

CG 24

ON THE USE OF PLAXIS: EMBEDDED PILES

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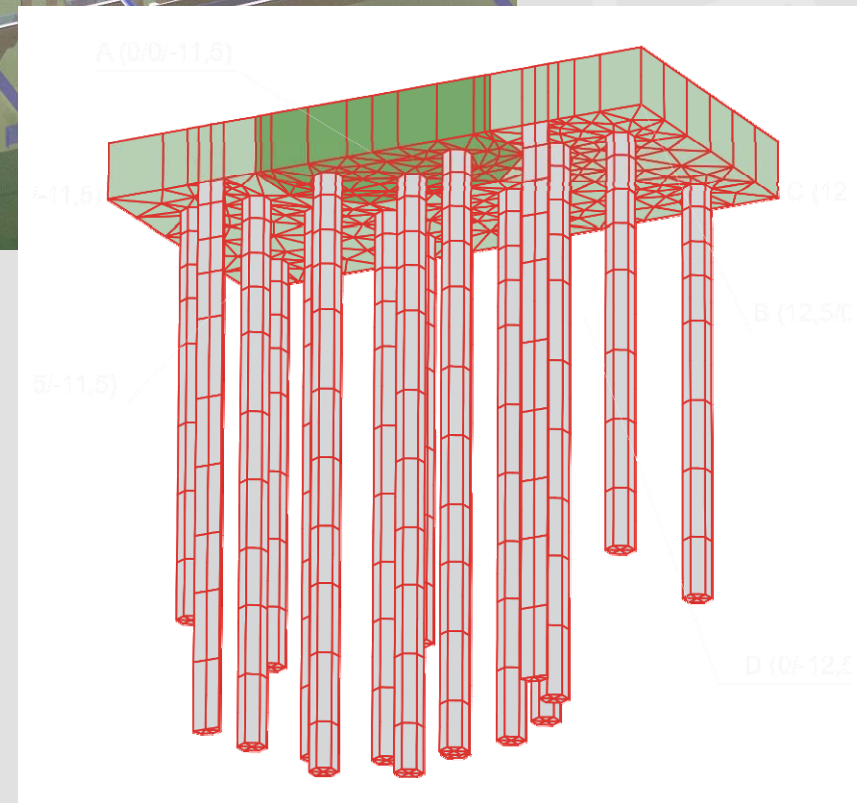
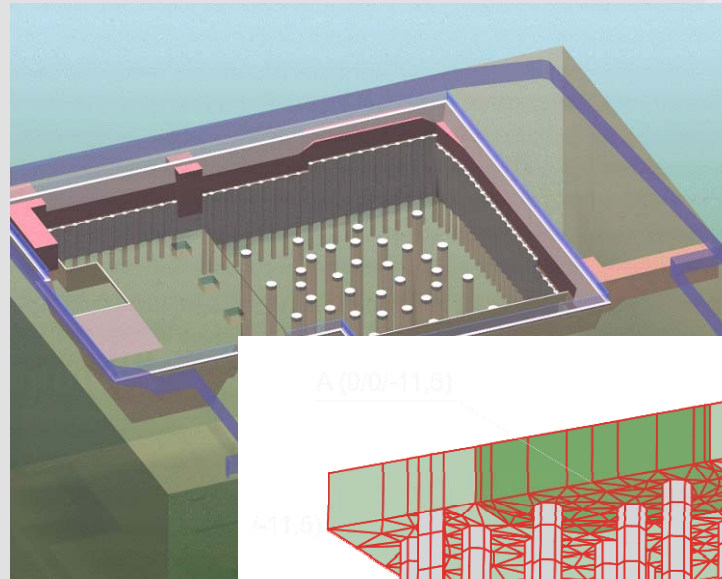
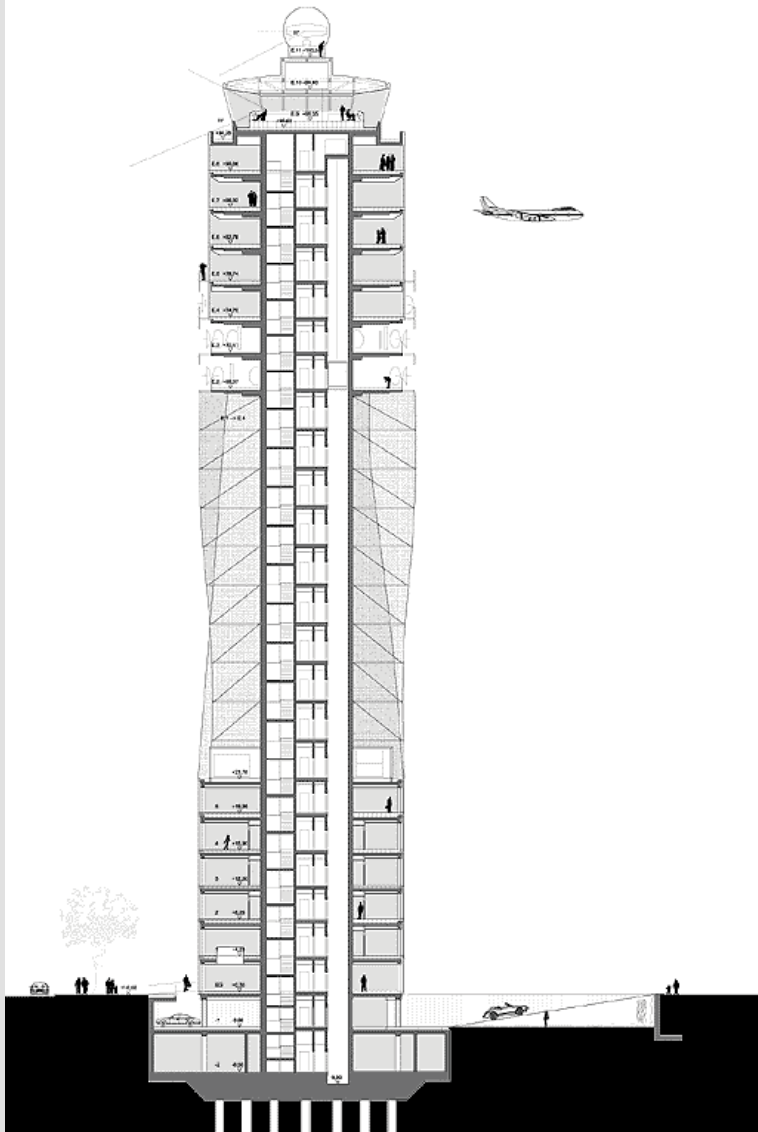
Acknowledgement for providing some of the material: E. Septanika, P.G. Bonnier

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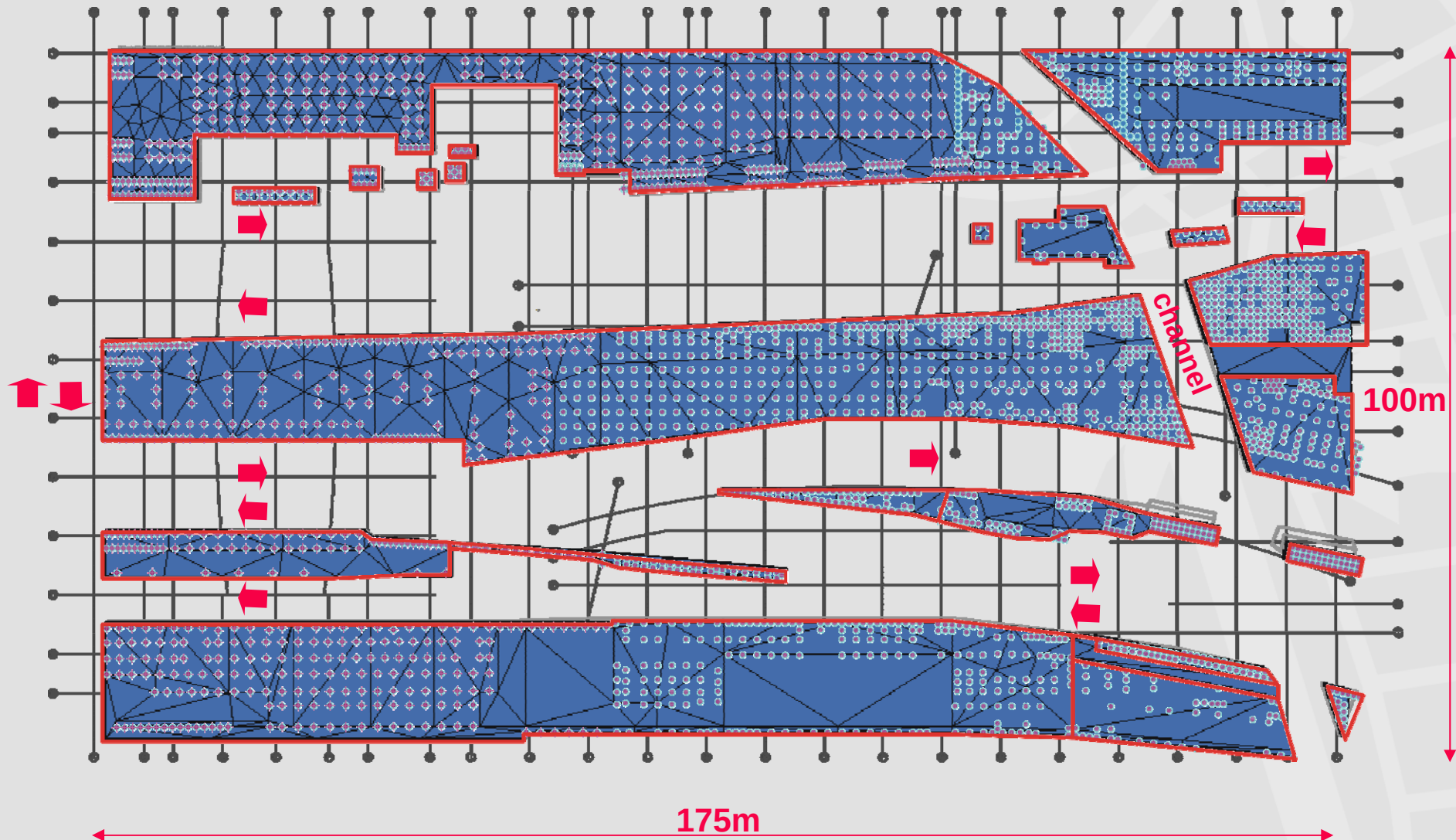
INTRODUCTION

Limited number of piles > volume discretisation feasible



INTRODUCTION

Large number of piles > volume discretisation not feasible

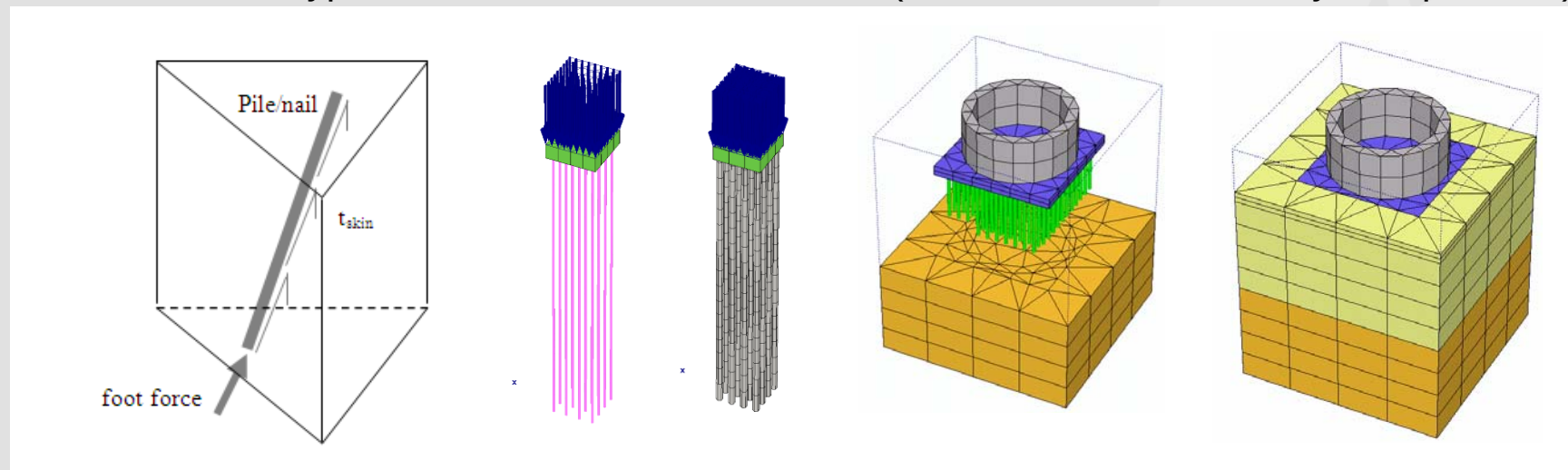


INTRODUCTION

Embedded Inclusion (Pile, Soil Nails & Ground Anchors)

