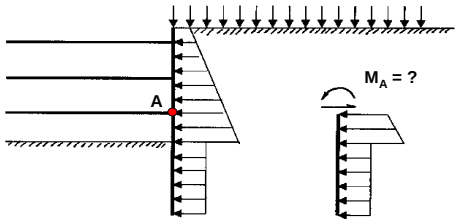
Toe Kick-in Stability



- Is it acceptable to have negative net pressure?
- How can we overcome negative net pressure?
- How do we compute M_A?
- What is the required penetration depth?

1

P_a & P_f are based on unfactored strength:

Toe Kick-out Stability

Method 1:

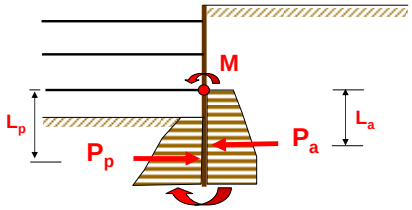
$$Fs = \frac{P_p L_p}{P_a L_a}$$

Method 2:

$$Fs = \frac{P_p L_p + M_{all}}{P_a L_a}$$

Method 3:

$$Fs = \frac{P_p L_p + M_{ult}}{P_a L_a}$$



P_{pf} & P_{af} are based on factored strength:

Method 4:

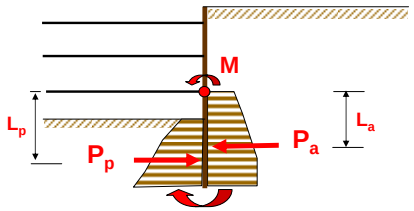
$P_{pf} L_p > P_{af} L_a$

Method 5:

$P_{pf} L_p + M_{all} > P_{af} L_a$

2

Toe Kick-out Stability

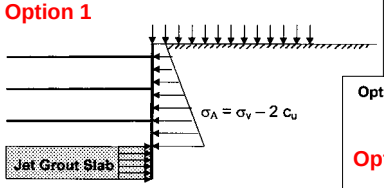


1. How do you determine the active and passive earth pressures?
2. Assuming P_a and P_p are known, which of the five methods would you use?

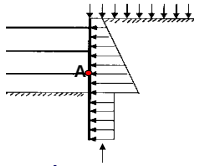
3

How to overcome the negative net pressure?

Option 1

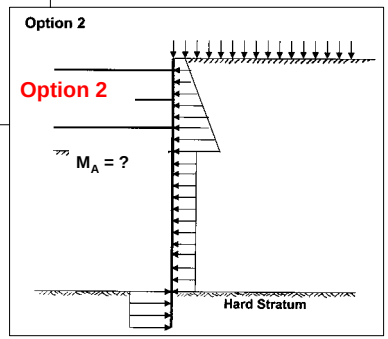


Add JGP slab



negative net pressure

Option 2

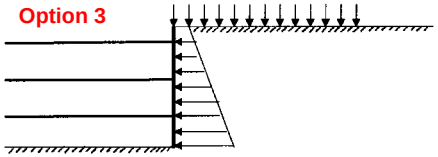


Penetrate into hard stratum

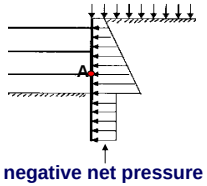
4

How to overcome negative net pressure?

Option 3



Use shorter wall



negative net pressure

Would it work?

It depends on the basal heave stability.

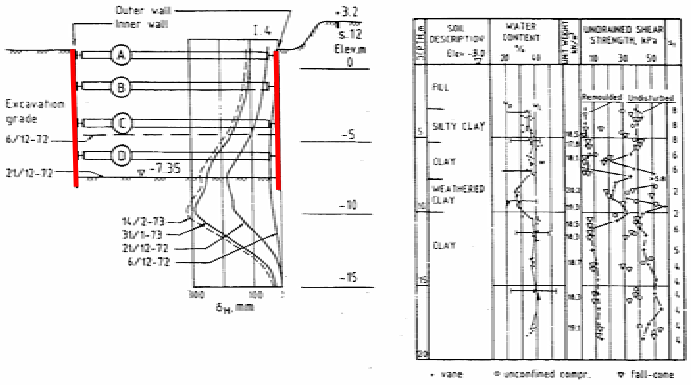
FS ⩽ 1.0 Don't try!

