# 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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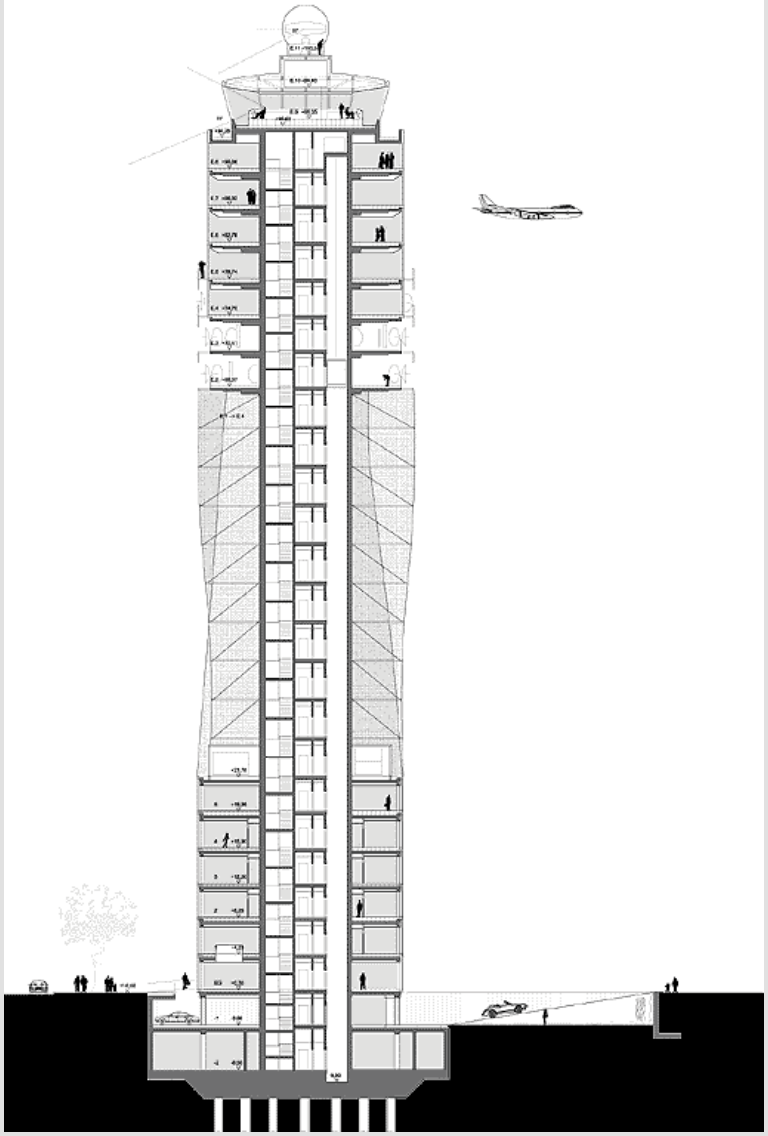
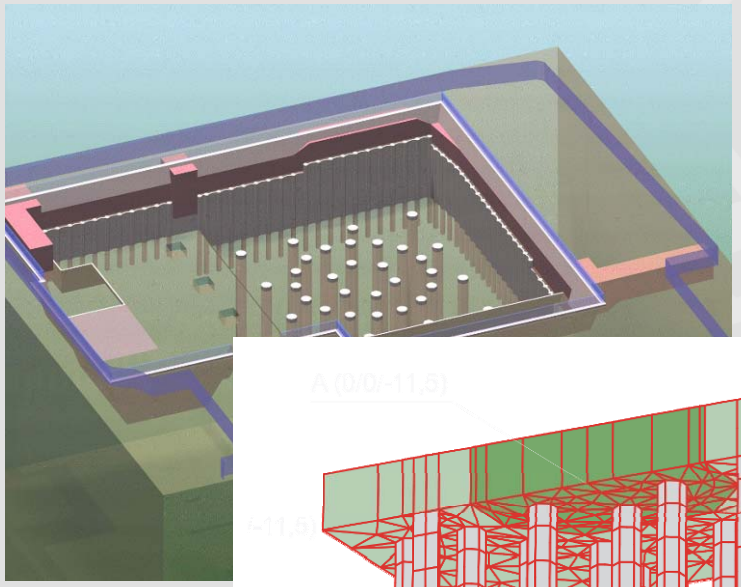
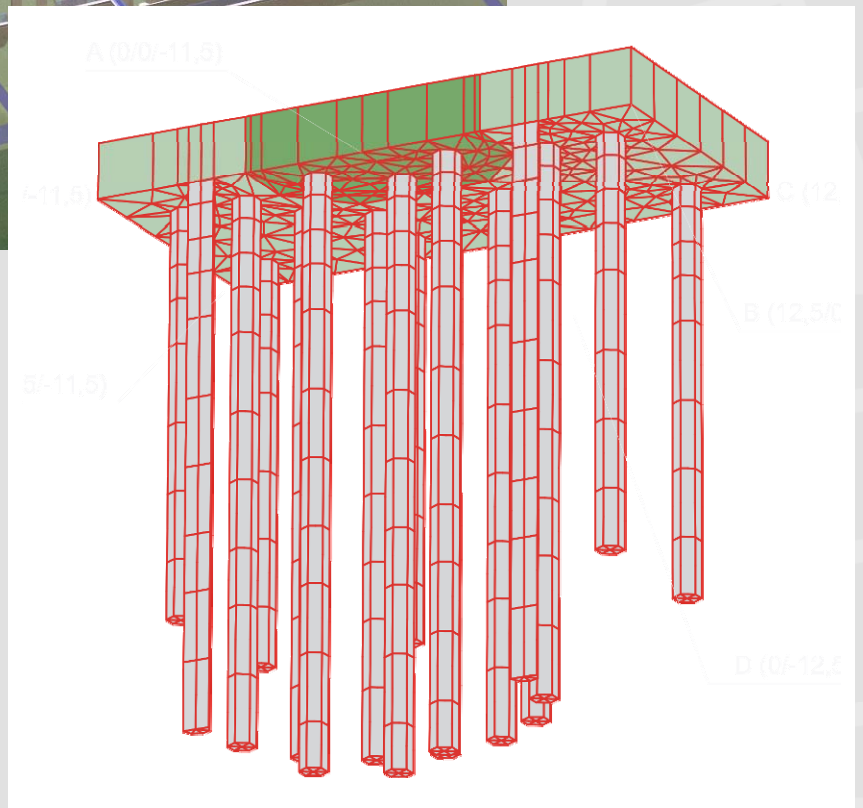
# INTRODUCTION

