Geotechnical challenges in the planning and construction of high-rise buildings in urban environment

Laurent Pitteloud

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30.11.2022


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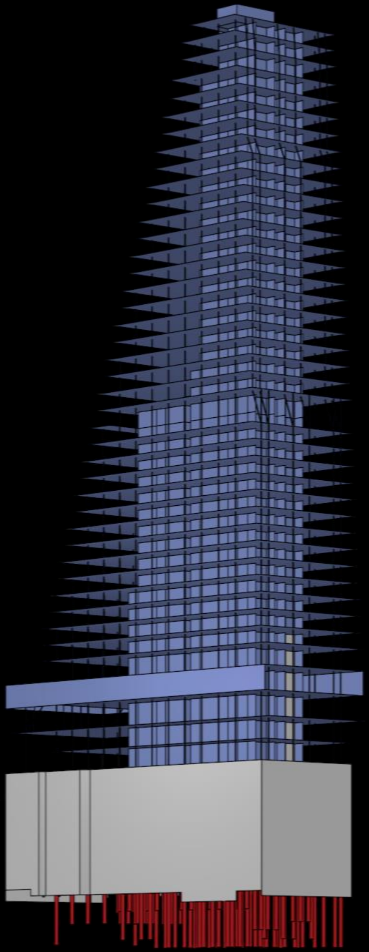
Mentimeter – Survey

What are the maximum settlements that can be expected?

178 m high, 41 storeys

143 piles (diameter 1.2 m, length 15 – 24 m), piled raft foundation

Molasse-subsoil (soft siltstone and sandstone, $M_E \approx 100$ MPa)



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Mentimeter – Survey

What are the maximum settlements that can be expected?

For your orientation:

- **1 cm - 381 m - Empire State Building, New York City**
- **14 cm - 250 m - Messeturm, Frankfurt**
- **46 cm - 197 m - Millenium Tower, San Francisco**

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Laurent Pitteloud

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Education:

Technische Universität Darmstadt
Diplom-Ingenieur (Diplomarbeit), Bauingenieur / Geotechnik
1995–1996

Ecole polytechnique fédérale de Lausanne
1996, Génie Civil - Bauingenieurwesen
1990–1996

Georgia Institute of Technology
Austausch-Jahr Master-Programm, Bauingenieur
1993–1994

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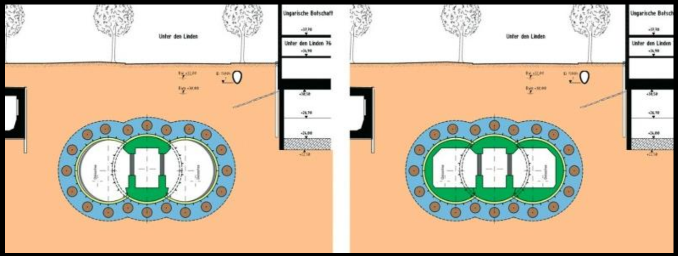
Professional Experience:

27 years

- Gallileo Tower Frankfurt
- U5 Subway Berlin
- SBB CEVA Geneva

Gallileo Tower Frankfurt



U5 Subway Berlin

SBB CEVA Geneva

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1100 employees

34 offices in 6 countries

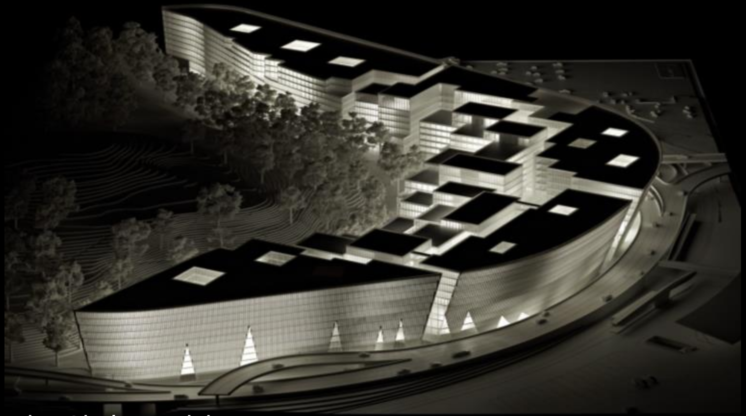
60 professions

Since 1862

Always looking for

passionate young professionals

Nurek dam and hydropower rehabilitation, Tajikistan



The Circle, Zurich

Roche 1, 2, pRed, 8, 10, 11, Basel

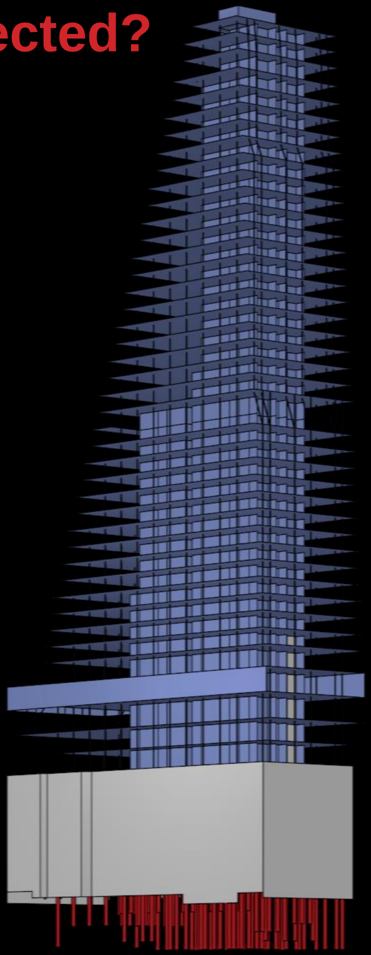
Mentimeter – Survey - Results

What are the maximum settlements that can be expected?

- 178 m high, 41 storey
- 143 piles (diameter 1.2 m, length 15 – 24 m), piled raft foundation
- Molasse-subsoil (soft siltstone and sandstone, ME ≈ 100 MPa)

⇨ *Survey - Results*

Max measured settlements 2.5 cm



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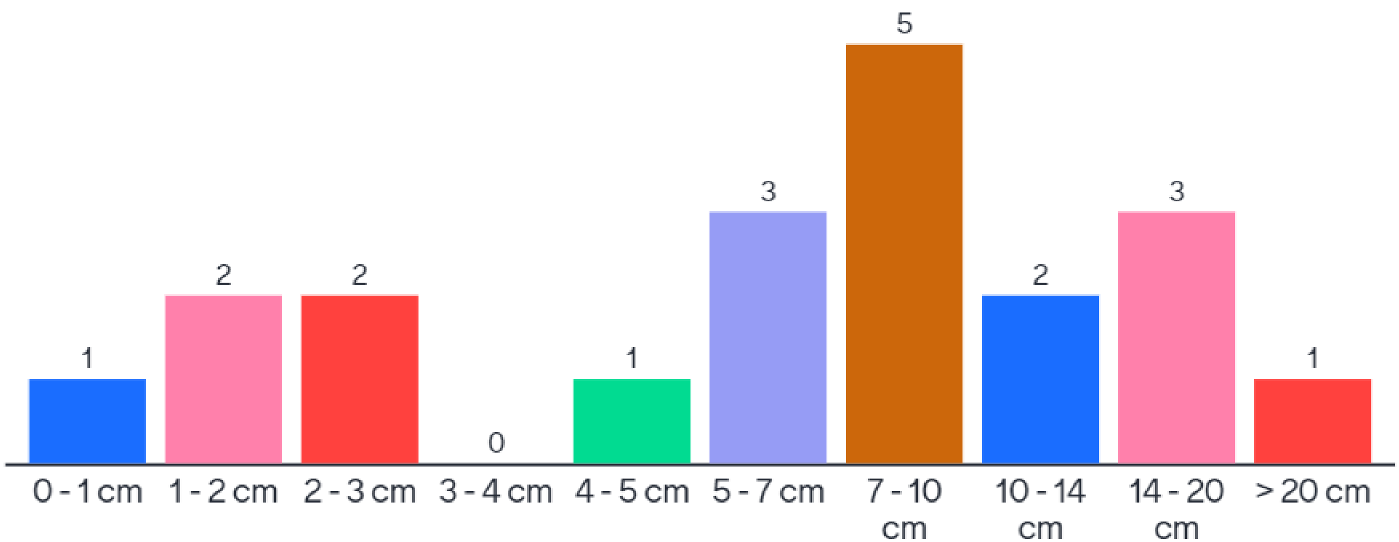
Mentimeter

What are the maximum settlements that can be expected?



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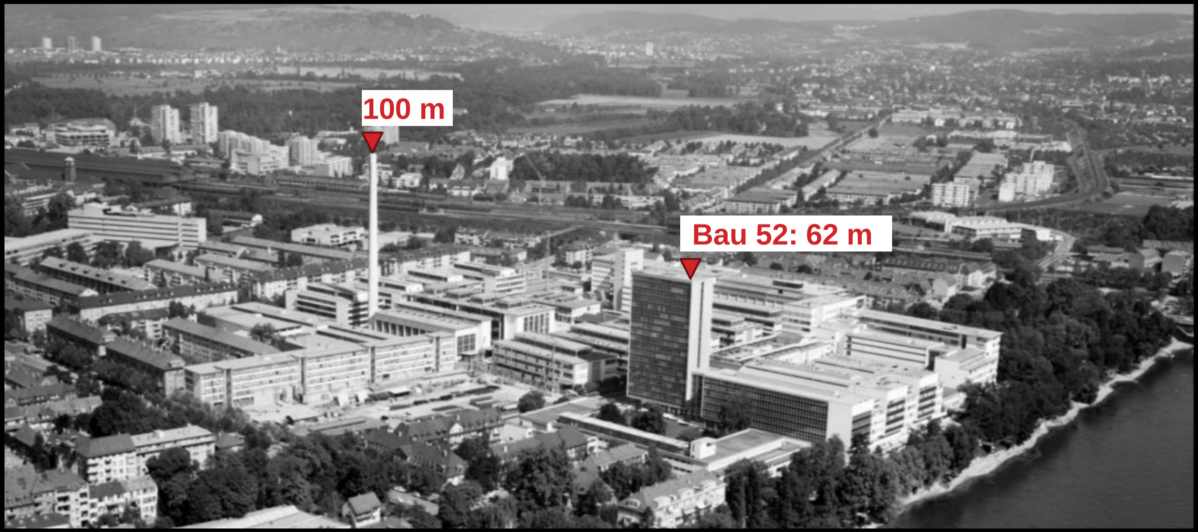
Hoffmann la Roche in Basel – a short history

Since 2006 program

to densify

and create better

work conditions



Roche Basel, 1964

Roche 1, 2, 3, pRed (Vision)

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The design goals - foundations for high-rise buildings

stability and **serviceability** of the new facility and its surroundings

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Agenda

- Bau 1: design process
- Bau 2: special features (top down)
- Bau 3: translocation of an historical building

Roche Bau 1, 2, 3, pRed (Vision)

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Bau 1 – design process

Step 1: soil investigation

Geotechnical report

In-situ testing and lab test

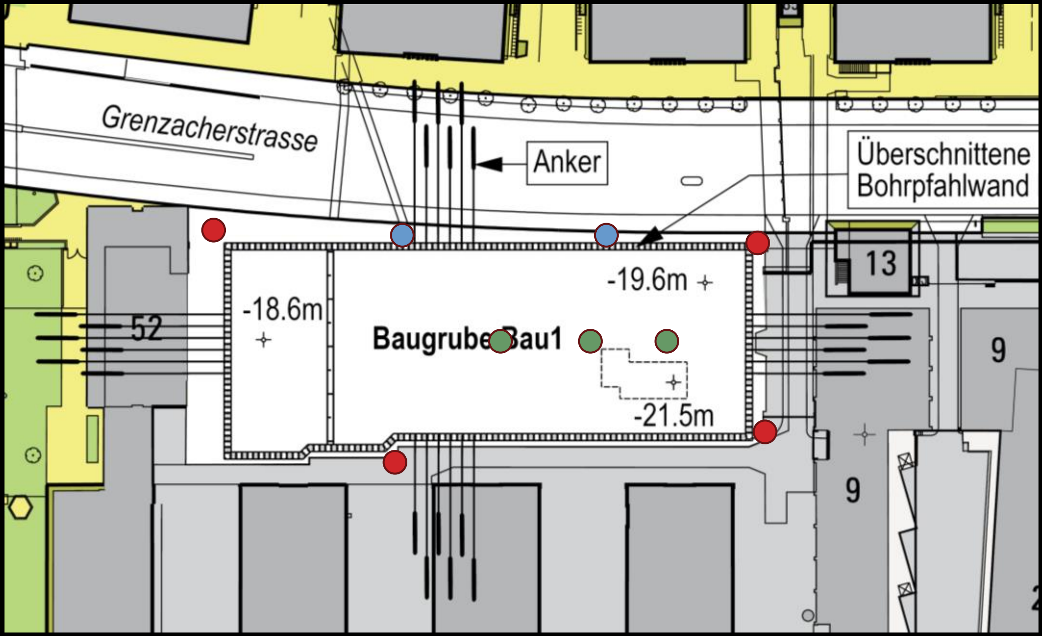
Soil parameters & recommendations

Discussion engineer ⇔ geologist

Investigation:

- 4 boreholes (2006), 32 m ●
- 2 boreholes (2010), 50 m ●
- 3 boreholes (2011), 50 m ●
  incl. cross-hole tests

Lab tests



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Footing base
(ca. – 20 m)

(soil pressure up to 1000 kN/m²)

Bau 1 – design process

Step 1: soil model

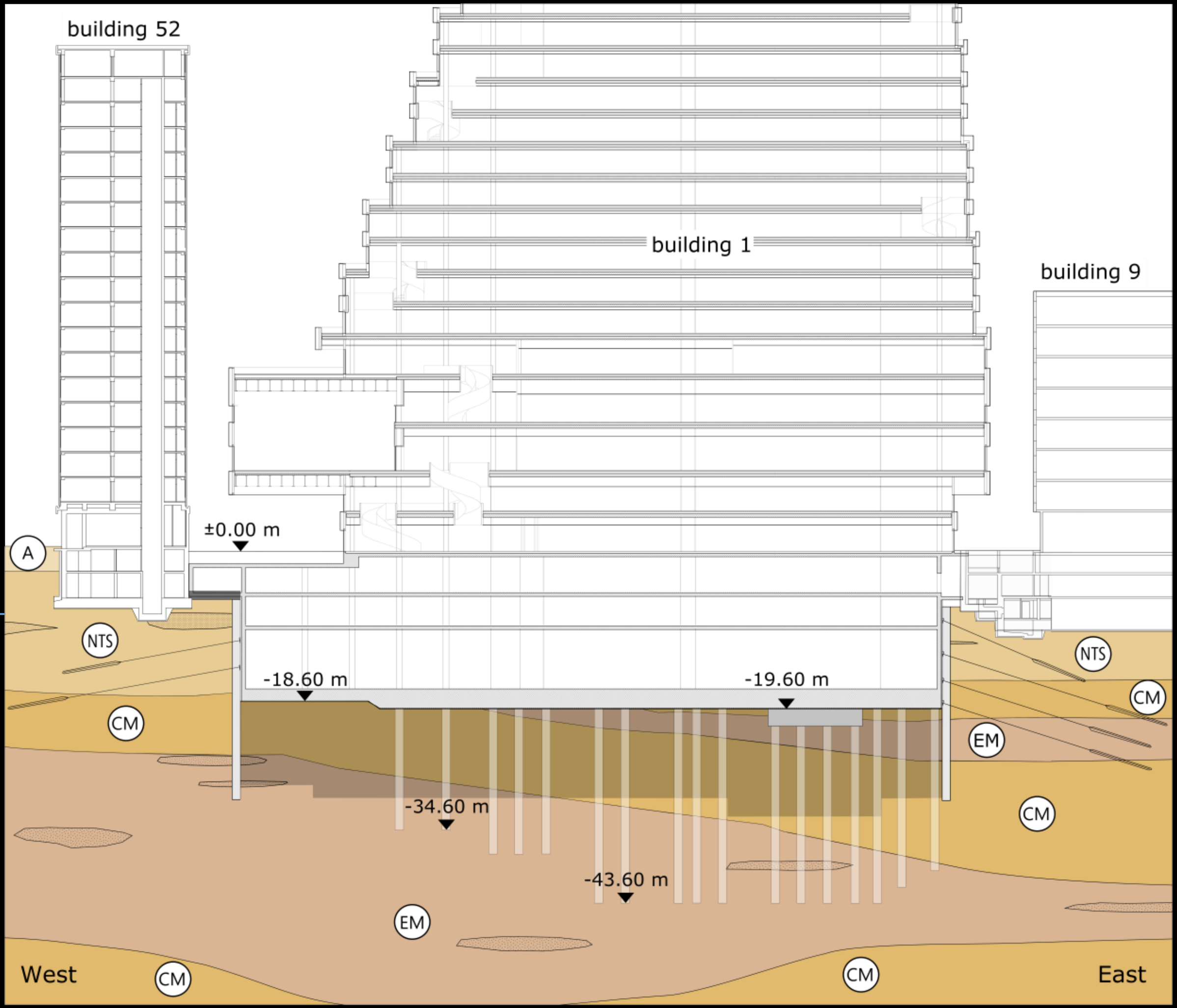
Water table -10.0 m

Fillings

Gravel

Marl CM

Marl EM



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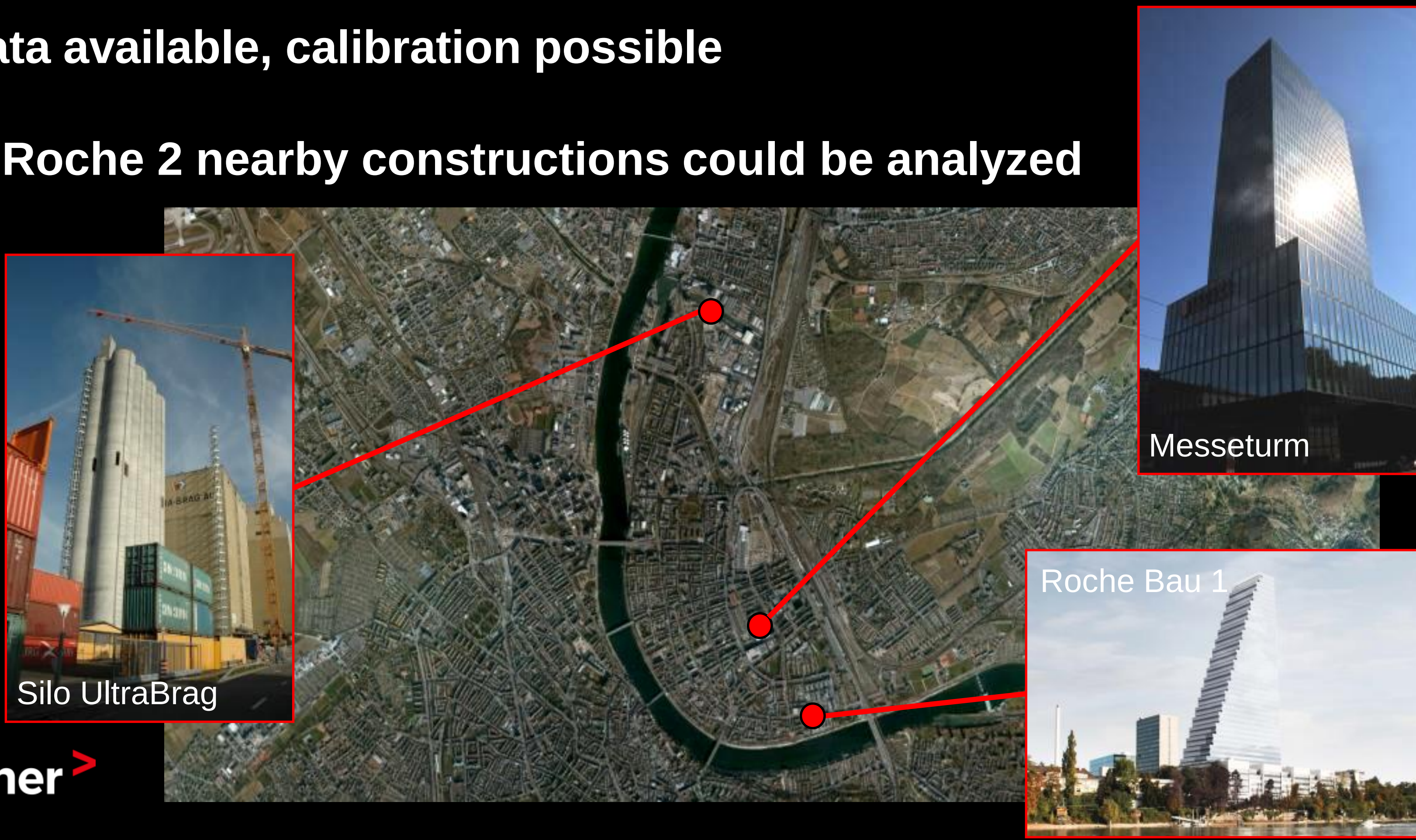
Bau 1 – design process

