Assignment 3

Task A: Parameter determination Modified-Cam-Clay

1. Model parameters calibration

1.1 Parameters fit diagram

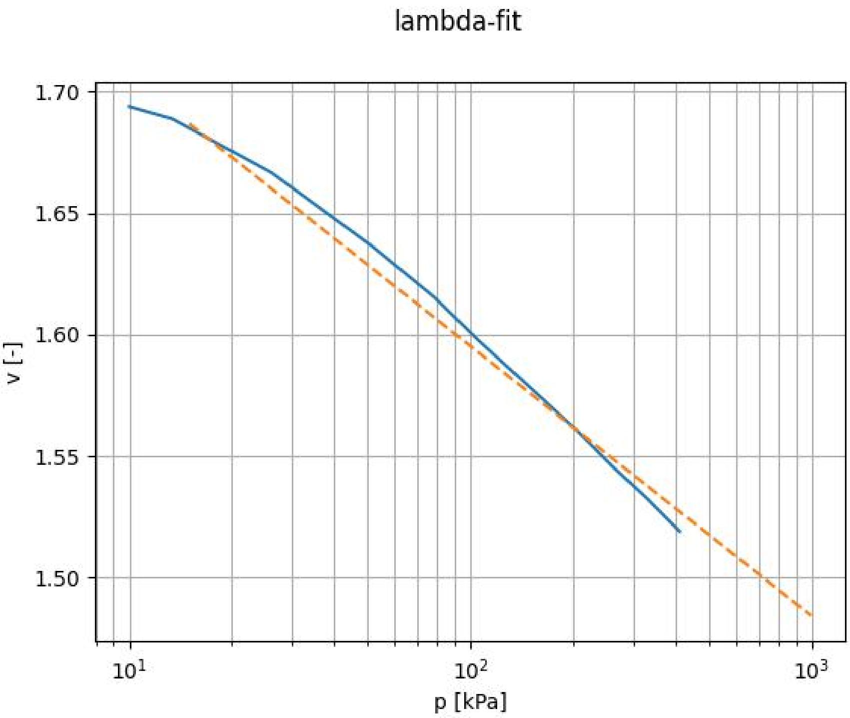


Figure 1 lambda-fit

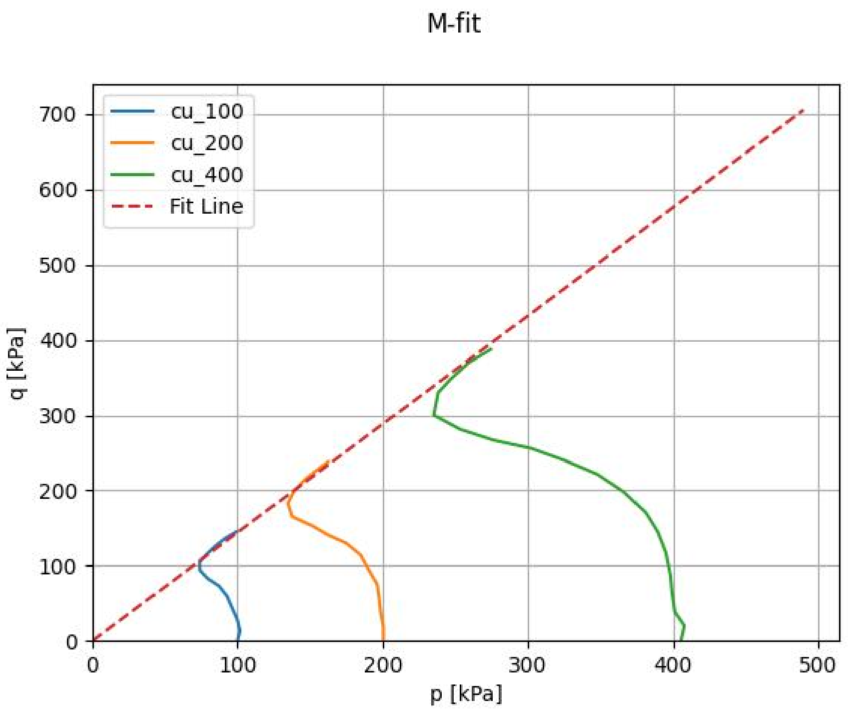


Figure 2 M-fit

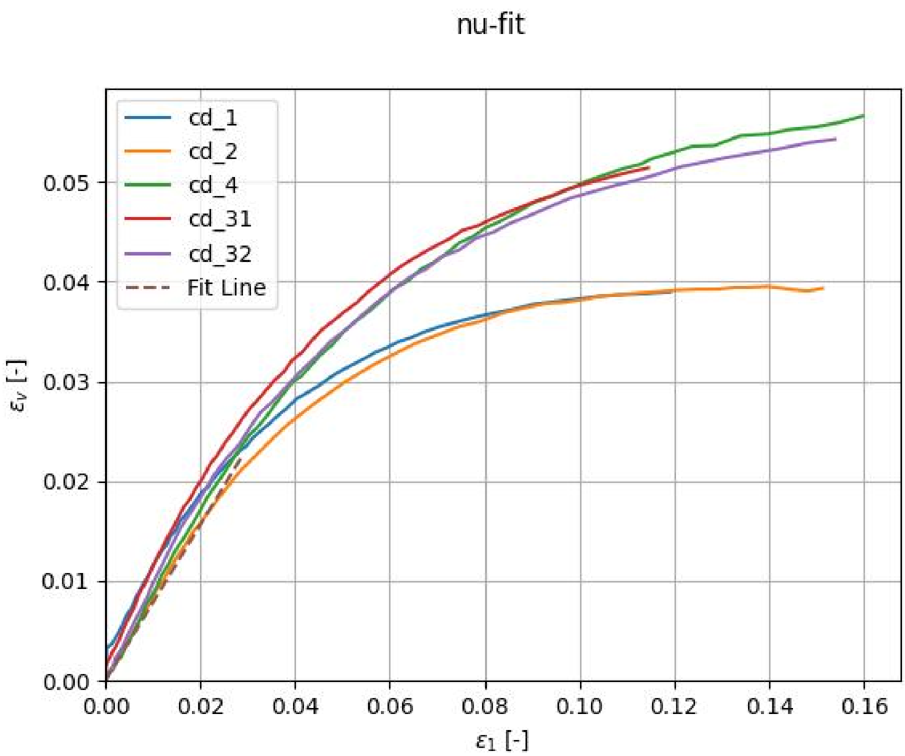


Figure 3 nu-fit

Table 1 Calibration results

M	λ	μ	k
1.440	0.048	0.110	0.005

Remark:

The k is estimated by $\kappa = \frac{1}{10} \times \lambda$

2 Laboratory tests and model predictions comparison

2.1 Drained triaxial test-cd1

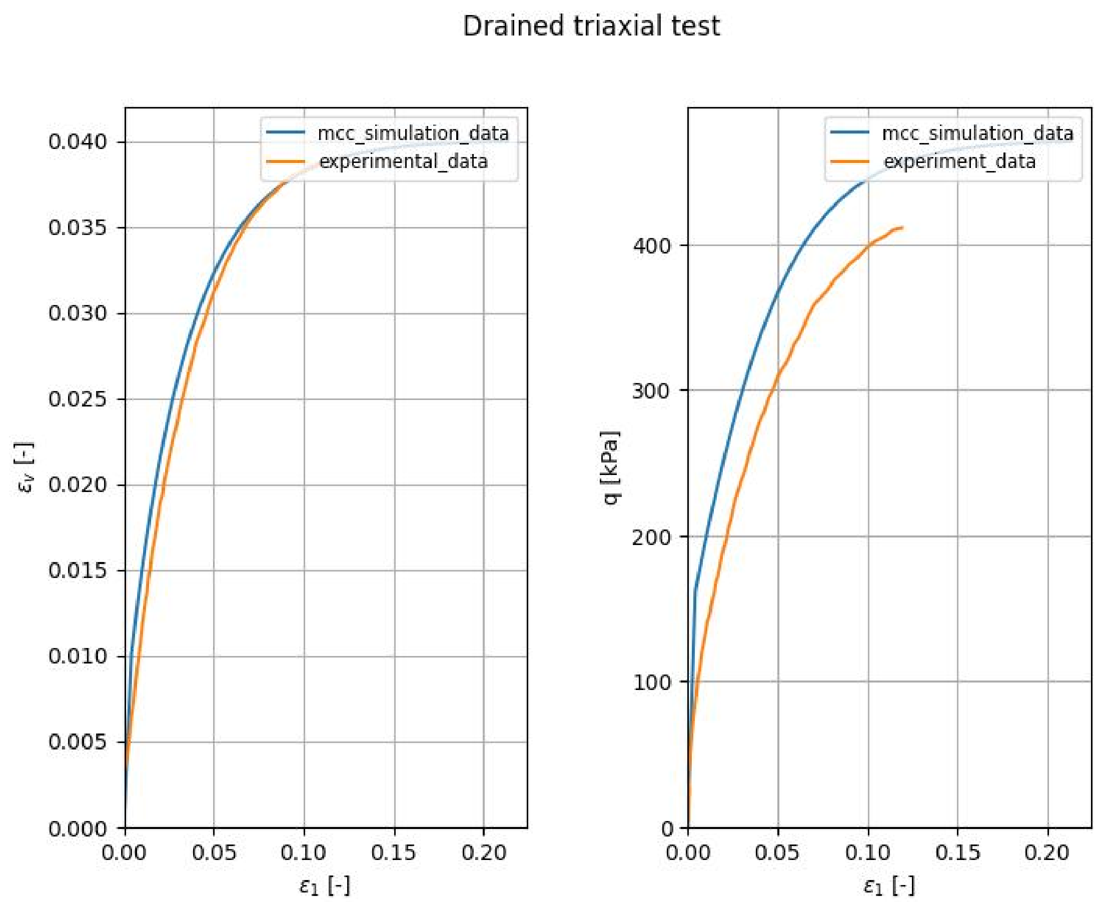


Figure 4 txdexpDataV.S.mcc_cd1

(1) Data analysis:

The simulation results above looks good. From $\varepsilon_1 - \varepsilon_v$ figure, with the increase of the vertical load, the state of soil appears contractancy, the soil should be loose soil. Because the positive ε_v And the slope of the linear part of the figure gives the Poisson's ratio, actually if increase the lambda value, the ε_v also increse. So the lambda value also can have an effect on the soil volume change situation.

From $q - \varepsilon_1$, the linear part slope of this figure gives the Young's modulus E, and the non-linear part gives the friction angle. But in mcc model, M also shows the change of $q - \varepsilon_1$ relationship, the larger M value will give the larger q at this figure. So it can also reflect the shear strength of soil in this general compression test. Also, if the K increase, the ε_v also increase but not significantly than q.

(2) The initial value and material parameters of cd-1 soil is below:

initial state

epor = 0.71 # void ratio

p = 150 # [kPa]

q = 0 # [kPa]

eps_1 = 0 # [-]

eps_2 = 0 # [-]

pC = 150   # [-] ... initial stress ratio for yield surface

# material models for the elastic and the plastic part
# "linelast" ... linear elasticity
# "mcc"   ... elastic part of modified cam clay
model_el = "mcc"
# "mc"   ... mohr-coulomb
# "edp" ... extended drucker-prager
# "mcc" ... modified cam clay
model_pl = "mcc"
model={"model_el":model_el, "model_pl":model_pl}

material parameters
M   = 1.44
Lambda = 0.048
kappa   = 0.005
nu   = 0.110
modelParam={"M":M, "nu":nu, "Lambda":Lambda, "kappa":kappa}