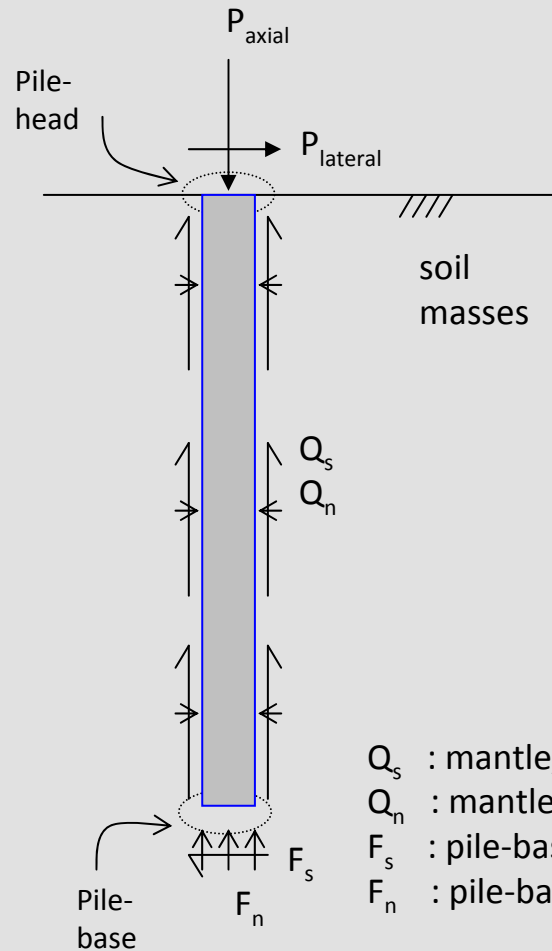
Implementation in PLAXIS

- Inclusion as line element (slender beam)
- Arbitrary inclination and position
- Connection between embedded inclusion and soil by special interface elements
- Non-linear spring representing the pile-soil contact at the base (Septanika, 2005)
- Different types of skin resistance behaviour (Linear, Multi-linear & Layer-dependent)



- Sadek, M. & Shahrour, I. 2004. A three dimensional embedded beam element for reinforced geomaterials. International journal for numerical and analytical methods in geomechanics 28:931–946.
- Septanika, E. G. 2005. A finite element description of the embedded pile model. Plaxis internal report.

BASIC ASSUMPTIONS



Pile behaviour depends on:

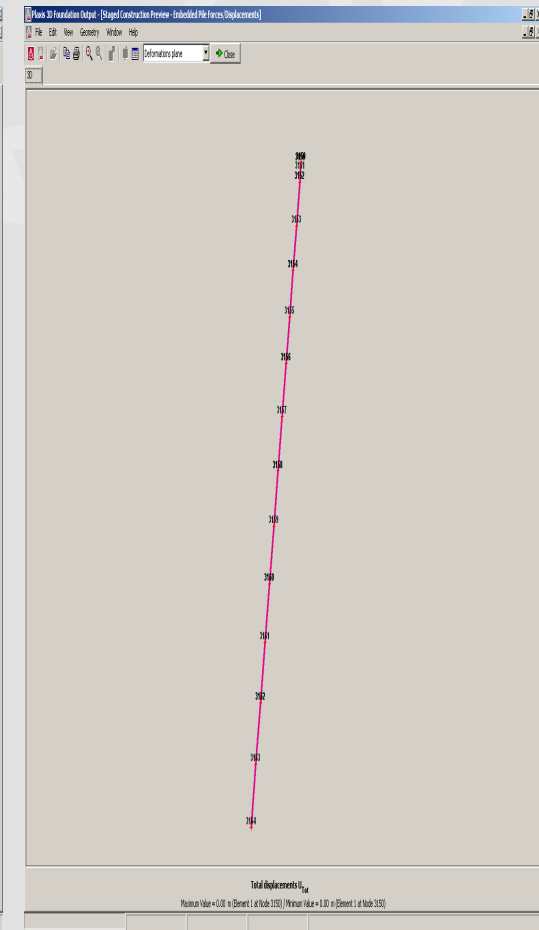
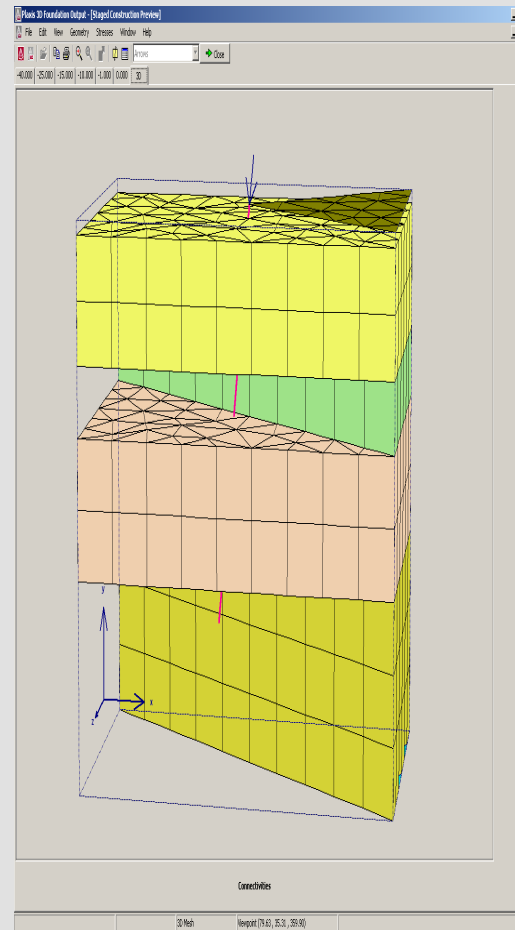
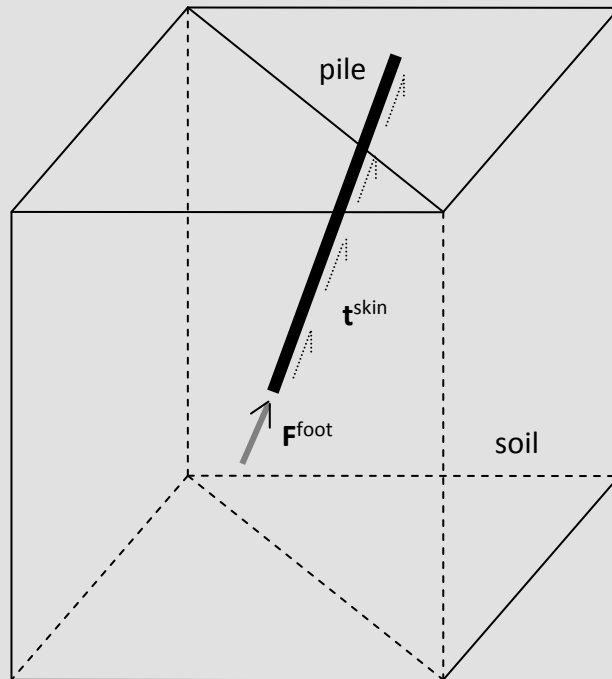
- Soil type
- Stress state
- Pile geometry
- Pile type (Steel, concrete, timber...etc.)
- Installation procedure



summarized in "interface behaviour"

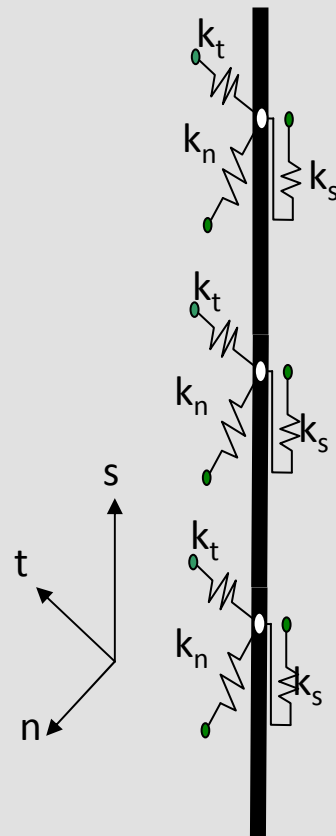
Q_s : mantle/skin shear forces
 Q_n : mantle/skin normal forces
 F_s : pile-base shear forces
 F_n : pile-base normal forces

DEFINITION IN PLAXIS



DEFINITION IN PLAXIS

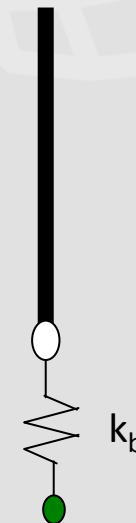
SKIN INTERACTION



Skin stiffness:
 k_s : axial stiffness
 k_n & k_t : lateral stiffness

Skin tractions:
 $t_s = q_s / \text{length} = k_s (u_s^{\text{pile}} - u_s^{\text{soil}}) \leq t_{\text{max}}$
 $t_n = q_n / \text{length} = k_n (u_n^{\text{pile}} - u_n^{\text{soil}})$
 $t_t = q_t / \text{length} = k_t (u_t^{\text{pile}} - u_t^{\text{soil}})$

BASE RESISTANCE



Base stiffness:
 k_b : base/foot stiffness

Base/Foot force:
 $0 \leq F_b = k_b (u_b^{\text{pile}} - u_b^{\text{soil}}) \leq F_{\text{max}}$

DEFINITION IN PLAXIS

Material set:

Comments:

Properties

E : kN/m²

γ : kN/m³

☒ Predefined Type

Diameter : m

☐ User-defined Type

A : m²

I₃ : m⁴

I₂ : m⁴

I₂₃ : m⁴

Skin Resistance

☒ Linear

T_{top, max} : kN/m

T_{bot, max} : kN/m

☐ Multi-linear

☐ Layer dependent

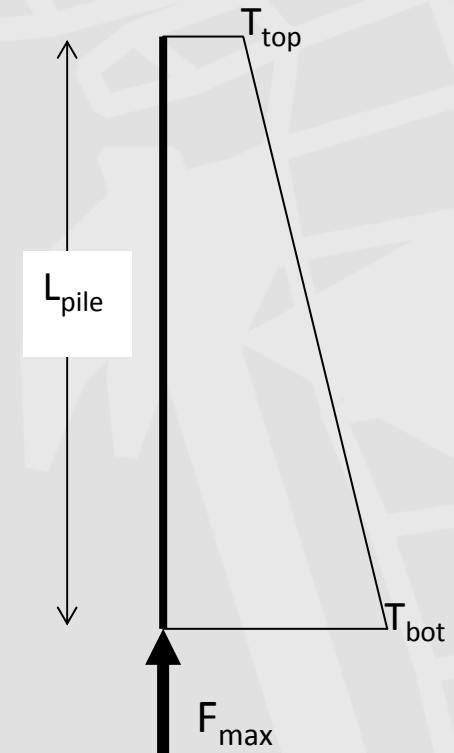
T_{max} : kN/m

Base Resistance

F_{max} : kN

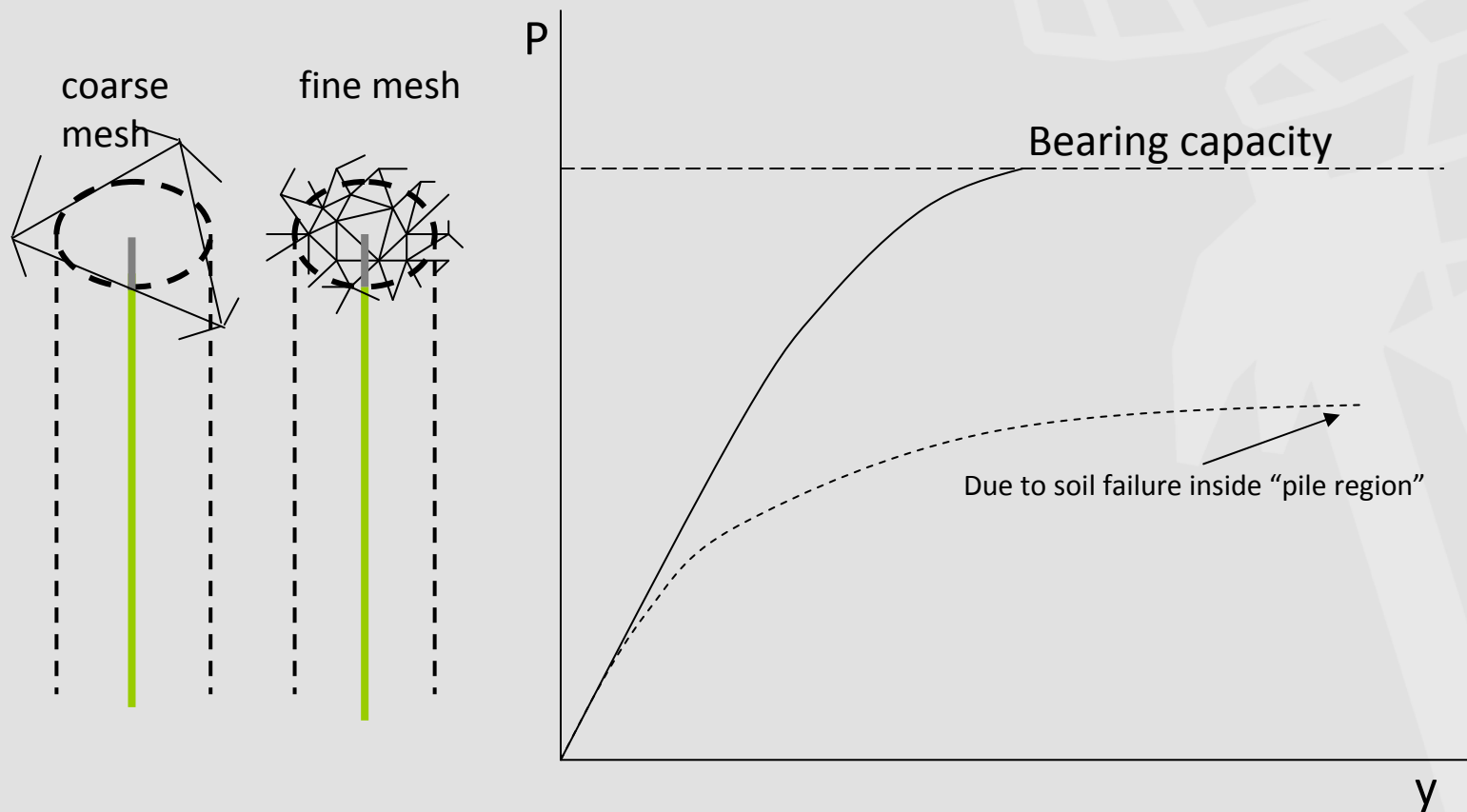
Bearing Capacity:

$$\frac{1}{2} (T_{\text{top}} + T_{\text{bot}}) * L_{\text{pile}} + F_{\text{max}}$$



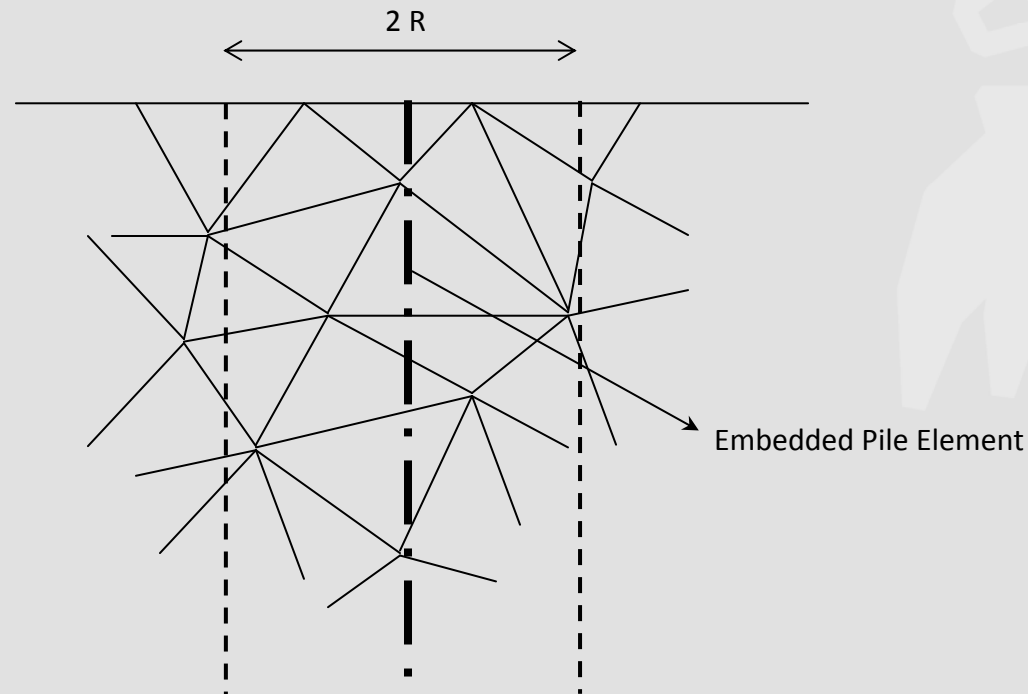
DEFINITION IN PLAXIS

- Problem of mesh dependency
- Embedding the inclusion into one adjacent element is insufficient
- To eliminate this problem an 'Elastic Zone' is introduced



DEFINITION IN PLAXIS

- “Elastic zone” is defined based on the volume of pile ($=\pi R^2 \cdot L$)
- Any small (soil) element that falls inside pile zone will be forced to remain elastic
- So far this approach seem to work robust and sufficient



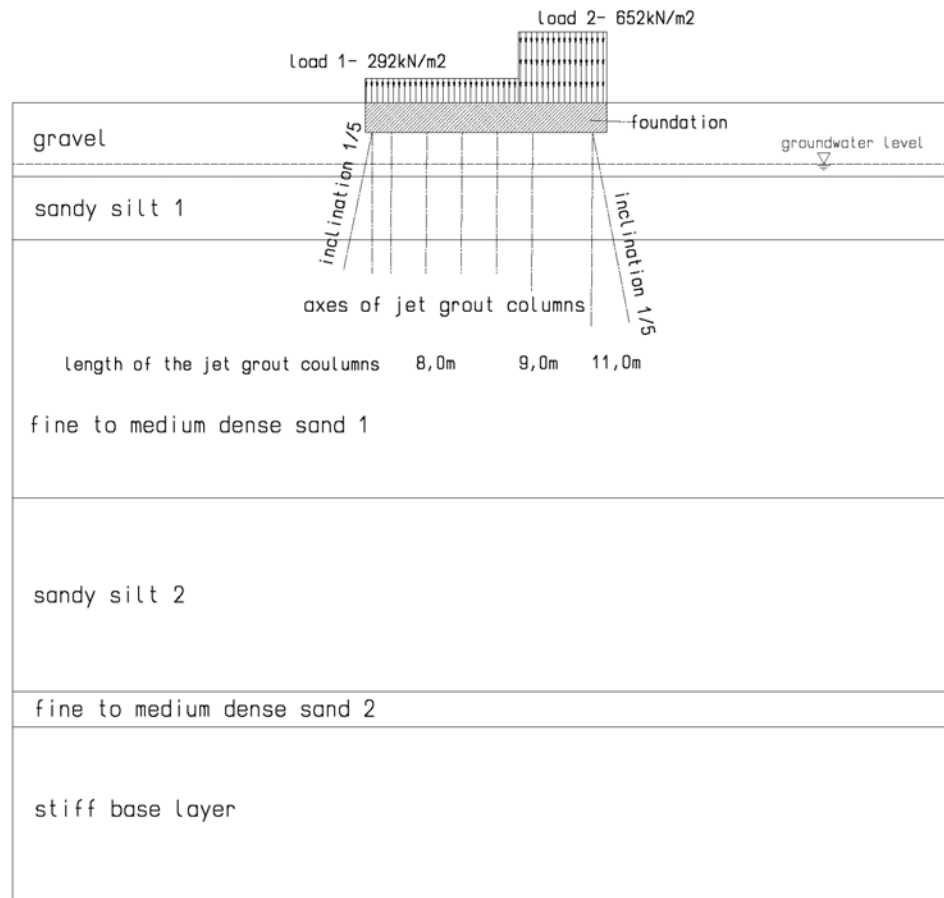
DEFINITION IN PLAXIS - SUMMARY

An embedded pile is a pile which consists of:

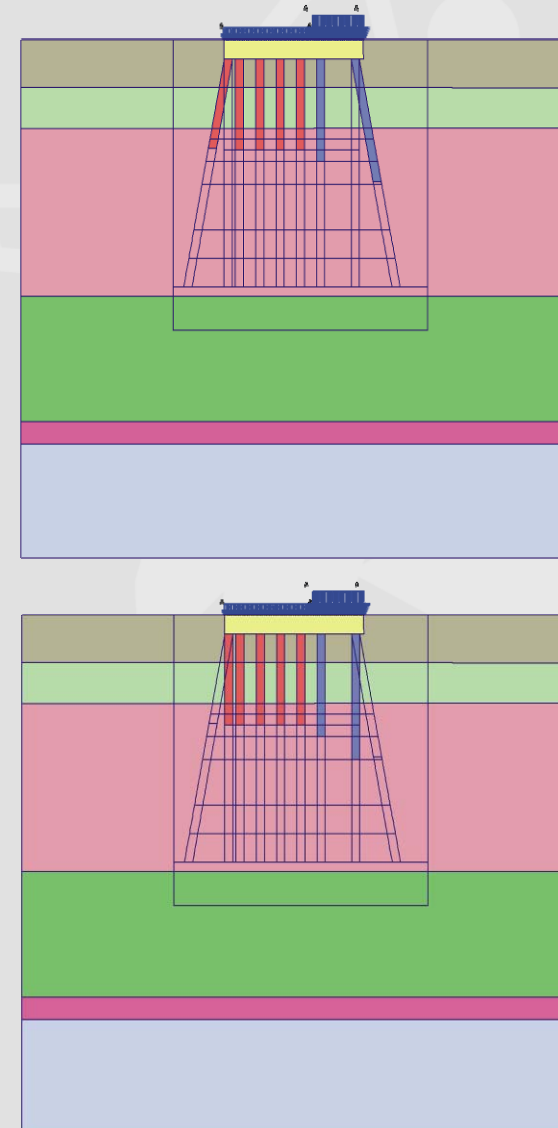
- **Beam elements**
 - Properties: E , γ , d
 - d determines the elastic zone in the soil around the beam
- **Special interface elements**
 - ➔ Interaction pile - soil
 - Properties: skin resistance, base resistance