Step 1.1: soil investigation / characterization back analysis

If data available, calibration possible

For Roche 2 nearby constructions could be analyzed

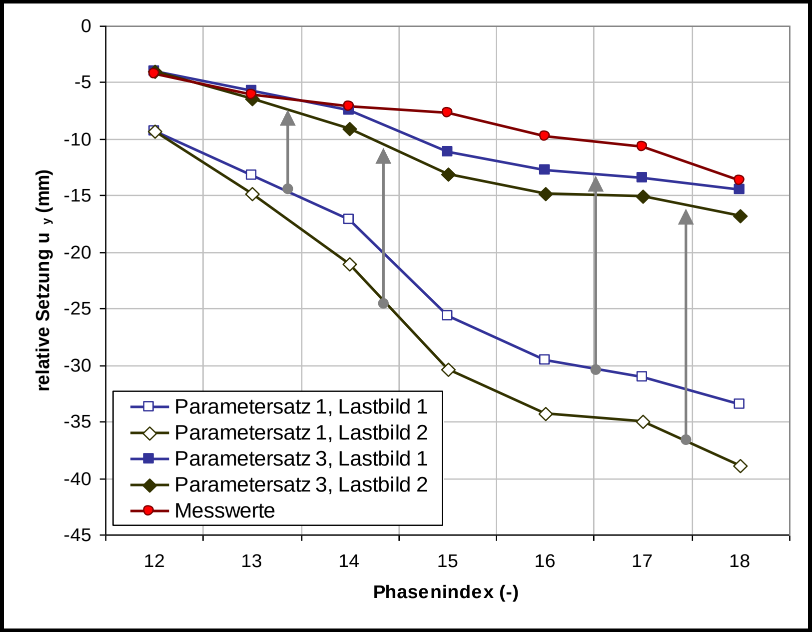


Bau 1 – design process

Step 1.1: soil investigation / back analysis

The calibration delivers a great benefit

⇨ Soil stiffness 2 higher as predicted



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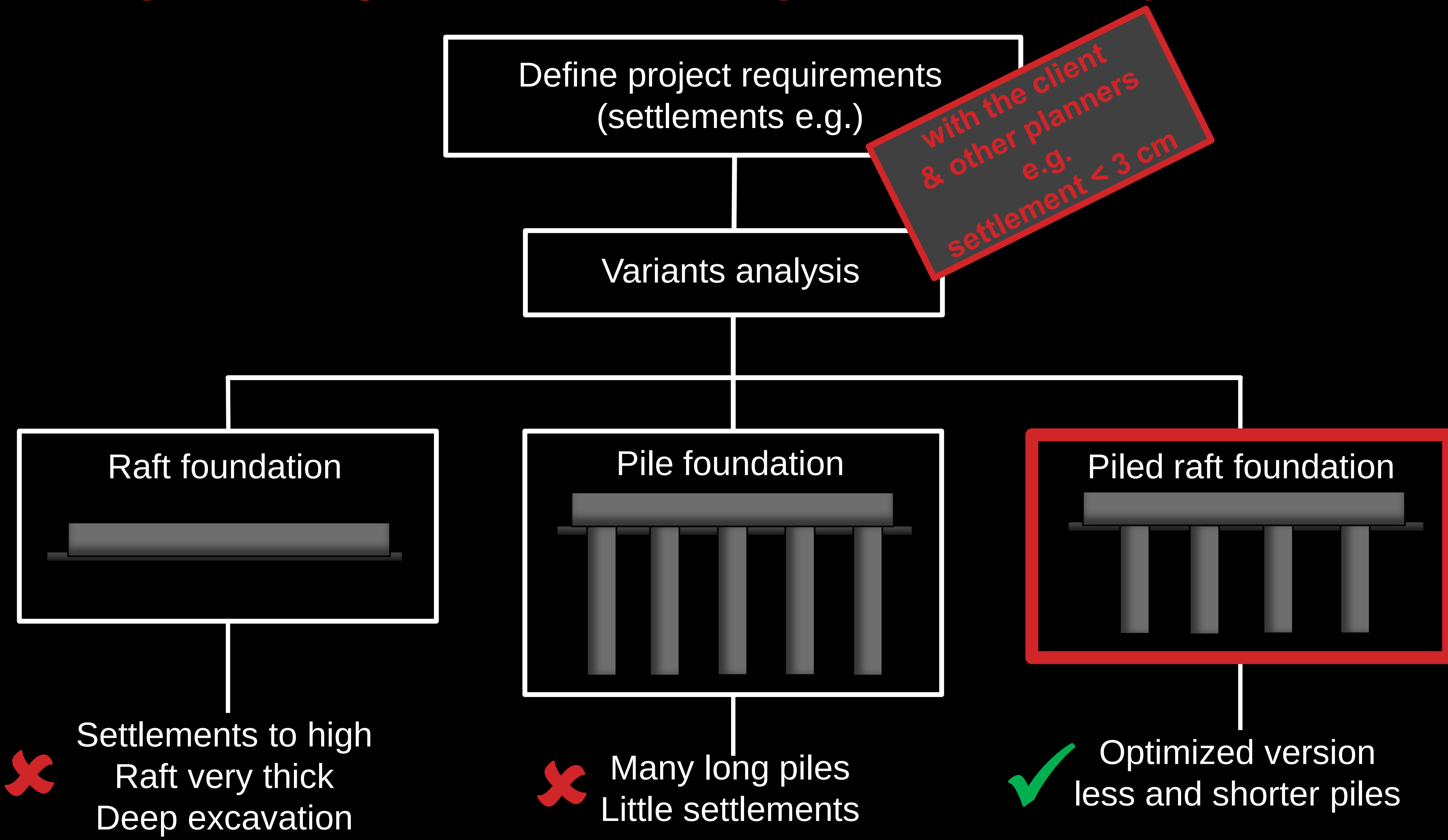
Bau 1 – design process - foundation

Step 2: design variants / computational analysis



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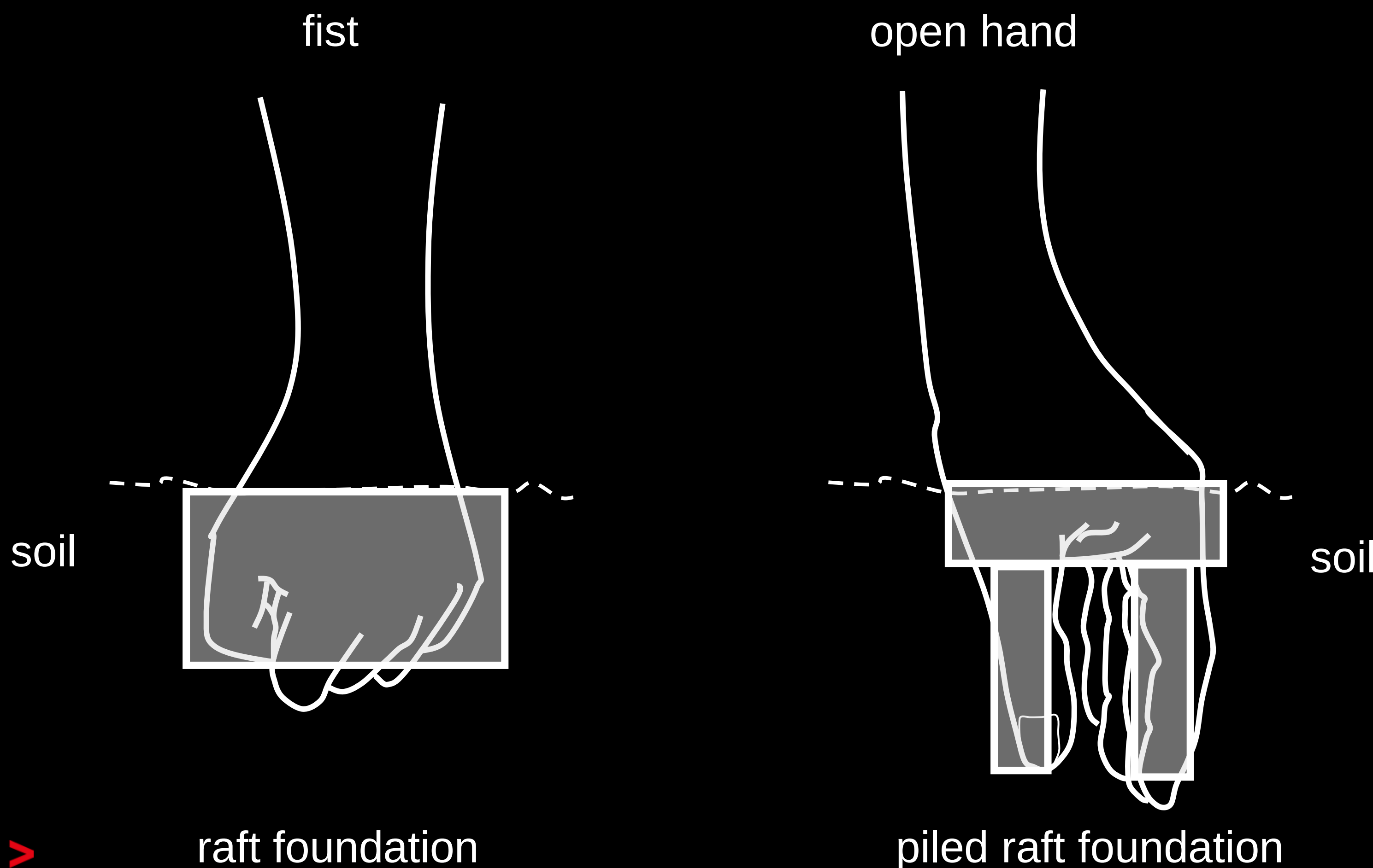
Bau 1 – design process

Step 2.1: behavior of piled raft foundation



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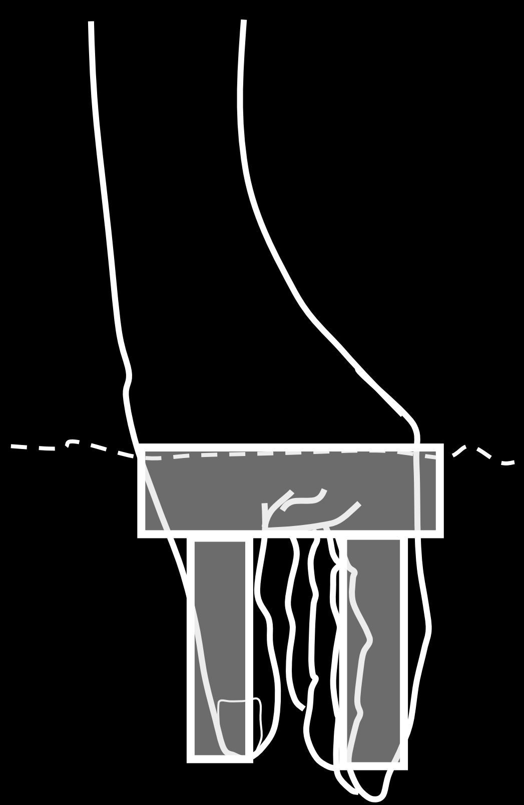
Bau 1 – design process

Step 2.2: design principles of piled raft foundation

- **Piles as settlement reducers (settlement brakes) ⇨**
- **Piles are used until failure ⇨**
- **Safety factor on pile ($R_{a,k}$) can be reduced to 1.0 (provided serviceability is fulfilled)**

Piled Raft will bring a reduction of construction costs and construction time



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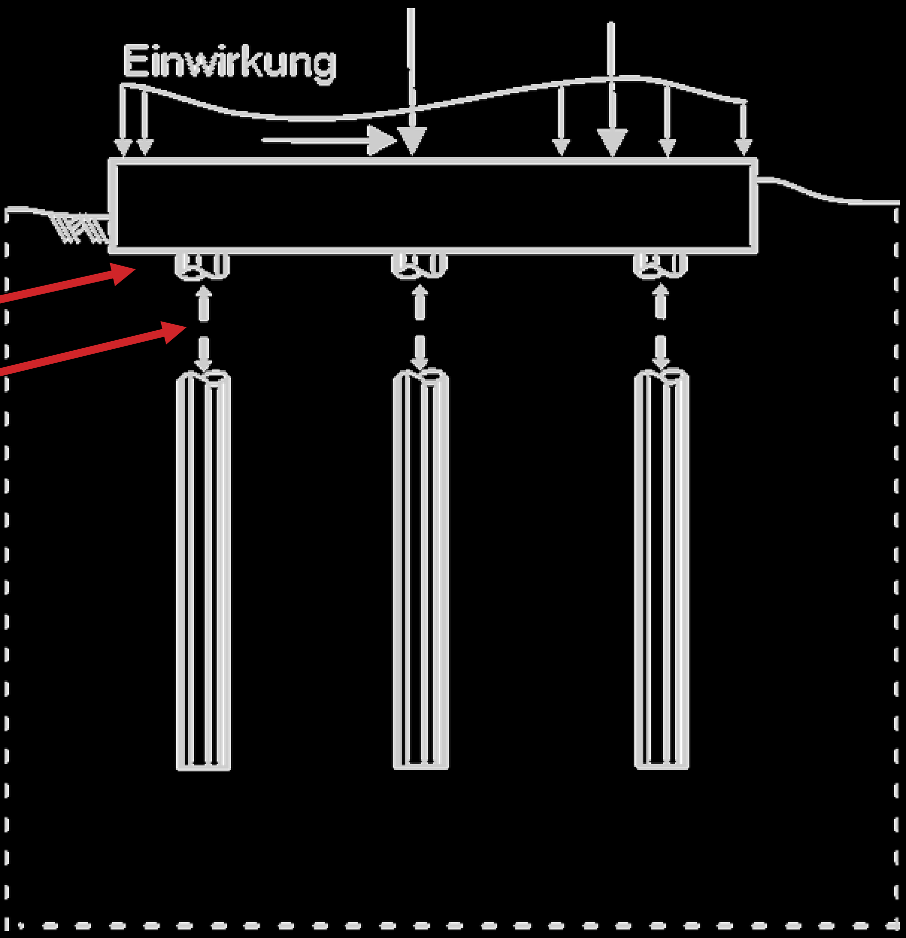
Bau 1 – design process

Step 2.2: design concept of piled raft foundation

- Determination
  - Modulus of reaction k_s
  - Pile spring stiffness C_i
  - max pile force N_i (punching)
- Design of raft and piles
- Monitoring

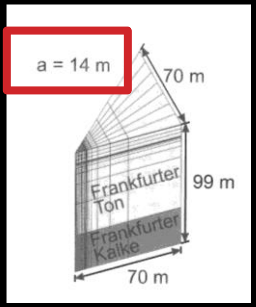


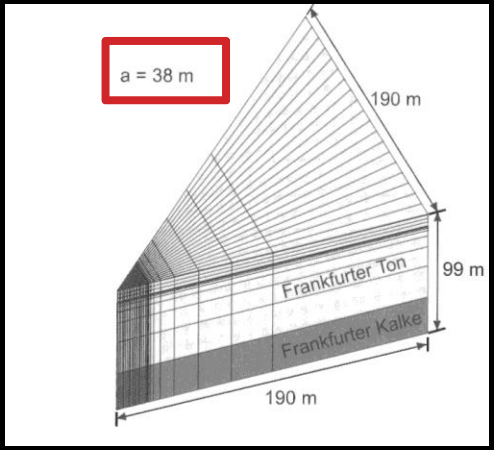
Bau 1 – design process

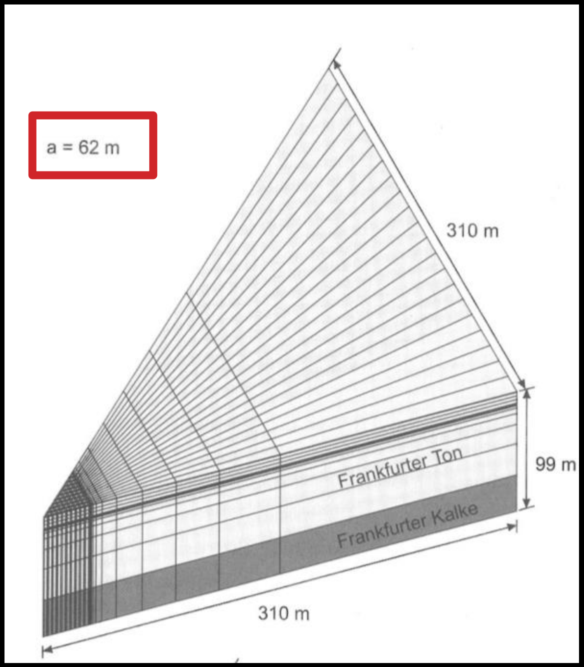
Step 2.3: preliminary design of piled raft foundation

Some simplified methods:

- Analytical solutions of **Poulos**, **Randolph**, or **Lutz**
- Simplified calculation method according to **Reul** in Frankfurt clay



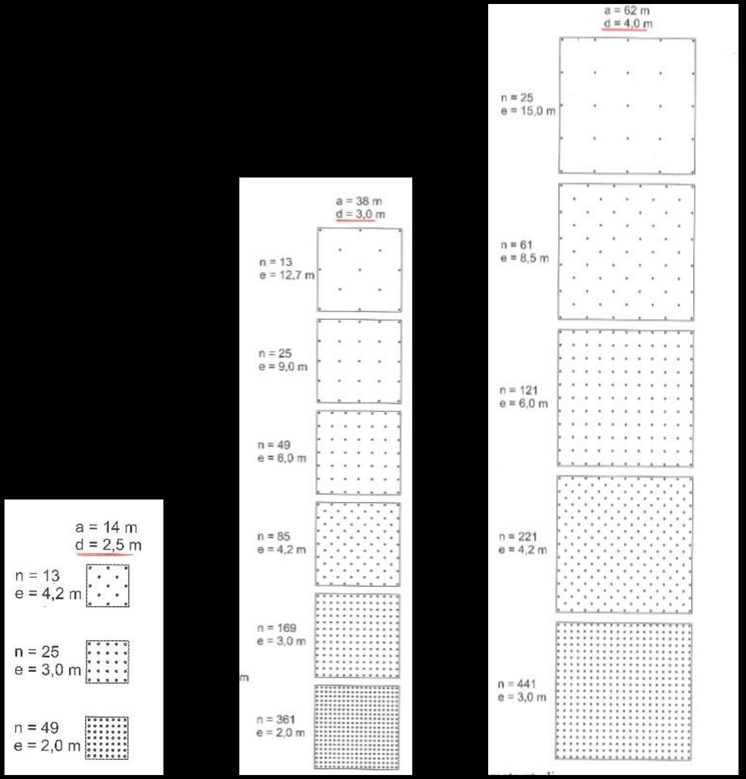




Bau 1 – design process

Step 2.3 preliminary design of piled raft foundation

- **Reul's method:** Based on numerical calculations for various piled raft configurations in Frankfurt clay.
- Results:
  - Pile spring stiffnesses
  - Modulus of subgrade reaction
  - Settlement



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Bau 1 – design process

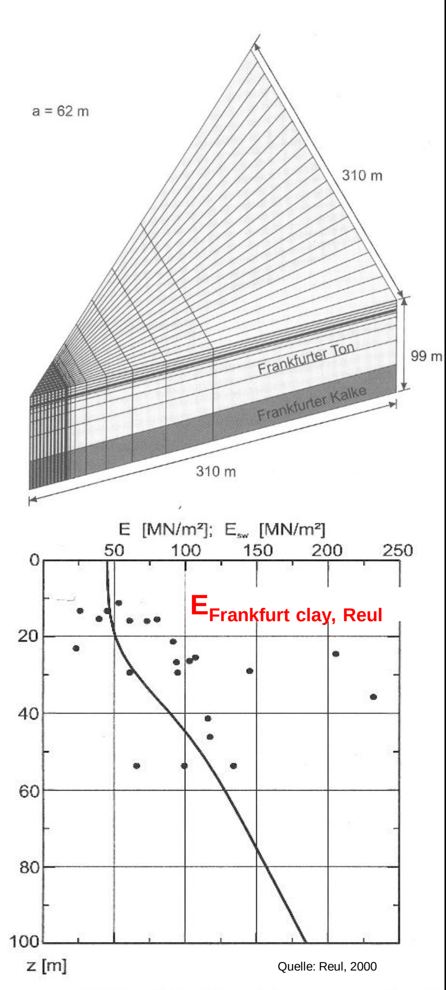
Step 2.3 preliminary design of piled raft foundation

Reul's method (2000)

- Transfer to other soils: linear approach for comparable soil stiffnesses
- $f = ME_{Project}/ME_{Frankfurt\ clay}$

  $c_{Project} = c_{Reul} \cdot f$

  $ME_{Frankfurter\ clay,\ Reul} = 45 \ldots 100\ MPa\ (z = 0 \ldots 45\ m)$



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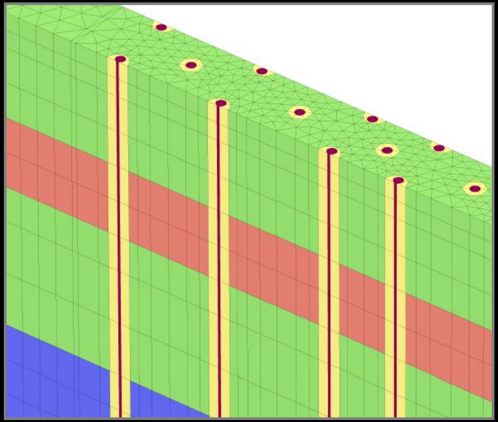
Bau 1 – design process

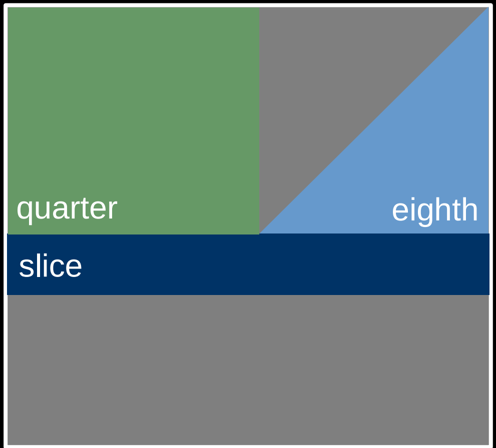
Step 2.4: FE-modelling of piled raft foundation

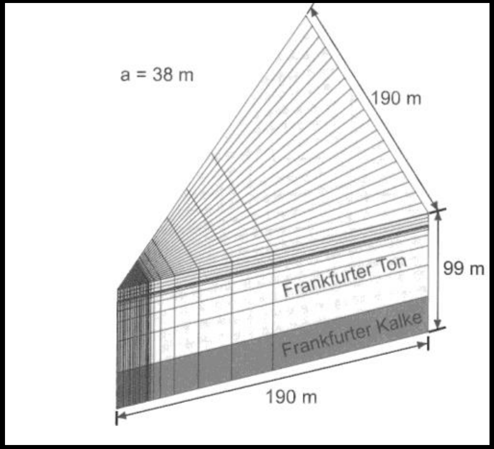
Simplification of models:

- Slice / Strip
- Quarter
- Eighth



slice





quarter

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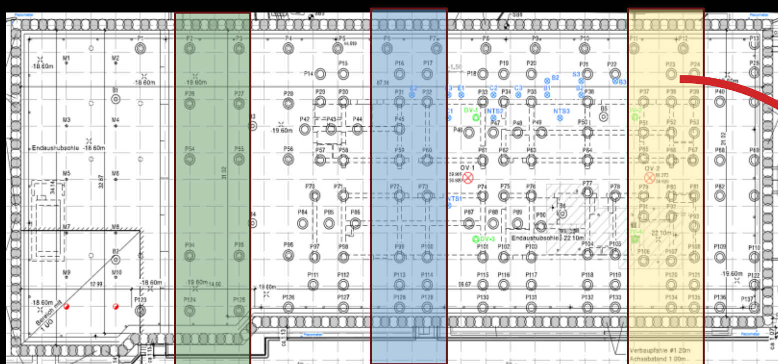
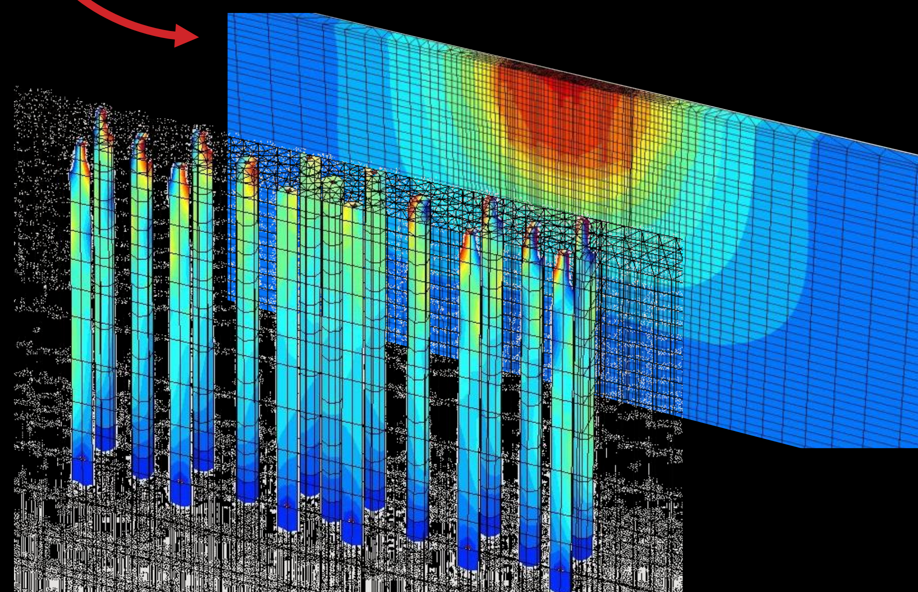
Bau 1 – design process

Step 2.4: design of pile raft foundation with FEA

non-linear modelling of soil-pile interaction,

high-rise building as superimposed load





Rheological model?