FS > 1.0 Should work!

5

A Deep Excavation in Oslo

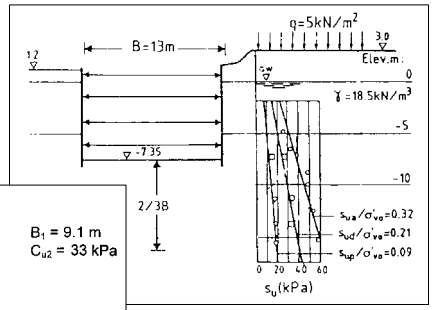
Gunnar Aas (NGI Publication No. 156, 1985)



6

A Deep Excavation in Oslo

(Aas, 1985)



Modified Terzaghi

H = 10.35 m B = 13 m B_1 = 9.1 m

γ = 18.5 kN/m³ C_{u1} = **30 kPa** C_{u2} = 33 kPa

q_s = 5 kPa

$$FS = \frac{5.7\, c_{u2}\, B_1 + c_{u1}\, H}{\gamma\, H\, B_1 + q_s\, B_s} = \mathbf{1.13}$$

Bjerrum & Eide (1956)

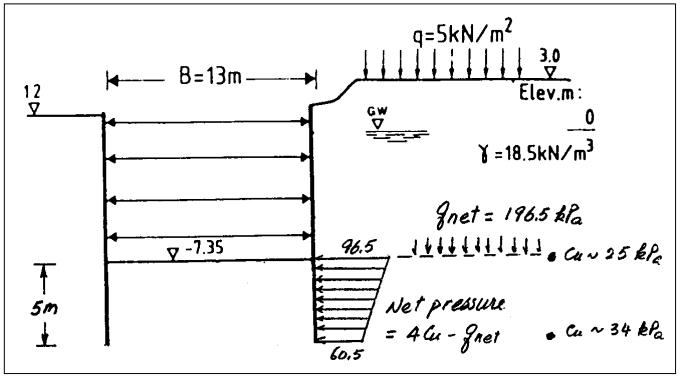
H / B = 0.8 B / L = 0.68 N_c = 7.1

$$FS = \frac{c_{u2}\, N_c}{\gamma\, H + q_s} = 1.20$$

7

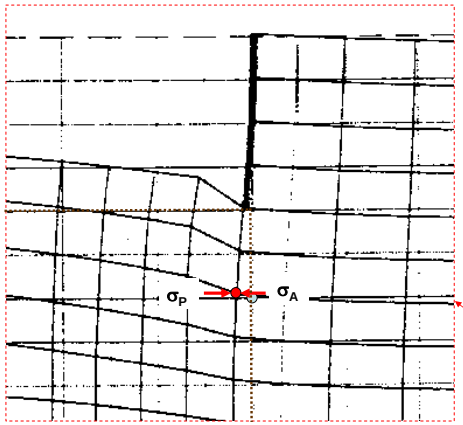
A Deep Excavation in Oslo

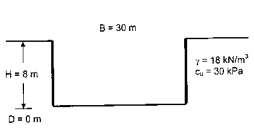
Gunnar Aas (NGI Publication No. 156, 1985)



