Parametertolkning i Plaxis for avanserte modeller

MED ET EKSEMPEL FRA ET PROSJEKT

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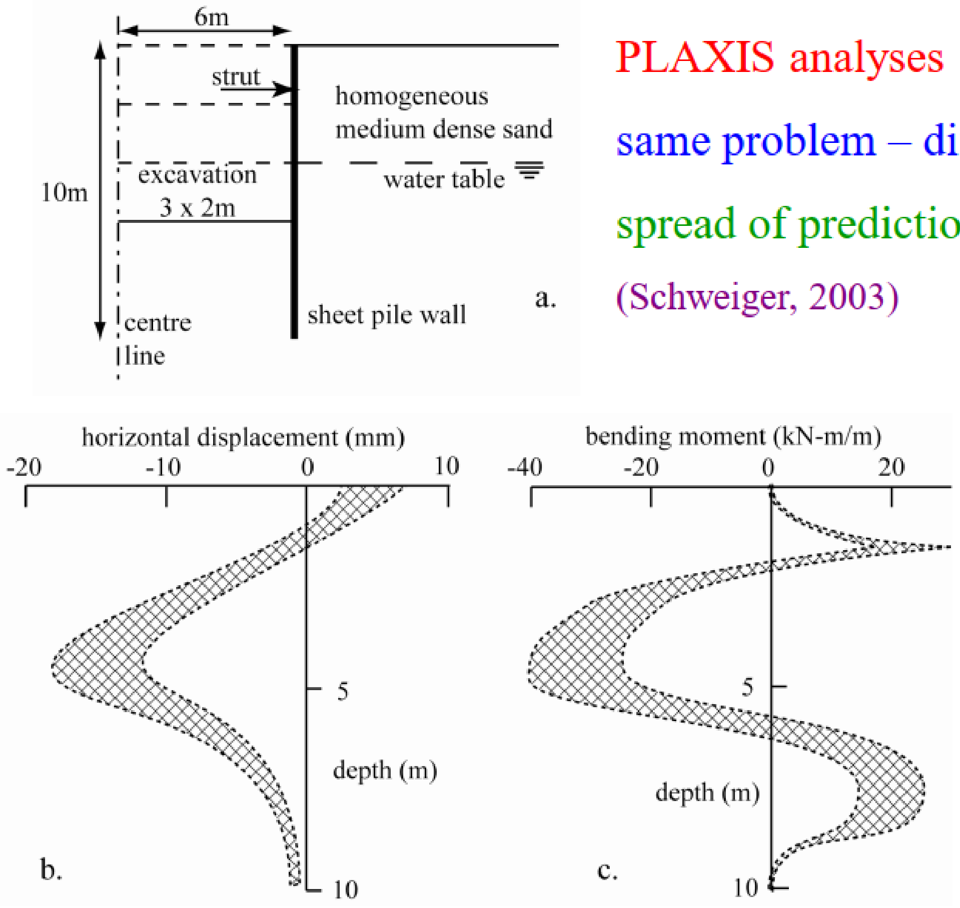
Motivasjon:

Stor variasjon!
Muligens årsak: ulike antagelser!



PLAXIS analyses

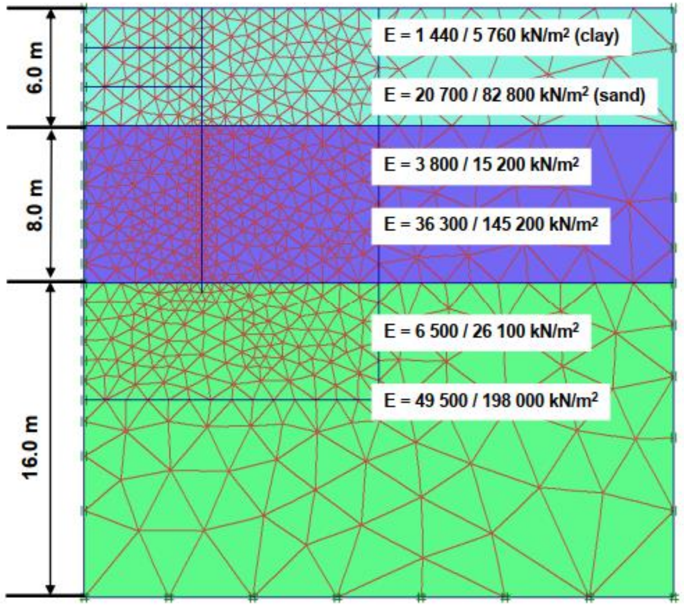
same problem – different modellers

spread of predictions

(Schweiger, 2003)

Fra «Soil modelling», NTNU kurs.

Et eksempel:



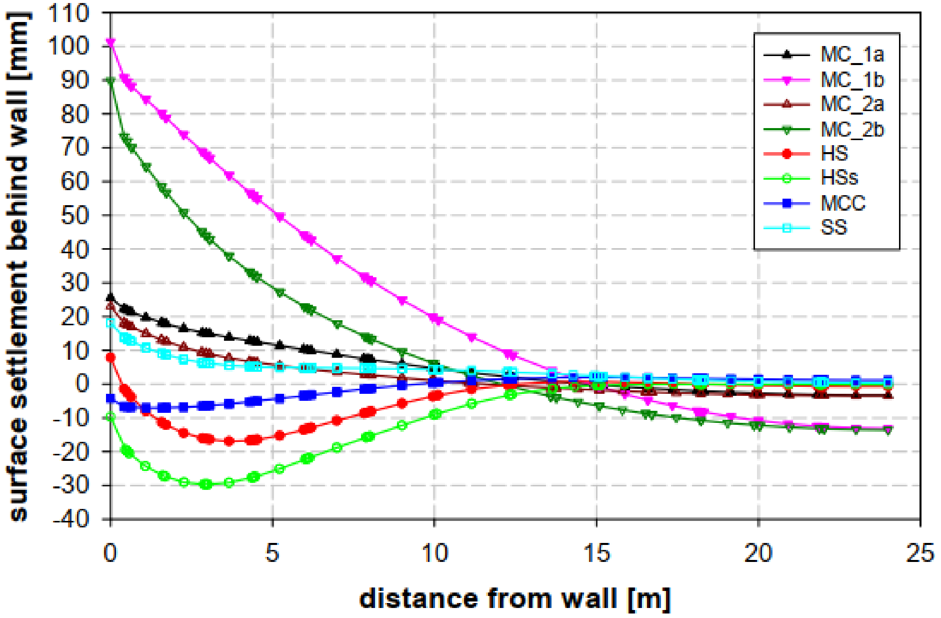
Mohr-Coulomb models

MC_1a: constant stiffness $E_{ur,ref}$

MC_1b: constant stiffness $E_{50,ref}$

MC_2a: 3 layers with average values based on E_{ur}

MC_2b: 3 layers with average values based on E_{50}



Fra «COMPUTATIONAL GEOTECHNICS», Plaxis kurs.

søppel inn → søppel ut

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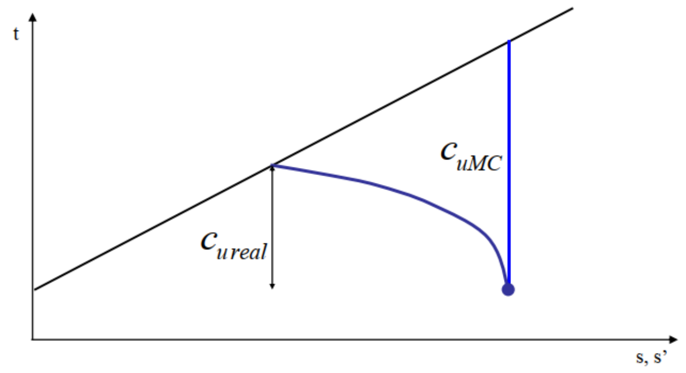
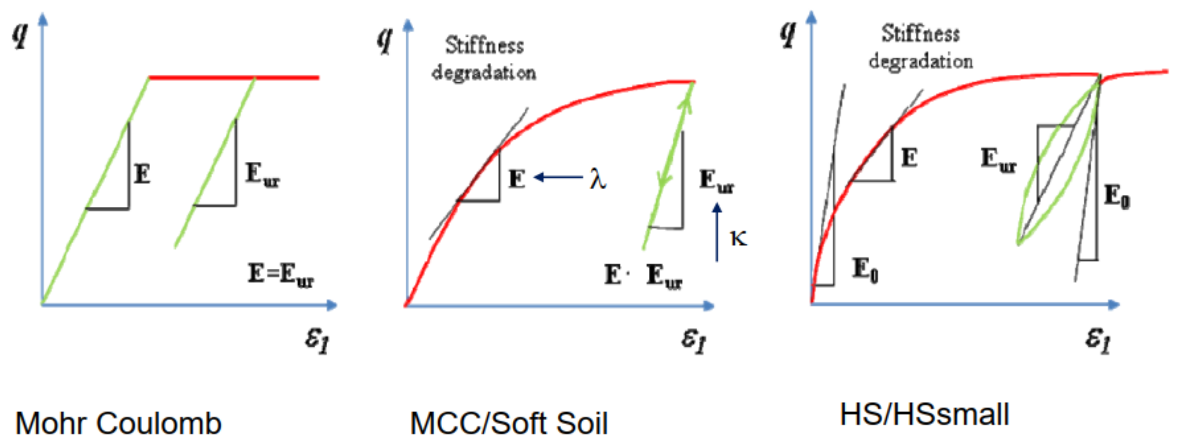
Begrensninger til Mohr Coulomb model

Modellen overestimerer udrenert skjærstyrke ved bruk av «undrained A»

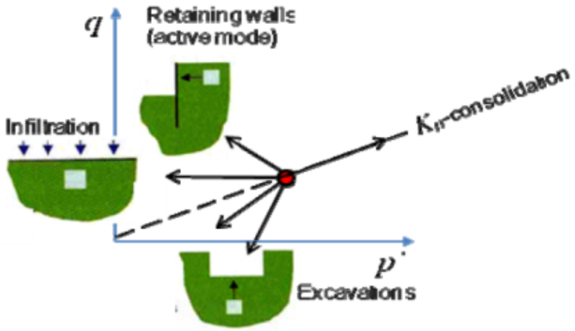


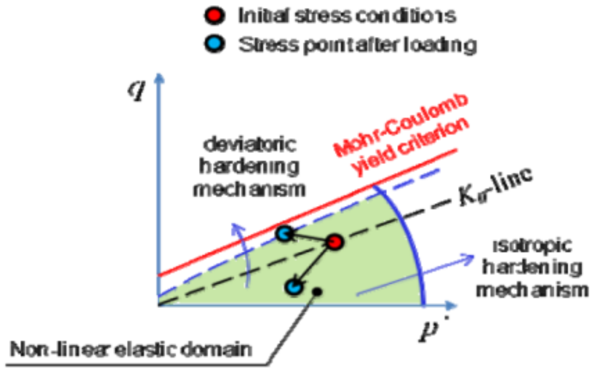
Kun en E-modul for MC modell:
Kan gi feil estimat på deformasjoner!



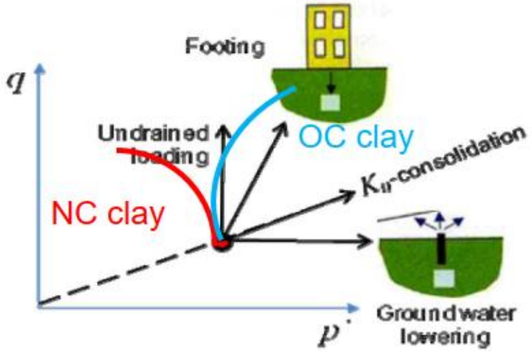
Fra «Soil Modelling and Numerical Analyses», AFRY/Chalmers kurs.

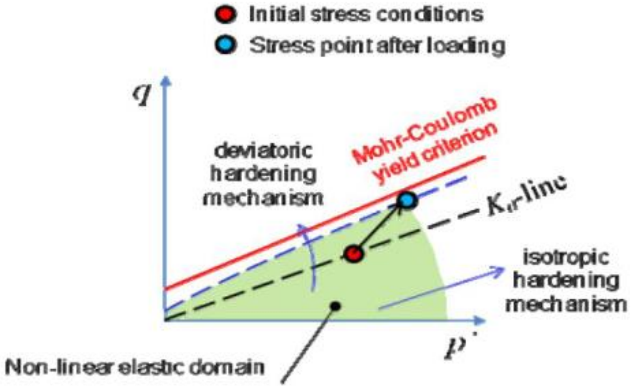
Eksempler på «avlasting»:





Eksempler på «pålasting»:





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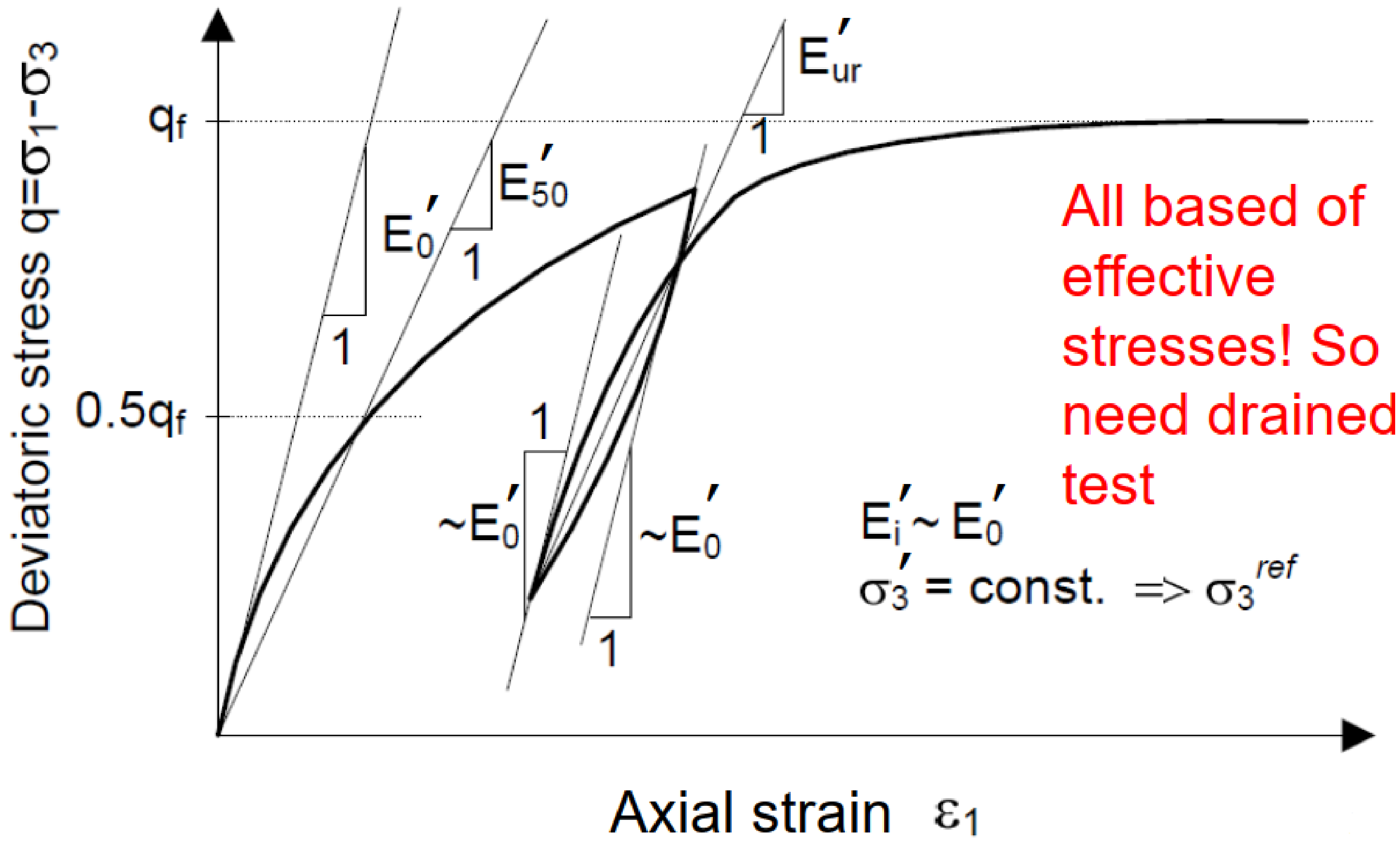
Ulike moduler for Hardening Soil modell



All based of effective stresses! So need drained test

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Parametere til ”hardening Soil/ HS small” modell

Parameter	Description
E_{50}^{ref}	Reference secant stiffness from drained triaxial test
E_{oed}^{ref}	Reference tangent stiffness from oedometer test
E_{ur}^{ref}	Reference unloading/reloading stiffness from drained triaxial test
p_{ref}	Reference stress level for which $E_{50} = E_{50}^{ref}, E_{oed} = E_{oed}^{ref}$ and $E_{ur} = E_{ur}^{ref}$
m	Power for stress-dependent stiffness
ν_{ur}	Unloading/reloading Poisson's ratio
c'	Effective cohesion
φ'	Effective friction angle
ψ	Dilatancy angle at failure
K_0^{NC}	Ratio between horizontal and vertical stresses at normally consolidated state
G_0^{ref}	Reference Small-strain shear stiffness (HSsmall only)
$\gamma_{0.7}$	Shear strain level where shear stiffness G has reduced to 70% of G_0 (HSsmall only)
K_0, OCR, POP	Initial stress state parameters (initial stress ratio, overconsolidation)

Referanse: 100 kPa

Fra Plaxis kurs/seminar om Hardening Soil

Stivhetsmodul for HS jordmodell

Stivhet avhenger av skjærtøyning, tøyning og avlasting/pålasting.

Shear hardening secant modulus:	$E_{50} = E_{50}^{ref}\left(\frac{\sigma_3{}' + a}{p_{ref} + a}\right)^m \Rightarrow E_{50} = E_{50}^{ref}\left(\frac{c\cos(\varphi) - \sigma_3' \sin(\varphi)}{c\cos(\varphi) + p_{ref}\sin(\varphi)}\right)^m$
Compression hardening tangent modulus:	$E_{oed} = E_{oed}^{ref}\left(\frac{\sigma_1{}' + a}{p_{ref} + a}\right)^m \Rightarrow E_{oed} = E_{oed}^{ref}\left(\frac{c\cos(\varphi) - \sigma_1' \sin(\varphi)}{c\cos(\varphi) + p_{ref}\sin(\varphi)}\right)^m$
Unloading/reloading tangent modulus:	$E_{ur} = E_{ur}^{ref}\left(\frac{\sigma_3{}' + a}{p_{ref} + a}\right)^m \Rightarrow E_{ur} = E_{ur}^{ref}\left(\frac{c\cos(\varphi) - \sigma_3' \sin(\varphi)}{c\cos(\varphi) + p_{ref}\sin(\varphi)}\right)^m$

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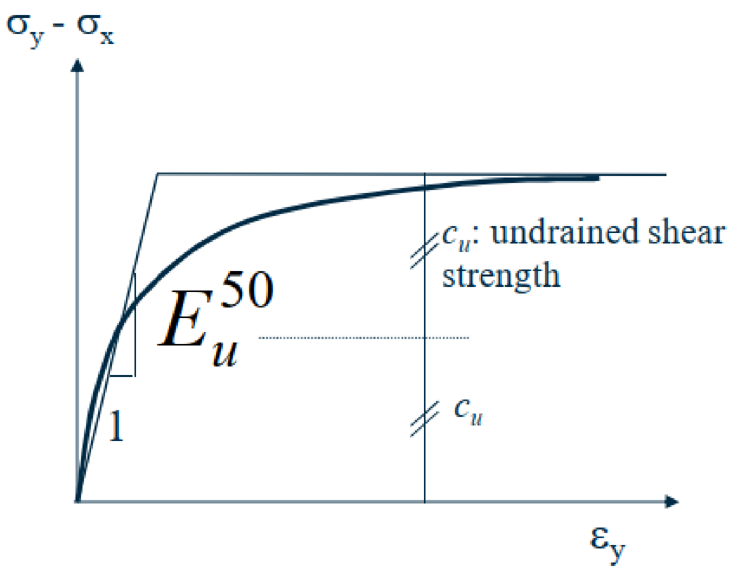
Modellen vil beregne stivhetsmodul for hvert «spenningspunkt».