Interface? Discretization

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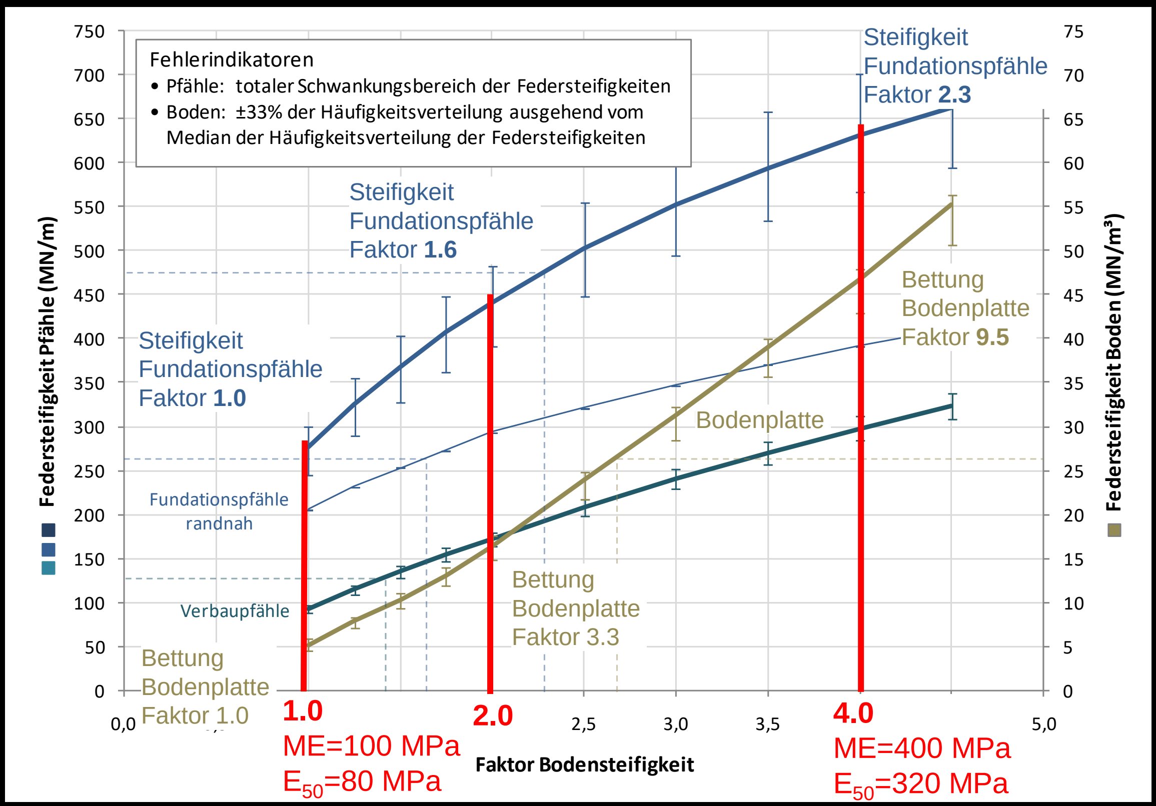
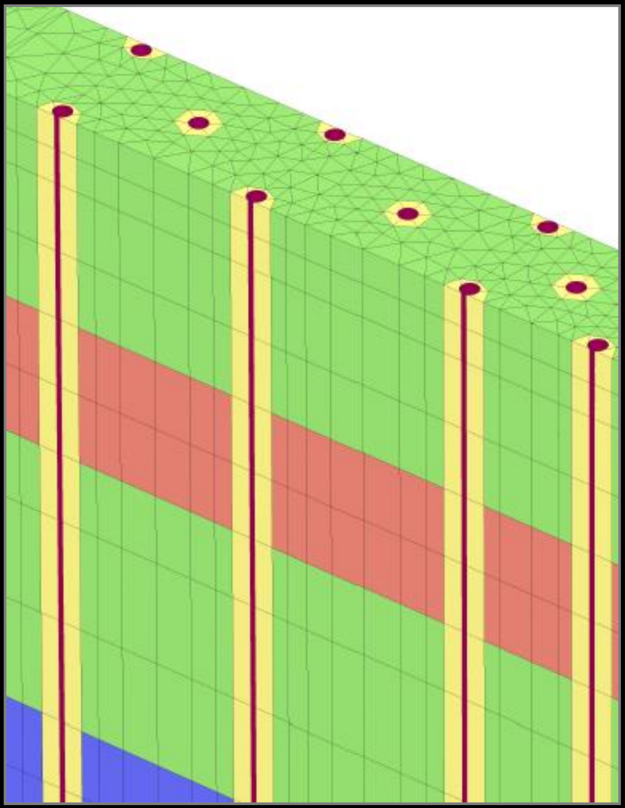
Bau 1 – design process

Step 2.4: sensitivity analysis





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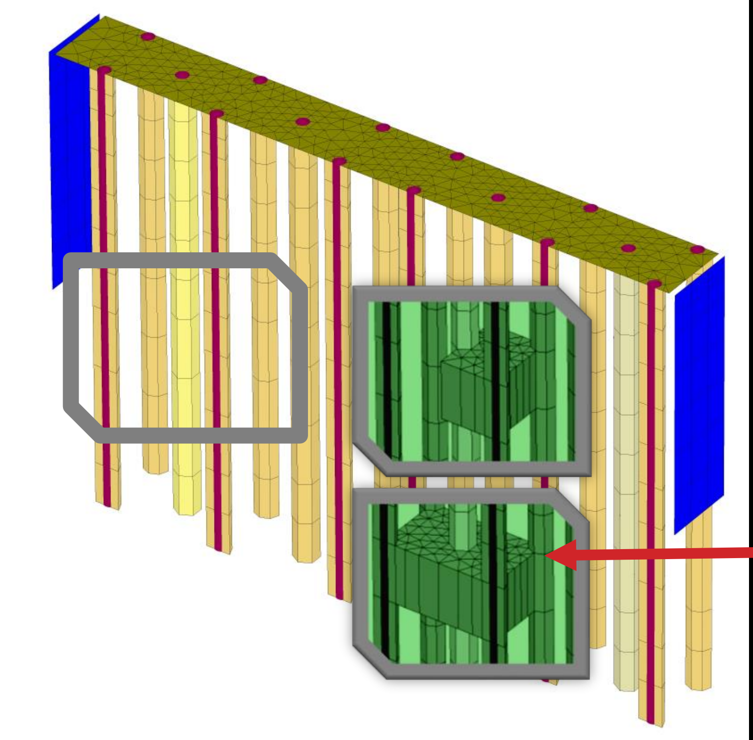
Bau 1 – design process

Step 2.4: sensitivity analysis & punching

Determination of punching load, influence of heterogeneity



Determination of the maximum pile load (punching load) by modelling sandstone benches in the molasse

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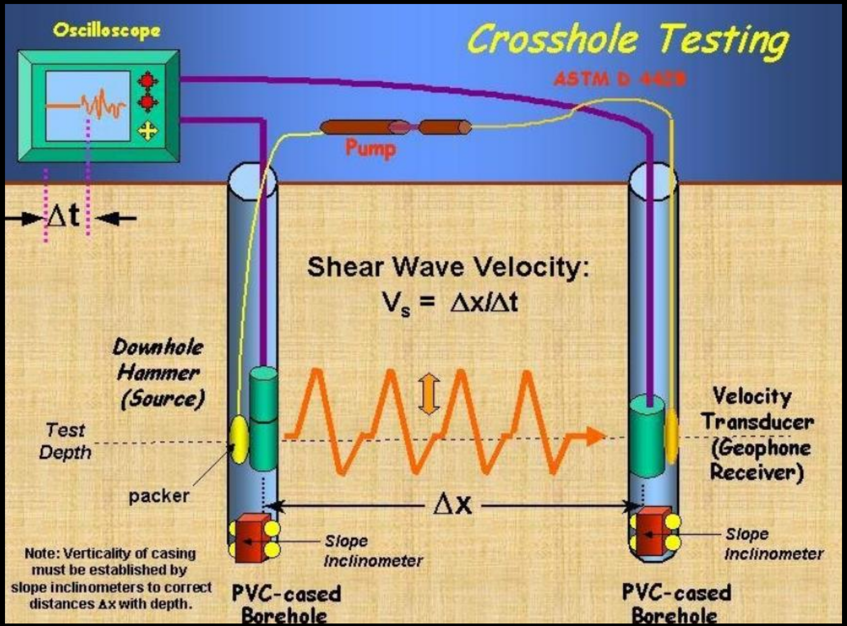
Bau 1 – design process

Step 3: testing on site

- Cross-hole sonic testing ⇨ dynamic stiffness of soil
- Dynamic pile testing ⇨ pile resistance
- Static pile testing ⇨ pile resistance & stiffness



Source: Researchgate

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Bau 1 – design process

Step 3: testing on site, Cross-hole sonic testing

- Objective: Determination of dynamic deformation behavior
- Measurements:
  - Gravel (Niederterrassenschotter) ME,dyn = 500 MN/m2
  - Marl (Elsässer Molasse) ME,dyn = 1500 MN/m2
  - Marl (Cyrenenmergel) ME,dyn = 2000 MN/m2

Rule of thumb: ME,dyn = 3 x ME,stat

Measurement: ME,dyn = 5-10 x ME,stat

Bau 1 – design process

Step 3: testing on site, Cross-hole sonic testing

> **Details**

Tabelle 22: Dynamische Elastizitätsmoduli, gemessen, ermittelt und angenommen

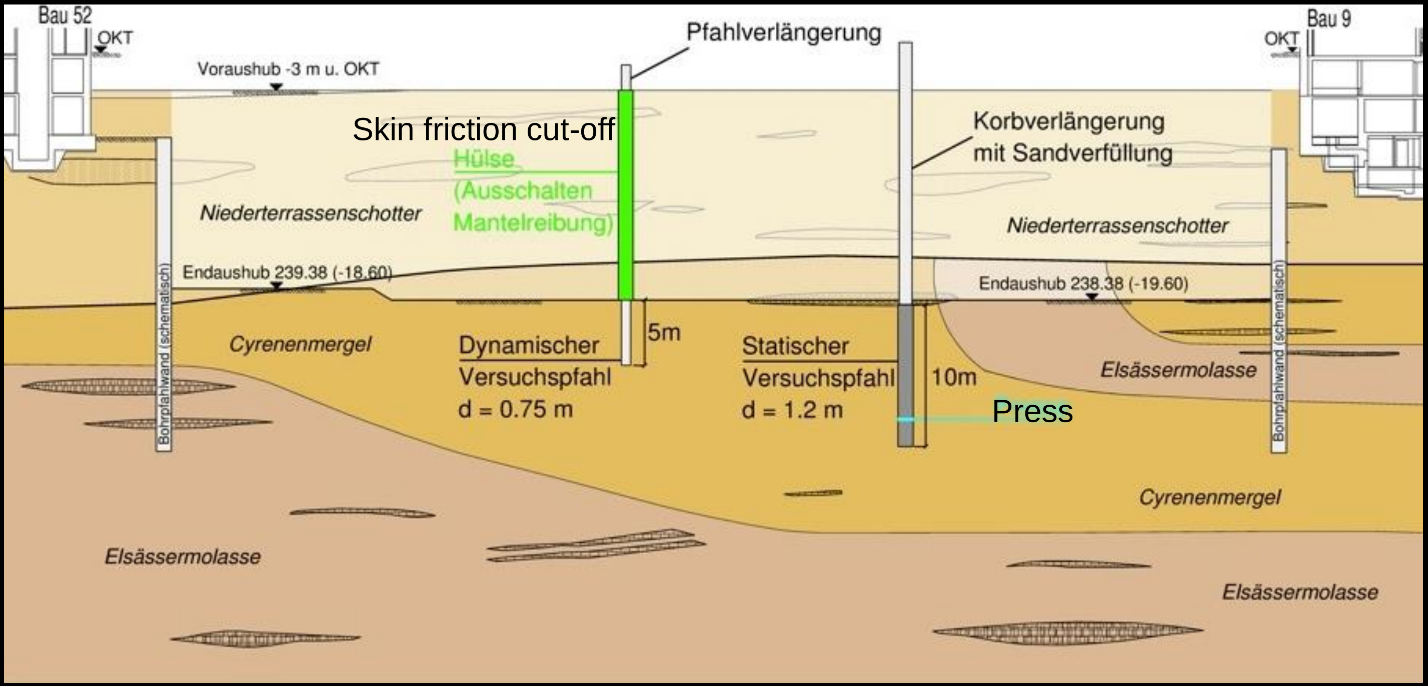
Material	dynam. Feld-Elastizitätsmodul $E_{dyn,ss}$ (MN/m²)	Reduktionsfaktor Feldversuch ⇨ Erdbeben (-)	dynam. Erdbeben-Elastizitäts-modul $E_{dyn,ms}$ * (MN/m²)	dynam. Erdbeben-ME-Modul gemäss [2]** (MN/m²)
Niederterrassen-schotter	1'395 … 1'748 (t) i. M. 1'500 (t)	0.15	225	-
	2'575 … 5'975 (g) i. . 3'200 (g)	0.15	480	-
Cyrenenmergel	2'443 … 9'500 i. M. 6'000	0.25	1500	400 - 1600
Elsässer Molasse	7'110 … 9'210 i. M. 7'500	0.25	1900	600 - 2400 (EM1) 1000 - 4000 (EM2)

(t) trocken
(g) gesättigt

Bau 1 – design process

Step 3: testing on site

- Dynamic pile testing (4 piles) ⇨ pile resistance
- Static pile testing (2 piles) ⇨ pile resistance & deformation



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Bau 1 – design process

Step 3.1: Pile Dynamic Testing - Procedure

- Test 3 to 4 weeks after pile installation
- Drop weight: 16 t
- 3 to 4 impulses from a height of 0.5 m to 1.5 m

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Bau 1 – design process

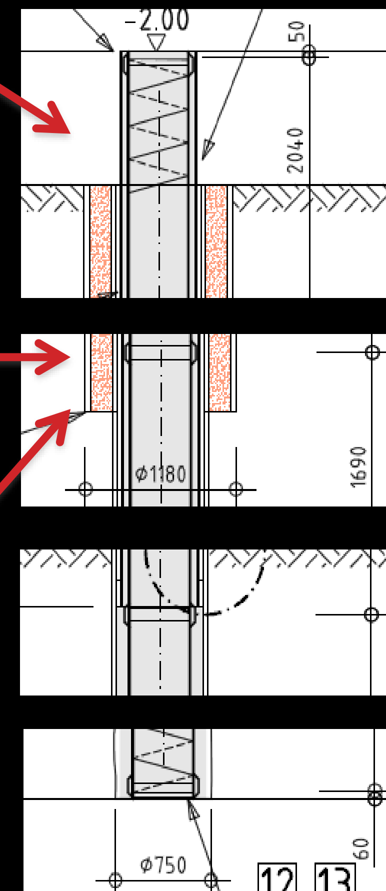
3.1: Pile Dynamic Testing – Construction

Skin friction cut-off

Bau 1 – design process

Step 3.1: Pile Dynamic Testing – Construction

Skin friction cut-off



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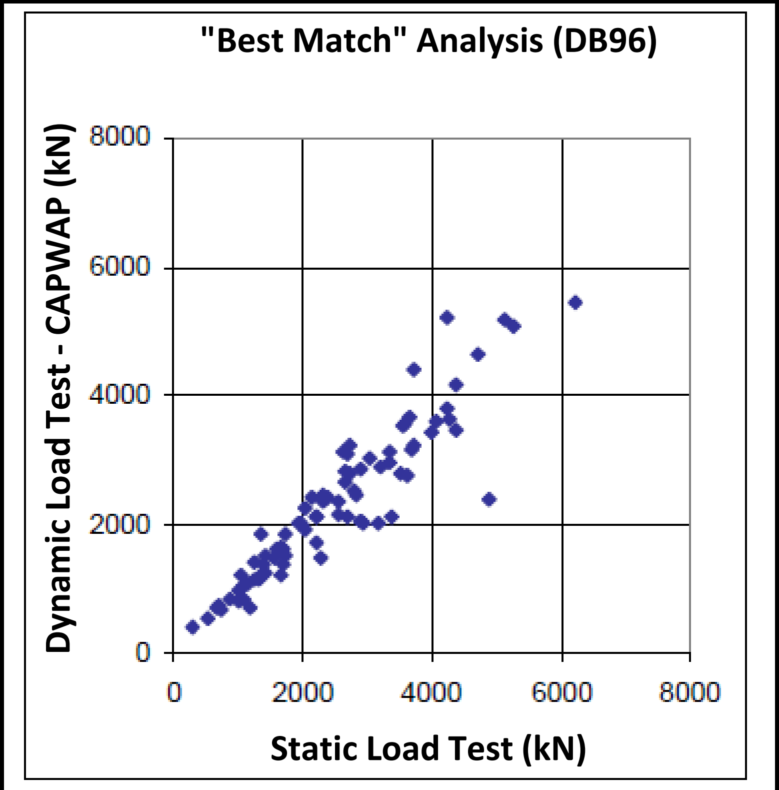
Bau 1 – design process

Step 3.1: Pile Dynamic Testing (PDA) – Background



Source: Likins & Rausche 2004 (Fig. 2)

Results later on

Skin friction cut-off

successful ☑

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Bau 1 – design process

Step 3.2: static pile testing

> benefit ⇨ pile **resistance & stiffness**

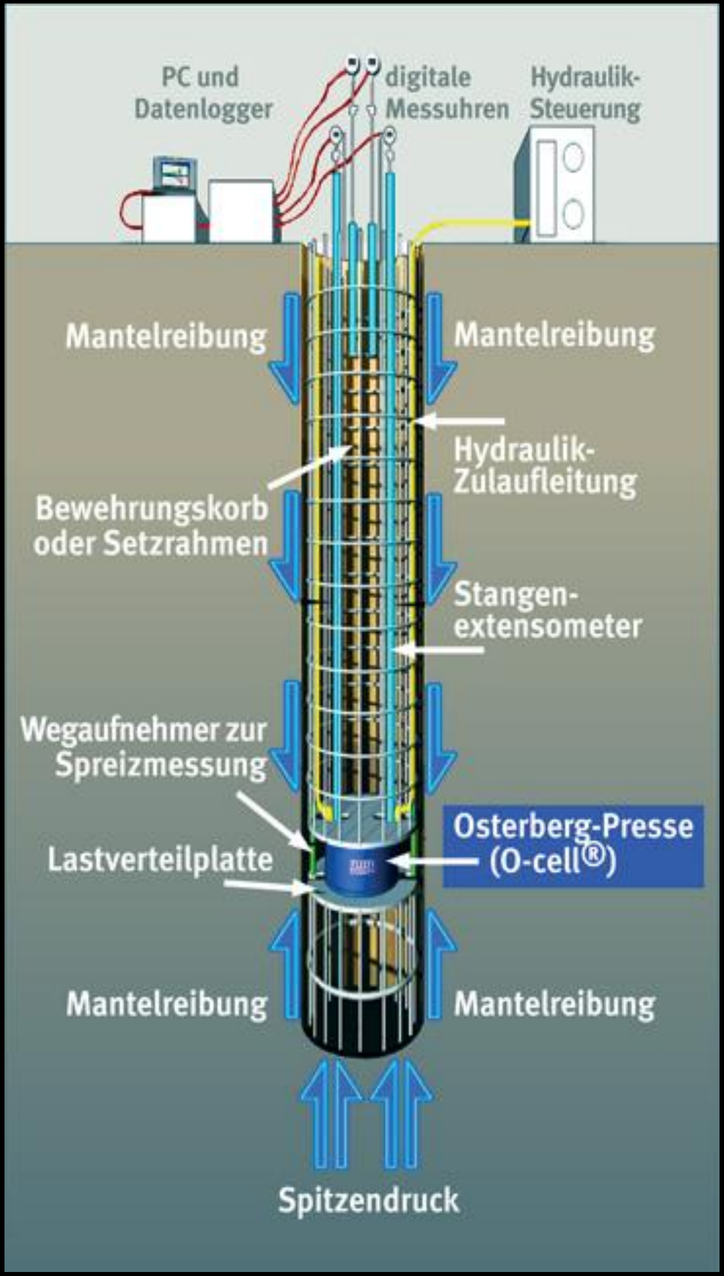
Reaction piles

Reaction anchors

Bau 1 – design process

Step 3.2: static pile testing

Osterberg-cell (bi-directional testing)

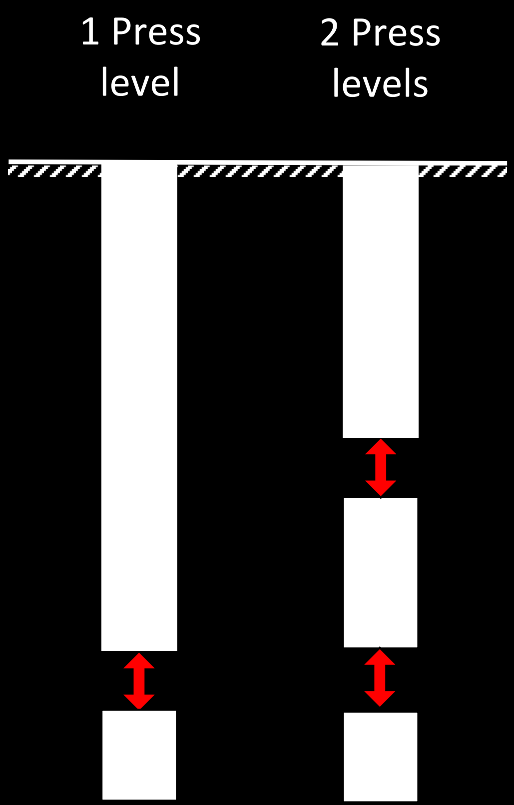


Bau 1 – design process

Step 3.2: Static pile testing

> **Advantage Osterberg cells: No tie-down piles, reaction anchors or dead loads; minimum space requirement.**