The bearing capacity of an embedded pile is an **INPUT** to the analyses and not a **RESULT!!**

VERIFICATION EXAMPLE

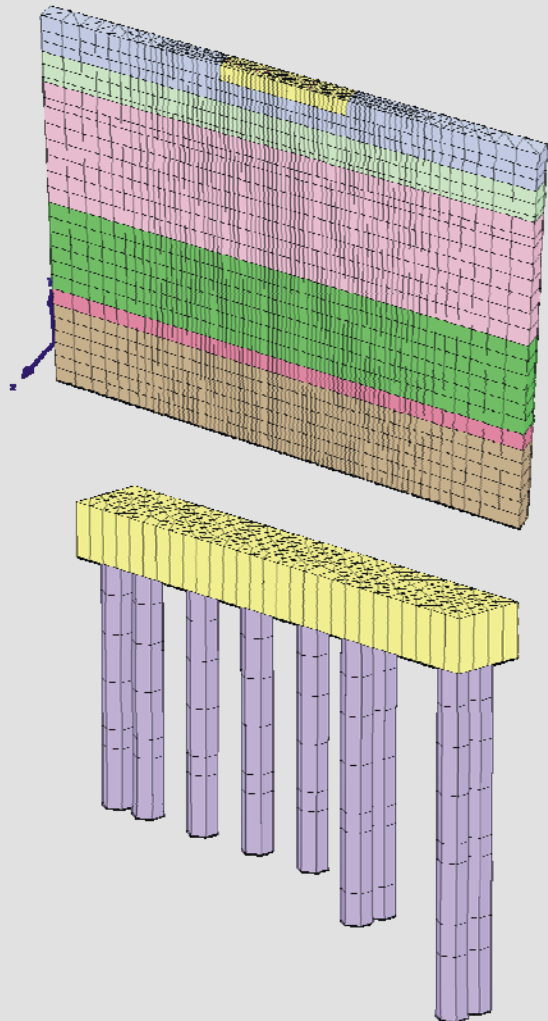


2D model



VERIFICATION EXAMPLE

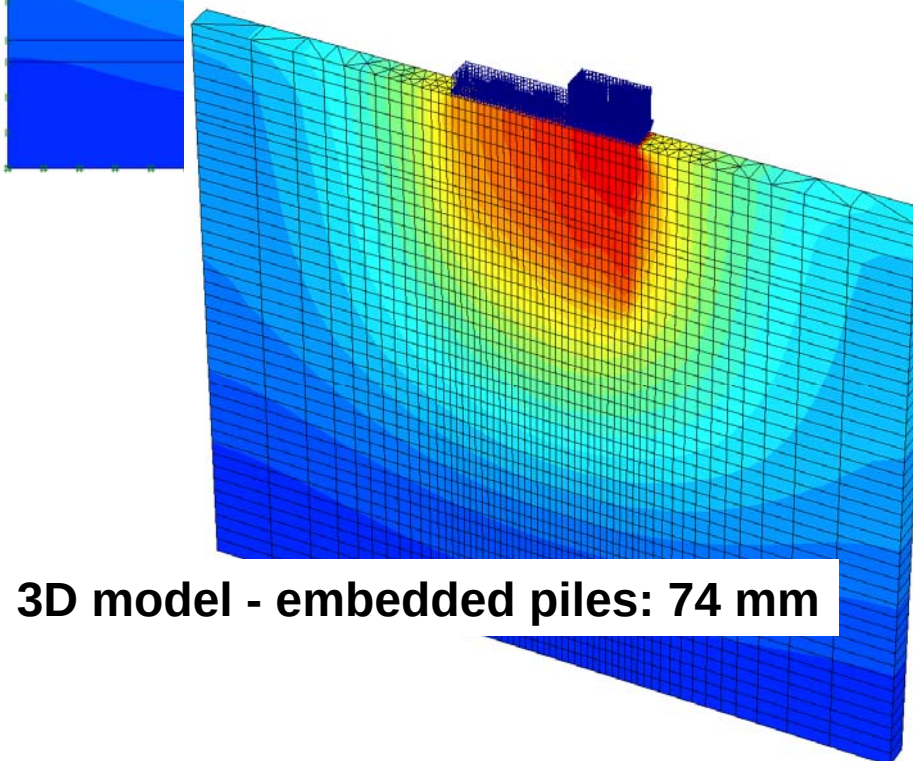
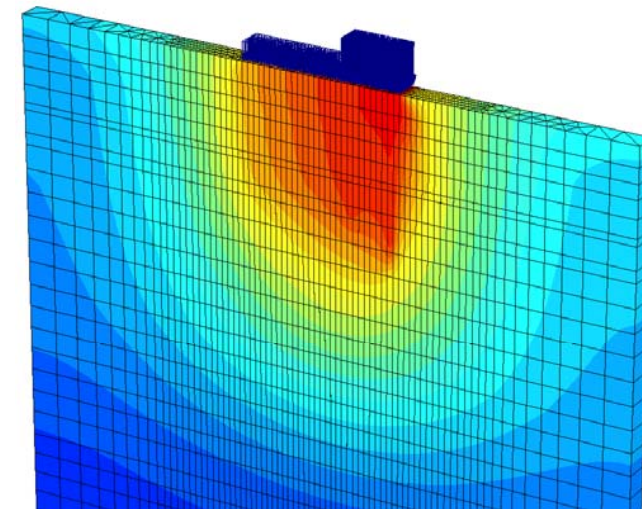
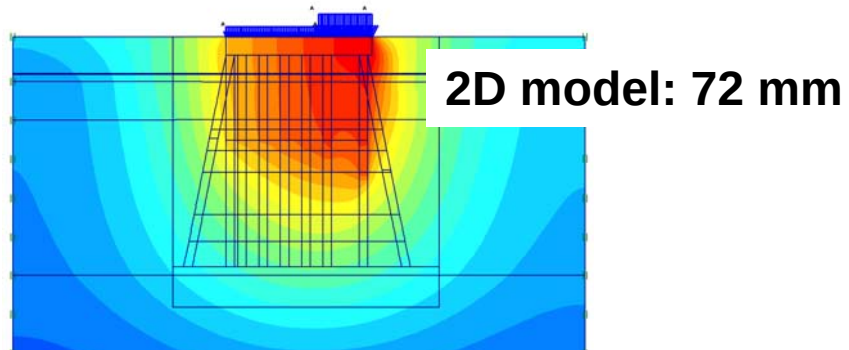
3D model - volume piles



