PLAXIS

DEEP EXCAVATIONS

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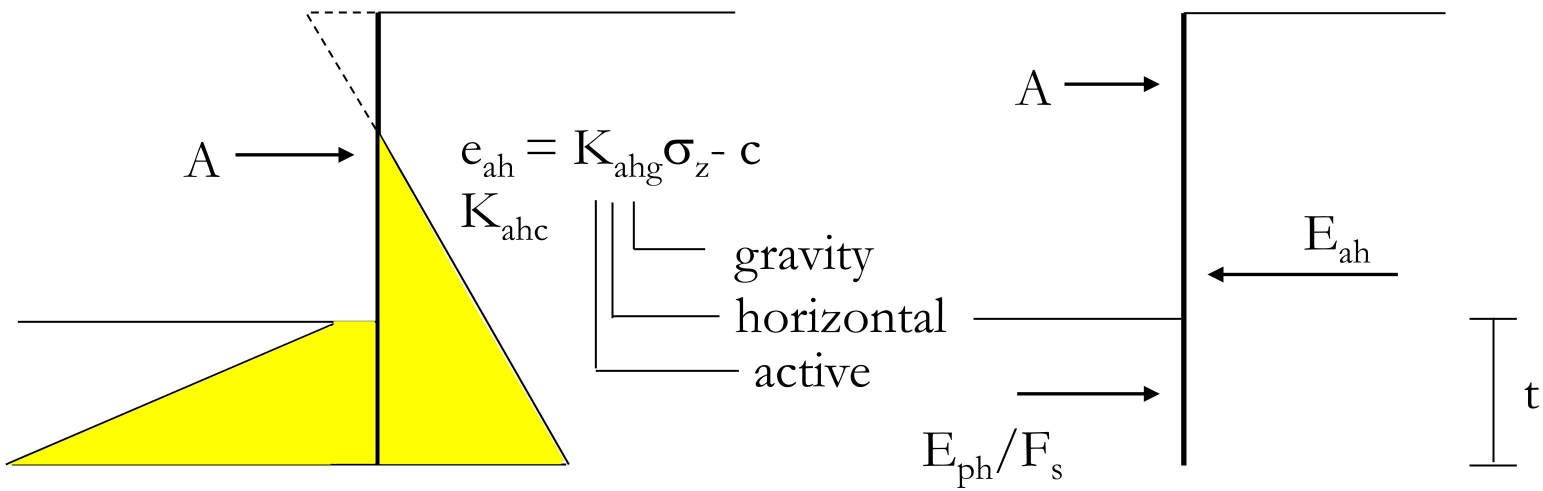
DEEP EXCAVATIONS

- **Open cut (in residual soils).**
- **Single-anchored retaining walls:**
  - design with free earth support
  - influence of soil stiffness
  - influence of wall stiffness
  - fixed earth support
- **Case study of open cut**
- **Case study of single-anchored wall**
- **Case study of multi-anchored wall**

Single-anchored or single-propped retaining wall with free-earth support, i.e. minimum embedment.

Traditional analysis after Blum (1930)



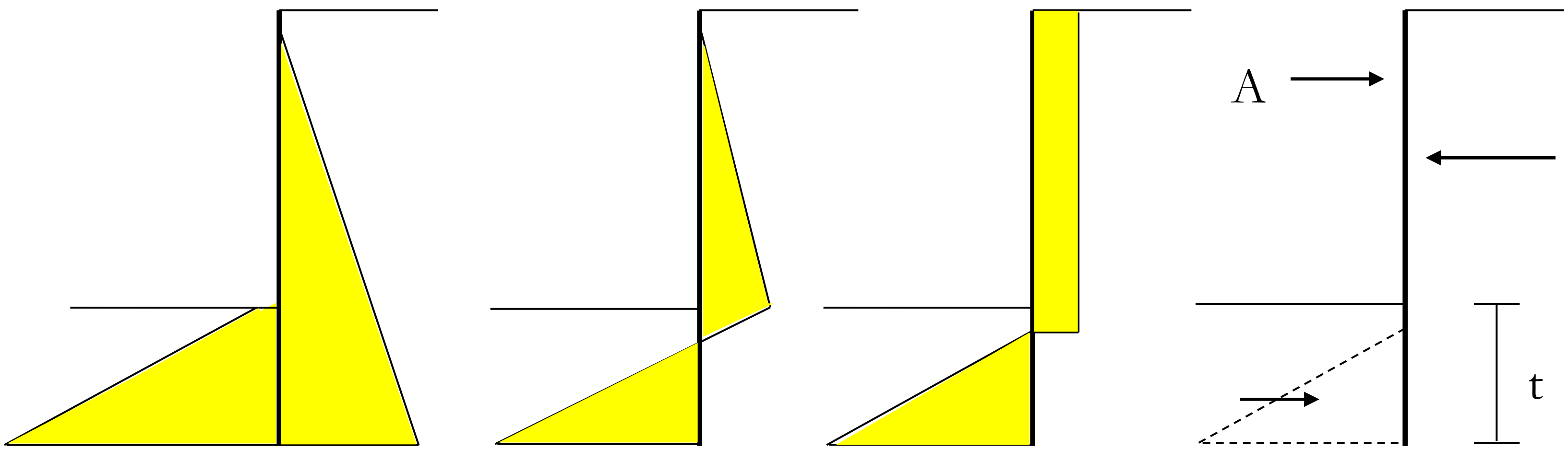
$e_{ph} = K_{phg}\sigma_z + c\ K_{phc}$

F_s = Factor of Safety = 1.5

Both E_{ph} and E_{ah} depend on t.

Moment equilibrium around A gives t.

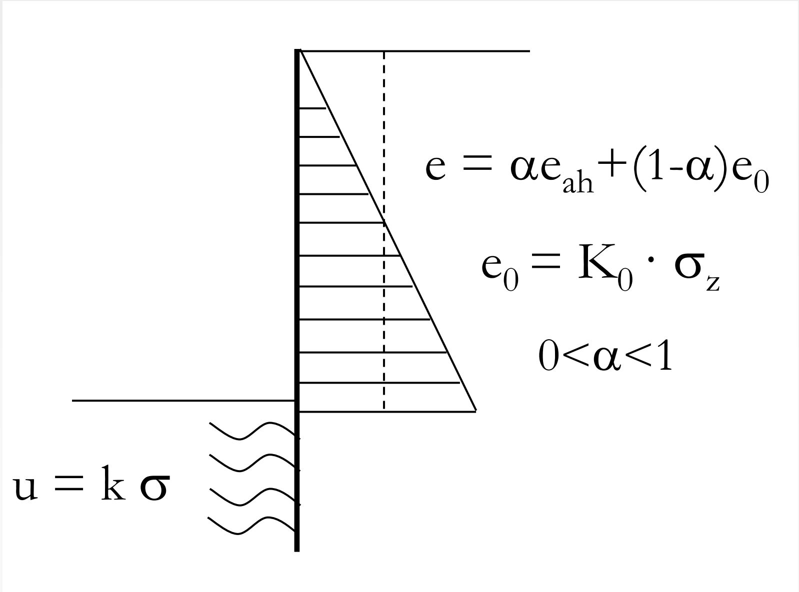
Extended Blum method for stiff anchors and stiff props

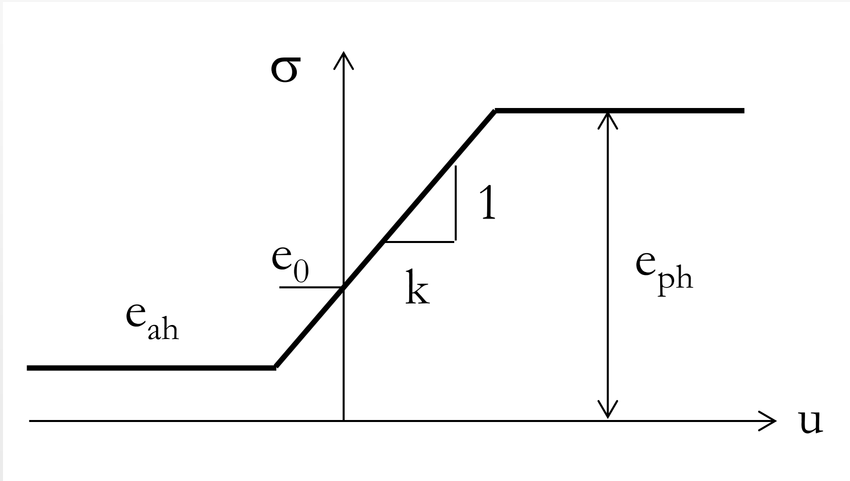


passive-active | resulting pressure | redistribution

The rectangular redistribution increases the anchor force A and reduces the embedment t. This is realistic for stiff anchors and stiff props.

