Application of cyclic accumulation models for undrained and partially drained general boundary value problems

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Introduction

Cyclic loads in geotechnical engineering

- Offshore structures are subjected to static and cyclic loading due to:

  Weight of the structure, wind, waves and current

- Under these load conditions,

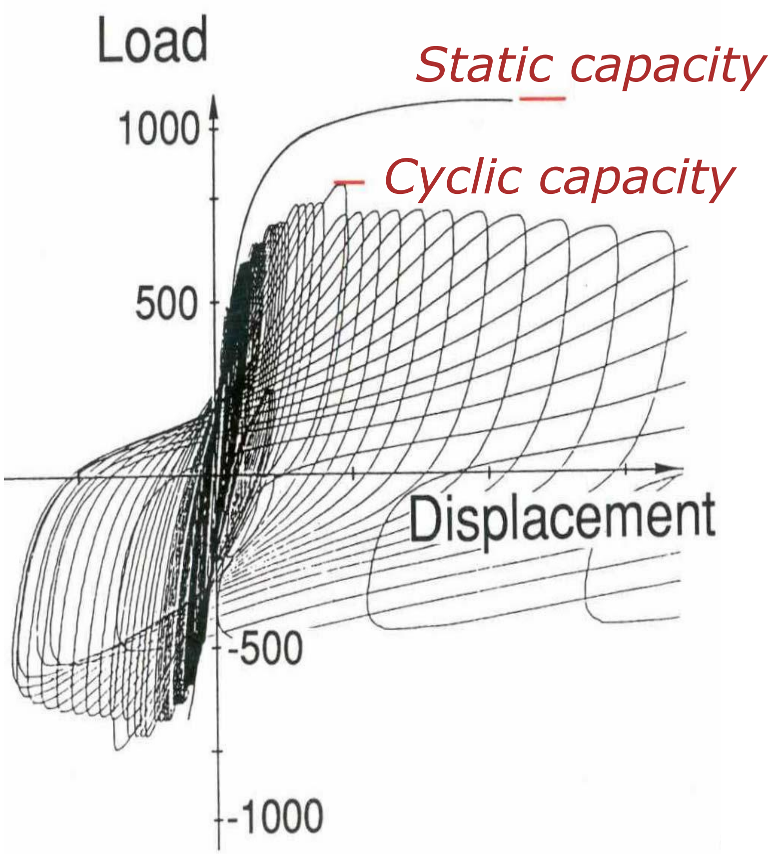
  the effect of **cyclic degradation** on the soil may be significant

Introduction

Cyclic degradation of the soil

Effects of the **cyclic degradation** of the soil:

- Reduction in strength and stiffness
- Strain rate effects (clays)
- Accumulated pore pressure
- Accumulated deformations
- Damping

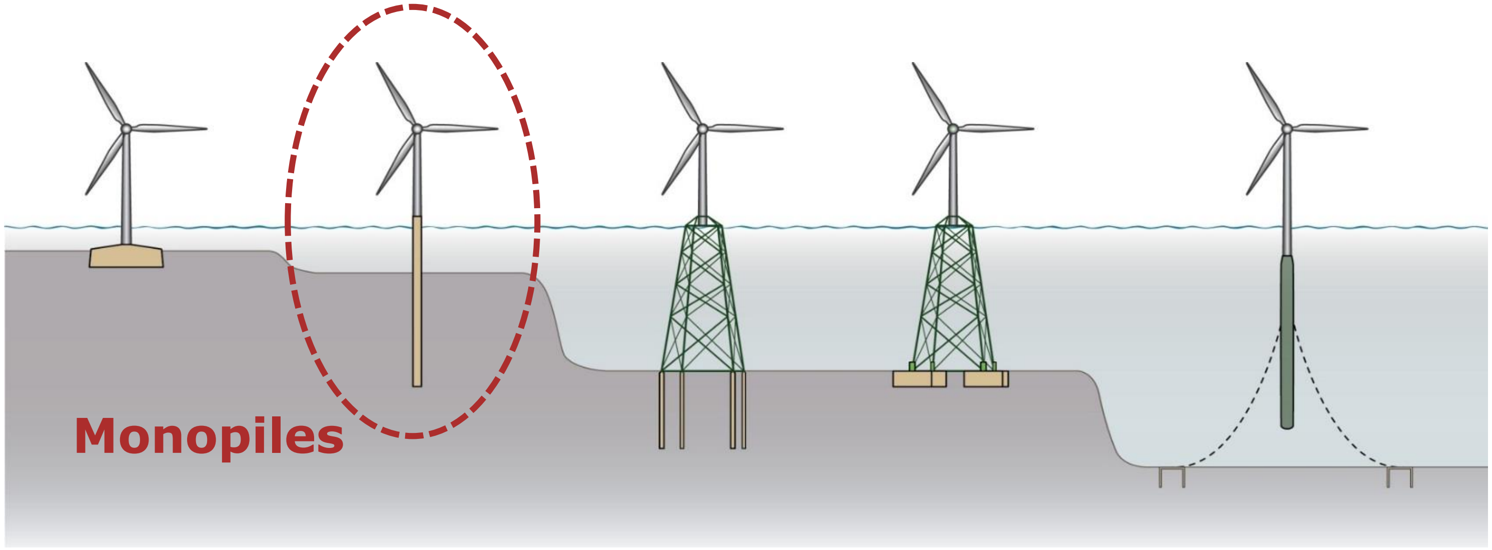


Results from a model test on a gravity platform on clay

Introduction

Cyclic degradation of the soil

The effect of cyclic loading has to be taken appropriately into account in the design!