3D model - embedded piles

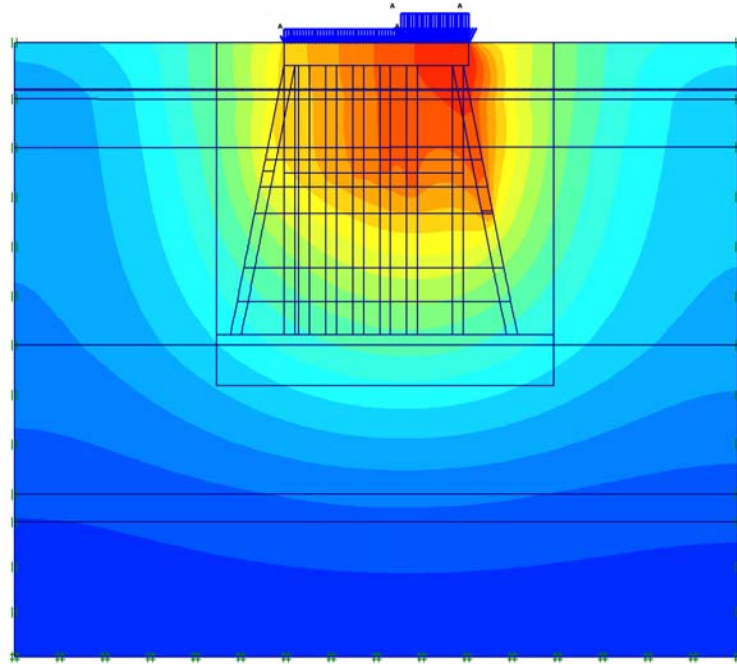


VERIFICATION EXAMPLE

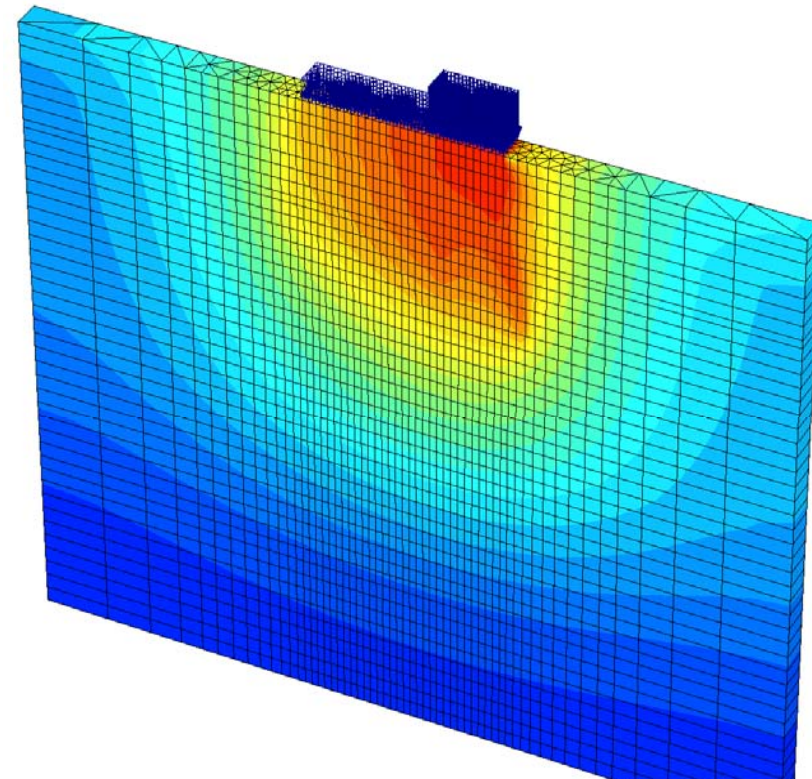


ALL PILES VERTICAL

VERIFICATION EXAMPLE



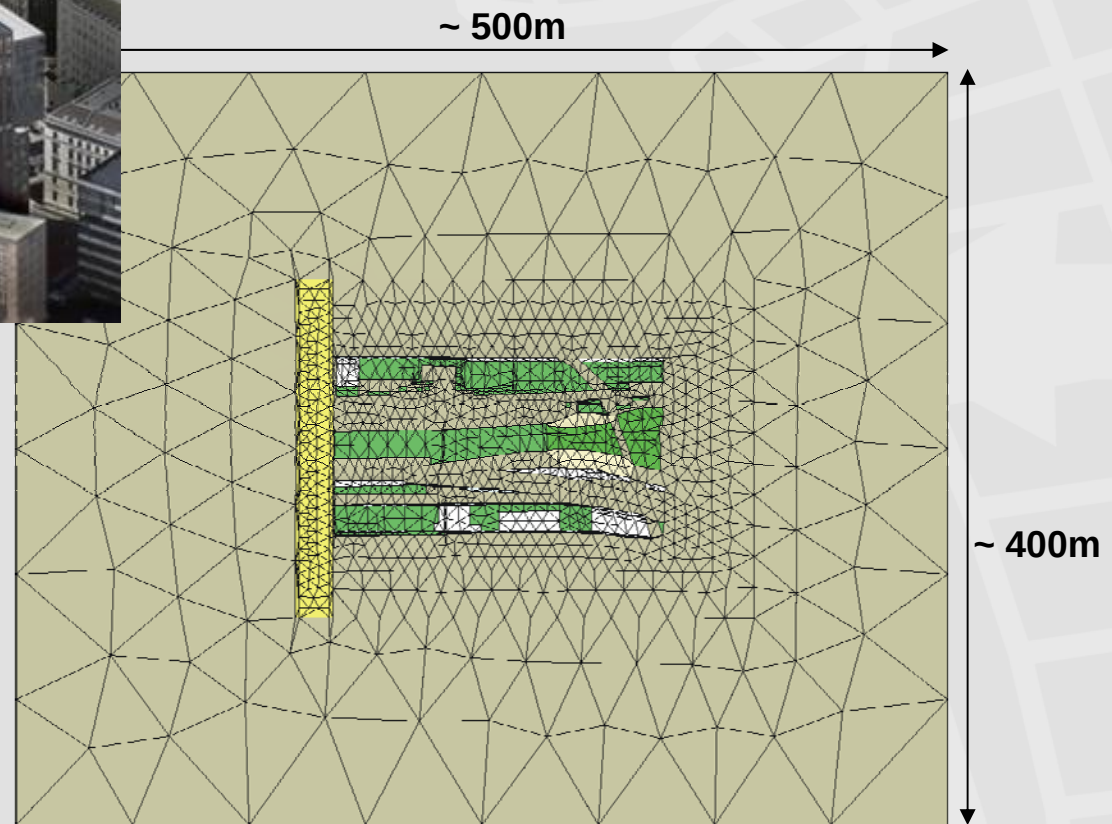
2D model: 68 mm



3D model - embedded piles: 70 mm

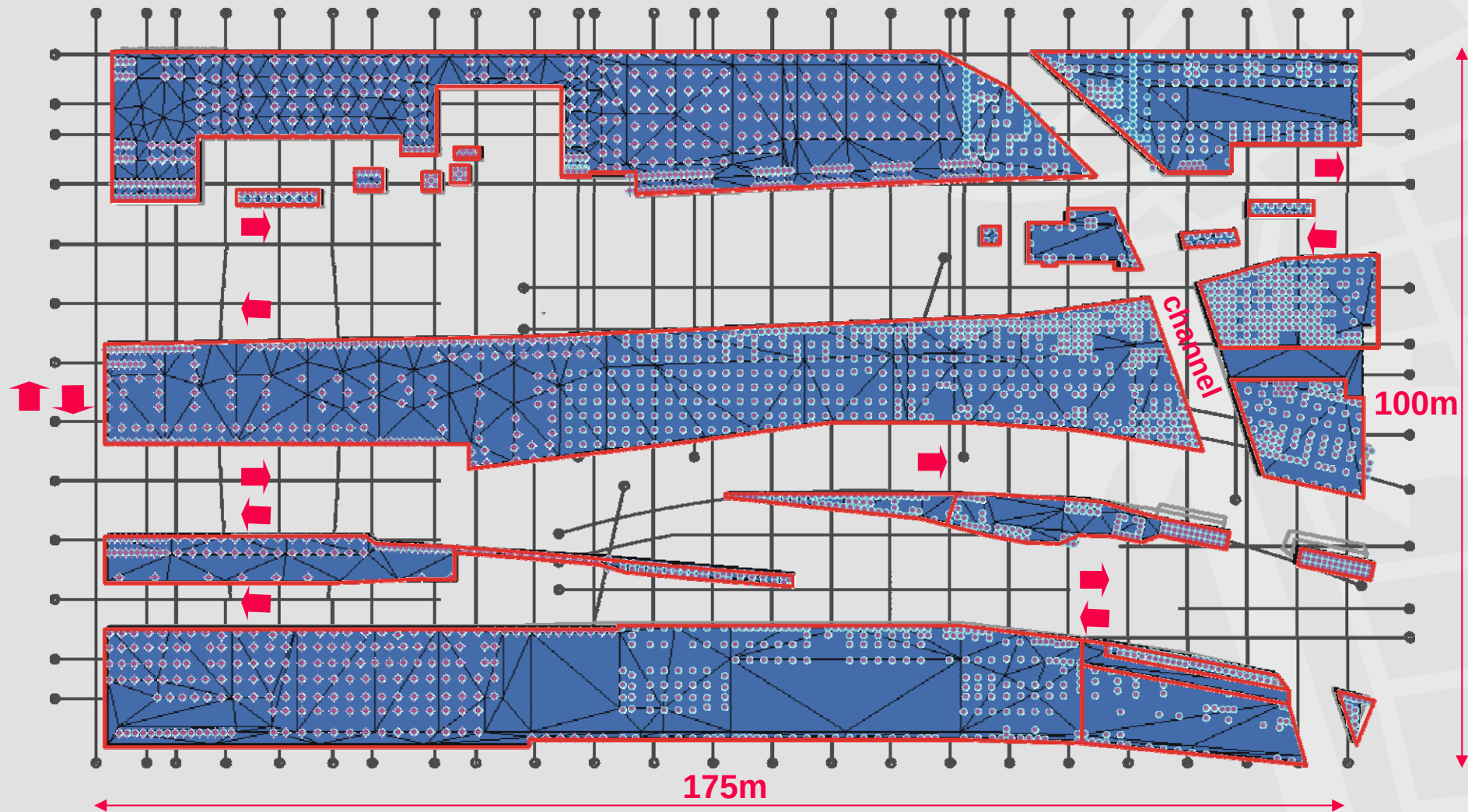
OUTER PILES INCLINED

PRACTICAL EXAMPLE



PLAN VIEW

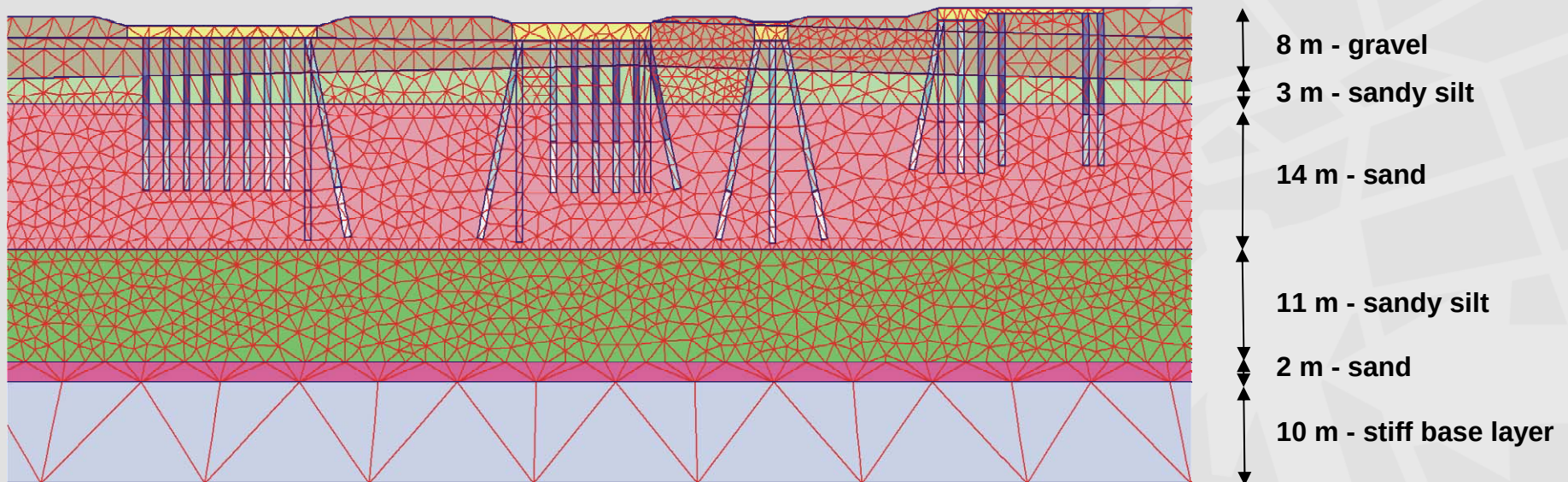
INTRODUCTION



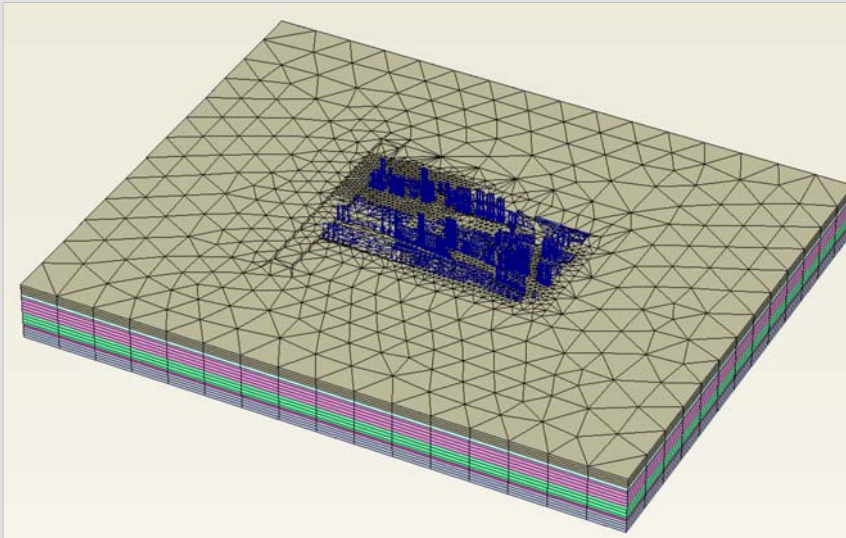
PLAN VIEW - ARRANGEMENT OF JET GROUT COLUMNS

PRACTICAL EXAMPLE

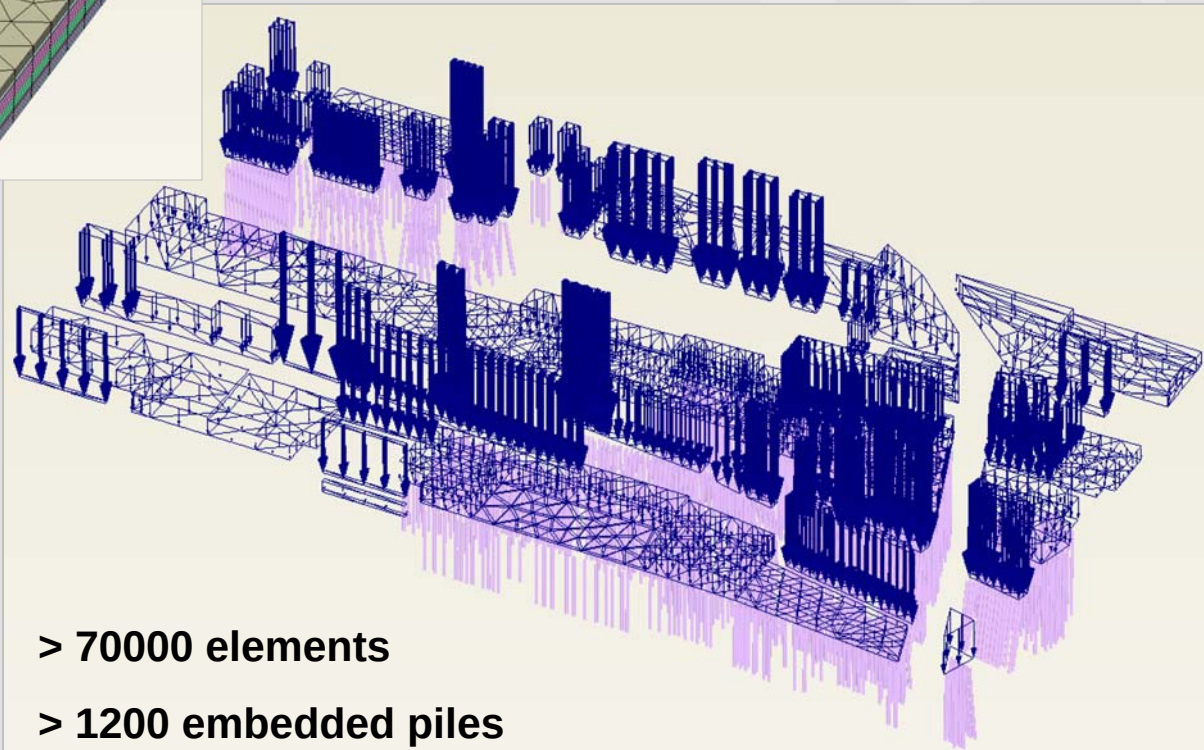