Drenert stivhetsmodul for HS modell

Fremgangsmåte:

1. Tolkning av E_{50}^{lab} av alle treaksialforsøkene. Det er best å ha en «drenert» treakisialforsøk (ikke vanlig for leire). Tolk $E_{u,50,lab}$ slik:



2. Finn effektiv E'_{50}

$$E'_{50} = f \cdot E_u^{50}$$

$$f = \frac{1+\nu}{1+\nu_u} \approx 0.8$$ Hooke

$$f \approx 0.7$$ Brukes i Nederland

Drenert stivhetsmodul for HS modell

3. Finn ved p_{ref} (lik 100 kPa).

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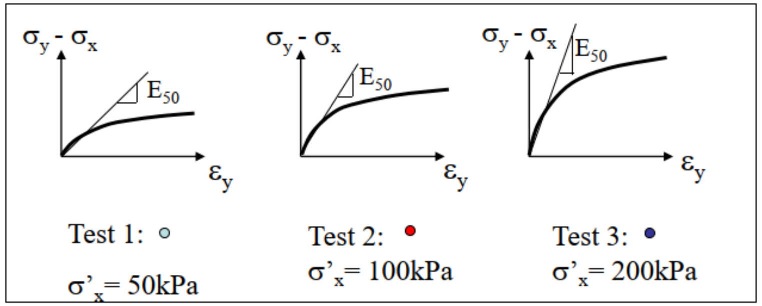
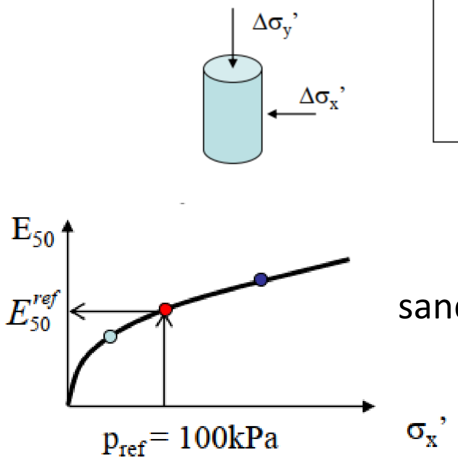
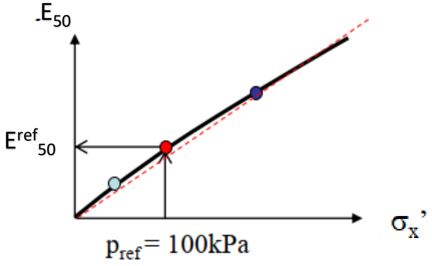


m kan variere mellom:
0,8 og 1,0 for leire
0,5 og 0,6 for sand
0,5 og 0,7 for silt



sand



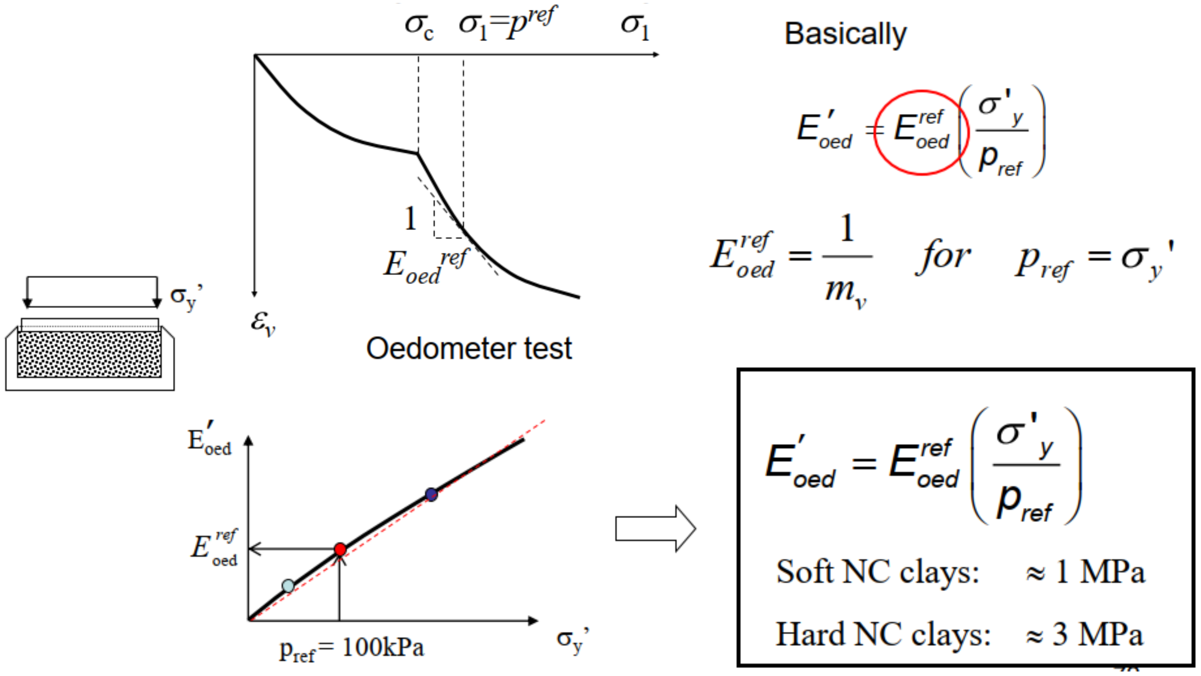
leire

4. Bruk «SoilTest» i Plaxis og modeller treaksforsøk ved spenningsnivåer som tilsvarer labforsøkene.

5. Iterasjon for å finne en fornuftig E_{50}^{ref} hvor $E_{50}^{lab} \approx E_{50}^{ref}$

Drenert stivhetsmodul for HS

6. Beregn $E'_{oed,lab}$ fra odometerforsøkene ved 100 kPa.



Fra «Soil Modelling and Numerical Analyses», AFRY/Chalmers kurs.

7. Bruk «SoilTest» i Plaxis for å modellere ødometerforsøkene.

8. Iterasjon for å finne en fornuftig E'^{ref}_{oed} hvor $E'^{lab}_{oed} \approx E'^{ref}_{oed}$

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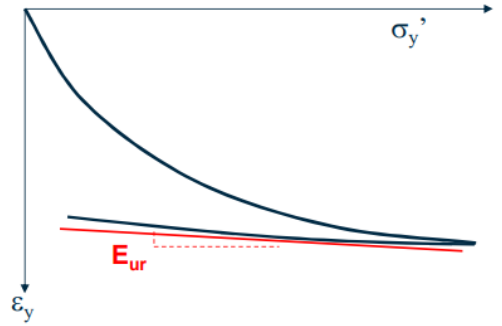
Drenert stivhetsmodul for HS

Fra Plaxis kurs.

9. Beregn $E_{ur,oed}$ hvis du har det.



For leire:

$$E_{ur,oed} = \alpha \cdot E_{oed} \text{ and } E_{ur} \approx 0.9 \cdot E_{ur,oed}$$

$$E_{ur}^{ref} = \alpha \cdot 0.9 \cdot E_{oed}^{ref} \left(\frac{\sigma_1' + a}{\sigma_3' + a} \right)^m = \alpha \cdot 0.9 \cdot E_{oed}^{ref} / (K_0)^m$$

$$K_0 \approx K_0^{NC} \cdot \sqrt{OCR}, K_0^{NC} \approx 1 - \sin(\varphi')$$

Clay (m=1):

Soft : $E_{ur,oed} \approx 10 E_{oed} \Rightarrow E_{ur}^{ref} \approx \frac{9}{K_0} E_{oed}^{ref} \approx (15 \text{ to } 20) \cdot E_{oed}^{ref}$

Stiff : $E_{ur,oed} \approx 3 E_{oed} \Rightarrow E_{ur}^{ref} \approx \frac{3}{K_0} E_{oed}^{ref} \approx (2 \text{ to } 4) \cdot E_{oed}^{ref}$

For sand:

$$E_{ur,oed} \approx 3 \cdot E_{oed} \text{ and } E_{ur,oed} \approx 1.1 \cdot E_{ur}:$$

$$1.1 \cdot E_{ur}^{ref} \left(\frac{\sigma_3' + a}{p_{ref}' + a} \right)^m = 3 \cdot E_{oed}^{ref} \left(\frac{\sigma_1' + a}{p_{ref}' + a} \right)^m \Rightarrow$$

$$E_{ur}^{ref} = \frac{3}{1.1} \cdot E_{oed}^{ref} \left(\frac{\sigma_1' + a}{\sigma_3' + a} \right)^m = \frac{2.7}{(K_0^{NC})^m} \cdot E_{oed}^{ref}$$

Sand (m=0.5):

$E_{ur,oed} \approx 3 \cdot E_{oed}$

$E_{ur}^{ref} \approx (3 to 5) \cdot E_{oed}^{ref}$

Geoteknikkdagen 2017:

BESTEMMELSE AV HVILETRYKK (K0) I NORSKE LEIRER – ANBEFALINGER (Jean-Sébastien L'Heureux)

$$K_0 = 0.48 \, I_p^{0.03} \, OCR^{0.47}$$

Input parametere til ”hardening Soil/ HS small” jordmodell

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K_0, OCR, POP	Initial stress state parameters (initial stress ratio, overconsolidation)

Referanse: 100 kPa

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Drenert stivhetsmodul for sand

Løs sand: $E_{50}^{ref} \approx 15\ MPa$ og $E_{oed}^{ref} \approx 15\ MPa$

Fast sand: $E_{50}^{ref} \approx 50\ MPa$ og $E_{oed}^{ref} \approx 15\ MPa$

Og: $E_{ur}^{ref} \approx (3-5) \times E_{oed}^{ref}$

Korrelasjoner:

Correlation	Remark	Author
$E_{oed}^{ref} \approx R_D \cdot 60MPa$	$RD = \frac{e_{\max} - e}{e_{max} - e_{min}}$	Lengkeek (for $\mathrm{p_{ref}} = 100\ \mathrm{kPa}$)
$E_{oed} = 4q_c$ $E_{oed} = 2q_c + 20\ \mathrm{MPa}$ $E_{oed} = 120\ \mathrm{MPa}$	$q_c < 10\ \mathrm{Mpa}$ $10\ \mathrm{MPa} < q_c < 50\ \mathrm{Mpa}$ $q_c > 50\ \mathrm{MPa}$	Lunne & Christophersen (1983) *For stress level where q_c is measured*
$E_{50}^{ref} \approx E_{oed}^{ref}$		Schanz

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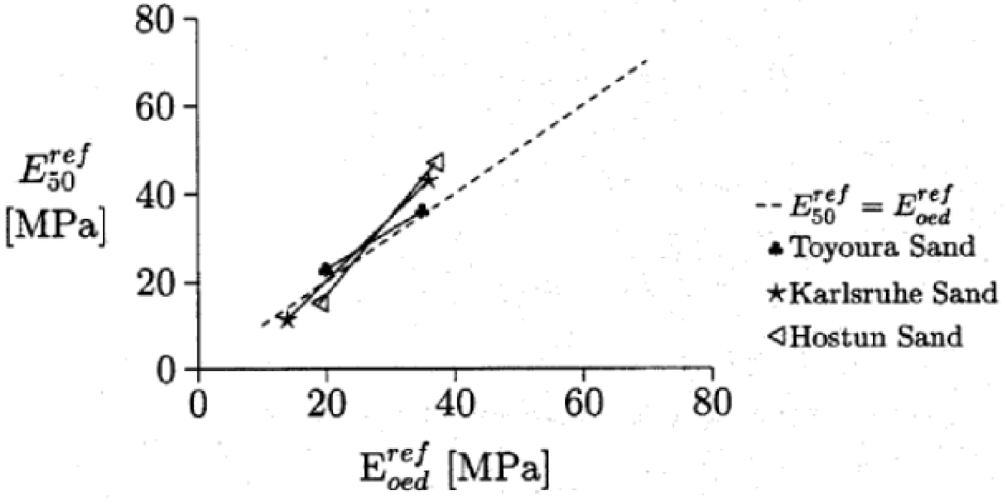
Drenert stivhetsmodul for sand

Korrelasjoner:

For sands ($m \approx 0.5$):



Schanz (1998)

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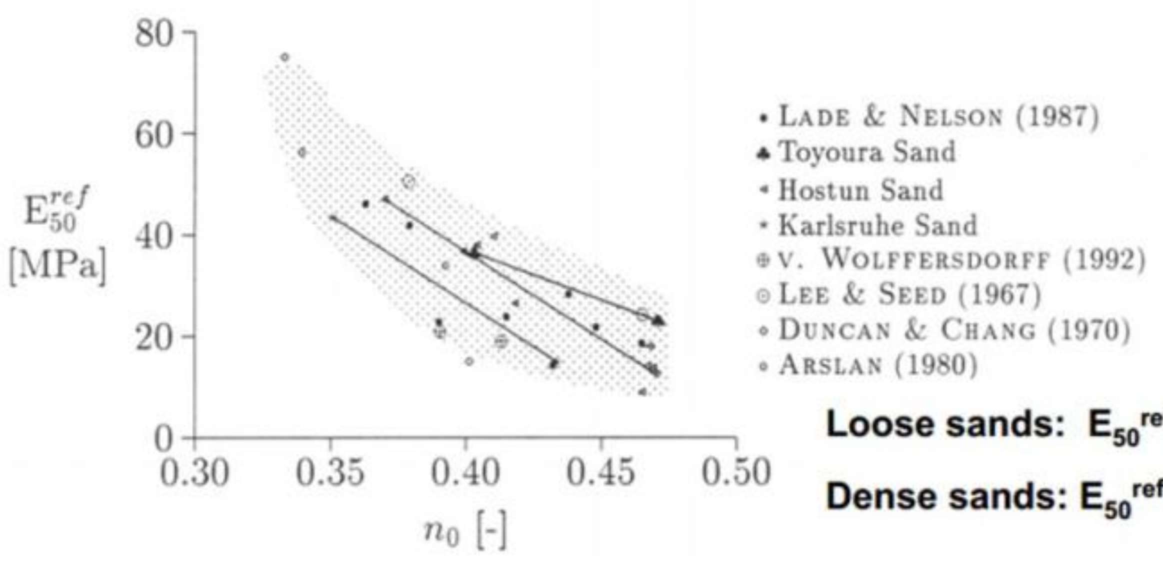
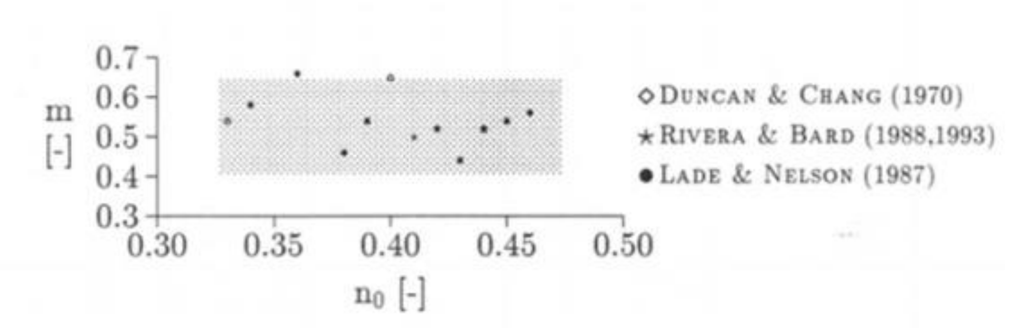
Drenert stivhetsmodul for sand

Korrelasjoner:



Loose sands: $E_{50}^{ref} \approx 15$ MPa

Dense sands: $E_{50}^{ref} \approx 50$ MPa



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Drenert stivhetsmodul for leire

Bløtt NC leire: $E_{oed}^{ref} \approx 1\ MPa$

NC: $E_{ur}^{ref} \approx (15-20) \times E_{oed}^{ref}$

Fast NC leire: $E_{oed}^{ref} \approx 3\ MPa$

OC: $E_{ur}^{ref} \approx (2-4) \times E_{oed}^{ref}$

Korrelasjoner:

$$E_{oed}^{ref} \approx \frac{50000\,kPa}{I_p}$$

Correlation with I_p for p^{ref}=100 kPa

$$E_{oed}^{ref} \approx \frac{500\,kPa}{w_L - 0.1}$$

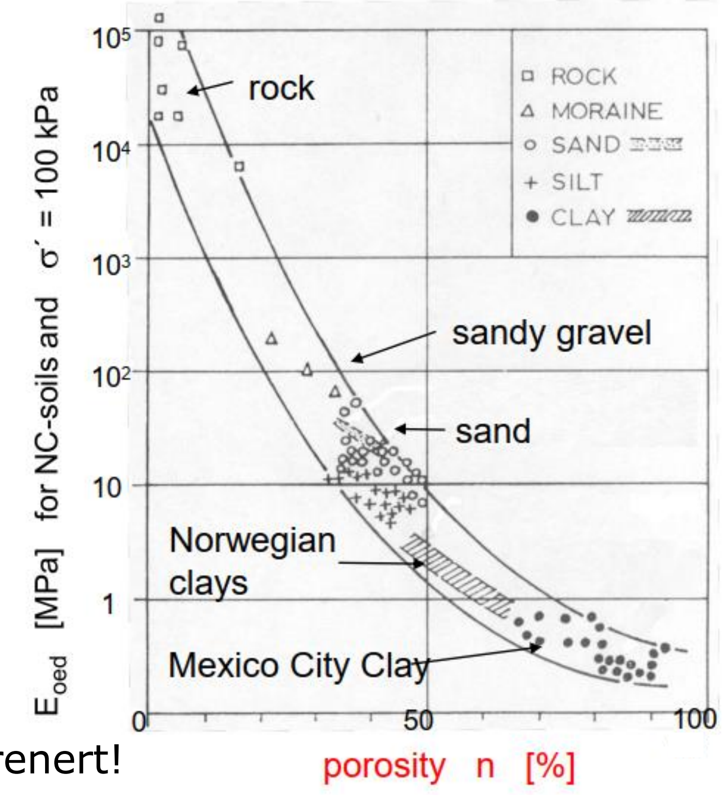
Correlation by Vermeer

$$E_{oed}^{ref} = p^{ref} / \lambda^*$$

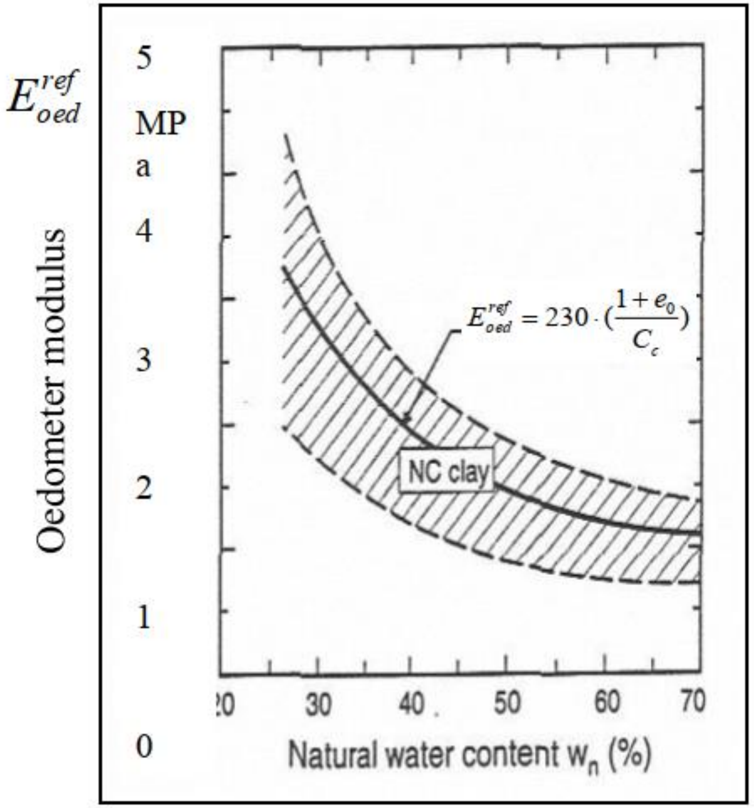
Relationship with Soft Soil model

Drenert stivhetsmodul for leire

Korrelasjoner:



Drenert!