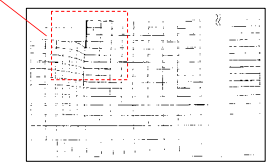
8

Excavation in Soft Clay with D=0 m





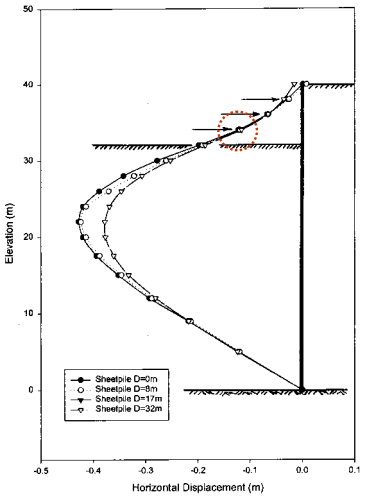
FS = 1.29 (Terzaghi)



9

Effect of Penetration Depth on Bending Moment

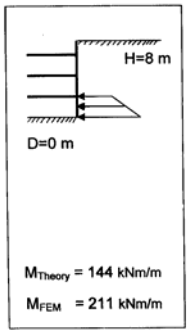
D=0, 8 & 17 m

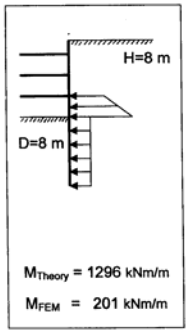


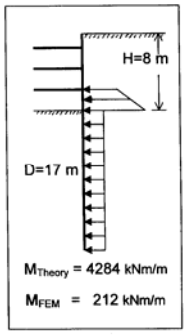
10

Excavation in Soft Clay with Sheetpile wall & D = 0, 8 & 17 m

FS = 1.29 (Terzaghi)

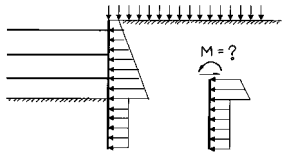






11

Should theoretical earth pressures be used in the analysis?



Before P.C.⇒ Acceptable

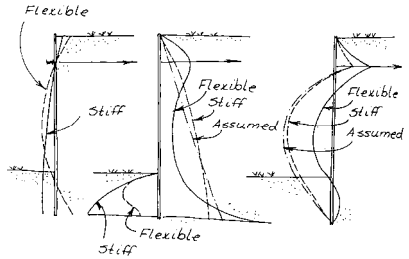
After P.C. ⇒ Can do better!

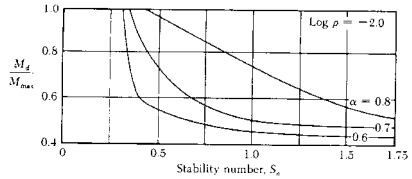
Main shortcomings of theoretical approach:

- Soil-structure interaction
- Soil arching
- Mode of deformation
- Soil conditions

12

Soil Arching & Rowe's Moment Reduction

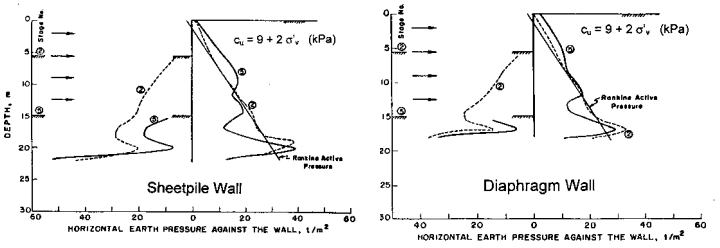




13

Horizontal Earth Pressures on Wall

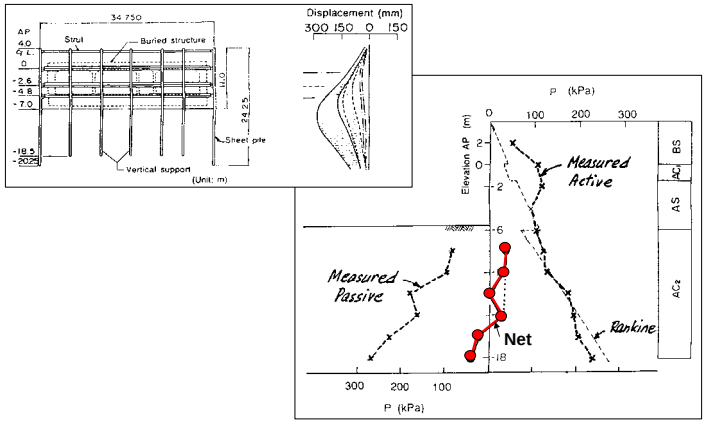
Mana (1986)