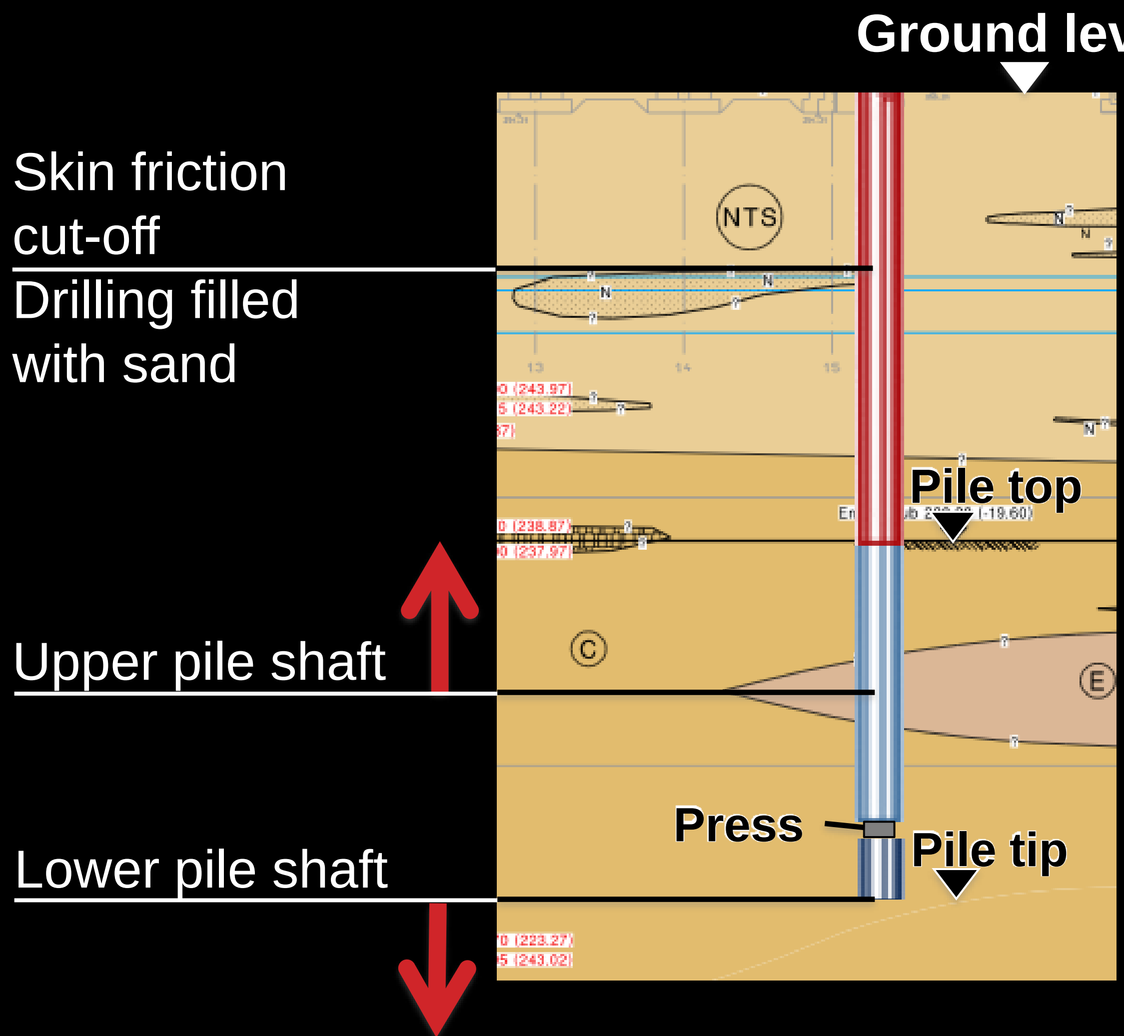
> **Disadvantage: Skillful adjustement of the position of the press levels necessary (prior knowledge!)**



Choice for Roche Bau 1: 1 press level

Bau 1 – design process

Step 3.2: Static pile testing - Osterberg



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Bau 1 – design process

Step 3.2: Bi-directional static pile testing

Skin-friction cut-off - risks

Reinforcement cage prior installation

Twisted reinforcement cage after pile dismanteling

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Bau 1 – design process

Step 3.2: Static pile testing - results

- Skin friction (Mantelreibung) $\tau_k = 250\,\mathrm{kN/m^2}$ $\tau_k = 300\,kN/m^2$
- End bearing (Spitzendruck) $\sigma_k = 2500\,\mathrm{kN/m^2}$ ($s = 3$ cm)
- Results below expectations $\sigma_k = 7000\,kN/m^2$

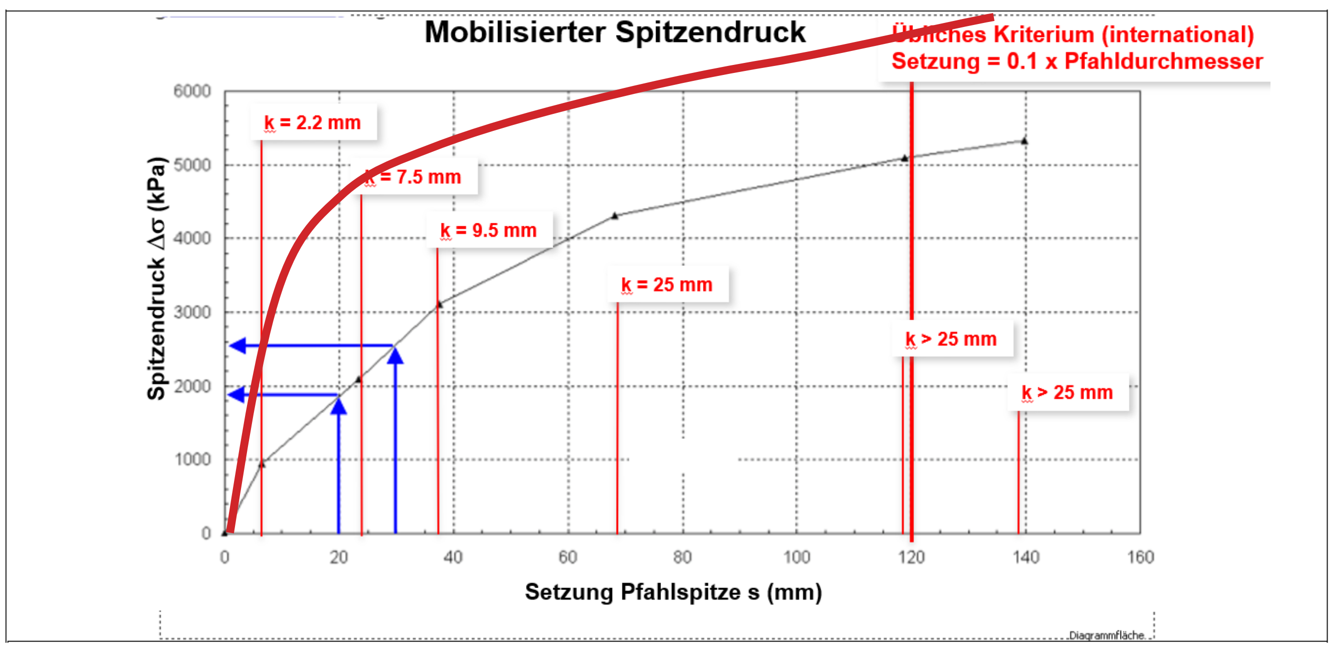


Abbildung 9: Lastsetzungs-Diagramm für den Versuchspfahl OV-02

Step 3.2 Static vs. dynamic tests

	Dynamic Pile test	Static Pile test	Expectations
Skin friction (kN/m^2)	190	250	>300
Base resistance (kN/m^2)	4700	2500	>5000-7000

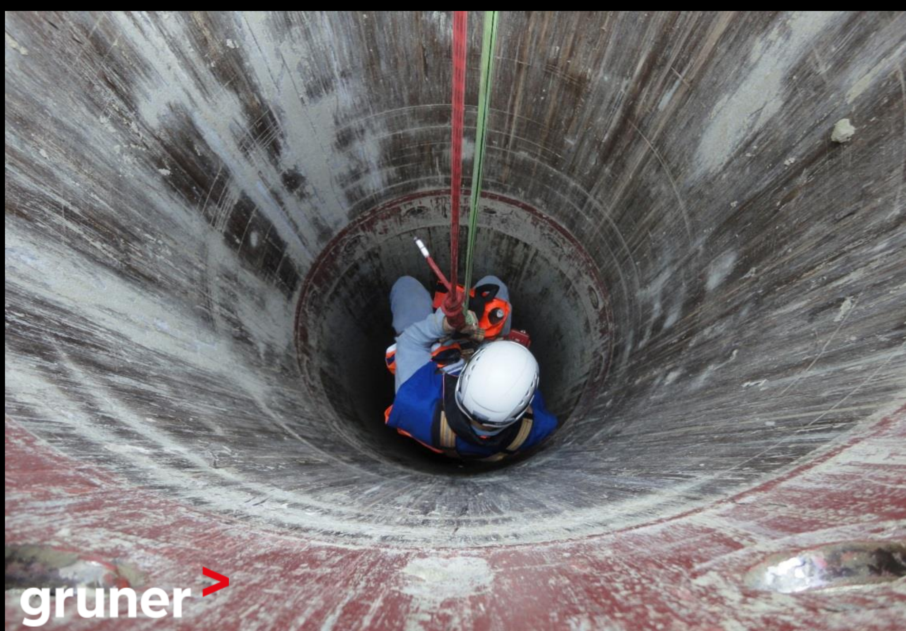
- Advantage static test: load – deformation behavior
- Static tests, expensive but always added value for
  - Either optimizing the design
  - Or minimizing risks

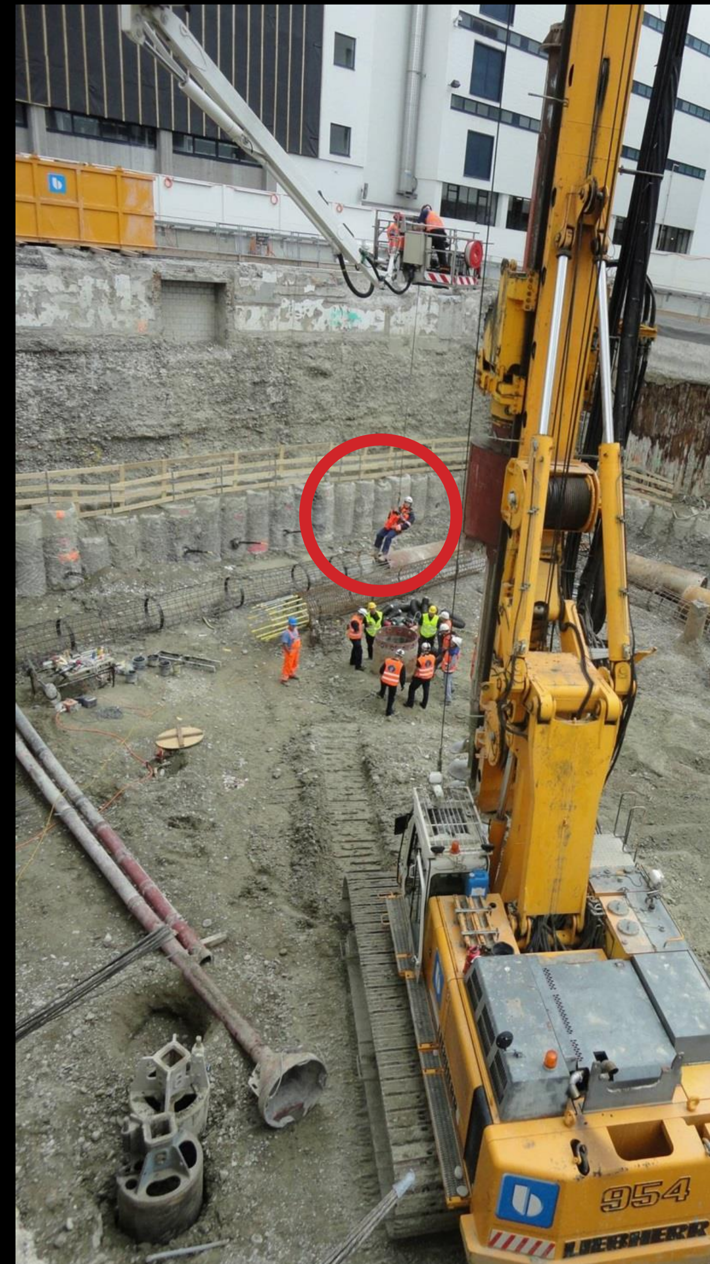
Bau 1 – design process

Step 3.3: Supervision pile construction process

Pile inspection

Examination of the pile bottom





Bau 1 – design process

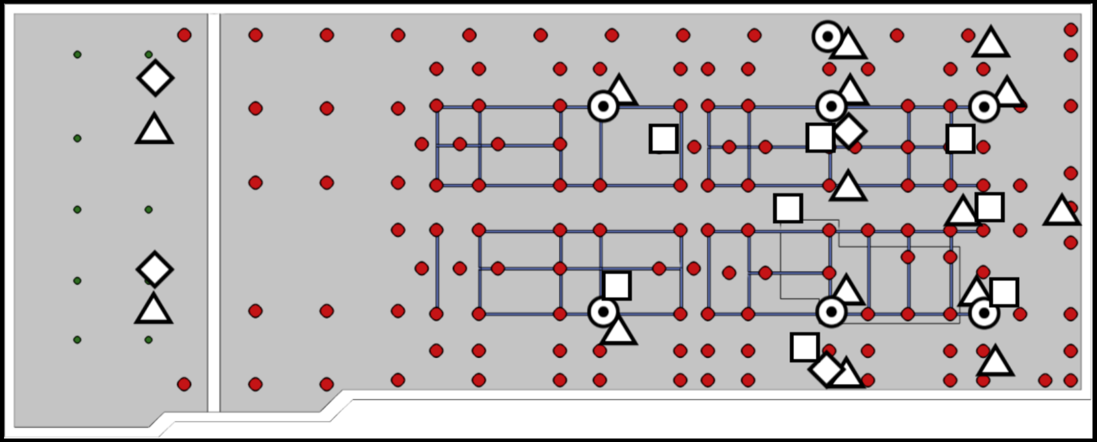
Step 3.3: Supervision pile construction process

Pile inspection

Findings on pile execution quality

Bau 1 – design process

Step 4: Monitoring piled raft foundation



⦿ load cell on pile head

□ earth pressure cell

◇ pore water pressure cell

△ geodetic point

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Bau 1 – design process

Step 4: Monitoring – how to install a pile load cell

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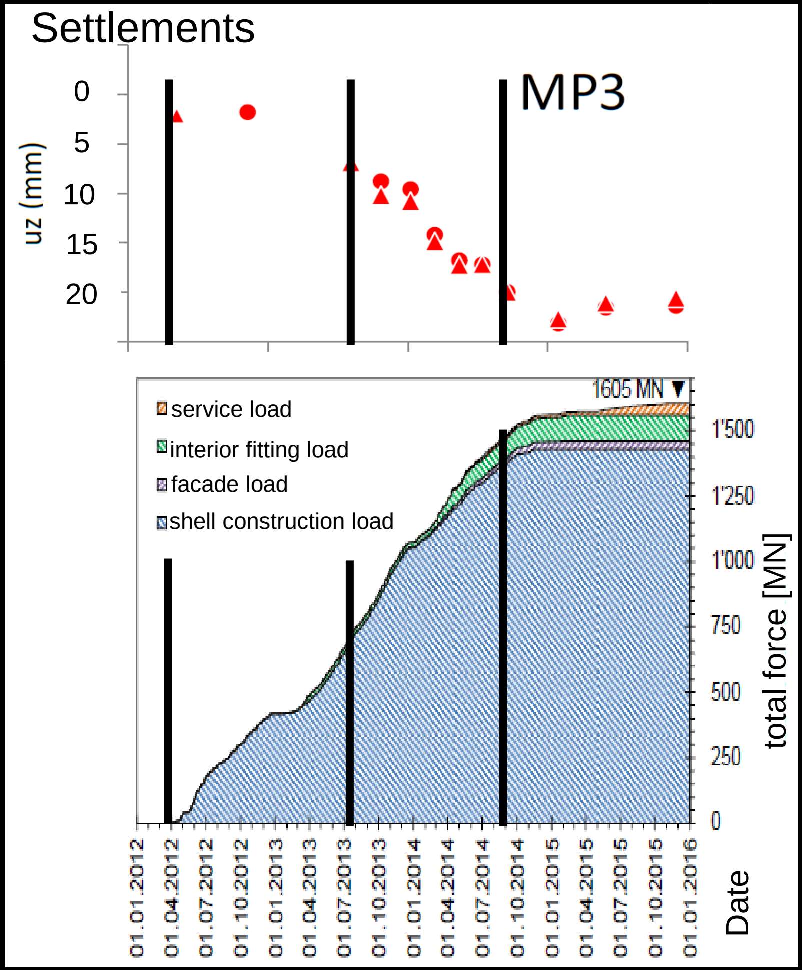
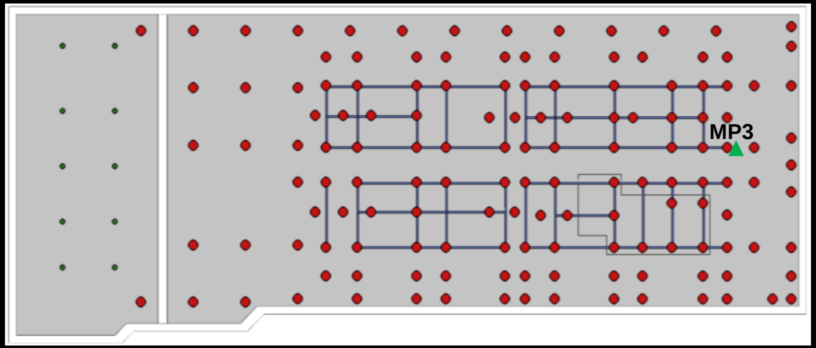
Bau 1 – design process

Step 4: Monitoring - settlements





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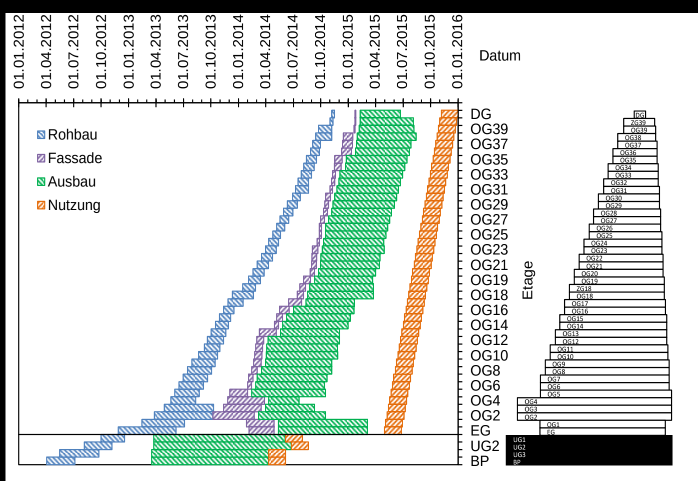
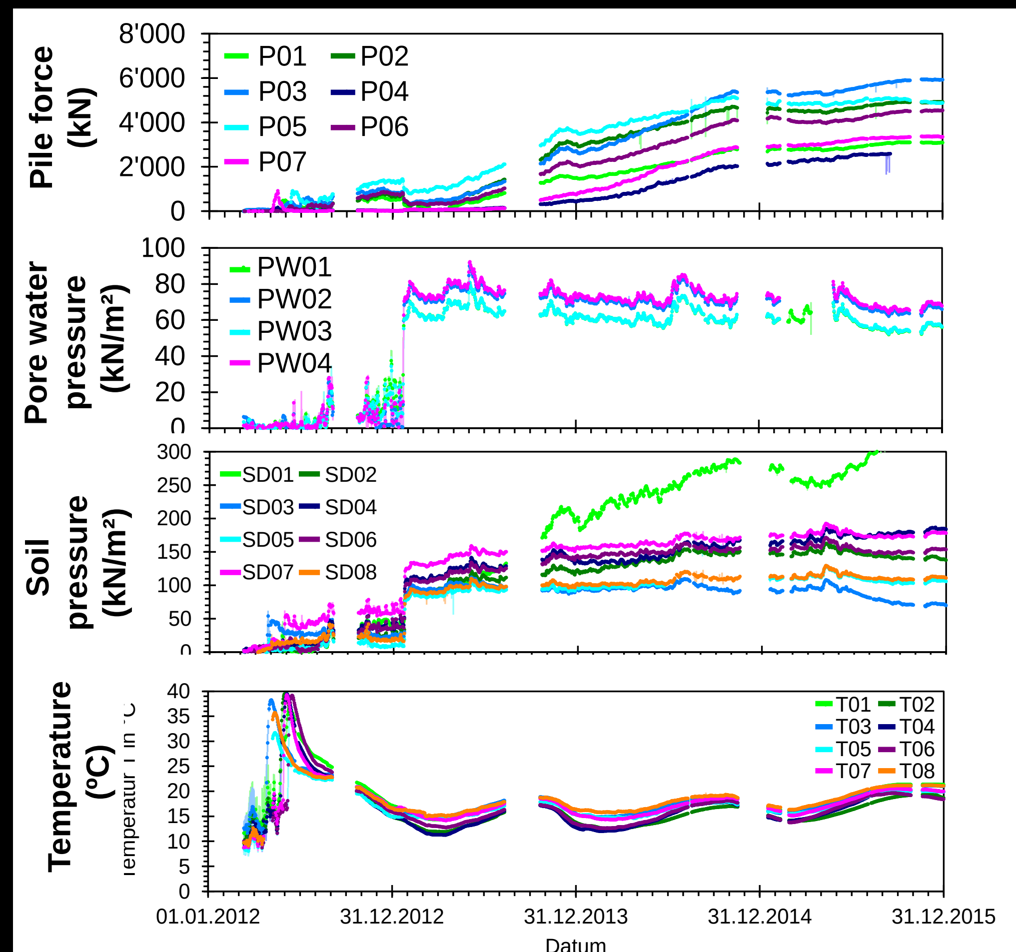
Bau 1 – design process