## Limited number of piles > volume discretisation feasible

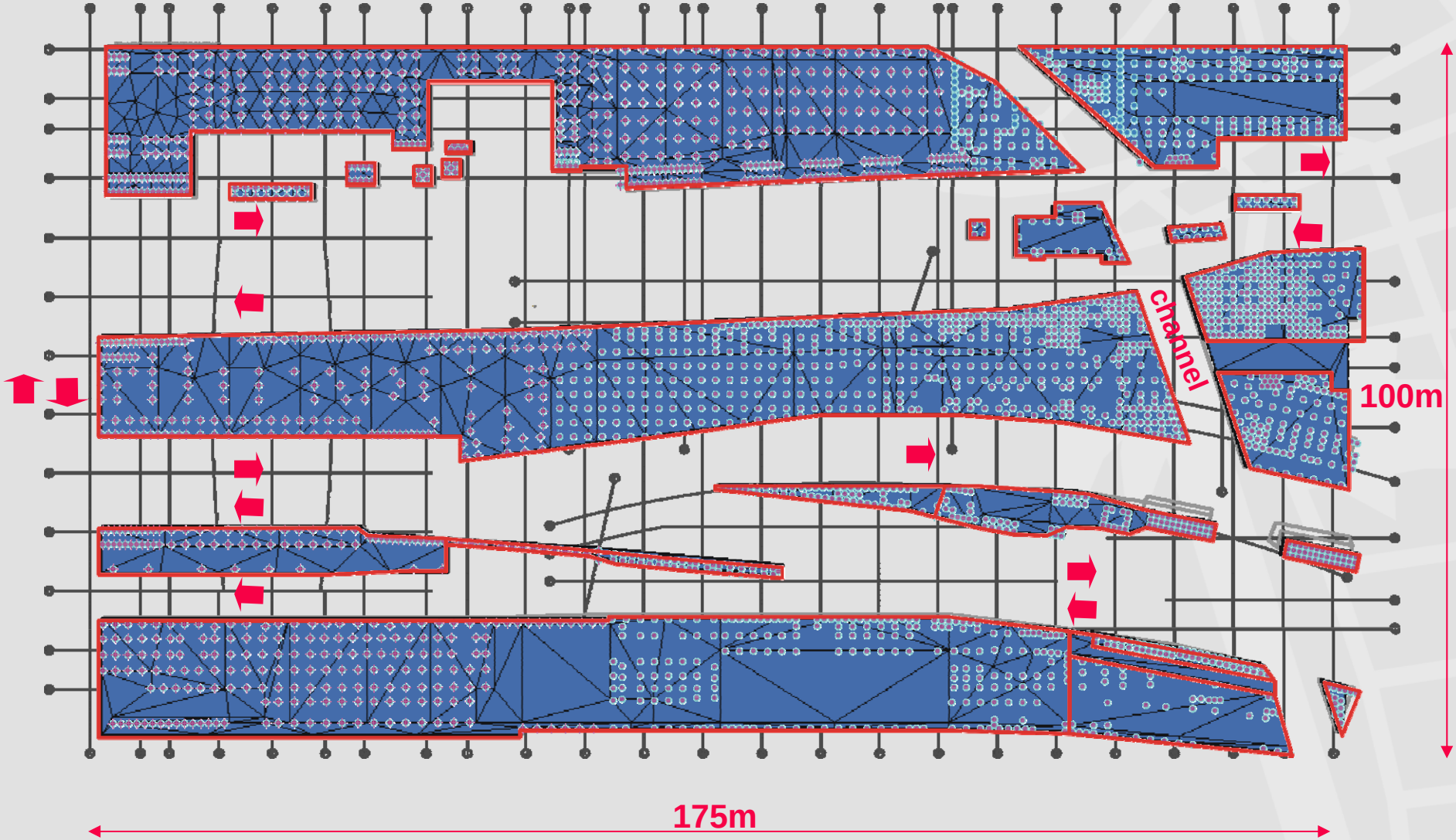






## INTRODUCTION

**Large number of piles > volume discretisation not feasible**

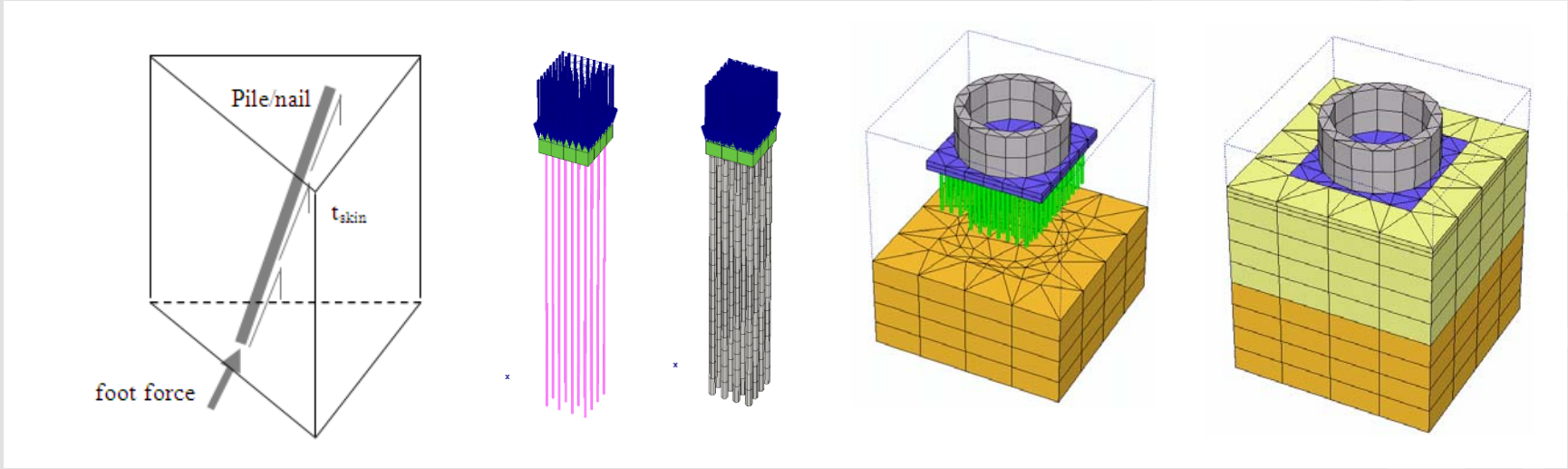


# INTRODUCTION

## Embedded Inclusion (Pile, Soil Nails & Ground Anchors)

### Implementation in PLAXIS

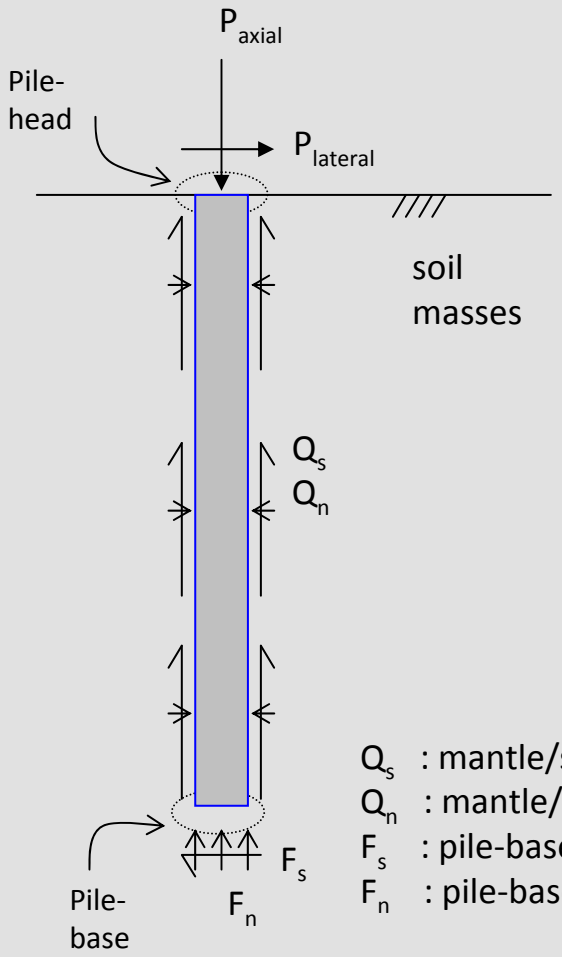
- Inclusion as line element (slender beam)
- Arbitrary inclination and position
- Connection between embedded inclusion and soil by special interface elements
- Non-linear spring representing the pile-soil contact at the base (Septanika, 2005)
- Different types of skin resistance behaviour (Linear, Multi-linear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

# BASIC ASSUMPTIONS



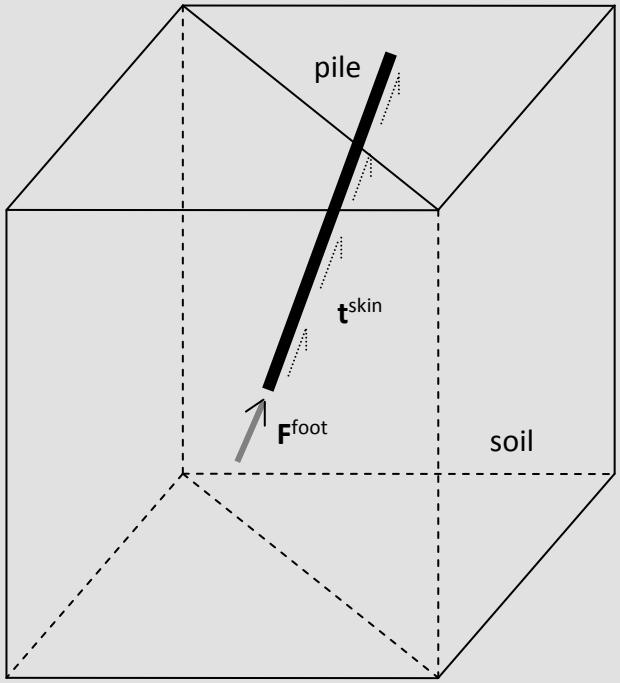

$Q_s$ : mantle/skin shear forces
$Q_n$ : mantle/skin normal forces
$F_s$ : pile-base shear forces
$F_n$ : pile-base normal forces

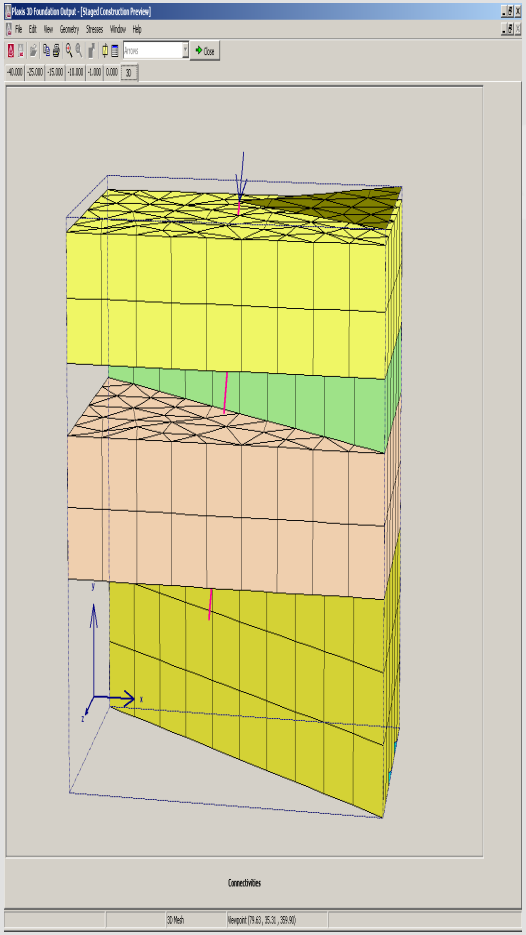
**Pile behaviour depends on:**

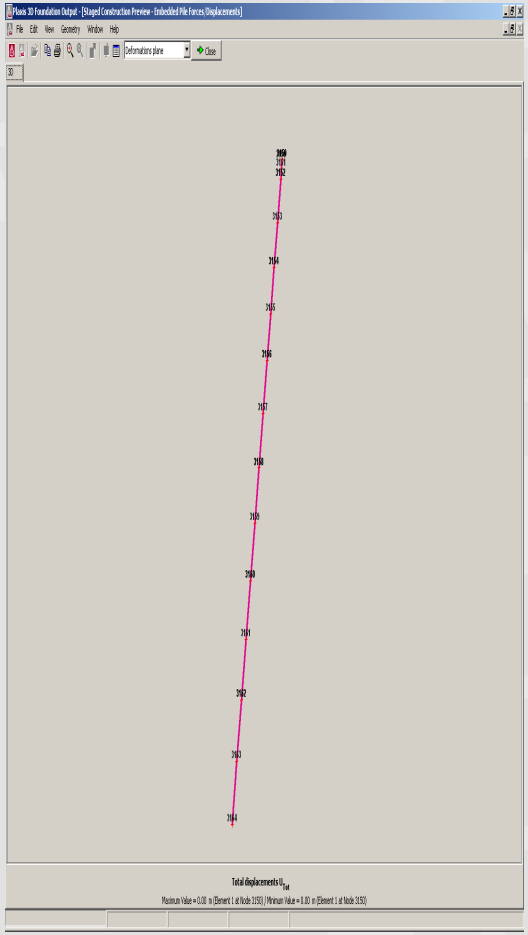
- Soil type
- Stress state
- Pile geometry
- Pile type (Steel, concrete, timber…etc.)
- Installation procedure

**summarized in "interface behaviour"**

# DEFINITION IN PLAXIS

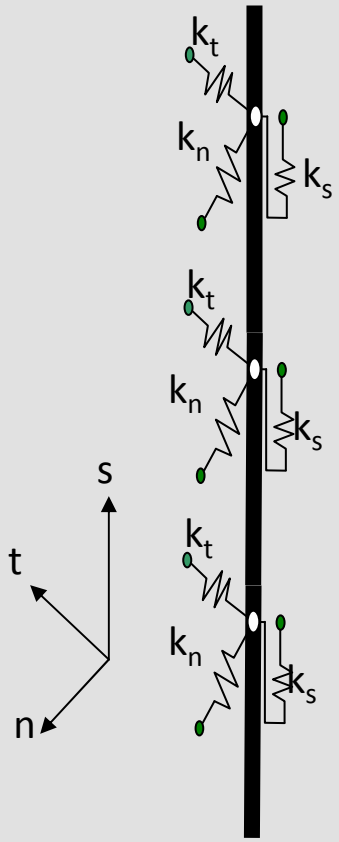




# DEFINITION IN PLAXIS

## SKIN INTERACTION




Skin stiffness:

$k_s$ : axial stiffness

$K_n$ & $k_t$ : lateral stiffness

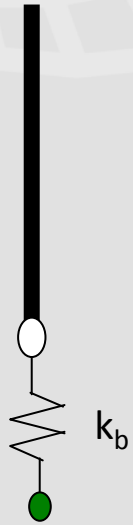
Skin tractions:

$t_s = q_s/\text{length} = k_s\,(u_s^{pile}-u_s^{soil}) \le t_{max}$

$t_n = q_n/\text{length} = k_n\,(u_n^{pile}-u_n^{soil})$

$t_t = q_t/\text{length} = k_t\,(u_t^{pile}-u_t^{soil})$

## BASE RESISTANCE



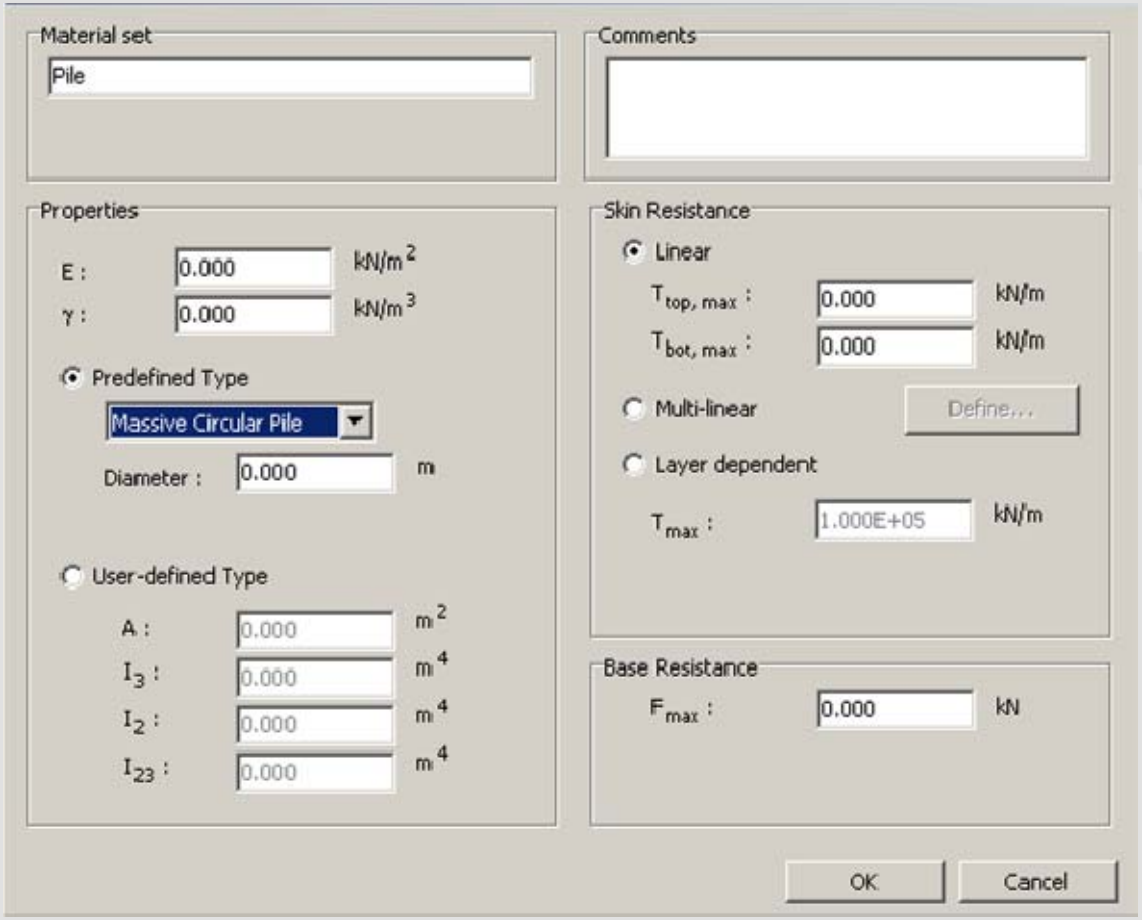

Base stiffness:

$k_b$ : base/foot stiffness

Base/Foot force:

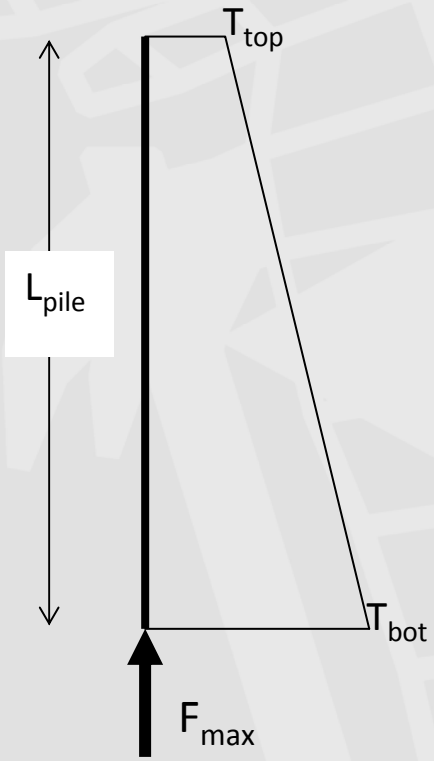
$0 \le F_b = k_b\,(u_b^{pile} - u_b^{soil}) \le F_{max}$

# DEFINITION IN PLAXIS



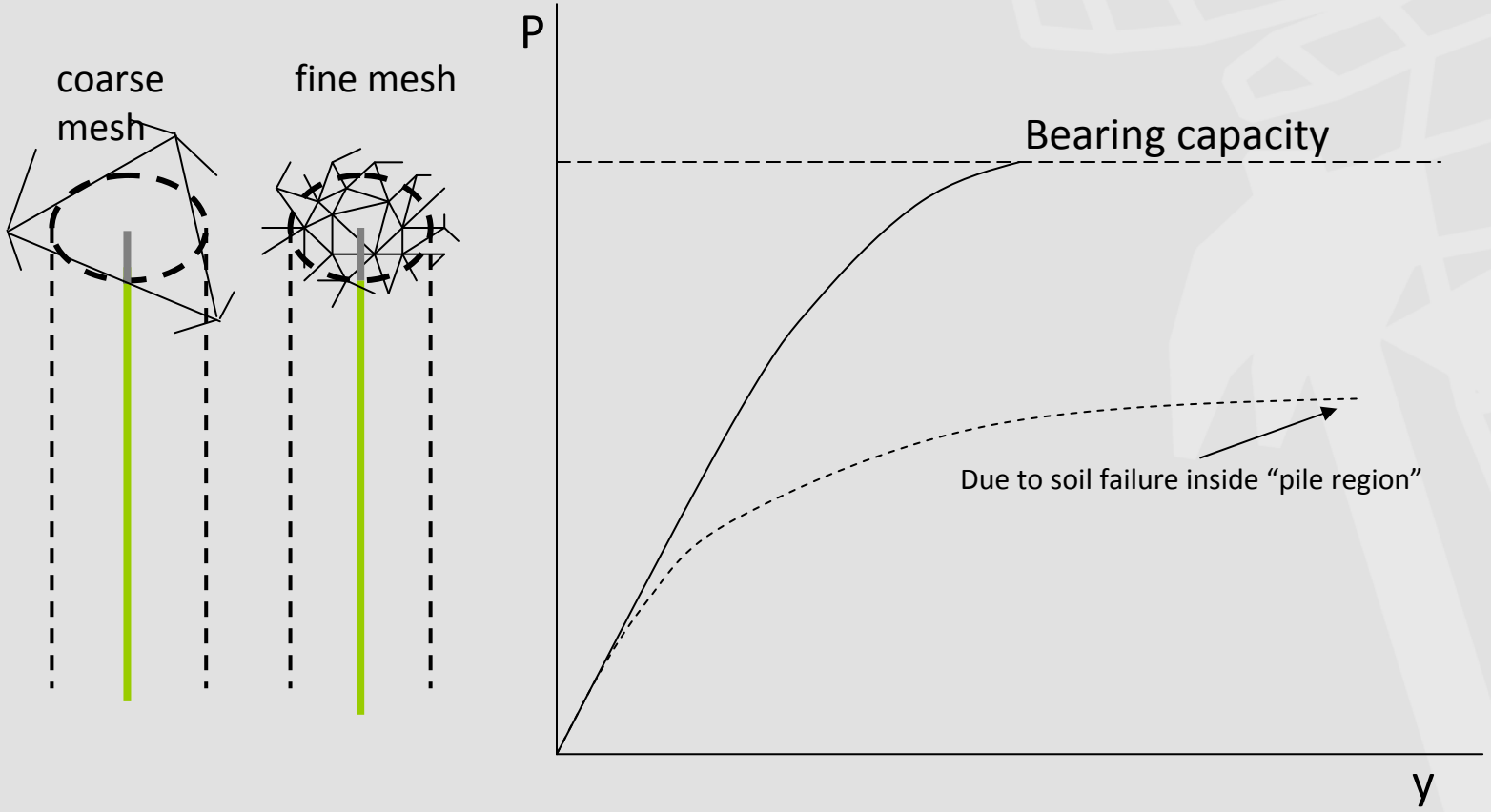

Bearing Capacity:

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



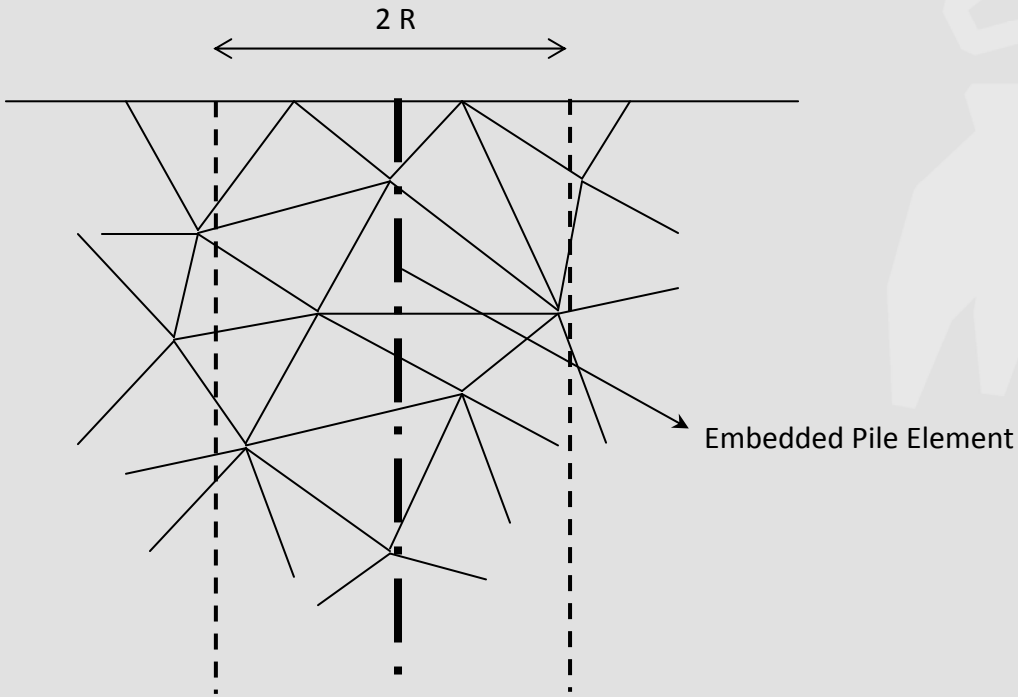
## DEFINITION IN PLAXIS

- 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 (=$\pi R^2 * L$)
- 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