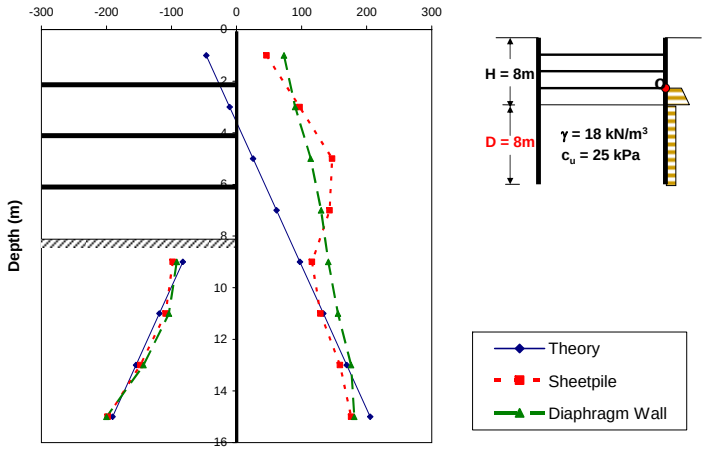
14

Earth Pressure on Wall of an Excavation in Clay

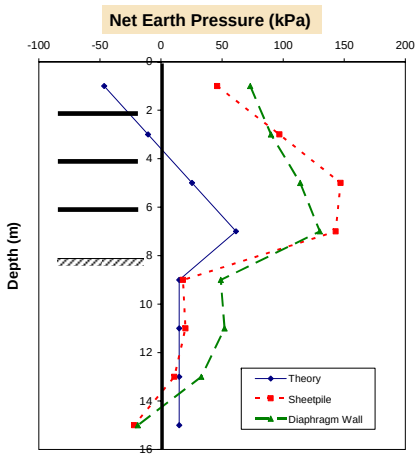
(Tanaka, 1996)

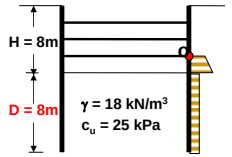


Earth Pressure (kPa)



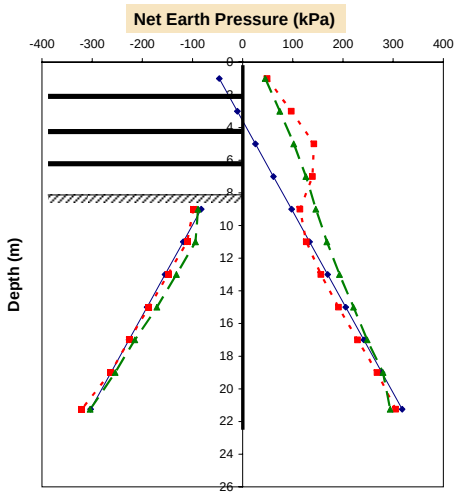
16



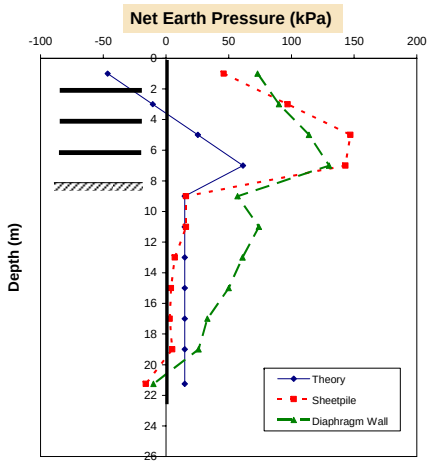


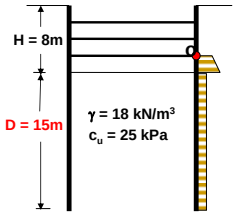
	M_o(kNm/m)
Theory	838
Sheetpile	304
Diaphragm	1120