Based on Janbu (1963)

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M~E_{oed}
(M fra ødometer)

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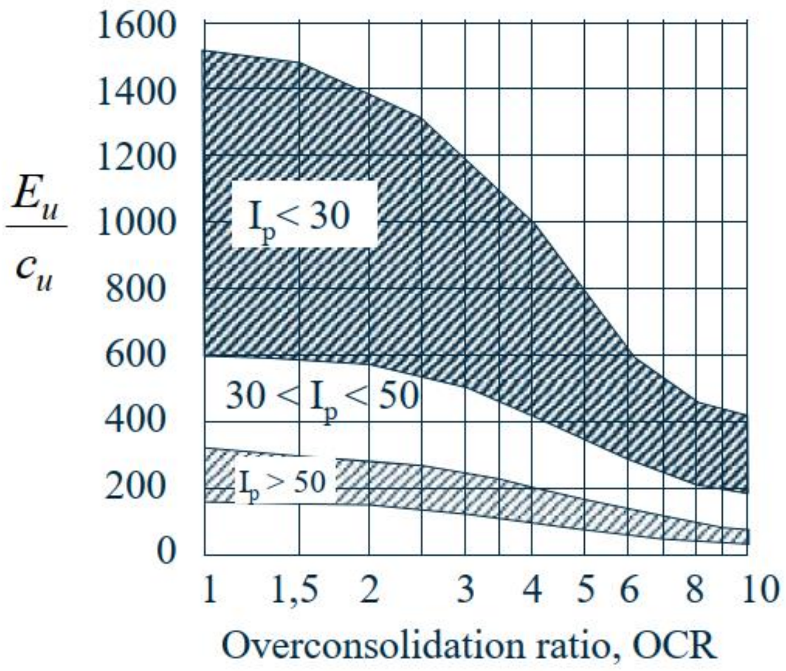
Drenert stivhetsmodul for leire

- Duncan & Buchignani (1976):



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Eksempel:

NC leire:

- S_u = 30 kPa
- OCR = 1,5
- I_p = 15%

Eu/Su varierende fra 600 til 1500 !!

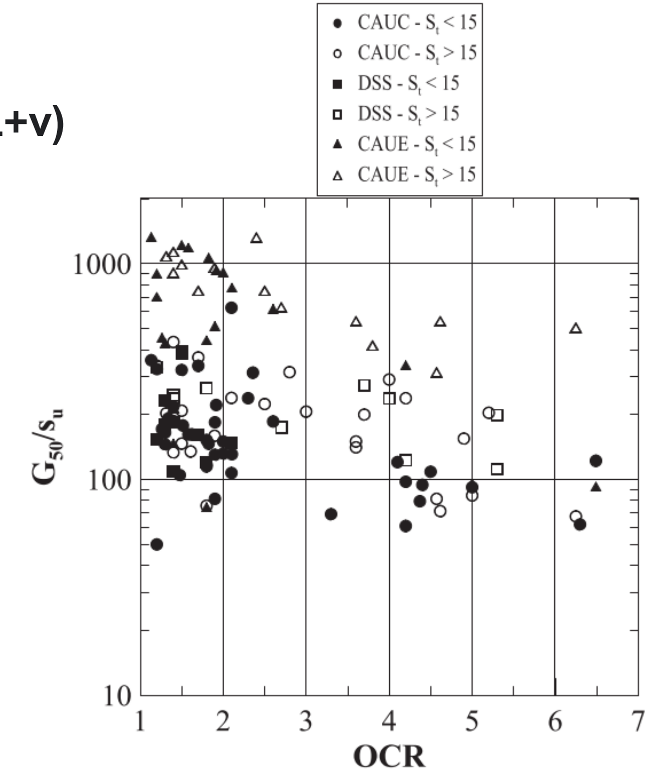
E_u vil variere fra 18 MPa til 45 MPa!!

Drenert stivhetsmodul for leire

— Strength and deformation properties of Norwegian clays from laboratory tests on high-quality block samples - Kjell Karlsrud (dx.doi.org/10.1139/cgj-2013-0298)

Fig. 33. Values of shear modulus at 50% mobilization normalized to the undrained strength (G_{50}/s_u) in relation to OCR, triaxial tests.

E=2G(1+v)



Eksempel:

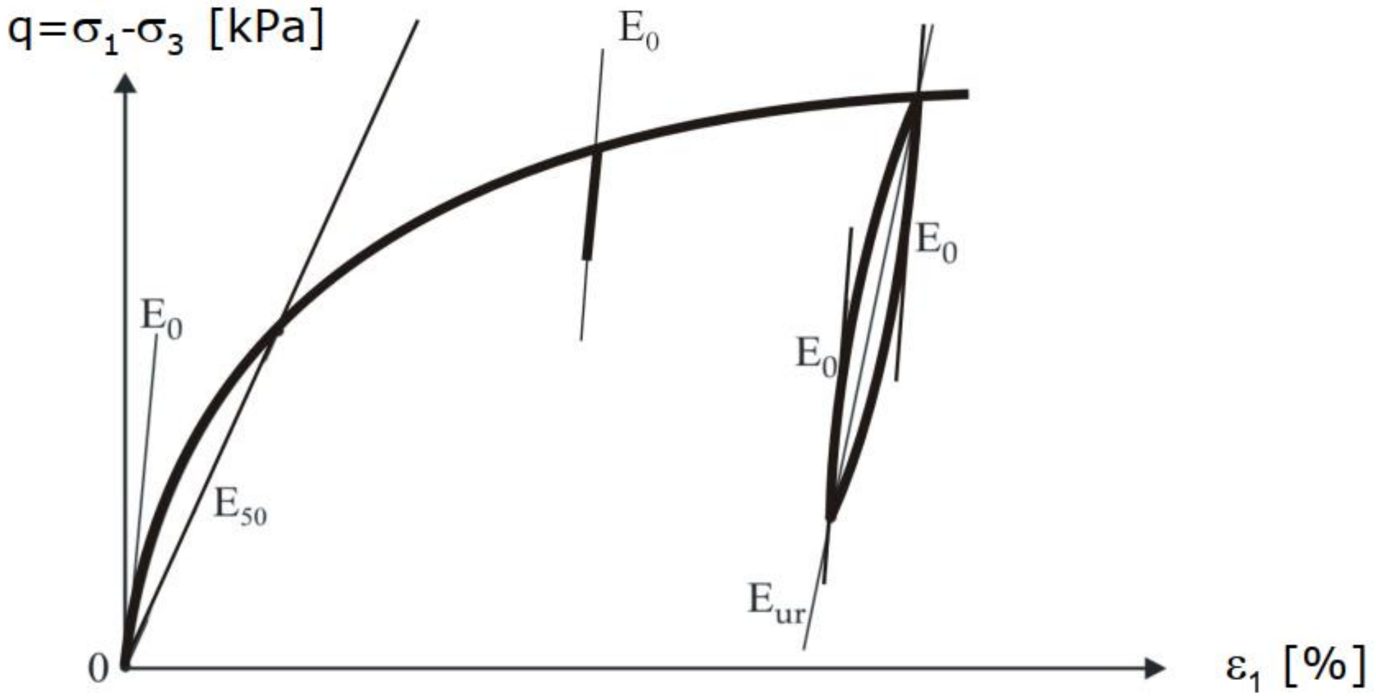
NC leire:

- S_u = 30 kPa (S_t under 15)
- OCR = 1,5
- I_p = 15%

G_{50}/Su varierende fra 100 til 300

G_{50} varier fra 3 MPa til 9 MPa! E_{50} Vil varier fra 8 MPa til 24 MPa

HS small modell



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Input parametere til ”hardening Soil/ HS small” jordmodell

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Referanse: 100 kPa

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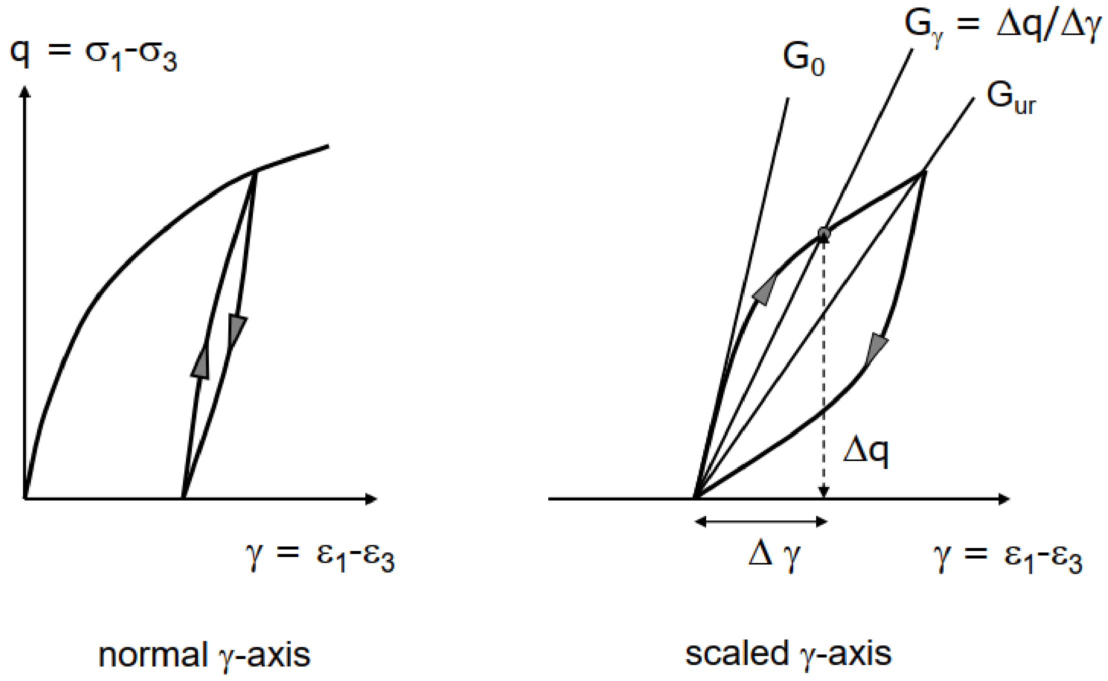
HS small modell

$$E_0 = 2\,(1 + \nu_{ur})\,G_0$$



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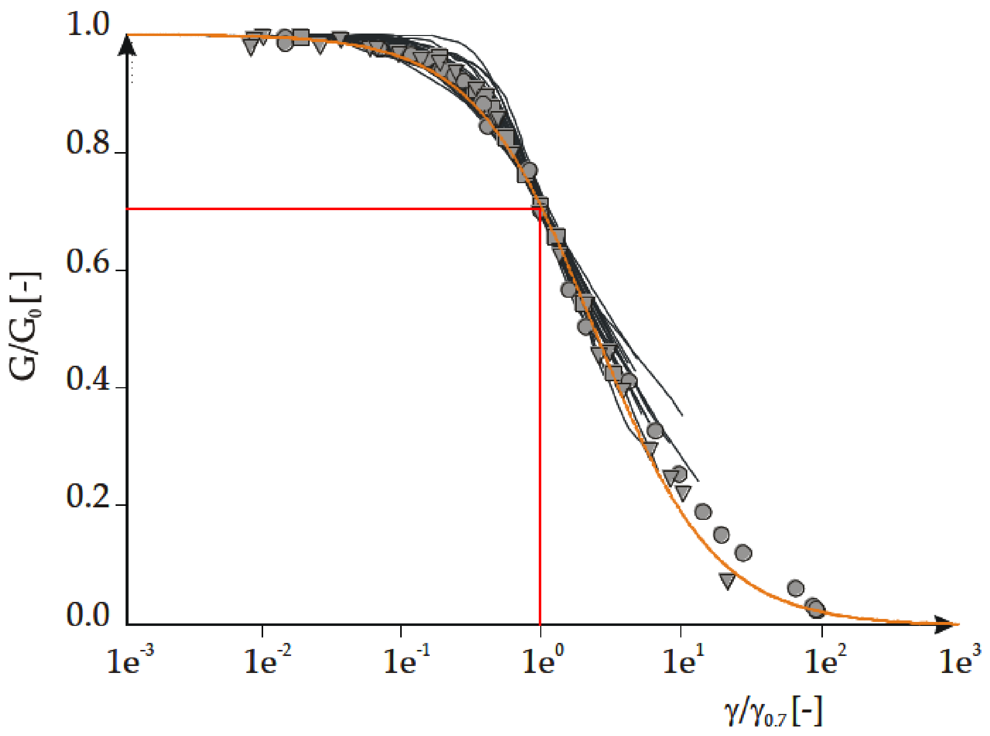
HS small modell



$$G_0^{ref} = \frac{E_0^{ref}}{2(1+\nu_{ur})}$$

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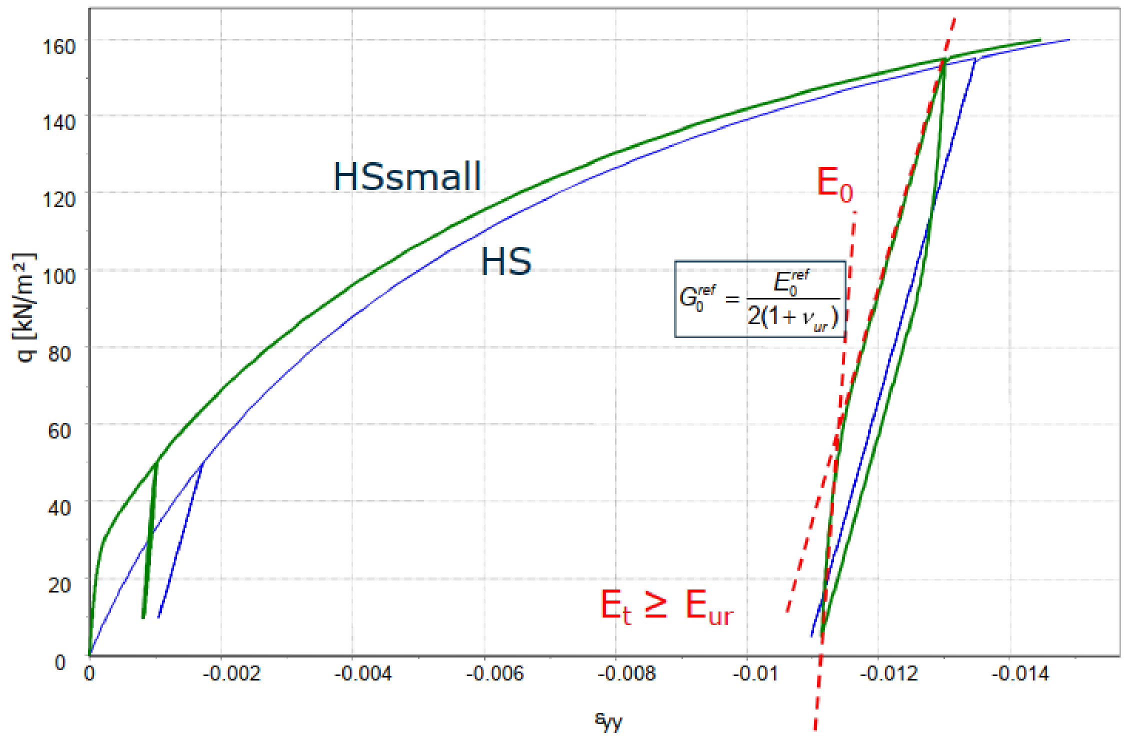
HS small modell

Drenert treaks:



FRA PLAXIS KURS/SEMINAR.

Small-strain stivhetsmodul for HS small

Korrelasjoner:

$$G_0^{ref} = \frac{(2.97-e)^2}{1+e} 33[MPa]$$ Harding & Black (1969)

$$G_0^{ref} \approx RD \bullet 70MPa + 60MPa$$ Lengkeek

$$\gamma_{0.7} = \frac{0.385}{4G_0}[2c(1+\cos(2\phi)) - \sigma_1(1+K_0)\sin(2\phi)]$$ Benz (2007)

Typiske verdier:

$$G_0^{ref} = (2.5 to 10) G_{ur}^{ref} \quad \text{where} \quad G_{ur}^{ref} = \frac{E_{ur}^{ref}}{2(1+\nu_{ur})}$$

$$\gamma_{0.7} = (1 to 2) \cdot 10^{-4}$$

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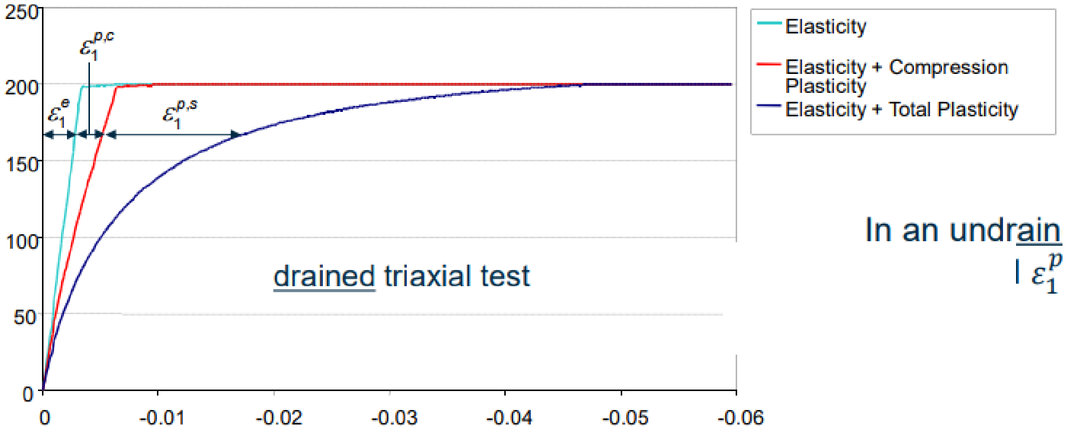
HS/HS Small modell

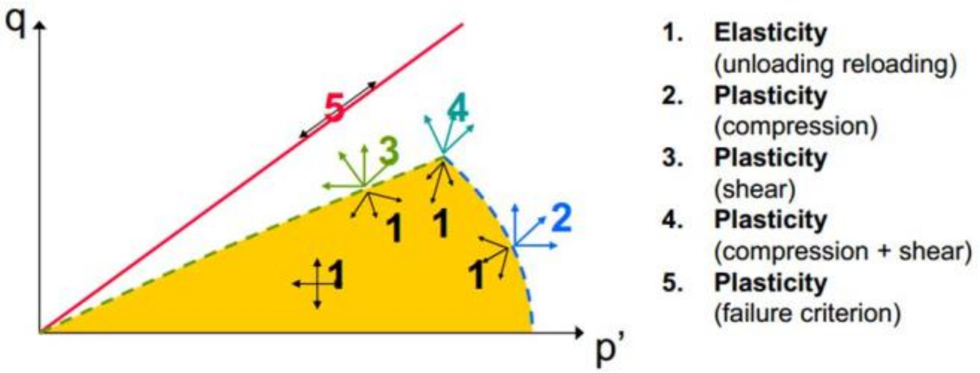
Deformasjon er styrt av både elastisk deformasjon, Volumetrisk plastisk deformasjon og skjær plastikk deformasjon.