Presently in Germany

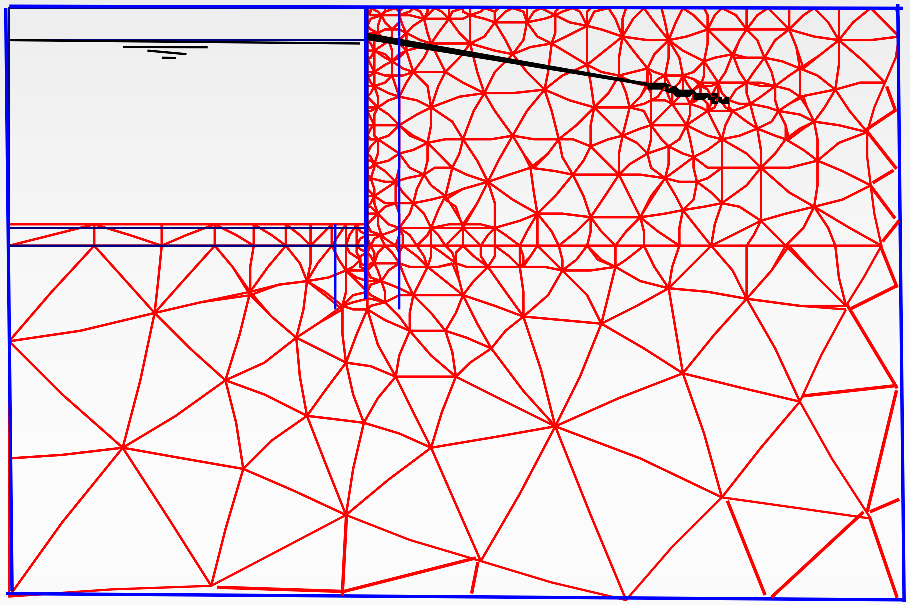




Assessment of spring constants is difficult.

For <u>deep</u> excavations we need FEM !

FE study of single-anchored wall with free-earth support



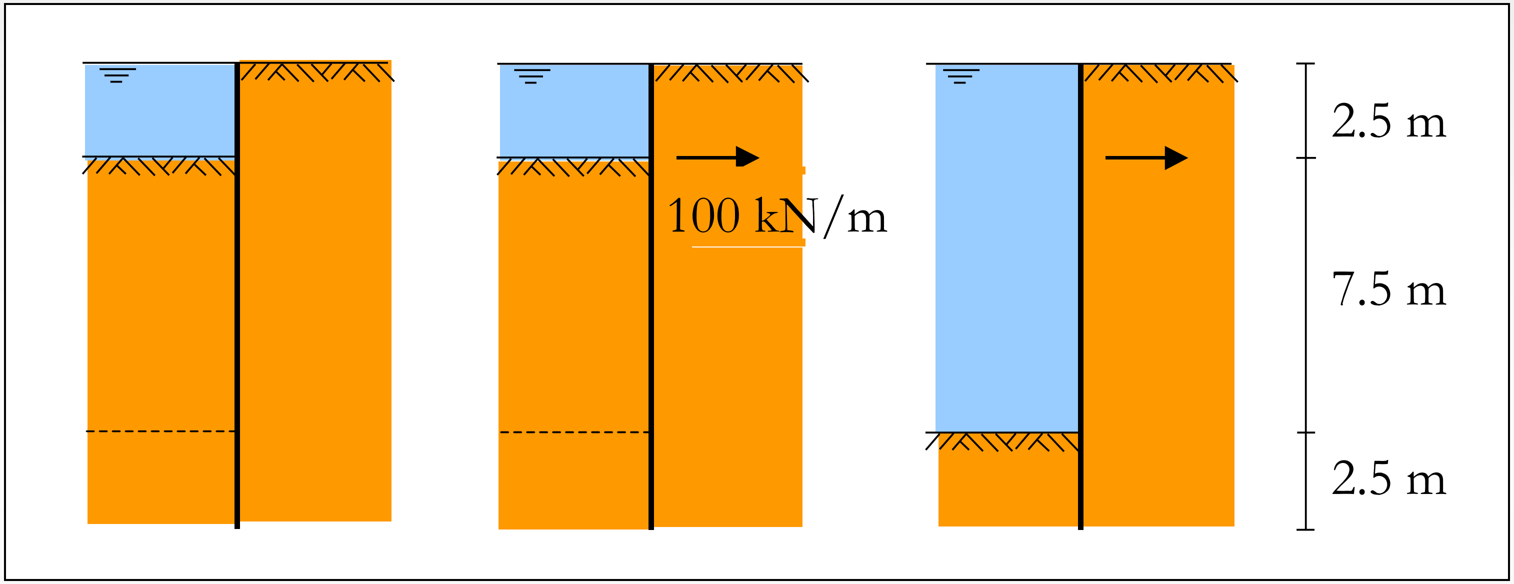
Finite Element Analysis

We will focus on input data and computational results, but not at all on the finite element method.

We will use the advanced Hardening Soil Model, rather than the Mohr-Coulomb Model, in order to obtain more realistic results.

Single anchored wall with free earth support

constant anchor force: 100 kN/m



soil properties:

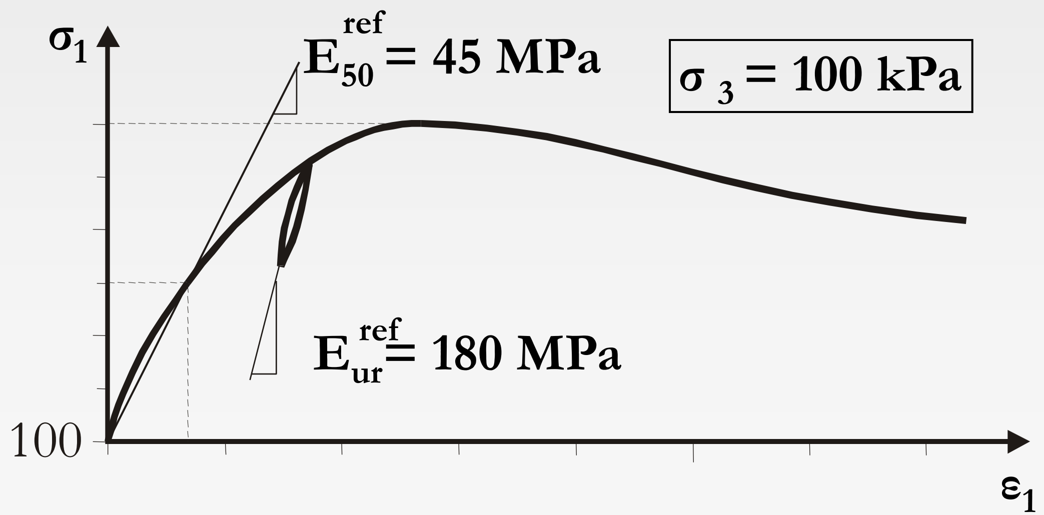
$\gamma' = 10 kN/m^3$ $c' = 2$ kPa $\varphi' = 30°$ $\delta = 20°$

dense sand: $E_{oed} = 45$ Mpa $E_{ur} = 180$ Mpa ($p_{ref} = 100$ kPa)