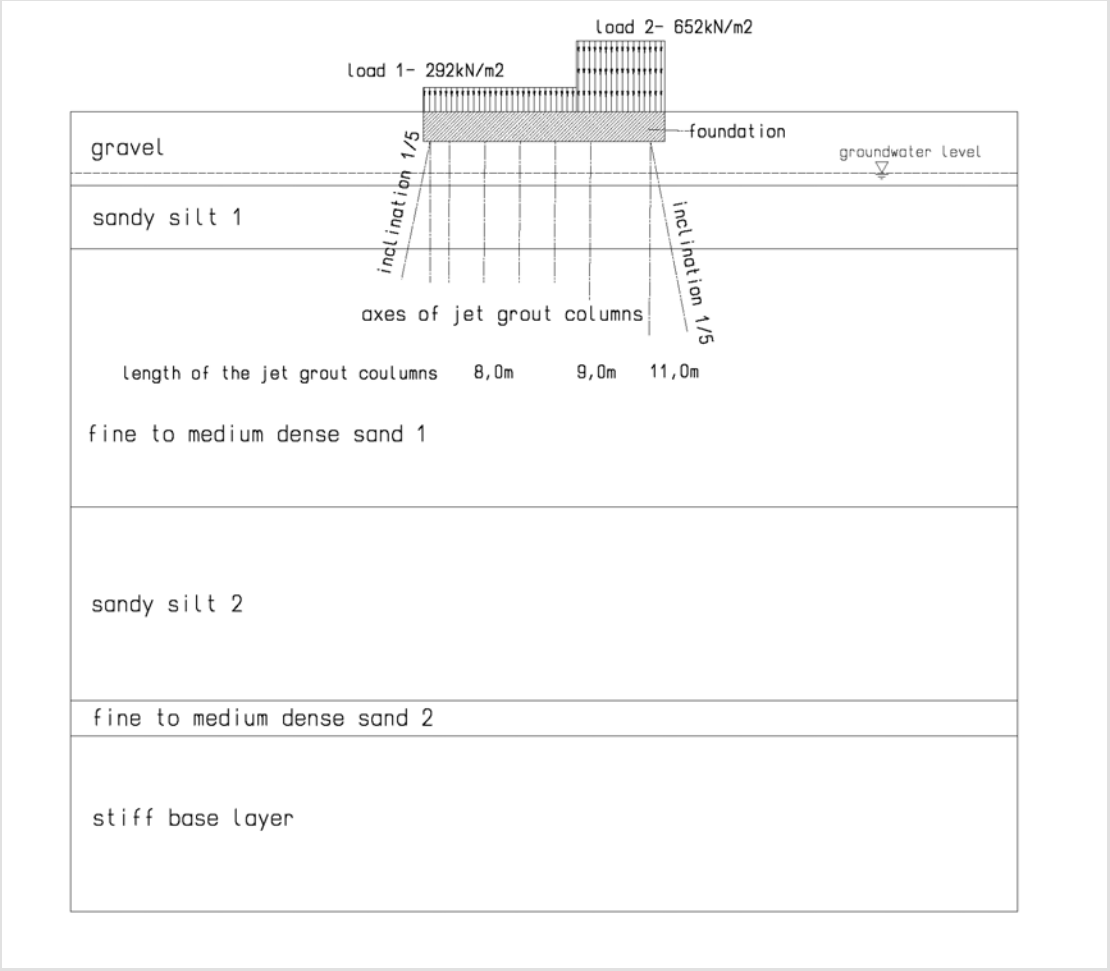
## DEFINITION IN PLAXIS - SUMMARY

**An embedded pile is a pile which consists of:**

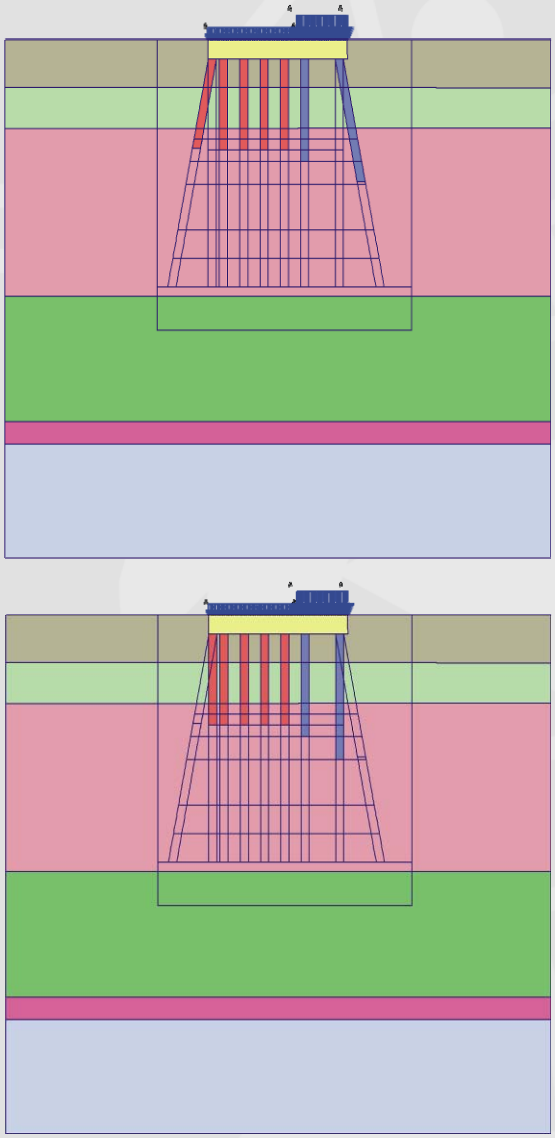
- **Beam elements**
  - **Properties: E, $\gamma$, d**
  - **d determines the elastic zone in the soil around the beam**
- **Special interface elements**
  - ➔ **Interaction pile - soil**
  - **Properties: skin resistance, base resistance**