Step 4: Monitoring results

Monitoring from March 2012 to December 2015: 24.5 millions data records

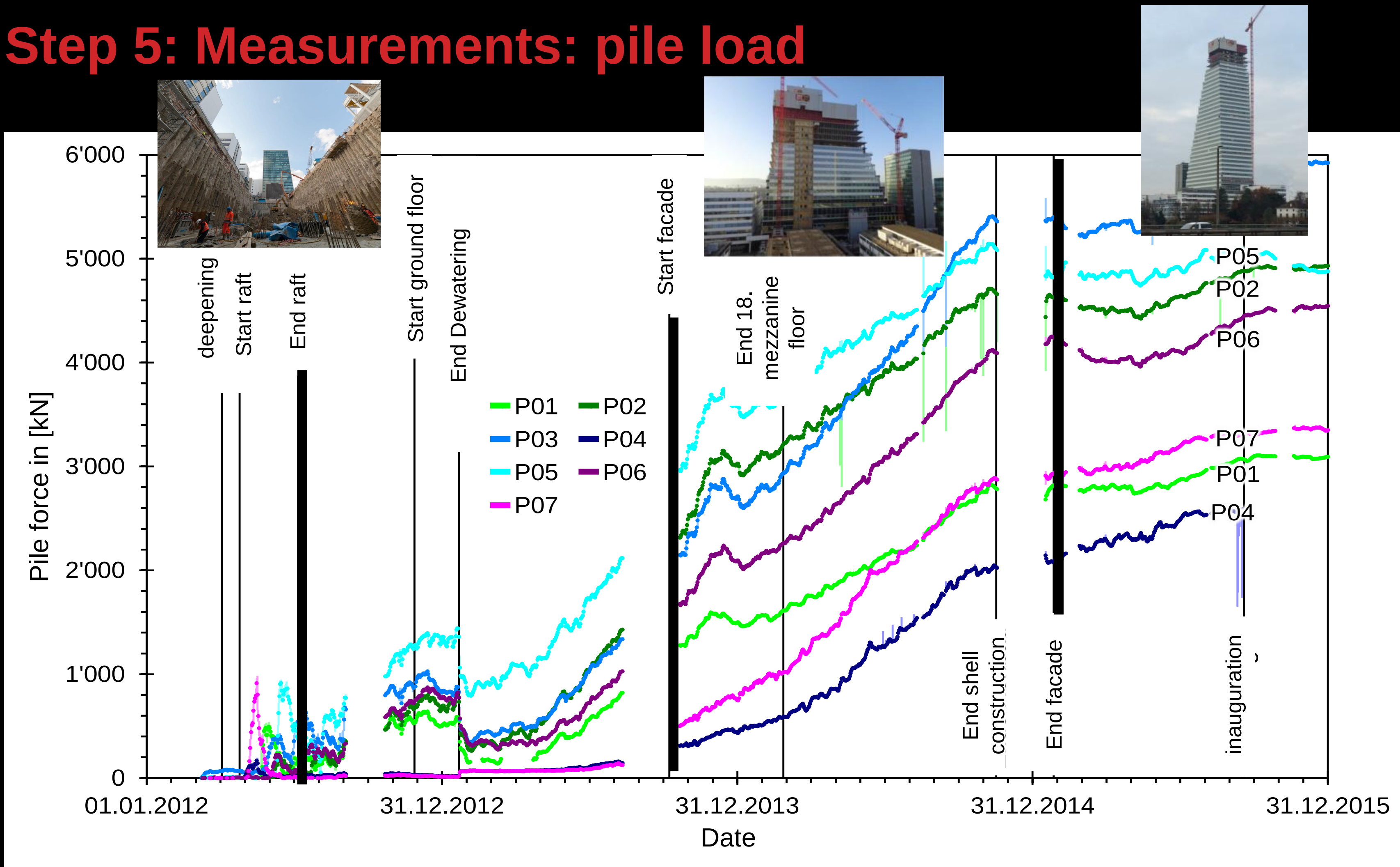
- groundwater level 2x
- pore water pressure 4x
- forces at pile head 7x
- earth pressure 8x
- temperature 8x





Bau 1 – design process

Step 5: Measurements: pile load



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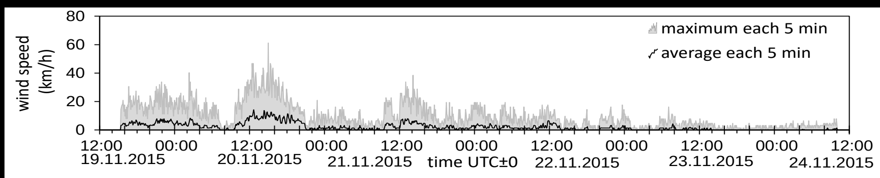
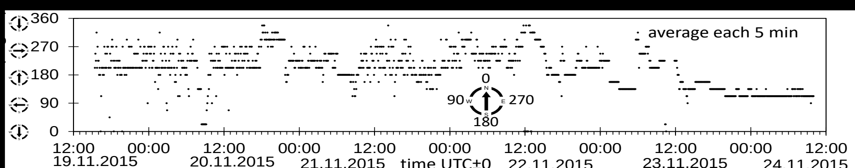
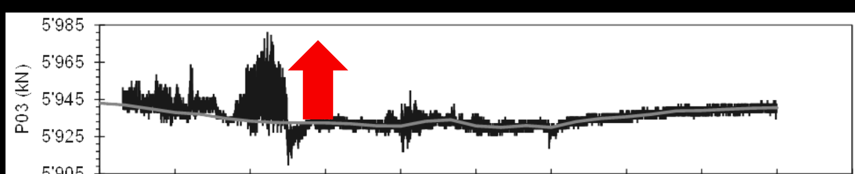
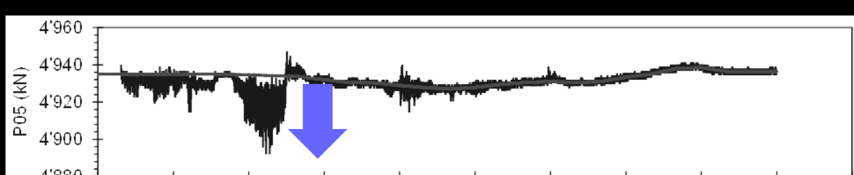
Bau 1 – design process

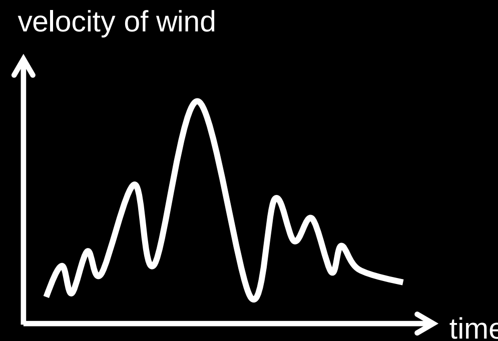
Step 4: Monitoring wind effects

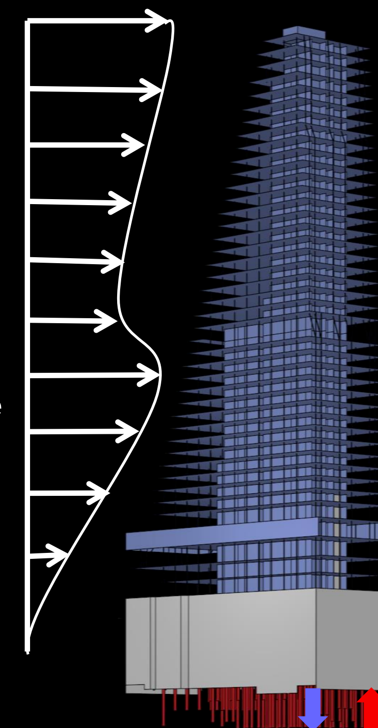


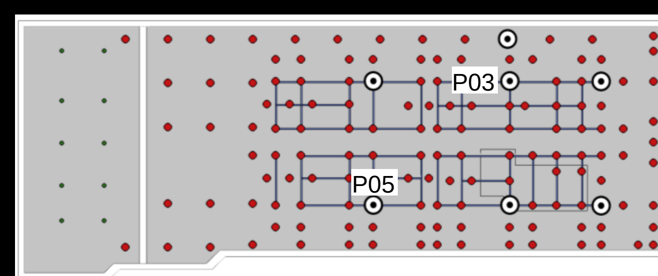












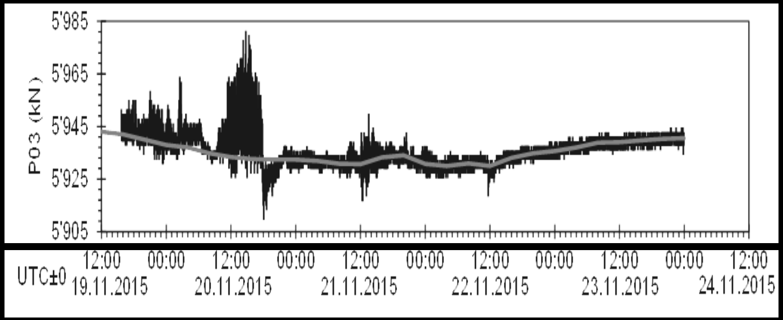
⊙ load cell on pile head

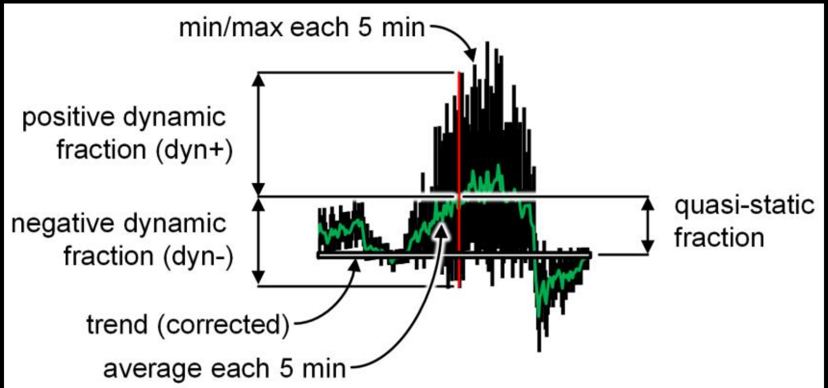
Bau 1 – design process

Step 4: Monitoring wind effects

Pile forces during wind event seem to be composed of several components:

- **Global trend (e.g. due to changes of groundwater level, total loading, …)**
- **Quasi-static fraction**
- **Dynamic fraction**
- **Observation: approx. 40 % static and 60 % dynamic component**





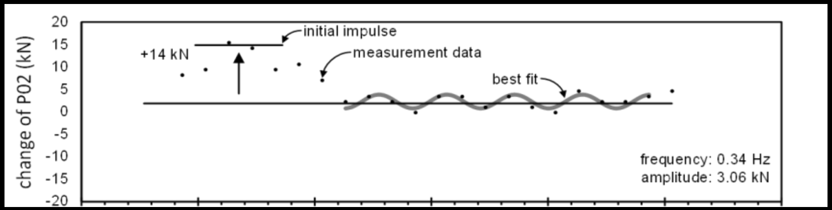
gruner

Bau 1 – design process

Step 4: Monitoring natural frequency of the structure

Idea:

- find a short loading impulse
- Expectation: building will oscillate (natural frequency)
- Event found for 20.11.2015 with south wind direction
- Using mathematical optimization algorithms to fit an harmonic oscillation
- Result: 0.35 Hz
- Frequency fits measurements by structural engineer (using accelerometers): 0.34 Hz (N-S)



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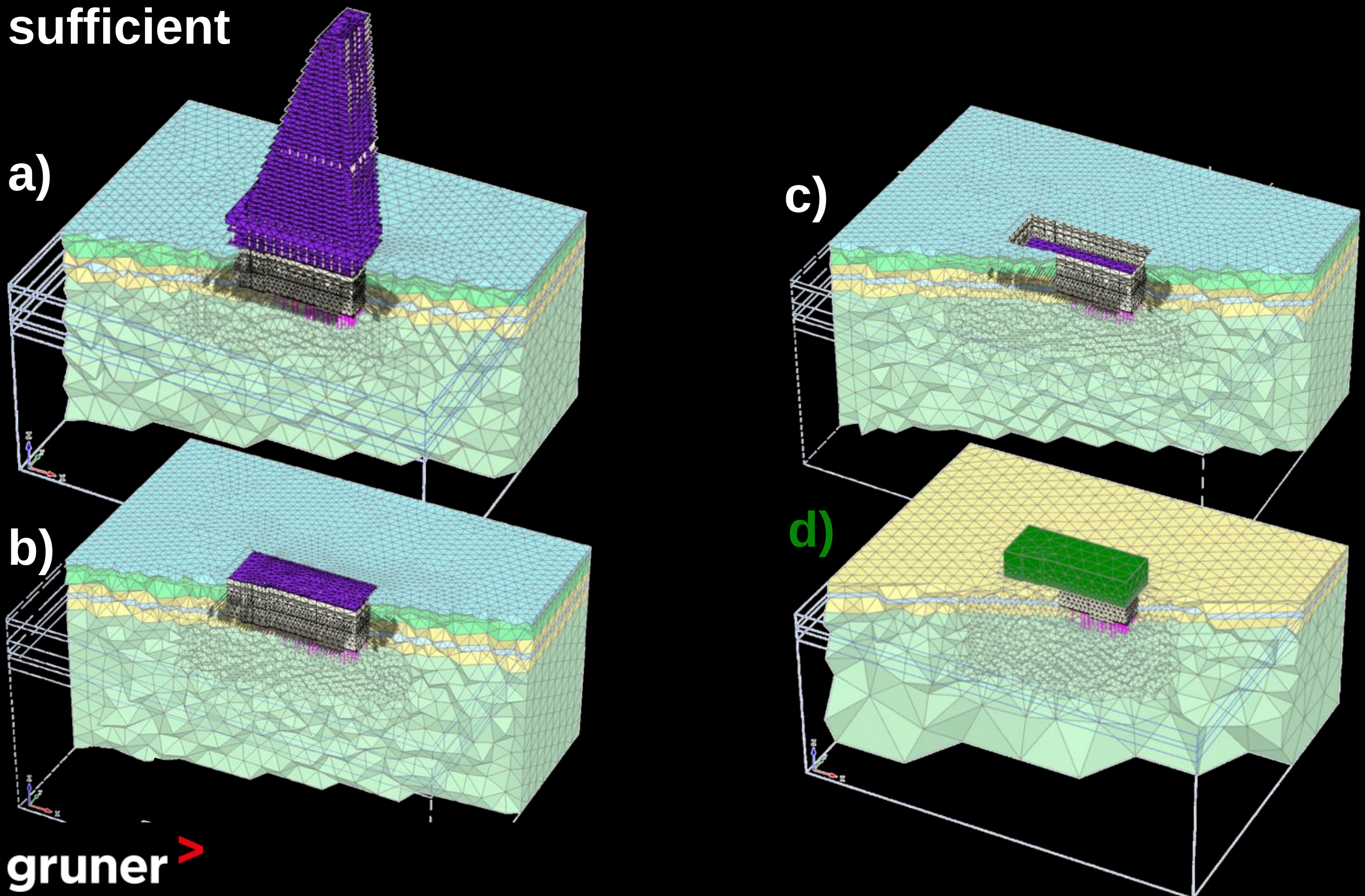
Bau 1 – design process

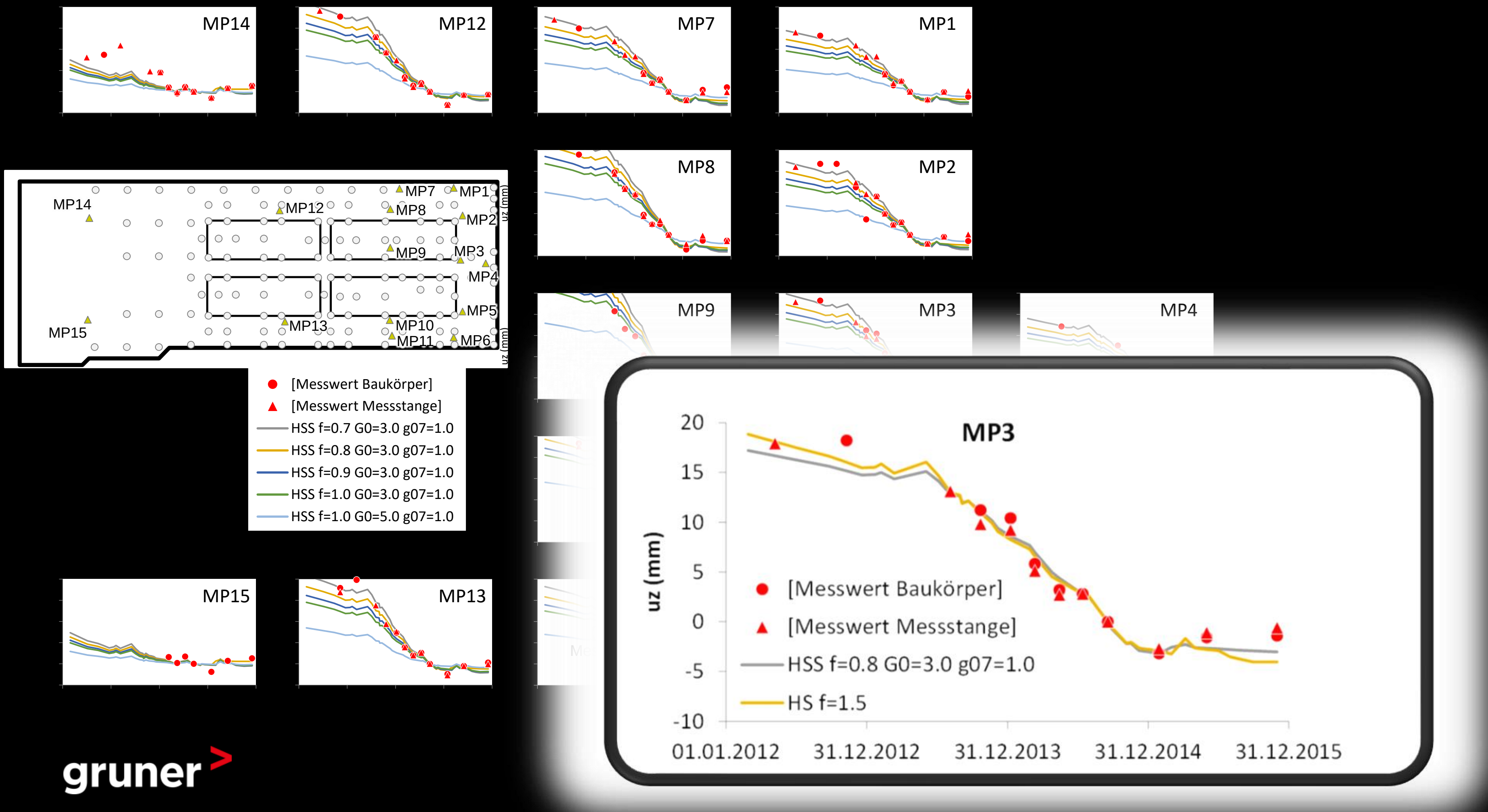
Step 5: Back analysis – calibration (f-value)

Recommendations for piled raft simulations: 3D models, model d) sufficient



Bau 1 – design process

Step 5: Back analysis – calibration (f-value)



Bau 1 – design process

Step 5: Back analysis – soil parameters

Tabelle 39: Finaler Parametersatz für das Materialmodell Hardening Soil

Parameter		Niederterrassen-schotter (NTS)	Cyrenenmergel (CM)	Elsässermolasse (EM1 | EM2)
γ	Wichte (ungesättigt = gesättigt)	23 kN/m³	21 kN/m³	22 kN/m³
E_{50}^{ref}	E-Modul (Erstbelastung)	90 MN/m²	120 MN/m²	180 | 300 MN/m²
E_{oed}^{ref}	Steifenmodul (ME-Wert)	110 MN/m²	150 MN/m²	225 | 375 MN/m²
E_{ur}^{ref}	E-Modul (Entlastung, Wiederbelastung)	300 MN/m²	390 MN/m²	562 | 937 MN/m²
m	Spannungsabhängigkeit der Steifigkeit	0.5	0.5	0.5
c'_{ref}	Kohäsion	1 kN/m²	50 kN/m²	75 kN/m²
φ'	Winkel der inneren Reibung	38°	27.5°	29°
ψ'	Dilatationswinkel	8°	0°	0°
ν_{ur}	Poissonzahl	0.3	0.25	0.25
R_f	Strength	0.9	0.9	0.9
τ	Tension cut off	1 kN/m²	25 kN/m²	37 kN/m²

Tabelle 40: Finaler Parametersatz für das Materialmodell Hardening Soil Small Strain

Parameter		Niederterrassen-schotter (NTS)	Cyrenenmergel (CM)	Elsässermolasse (EM1 | EM2)
γ	Wichte (ungesättigt = gesättigt)	23 kN/m³	21 kN/m³	22 kN/m³
E_{50}^{ref}	E-Modul (Erstbelastung)	48 MN/m²	64 MN/m²	96 | 160 MN/m²
E_{oed}^{ref}	Steifenmodul (ME-Wert)	58 MN/m²	80 MN/m²	120 | 200 MN/m²
E_{ur}^{ref}	E-Modul (Entlastung, Wiederbelastung)	160 MN/m²	208 MN/m²	300 | 500 MN/m²
$\gamma_{0.7}$		1×10^{-4}	1×10^{-4}	1×10^{-4}
G_0^{ref}		246 MN/m²	250 MN/m²	360 | 600 MN/m²
m	Spannungsabhängigkeit der Steifigkeit	0.5	0.5	0.5
c'_{ref}	Kohäsion	1 kN/m²	50 kN/m²	75 kN/m²
φ'	Winkel der inneren Reibung	38°	27.5°	29°
ψ'	Dilatationswinkel	8°	0°	0°
ν_{ur}	Poissonzahl	0.3	0.25	0.25
R_f	Strength	0.9	0.9	0.9
τ	Tension cut off	1 kN/m²	25 kN/m²	37 kN/m²

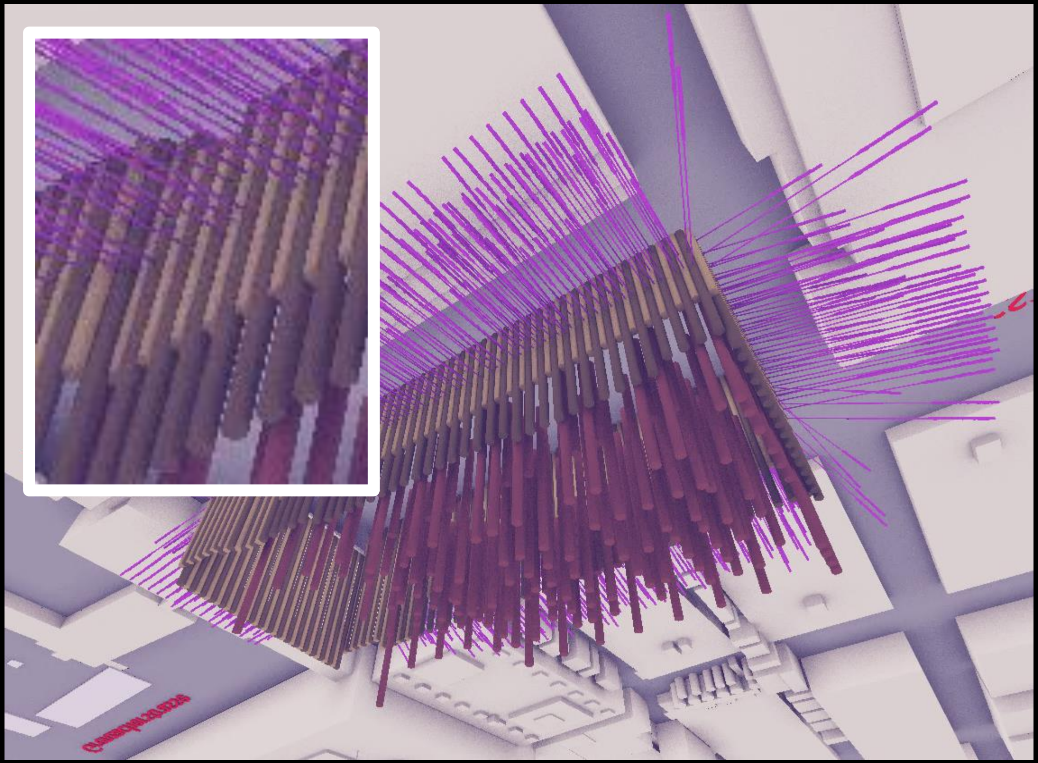

Excavation pit

Bau 1 – design process – excavation pit

Step 2: concept

Pile wall: low vibration, stiff and impervious

Anchors: low vibration, robust, positive experience



Optimization:

primary pile shorter ⇨

- > **Water pressure reduction**
- > **Less anchors**
- > **secondary pile shorter**

