Graphical approach to barodesy

distant learning

Dimitrios Kolymbas

Division of Geotechnical and Tunnel Engineering
Innsbruck University

Innsbruck 2020

UNIVERSITÄT IGT INNSBRUCK

Aim

This short presentation should show, that the entire mechanical behaviour of sand can be inferred from two rules by Goldscheider.

In this lecture the derivation is purely graphical.

Mathematically, the derivation is accomplished by the theory of barodesy.

UNIVERSITÄT IGT INNSBRUCK

Aim

This short presentation should show, that the entire mechanical behaviour of sand can be inferred from two rules by Goldscheider.

In this lecture the derivation is purely graphical.

Mathematically, the derivation is accomplished by the theory of barodesy.

UNIVERSITÄT IGT INNSBRUCK

Aim

This short presentation should show, that the entire mechanical behaviour of sand can be inferred from two rules by Goldscheider.

In this lecture the derivation is purely graphical.

Mathematically, the derivation is accomplished by the theory of barodesy.

Aim

This short presentation should show, that the entire mechanical behaviour of sand can be inferred from two rules by Goldscheider.

In this lecture the derivation is purely graphical.

Mathematically, the derivation is accomplished by the theory of barodesy.

Aim

This short presentation should show, that the entire mechanical behaviour of sand can be inferred from two rules by Goldscheider.

In this lecture the derivation is purely graphical.

Mathematically, the derivation is accomplished by the theory of barodesy.

Goldscheider's rules

We consider

- proportional ϵ-Paths (i.e. $\epsilon_1 : \epsilon_2 = \text{const}$)
- proportional σ-Paths (i.e. $\sigma_1 : \sigma_2 = \text{const}$).

Proportional paths (PP) are thus straight lines through the origin

(For illustration here only 2 dimensions, i.e. plane deformation)

1. Goldscheider rule:

Starting from $\sigma = \mathbf{0}$: PϵP $\rightarrow$ PσP

2. Goldscheider rule:

Starting from $\sigma \neq \mathbf{0}$: PϵP lead asymptotically to PσP

Follows from the principle of fading memory: The initial state is gradually forgotten.

UNIVERSITÄT IGT INNSBRUCK

Goldscheider's rules

We consider

- proportional ϵ-Paths (i.e. $\epsilon_1 : \epsilon_2 = \text{const}$)
- proportional σ-Paths (i.e. $\sigma_1 : \sigma_2 = \text{const}$).

Proportional paths (PP) are thus straight lines through the origin

(For illustration here only 2 dimensions, i.e. plane deformation)

1. Goldscheider rule:

Starting from $\sigma = \mathbf{0}$: PϵP $\rightarrow$ PσP

2. Goldscheider rule:

Starting from $\sigma \neq \mathbf{0}$: PϵP lead asymptotically to PσP

Follows from the principle of fading memory: The initial state is gradually forgotten.

UNIVERSITÄT IGT INNSBRUCK

Goldscheider's rules

We consider

- proportional ϵ-Paths (i.e. $\epsilon_1 : \epsilon_2 = \text{const}$)
- proportional σ-Paths (i.e. $\sigma_1 : \sigma_2 = \text{const}$).

Proportional paths (PP) are thus straight lines through the origin

(For illustration here only 2 dimensions, i.e. plane deformation)

1. Goldscheider rule:

Starting from $\sigma = \mathbf{0}$: PϵP $\rightarrow$ PσP

2. Goldscheider rule:

Starting from $\sigma \neq \mathbf{0}$: PϵP lead asymptotically to PσP

Follows from the principle of fading memory: The initial state is gradually forgotten.

Goldscheider's rules

We consider

- proportional ϵ-Paths (i.e. $\epsilon_1 : \epsilon_2 = \text{const}$)
- proportional σ-Paths (i.e. $\sigma_1 : \sigma_2 = \text{const}$).

Proportional paths (PP) are thus straight lines through the origin

(For illustration here only 2 dimensions, i.e. plane deformation)

1. Goldscheider rule:

Starting from $\sigma = \mathbf{0}$: PϵP $\rightarrow$ PσP

2. Goldscheider rule:

Starting from $\sigma \neq \mathbf{0}$: PϵP lead asymptotically to PσP

Follows from the principle of fading memory: The initial state is gradually forgotten.

UNIVERSITÄT IGT INNSBRUCK

Goldscheider's rules

We consider

- proportional ϵ-Paths (i.e. $\epsilon_1 : \epsilon_2 = \text{const}$)
- proportional σ-Paths (i.e. $\sigma_1 : \sigma_2 = \text{const}$).

Proportional paths (PP) are thus straight lines through the origin

(For illustration here only 2 dimensions, i.e. plane deformation)

1. Goldscheider rule:

Starting from $\sigma = \mathbf{0}$: PϵP $\rightarrow$ PσP

2. Goldscheider rule:

Starting from $\sigma \neq \mathbf{0}$: PϵP lead asymptotically to PσP

Follows from the principle of fading memory: The initial state is gradually forgotten.

UNIVERSITÄT IGT INNSBRUCK

Goldscheider's rules

We consider

- proportional ϵ-Paths (i.e. $\epsilon_1 : \epsilon_2 = \text{const}$)
- proportional σ-Paths (i.e. $\sigma_1 : \sigma_2 = \text{const}$).

Proportional paths (PP) are thus straight lines through the origin

(For illustration here only 2 dimensions, i.e. plane deformation)

1. Goldscheider rule:

Starting from $\sigma = \mathbf{0}$: PϵP $\rightarrow$ PσP

2. Goldscheider rule:

Starting from $\sigma \neq \mathbf{0}$: PϵP lead asymptotically to PσP

Follows from the principle of fading memory: The initial state is gradually forgotten.

UNIVERSITÄT IGT INNSBRUCK

Goldscheider's rules

We consider

- proportional ϵ-Paths (i.e. $\epsilon_1 : \epsilon_2 = \text{const}$)
- proportional σ-Paths (i.e. $\sigma_1 : \sigma_2 = \text{const}$).

Proportional paths (PP) are thus straight lines through the origin

(For illustration here only 2 dimensions, i.e. plane deformation)

1. Goldscheider rule:

Starting from $\sigma = \mathbf{0}$: PϵP $\rightarrow$ PσP

2. Goldscheider rule:

Starting from $\sigma \neq \mathbf{0}$: PϵP lead asymptotically to PσP

Follows from the principle of fading memory: The initial state is gradually forgotten.

Goldscheider's rules

We consider

- proportional ϵ-Paths (i.e. $\epsilon_1 : \epsilon_2 = \text{const}$)
- proportional σ-Paths (i.e. $\sigma_1 : \sigma_2 = \text{const}$).

