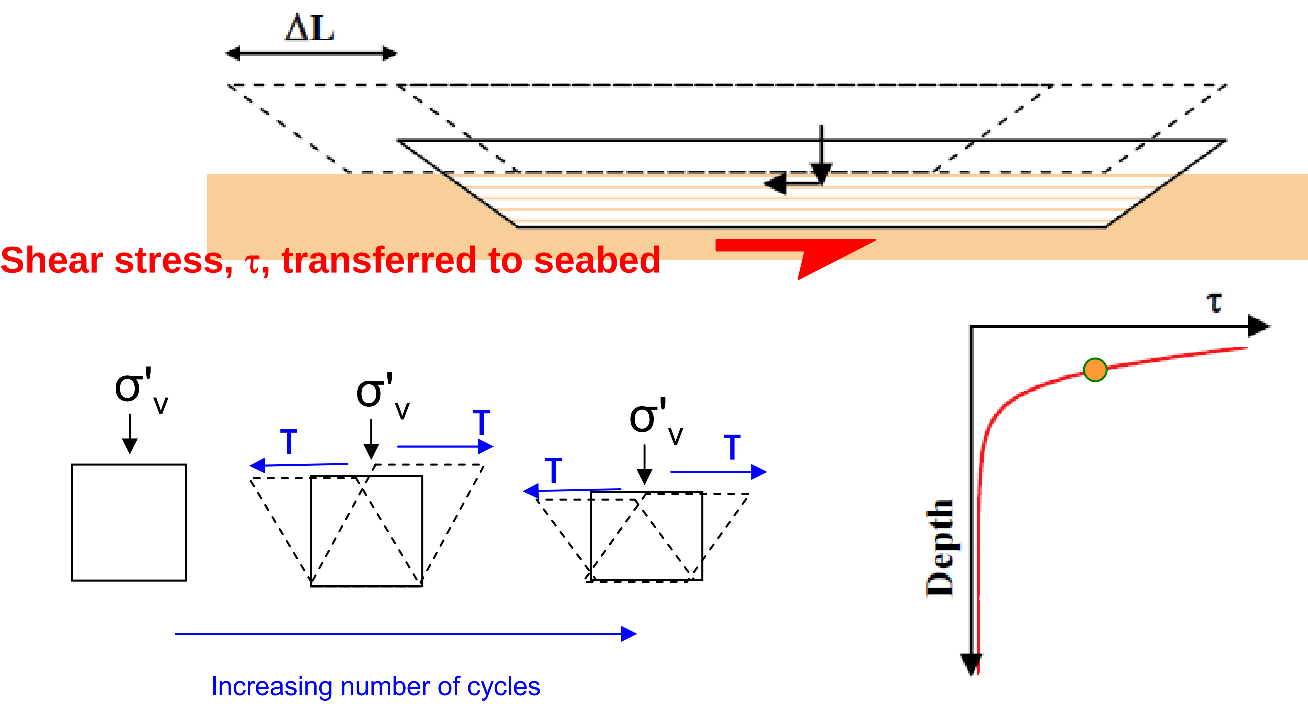
Cycle by cycle densification - shakedown



[Soil densification]

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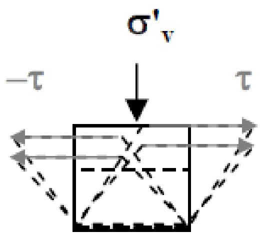
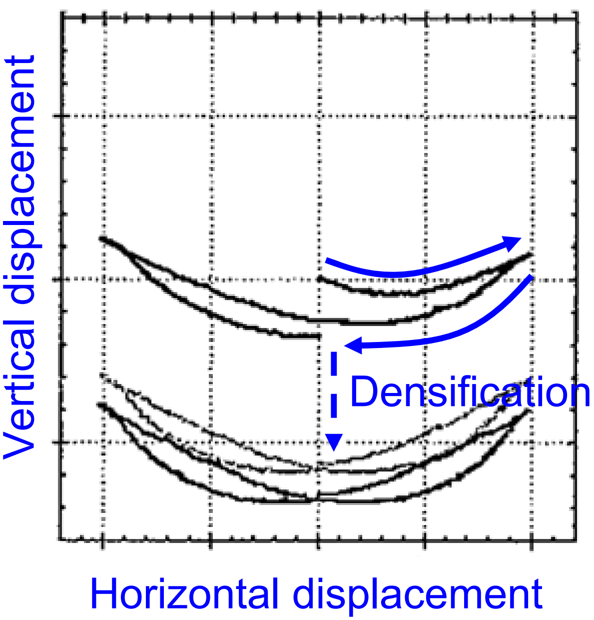
Cycle-by-cycle densification – Shakedown