Plaxis bruke inndataparametere for å finne deformasjon som oppstår ved økt spenning.

Dvs. inndata stemmer ikke nødvendigvis med en simulering av treaks/ødometer.

Anbefales å justere parametere mot SoilTest!





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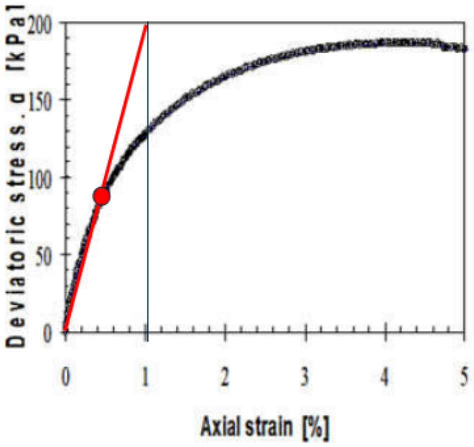
HS modell: eksempel

eksempel fra Plaxis/Bentley seminar

Treaks på fast Hokksund sand ved 40 kPa – Shaoli, 2004
N= 35,9 % (start) – 39,6% (slut)



$$E_{50}^{ref} = E_{50}\sqrt{\frac{p_{ref}+a}{\sigma'_x + a}}$$

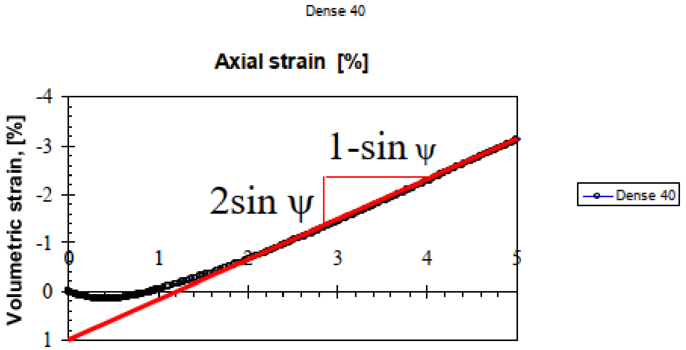
$$= 20000kPa\sqrt{\frac{100kPa}{40kPa}} = \mathbf{32MPa}$$

$$\sin(\varphi') = \frac{\sigma_1' - \sigma_3'}{\sigma_1' + \sigma_3'} = \frac{185}{225+40}$$

$$\varphi' = 44^0$$

Hence,

$$K_0^{NC} \approx 1 - \sin(\varphi') = 0.31$$



$$\frac{1-\sin\psi}{2\sin\psi} = \frac{5}{4{,}2} = 1{,}2$$

$$\sin\psi = 0{,}29$$

$$\psi = 17°$$

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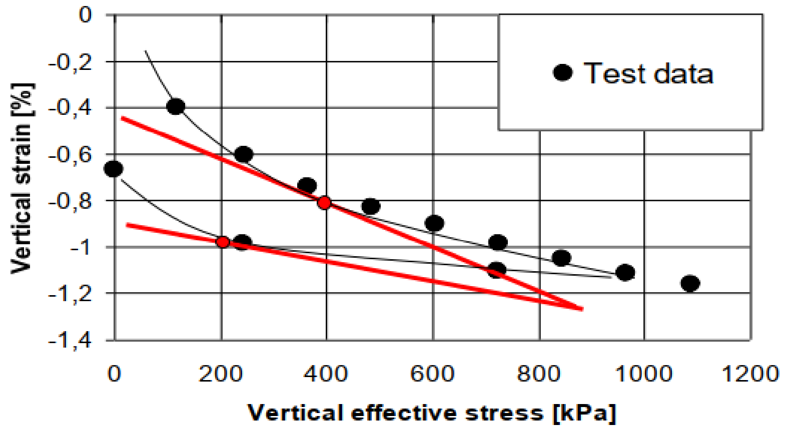
HS modell: eksempel

eksempel fra Plaxis/Bentley seminar

Odometer på fast Hokksund sand ved 40 kPa – Morn, 1975



Loading:

$$E_{oed} = E_{oed}^{ref}\sqrt{\frac{\sigma_1'+a}{p_a'+a}}$$

$$E_{oed}^{ref} = E_{oed}\sqrt{\frac{p_a'+a}{\sigma_1'+a}}$$

$$= \frac{850kPa}{0,008}\sqrt{\frac{100kPa}{400kPa}}$$

$$= 53MPa$$

Unloading:

Low Poisson Ratio

$$E_{ur\,oed} \approx 1.1\cdot E_{ur}\,,\; E_{ur} = E_{ur}^{ref}\sqrt{\frac{\sigma_3'+a}{p_a'+a}}$$

$$\Rightarrow E_{ur}^{ref} \approx 0.9\cdot E_{ur\,oed}\sqrt{\frac{p_a'+a}{\sigma_3'+a}} = 0.9\cdot\frac{850kPa}{0,0028}\sqrt{\frac{100}{200}} = 195MPa$$

HS modell: eksempel

eksempel fra Plaxis/Bentley seminar

SoilTest med tolkede parametere og gjennom Trial and error, kan man få verdier som blir like for laboratorieforsøk og HS jordmodell.

Her:

E_{50}^{ref} = 35 MPa (estimated 32 MPa)

E_{oed}^{ref} = 45 MPa (estimated 53 MPa)

E_{ur}^{ref} = 180 MPa (estimated 195 MPa)

m = 0,6

c' = 1 kPa

$\varphi' = 44^0$

$\psi = 18^0$ (estimated 17^0)

K_0^{NC} = 0,4

ν'_{ur} = 0,2

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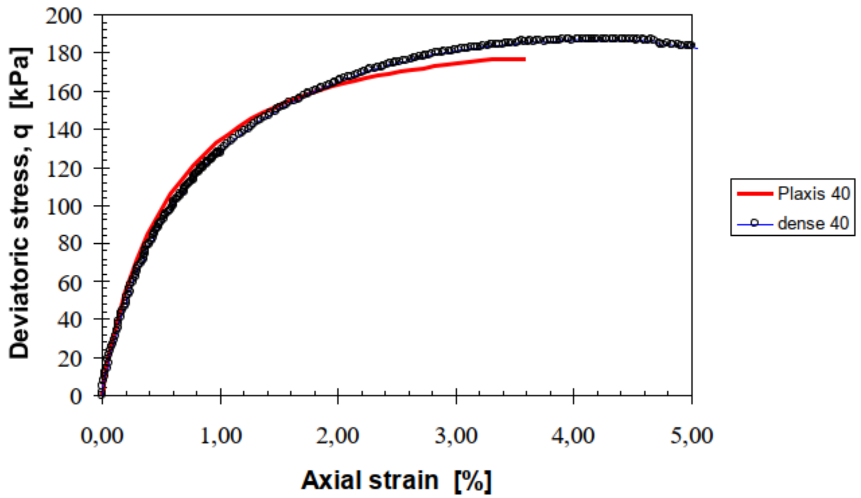
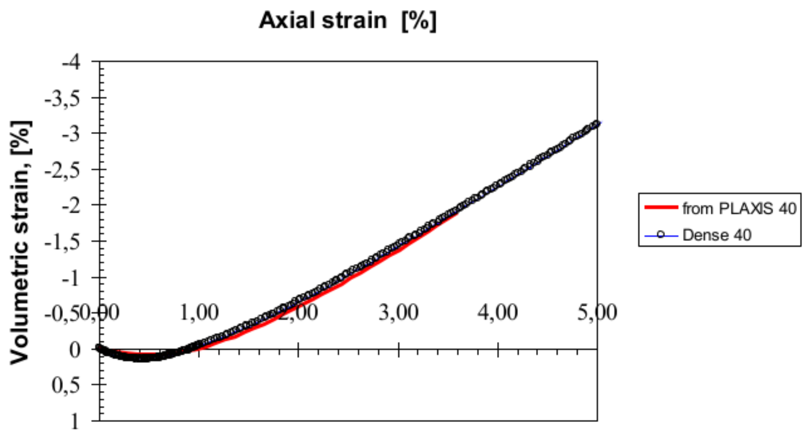
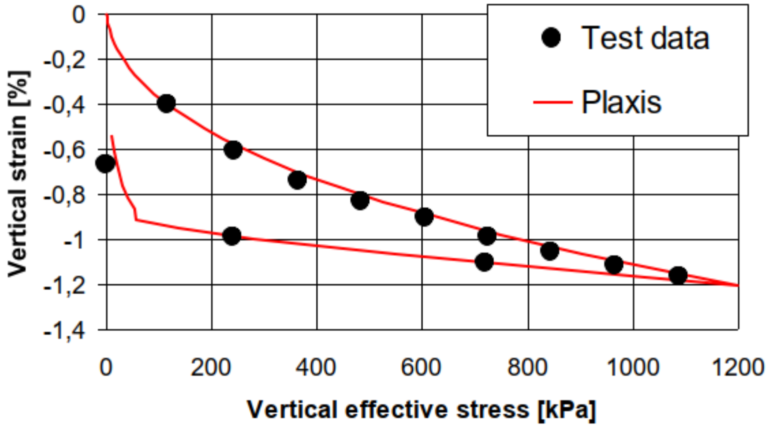
HS modell: eksempel

eksempel fra Plaxis/Bentley seminar







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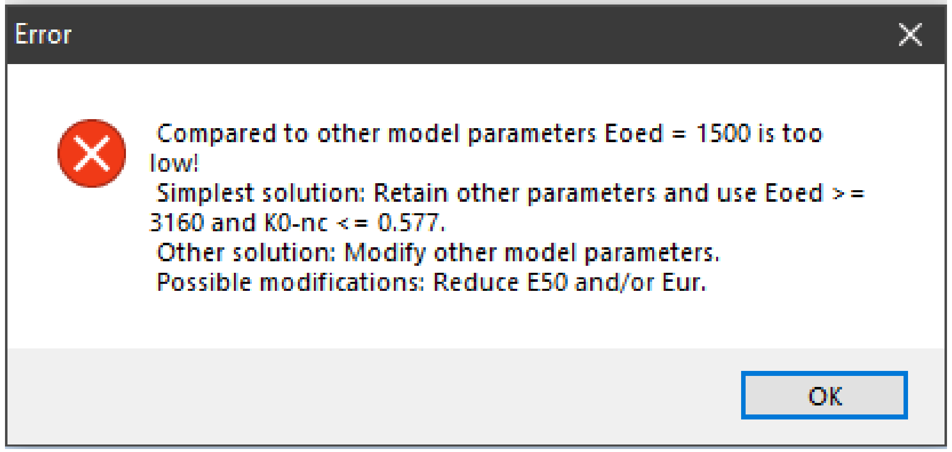
HS/HS Small modell

Ikke alle kombinasjoner av E moduler er tillatt. Dersom E_{50}/E_{oed} er større enn 2, får man en sånn feilmelding:



Et «vanlig» problem for setningsømfintlig leire.

Soft Soil må brukes!

$$\lambda^* = \frac{p^{ref}}{E_{oed}^{ref}}$$

$$\kappa^* \approx 3 \times p_{ref} \times (1 - 2 \cdot \nu_{ur})/E_{ur}^{ref}$$

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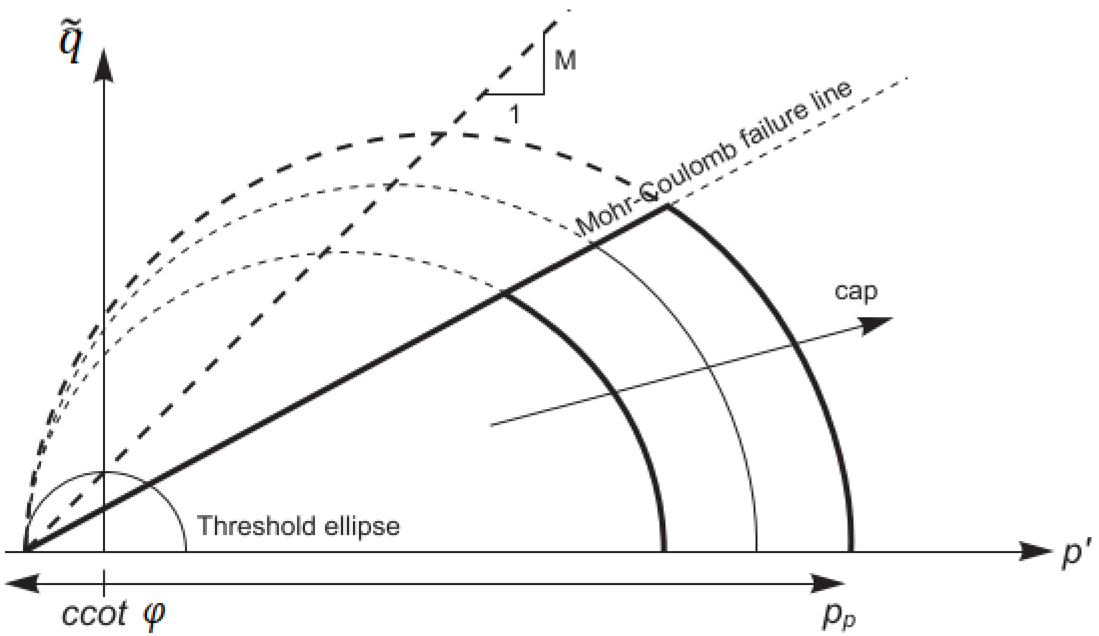
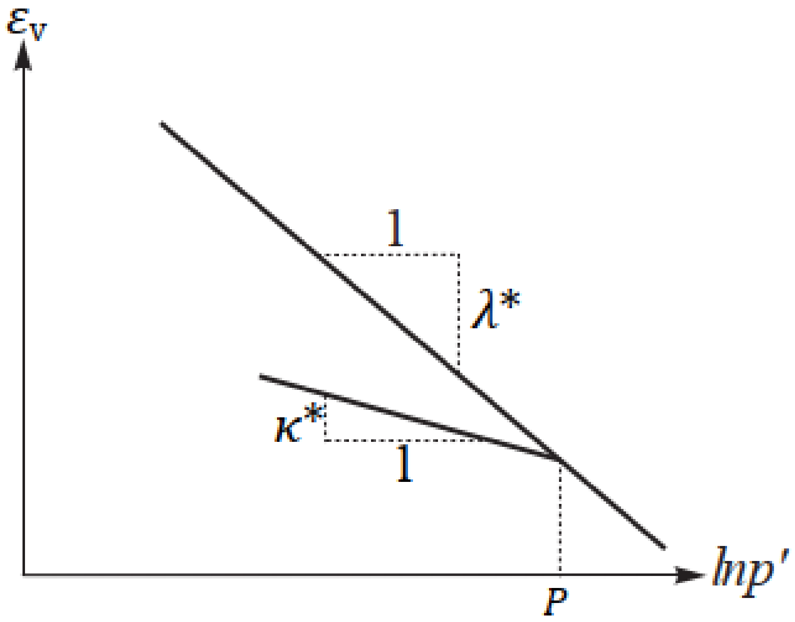
Soft Soil Jordmodell

Basert på «Cam Clay» modell:





Obs: Naturlig logaritme!

Fra Plaxis manualer.

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Soft Soil Jordmodell

Inndata:

Basic:

λ^*	Modified compression index	[-]
κ^*	Modified swelling index	[-]
c	Effective cohesion	[kN/m^2]
φ	Friction angle	[°]
ψ	Dilatancy angle	[°]

Avansert (bruk default):

ν_{ur}	Poisson's ratio for unloading / reloading	[-]
K_0^{nc}	Coefficient of lateral stress in normal consolidation	[-]
M	K_0^{nc}-parameter	[-]

Fra Plaxis manualer.

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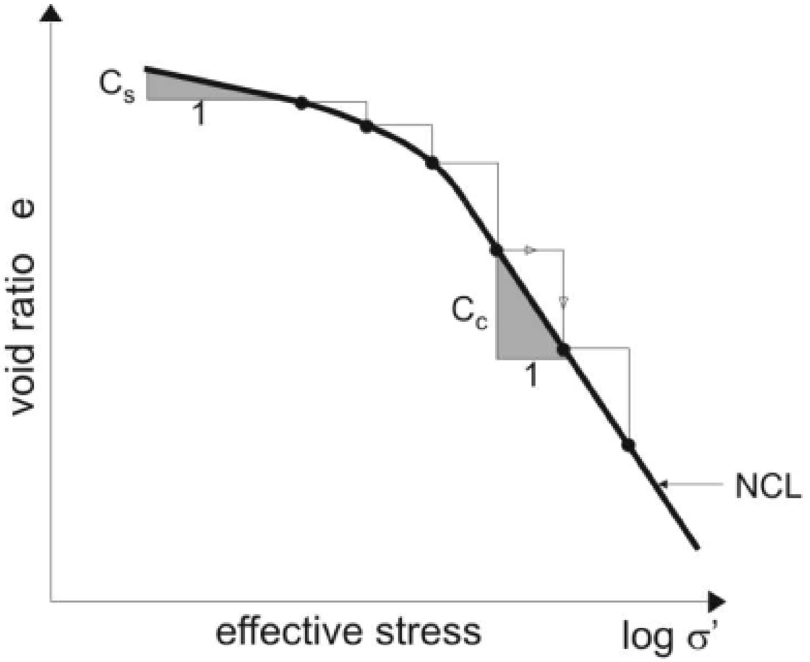
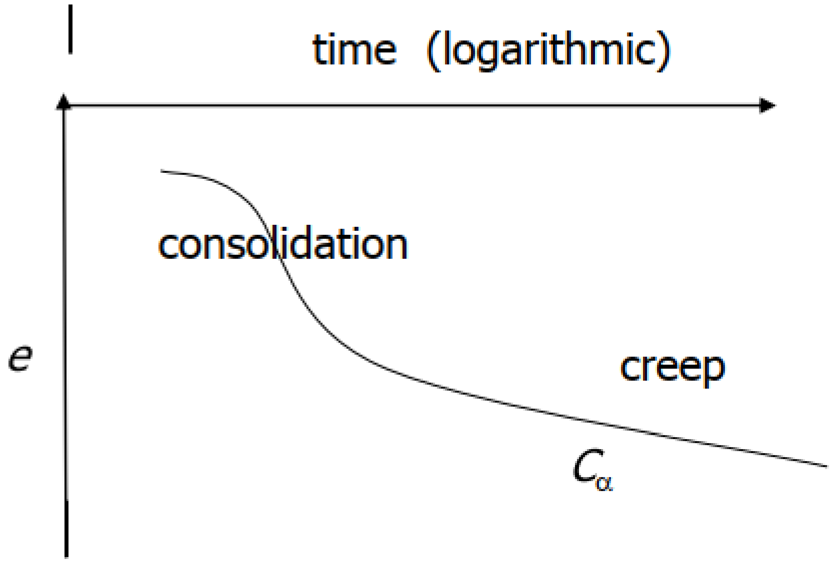
Soft Soil Jordmodell

Ødometerforsøk plottes slik i internasjonal litteratur:





$$\kappa^* \approx \frac{2 \times C_s}{2{,}3 \times (1 + e_0)}$$

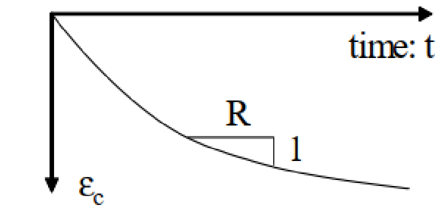
$$\lambda^* \approx \frac{C_c}{2{,}3 \times (1 + e_0)}$$

Det finnes mye korrelasjoner for Cc og Cs! Nyttig informasjon!