TYPICAL CROSS SECTION - SOIL PROFILE



PRACTICAL EXAMPLE



> Model is too big - in phase
„activating the jet grout
piles“ failure occurred

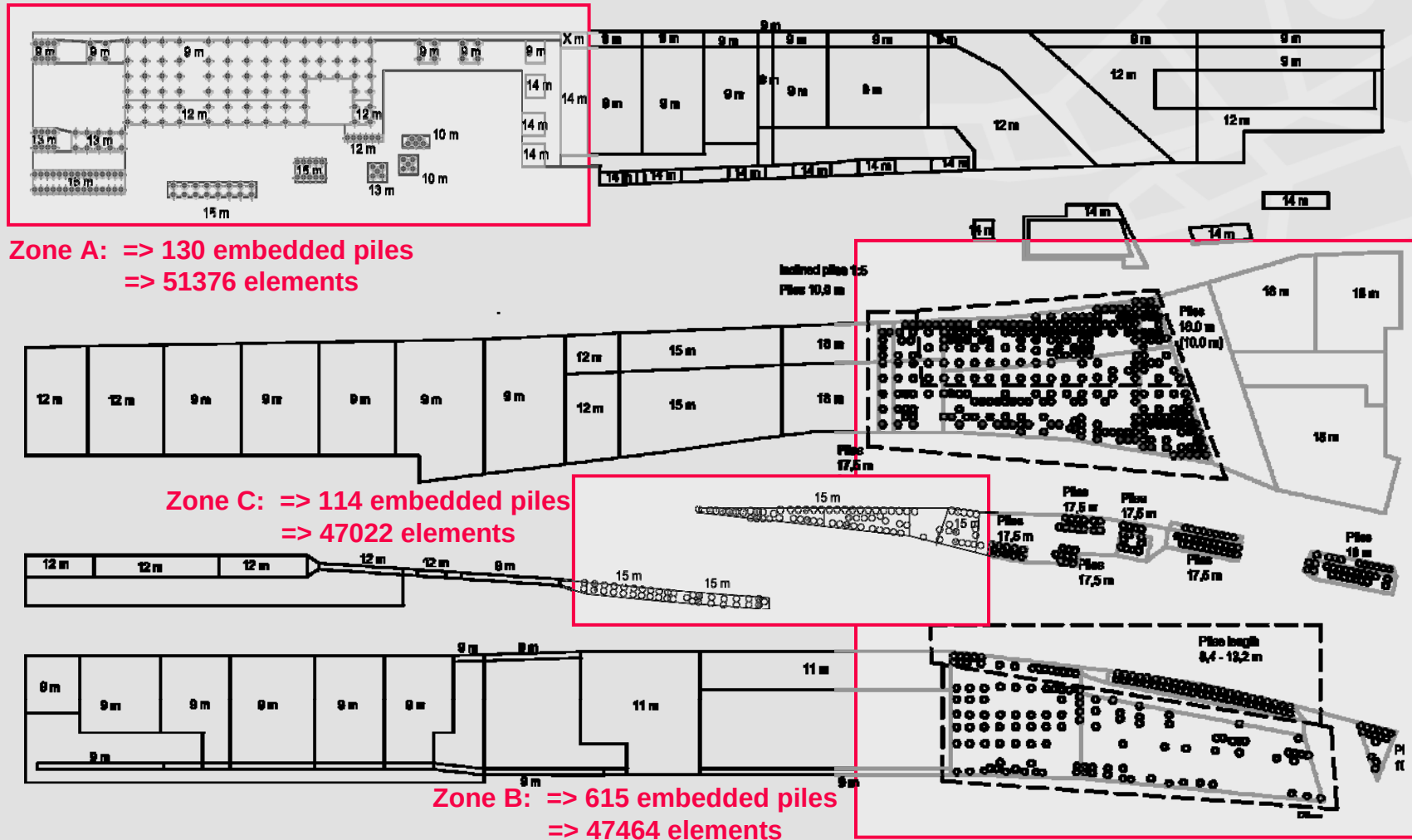


> 70000 elements

> 1200 embedded piles

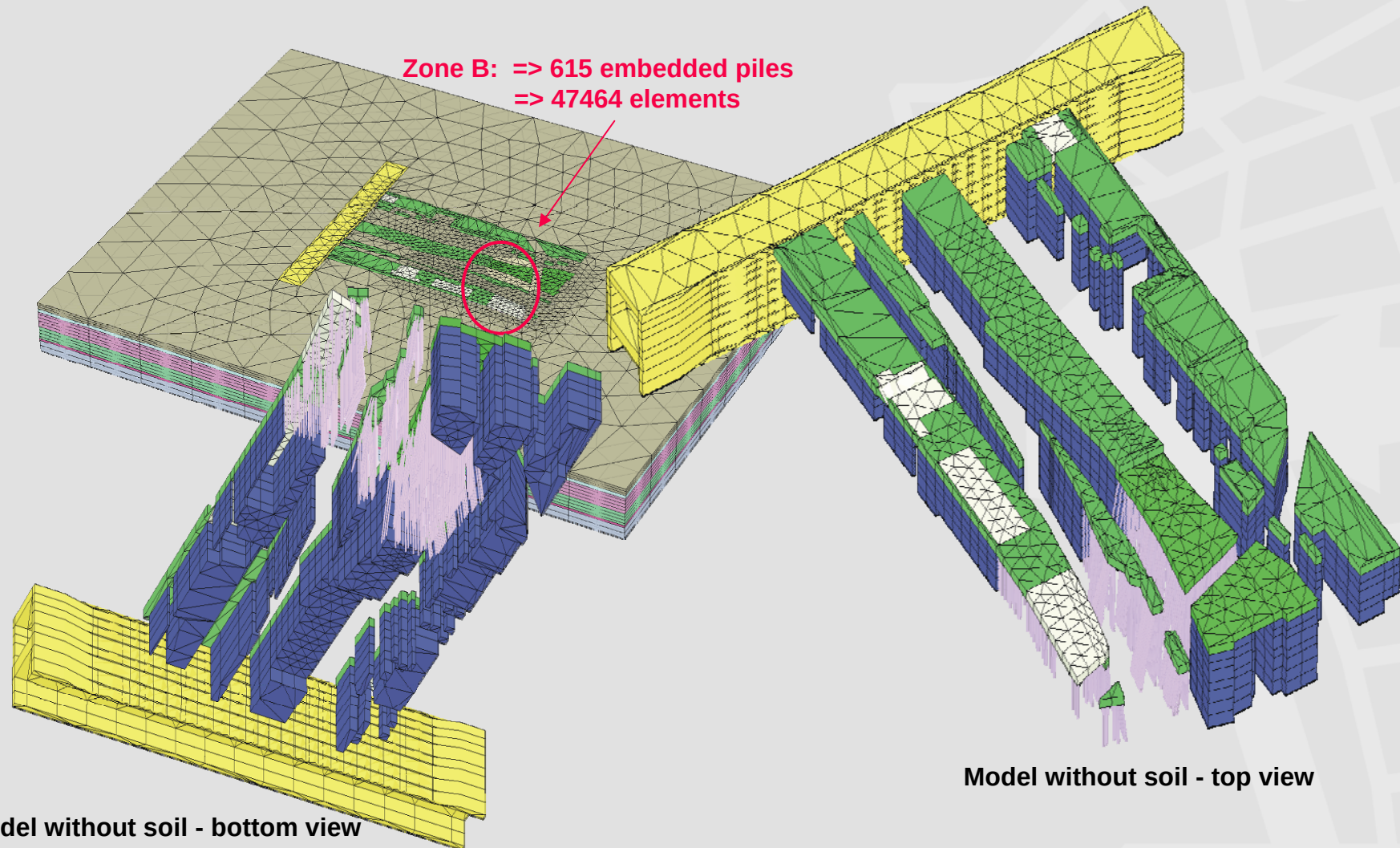
PRACTICAL EXAMPLE

→ Three different models for the sensitive zones



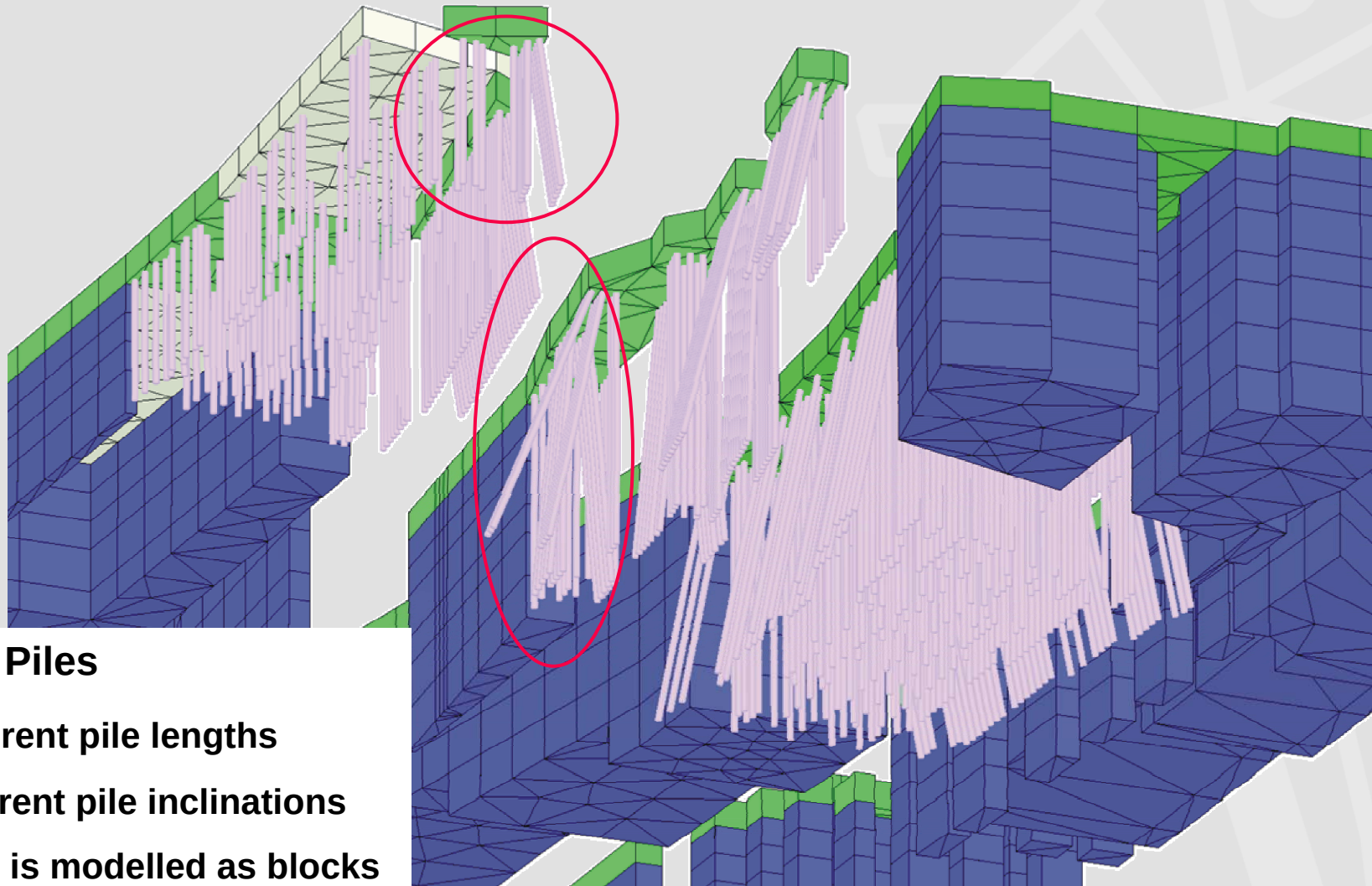
PRACTICAL EXAMPLE

Embedded pile model for zone B



PRACTICAL EXAMPLE

Embedded pile model for zone B



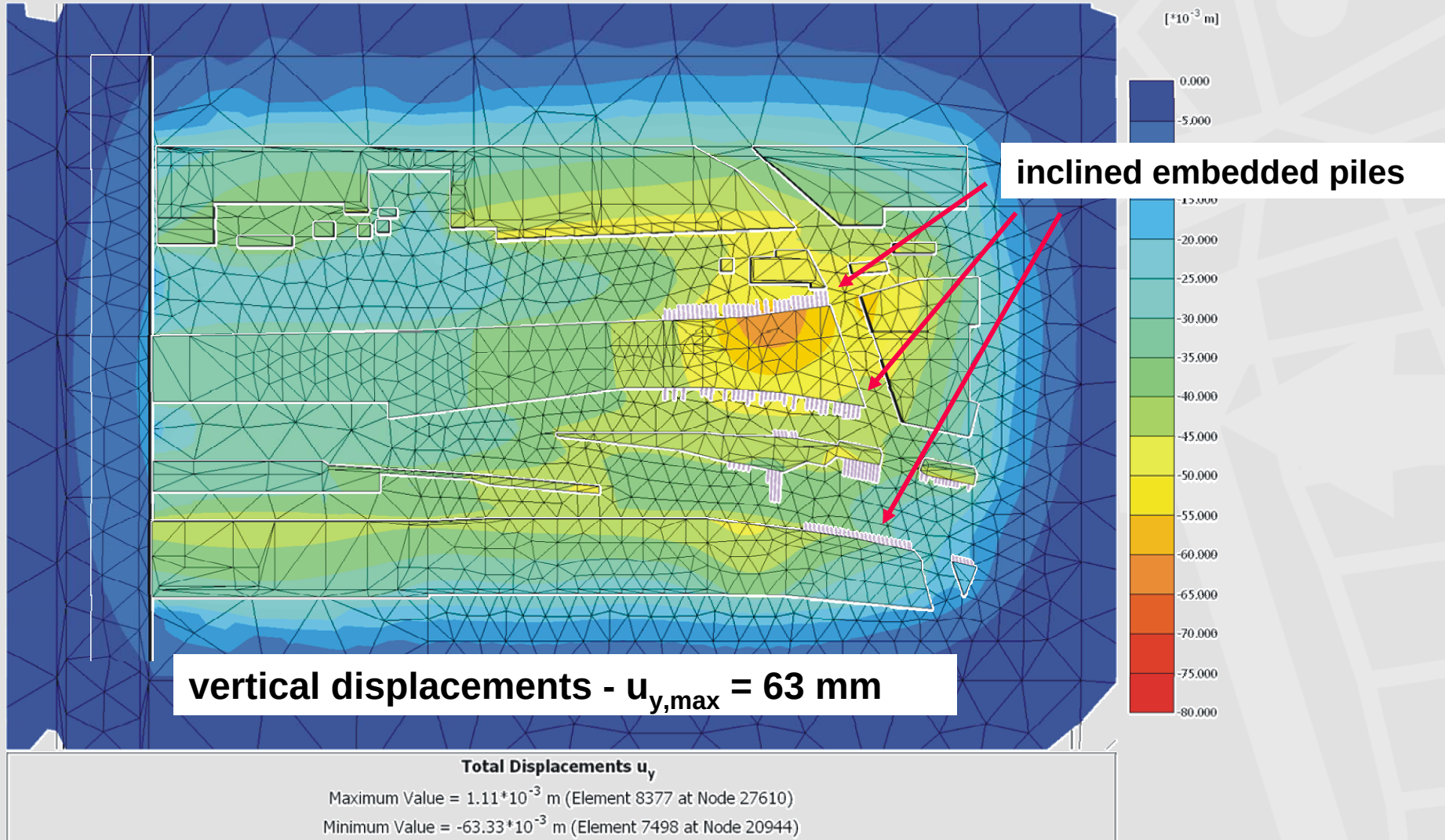
> 615 Piles

- Different pile lengths
- Different pile inclinations