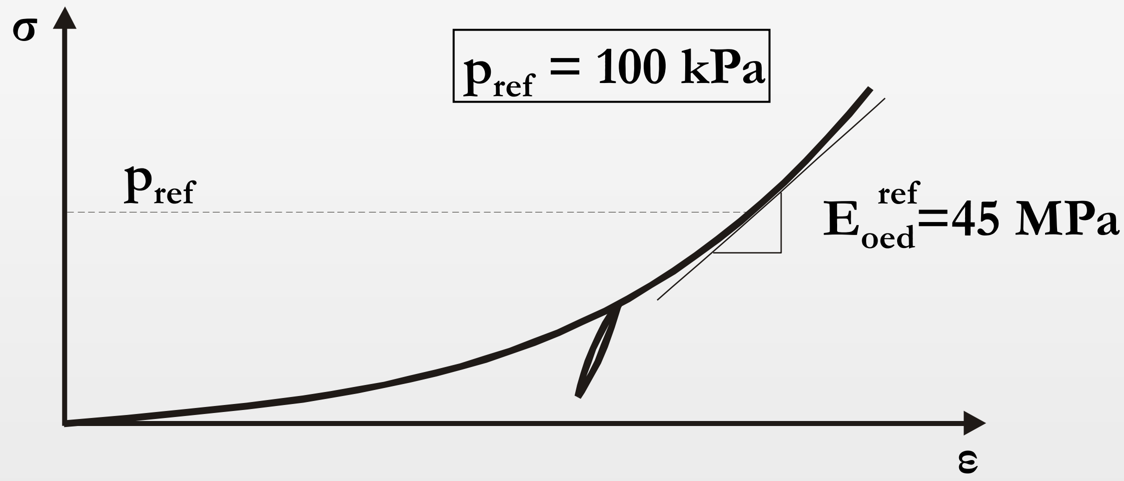
wall stiffness: stiff diaphragm wall: $EI = 225\ MNm^2/m$