The cyclic degradation of the soil varies along the pile

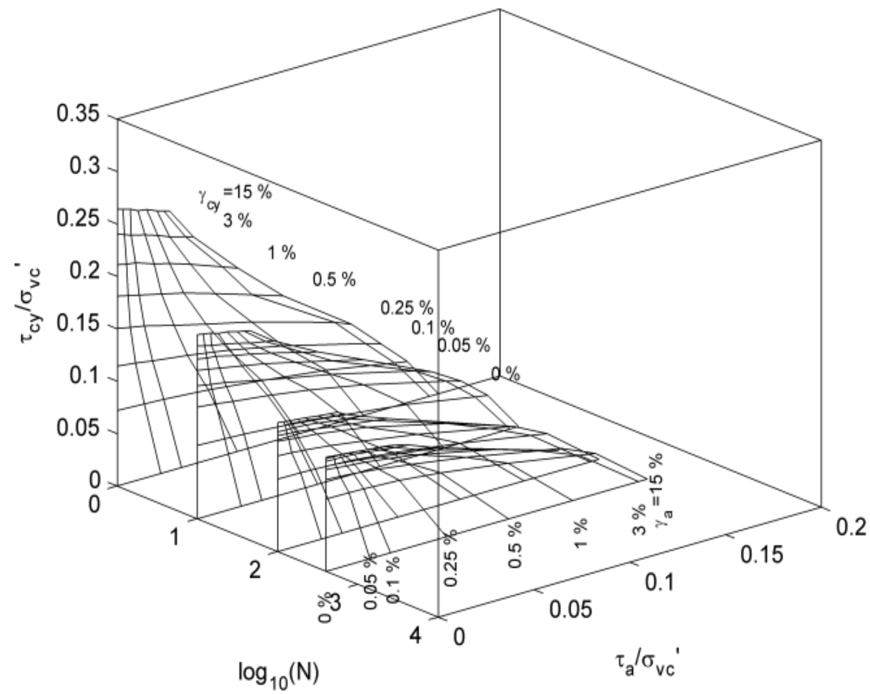
How do we account for cyclic degradation?

Contour diagrams

The behaviour of the soil under cyclic loading is based on

Contour diagrams, which relate:

- Cyclic shear stress, τ_{cy}
- Cyclic shear strain, γ_{cy}
- Average shear stress, τ_a
- Average shear strain, γ_a
- Number of cycles, N
- Accumulated pore pressure, u_p

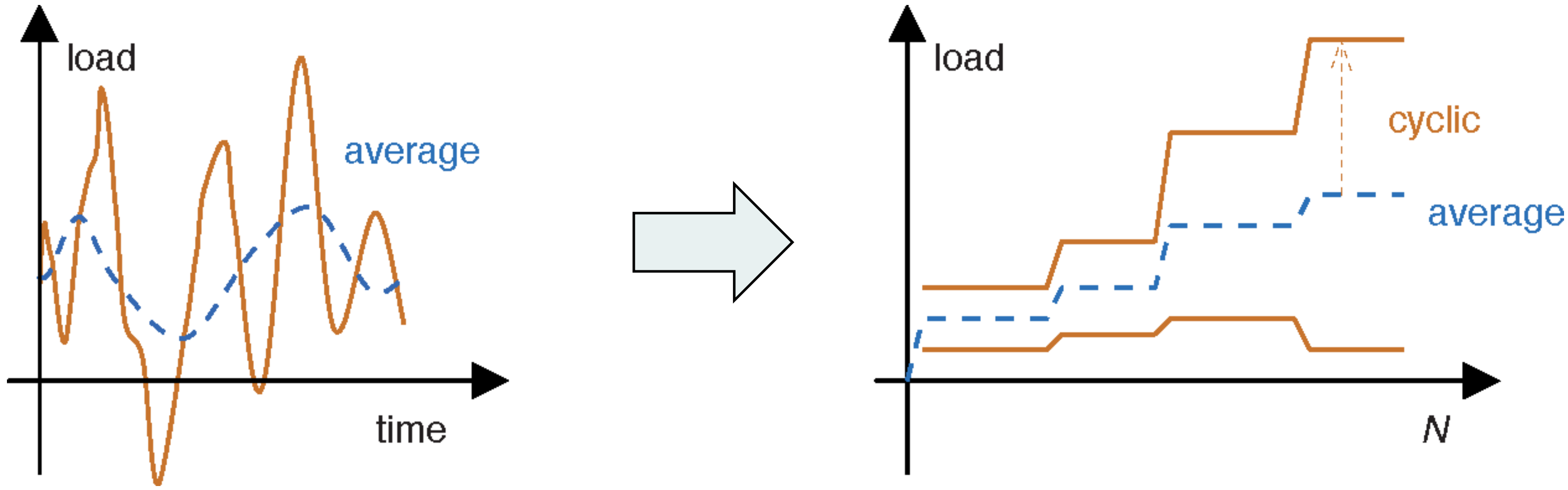


They are established from laboratory tests

How do we account for cyclic degradation?