Proportional paths (PP) are thus straight lines through the origin

(For illustration here only 2 dimensions, i.e. plane deformation)

1. Goldscheider rule:

Starting from $\sigma = \mathbf{0}$: PϵP $\rightarrow$ PσP

2. Goldscheider rule:

Starting from $\sigma \neq \mathbf{0}$: PϵP lead asymptotically to PσP

Follows from the principle of fading memory: The initial state is gradually forgotten.

Goldscheider's rules

We consider

- proportional ϵ-Paths (i.e. $\epsilon_1 : \epsilon_2 = \text{const}$)
- proportional σ-Paths (i.e. $\sigma_1 : \sigma_2 = \text{const}$).

Proportional paths (PP) are thus straight lines through the origin

(For illustration here only 2 dimensions, i.e. plane deformation)

1. Goldscheider rule:

Starting from $\sigma = \mathbf{0}$: PϵP $\rightarrow$ PσP

2. Goldscheider rule:

Starting from $\sigma \neq \mathbf{0}$: PϵP lead asymptotically to PσP

Follows from the principle of fading memory: The initial state is gradually forgotten.

UNIVERSITÄT IGT INNSBRUCK

Goldscheider's rules

We consider

- proportional ϵ-Paths (i.e. $\epsilon_1 : \epsilon_2 = \text{const}$)
- proportional σ-Paths (i.e. $\sigma_1 : \sigma_2 = \text{const}$).

Proportional paths (PP) are thus straight lines through the origin

(For illustration here only 2 dimensions, i.e. plane deformation)

1. Goldscheider rule:

Starting from $\sigma = \mathbf{0}$: PϵP $\rightarrow$ PσP

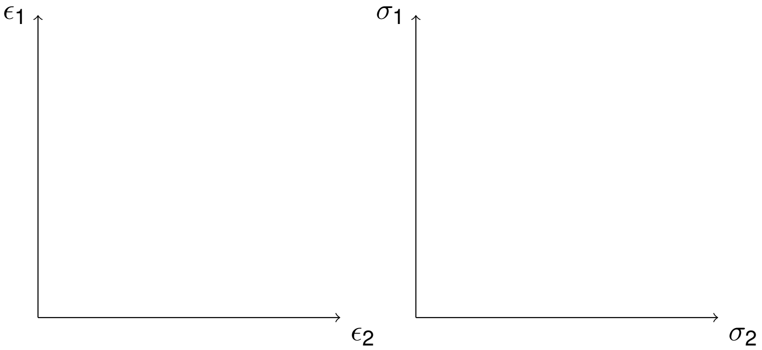
2. Goldscheider rule:

Starting from $\sigma \neq \mathbf{0}$: PϵP lead asymptotically to PσP

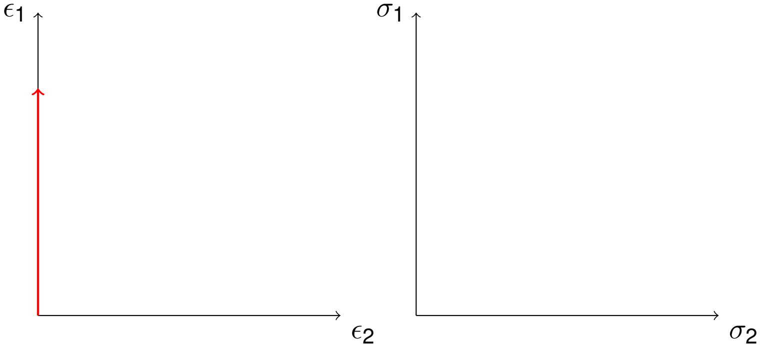
Follows from the principle of fading memory: The initial state is gradually forgotten.

UNIVERSITÄT IGT INNSBRUCK

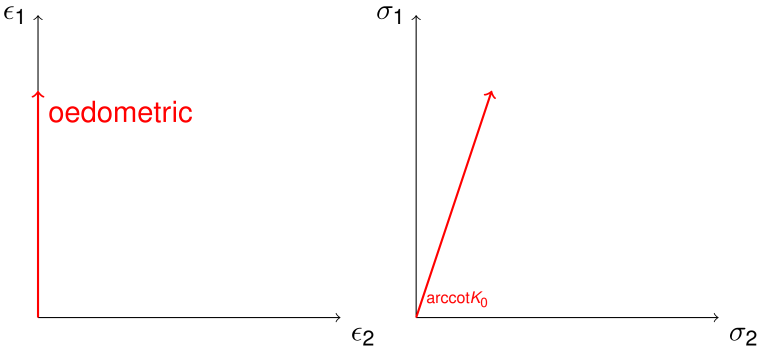
Goldscheider's rules, oedometric example



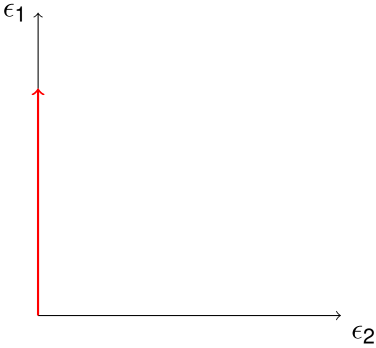
Goldscheider's rules, oedometric example



Goldscheider's rules, oedometric example

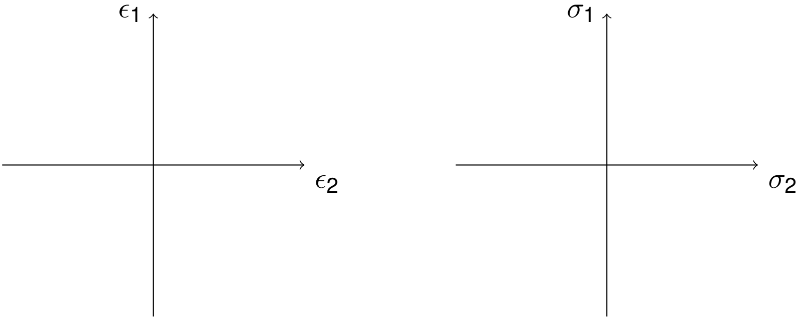


Goldscheider's rules, oedometric example



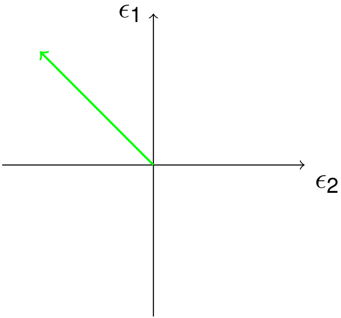
Goldscheider's rules, oedometric example