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

# VERIFICATION EXAMPLE

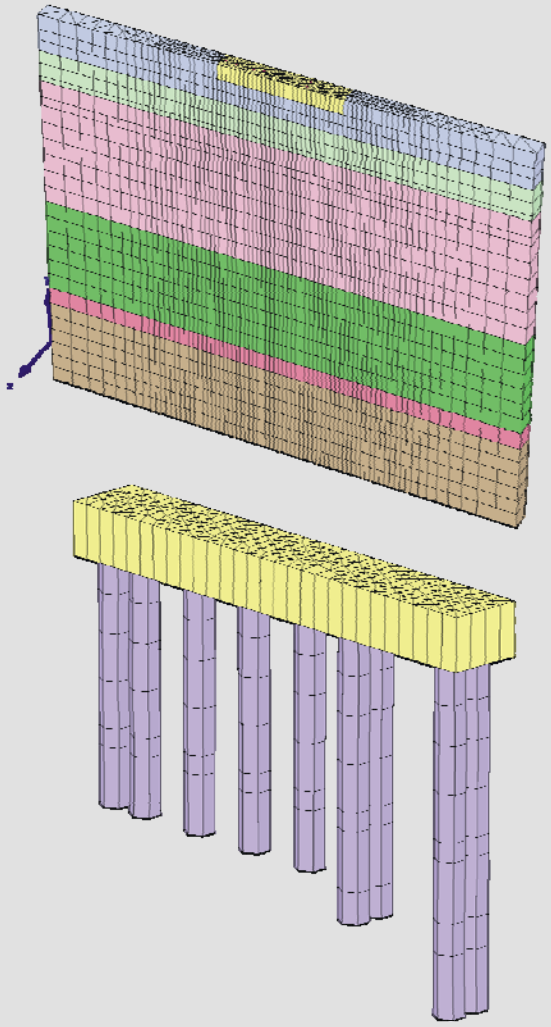



## 2D model



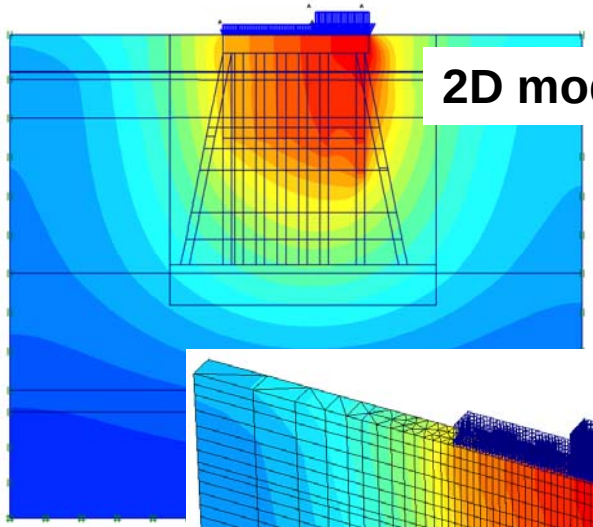
## VERIFICATION EXAMPLE

### 3D model - volume piles

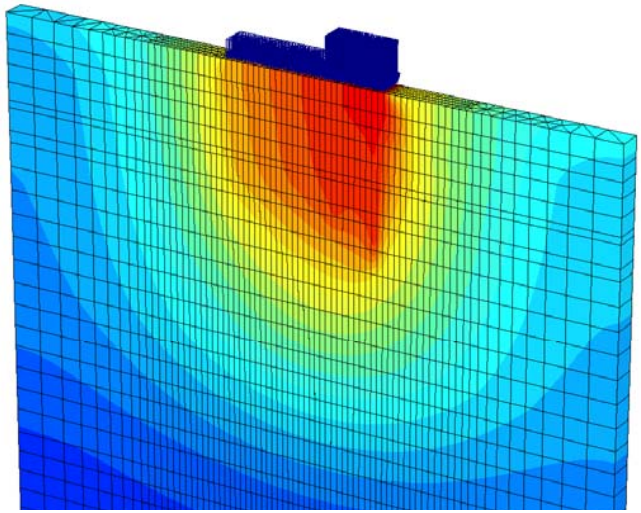


### 3D model - embedded piles

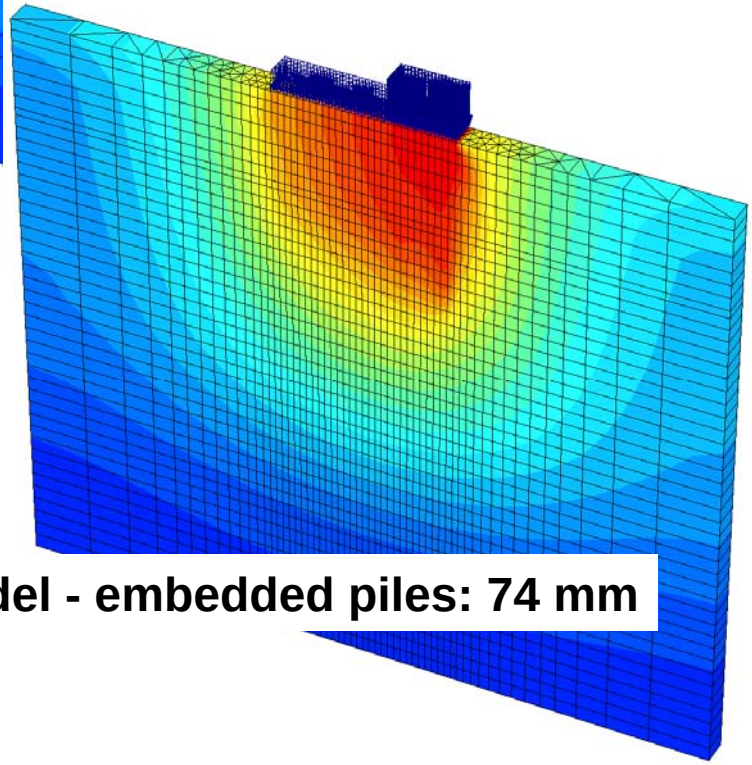
## VERIFICATION EXAMPLE



2D model: 72 mm



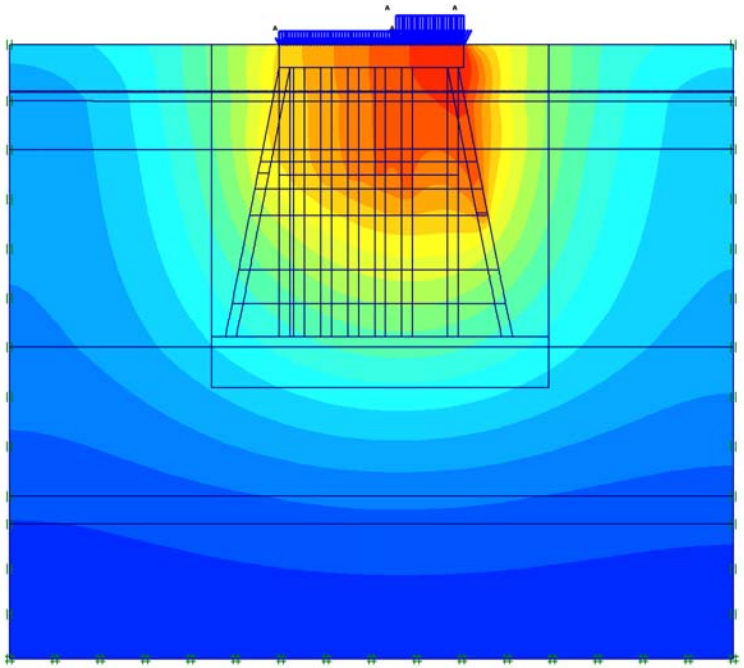
3D model - volume piles: 70 mm



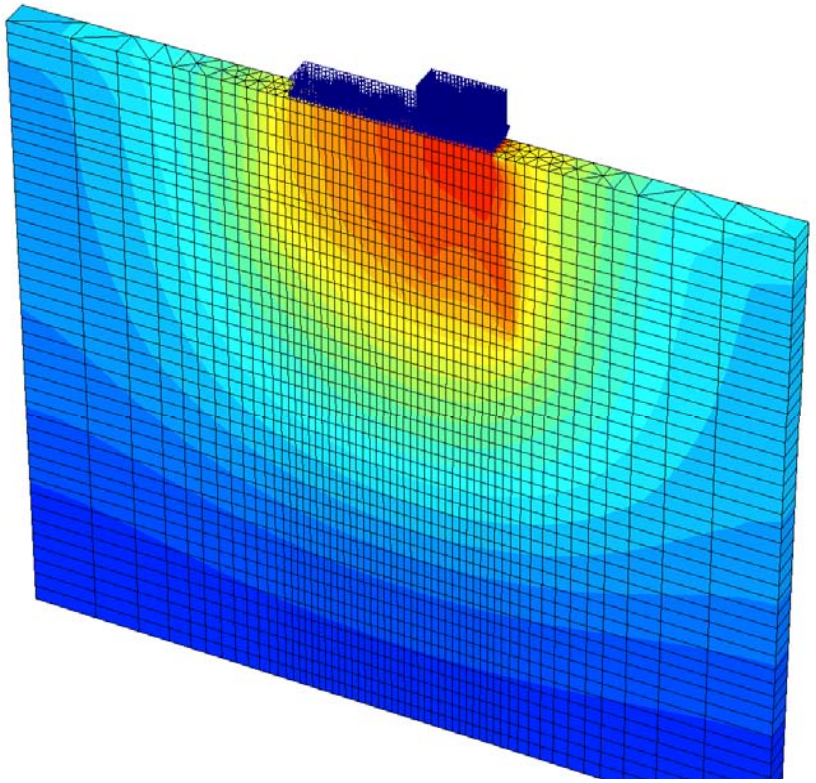
3D model - embedded piles: 74 mm

**ALL PILES VERTICAL**

## VERIFICATION EXAMPLE



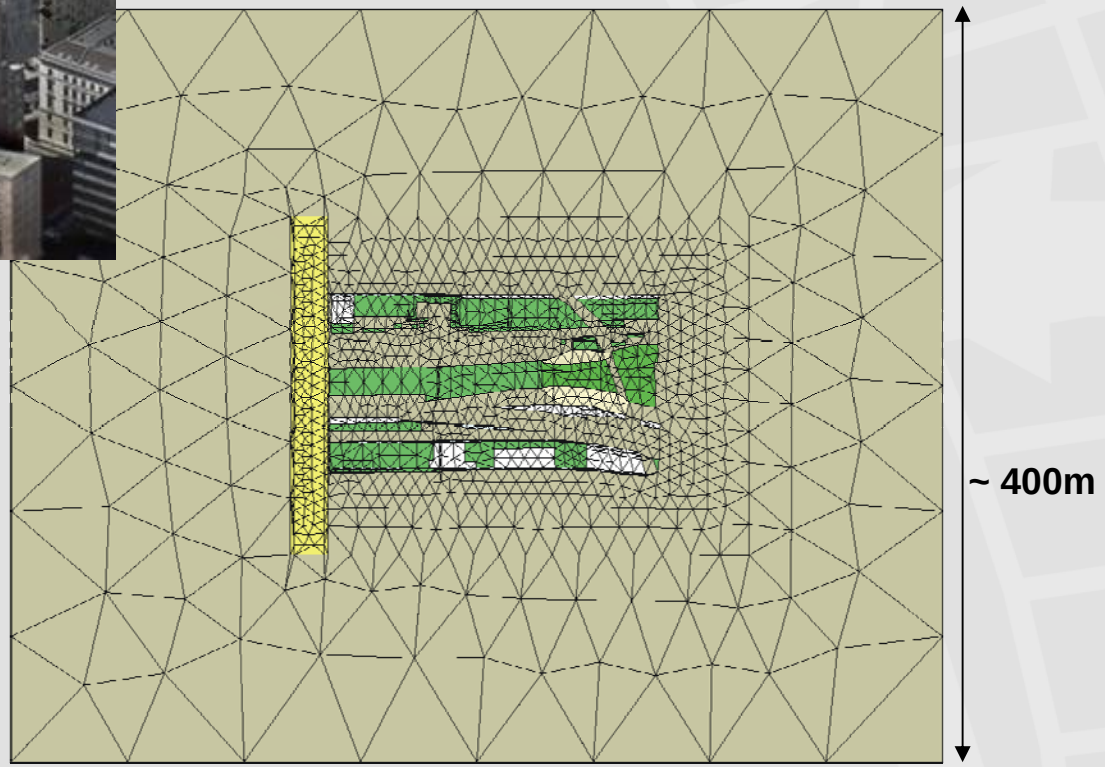