> Rest is modelled as blocks

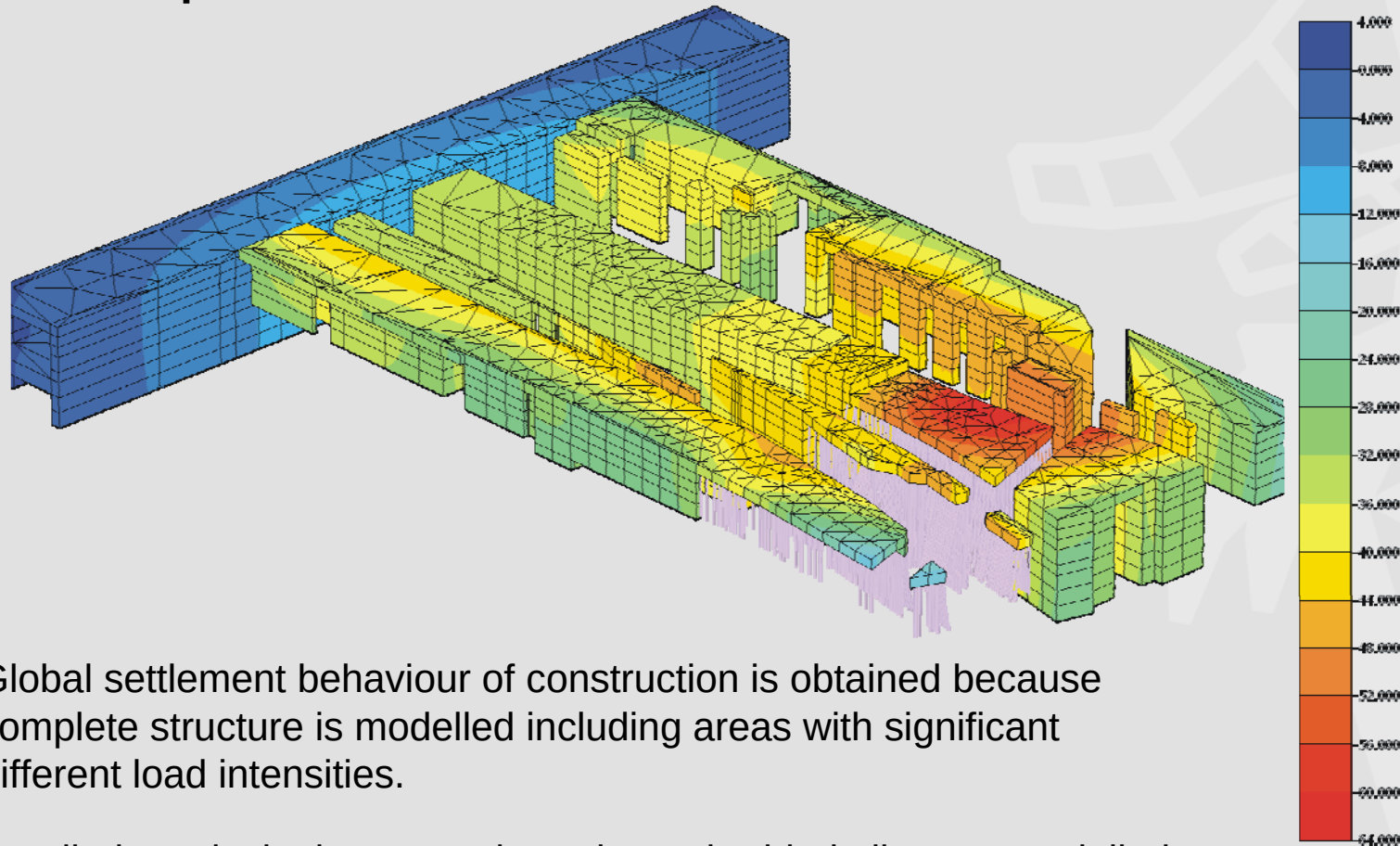
PRACTICAL EXAMPLE

Embedded pile model for zone B - results



PRACTICAL EXAMPLE

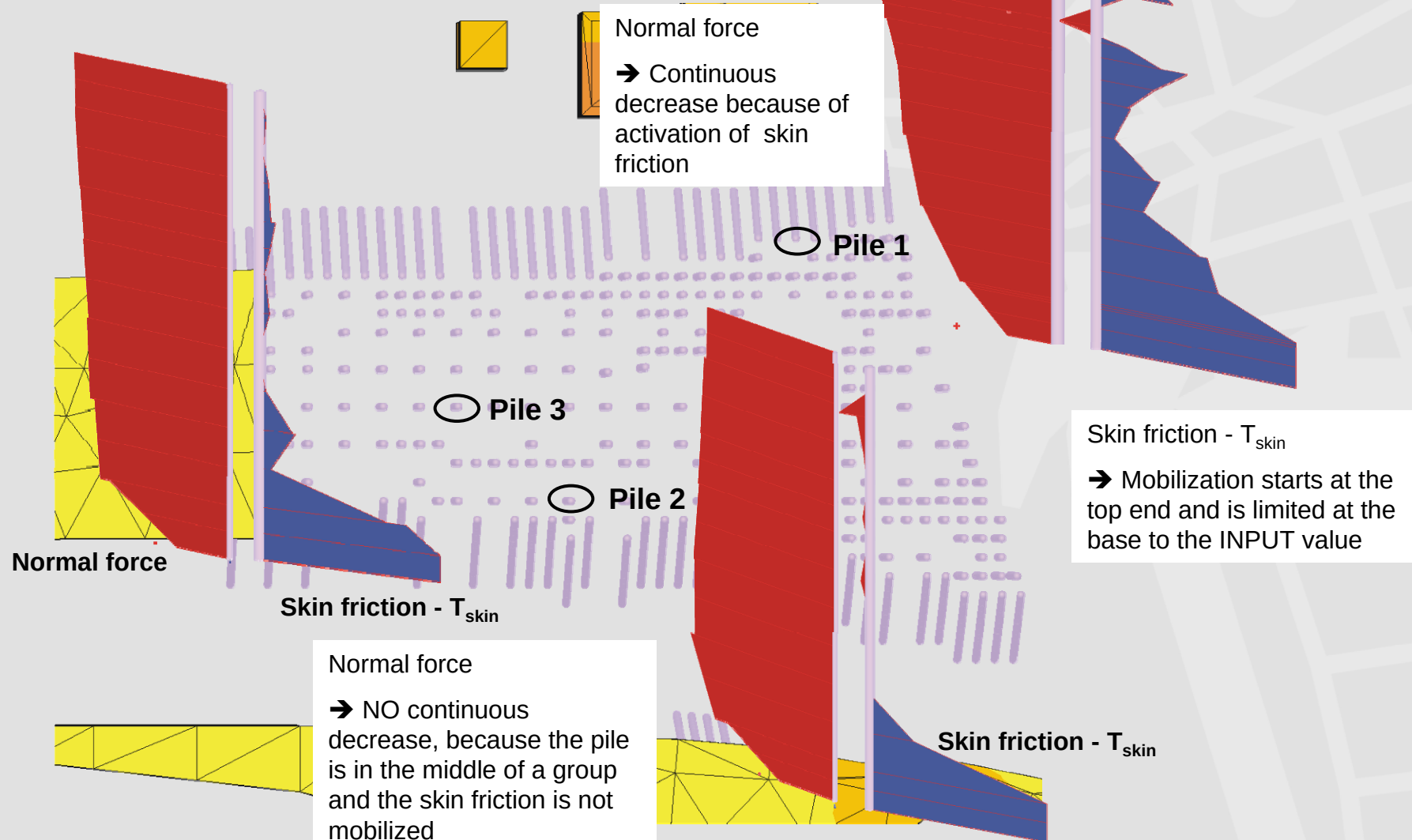
Embedded pile model for zone B - results



- Global settlement behaviour of construction is obtained because complete structure is modelled including areas with significant different load intensities.
- Detailed results in the zone where the embedded piles are modelled.
- Benefit of zone B (embedded piles): spacing, pile length and pile diameter can be modified with reasonable effort.