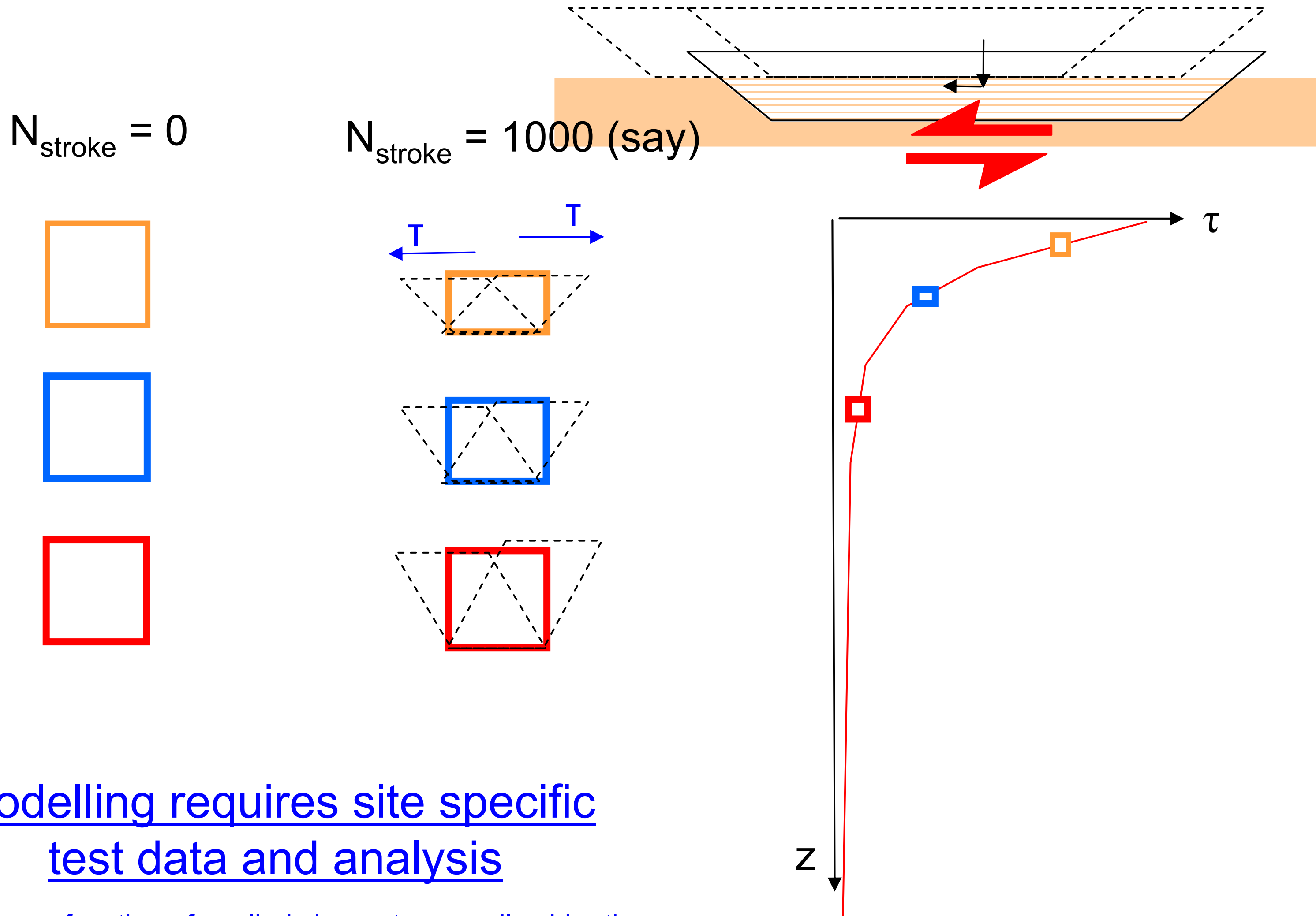




[audience members saw a movie here…]

