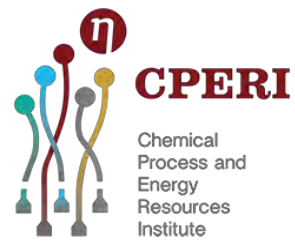




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Slope stability of reclaimed coal mines through a new water filling index

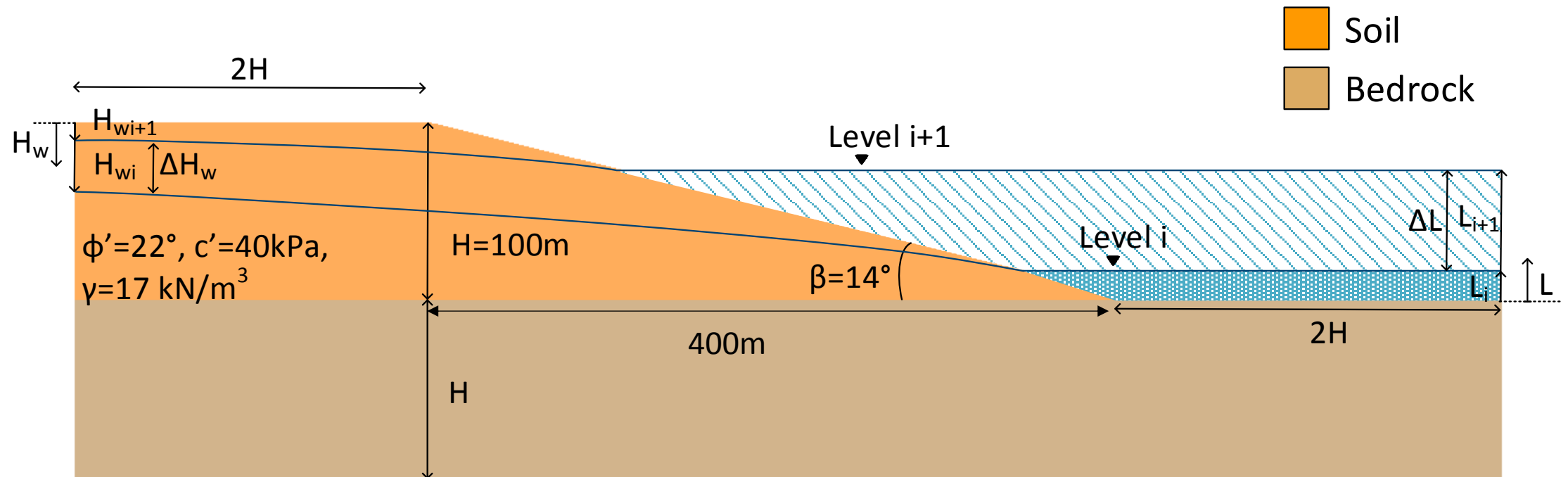
Alexandros Theocharis, Ioannis Zevgolis, Nikolaos Koukouzas