Berlin Sand

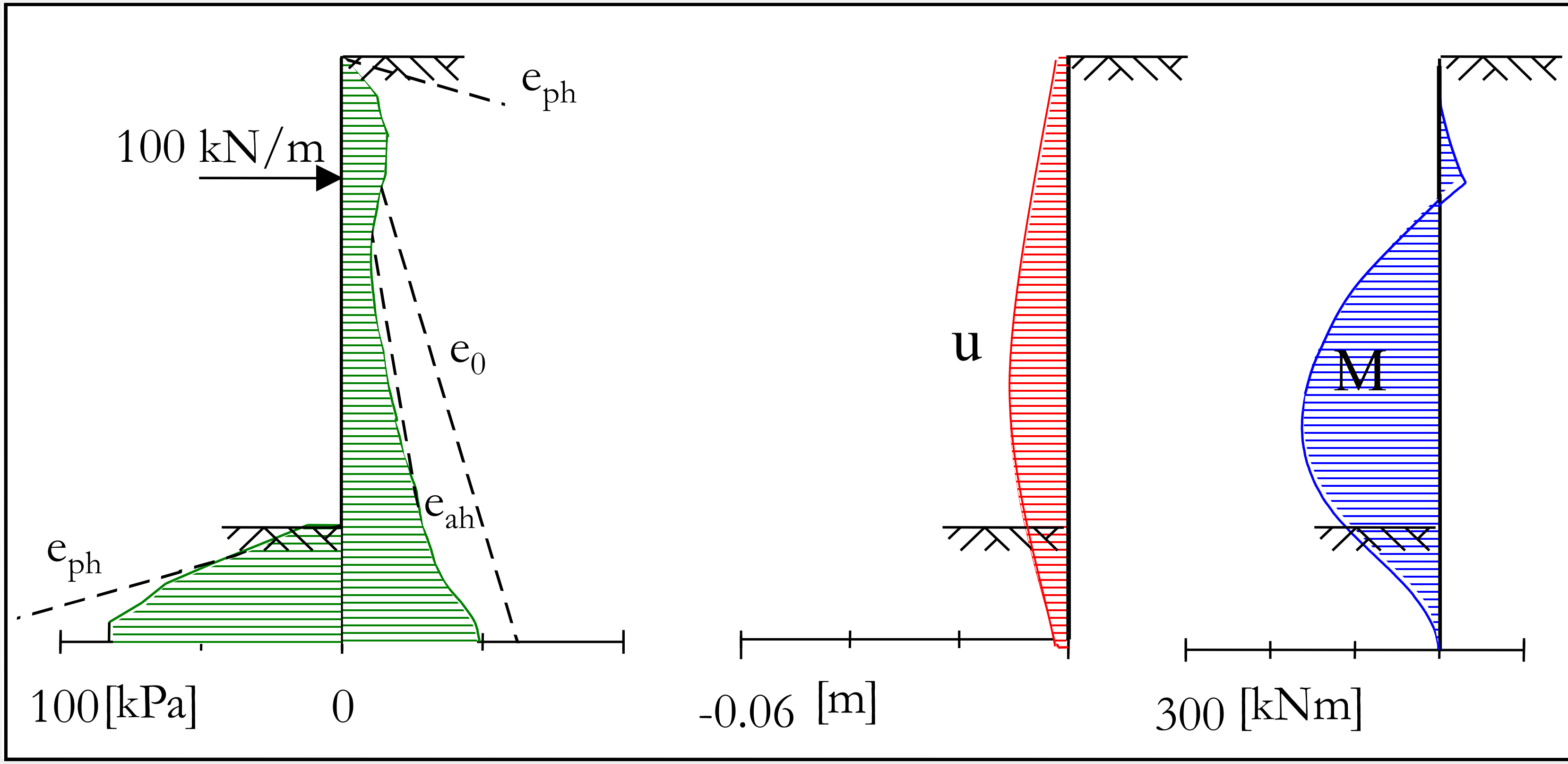
triaxial test



oedometer test



Results of finite element analysis



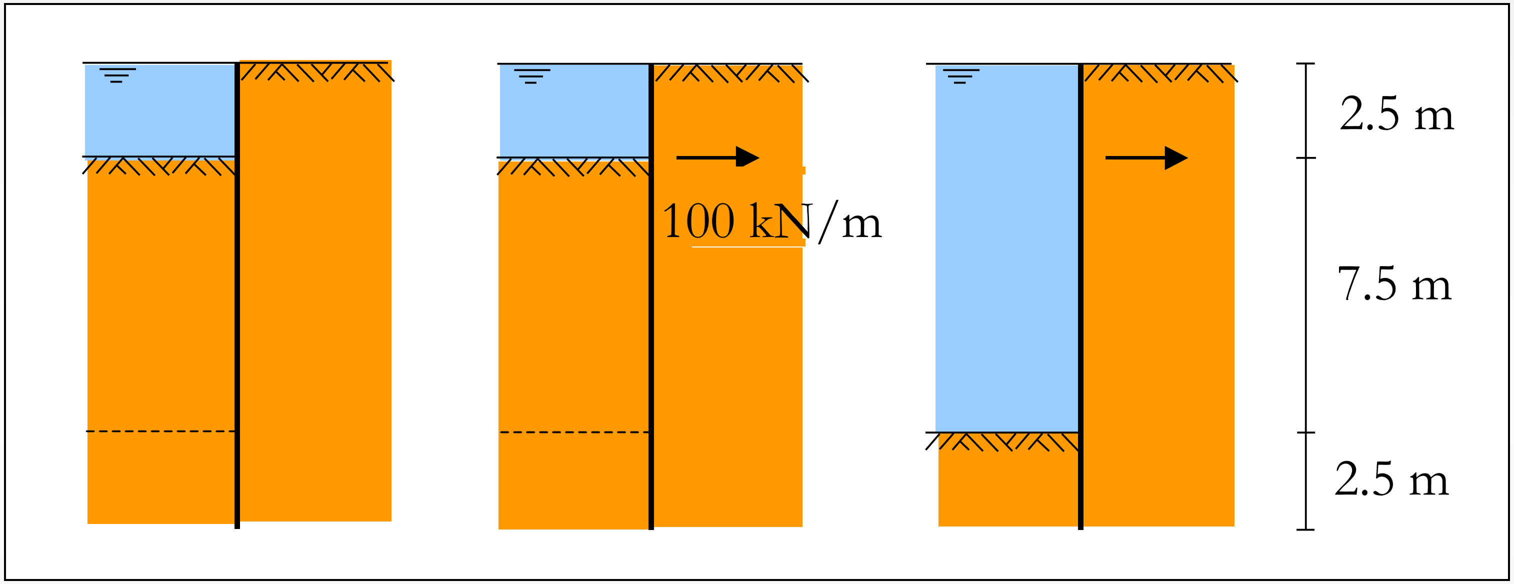
effective earth pressure

horizontal displacements

bending moments

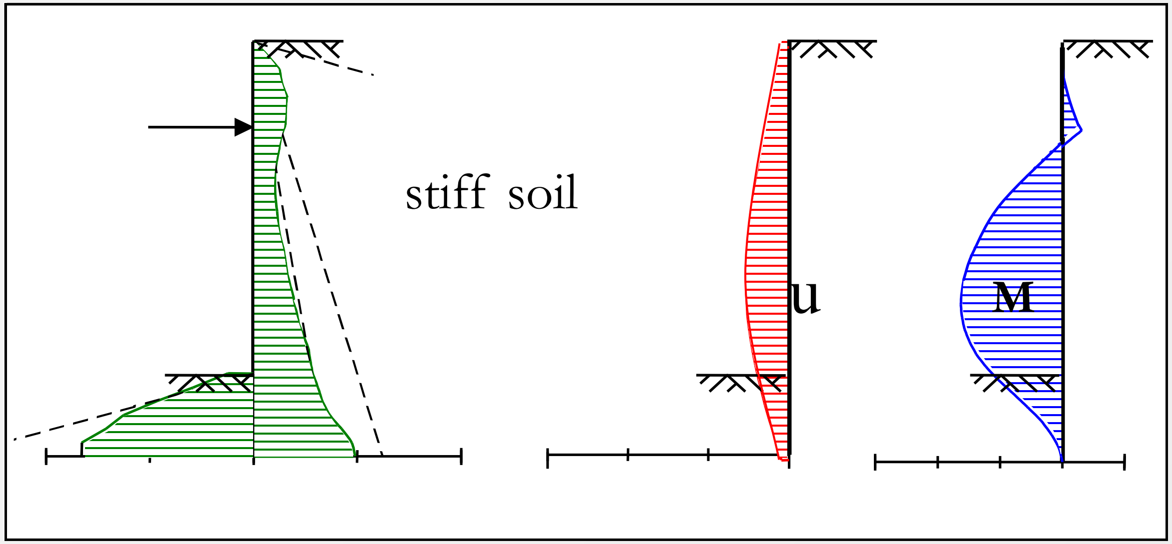
Extended FE study of single anchored wall with free earth support

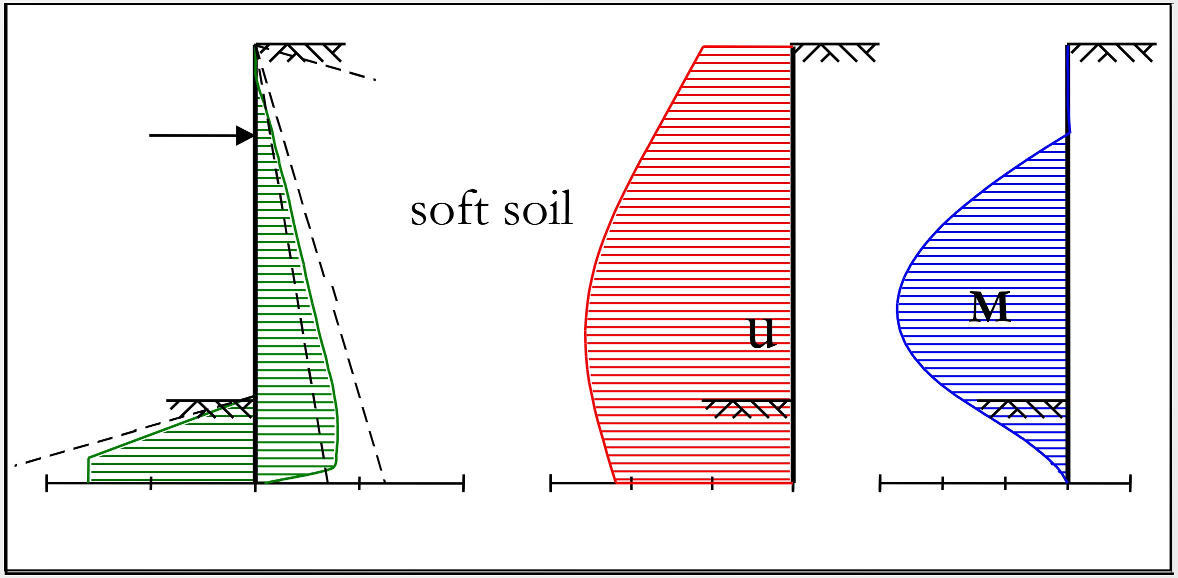
- stiff soil versus soft soil -



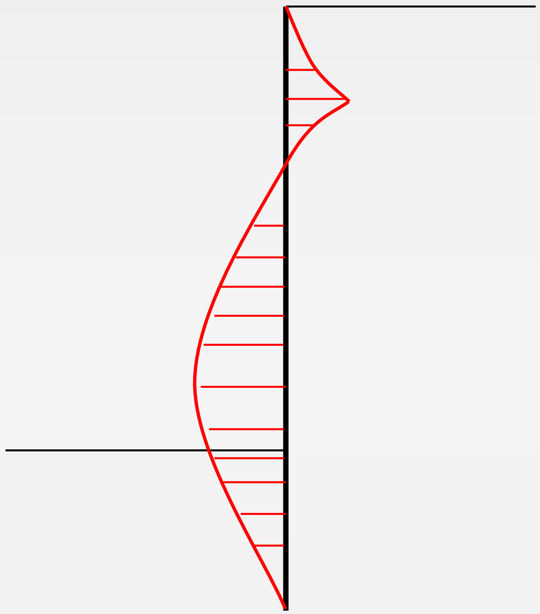
- stiff soil: $E_{oed} = 45$ Mpa $E_{ur} = 180$ Mpa ($p_{ref} = 100$ kPa)
- soft soil: $E_{oed} = 3$ Mpa $E_{ur} = 12$ Mpa ($p_{ref} = 100$ kPa)