17



18

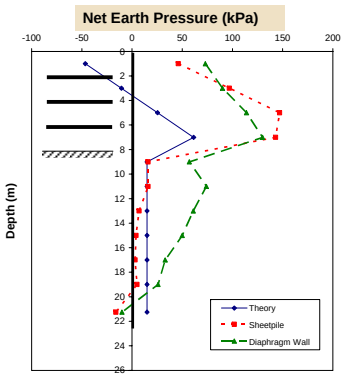




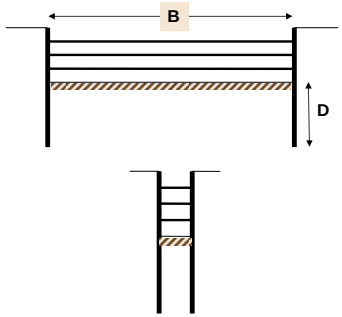
	M_o(kNm/m)
Theory	2121
Sheetpile	298
Diaphragm Wall	601 (M_{max}=1010)

19

Soil-structure interaction affects P_A & P_P



B & D can affect P_A & P_P



Analysis based on earth pressure theories can lead to unrealistic results!

20

Toe Kick-out Stability

P_a & P_p are based on unfactored strength:

Method 1:

$$Fs = \frac{P_p L_p}{P_a L_a}$$

Method 2:

$$Fs = \frac{P_p L_p + M_{all}}{P_a L_a}$$

Method 3:

$$Fs = \frac{P_p L_p + M_{ult}}{P_a L_a}$$

1. P_a should be obtained from FEA and not earth pressure theory .
2. P_p can be determined from earth pressure theory using unfactored strength.
3. Methods 4 & 5 not applicable because of (1).
4. Method 1 is conservative.
5. Method 2 is illogical. → M_{all} / Fs
6. Method 3 is a reasonable choice.

P_{pf} & P_{af} are based on factored strength:

Method 4:

$$P_{pf} L_p > P_{af} L_a$$

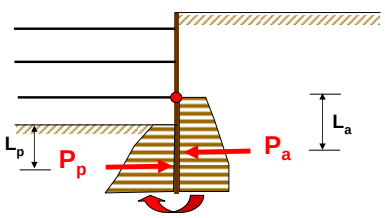
Method 5:

$$P_{pf} L_p + M_{all} > P_{af} L_a$$

21

Proposed Method for Toe Kick-in Stability

If FS against basal heave is adequate, it is not necessary to check toe stability.



$$Fs = \frac{P_p L_p + M_{ult}}{P_a L_a}$$

P_a from FEA

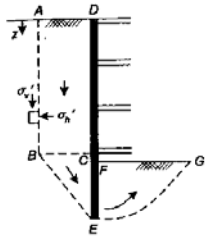
P_p from earth pressures theory

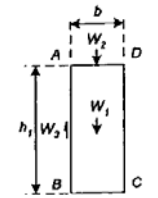
22

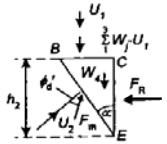
Method Endorsed by CIRIA C580 (2003)

Toe Stability

(Philips et al., 1993)



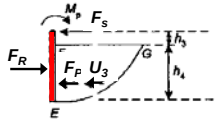




Stability requirements:

$$F_R \geq F_p + U_3 + F_s$$

$$F_R \cdot \tfrac{1}{2} h_2 \geq M_p + (F_p + U_3) \cdot (h_3 + \tfrac{2}{3} h_4)$$



23

Comments in CIRIA C580 (2003)

Such a method will provide only an approximate solution that is dependent upon the simplifying assumptions made in the calculations. **There is significant soil-structure interaction in a multi-propped wall and therefore soil-structure interaction analysis should be carried.**

24