2.2 Drained triaxial test-cd2

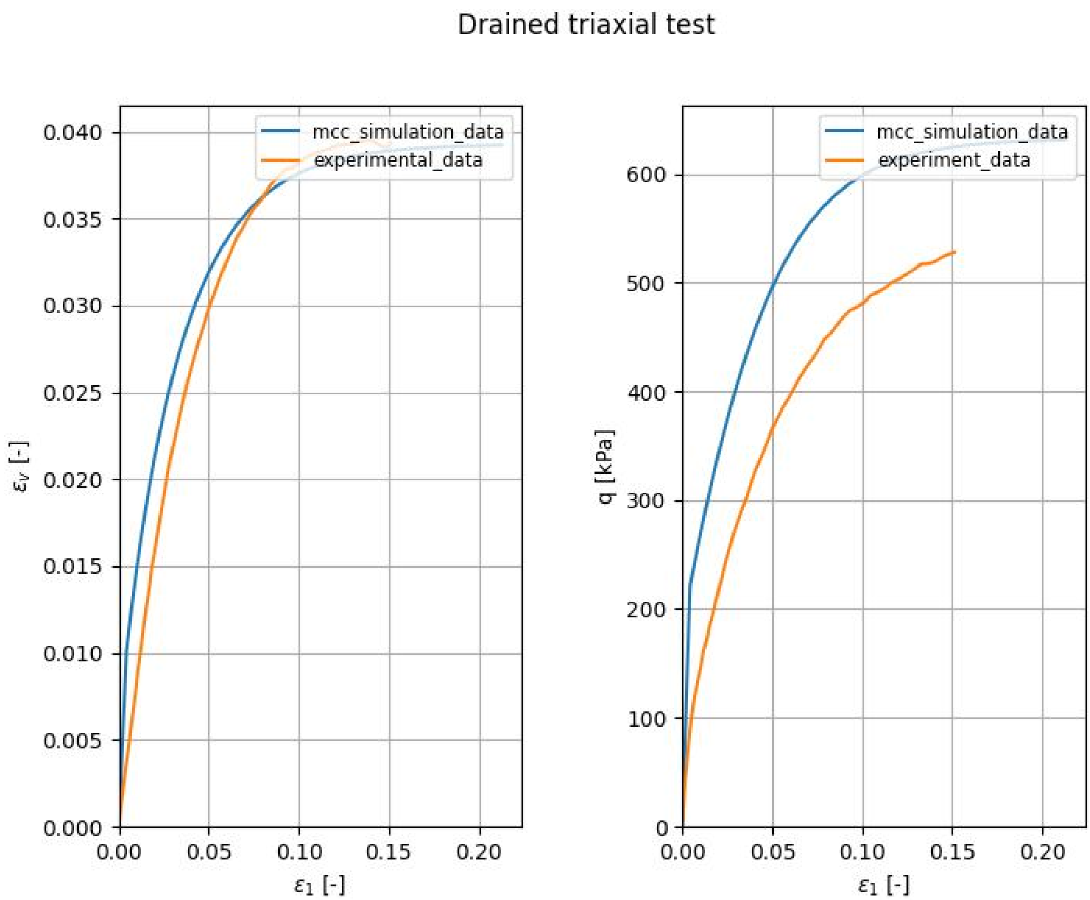


Figure 5 txdexpDataV.S.mcc_cd2

(1) Data analysis:

From above figure, it shows the similar results with “txdexpDataV.S.mcc_cd1”, but some difference in details, for example, q is increase. The reason should be the different initial state of these two state of soil.

(2) The initial value and material parameters of cd-2 soil is below:

```
# initial state
epor = 0.75         # void ratio
p = 200   # [kPa]
q = 0   # [kPa]
eps_1 = 0          # [-]
eps_2 = 0      # [-]
pC = 200         # [-] ... initial stress ratio for yield surface

# material models for the elastic and the plastic part
# "linelast" ... linear elasticity
# "mcc"           ... elastic part of modified cam clay
model_el = "mcc"
# "mc"    ... mohr-coulomb
# "edp" ... extended drucker-prager
# "mcc" ... modified cam clay
model_pl = "mcc"
model={"model_el":model_el, "model_pl":model_pl}

# material parameters
M          = 1.44
Lambda = 0.048
kappa   = 0.005
nu        = 0.110
modelParam={"M":M, "nu":nu, "Lambda":Lambda, "kappa":kappa}
```

2.3 Drained triaxial test-cd4

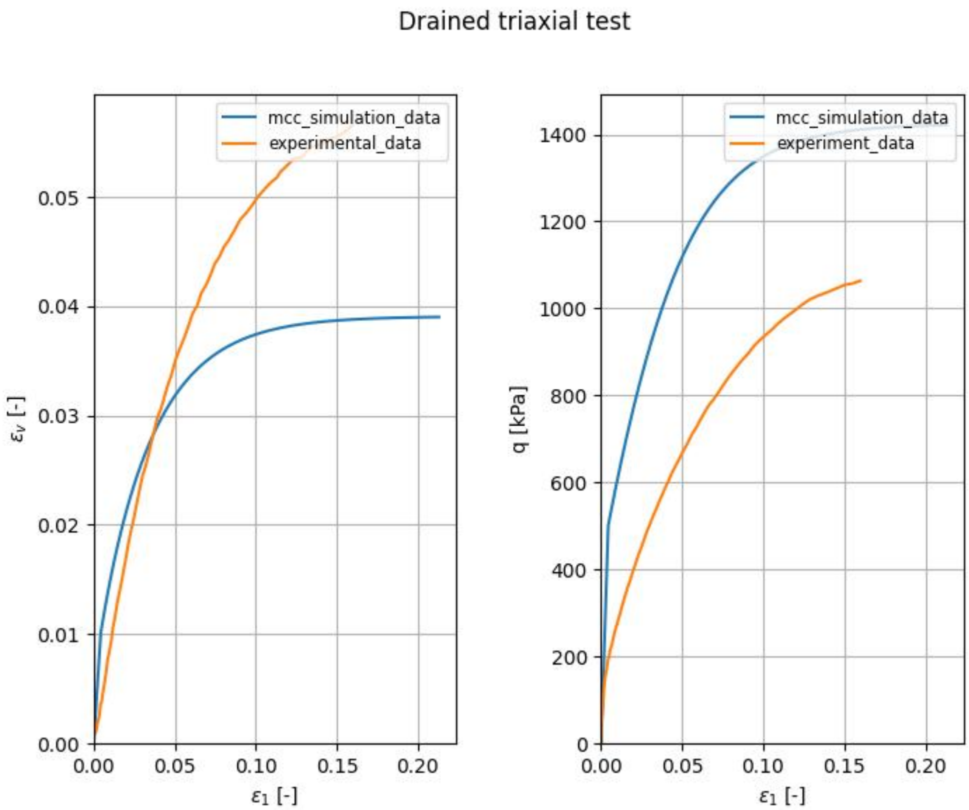


Figure 6_1 txdexpDataV.S.mcc_cd4

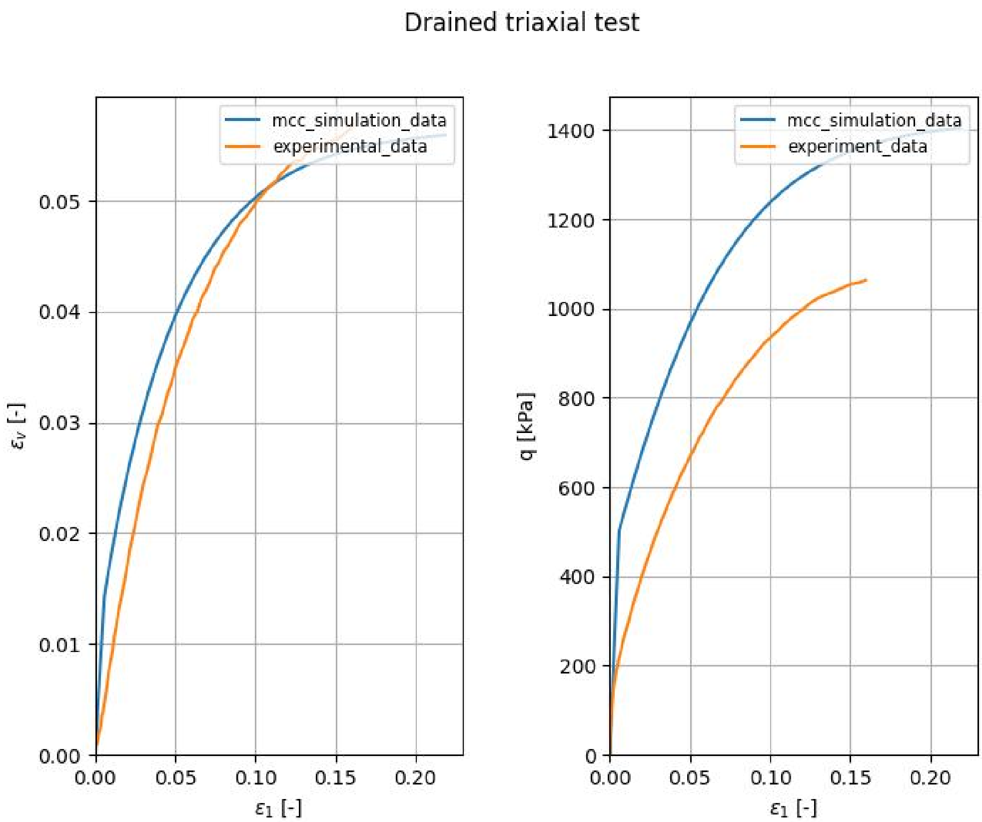


Figure 6_2 txdexpDataV.S.mcc_cd4

(1) Data analysis:

From figure 6_1, we can see the simulation results shows larger deviation than the figure 4 and figure 5. The reason is because the change of initial state, the initial state of the P is increased to 450 kPa comparing to the 150kPa and 200Kpa in figure 4 and figure 5. So the q-ε_1 shows the big difference. To tackle that, if I increase the M value, the difference between the simulation results and labtest results can be decresed.

From figure 6_2, we can see $\varepsilon_1 - \varepsilon_v$ is more closer to the labtest results, because I increase the lambda to 0.068 than the former one 0.048. It further shows that the lambda will have an effect on the change of soil volume.

(2) The initial value and material parameters of cd-4 soil is below:

```
# initial state
epor = 0.76         # void ratio
p = 450   # [kPa]
q = 0   # [kPa]
eps_1 = 0           # [-]
eps_2 = 0      # [-]
pC = 450          # [-] ... initial stress ratio for yield surface

# material models for the elastic and the plastic part
# "linelast" ... linear elasticity
# "mcc"           ... elastic part of modified cam clay
model_el = "mcc"
# "mc"    ... mohr-coulomb
# "edp" ... extended drucker-prager
# "mcc" ... modified cam clay
model_pl = "mcc"
model={"model_el":model_el, "model_pl":model_pl}

# material parameters
M          = 1.44
Lambda1 = 0.048
Lambda2 = 0.068
kappa   = 0.005
nu=0.45
modelParam={"M":M, "nu":nu, "Lambda":Lambda, "kappa":kappa}
```

2.4 Drained triaxial test-cd31

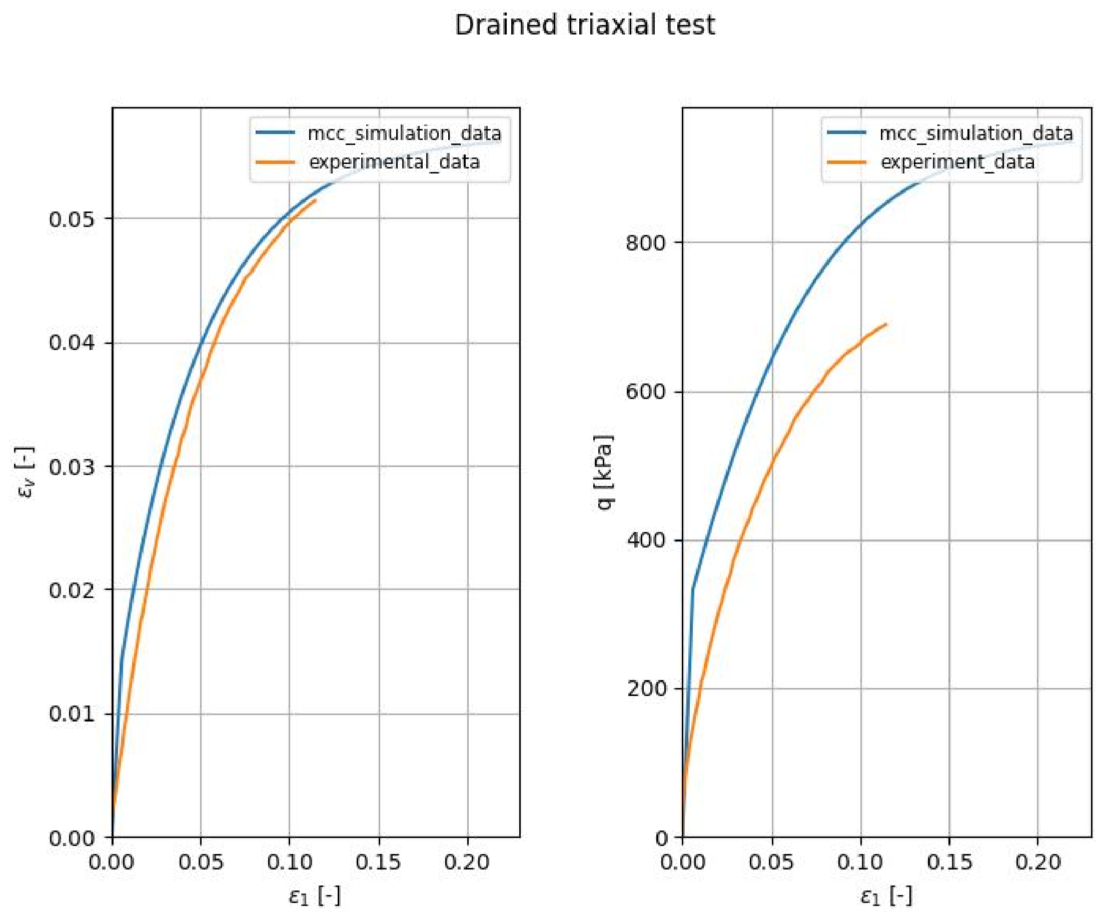


Figure 7 txdexpDataV.S.mcc_cd31

(1) Data analysis:

The results similar to Figure 5 txdexpDataV.S.mcc_cd2, reason is the same, different initial state. And $\varepsilon_1 - \varepsilon_v$ looks fine, and we can also calibrate again by decresing the M value, then the right hand figure above will be better approach the simulation results.