Results of finite element analyses

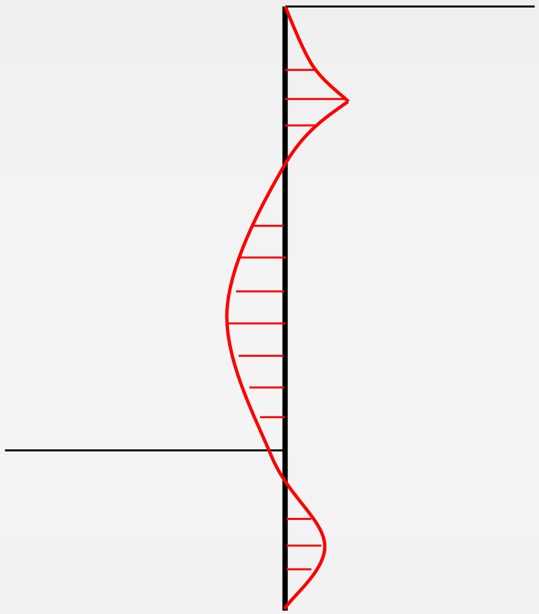




From free to fixed earth support

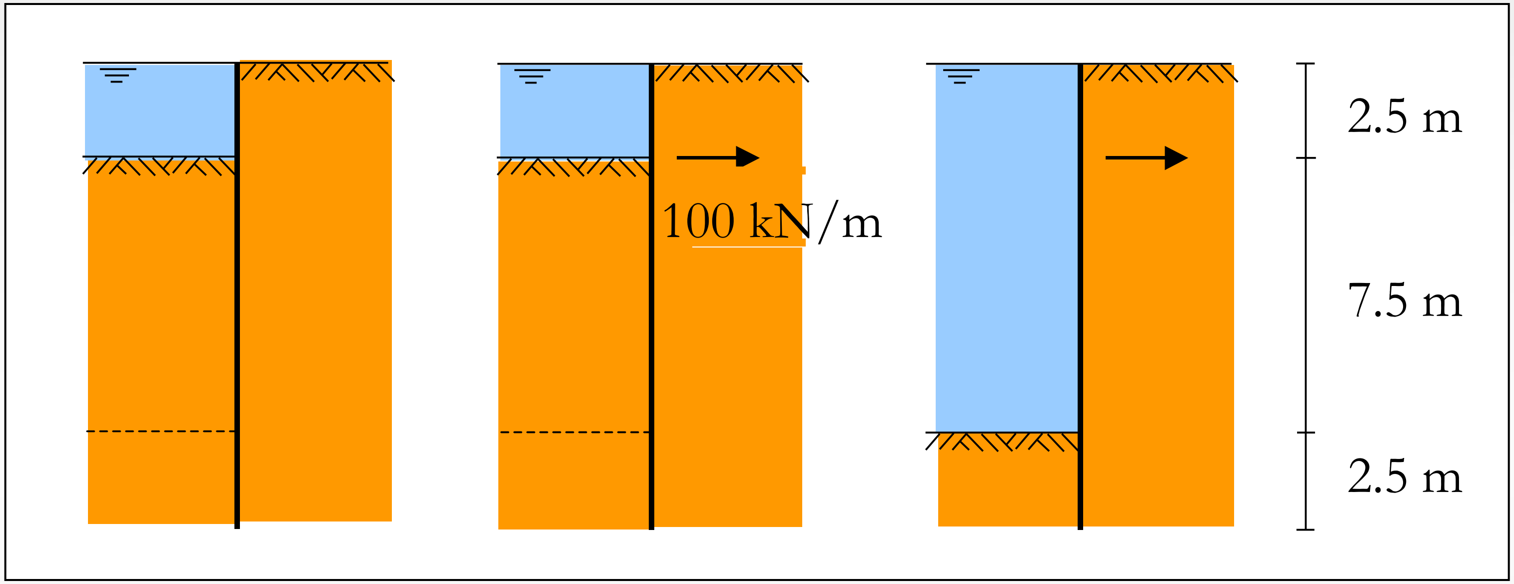


bending moments for free earth support



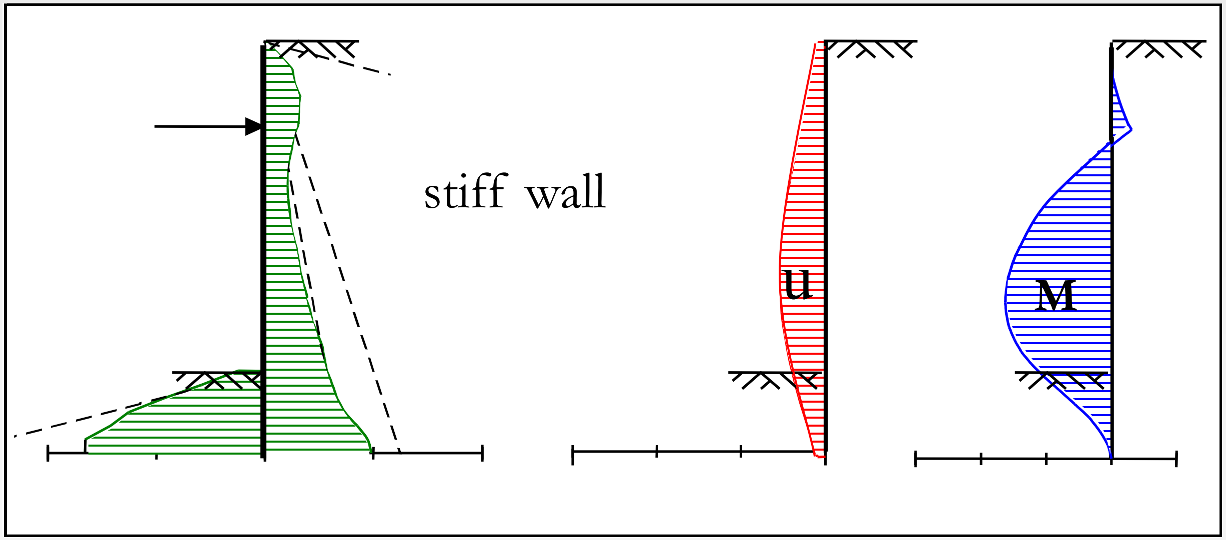
bending moments for fixed earth support

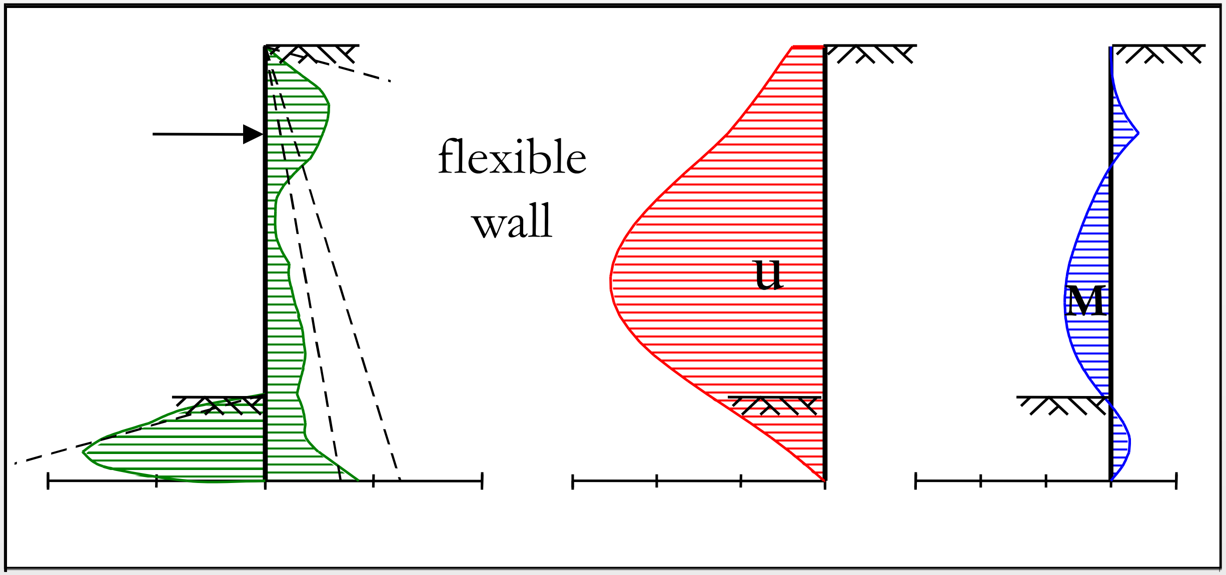
Single anchored wall with free and fixed earth support