Bau 1 – design process – excavation pit

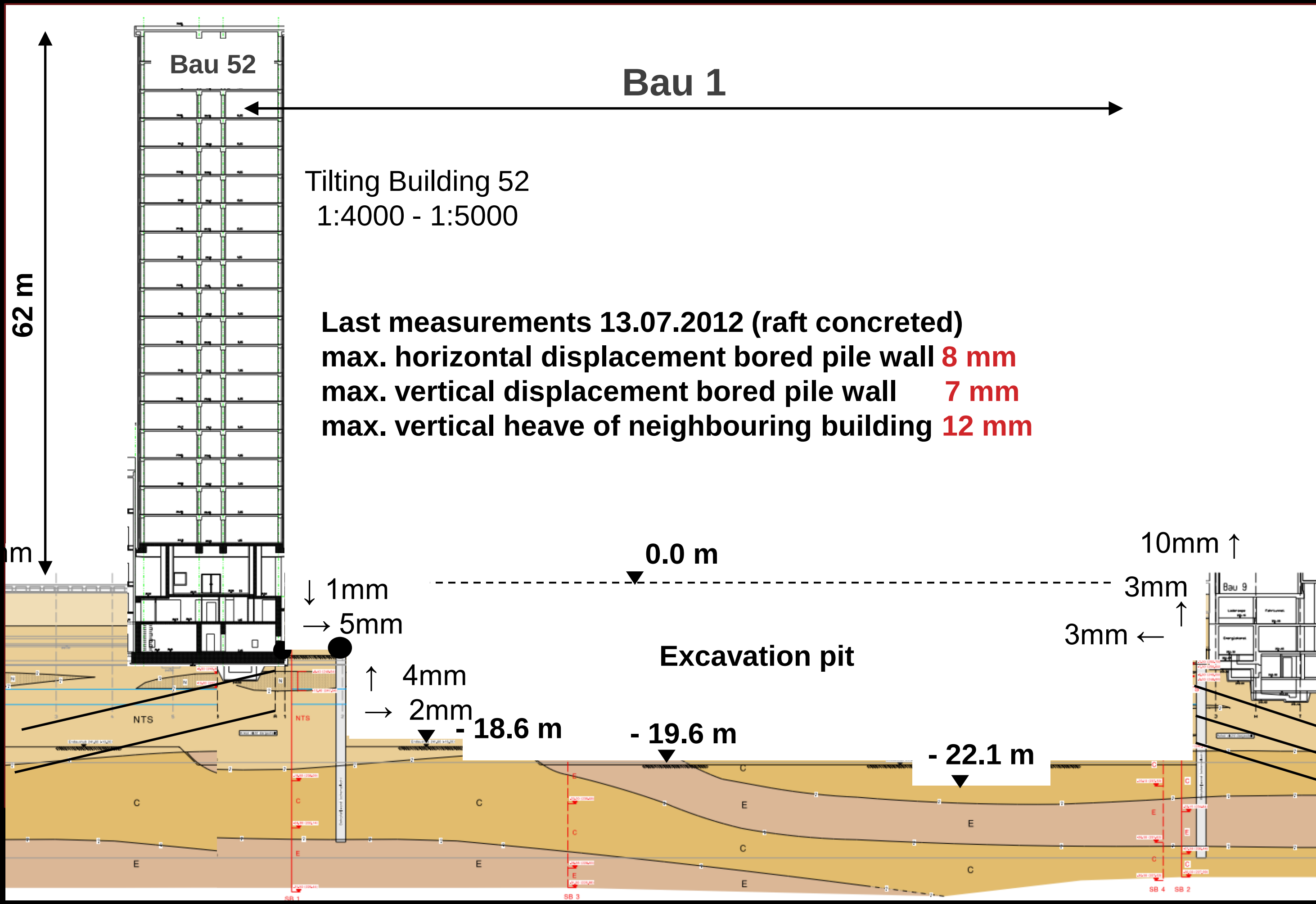
Step 2: Risks (water pressure)

Dubai, 2007

gruner

Bau 1 – design process – excavation pit

Step 2: Risks (deformations)



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Bau 1 – design process – excavation pit

Step 2: Risks (research operations disturbance)

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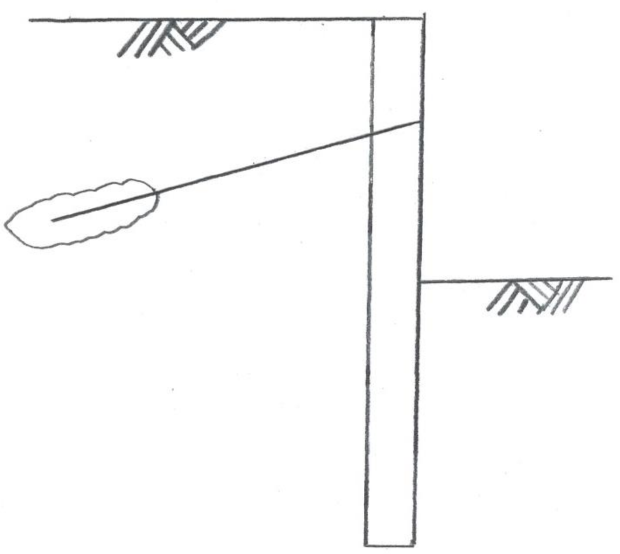
Bau 1 – design process – excavation pit

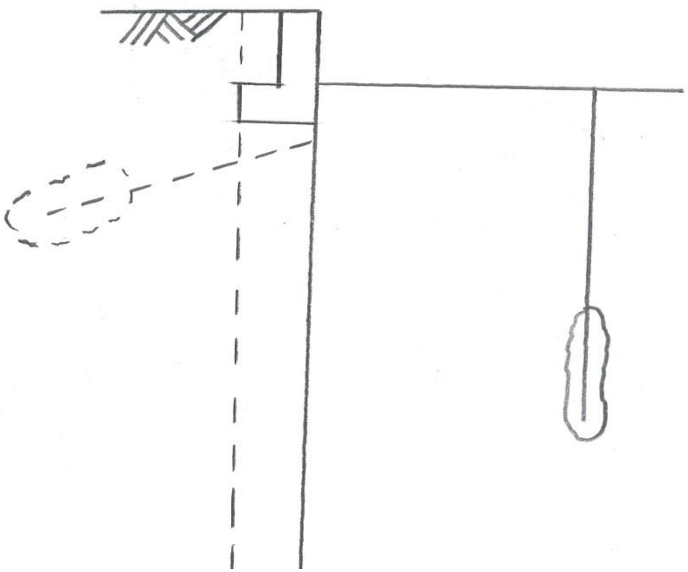
Step 2: In situ testing - anchors

Common



Test anchor inclined, as part of the later construction
⇨ no time for optimization of planning

Solution Gruner/Roche



Test anchor vertical

Beware: anchor slightly pretensioned during hardening (corkscrew effect)

Bau 1 – design process – excavation pit

Step 2: In situ testing - anchors

Test anchor: 5 x 3 pieces:

> **3 in Gravel** (Niederterrassenschotter)

> **3 in Marl EM** (Elsässer Molasse)

> **3 in Marl CM** (Cyrenenmengel)

> **6 removable anchors with different techniques (pre-determined breaking point, induction coil) (proposal contractor)**

gruner

Bau 1 – design process – excavation pit

Step 2: In situ testing - anchors

Test anchor - load capacity

	usual	Test	Design	Potential*
- 3 in Gravel (Niederterrassenschotter)	1200	1800	1600 kN (550 kN/m²)	☑
- 3 in Marl EM (Elsässer Molasse)	800	1600	1200 kN (400 kN/m2)	⬈
- 3 in Marl CM (Cyrenenmergel)	800	1600	1200 kN (400 kN/m2)	⬈

+ 50% compared to previous

⇨ Saving 200 anchors

*Qualitative assessment in the course of the tensioning test for a total of 480 anchors

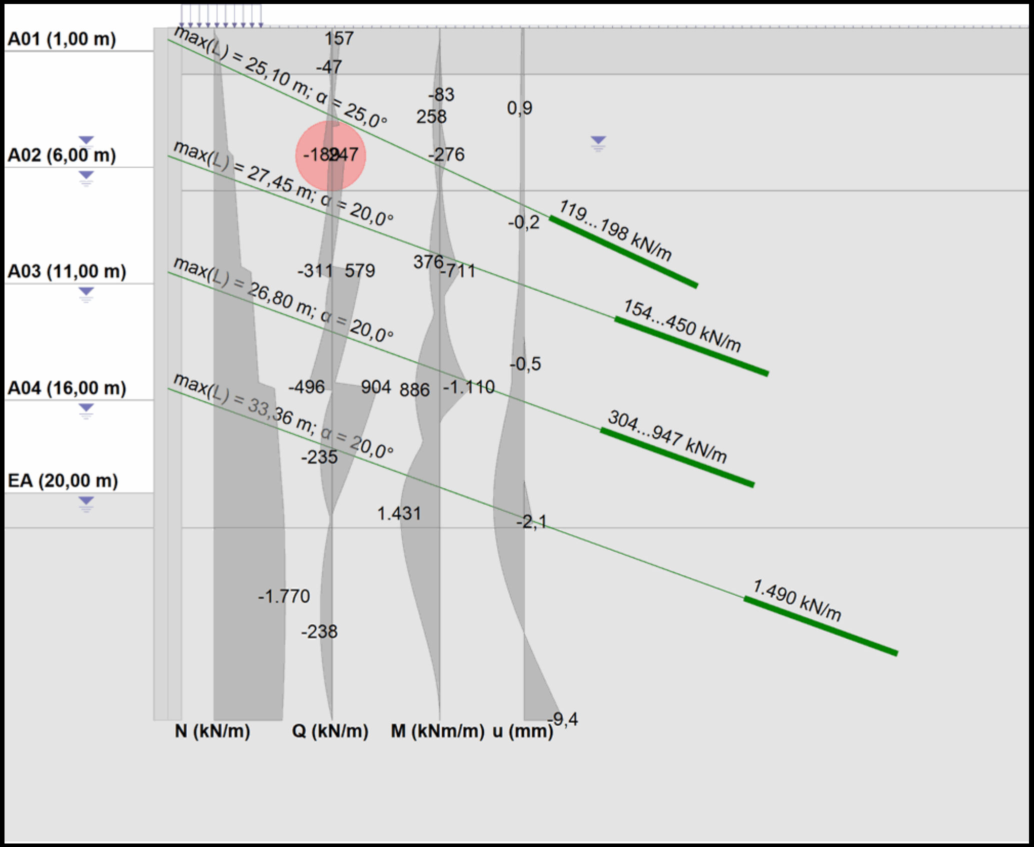
gruner

Bau 1 – design process – excavation pit

Step 3: Design - optimization

Optimization:

- Pile length
- Pile reinforcement cage
- Anchors
- Costs
- Time
- Deformations



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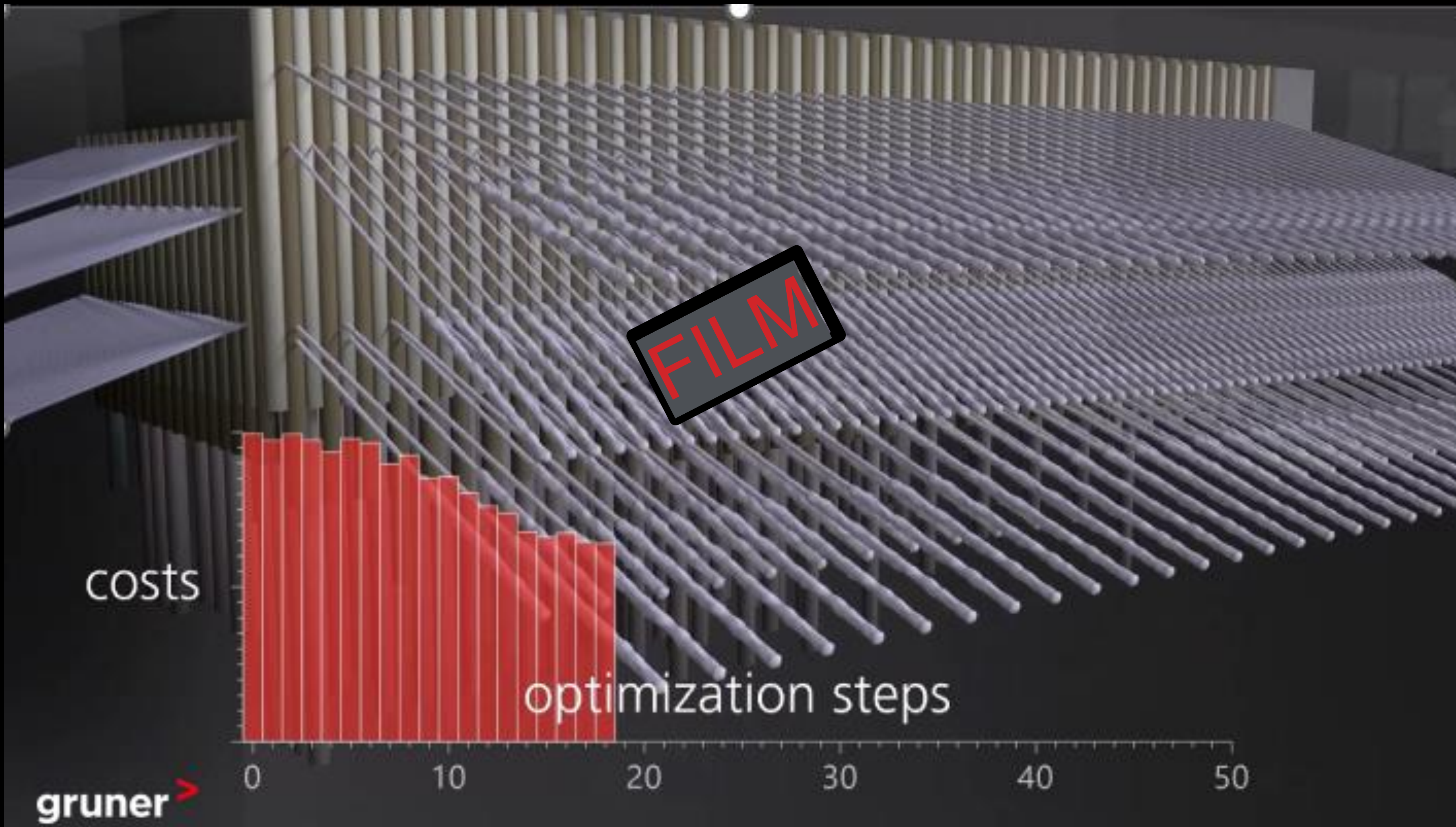

FILM
costs
optimization steps
0
10
20
30
40
50
gruner

Bau 2

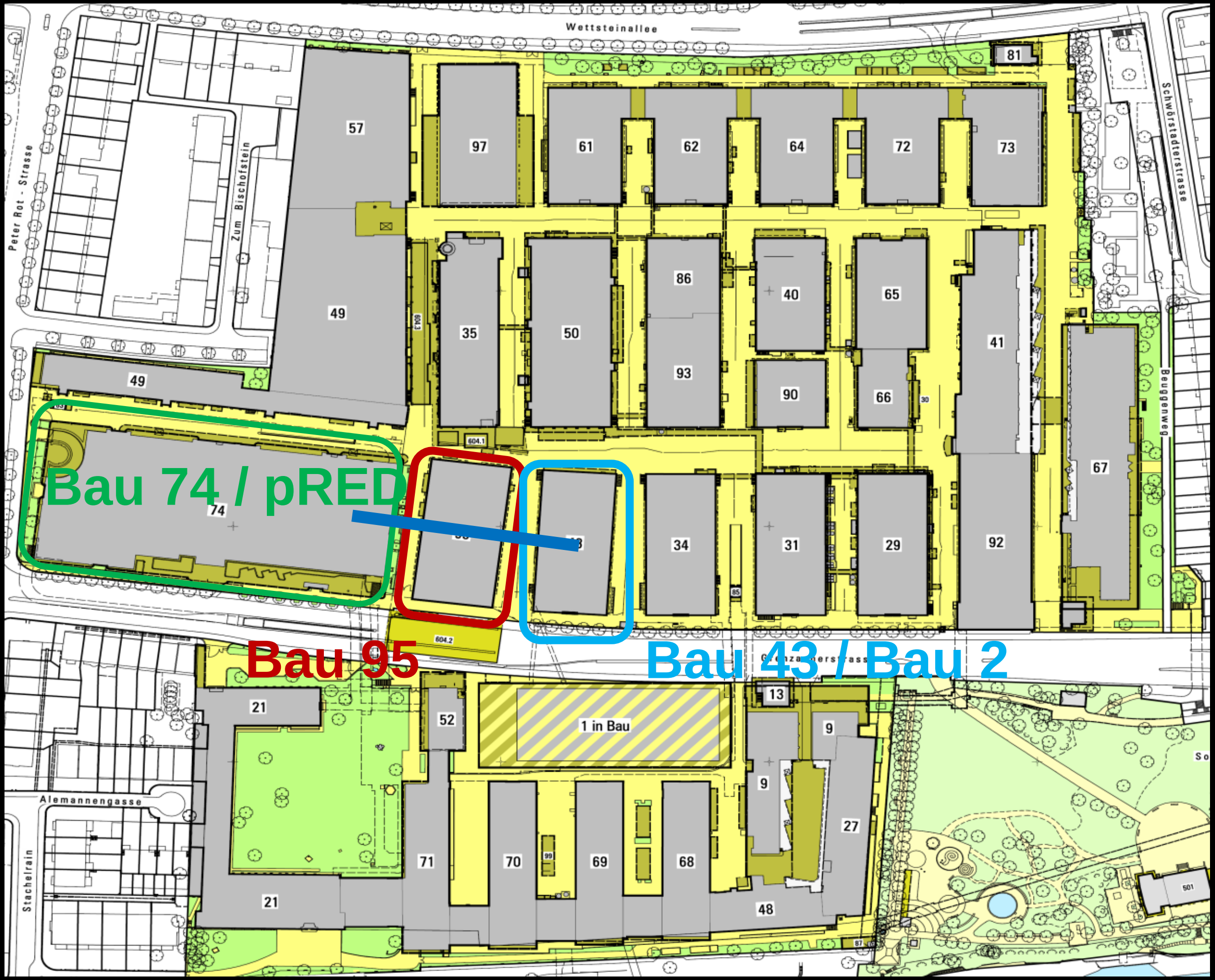
Features

- 205 m high
- 50 storeys
- Piled raft foundation

gruner

Bau 2

Special features – modified top-down method



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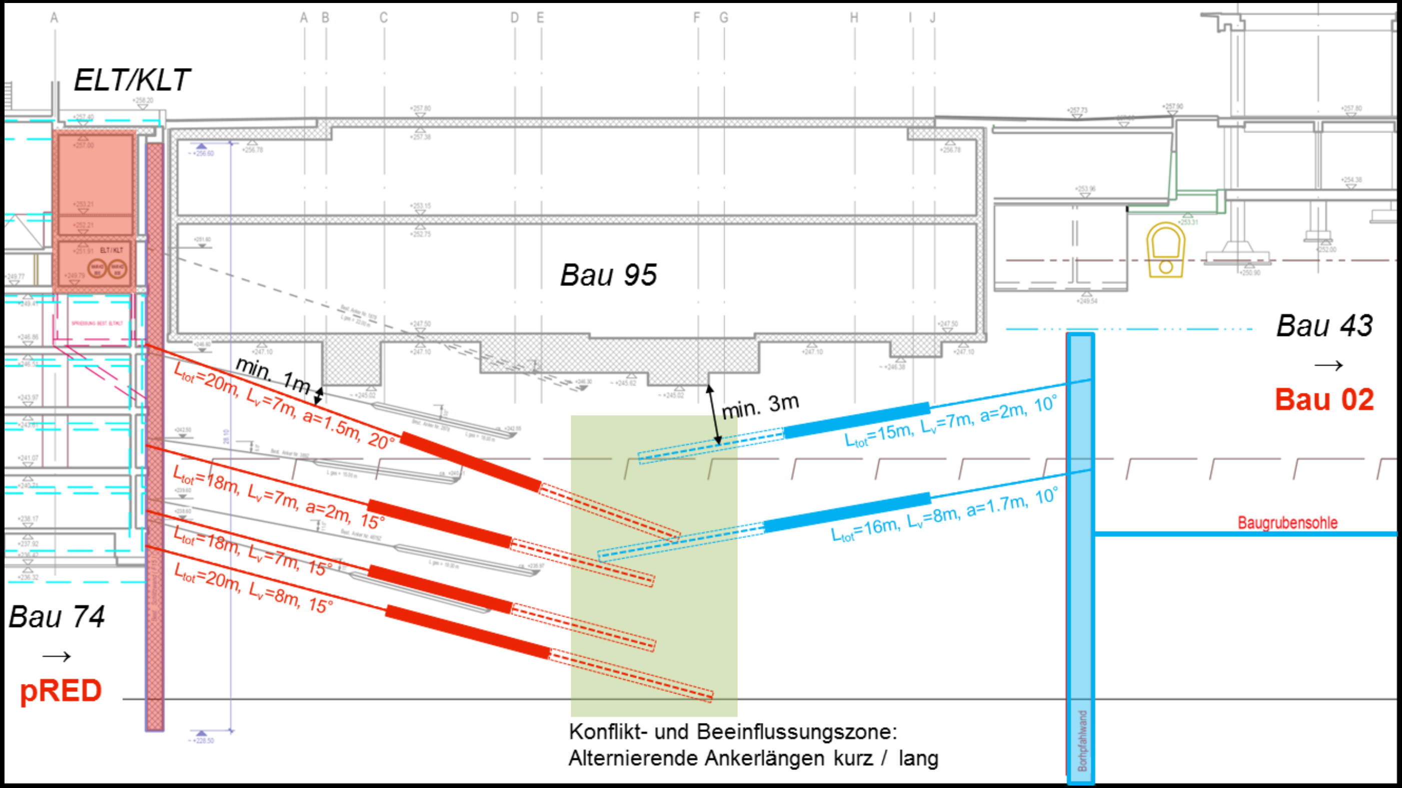
Bau 2