(2) The initial value and material parameters of cd-31 soil is below:

initial state

epor = 0.75 # void ratio

p = 300 # [kPa]

q = 0 # [kPa]

eps_1 = 0 # [-]

eps_2 = 0 # [-]

pC = 300 # [-] ... initial stress ratio for yield surface

material models for the elastic and the plastic part

"linelast" ... linear elasticity

"mcc" ... elastic part of modified cam clay

model_el = "mcc"

"mc" ... mohr-coulomb

```
# "edp" ... extended drucker-prager
# "mcc" ... modified cam clay
model_pl = "mcc"
model={"model_el":model_el, "model_pl":model_pl}

# material parameters
M        = 1.44
Lambda = 0.048
kappa   = 0.005
nu       = 0.110
modelParam={"M":M, "nu":nu, "Lambda":Lambda, "kappa":kappa}
```

2.5 Drained triaxial test-cd32

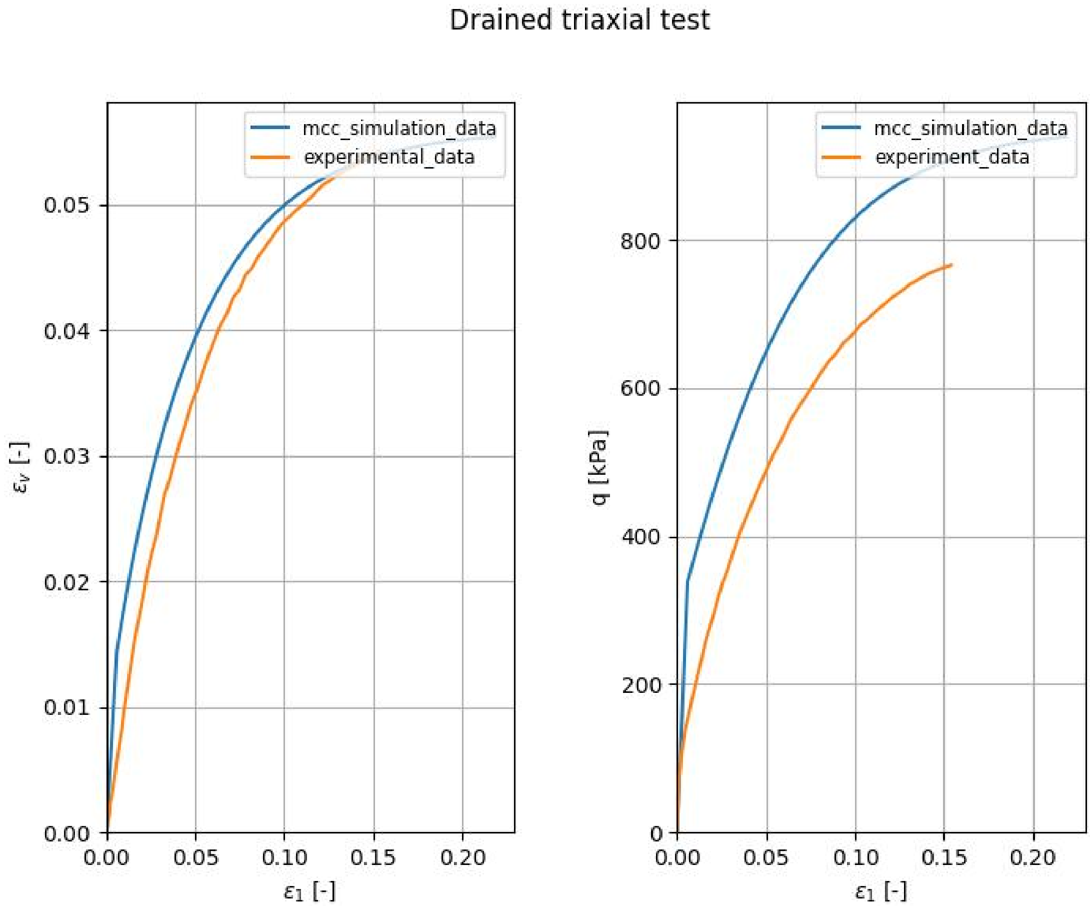


Figure 8 txdexpDataV.S.mcc_cd32

(1) The initial value and material parameters of cd32 soil is below:

```
# initial state
epor = 0.78          # void ratio
p = 300    # [kPa]
q = 0    # [kPa]
eps_1 = 0           # [-]
```

eps_2 = 0   # [-]
pC = 300   # [-] ... initial stress ratio for yield surface

# material models for the elastic and the plastic part
# "linelast" ... linear elasticity
# "mcc"   ... elastic part of modified cam clay
model_el = "mcc"
# "mc"   ... mohr-coulomb
# "edp" ... extended drucker-prager
# "mcc" ... modified cam clay
model_pl = "mcc"
model={"model_el":model_el, "model_pl":model_pl}

material parameters
M   = 1.44
Lambda = 0.048
kappa   = 0.005
nu   = 0.110
modelParam={"M":M, "nu":nu, "Lambda":Lambda, "kappa":kappa}