**2D model: 68 mm**



**3D model - embedded piles: 70 mm**

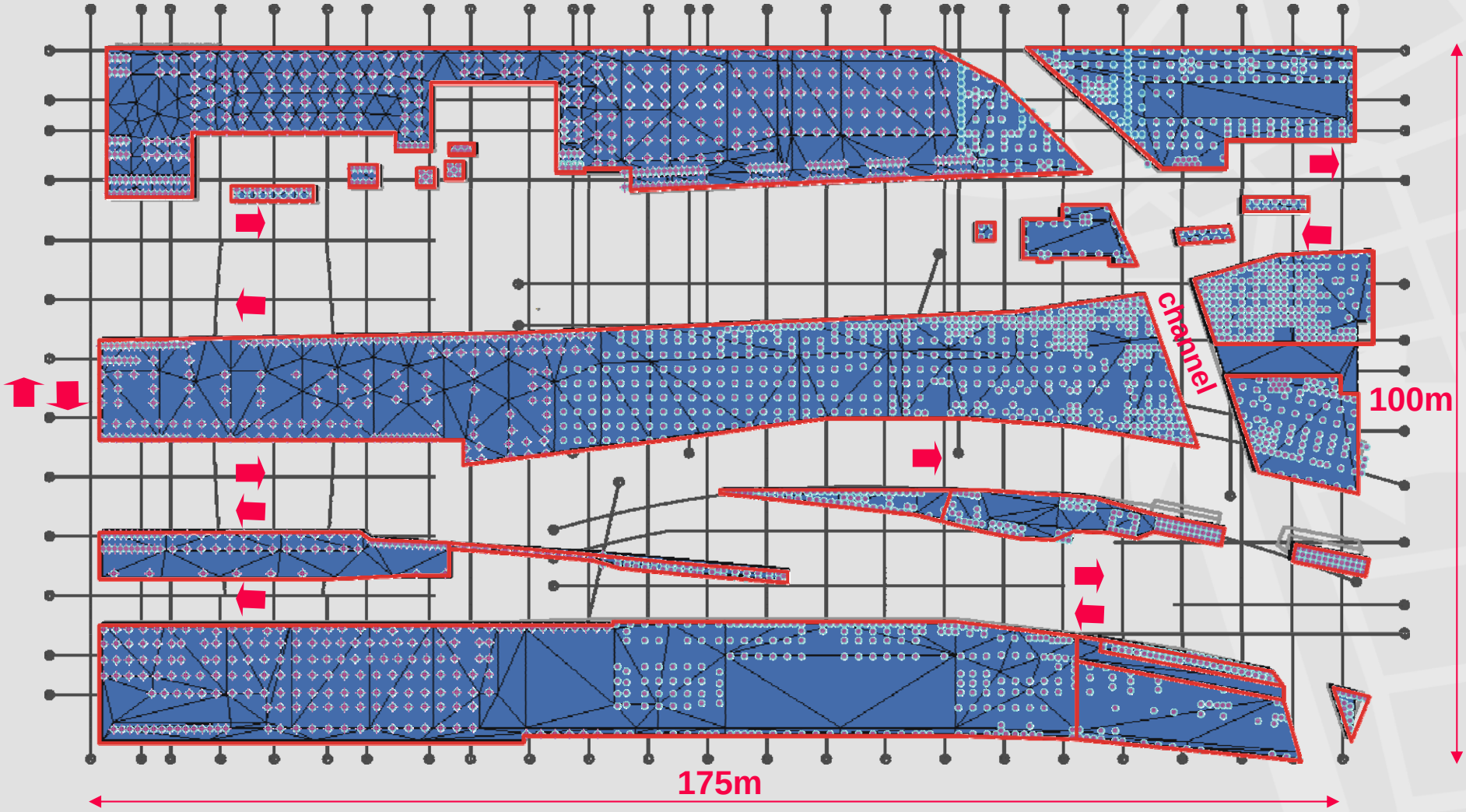
# OUTER PILES INCLINED

# PRACTICAL EXAMPLE




**PLAN VIEW**

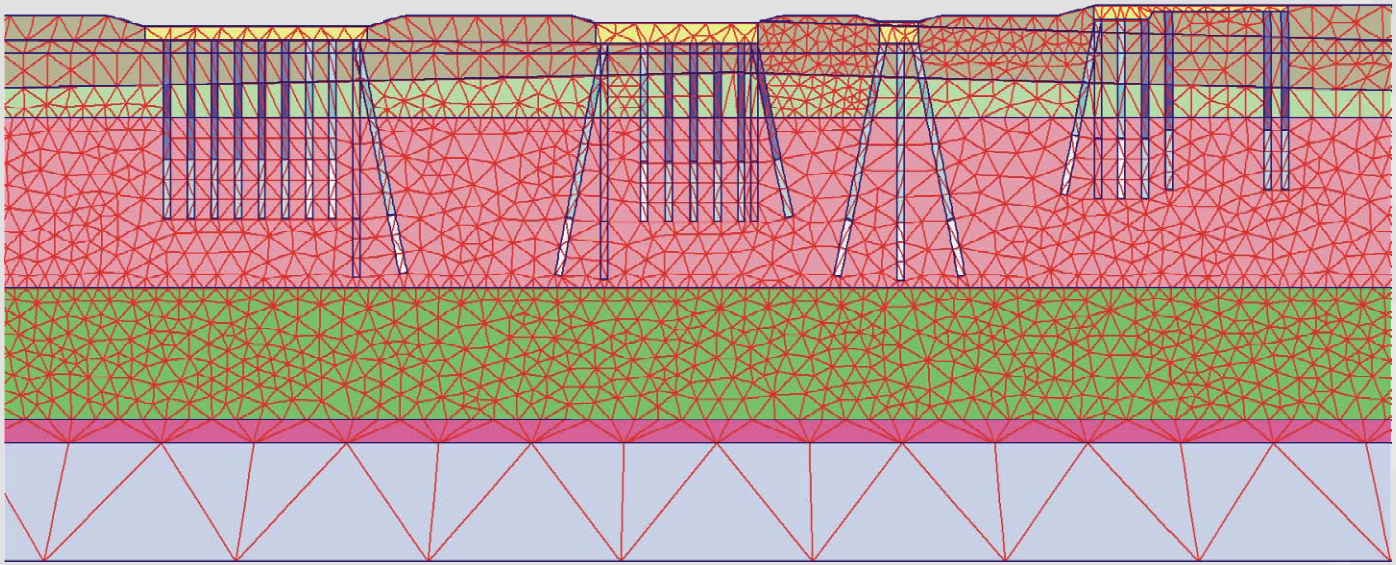
## INTRODUCTION



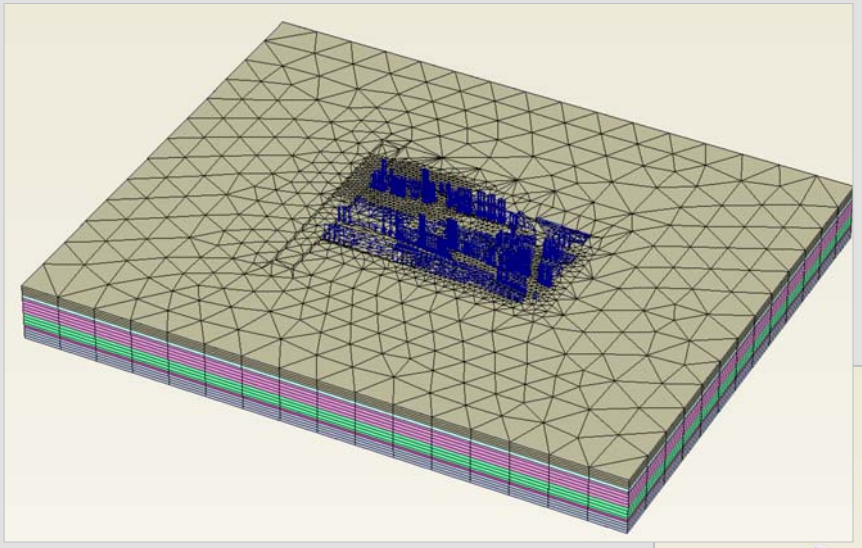

**PLAN VIEW - ARRANGEMENT OF JET GROUT COLUMNS**

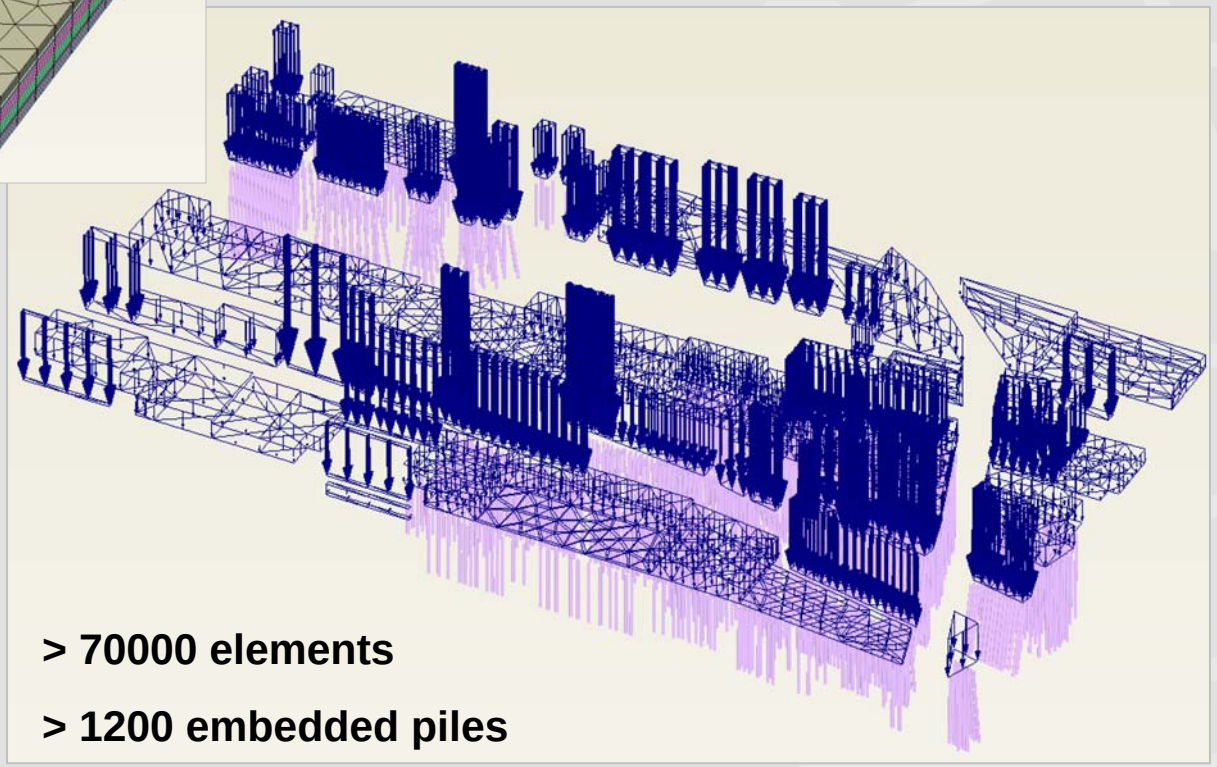
## PRACTICAL EXAMPLE

# TYPICAL CROSS SECTION - SOIL PROFILE



# PRACTICAL EXAMPLE





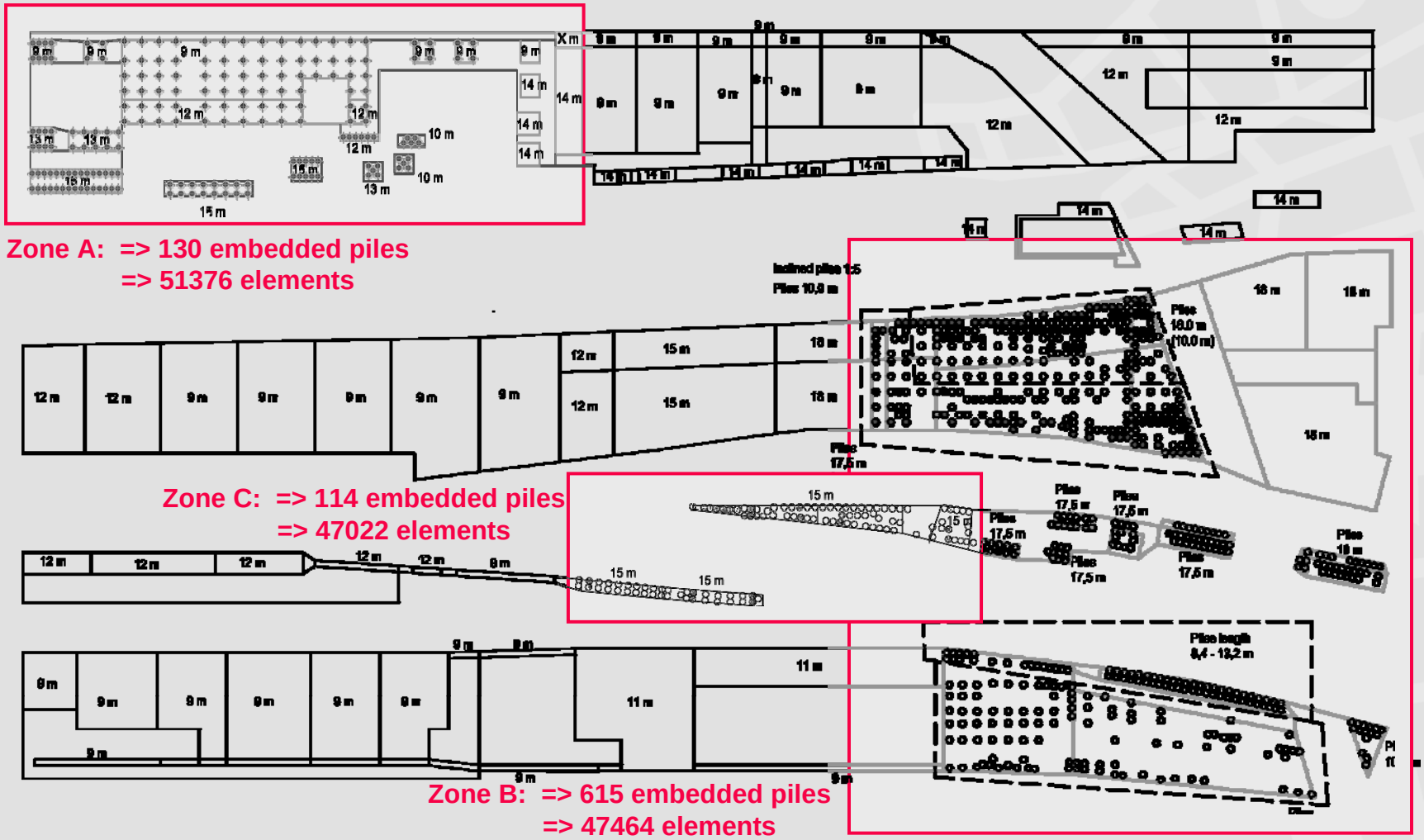
**> Model is too big - in phase „activating the jet grout piles“ failure occurred**