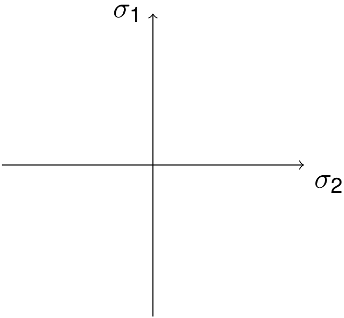
Isochoric PϵP (2D)



Green: Volume-reducing proportional paths

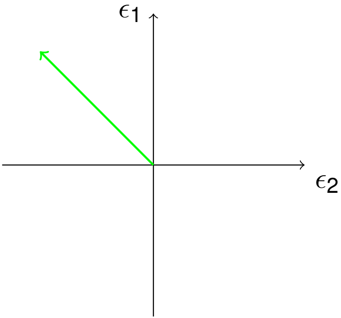
Isochoric PϵP (2D)

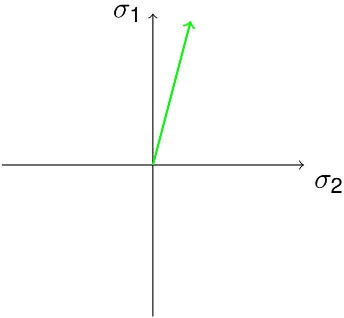




Green: Volume-reducing proportional paths

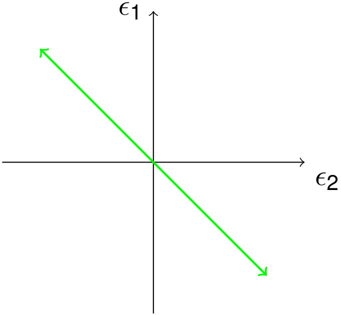
Isochoric PϵP (2D)

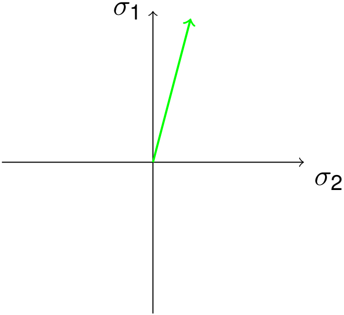




Green: Volume-reducing proportional paths

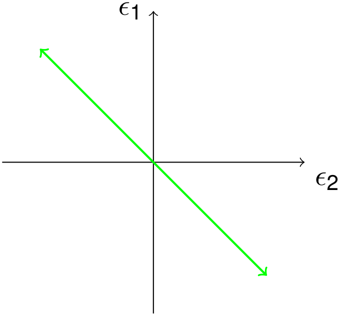
Isochoric PϵP (2D)

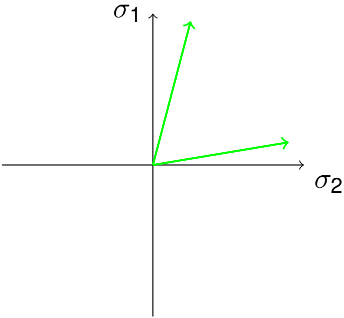




Green: Volume-reducing proportional paths

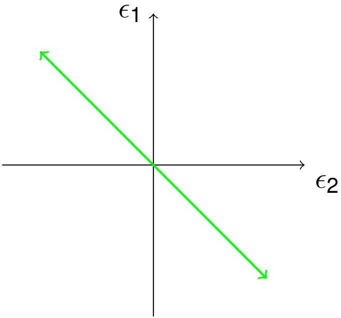
Isochoric PϵP (2D)

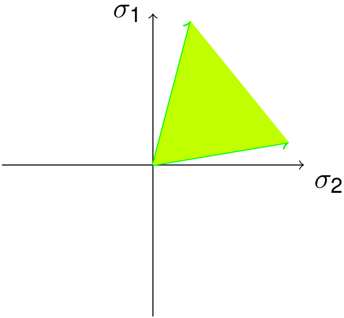




Green: Volume-reducing proportional paths

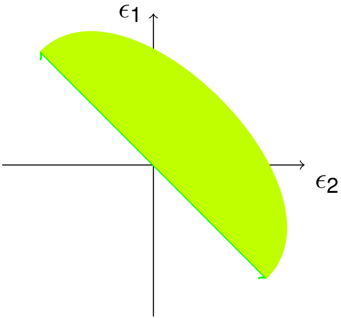
Isochoric PϵP (2D)

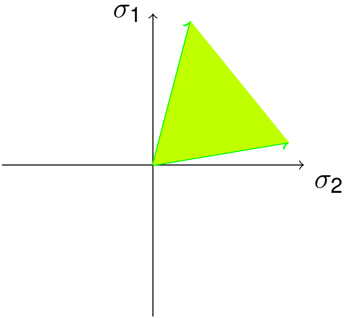




Green: Volume-reducing proportional paths

Isochoric PϵP (2D)





Green: Volume-reducing proportional paths

Asymptotic direction of stress paths

Stress paths generated with proportional deformation (i.e. **D**=const) have the following course:

tr**D** $<$ 0, i.e. volume is reduced: They grow limitlessly, *within the green cone.*

tr**D** $>$ 0, i.e. volume becomes larger: They are striving towards the stress-free state.

Reason: It could not be otherwise!

UNIVERSITÄT IGT INNSBRUCK

Asymptotic direction of stress paths

Stress paths generated with proportional deformation (i.e. **D**=const) have the following course:

tr**D** $<$ 0, i.e. volume is reduced: They grow limitlessly, *within the green cone.*

tr**D** $>$ 0, i.e. volume becomes larger: They are striving towards the stress-free state.

Reason: It could not be otherwise!

UNIVERSITÄT IGT INNSBRUCK

Asymptotic direction of stress paths

Stress paths generated with proportional deformation (i.e. **D**=const) have the following course:

tr**D** < 0, i.e. volume is reduced: They grow limitlessly, *within the green cone.*

tr**D** > 0, i.e. volume becomes larger: They are striving towards the stress-free state.

Reason: It could not be otherwise!