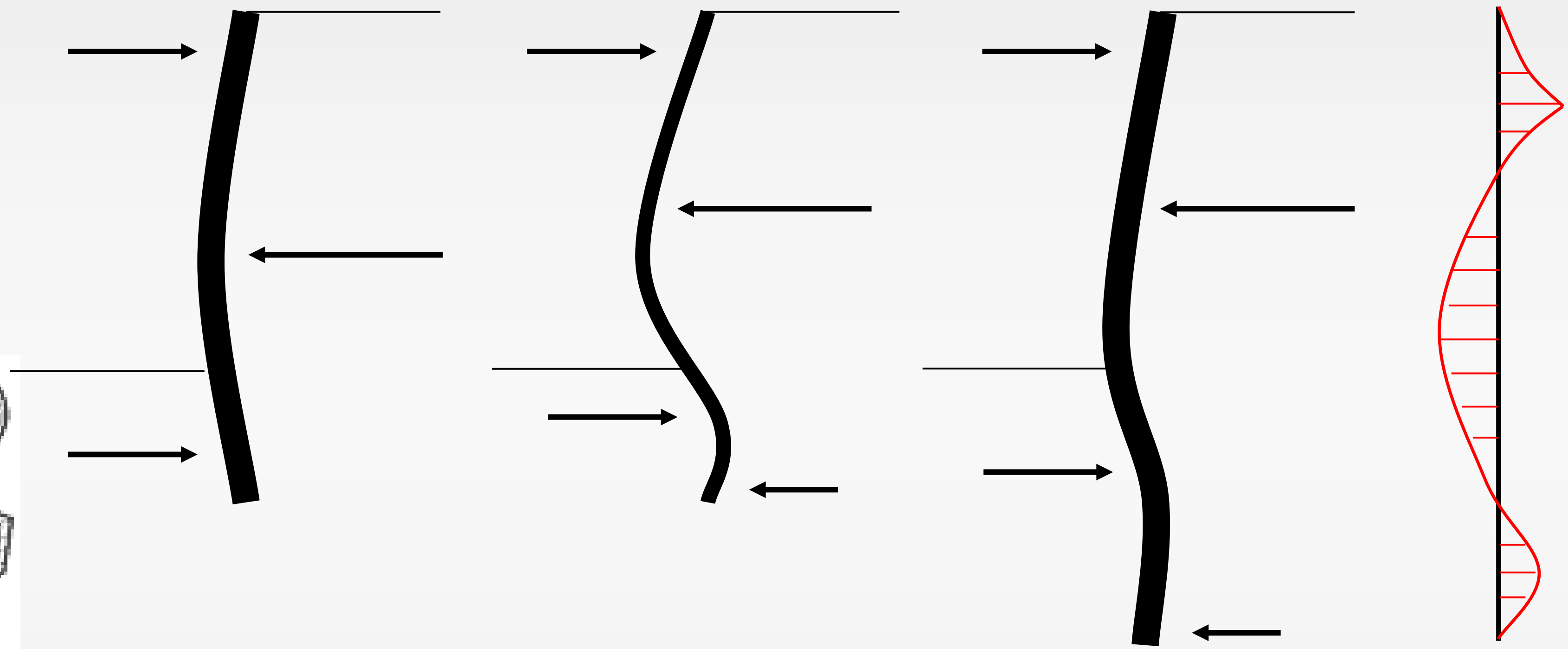
- stiff wall: EI = 225 MNm^2/m
- flexible wall: EI = 15 MNm^2/m