Fra «COMPUTATIONAL GEOTECHNICS», Plaxis kurs.

Soft Soil Jordmodell

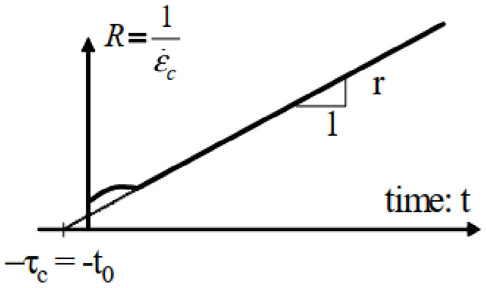
Ødometerforsøk plottes slik i norsk litteratur:

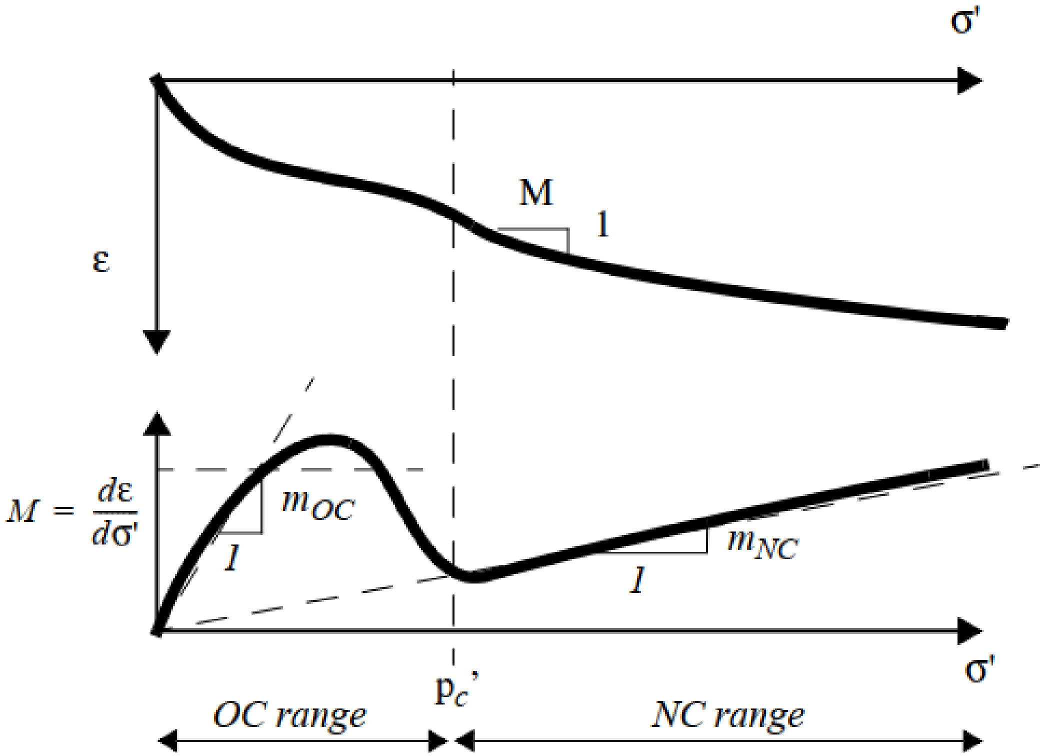


$\kappa^* = 1/m_{oc}$

$\lambda^* = 1/m_{nc}$

$\mu^* = 1/r$





Fra «Geotechnical engineering, advanced course, NTNU»

Soft Soil Jordmodell

Fremgangsmåte:

1. Tolk parametere for HS modell. Bruk de for et innledende estimat.
2. Tolk odometerforsøkene og sammenlign dem med HS parametere.
3. Kjør «SoilTest» for å se om tolkede parametere stemmer.
4. Iterasjon for å få «riktig» parametere.

Paramtertolkning fra et prosjekt Saupstad g/s bru

Typisk jordprøve:

RAMBØLL

DATAKORT FOR JORDPRØVER

Sted: Bjørndalen Oppdrag: 41818

Boring: S8 Dybde: 5,2 - 6,0 Lab.nr.: 08

w%	cm		
35,7	10–20	∇_1	
34,9	20–30	Ø	18,7
33,7	30–40	T_1	
	40–50	T_2	
32,2	60	U	
32,8	70	∇_2	
	80		
	90		
	100 cm		

Prøven tatt: 16.09.20 Åpnet: 06.11.20

Jordartbeskrivelse:

Leire m/ enkelte små gruskorn

Trykkforsøk		su KN/m²	εs %	E-modul
Prøve	1	41	8	
"				

Konusforsøk		su KN/m²	$\bar{s}u$ KN/m²	S_t
Prøve	1	40	2,9	
"	2	41	4,2	
"				

Flytegrense W_L .... %

Utrull. grense W_P .... %

Tyngdetetthet hel syl. γ 18,9 KN/m³

Prøve 18,7 KN/m³

Densitet ρ_s .... t/m³

Porøsitet n .... %

Poretall e ....

Humusinnhold .... %

Saltinnhold .... g/l

Notater:

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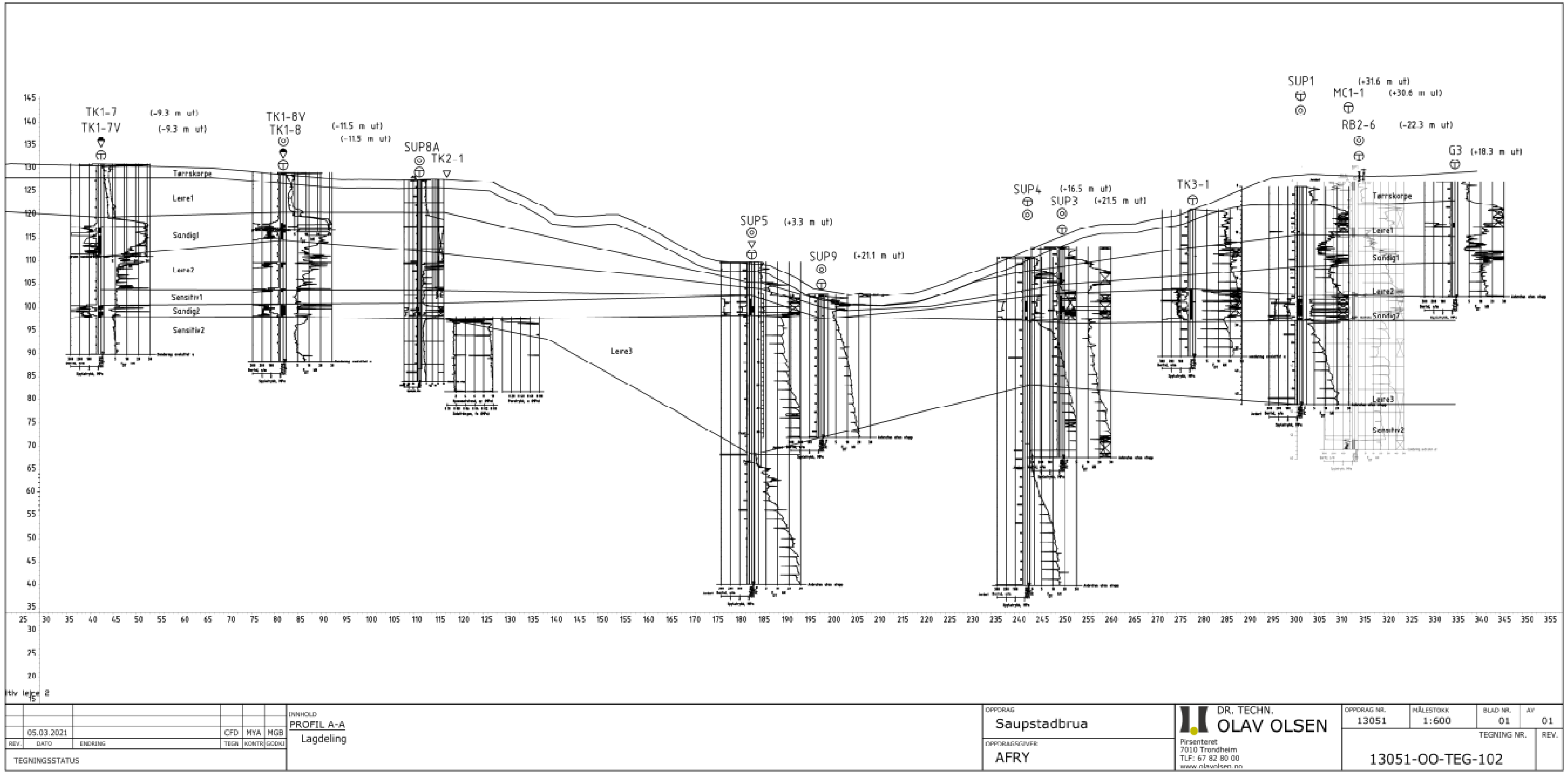
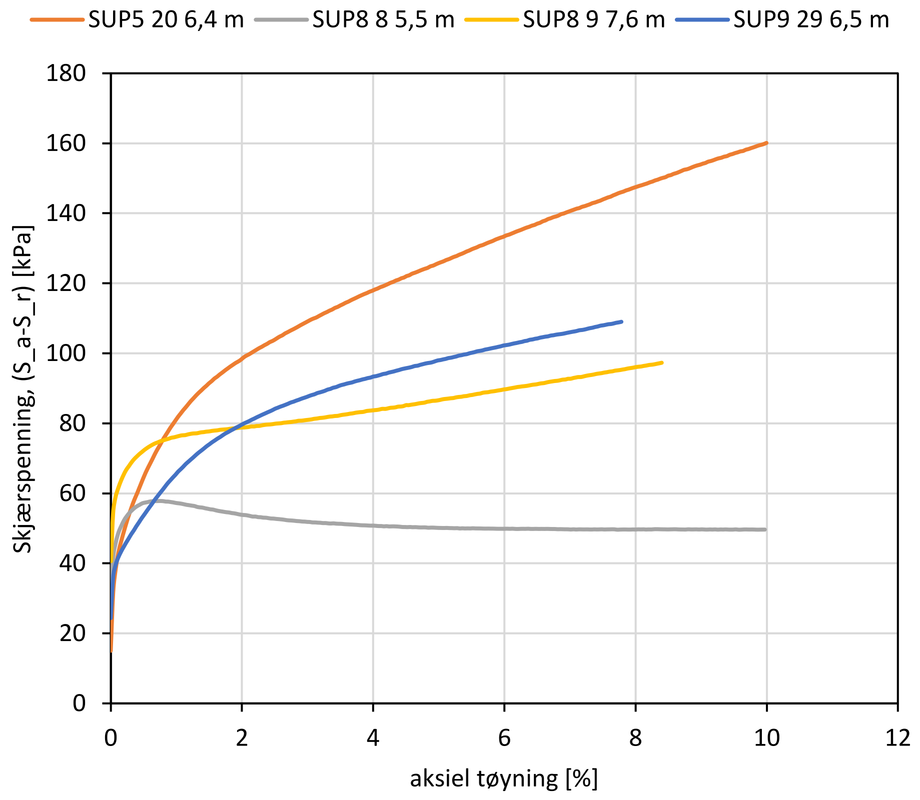
Paramtertolkning: Saupstad g/s bru

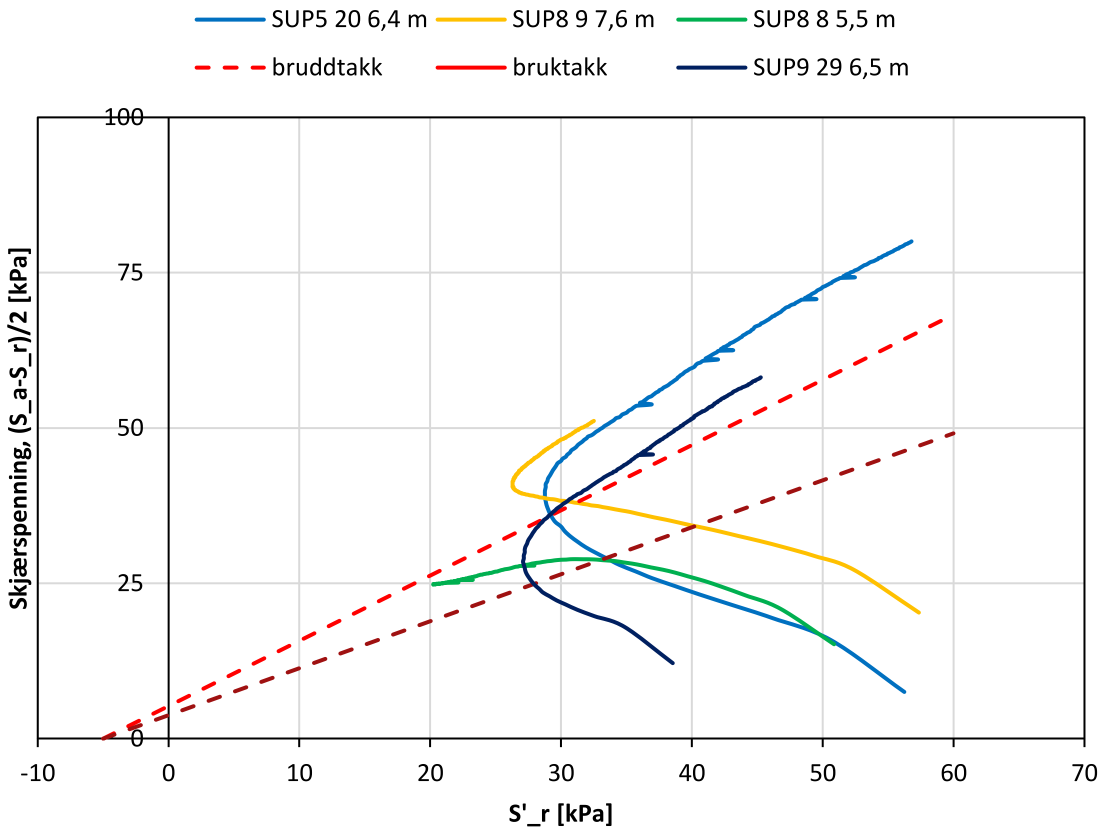
Lagdeling:



HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet; ”leire 1”:

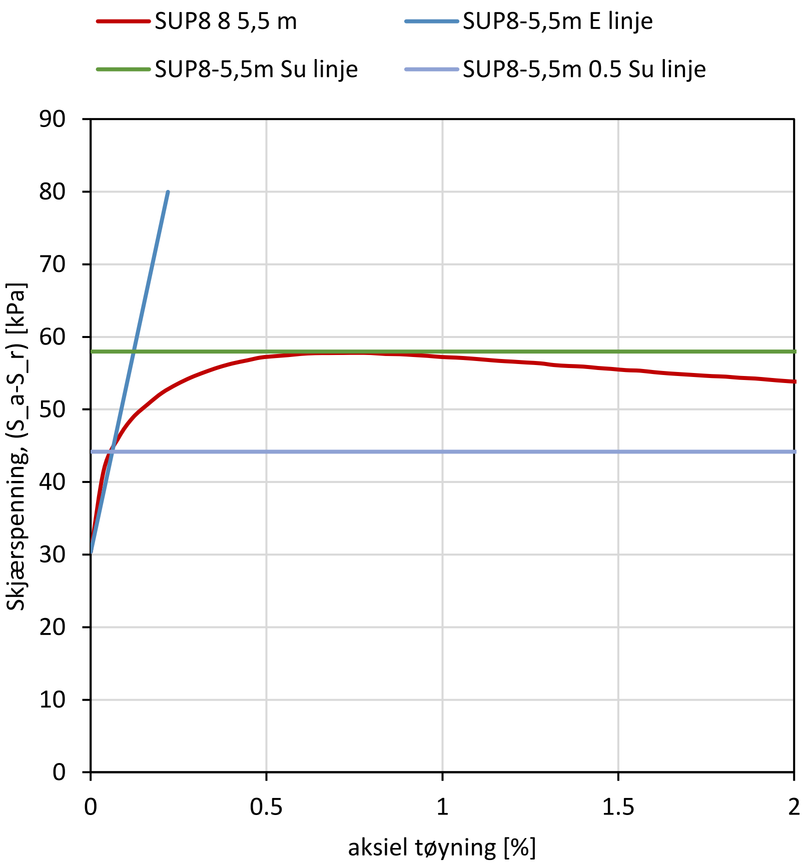


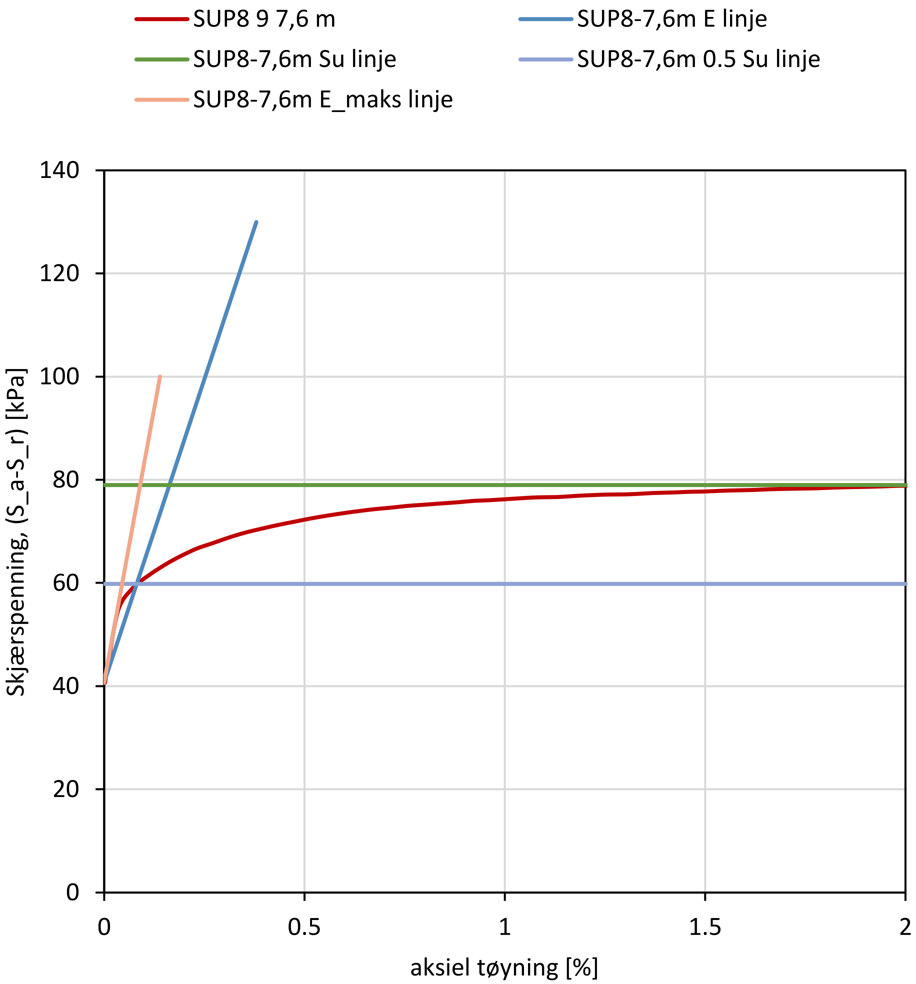


→ a= 5kPa ; phi=30,8°

HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:





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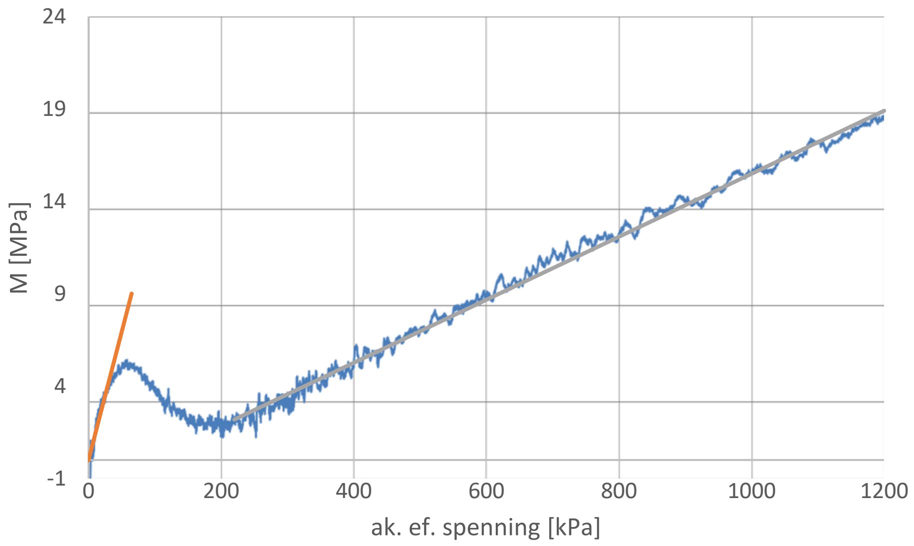
HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

Kvalitet	BH	dybde	S'3	E_modul, u	G_mudul	S_u	G/Su	E'-modul	E_maks	G_maks
[]	[]	[m]	[kPa]	[kPa]	[kPa]	[kPa]	[]	[MPa]	[kPa]	[MPa]
god	5	6.4	56.2	22994.8	7664.9	36.0	212.9	18.4	22994.8	7.7
god	8	5.5	50.9	22554.5	7518.2	29.0	259.2	18.0	22554.5	7.5
god	8	7.6	57.4	23521.1	7840.4	39.5	198.5	18.8	42414.3	14.1
brukbar	9	6.5	38.5	20618.5	6872.8	32.8	209.9	16.5	20618.5	6.9

Odometer:

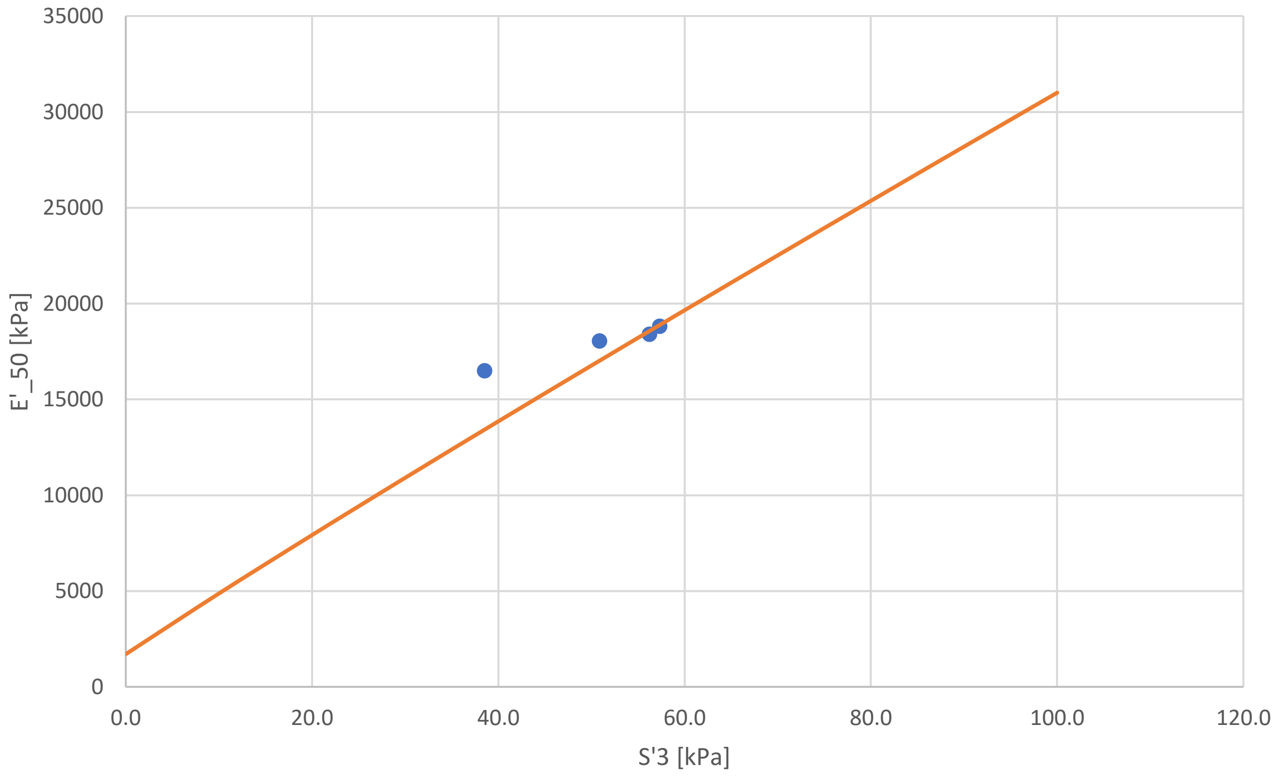
P'c ~130kPa
m_oc ~138
m_nc~17
M = 5 MPa



HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

m~0,95
E'_{50} ~ 31 MPa



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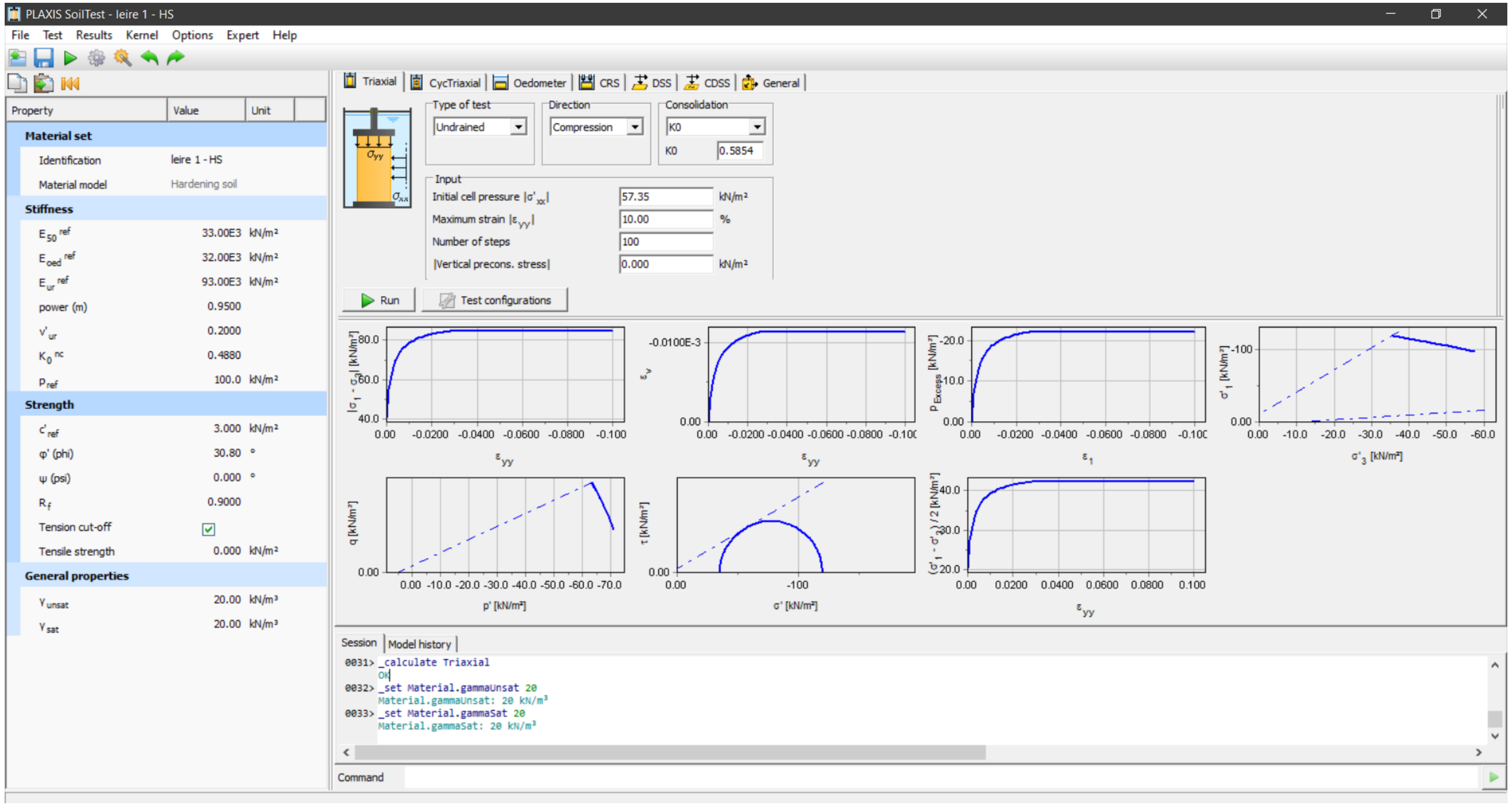
HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

SoilTest -> treaks ved tilsvarende S'_3 og K_0:

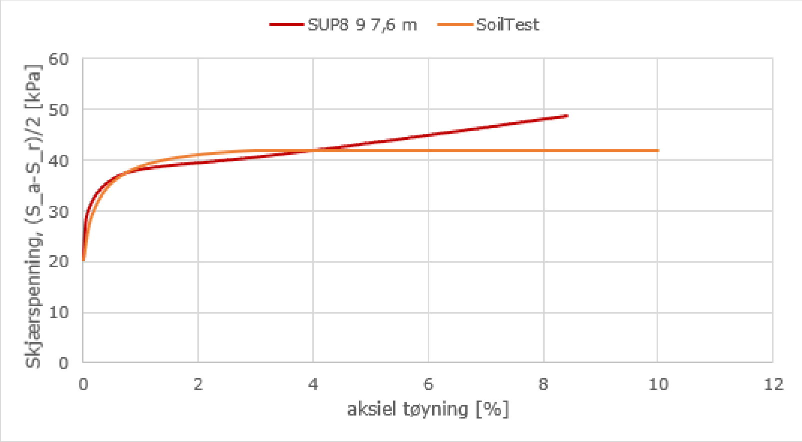


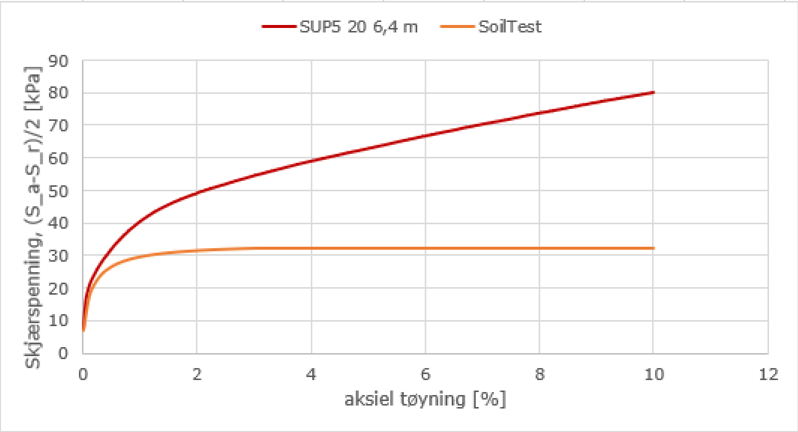
HS modell: eksempel for leire

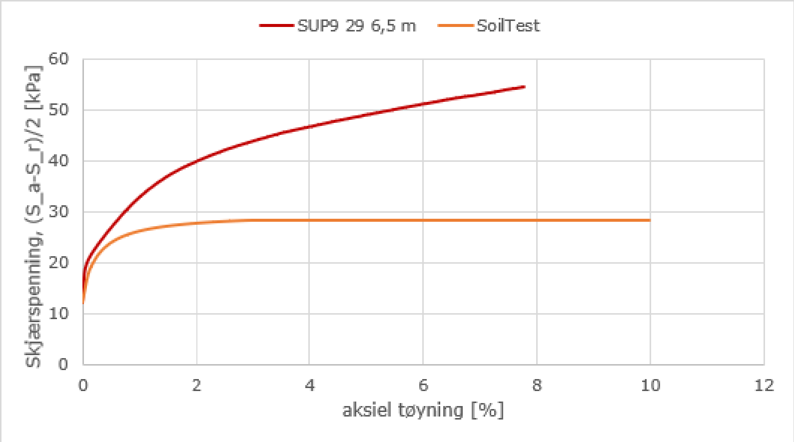
eksempel fra Saupstadbru prosjektet:

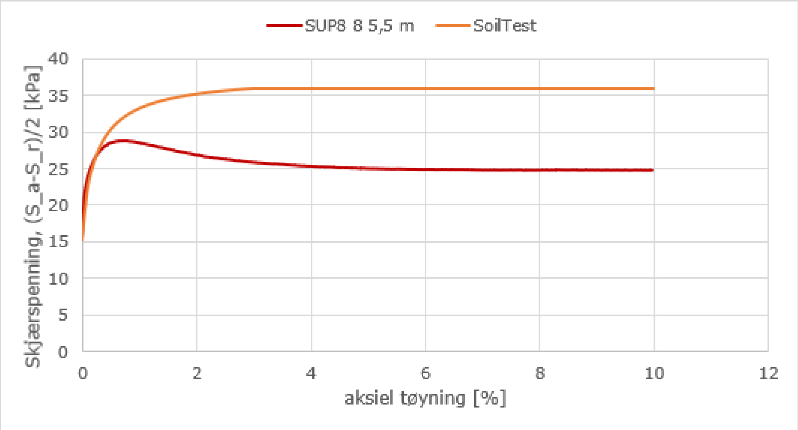
Runde 1:

Litt stivere E_{50}?









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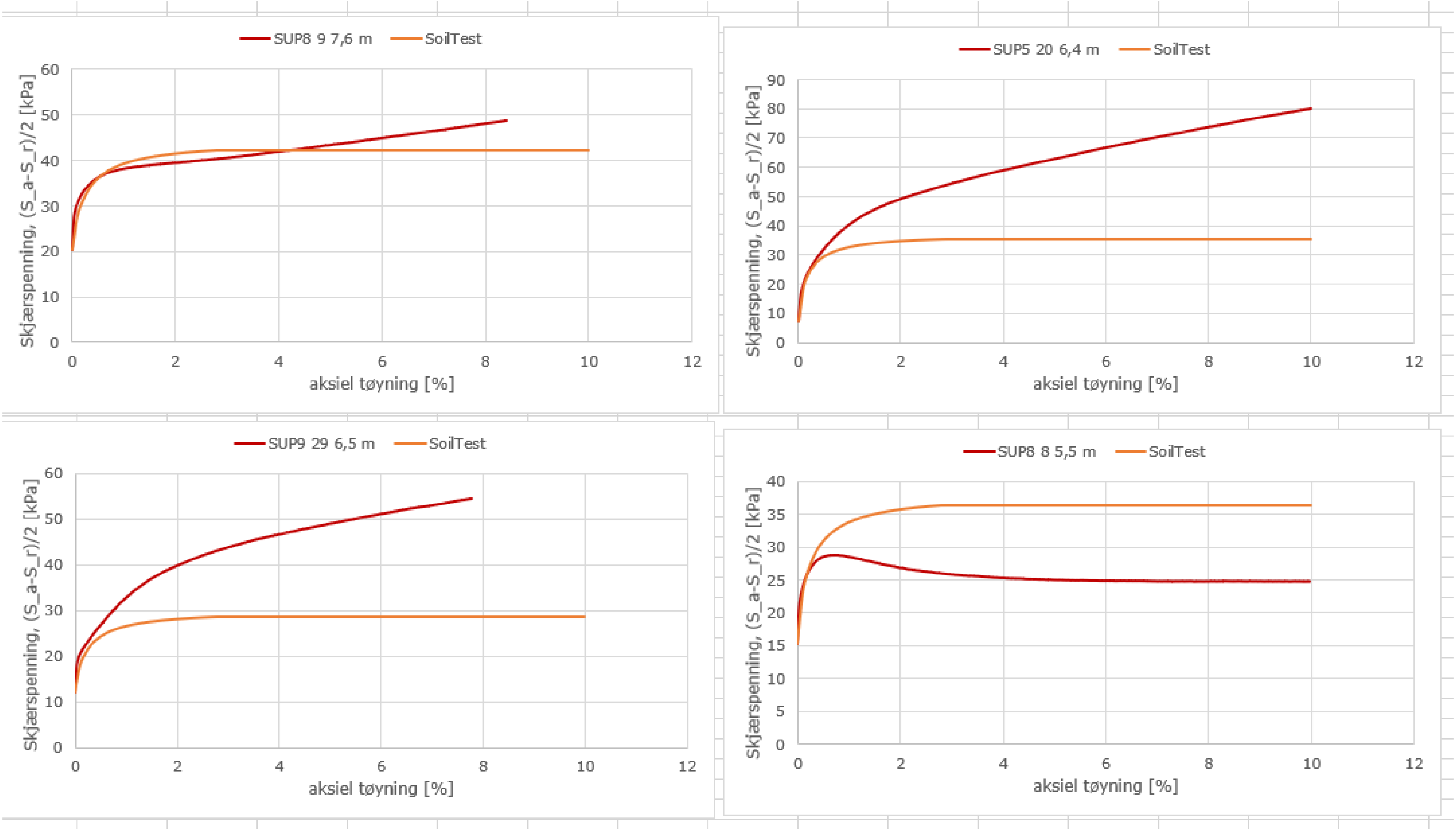
HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