2.6 Undrained triaxial test cu100

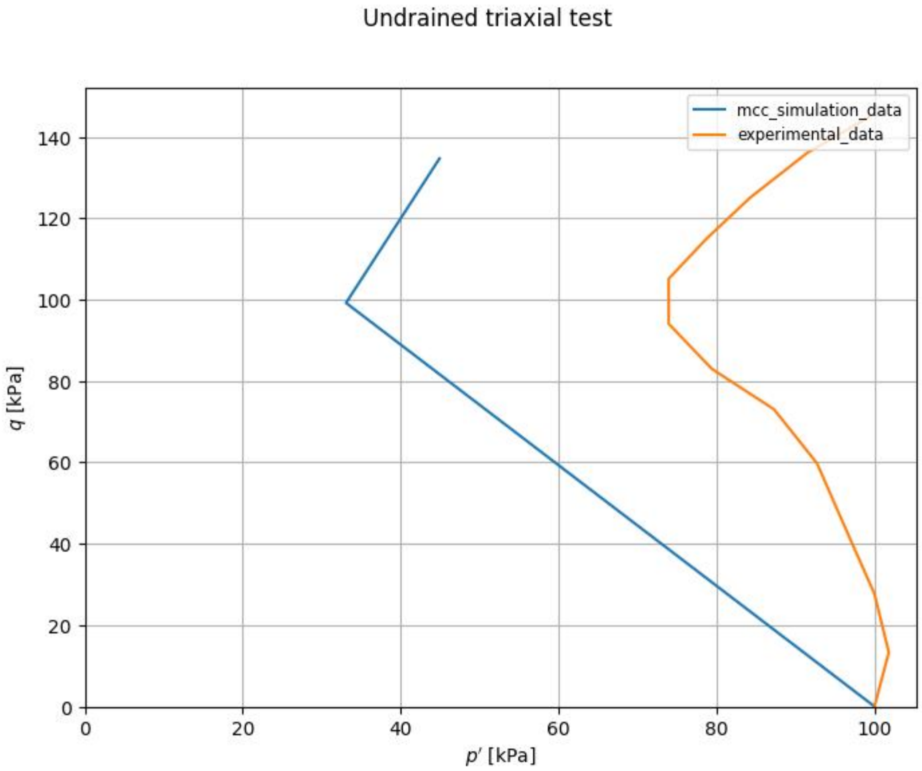


Figure 9 txdexpDataV.S.mcc_cu100

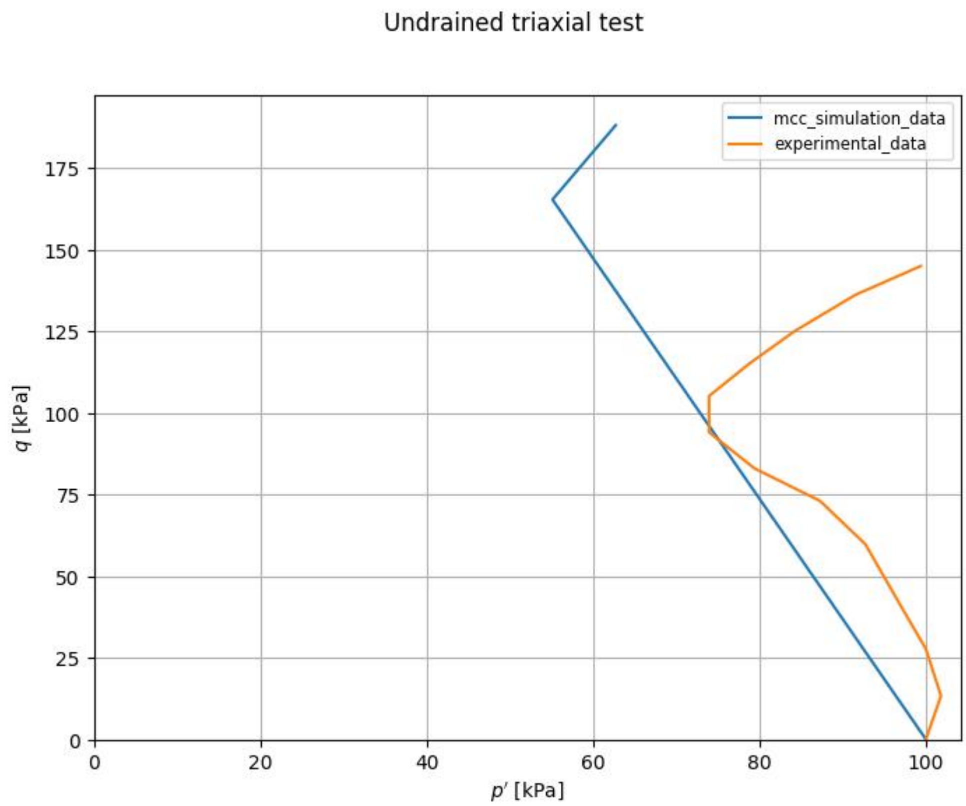


Figure 10 txdexpDataV.S.mcc_cu100, with kappa = 0.003

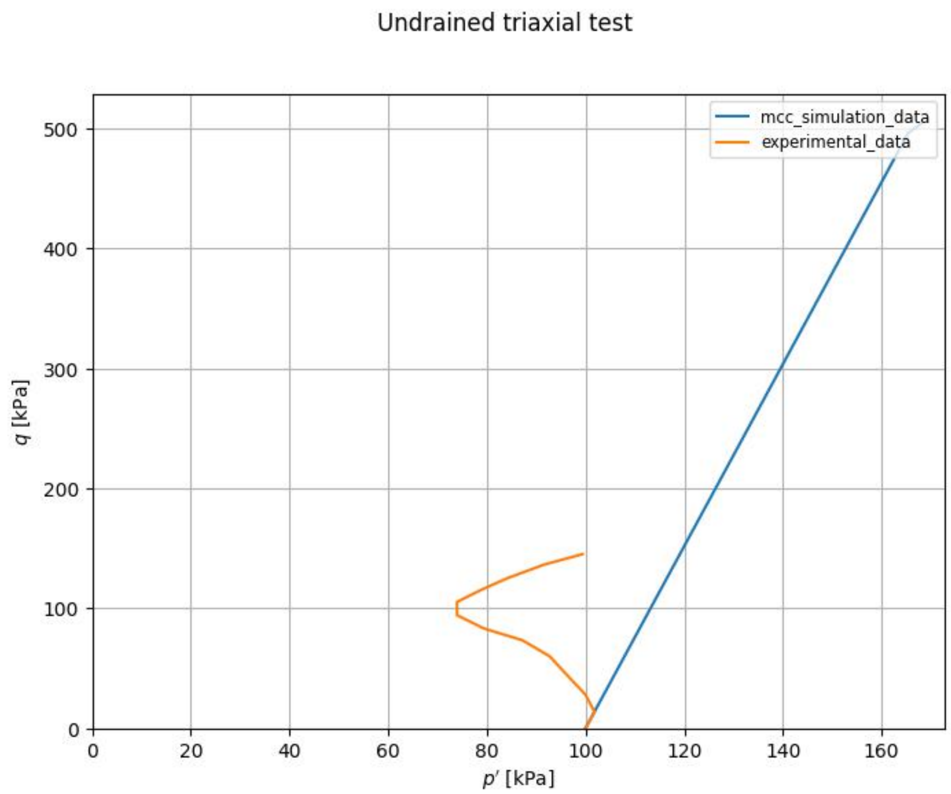


Figure 11 txdexpDataV.S.mcc_cu100, with kappa = 0.001

(1) Data analysis:

From the above figure 9, we can see at first trend the effective stress decrease, because the pore water pressure increase and positive excess pore water pressure at plastic range. At the same time, we can known from the figure, this soil sample is loose soil. And after it reach the limit state condition, the the effective stress increases and soil start to bear the load. But the simulation results not seen good, but at least the trend can be acceptable.

From figure 10 with changing the calibration date kappa to more lower, the simulation result more close to experimental results at first stage(soil not limit to the critical state line), and when I change it to lower than 0.001 the trend of this figure also change see the figure 11. The possible reason is with the kappa increase, the slope of the v-p' increase, meaning that the volume change speed will increase with increasing the mean stress. So the devitoric stress rate also increse.