**> 70000 elements**

**> 1200 embedded piles**

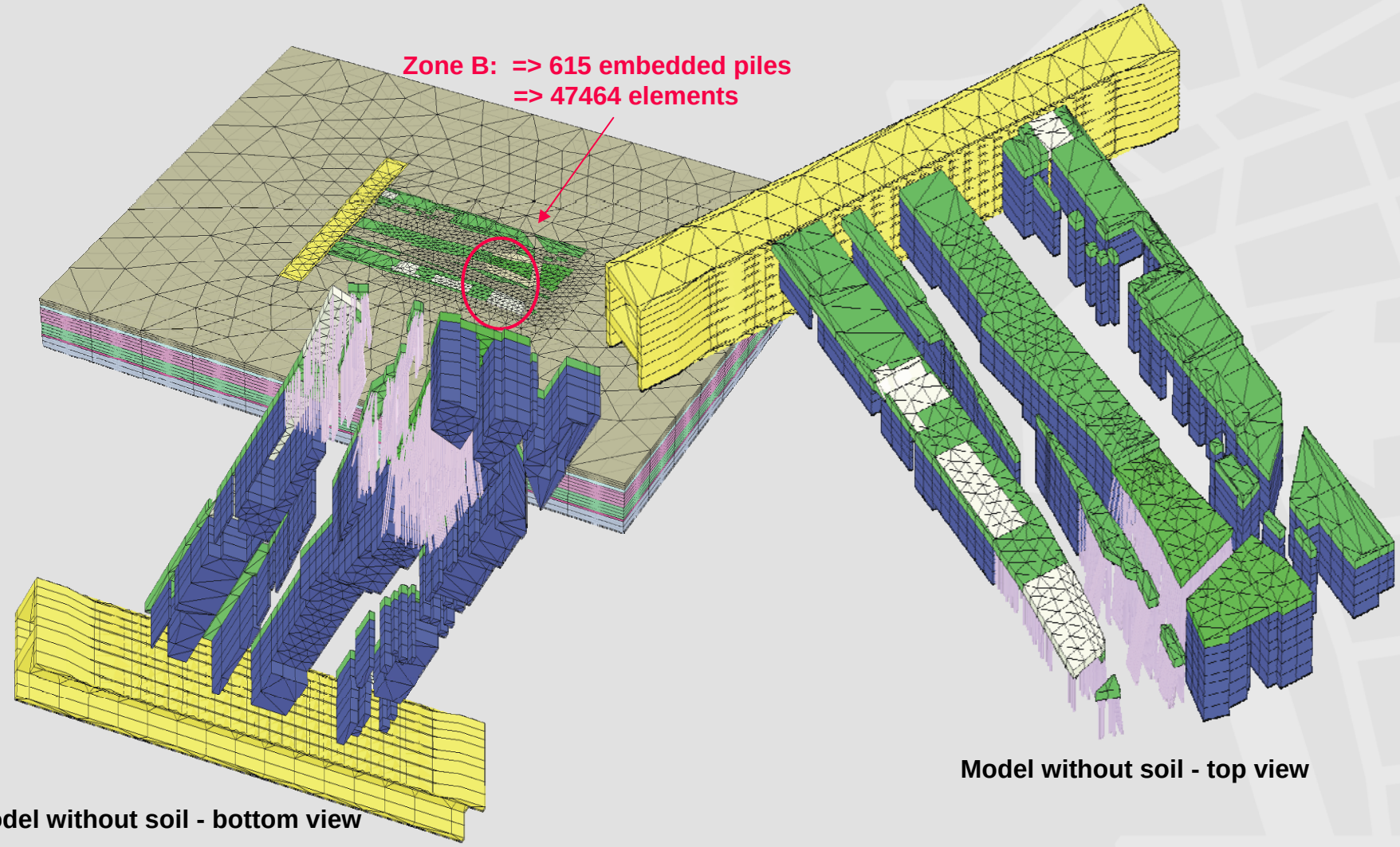
# PRACTICAL EXAMPLE

➔ **Three different models for the sensitive zones**



# PRACTICAL EXAMPLE

## Embedded pile model for zone B

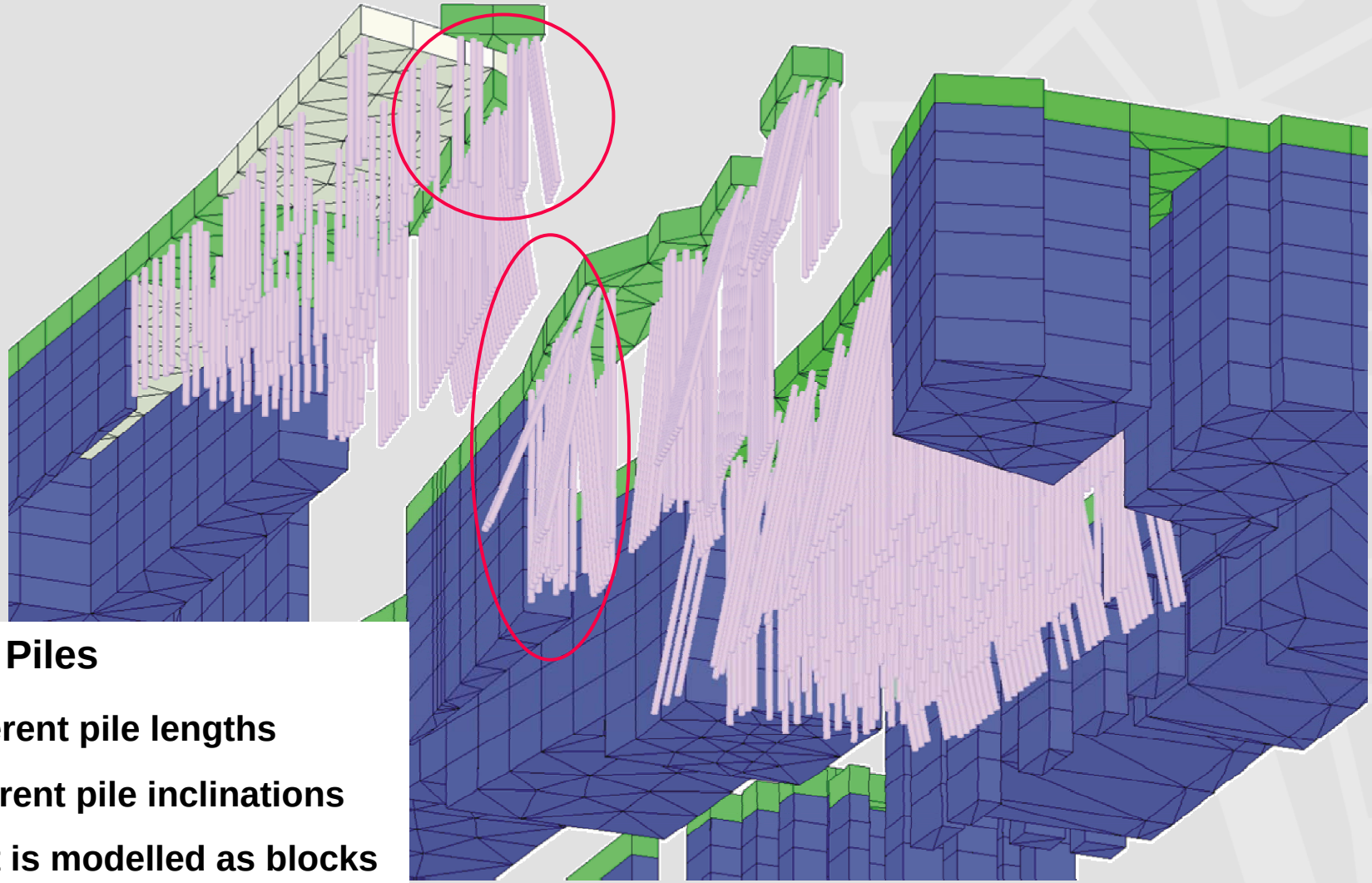



Model without soil - bottom view

Model without soil - top view

# PRACTICAL EXAMPLE

## Embedded pile model for zone B



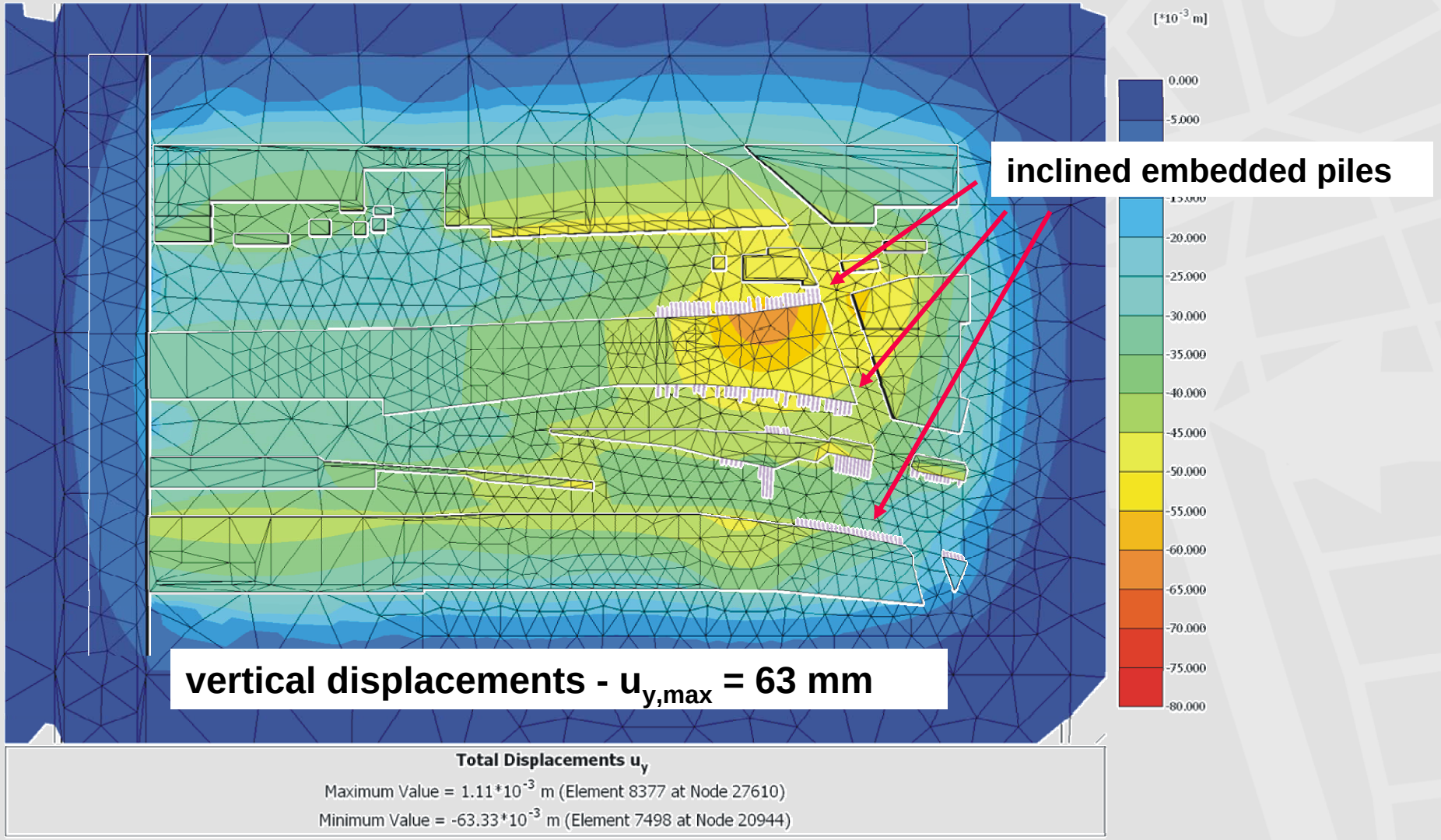
**> 615 Piles**

- **Different pile lengths**
- **Different pile inclinations**

**> Rest is modelled as blocks**

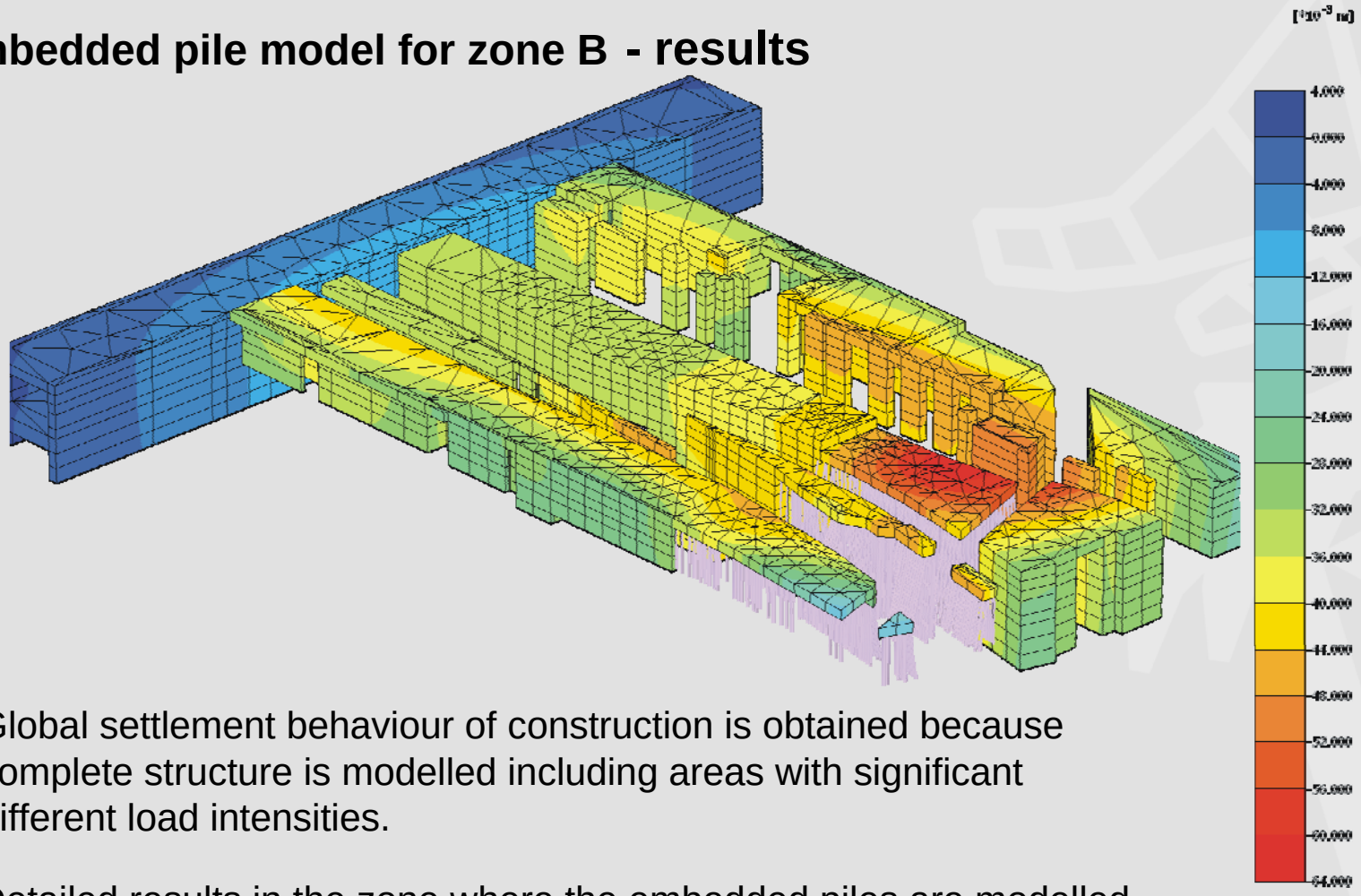
# PRACTICAL EXAMPLE

## Embedded pile model for zone B - results



# PRACTICAL EXAMPLE

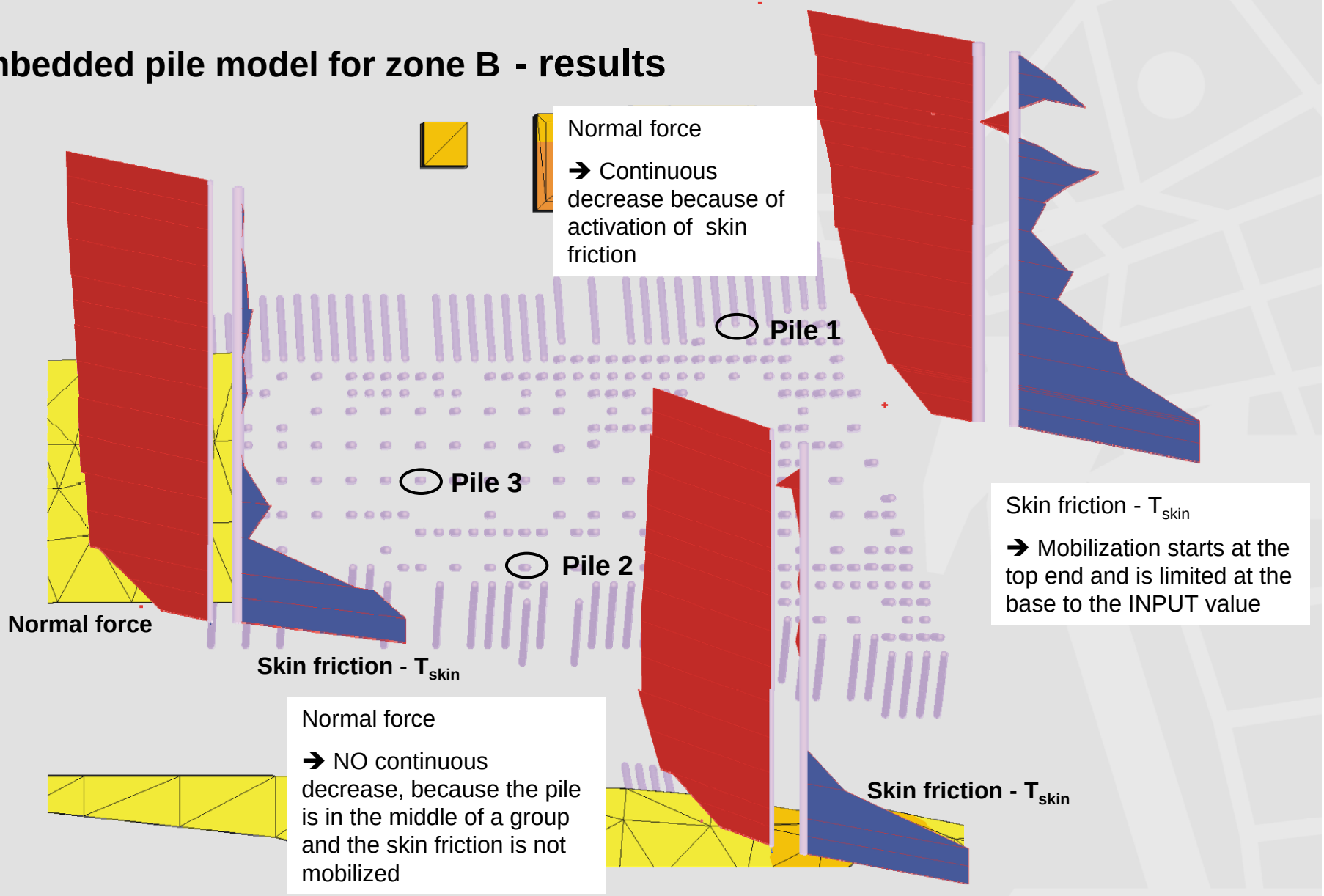
## Embedded pile model for zone B - results