Runde 2:

E_{50} ~ 33 MPa



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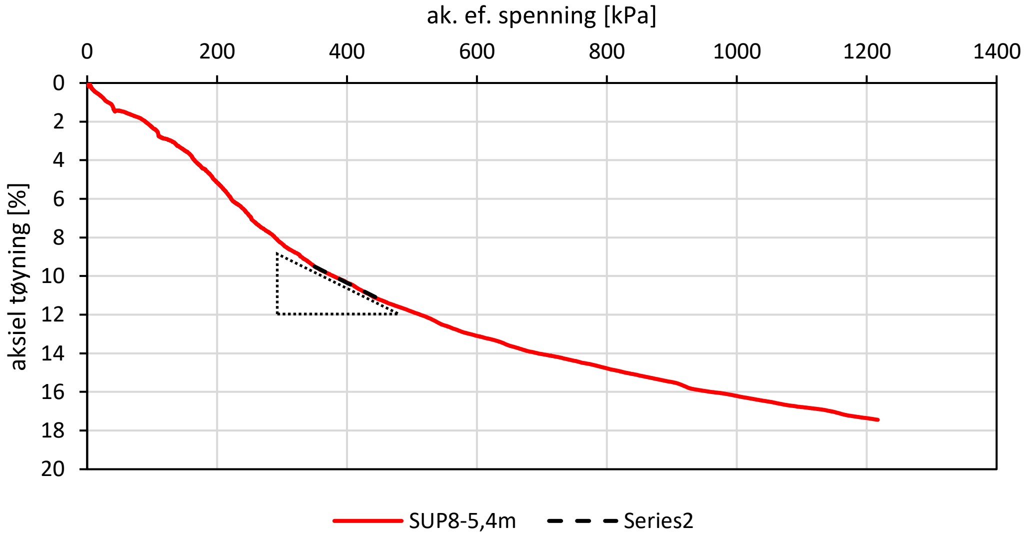
HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

E_{oed} ~ 1,2 MPa → E_{50}/E_{oed} større enn 2! Vil gi Feilmelding:



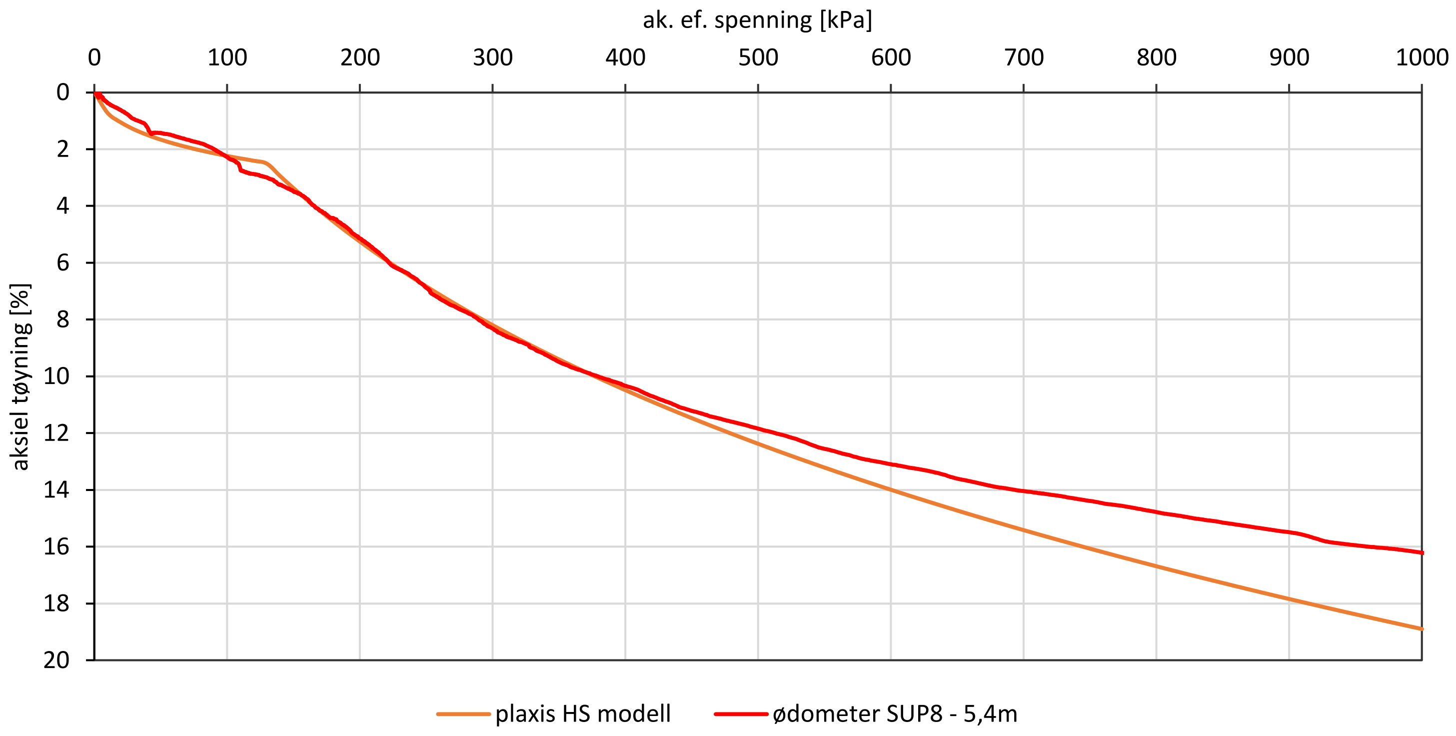
Soft Soil bør brukes!

Alternativ: Tolk E_{oed} først og anta E_{50} ~ 2x E_{oed}

HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

E_{oed} ~ 1,2 MPa
E_{50} ~ 3,0 MPa
E_{ur} ~ 15 til 20 E_{oed} ~ 22 MPa



Fokus er på 0 – 400 kPa:
Iterasjon med Høyere E_{oed}

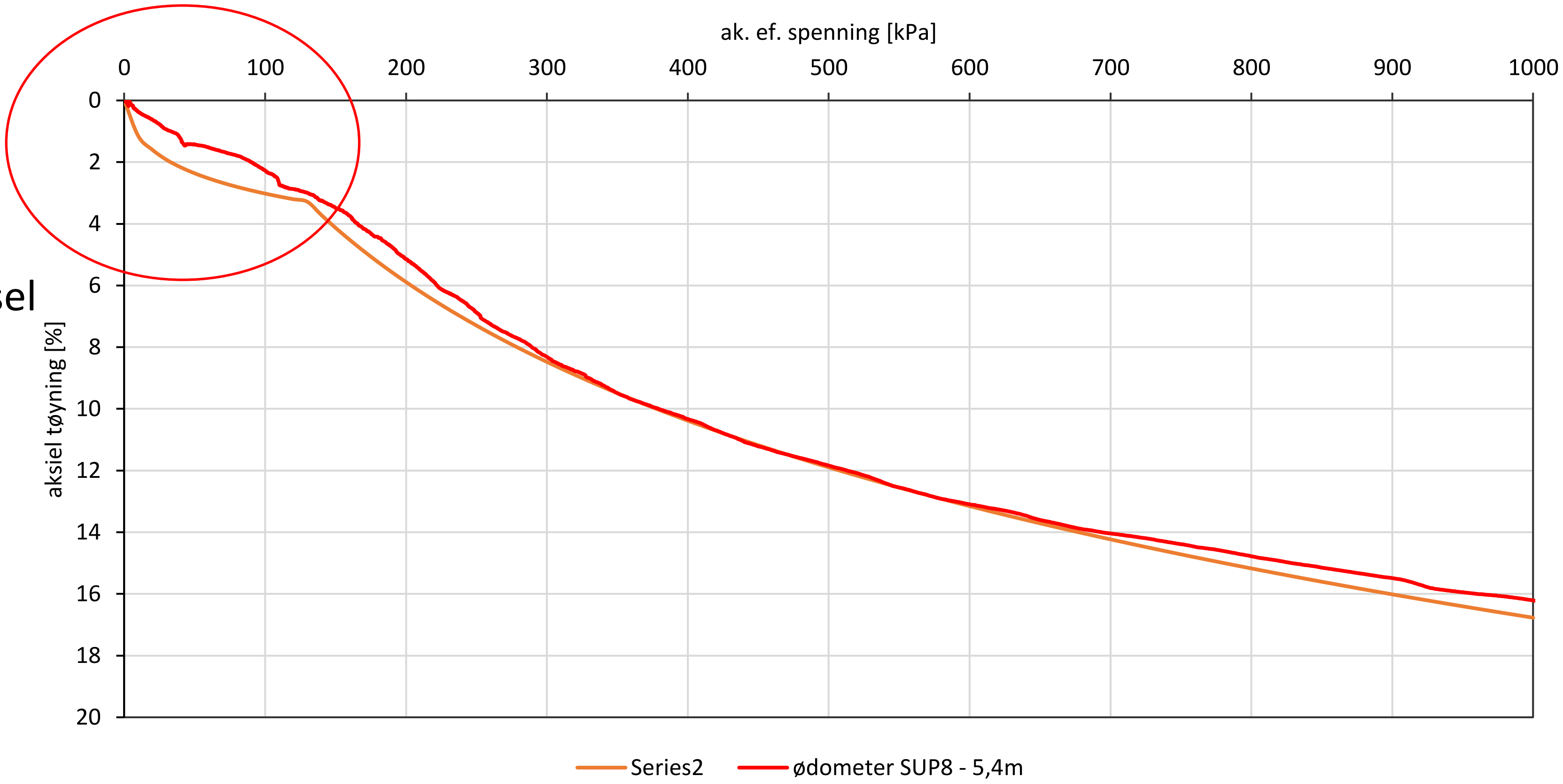
HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

E_{oed} ~ 1,6 MPa
E_{50} ~ 2,5 MPa
E_{ur} ~ 22 MPa

Lavere m vil gi «flatere» oppførsel

Iterasjon 2 med m ~0,8



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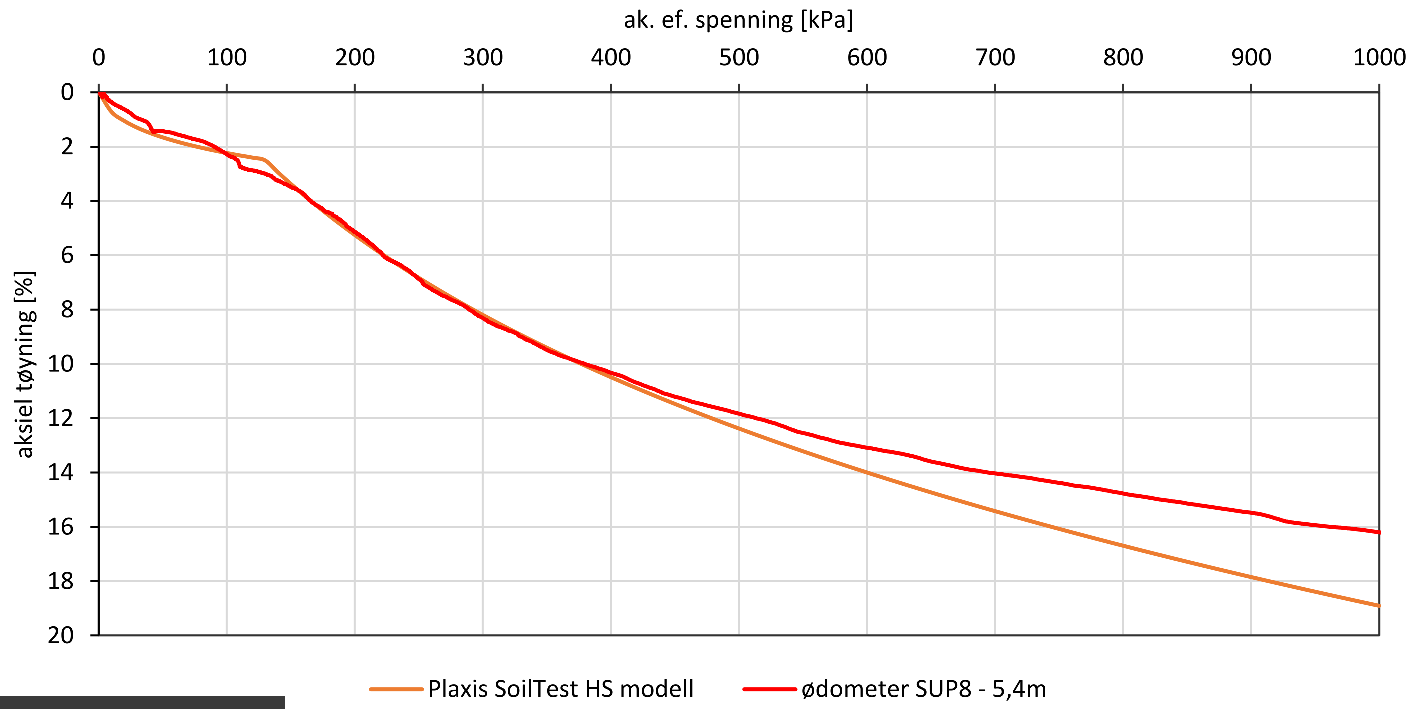
HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

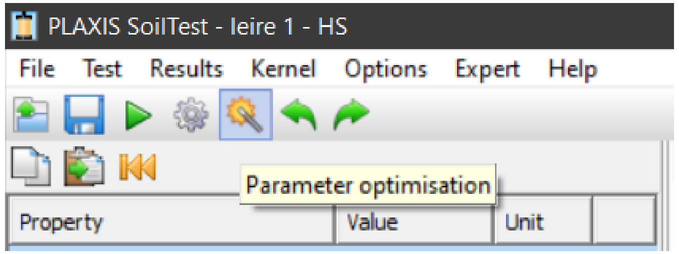
E_{oed} ~ 1,2 MPa
E_{50} ~ 3,0 MPa
E_{ur} ~ 22 MPa
m ~0,8



Bedre oppførsel fra 0 til P'c!
God match mellom 0 og 400 kPa

Vurdering: Er det god nok?

Alternativ:



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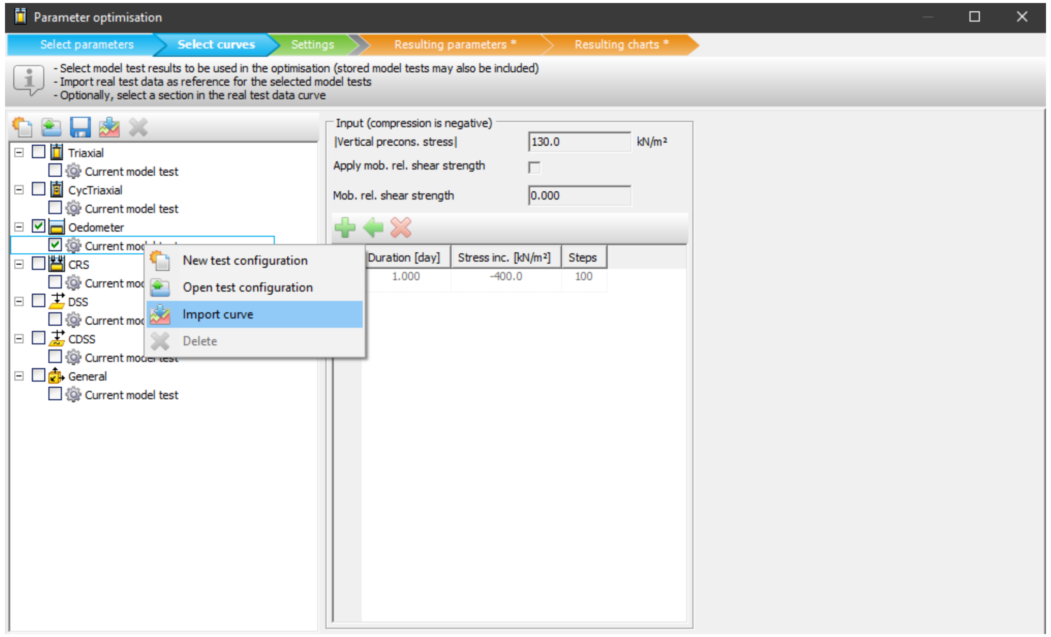
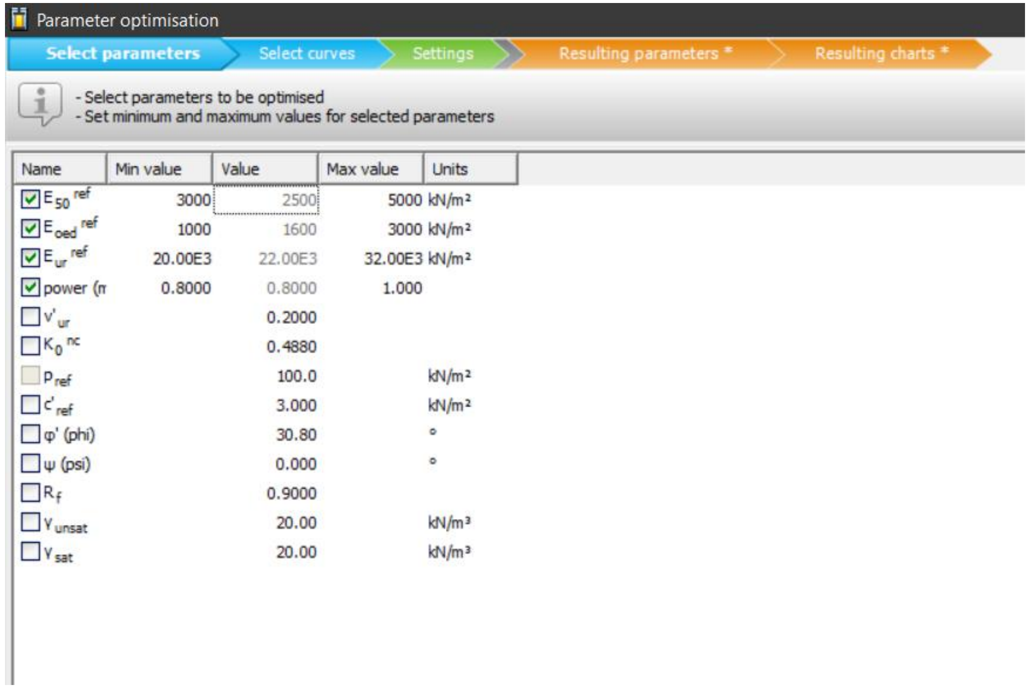
HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

I «select curves» kan man importere labforsøkene:

Optimalization verktøy:





HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

Optimalization resultater:

Select parameters | Select curves | Settings | **Resulting parameters** | Resulting charts