(2) The initial value and material parameters of cu100 soil is below:

```
# initial state
epor = 0.569        # void ratio
p = 100   # [kPa]
q = 0   # [kPa]
eps_1 = 0         # [-]
eps_2 = 0     # [-]
pC = 100        # [-] ... initial stress ratio for yield surface

# material models for the elastic and the plastic part
# "linelast" ... linear elasticity
# "mcc"          ... elastic part of modified cam clay
model_el = "mcc"
# "mc"   ... mohr-coulomb
# "edp" ... extended drucker-prager
# "mcc" ... modified cam clay
model_pl = "mcc"
model={"model_el":model_el, "model_pl":model_pl}

# material parameters
M         = 1.44
Lambda = 0.048
kappa   = 0.005
nu        = 0.110
modelParam={"M":M, "nu":nu, "Lambda":Lambda, "kappa":kappa}
```

2.7 Undrained triaxial test cu200

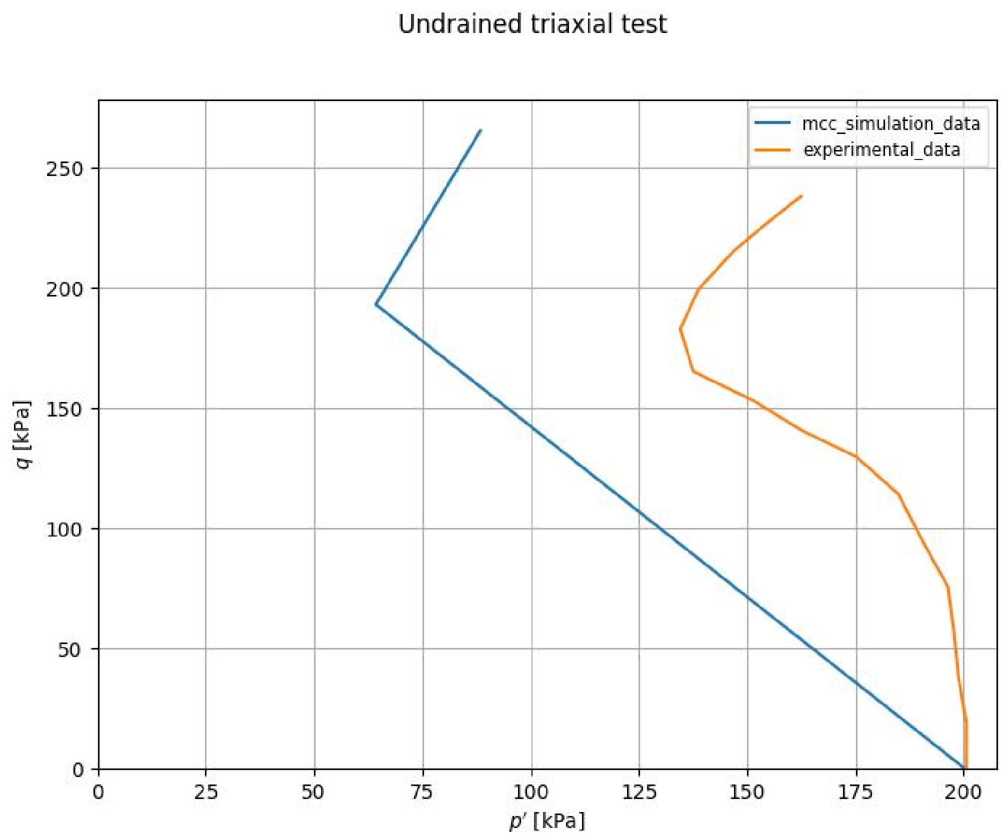


Figure 12 txdexpDataV.S.mcc_cu200

(1) Data analysis:

The difference between Figure 12 and Figure 9 is small, which shows the increasing of the yield surface value pC and initial p value have slight influence on p'-q. The reason may be the unloading reloading line is parallel for a specific soil. So the kappa almost same.

(2) The initial value and material parameters of cu100 soil is below:

```
# initial state
epor = 0.525        # void ratio
p = 200    # [kPa]
q = 0    # [kPa]
eps_1 = 0          # [-]
eps_2 = 0      # [-]
pC = 200         # [-] ... initial stress ratio for yield surface

# material models for the elastic and the plastic part
# "linelast" ... linear elasticity
# "mcc"          ... elastic part of modified cam clay
model_el = "mcc"
# "mc"    ... mohr-coulomb
# "edp" ... extended drucker-prager
# "mcc" ... modified cam clay
```

model_pl = "mcc"
model={"model_el":model_el, "model_pl":model_pl}

# material parameters
M = 1.44
Lambda = 0.048
kappa = 0.005
nu = 0.110
modelParam={"M":M, "nu":nu, "Lambda":Lambda, "kappa":kappa}

2.8 Undrained triaxial test cu400

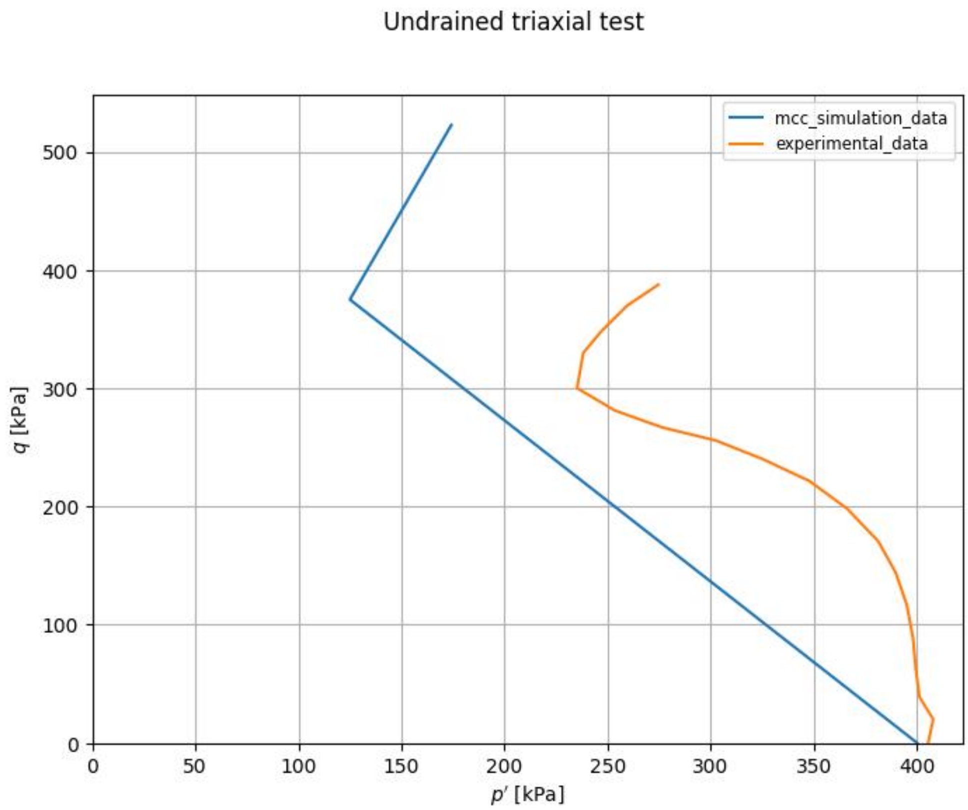


Figure 13 txdexpDataV.S.mcc_cu400

(1) The initial value and material parameters of cu100 soil is below:
# initial state
epor = 0.482 # void ratio
p = 400 # [kPa]
q = 0 # [kPa]
eps_1 = 0 # [-]
eps_2 = 0 # [-]
pC = 400 # [-] ... initial stress ratio for yield surface

material models for the elastic and the plastic part
"linelast" ... linear elasticity

```
# "mcc"         ... elastic part of modified cam clay
model_el = "mcc"
# "mc"    ... mohr-coulomb
# "edp" ... extended drucker-prager
# "mcc" ... modified cam clay
model_pl = "mcc"
model={"model_el":model_el, "model_pl":model_pl}

# material parameters
M        = 1.44
Lambda = 0.048
kappa   = 0.005
nu       = 0.110
modelParam={"M":M, "nu":nu, "Lambda":Lambda, "kappa":kappa}
```