UNIVERSITÄT IGT INNSBRUCK

Asymptotic direction of stress paths

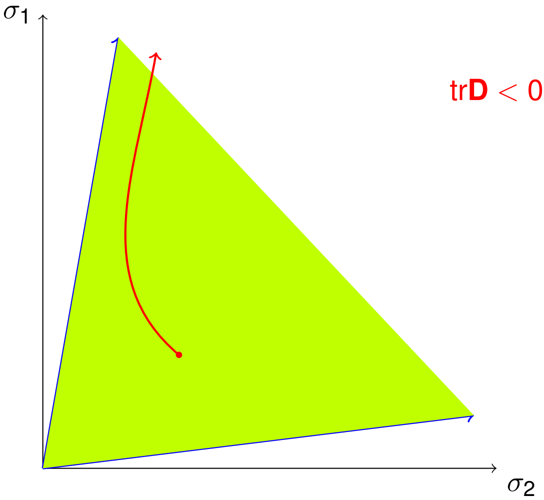
Stress paths generated with proportional deformation (i.e. **D**=const) have the following course:

tr**D** < 0, i.e. volume is reduced: They grow limitlessly, *within the green cone.*

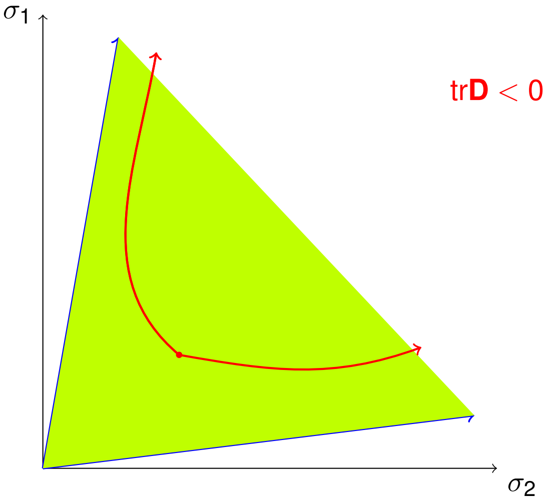
tr**D** > 0, i.e. volume becomes larger: They are striving towards the stress-free state.

Reason: It could not be otherwise!

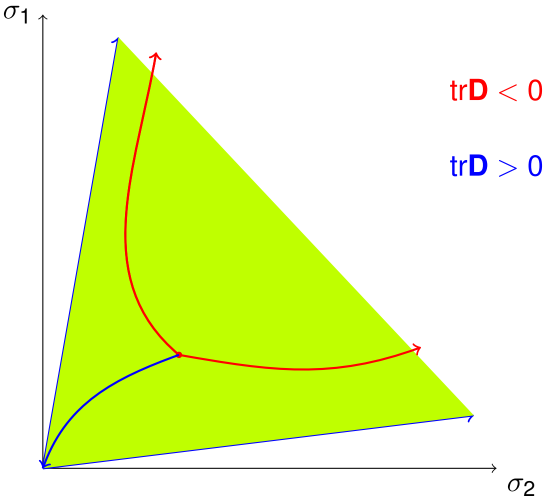
PεP with tr$\mathbf{D} < 0$ and tr$\mathbf{D} > 0$



PεP with tr$\mathbf{D} < 0$ and tr$\mathbf{D} > 0$



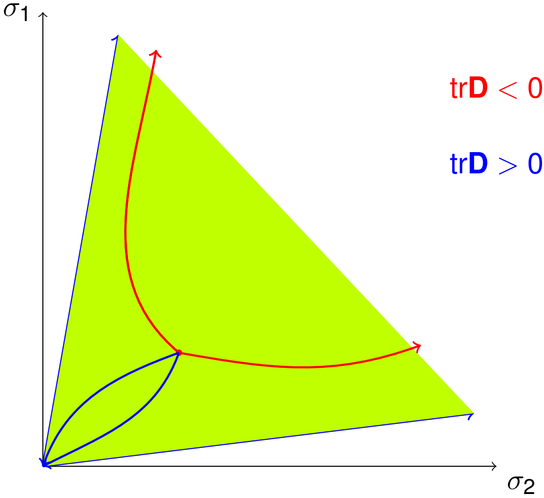
PεP with tr$\mathbf{D} < 0$ and tr$\mathbf{D} > 0$



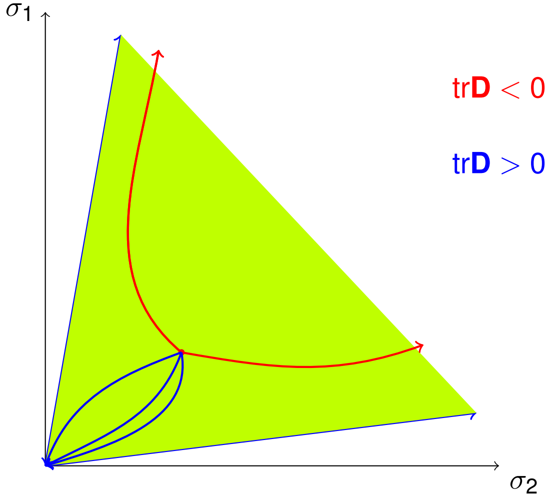
tr$\mathbf{D} < 0$

tr$\mathbf{D} > 0$

PεP with tr$\mathbf{D} < 0$ and tr$\mathbf{D} > 0$



PεP with tr$\mathbf{D} < 0$ and tr$\mathbf{D} > 0$



PεP witht tr$\mathbf{D} = 0$

Isochoric (i.e. undrained) proportional deformation paths lead to critical states.

These are stress states on the boundary of the green area.

Their shape and orientation depend on the void ratio e.

PεP witht tr$\mathbf{D} = 0$

Isochoric (i.e. undrained) proportional deformation paths lead to critical states.

These are stress states on the boundary of the green area.

Their shape and orientation depend on the void ratio e.

UNIVERSITÄT IGT INNSBRUCK

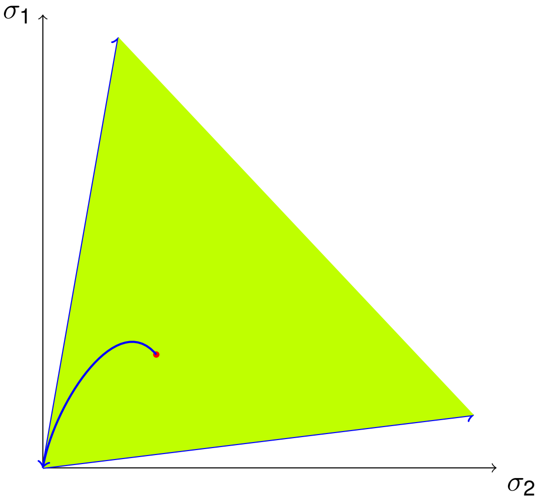
PεP witht tr$\mathbf{D} = 0$

Isochoric (i.e. undrained) proportional deformation paths lead to critical states.

These are stress states on the boundary of the green area.