(DeJong et al. 2003, 2006)

Shakedown predictions



[Modelling requires site specific test data and analysis]

[shakedown a function of applied shear stress, soil void ratio, compressibility, 'state' c.f. CSL and PTL, movement rate etc.]

Deeks et al. 2014 (OMAE, 2014)

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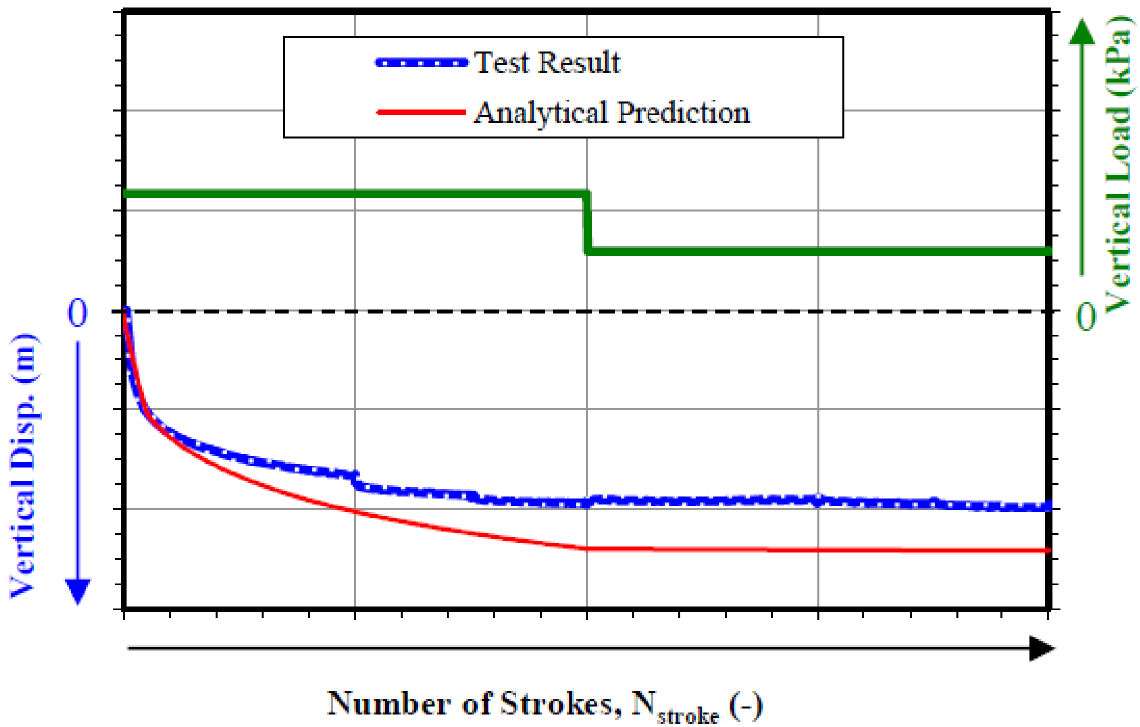
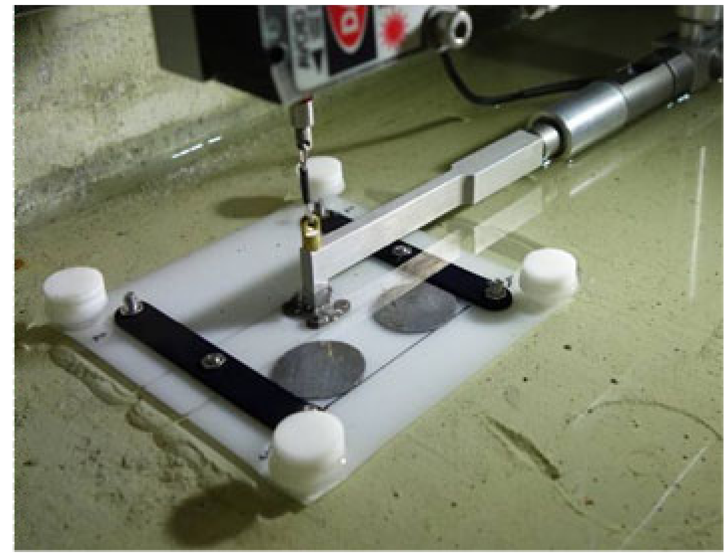
Shakedown predictions