Task B: Determination of different soil states

TASK B Determination of different soil states

a) Data Calculation

known: $P_1 = 400\,kPa$, $P_2 = \overset{3}{\cancel{6}}00\,kPa$, $\sigma_1 = 600\,kPa$, $u = 130\,kPa$, $e_0 = 1.3$, $P_0' = 1\,kPa$

$\nu = 0.132$, $M = 1.4$, $\lambda = 0.1093$, $K = 0.0082$

Find: q, p', e, σ_1, σ_2, p each loading step.

state	σ_1 [kPa]	σ_2 [kPa]	p [kPa]	p' [kPa]	q [kPa]	e [-]	u [kPa]	σ_1' [kPa]	σ_2' [kPa]
1	400	400	400	400	0	0.645		400	400
2	300	300	300	300	0	0.647		300	300
3	600	300	400	270	300	0.647	130	470	170

state 1: $P_1 = 400\,kPa$ (isotropic compressed) $\sigma_1 = \sigma_2$

① $\underline{\underline{q_1 = 0}}$

② $\underline{P_1} = \frac{\sigma_1 + 2\sigma_2}{3} = \underline{\sigma_1 = \sigma_2} = \underline{\underline{400\,kpa}}$

③ seek e_1, $e = e_0 - \lambda \ln(\frac{P'}{P_0'})$ (Formula 1)

$\underline{\underline{e_1}} = e_0 - \lambda \ln(\frac{P_1'}{P_0'})$

$e_0 = 1.3$, $\lambda = 0.1093$, $P_1' = 400\,kPa$, $P_0' = 1\,kPa$

$= 1.3 - 0.1093 \cdot \ln(\frac{400\,kPa}{1\,kPa})$

$= \underline{\underline{0.645}}$

state 2: isotropic ~~compressed~~ compressed to $P_1 = 400\,kpa$, then unloaded to $P_2 = 300\,kpa$.

① $\underline{\underline{q_2 = 0}}$

② $\underline{\underline{P_2 = P_2'}} = \frac{\sigma_1 + 2\sigma_2}{3} = \underline{\sigma_1 = \sigma_2} = \underline{300\,kpa}$ (drained)

③ seek e_2, $e = e_1 - k \ln(P'/P_1)$ (Formula 2)

$\underline{\underline{e_2}} = e_1 - k \ln \frac{P_2'}{P_1'}$

$= 0.645 - 0.0082 \cdot \ln(\frac{300\,kPa}{400\,kPa})$

$= \underline{\underline{0.647}}$

State 3: undrained triaxial shearing

① $\Delta e = 0$

$e_3 - e_2 = 0$

$e_3 = e_2 = 0.647$

② $\sigma_1' = \sigma_1 - u$

$\overset{!}{=} 600\,kPa - 130\,kPa$

$\overset{!}{=} 470\,kPa$

③ $\sigma_2 = 300\,kPa$ (same as state 2, because $\Delta\sigma_2 = const$)

$\sigma_2' = \sigma_2 - u$

$\overset{!}{=} 300\,kPa - 130\,kPa$

$\overset{!}{=} 170\,kPa$

④ $p_3' = \frac{\sigma_1' + 2\sigma_2'}{3}$

$\overset{!}{=} \frac{470\,kPa + 2 \cdot 170\,kPa}{3}$

$\overset{!}{=} 270\,kPa$

$q = \sigma_1 - \sigma_2$

$\overset{!}{=} 600\,kPa - 300\,kPa$

$\overset{!}{=} 300\,kPa$

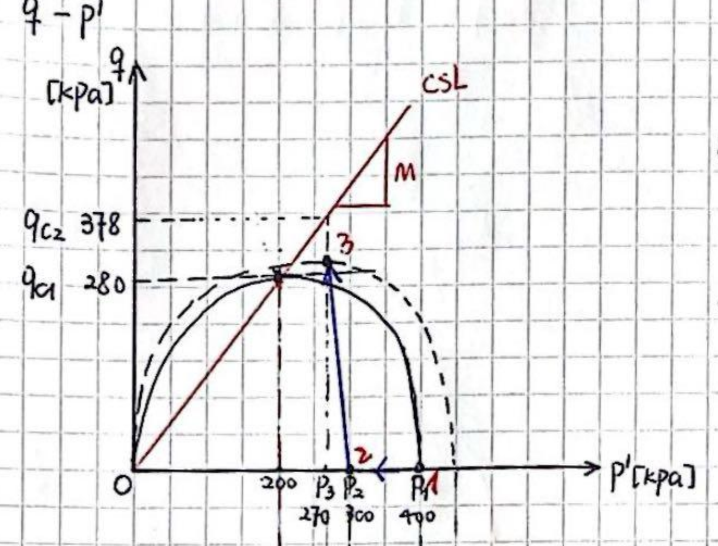
$p_3 = p_3' + u$

$\overset{!}{=} 270\,kPa + 130\,kPa$

$\overset{!}{=} 400\,kPa$

b) Data Plotting

① $q - p'$



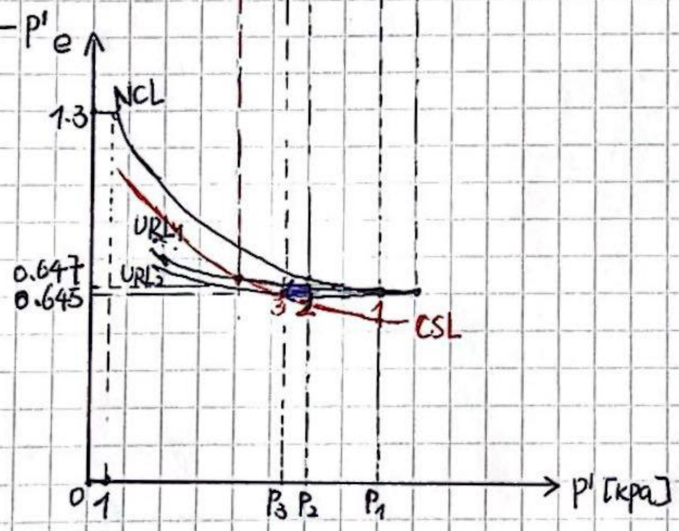
From. $\left(\frac{q}{p'}\right)_c = M$,

$q_{c1} = 280$ kpa, $q_{c2} = 378$ kpa

Because $q_{c1} < q_3 < q_{c2}$

So state 3 will not located on the critical state line.

② $e - p'$



③