Special features – modified top-down method



pRed

Anchor clash

Bau 2

gruner

Bau 2

Special features – modified top-down method

Ground plan

Plunge column
Foundation pile

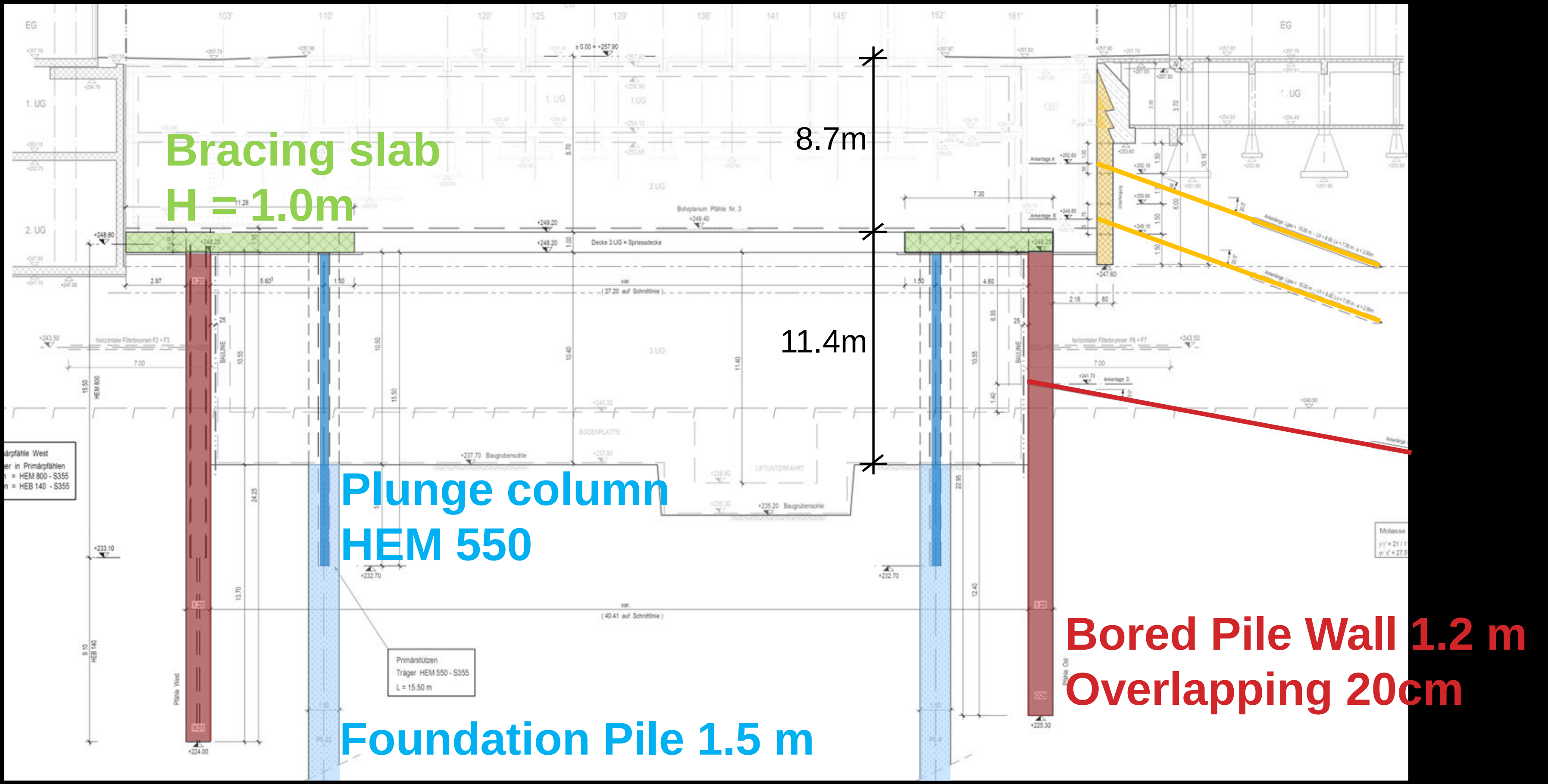
Bored Pile Wall
Overlapping 20cm

Bracing slab
H = 1.0m

Bau 2

Special features – modified top-down method

Cross section



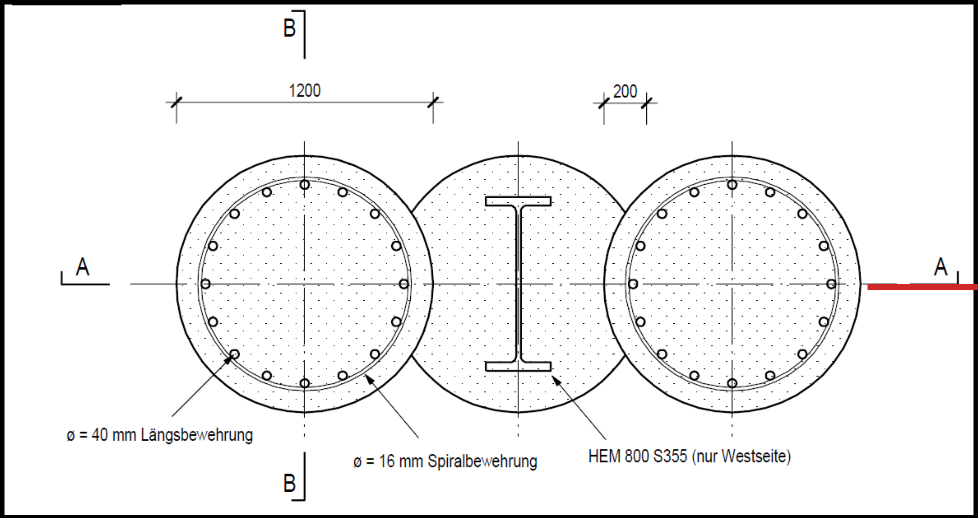
Bau 2

Special features – modified top-down method

Reinforcement of the pile wall

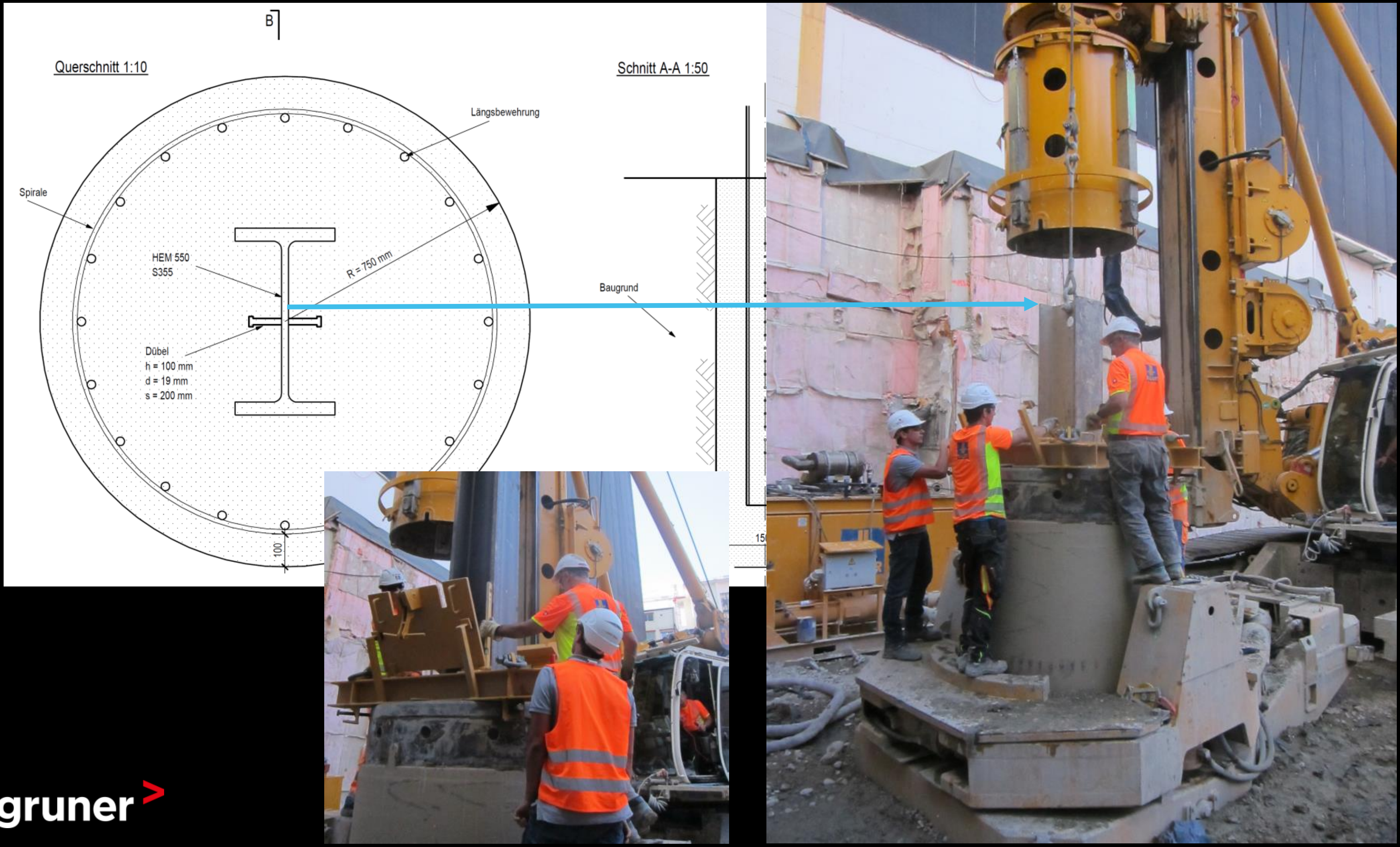
> **Maximum reinforcement (ø 40mm, 32 pcs.) for bored pile wall with D = 1.2m not sufficient to resist to the bending moment!**

→Additional beam HEM 800, S355 in primary piles on the west side



Bau 2

Special features – plunge columns installation



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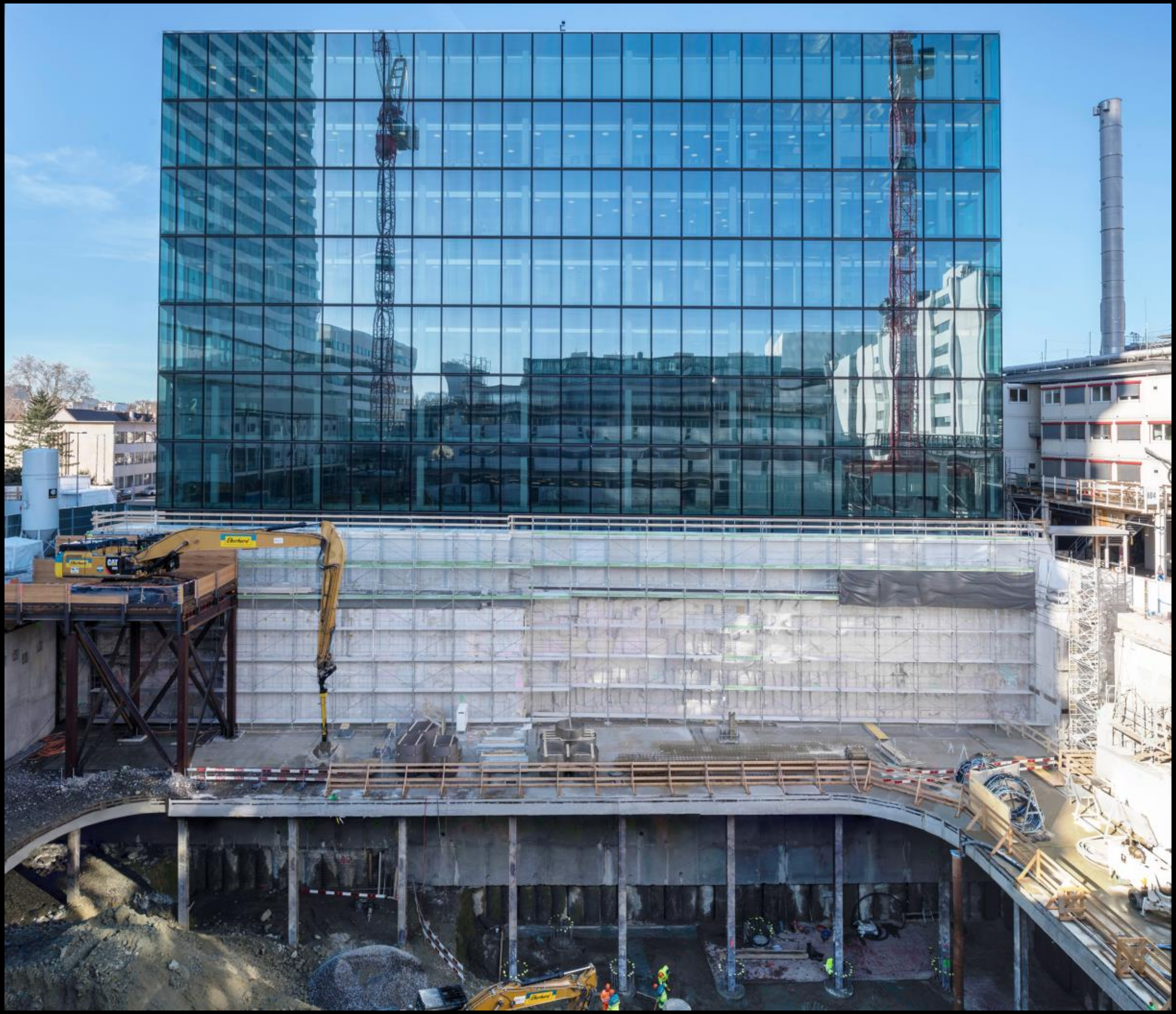
Bau 2

Special features – modified top-down method

Bau 95
very sensitive



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Bau 2

Special features – modified top-down method

Bracing slab

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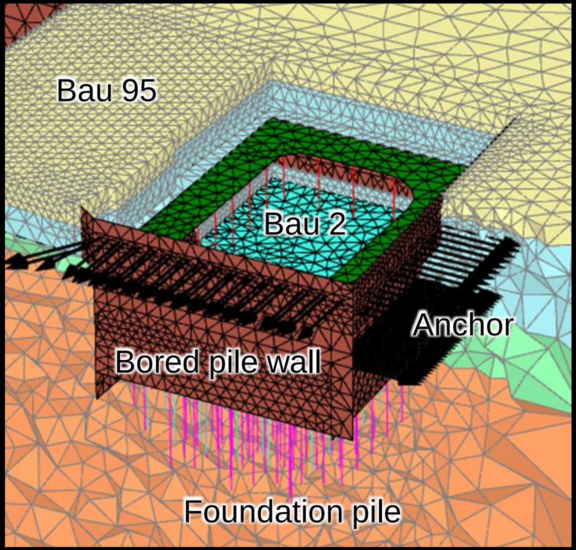
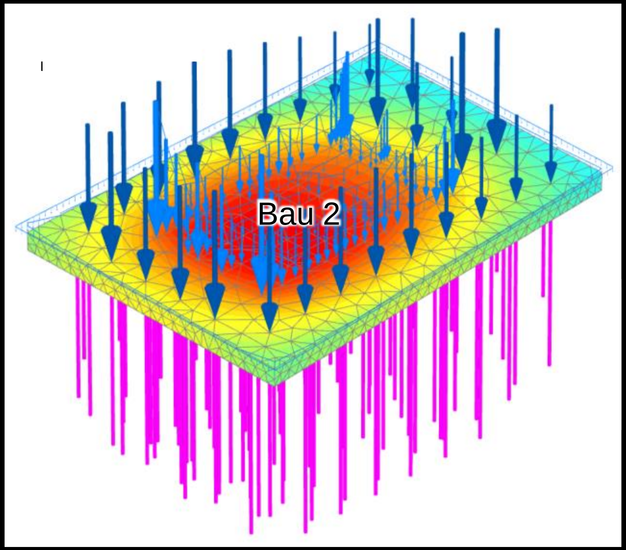
Bau 2

Special features – modified top-down method

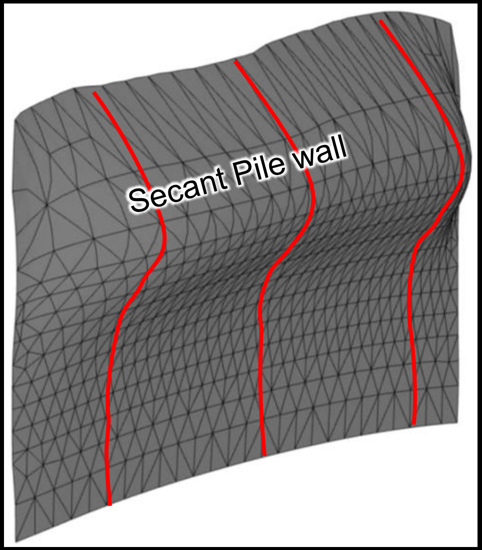
Observational method



▲ Simulation with view towards north-west



▲ Displacements due to Bau 2



▲ Strongly exaggerated representation of the deformations of the pile wall west

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Bau 2

Special features – modified top-down method

Observational method

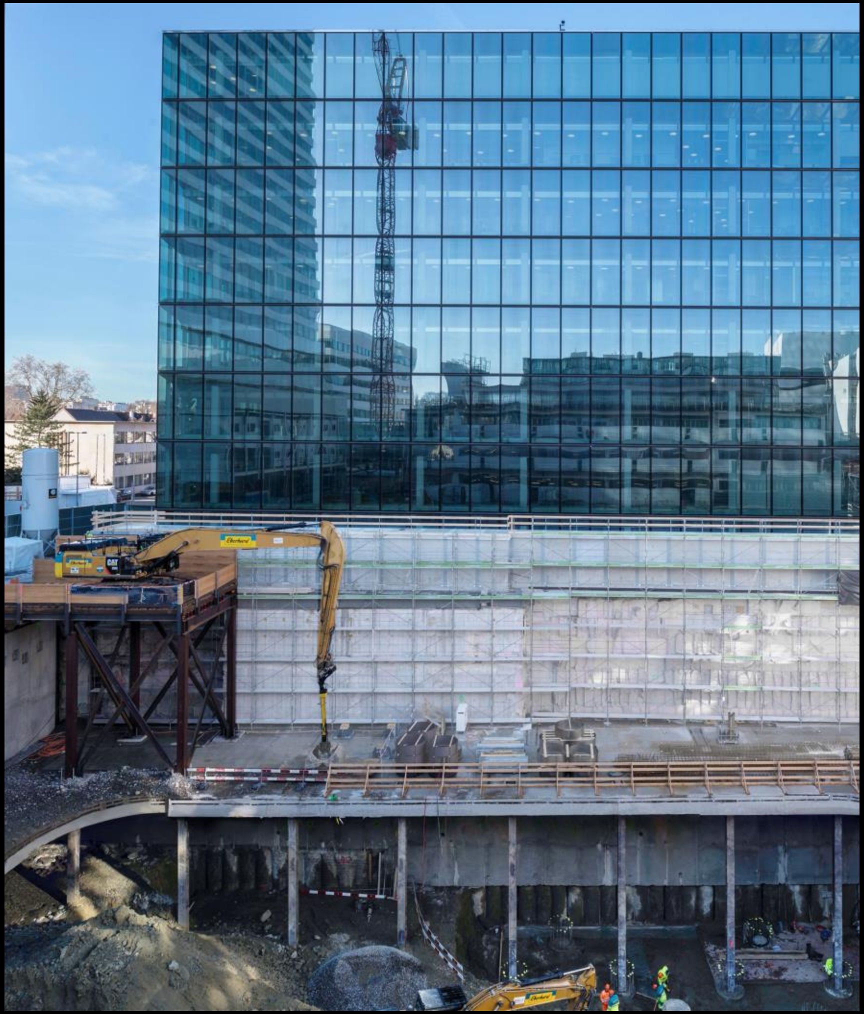
> High risk

adjacent building Bau 95

> Monitoring

> Values < Limit

⇨ No extra anchors



Bau 2 – design process - foundation

Coupling foundation and structure models

For the design of piled raft foundations

Use automated iteration of coupled models

Initial stiffness

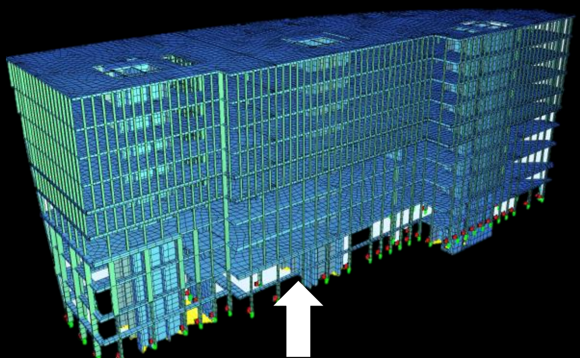
Spring stiffness

Model foundation and soil
Modelling of piles and soil-structure interaction

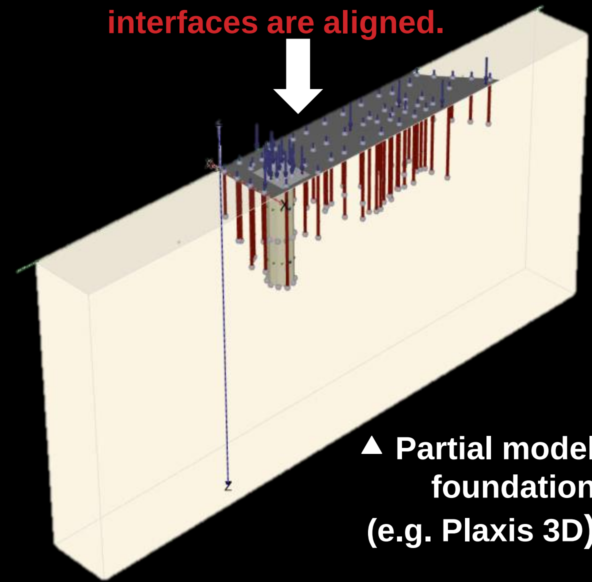
Model structure & building
Modelling of the rising structure

Load

Partial model structure (e.g. SOFiSTiK) ▼



Iterative adaptation of both models so that the simulation results in the interfaces are aligned.