- Cycle-by-cycle settlement assessment
- “Hardening” rule added to existing cyclic strength frameworks
- Prediction based on site specific soil element testing

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(OMAE, 2014)

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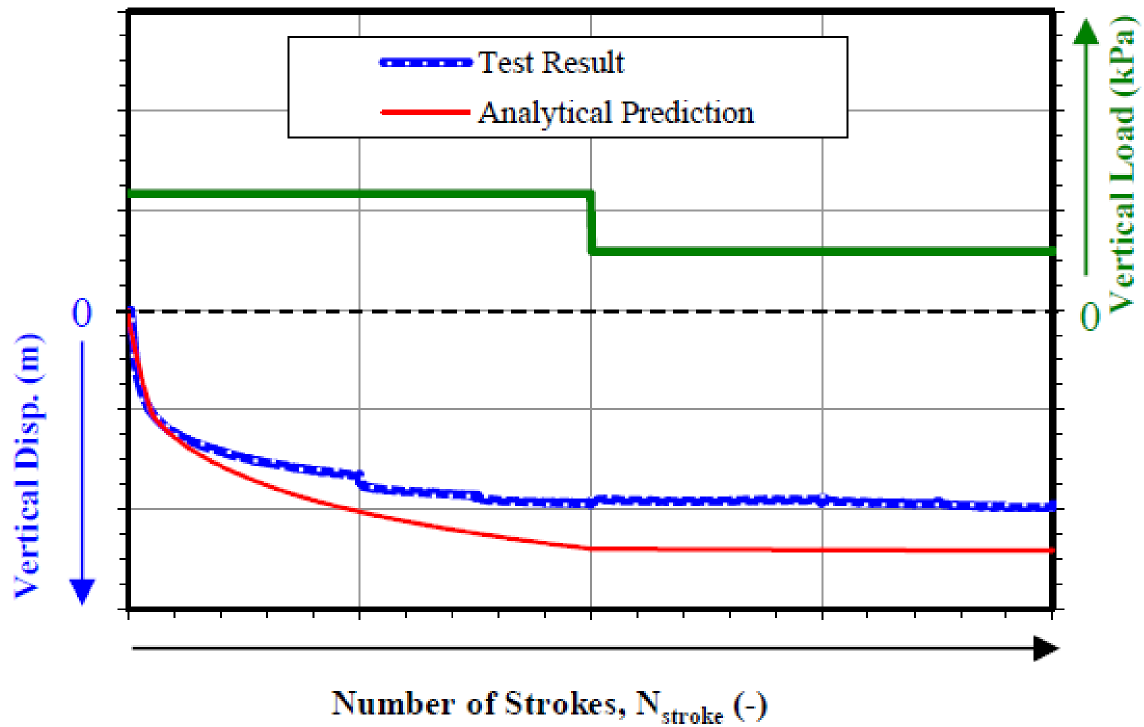
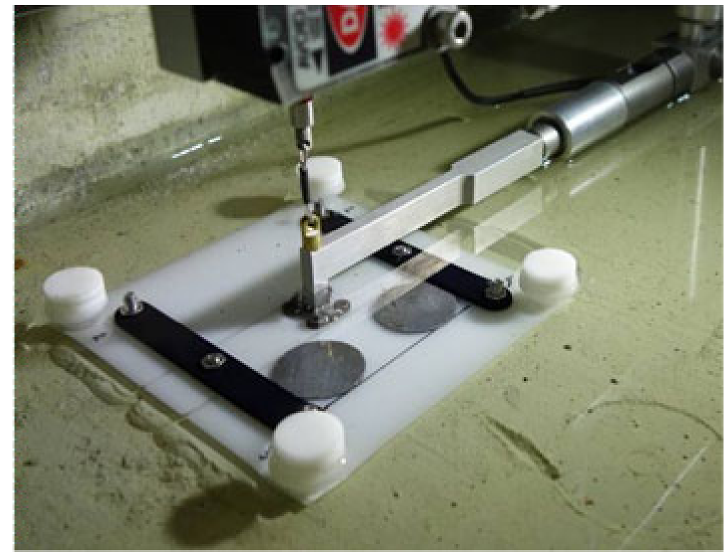
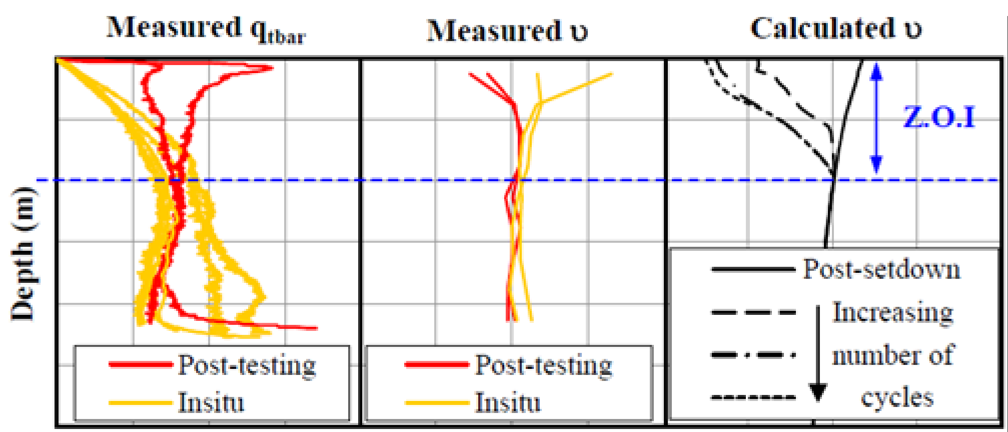
Shakedown predictions