- Optimised parameters can be copied to material set

Name	Min value	Value	Max value	Units	Optimal	Sensitivity
E_{50}^{ref}	3000	2500	5000	kN/m²	**4582**	36.0 %
E_{oed}^{ref}	1000	1600	3000	kN/m²	**1694**	2.37 %
E_{ur}^{ref}	20.00E3	22.00E3	32.00E3	kN/m²	**23.03E3**	18.1 %
power (m)	0.8000	0.8000	1.000		**0.8091**	100 %
ν'_{ur}		0.2000			**0.2000**	0.00 %
K_0^{nc}		0.4880			**0.4880**	0.00 %
p_{ref}		100.0		kN/m²	**100.0**	0.00 %
c'_{ref}		3.000		kN/m²	**3.000**	0.00 %
φ' (phi)		30.80		°	**30.80**	0.00 %
ψ (psi)		0.000		°	**0.000**	0.00 %
R_f		0.9000			**0.9000**	0.00 %
γ_{unsat}		20.00		kN/m³	**20.00**	0.00 %
γ_{sat}		20.00		kN/m³	**20.00**	0.00 %

HS modell: eksempel for leire

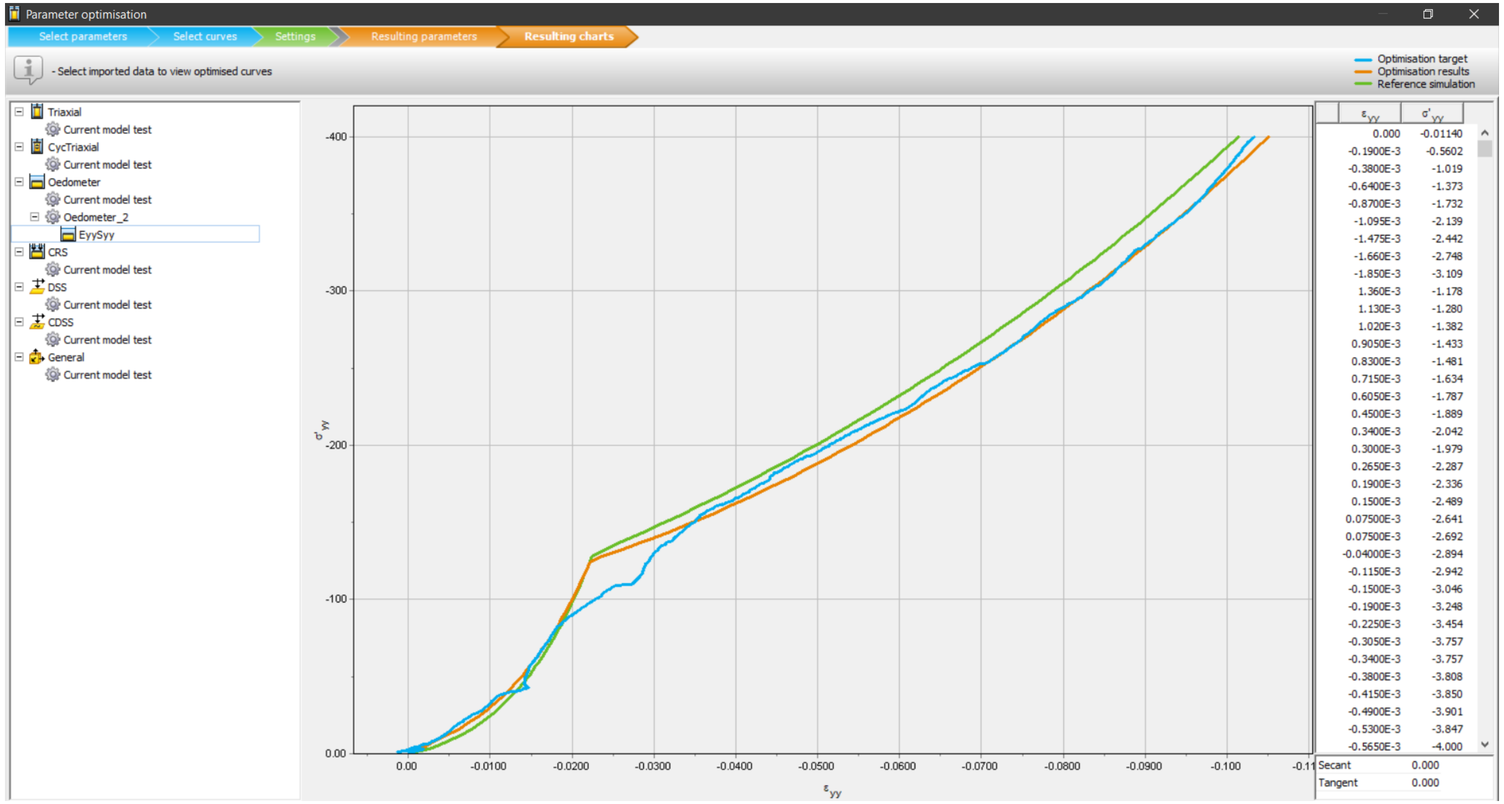
eksempel fra Saupstadbru prosjektet:

Optimalization resultater:

For ødometer, 0 til 400 kPa
Prekons. På 130 kPa

Ender opp med:

E_{oed} ~ 1,69 MPa
E_{50} ~ 4,58 MPa
E_{ur} ~ 23 MPa
m ~0,81



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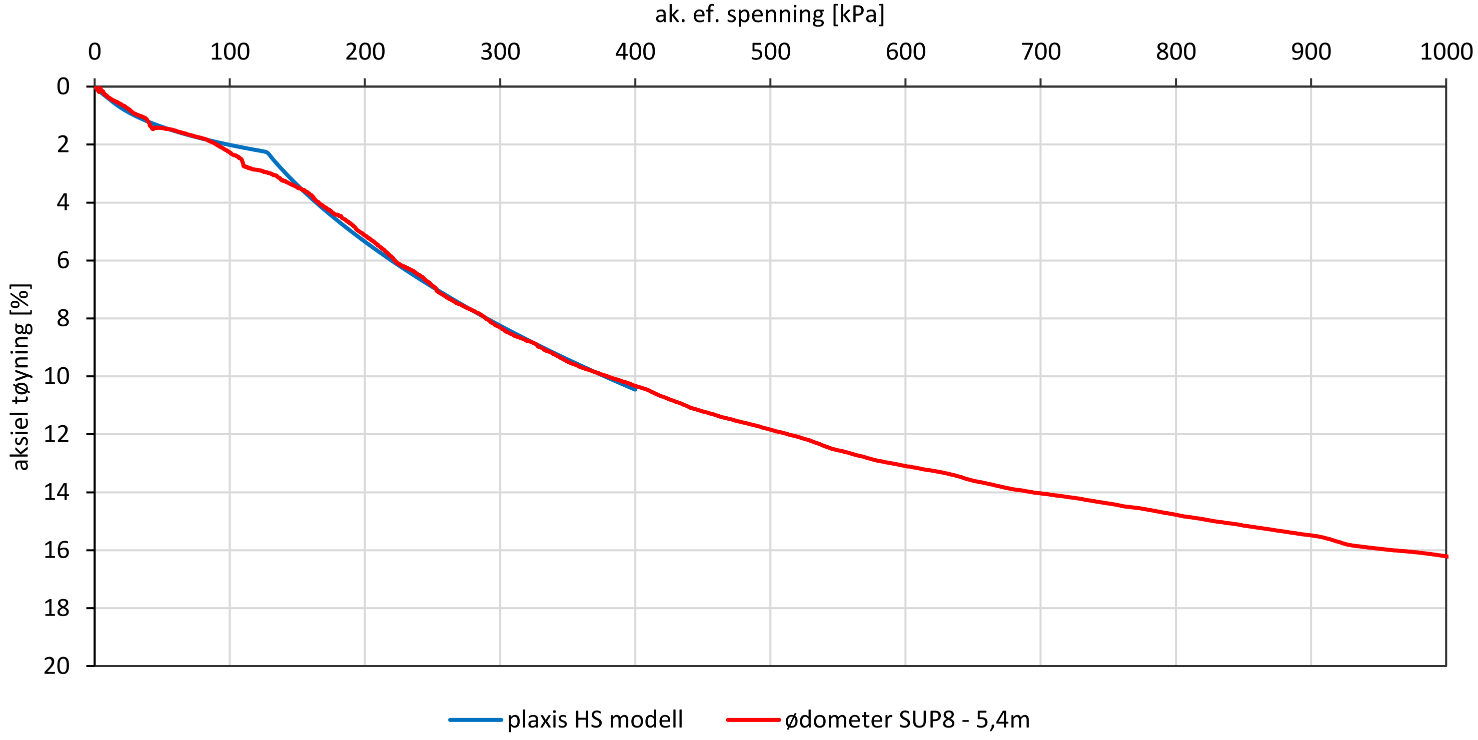
HS modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

Endte opp med:

E_{oed} ~ 1,69 MPa
E_{50} ~ 4,58 MPa
E_{ur} ~ 23 MPa
m ~0,81



Hva er «god nok»?
Sensitivitetsanalyser?

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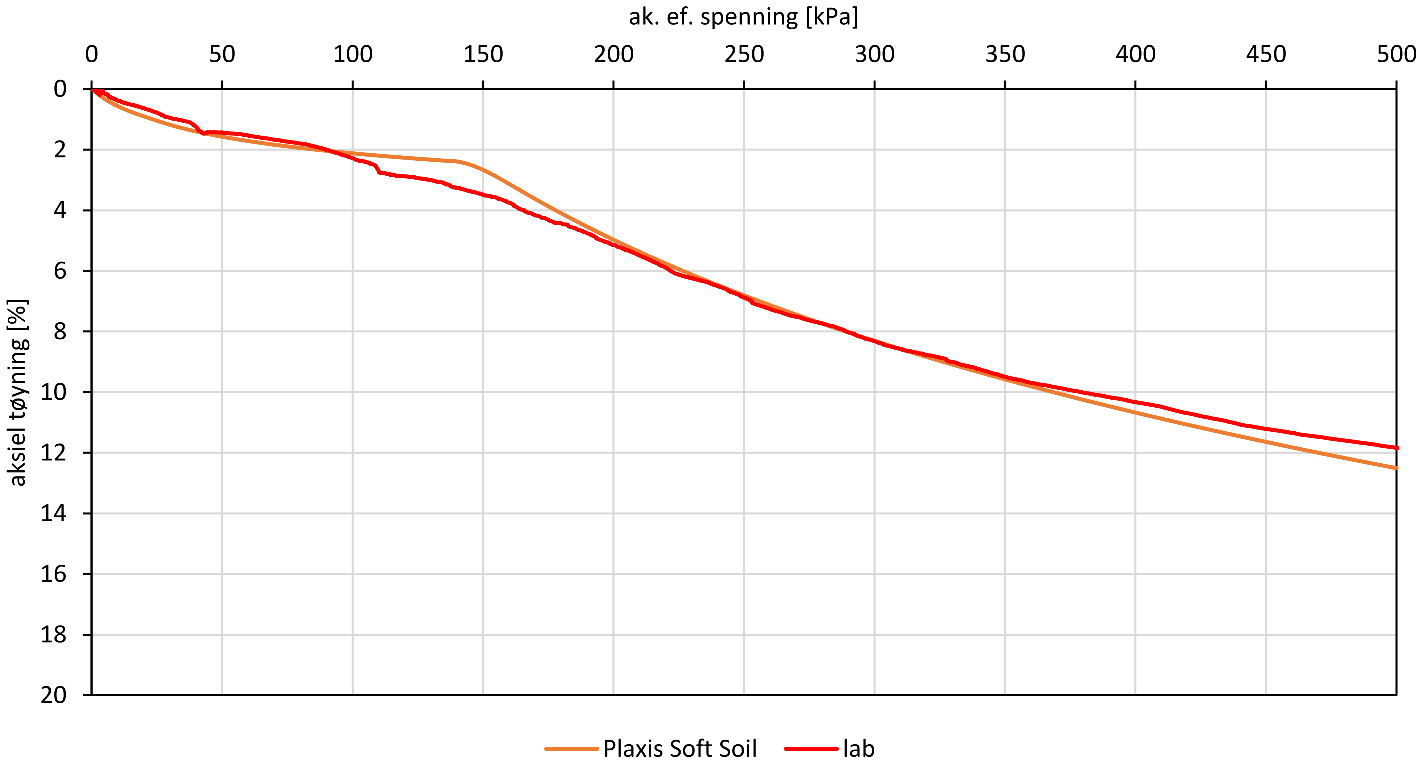
Soft Soil modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

Endte opp med:

Kappa* ~ 8,2E-3
Lambda* ~0,082

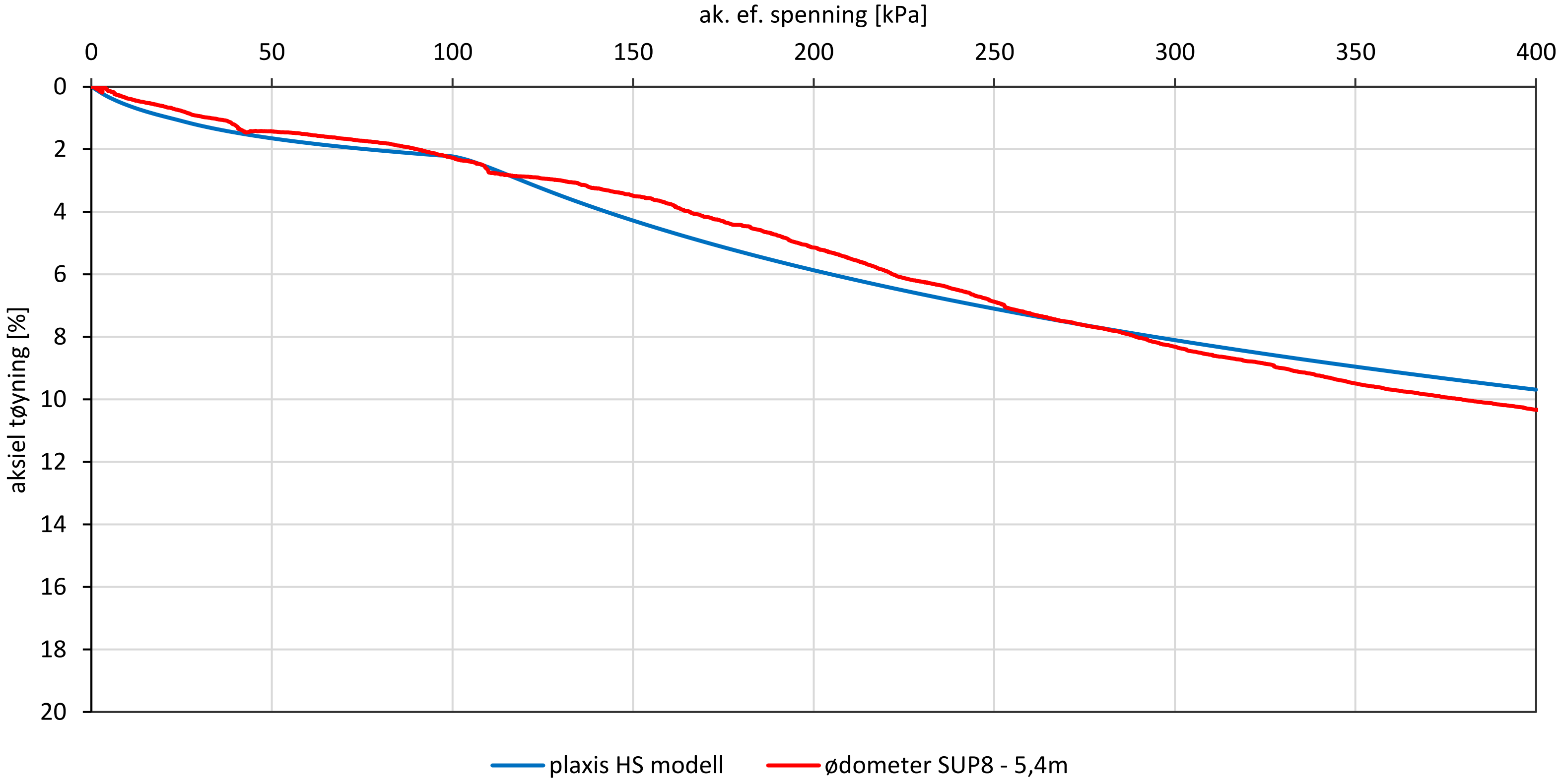


Soft Soil modell: eksempel for leire

eksempel fra Saupstadbru prosjektet:

Sensitivity analysis:

Kappa* ~ 8,7E-3
Lambda* ~0,055



Anbefaling om HS modell:

Possibilities and advantages compared to Mohr-Coulomb:

- Better non-linear formulation of soil behaviour in general (both soft soils and harder types of soil)
- Distinction between primary loading and unloading / reloading
- Memory of preconsolidation stress
- Different stiffnesses for different stress paths based on standard tests
- Well suited for unloading situations with simultaneous deviatoric loading (excavations)

Limitations and disadvantages:

- No peak strength and softening (immediate residual strength)
- No secundary compression (Creep)
- No anisotropy
- E_{50} / E_{oed} > 2 difficult to input

Fra «COMPUTATIONAL GEOTECHNICS», Plaxis kurs.

Small-strain stiffness: The HSsmall model

Advantages:

- Improved settlement trough behind retaining walls and above tunnels
- Less sensitive for position of model boundaries
- Hysteretic damping in dynamic applications

Fra «COMPUTATIONAL GEOTECHNICS», Plaxis kurs.

Anbefaling om Soft Soil modell:

Possibilities and *advantages* compared to LEPP (Mohr-Coulomb):

- Better non-linear formulation of soft soil behaviour (NC-clay; logarithmic compression)
- Distinction between primary loading and unloading / reloading
- Memory of preconsolidation stress
- Stiffness parameters based on oedometer tests
- Primarily suitable for compressive stress paths

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Anbefaling om Soft Soil modell:

Limitations and *disadvantages*:

- Not suitable for other types than soft soils
- Less suitable for non-compressive stress paths
- Not recommended to be used for excavations and pure unloading situations
- No peak strength and softening (directly to residual strength)
- No secondary compression (creep)
- No anisotropy
- Not possible to get "dry" side

Fra «COMPUTATIONAL GEOTECHNICS», Plaxis kurs.

Anbefaling om ulike jordmodeller:

	Soft soil (NC-clay, peat)	**Hard soils (OC-clay, sand, gravel)**
Primary loading (surcharge)	Soft Soil (Creep), HS, HSsmall	HS, HSsmall
Unloading + deviatoric load (excavation)	HS, HSsmall	HS, HSsmall
Deviatoric loading	Soft Soil (Creep), HS, HSsmall	HS, HSsmall
Secundary compression	Soft Soil Creep	N/A

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Anbefaling om ulike jordmodeller:

MC model: for simple estimates and for safety factors (stability)
Advanced soil models: for more accurate deformation predictions

Hardening Soil model:

- Use previous experience from lab, field and case records for strength and stiffness (E_{50} etc)
- Simulate an oedometer or/and a triaxial test to calibrate your soil parameter set
- Run your design problem
- Check the results and compare to hand calculations or other estimates / experience

Fra «Soil Modelling and Numerical Analyses», AFRY/Chalmers kurs.

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Takk for oppmerksomheten!

Making Future