▲ Partial model foundation (e.g. Plaxis 3D)

gruner

Bau 3

Translocation of an historical building

Roche Bau 1, 2, 3, pRed (Vision)

gruner

Bau 3

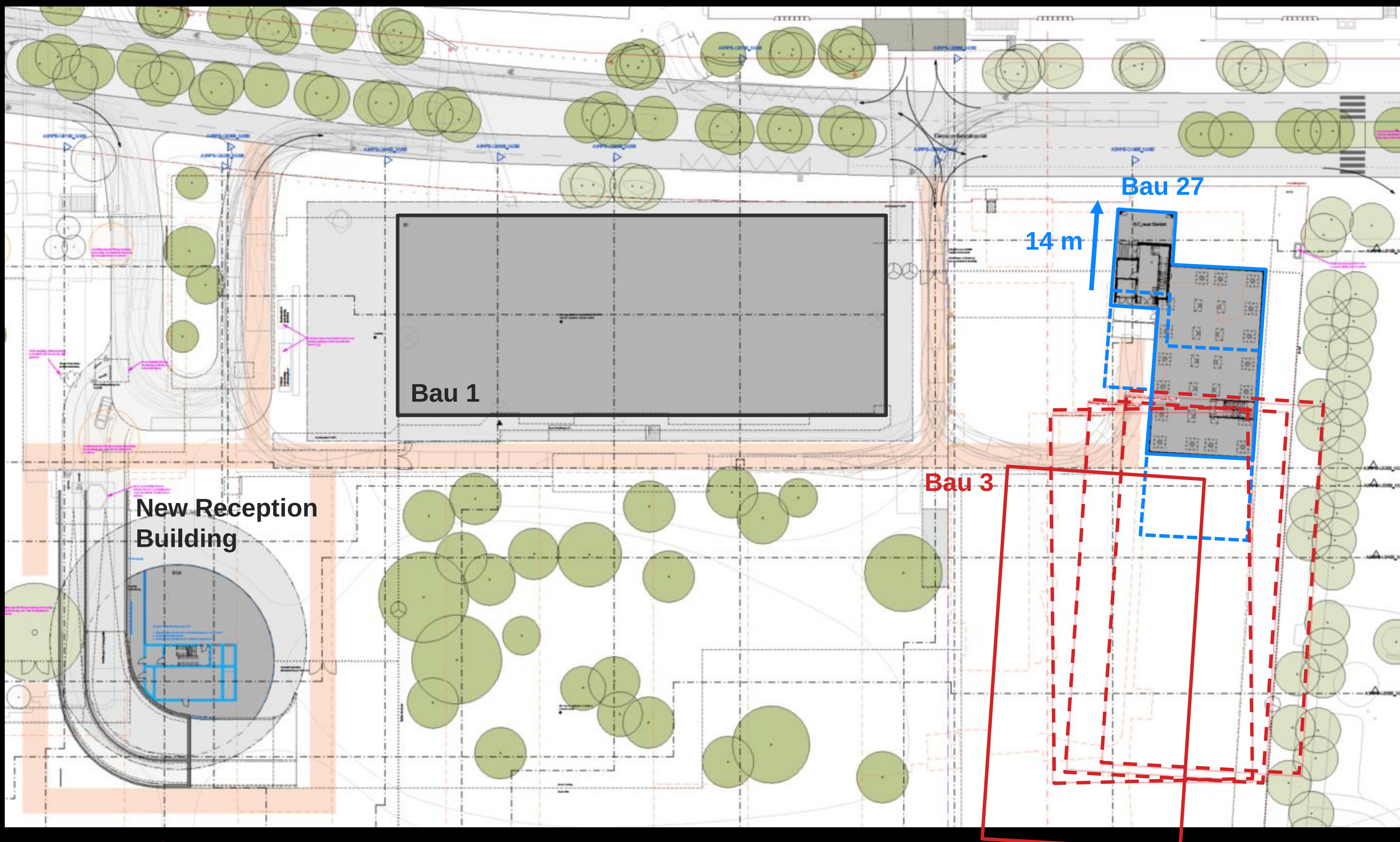
Translocation of an historical building

Roche Bau 27

gruner

Bau 3

Translocation of an historical building - context



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Bau 3

Translocation of an historical building

Figures

- Year of construction 1937
- Architect Otto Salvisberg
- Weight 4800 Tons
- Translocation distance 14 m
- Levels: 7 (tower: 8)
  - 1 basement level
  - 1 ground floor
  - 5 upper floors (tower: 6)


Roche Bau 27


Roche Bau 27

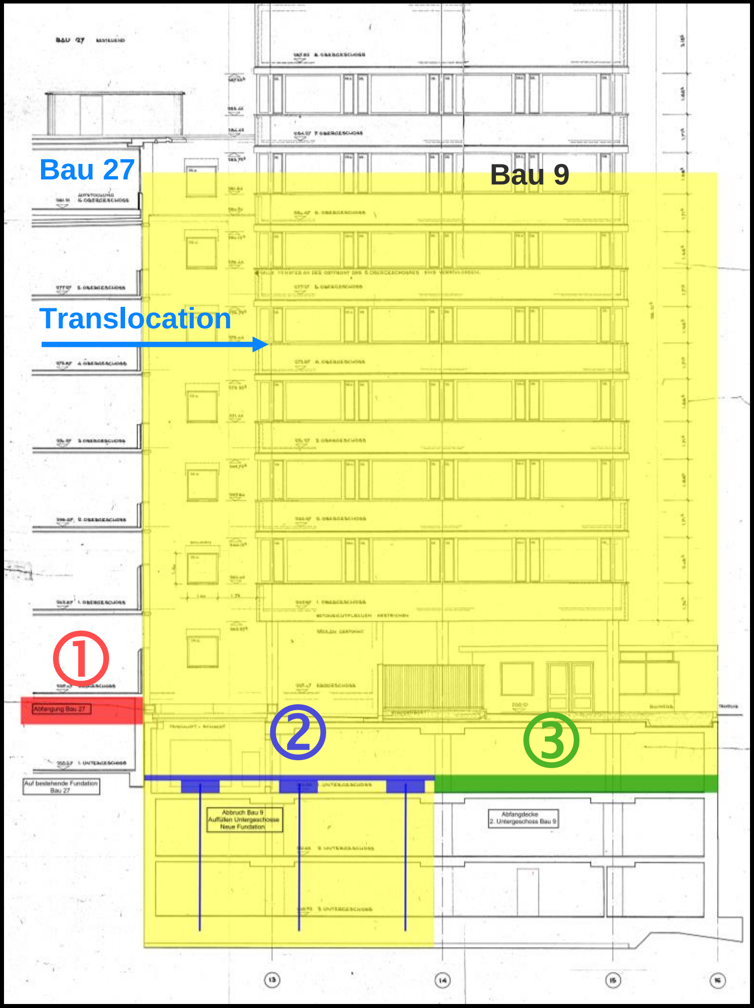
gruner

Bau 3

Translocation of an historical building

Challenges

- > Existing structure: earthquake resistance and verification of basement Bau 9
- > New location with three different foundation types:
  - > ① Foundations Bau 27
  - > ② demolished area Bau 9
  - > ③ Basement Bau 9



Grenzacher-street

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Bau 3

Translocation of an historical building

Approach

- Translocation level in basement Bau 27
- Interception construction for mushroom slab
- Load transfer slab in Bau 9

Roche Bau 27

Projekt Villa Blumenthal in Zürich, Quelle Fotos: Iten Bau AG,

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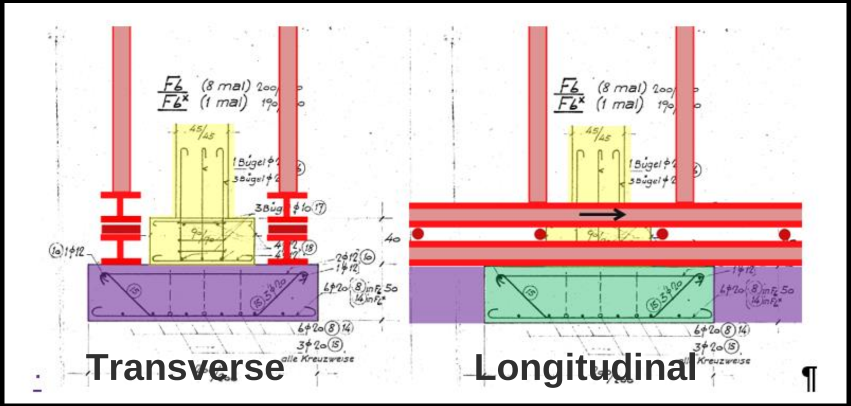
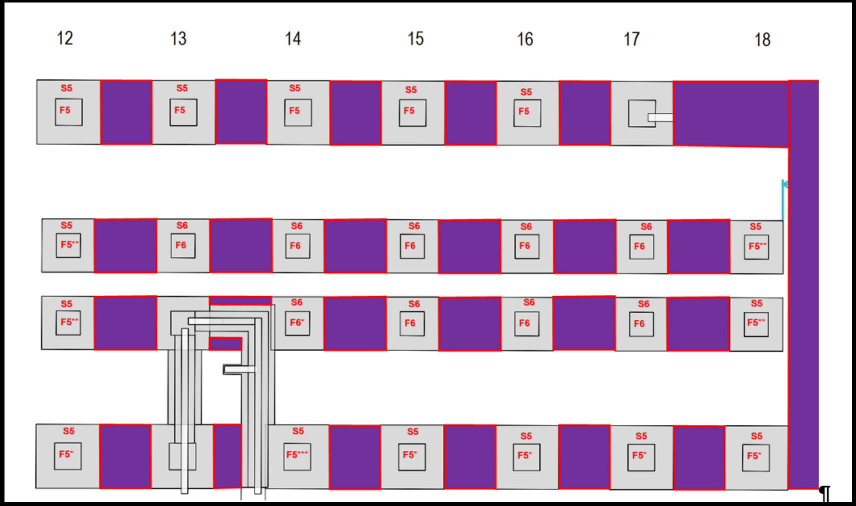
Bau 3

Translocation of an historical building

Concept

- Strengthening of the cores (reinforced concrete)
- Installation of temporary foundations
- Erection of lower and upper double longitudinal beams along each row of columns





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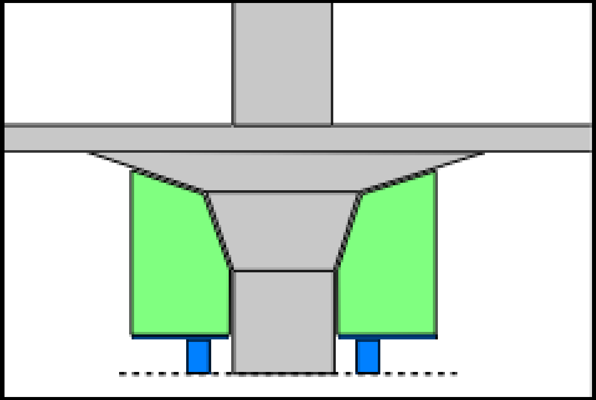
Bau 3

Translocation of an historical building

Concept



- Support of each column in a concrete corset

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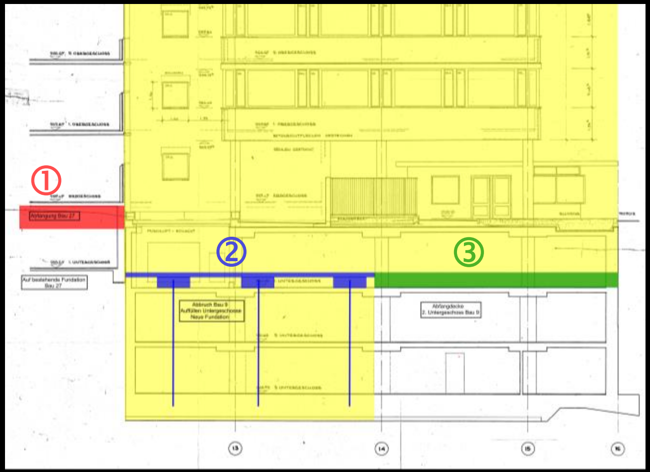
Bau 3

Translocation of an historical building

Monitoring & settlement compensation



Grenzacher-street

> Bau 27 is moved to 3 different types of foundations ①, ②, ③ with different stiffnesses

> Solution
>
> > Monitoring (e.g. water hose levelling)
>
> > synchronal force and displacement control of the jacks (vertical compensation)

gruner

Bau 3

Translocation of an historical building

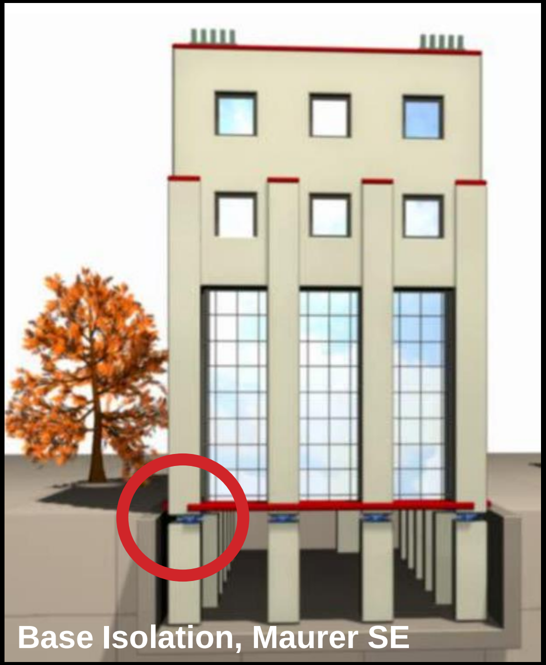
Seismic reinforcement design

- Earthquake degree of fulfillment 0.25 << 1.00
- Reinforcement of cores by new bracing walls

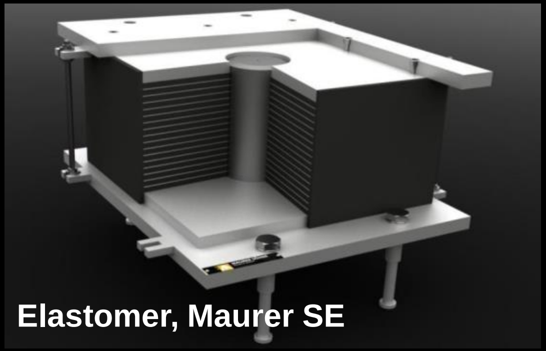
  ⇨ Fulfillment ratio << 1.00

Solutions:

- Base Isolation, since building is already decoupled after displacement. ⇨ Classical base isolation with elastomeric bearings not sufficient



Base Isolation, Maurer SE



Elastomer, Maurer SE

Bau 3

Translocation of an historical building

Seismic reinforcement design

> Earthquake degree of fulfillment 0.25 << 1.00

> Reinforcement of cores by new bracing walls

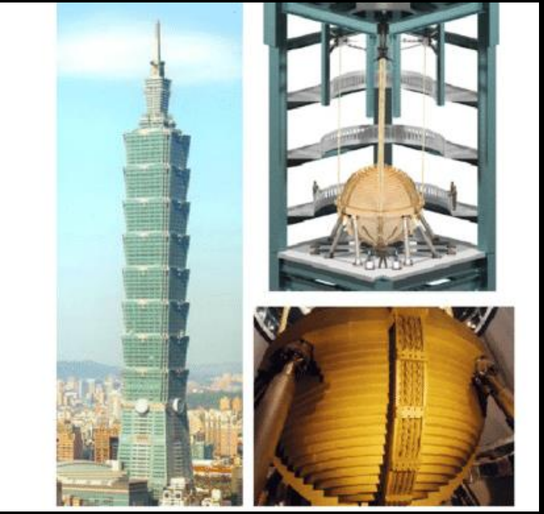
⇨ Fulfillment ratio << 1.00

Solutions:

> Base Isolation, since building is already decoupled after displacement. ⇨ Classical base isolation with elastomeric bearings not sufficient

> active or passive tuned mass damper (e.g. translational tuned mass damper for Hancock Tower in Boston) ⇨ Not sufficient

Tuned Mass Damper, Baku Tower, Maurer



Passive Tuned Mass Damper, Taipei 101, Kayabekir et al.(2020)

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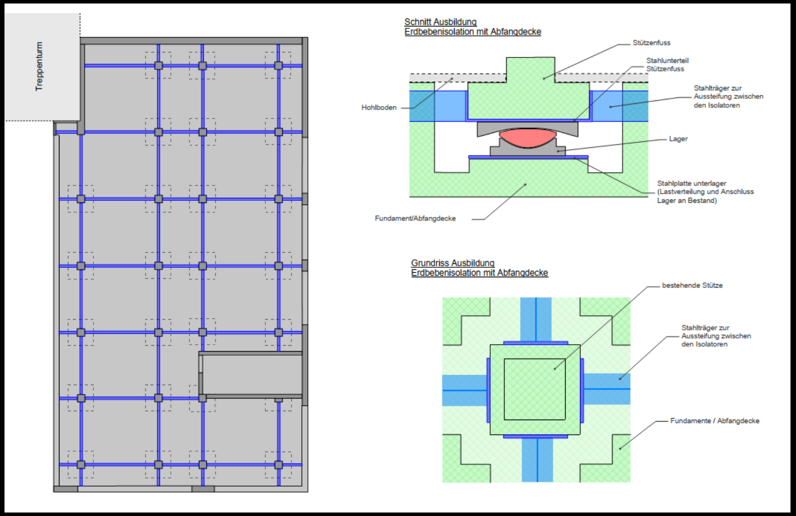
Bau 3

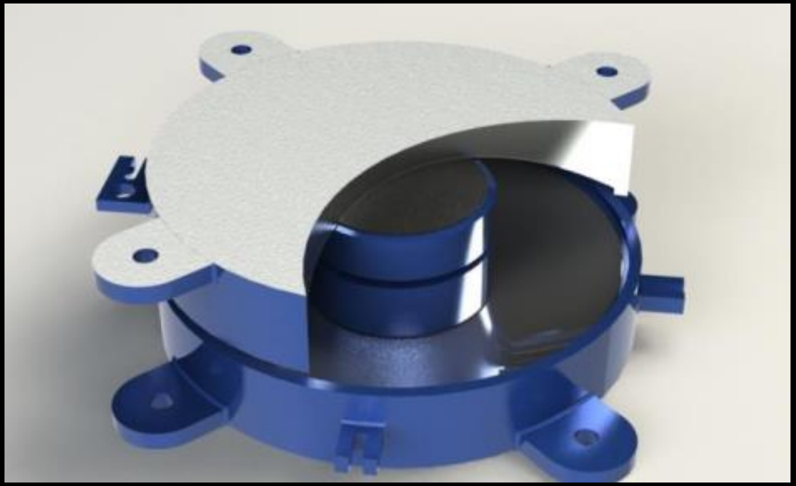
Translocation of an historical building

Seismic design

- Base Isolation with Sliding Isolation Pendulum: degree of fulfillment ≈ 1.0
- Principle: These Sliding Isolation Pendulums have a concave sliding plate and act like a pendulum. Part of the kinetic energy is converted into potential energy. This storage of potential energy provides the required ability to re-center the isolator.



Concept Sliding Isolation Pendulum, Gruner AG



Sliding Isolation Pendulum, Maurer SE

Bau 3

Translocation of an historical building

Visualization after displacement

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Gruner Geotechnics Award

for the best Master-thesis at the ETHZ

Dotation 2000.-

Winner can present his findings

in a conference of the Swiss

Geotechnical Society (GS)

GS

www.geotechnik-schweiz.ch

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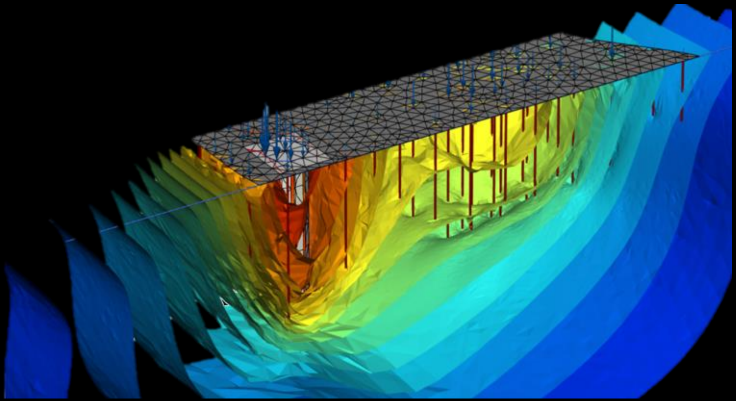
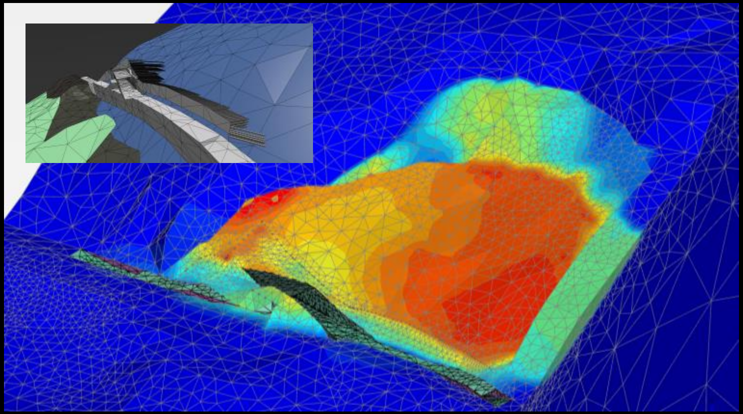


The Circle, Zurich

CEVA, Tunnel de Pinchat, Geneva



SBB Tunnel Ligerz

Swiss Geotechnical Society

Geotechnik Schweiz

Free?

www.geotechnik-schweiz.ch

Swiss Geotechnical Society

Geotechnik Schweiz

Paris - Technical Excursion Grand Paris Express

Swiss Geotechnical Society

Geotechnik Schweiz

Munich - Technical Excursion “2.Stammstrecke”

Swiss Geotechnical Society

Geotechnik Schweiz

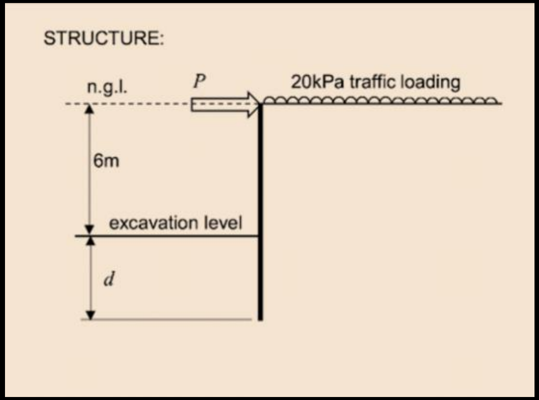
Zürich – GS-Anniversary Event

Swiss Geotechnical Society

Geotechnik Schweiz

Young Members Activities

1. Geotechnical Design Challenge



2. Swiss Geotech Abroad 02.06.2022 (EPFL)

3. Visit tunnel Evouettes

www.geotechnik-schweiz.ch

Swiss Geotechnical Society

Geotechnik Schweiz

2 Conferences / Year

Available:

- all videos of the conferences
- All papers

Free?

Geotechnical Challenge

«Prediction of the bearing capacity of a superficial footing»

Win an iPad and free GS-membership

More Infos:

GS

www.geotechnik-schweiz.ch

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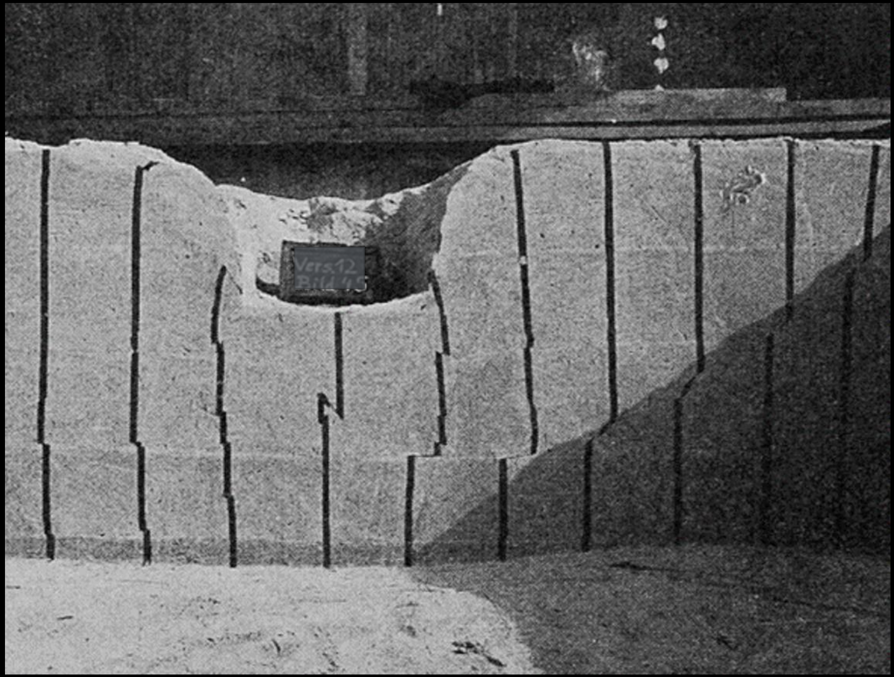

Bearing capacity testing (1969?)

Bau 1, 2 & 3

Challenges in geotechnical engineering

Roche Bau 1, 2, 3, pRed (Vision)

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运会的奖台

" If you want to build high towers, you have to spend a long time at the foundations "
Chinese proverb

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Thank you for your attention!
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