Results of finite element analyses





Free and fixed earth support



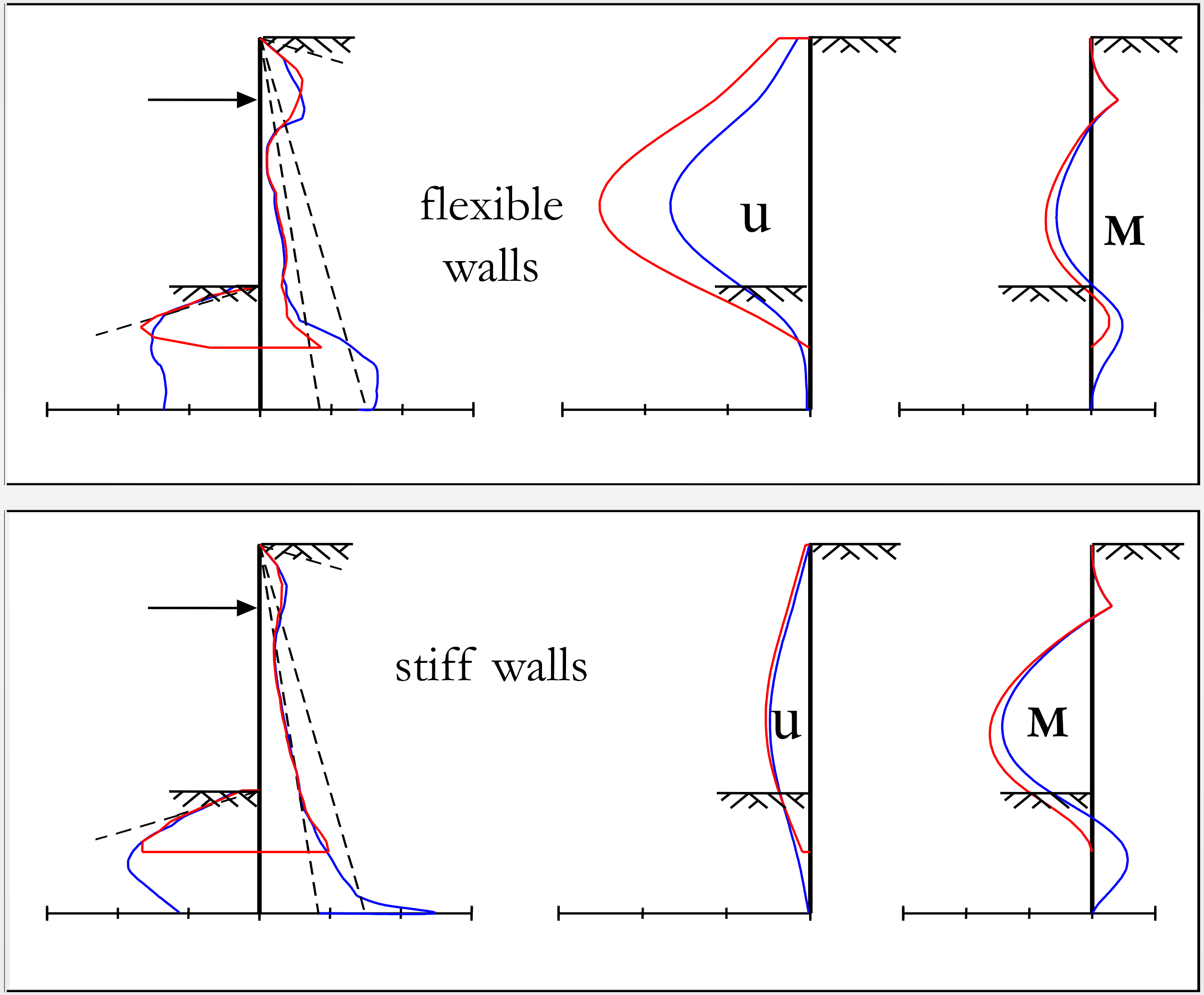
stiff wall
free earth support

flexible wall
fixed earth support

long wall
fixed earth support

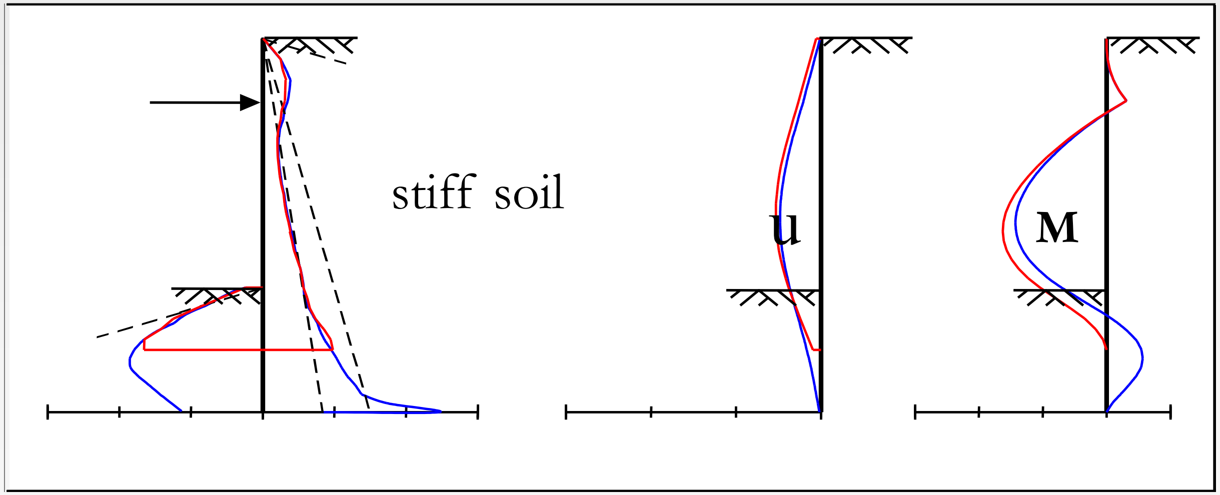
bending
moments

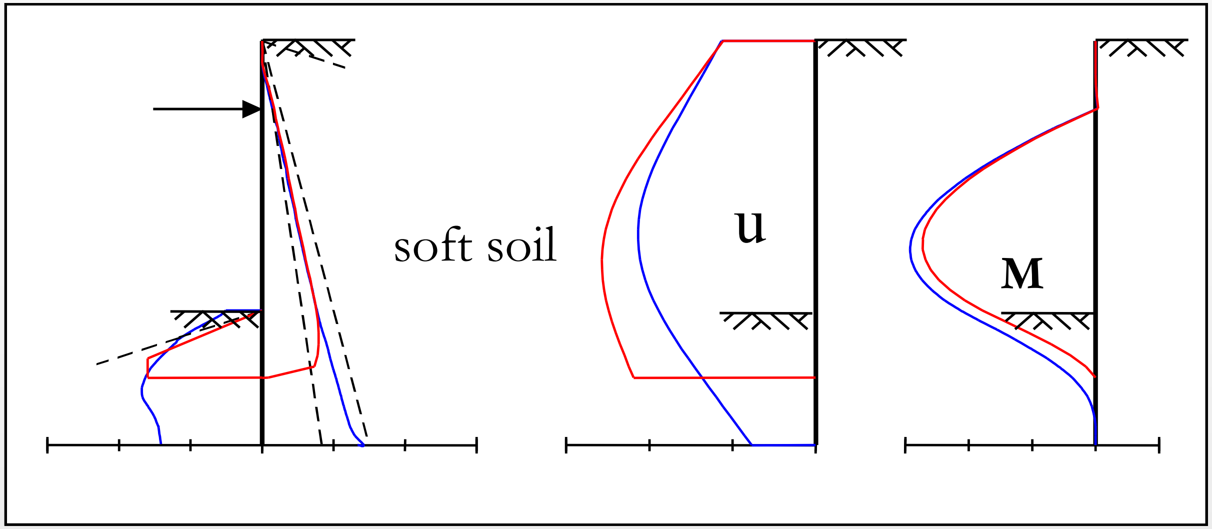
Walls with penetration depths of 2.5 m and 5 m in stiff soil
- short wall versus long wall -



→ **Long walls in stiff soil give fixed earth support**

Stiff wall with penetration depths of 2.5 m and 5 m
- short wall versus long wall -