Load application

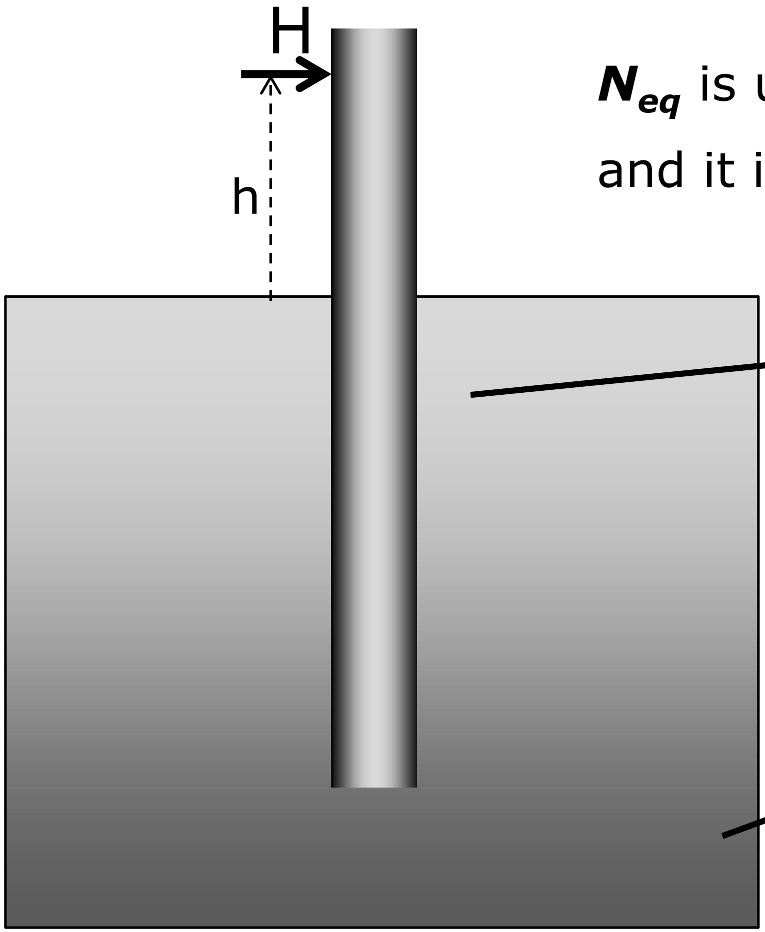
The real cyclic load history is rearranged in load parcels:



And the equivalent number of cycles, N_{eq} is calculated { soil, geometry

How do we account for cyclic degradation?

Load application



$\boldsymbol{N_{eq}}$ is used as a memory of the cyclic effect, and it is different at each point of the soil

High $\boldsymbol{N_{eq}}$: high cyclic degradation

$\boldsymbol{N_{eq}}$=1: No cyclic degradation

Material models for cyclic response of soil

This procedure has been implemented as 2 user-defined models in PLAXIS:

- UDCAM: for undrained materials
- PDCAM: for partially drained materials

Material models for cyclic response of soil

UnDrained Cyclic Accumulation Model

Main features:

- Undrained behaviour under both average and cyclic loads (clays)
- Non-linear average and cyclic stress-strain relationships
- Cyclic degradation of stiffness and strength (N_{eq})
- Accumulated shear deformation
- Anisotropic behaviour (ADP)
- Based on input of laboratory results (interpolation and extrapolation between test results), instead of based on an elasto-plastic framework
- Implemented as a UDSM (DLL) in PLAXIS

Material models for cyclic response of soil

This procedure has been implemented as 2 user-defined models in PLAXIS:

- UDCAM: for undrained materials
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Material models for cyclic response of soil

<u>P</u>artially <u>D</u>rained <u>C</u>yclic <u>A</u>ccumulation <u>M</u>odel

Used in coupled FE consolidation analyses (silts and sand)

<u>Main features:</u>

- Undrained behaviour during one single cycle
- Effective stress based (partly drained) relationship under the average loads
- Non-linear average and cyclic stress-strain relationships

Material models for cyclic response of soil

<u>P</u>artially <u>D</u>rained <u>C</u>yclic <u>A</u>ccumulation <u>M</u>odel

Main features:

- Pore pressure accumulation due to cyclic loading
- Degradation of cyclic stiffness and cyclic strength (N_{eq})
- Accumulated shear and volume deformations
- Anisotropic behaviour (ADP)
- Based on input of laboratory results (interpolations and extrapolations)
- Implemented as a UDSM (DLL) in PLAXIS