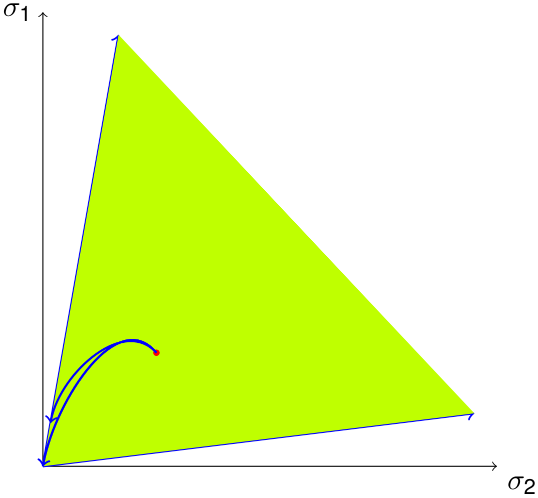
Their shape and orientation depend on the void ratio e.

PεP with tr$\mathbf{D} = 0$

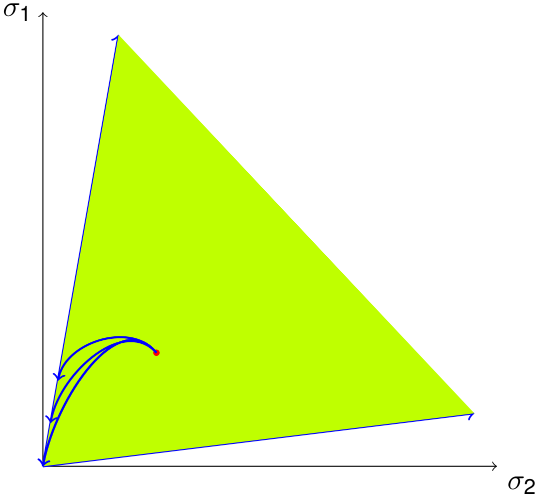


UNIVERSITÄT IGT INNSBRUCK

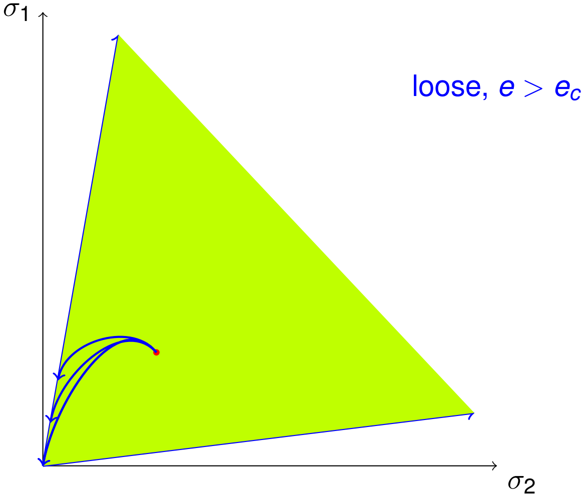
PεP with tr$\mathbf{D} = 0$



PεP with tr$\mathbf{D} = 0$

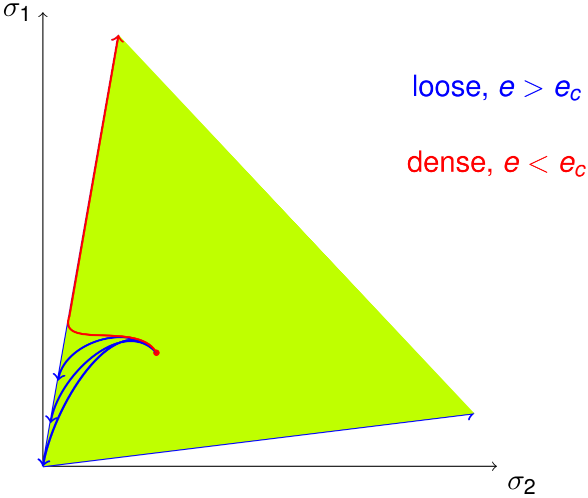


PεP with tr$\mathbf{D} = 0$

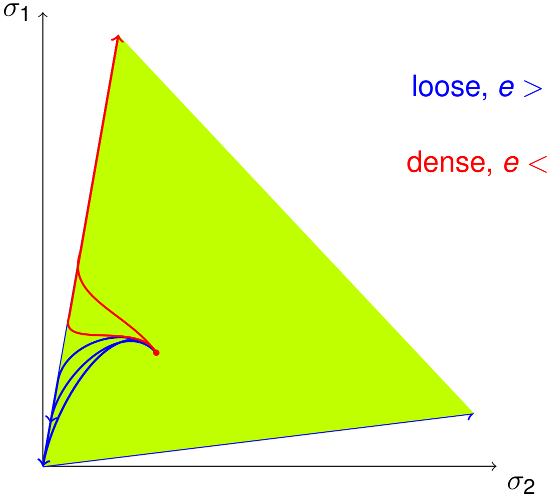


UNIVERSITÄT IGT INNSBRUCK

PεP with tr$\mathbf{D} = 0$



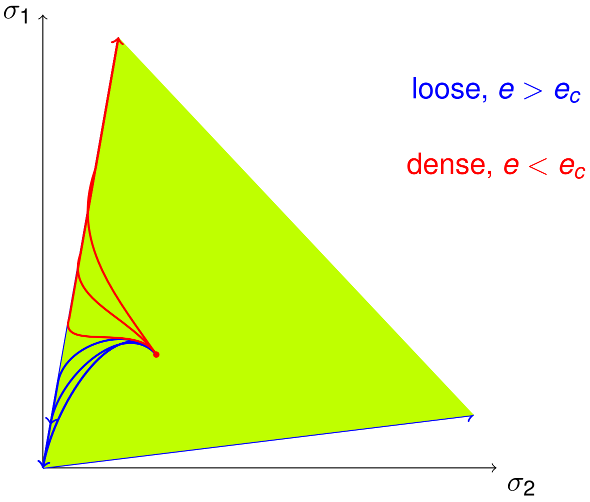
PεP with tr$\mathbf{D} = 0$



loose, $e > e_c$

dense, $e < e_c$

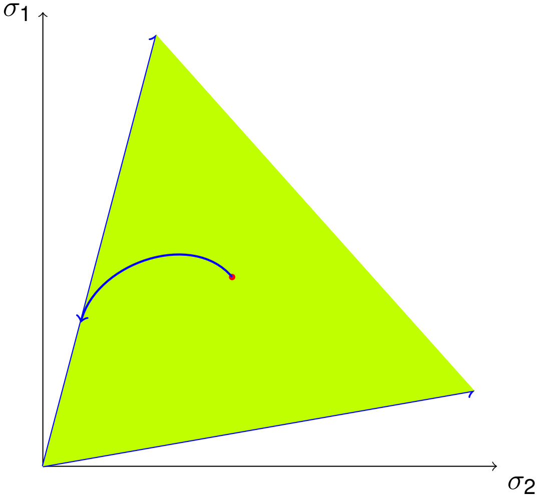
PεP with tr$\mathbf{D} = 0$



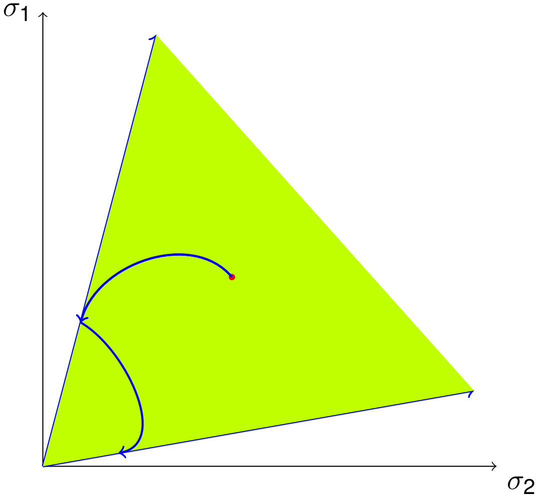
Loading reversals

The stress paths just shown can also be observed at load reversals

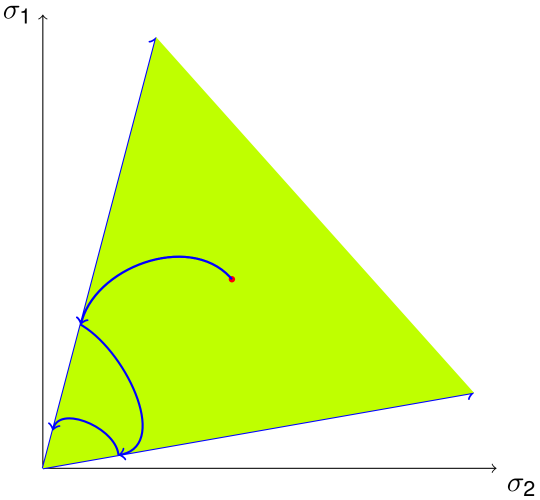
Undrained loading-unloadings with very loose sand



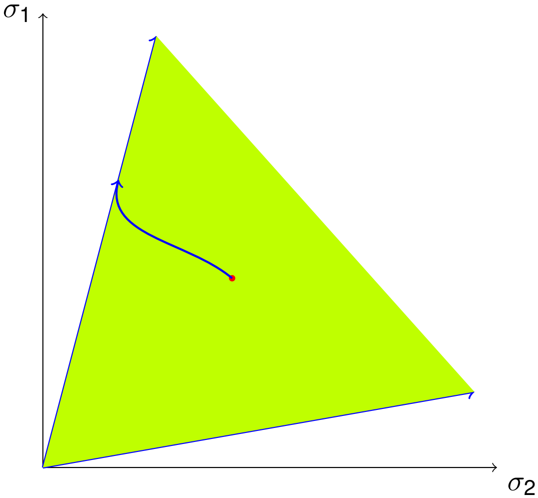