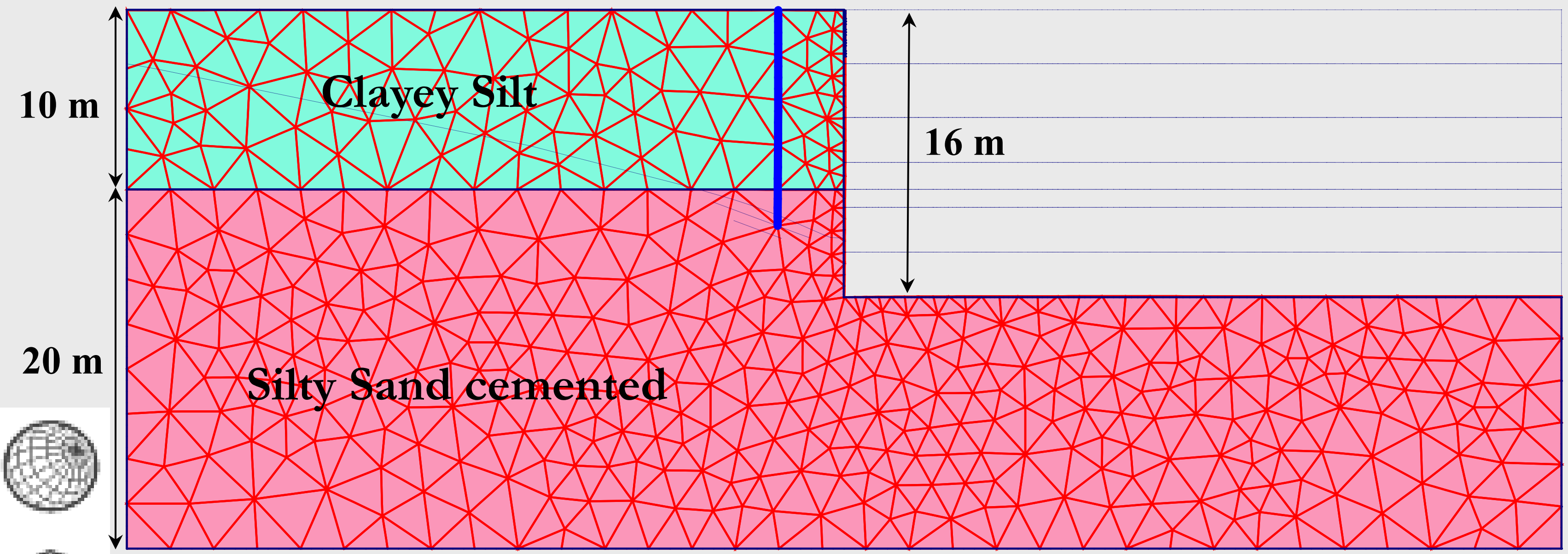




→ **Stiff long wall in soft soil does not give fixed earth support**

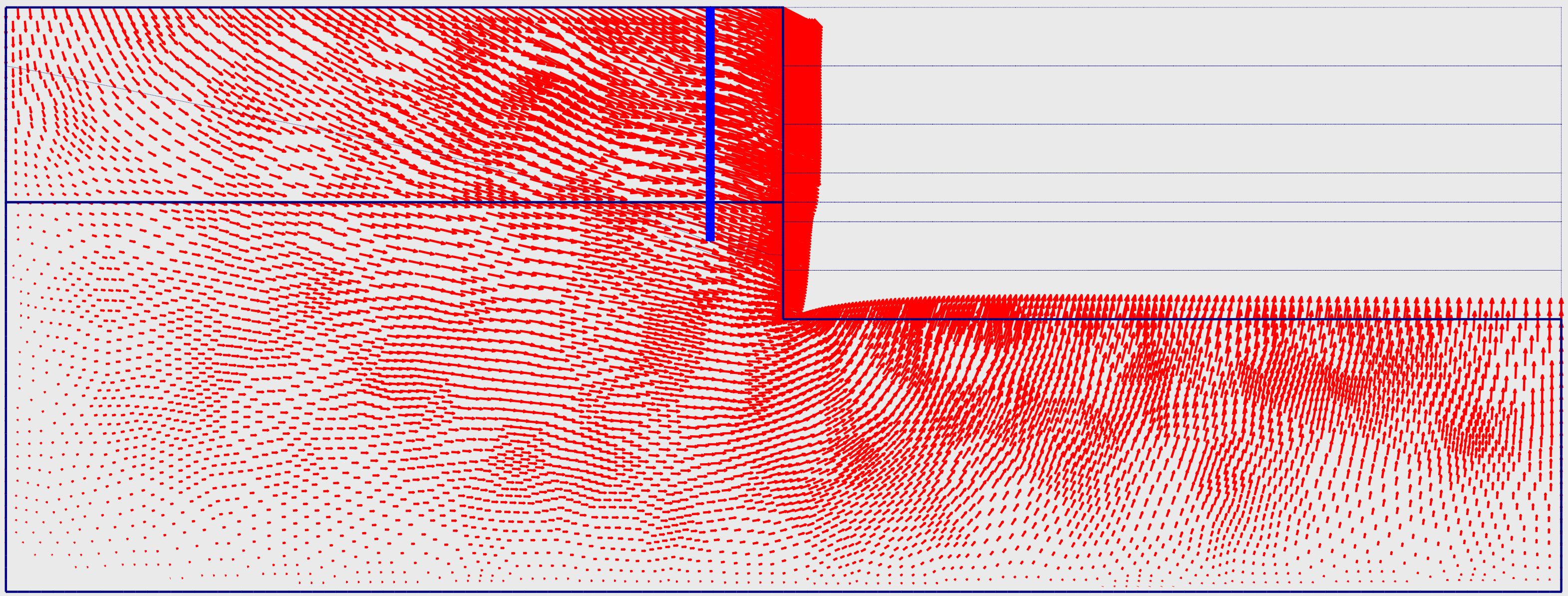
Case study: POINS Project in Jakarta-Indonesia

Deep excavation in residual soil is possible to be constructed with open cut method.

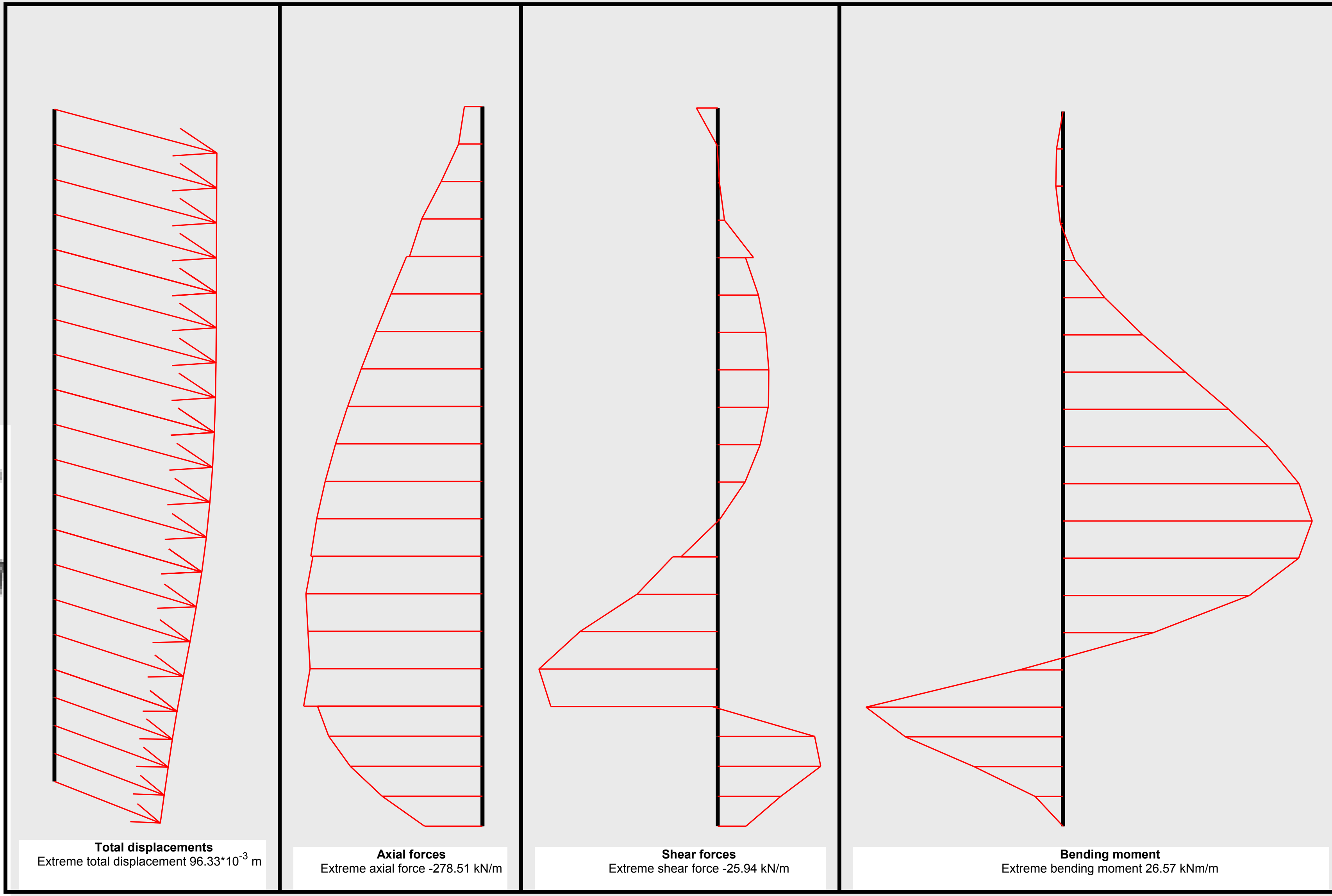


Bored Piles: EI = 17.6 MNm^2/m (d = 0.5m c/c 1.5 m L = 12 m)

Number	Identification	Type	gam_dry [kN/m^3]	gam_wet [kN/m^3]	k_x [m/day]	k_y [m/day]	nu [-]	E_ref [kN/m^2]	c_ref [kN/m^2]	phi [°]	R_inter [-]	Interface Permeability [-]
1	Clayey Silt	Undrained	10	14.2	0.0127	0.127	0.3	6300	56.25	0	1	Drain
2	Silty Sand Cemented	Drained	12.65	16.45	1.27	1.27	0.2	25200	100	40	1	Drain



Total displacements
Extreme total displacement 111.53×10^{-3} m


Total displacements
Extreme total displacement 96.33*10^{-3} m
Axial forces
Extreme axial force -278.51 kN/m
Shear forces
Extreme shear force -25.94 kN/m
Bending moment
Extreme bending moment 26.57 kNm/m

Case study: "Daimler" Excavation in Berlin

Single-anchored walls were a.o. applied for the excavation of the "Daimler-Benz" project in Berlin (early nineties). This very large and deep excavation had a varying excavation depth between 18 and 22 m. The construction sequence included underwater excavation and underwater concreting to provide a groundwater cut before dewatering. The anchors were obviously installed just above the groundwater level at a depth of about 3 m below the soil surface. Anchors were prestressed up to 550 kN/m.

Considering a wide excavation, we focus on a quasi-symmetrical half with a width of 30 m and a depth of 18.2 m. At this cross section the diaphragm wall had a total length of 25 m and a thickness of 1.2 m (EI = 2880 MN m^2/m). On modelling Berlin soil conditions, we neglected a man made fill of about 3 m and also a layer of marl. Instead the entire first 20 m were modelled as a medium dense sand with $\varphi' = 35°$. For depths beyond 20 m, there is a dense sand with $\varphi'=37.5°$. The stiffness moduli of this deep sand are 25% higher that those of the top sand.

Codes of practise tend to prescribe very low wall friction angles for diaphragm walls, as the filter cake is supposed to produce a kind of lubrication. The author, however, considers such a wall macroscopically rough and tends to use relatively large values for the wall friction angle. We used a factor of 0.8 for the ratio of $\tan\delta$ over $\tan\varphi'$. The finite element mesh was given a depth of 100 m as we were also interested in assessing heave at the base of the excavation.