- 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

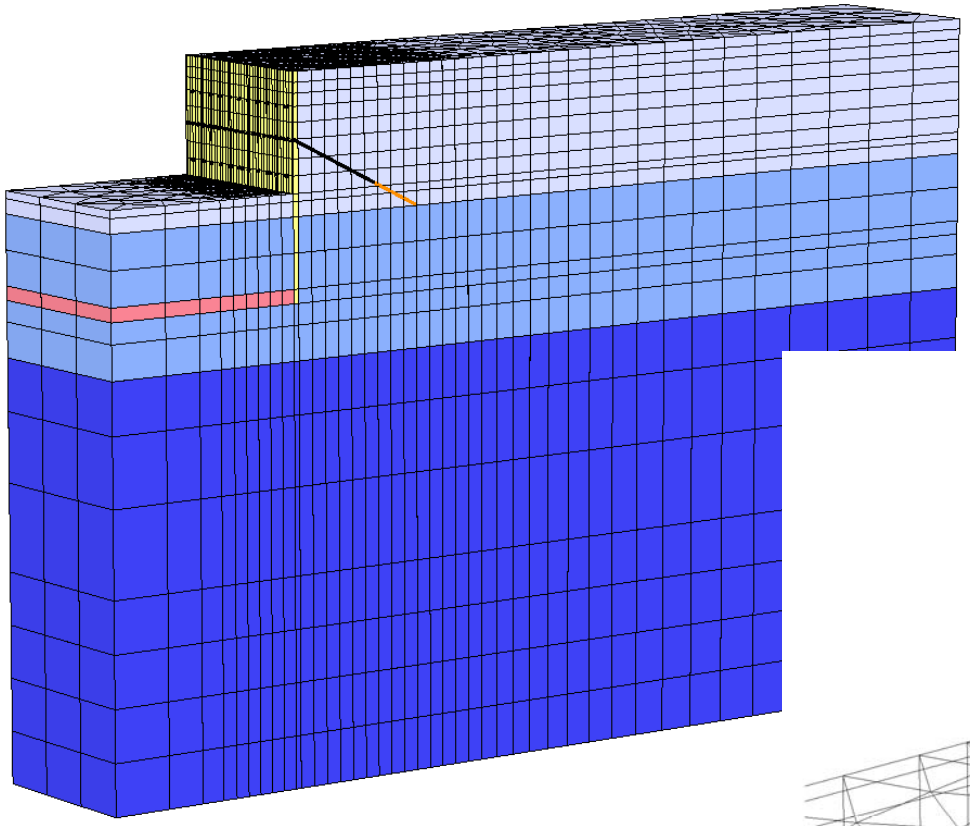
## Embedded pile model for zone B - results

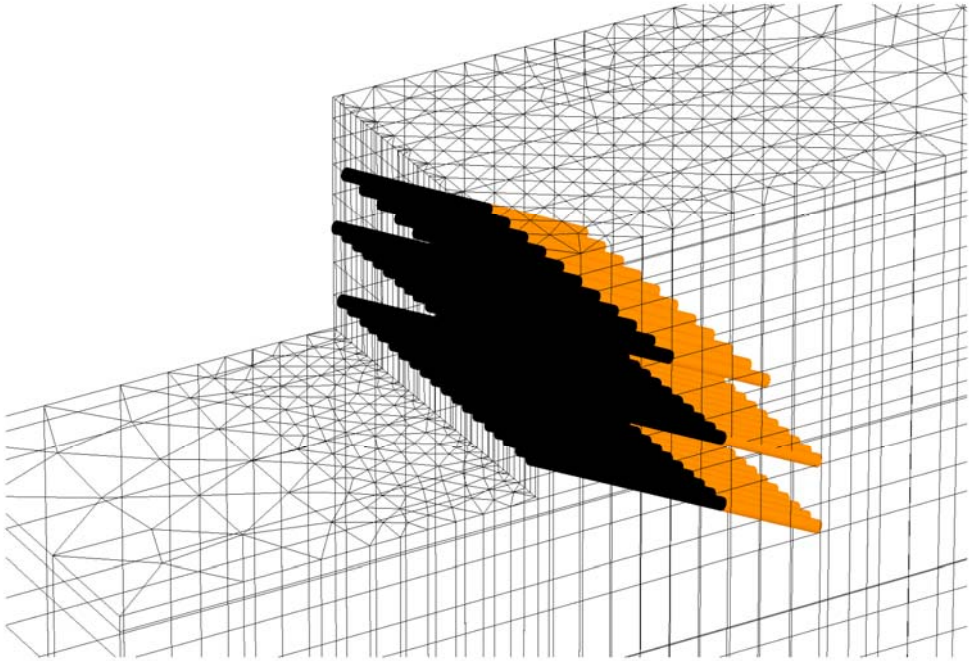


## SUMMARY

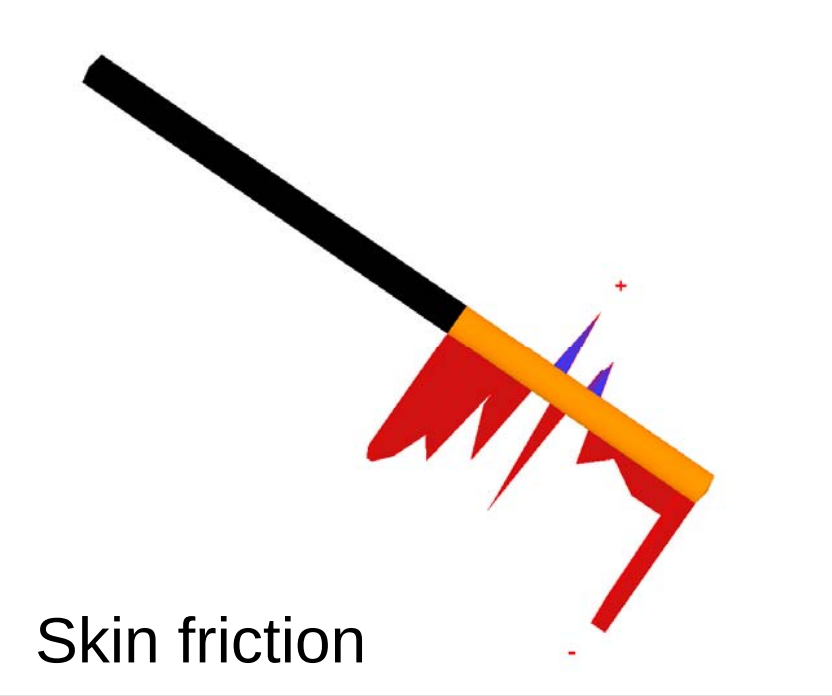
- When creating embedded piles additional geometry points are created but embedded piles do not influence the finite element discretisation.
- The bearing capacity is an INPUT: these values should be based on practical experience or pile load tests.
- With embedded piles it is possible to take different 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

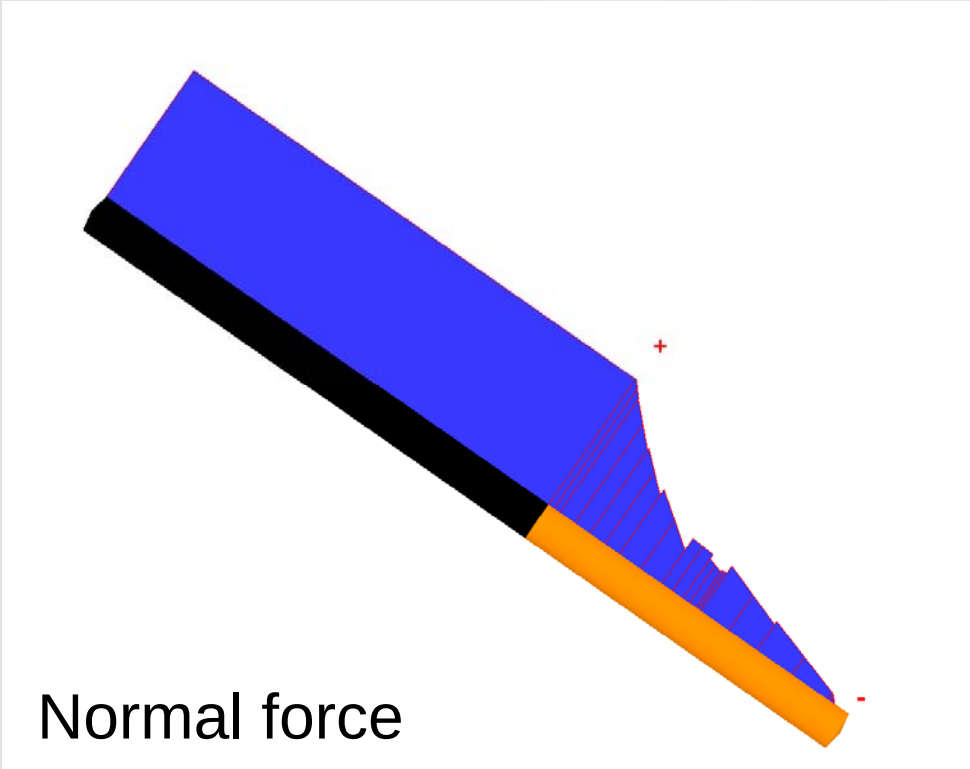




# EMBEDDED PILE OPTION > USE FOR MODELLING GROUND ANCHORS

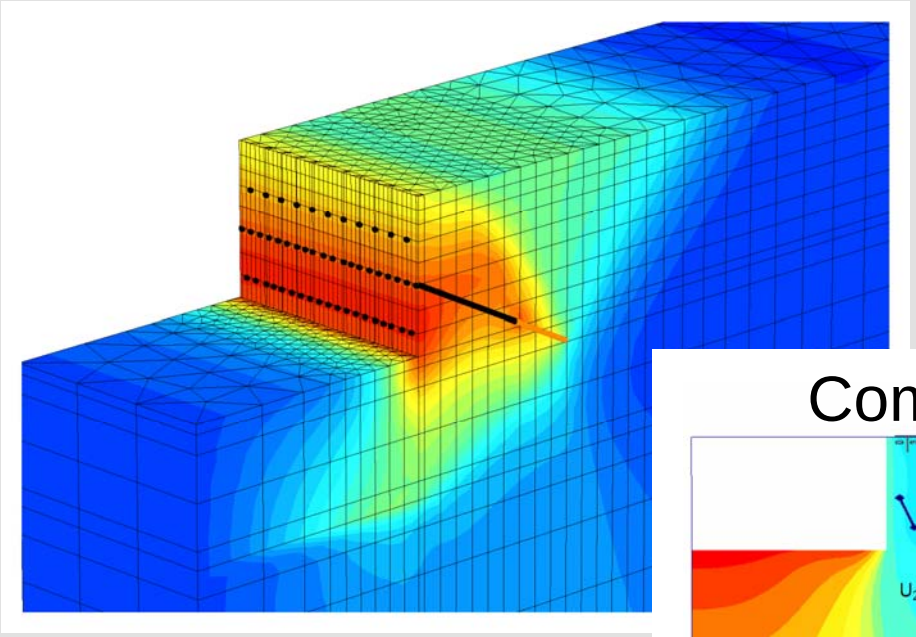



Skin friction




Normal force

# EMBEDDED PILE OPTION > USE FOR MODELLING GROUND ANCHORS



## Comparison with 2D analysis