Undrained loading-unloadings with very loose sand



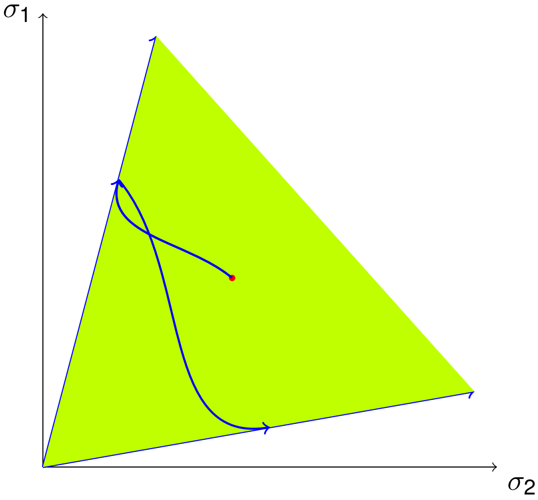
Undrained loading-unloadings with very loose sand



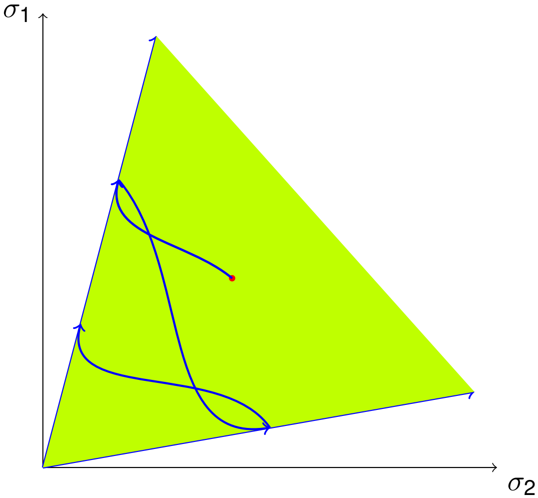
Undrained loading-unloadings with medium density sand



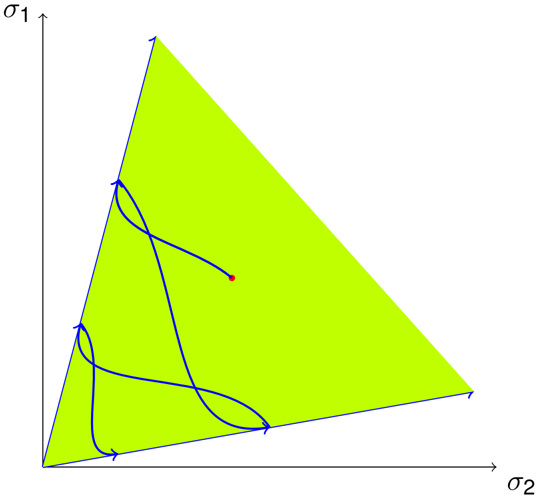
Undrained loading-unloadings with medium density sand



Undrained loading-unloadings with medium density sand



Undrained loading-unloadings with medium density sand



Critical surface is attractor

For straight stress paths (e.g. conventional triaxial experiment) the critical state surface (=boundary of the green area) is an attractor,

i.e. the stress paths must end there (whereby they can first cross the surface as long as $e < e_c$)

Critical surface is attractor

For straight stress paths (e.g. conventional triaxial experiment) the critical state surface (=boundary of the green area) is an attractor,