PRACTICAL EXAMPLE

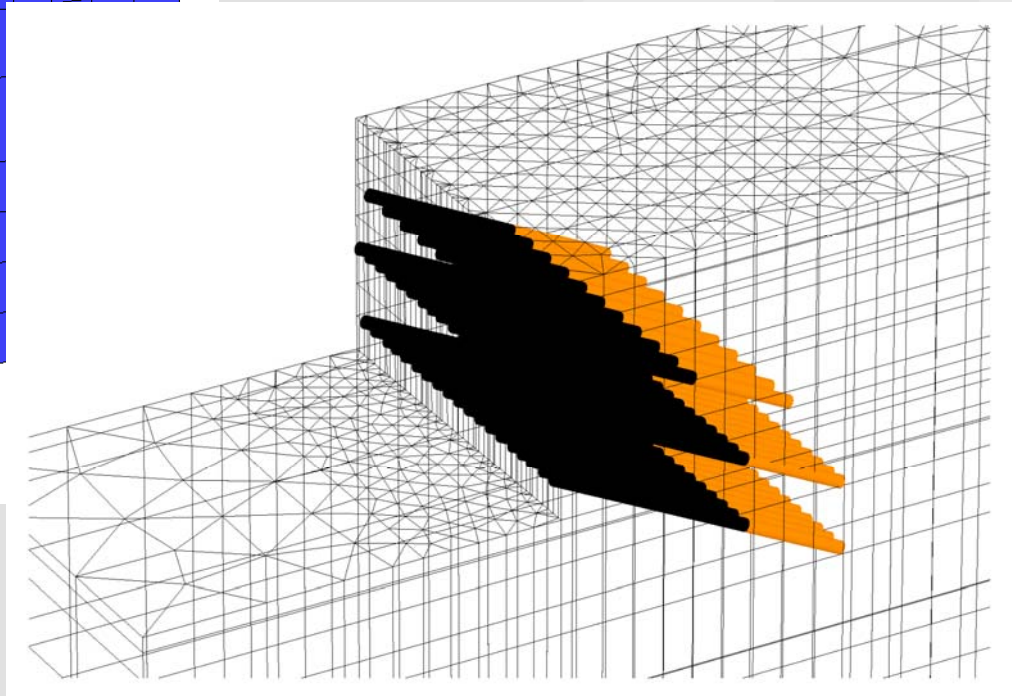
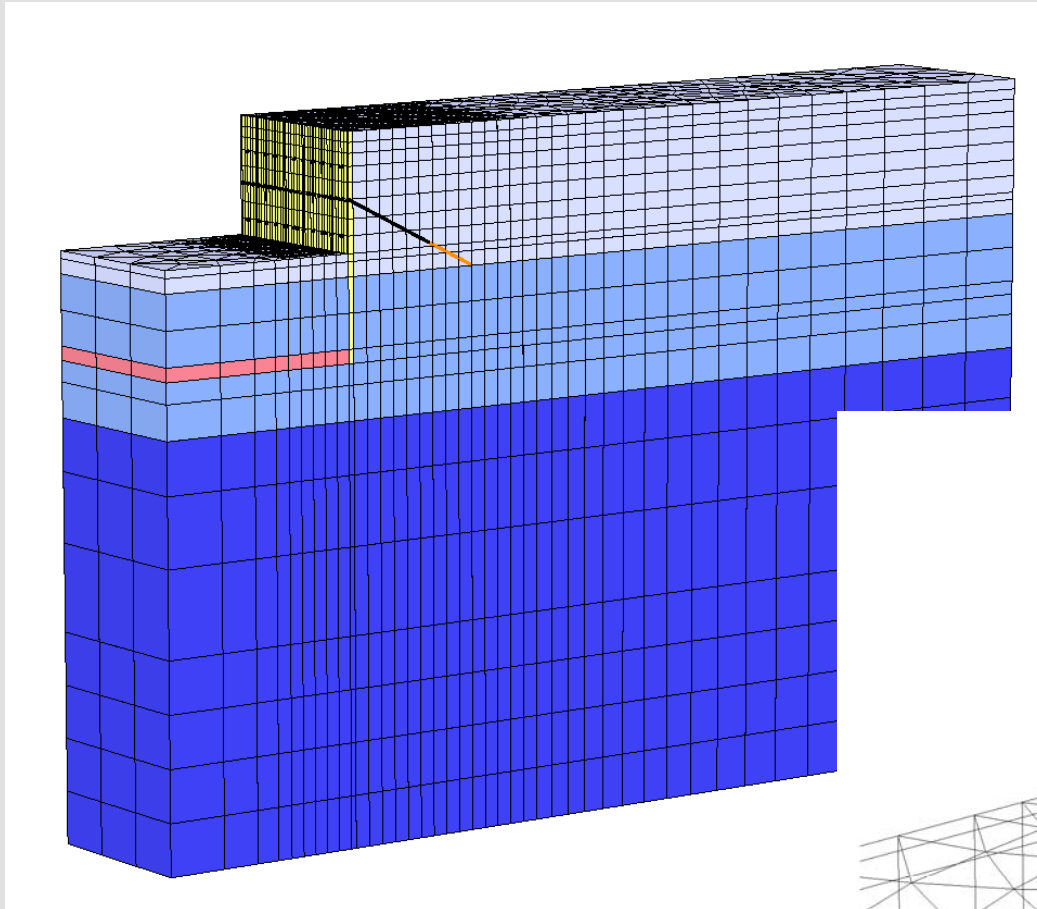
Embedded pile model for zone B - results



SUMMARY

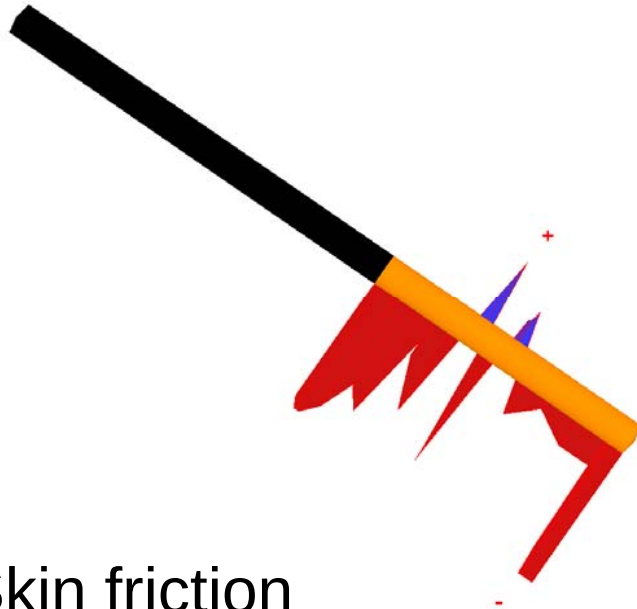
- When creating embedded piles additional geometry points are created but embedded piles do not influence the finite element discretisation.
- The bearing capacity is an **INPUT**: these values should be based on practical experience or pile load tests.
- With embedded piles it is possible to take different spacings, inclinations and lengths into account with reasonable computational effort.
- The distribution of the skin friction along the embedded pile is influenced by the distribution of the skin friction at the failure state (which is an INPUT).
- The embedded piles in Plaxis 3D Foundation are an efficient tool for working load conditions, such as settlement predictions. But for ultimate limit state analysis assumptions such as bearing capacity, pile diameter and the mesh coarseness may have a significant influence on the result.
- So far no experience with horizontal loading.

EMBEDDED PILE OPTION > USE FOR MODELLING GROUND ANCHORS

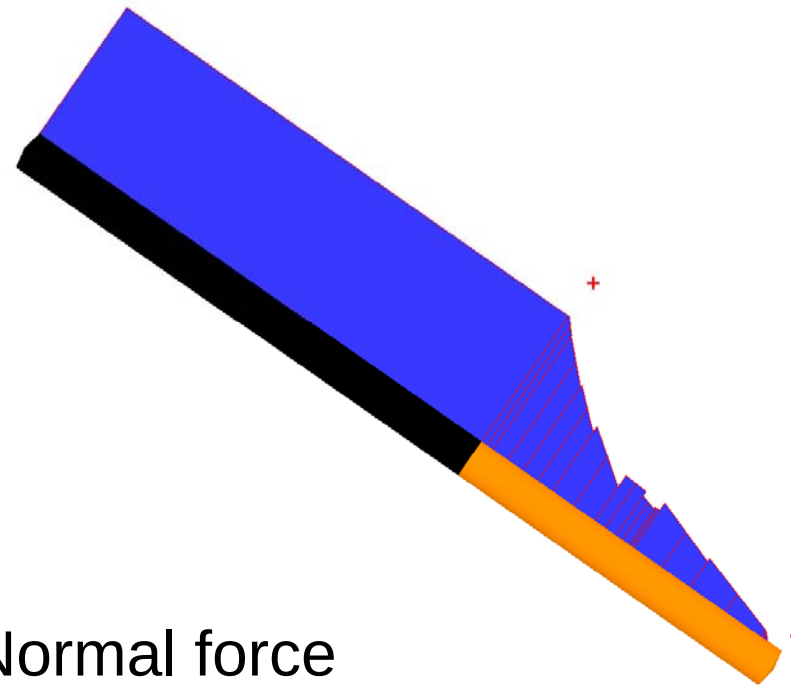


EMBEDDED PILE OPTION > USE FOR MODELLING GROUND ANCHORS

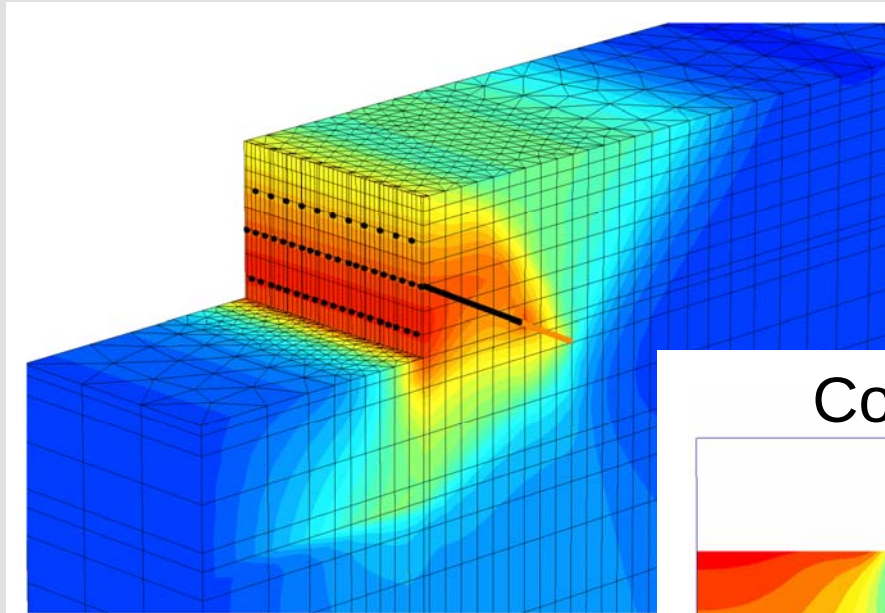
Skin friction



Normal force



EMBEDDED PILE OPTION > USE FOR MODELLING GROUND ANCHORS



Comparison with 2D analysis