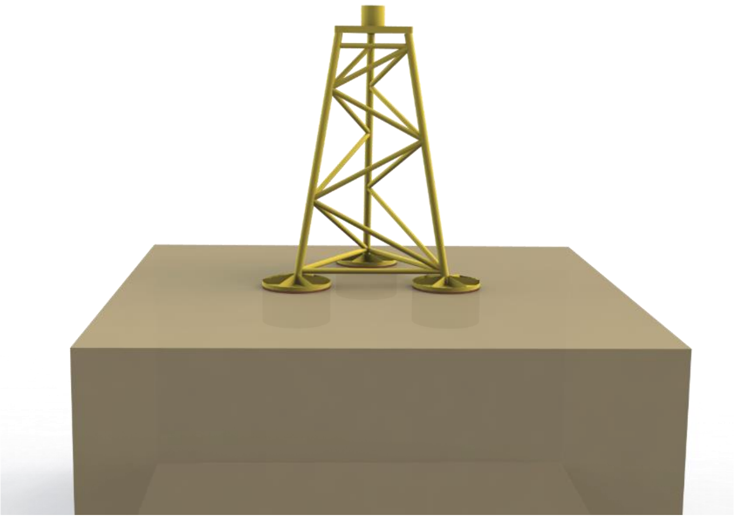
Applications

Comparison of the performance of UDCAM and PDCAM

with some simplified approaches

Case 1: Monopile foundation

Case 2: Bucket foundation

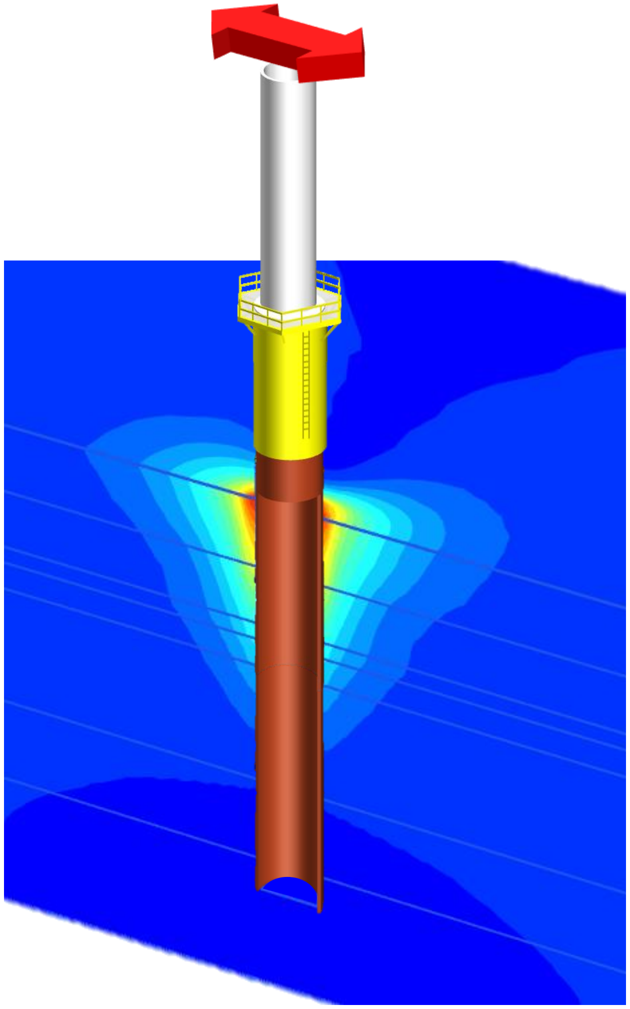


Applications

Monopile

Joint study between
- GS E&C
- NGI

Objective: see the effect of using more advanced models instead of p-y curves in the behaviour of a monopile



Horizontal displacements

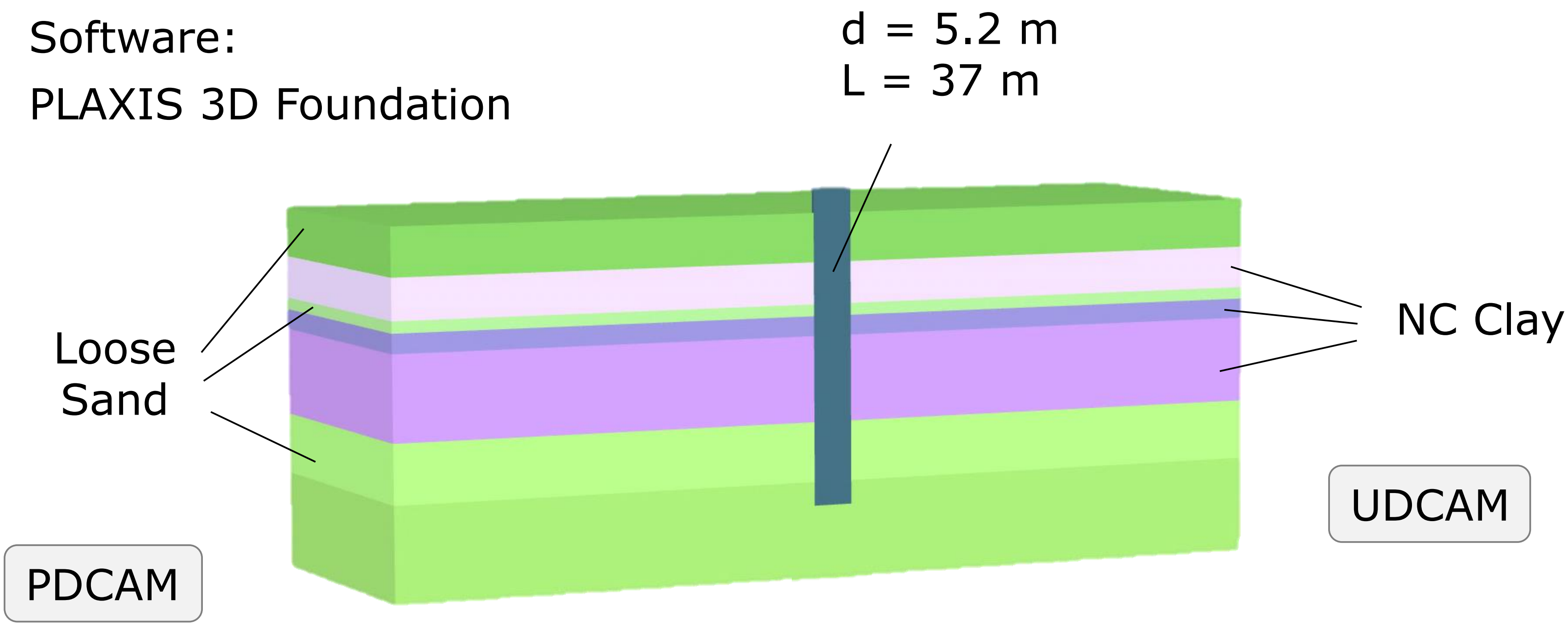
Applications

Monopile in a layered profile

Soil stratigraphy (Korean West Sea)