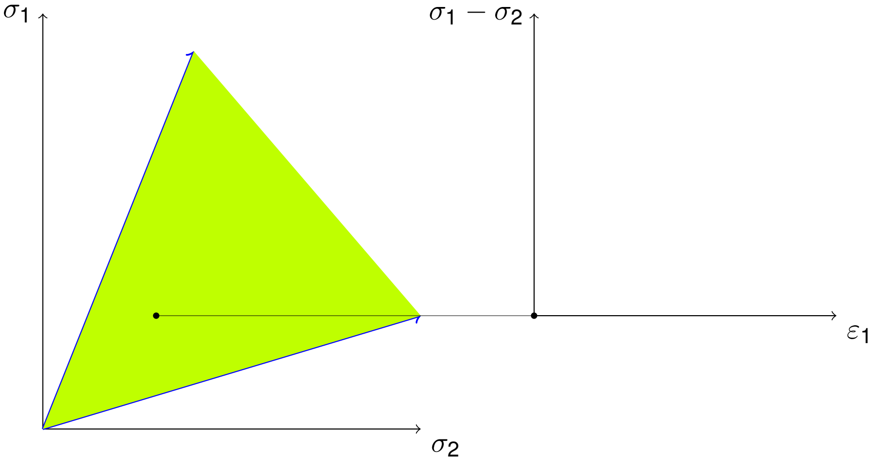
i.e. the stress paths must end there (whereby they can first cross the surface as long as $e < e_c$)

Critical surface is attractor

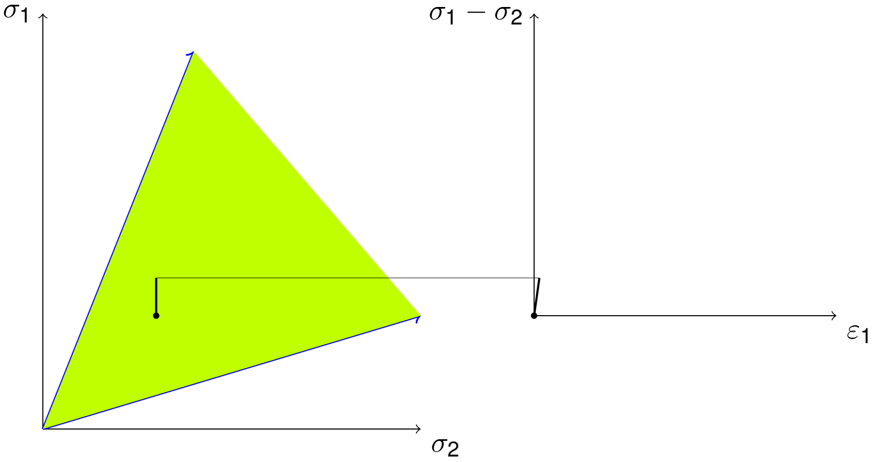
For straight stress paths (e.g. conventional triaxial experiment) the critical state surface (=boundary of the green area) is an attractor,

i.e. the stress paths must end there (whereby they can first cross the surface as long as $e < e_c$)