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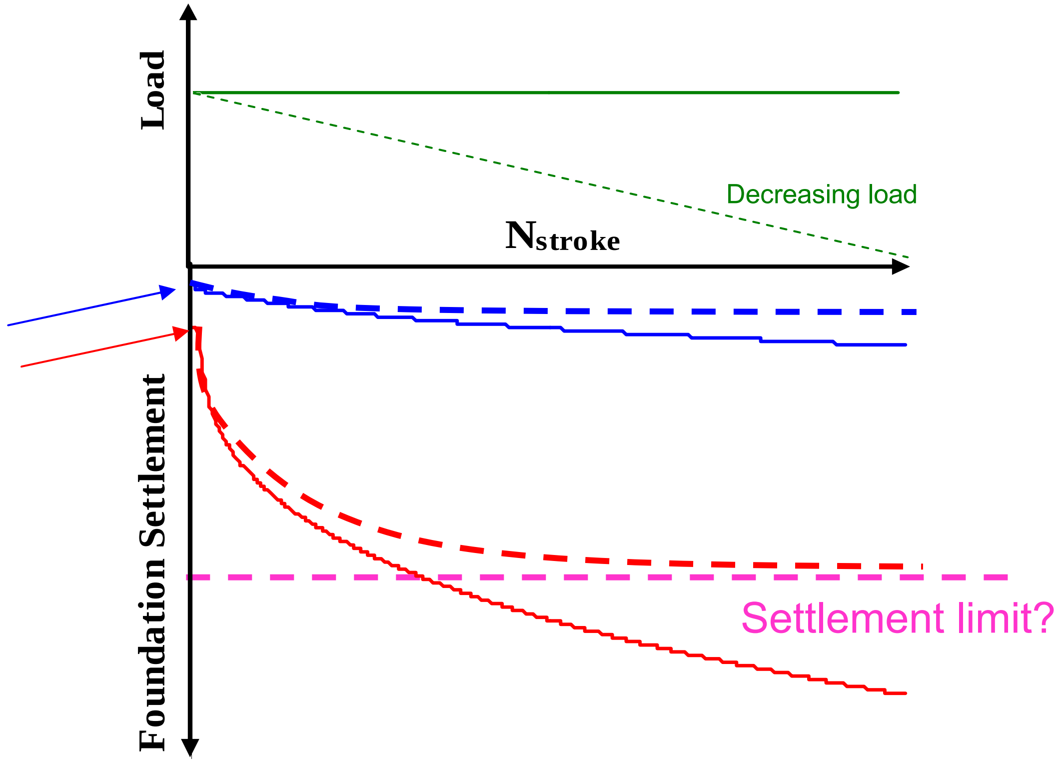
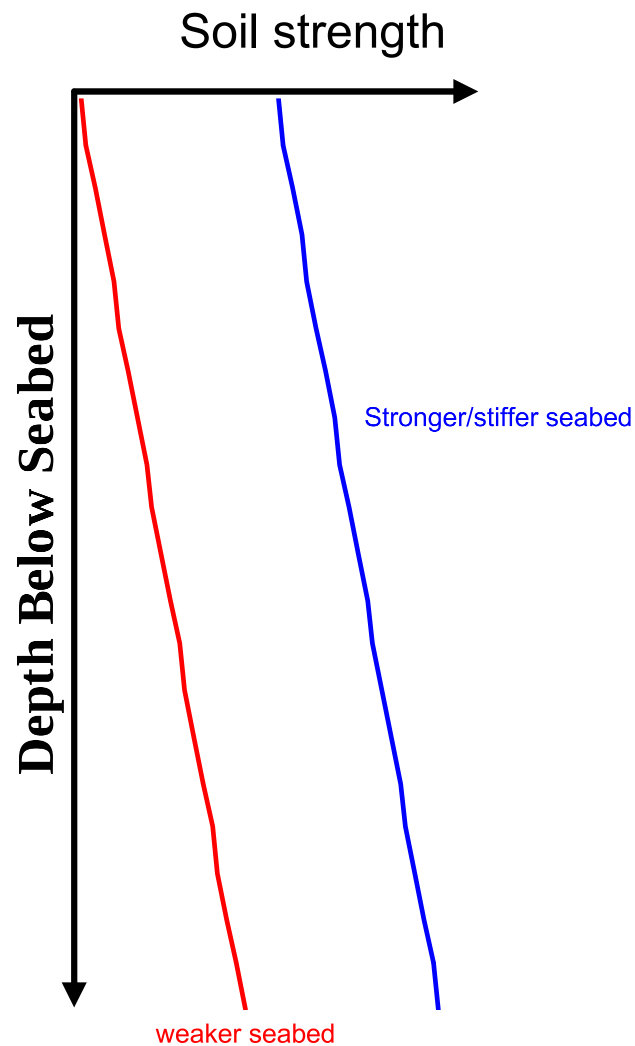
Influence of soil state: example settlement calculations