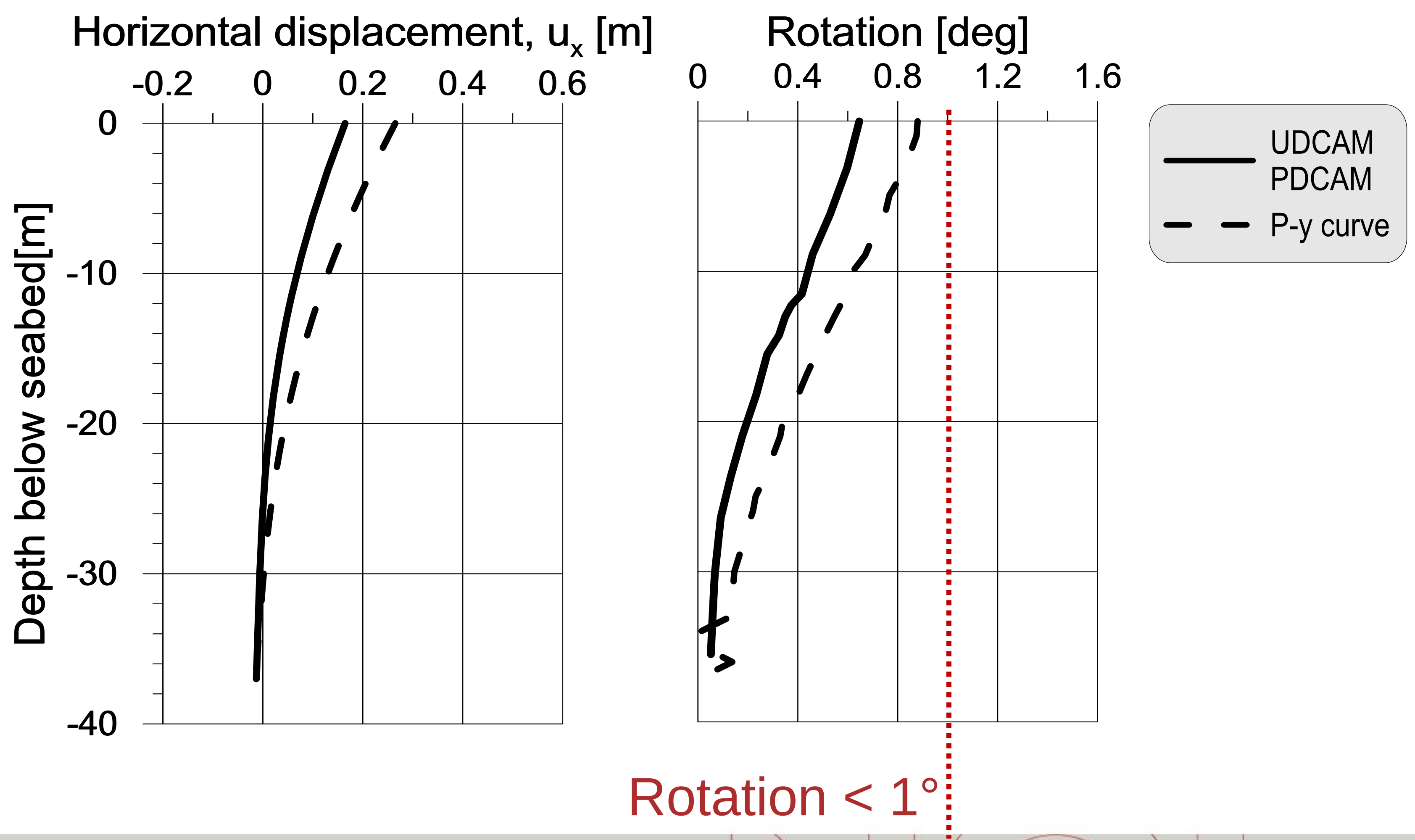
Software:

PLAXIS 3D Foundation



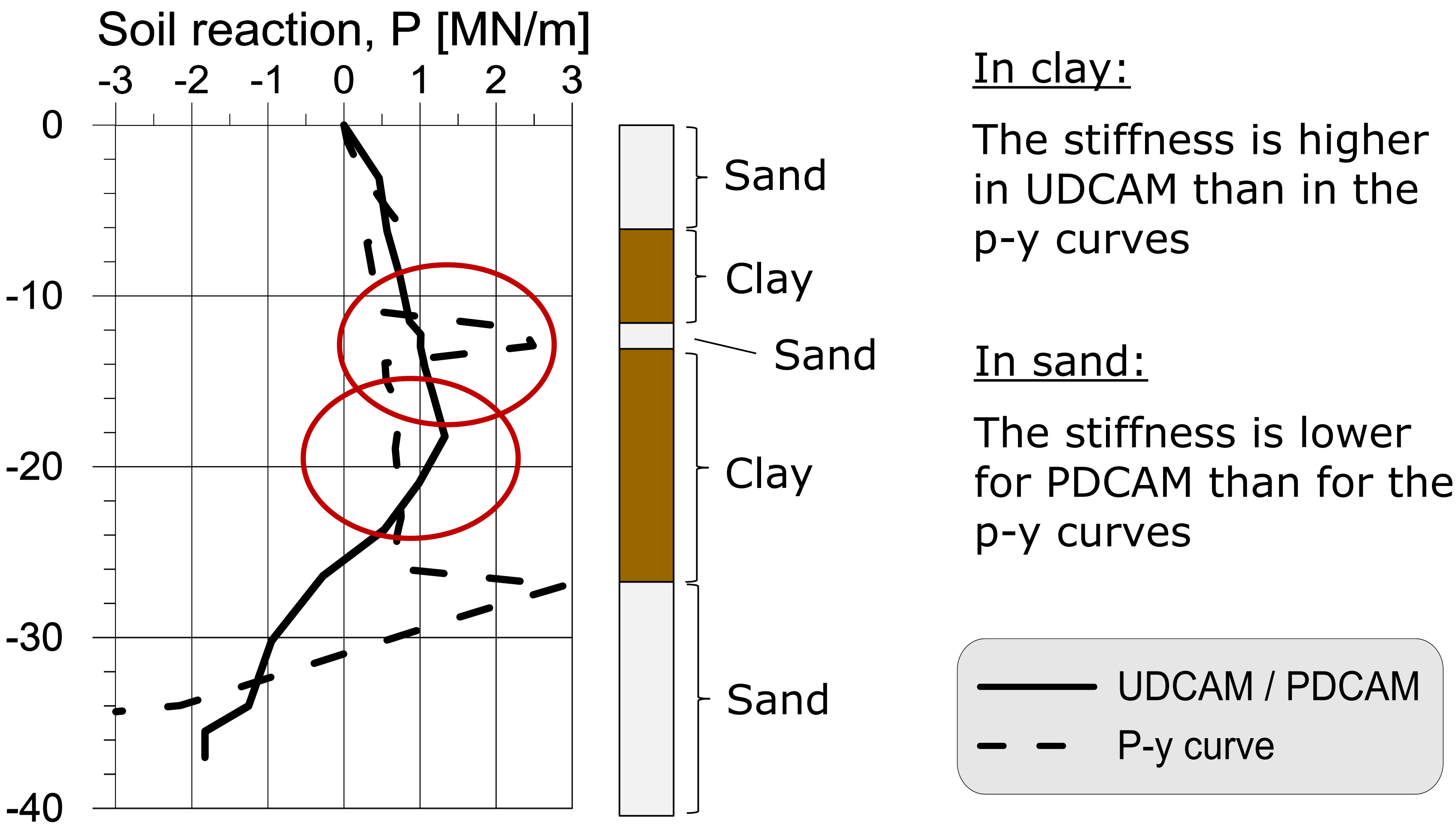
Applications

Monopile in a layered profile



Applications

Monopile in a layered profile



<u>In clay:</u>

The stiffness is higher in UDCAM than in the p-y curves

<u>In sand:</u>

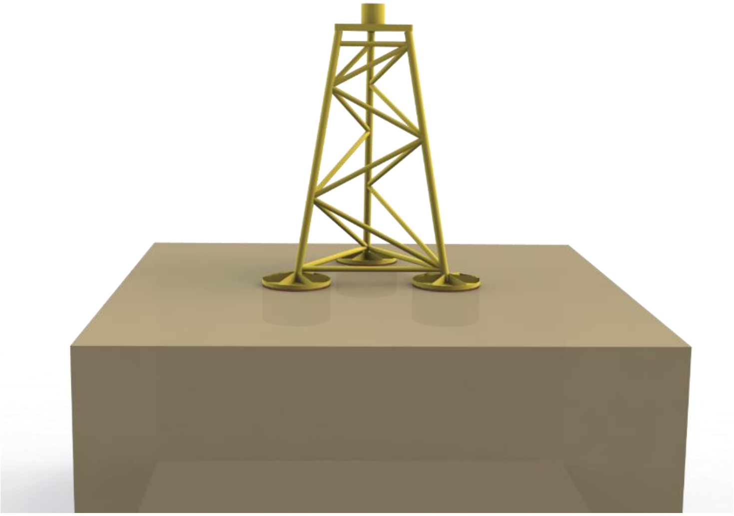
The stiffness is lower for PDCAM than for the p-y curves

Applications

Comparison of the performance of UDCAM and PDCAM
with some simplified approaches

Case 1: Monopile foundation

Case 2: Bucket foundation



Applications

Bucket foundation

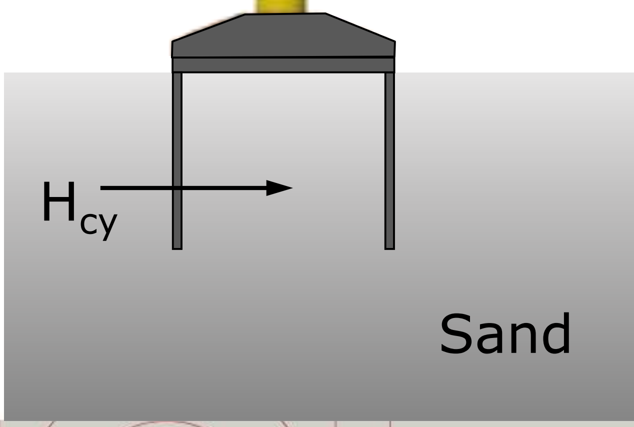
Simplified approach vs. PDCAM

Simplified conditions | More realistic conditions

Compare:

- N_{eq}
- the accumulated pore pressure

For the same cyclic load history

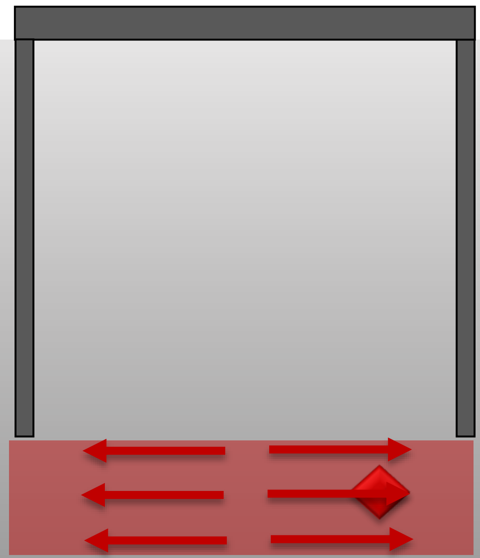


Applications

Bucket foundation

<u>Simplified conditions</u>

Assumptions:



Linear-elastic soil

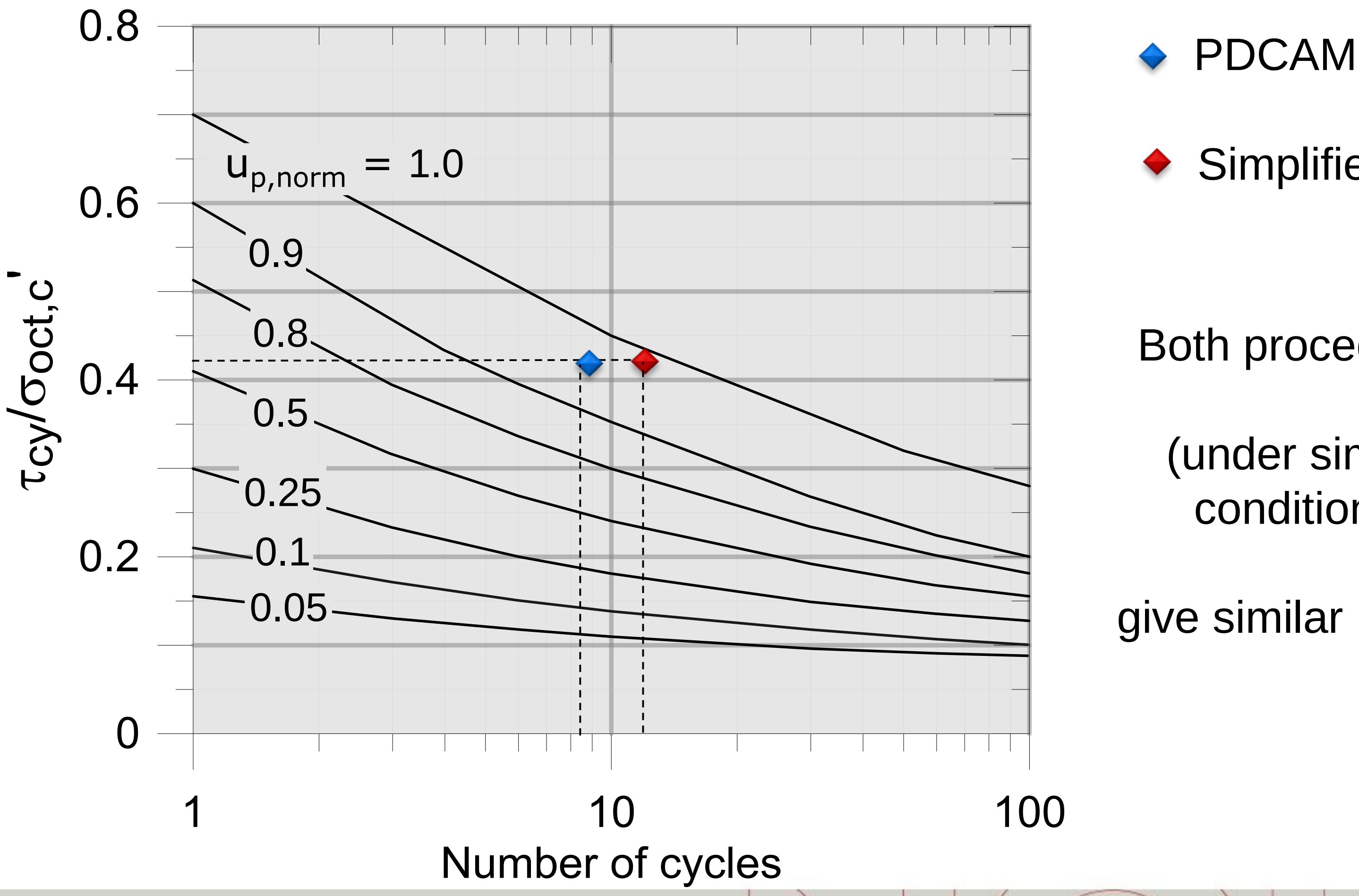
Pore pressures generated only below the bucket

Only radial disipation

The cyclic degradation is evaluated in one representative point

Applications

Bucket foundation



Both procedures

(under similar conditions)

give similar results

Applications

Bucket foundation

PDCAM: more realistic conditions

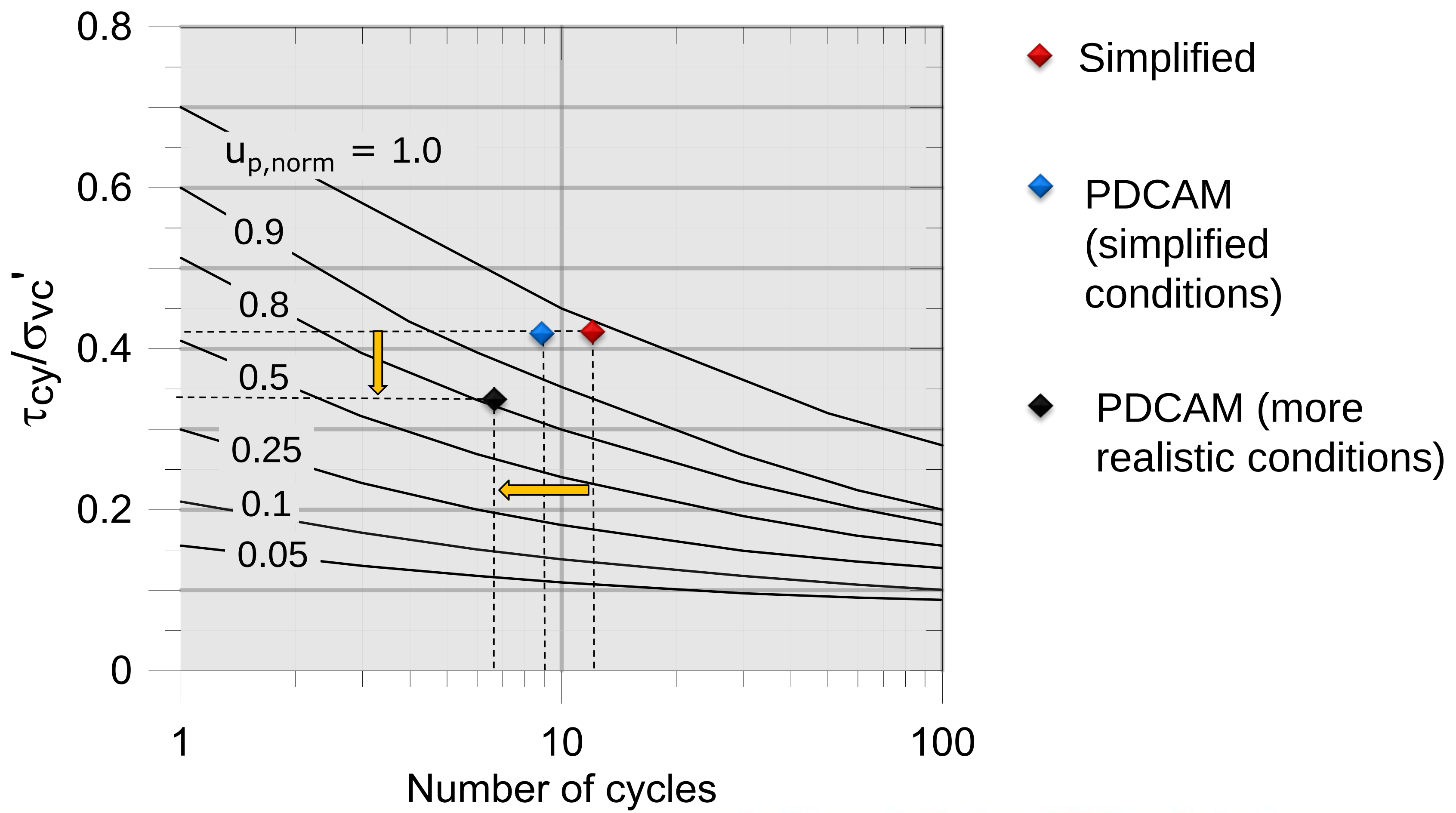
Assumptions:

- soil with non-linear stress-strain relationship
- pore pressure generation and dissipation in any area and direction

We apply the same cyclic load history

Applications

Bucket foundation

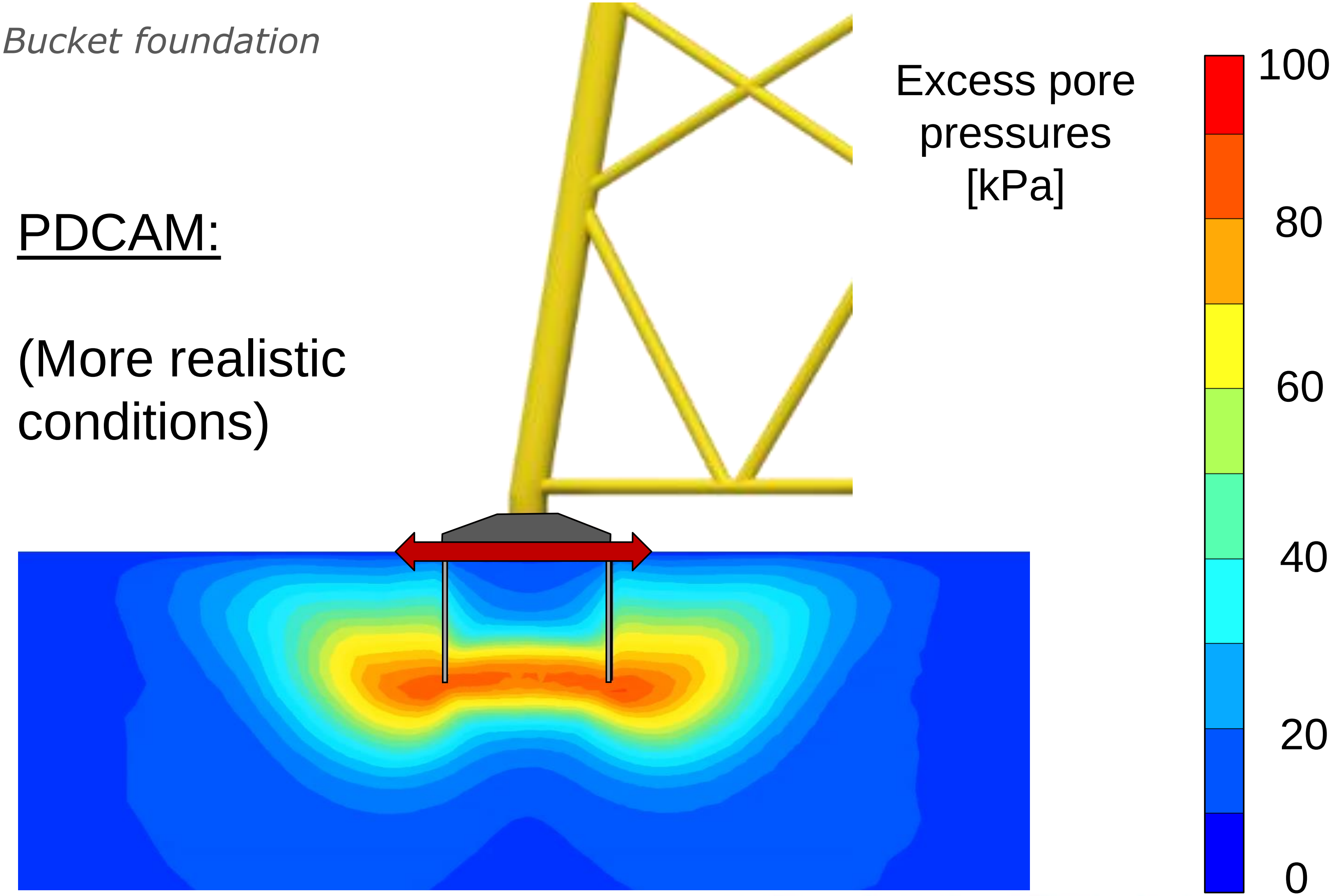


Applications

Bucket foundation

PDCAM:

(More realistic conditions)



Conclusions

- 2 material models (UDCAM/PDCAM)
  - ⮡ account for the cyclic degradation of the soil
  - ⮡ implemented in a Finite Element program

- The models are suitable when
  - + the cyclic degradation of the soil varies along the structure
  - + stratigraphy with undrained and partially drained behavior

Conclusions

- Comparison p-y curves vs. UDCAM and PDCAM:
  - ⮡ UDCAM and PDCAM can be both stiffer and softer than standard (API) p-y curves

- Comparison simplified approach vs. PDCAM:
  - + Both procedures, under similar conditions, give similar results
  - + By using more realistic assumptions, we can quantify the conservatism

Thank you for your attention!