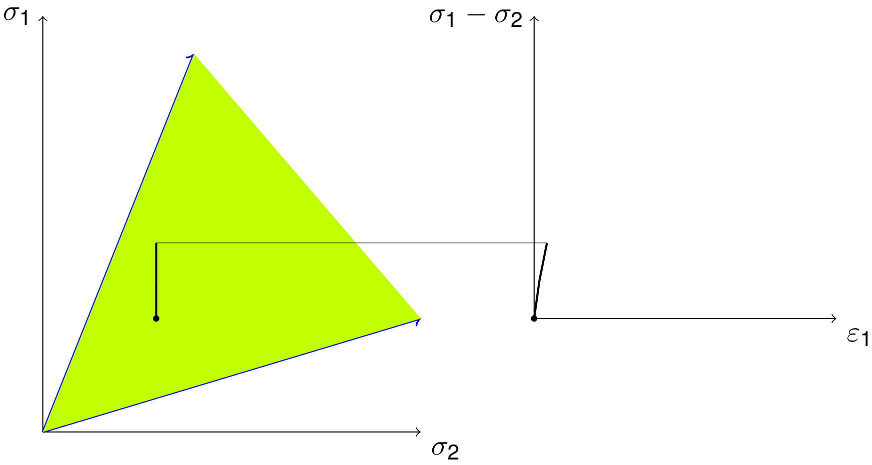
Critical state surface is attractor



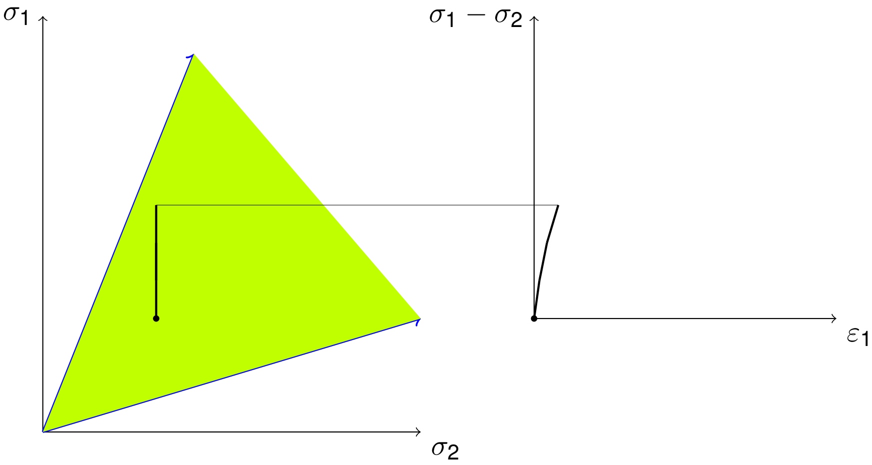
Critical state surface is attractor



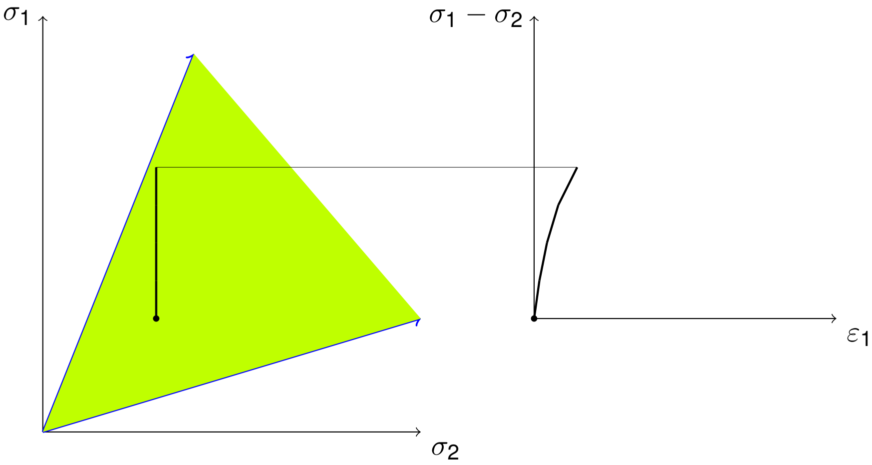
Critical state surface is attractor



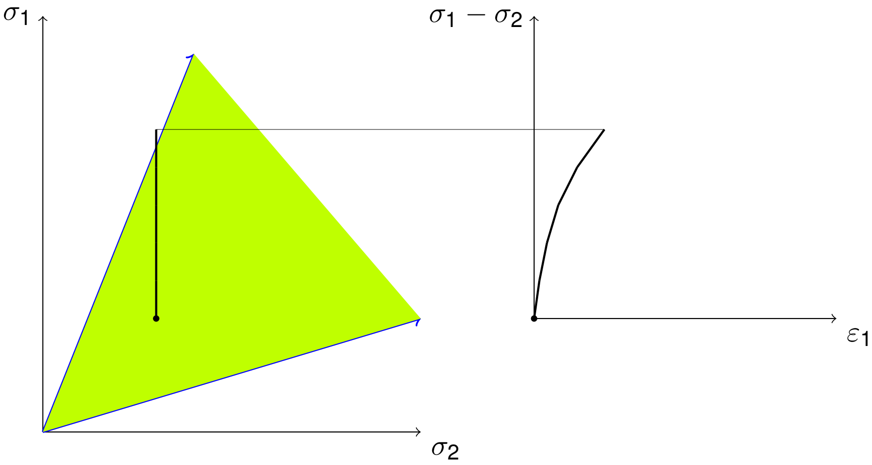
Critical state surface is attractor



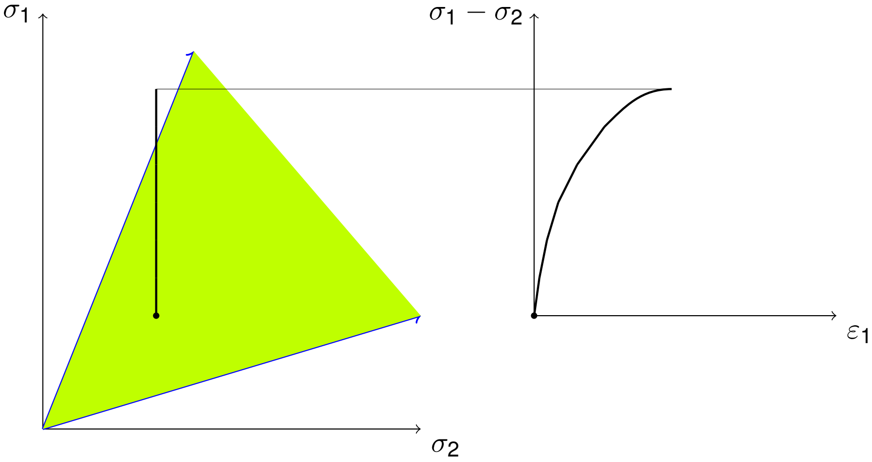
Critical state surface is attractor



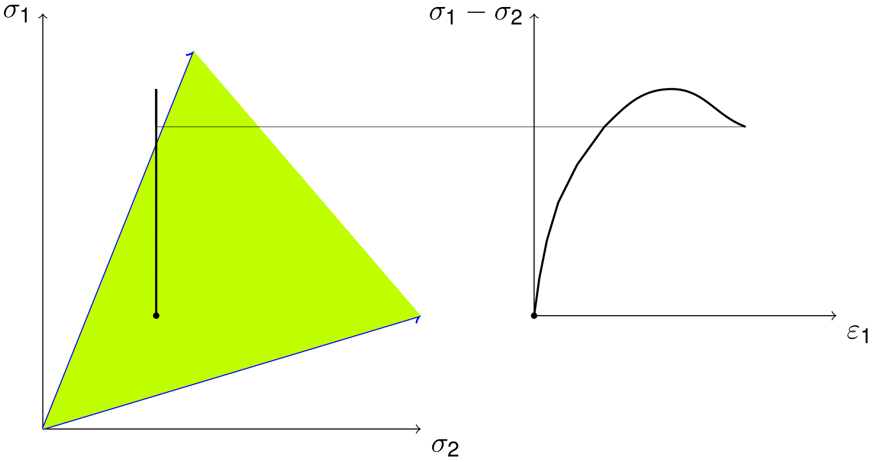
Critical state surface is attractor



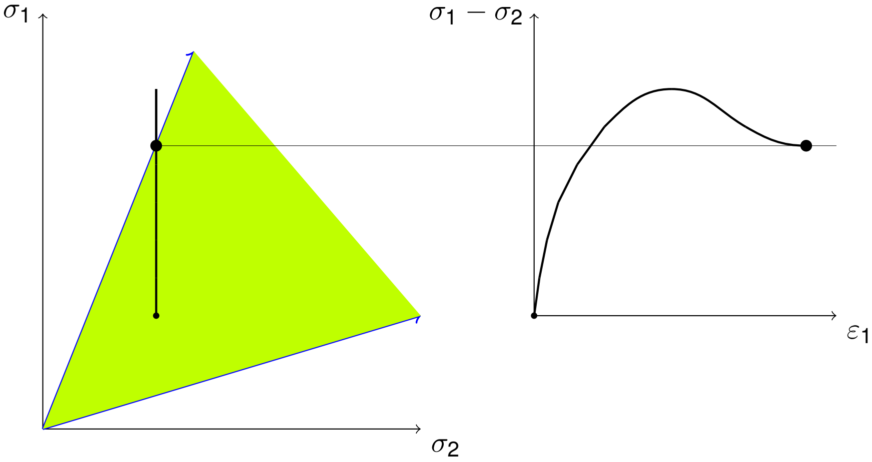
Critical state surface is attractor



Critical state surface is attractor



Critical state surface is attractor



CONCLUSION

You can visualize the behavior of sand very easily.

It is possible without theory of plasticity! Much easier!

Thank you for your attention!

CONCLUSION

You can visualize the behavior of sand very easily.

It is possible without theory of plasticity! Much easier!

Thank you for your attention!

UNIVERSITÄT IGT INNSBRUCK

CONCLUSION

You can visualize the behavior of sand very easily.

It is possible without theory of plasticity! Much easier!

Thank you for your attention!

CONCLUSION

You can visualize the behavior of sand very easily.

It is possible without theory of plasticity! Much easier!

Thank you for your attention!