Offsets represent consolidation component





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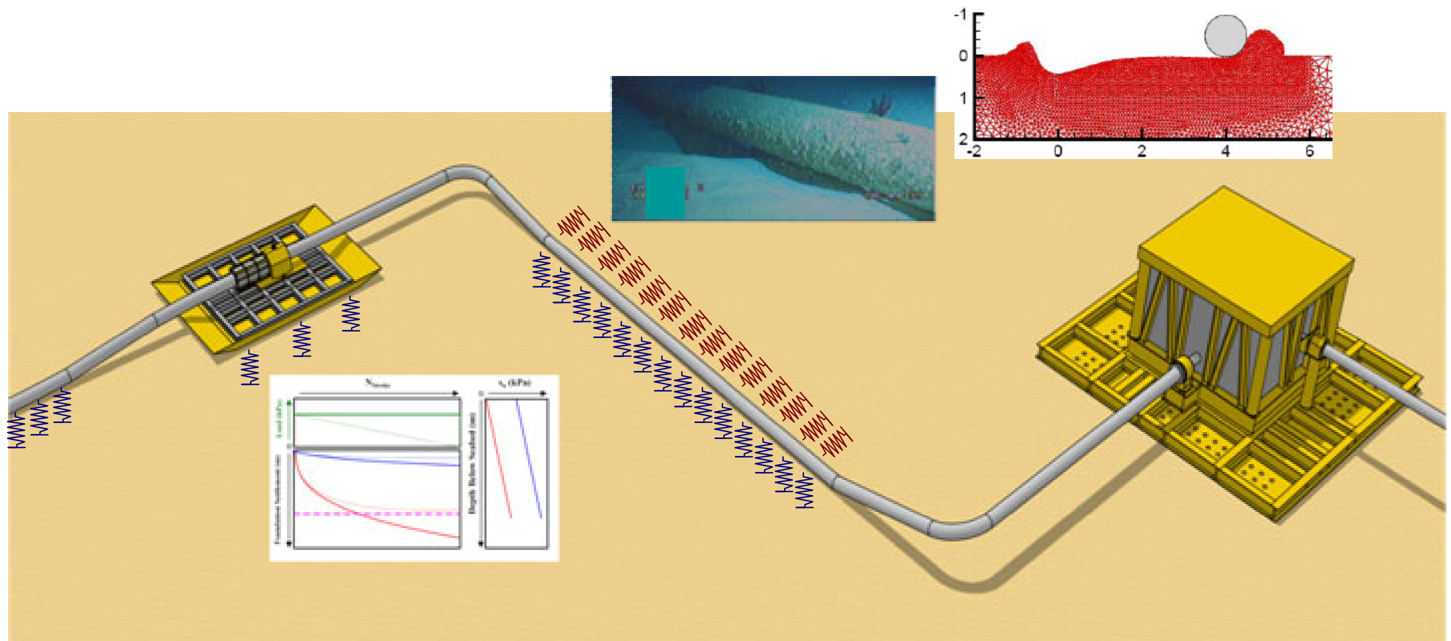
System integration & modelling

- Validate pipeline-plet-spool-structure system integrity
- Interaction & iteration between pipeline, geotechnical, and structural team is vital for successful implementation
- Reliable analysis: consider appropriate LE/ BE/ HE combinations



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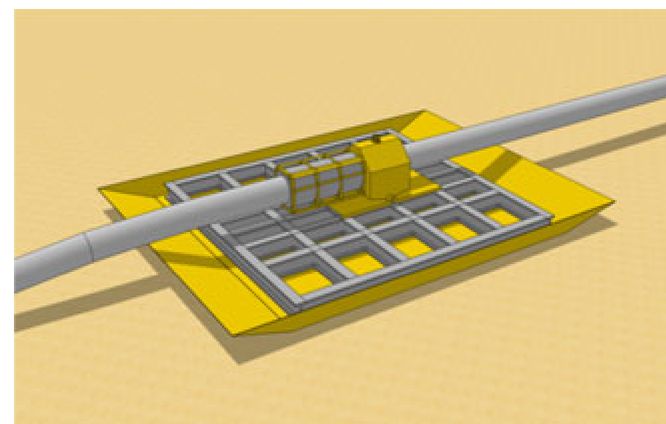
Summary

- Allowing direct on-seabed sliding can allow for smaller and lighter foundations which are cheaper to manufacture and install
- Design team interaction is required for successful implementation
- Shakedown (cycle-by-cycle densification) is typically the dominant cause of long-term settlement (and can be modelled on a site specific basis).
- Opportunities for design method optimisation
  - Other seabed interactions include:
    - Berm build up vs. axial movement history
    - Mobile seabeds (flexible/ moving scour protection)
    - Sand waves



Thanks for listening
& thank you to AG and industry colleagues