7-10-2022, Wroclow, Poland

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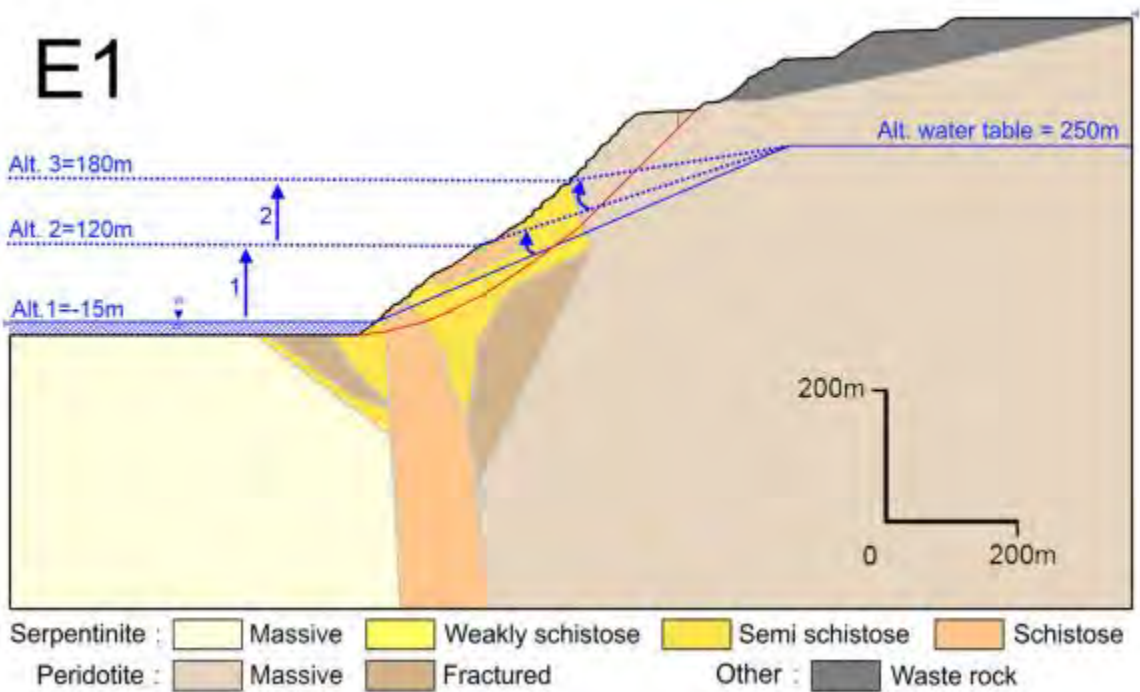
Water filling of pit lakes and hydraulic conditions



What happens with the water inside the slope?

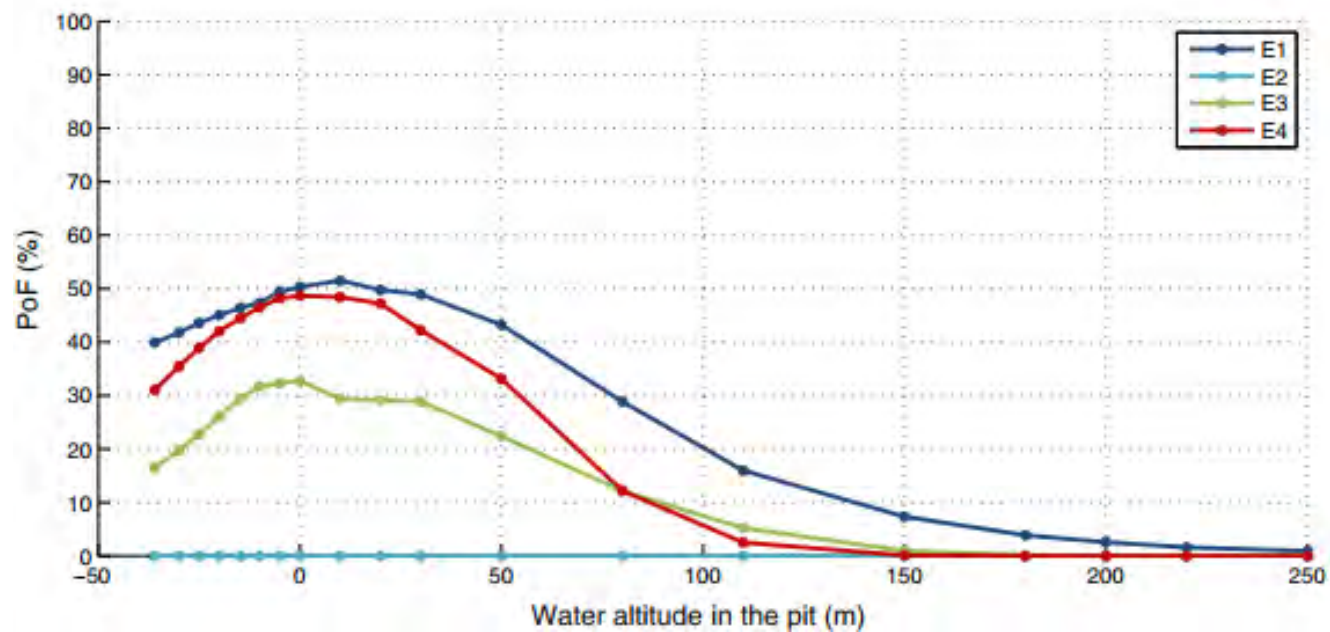
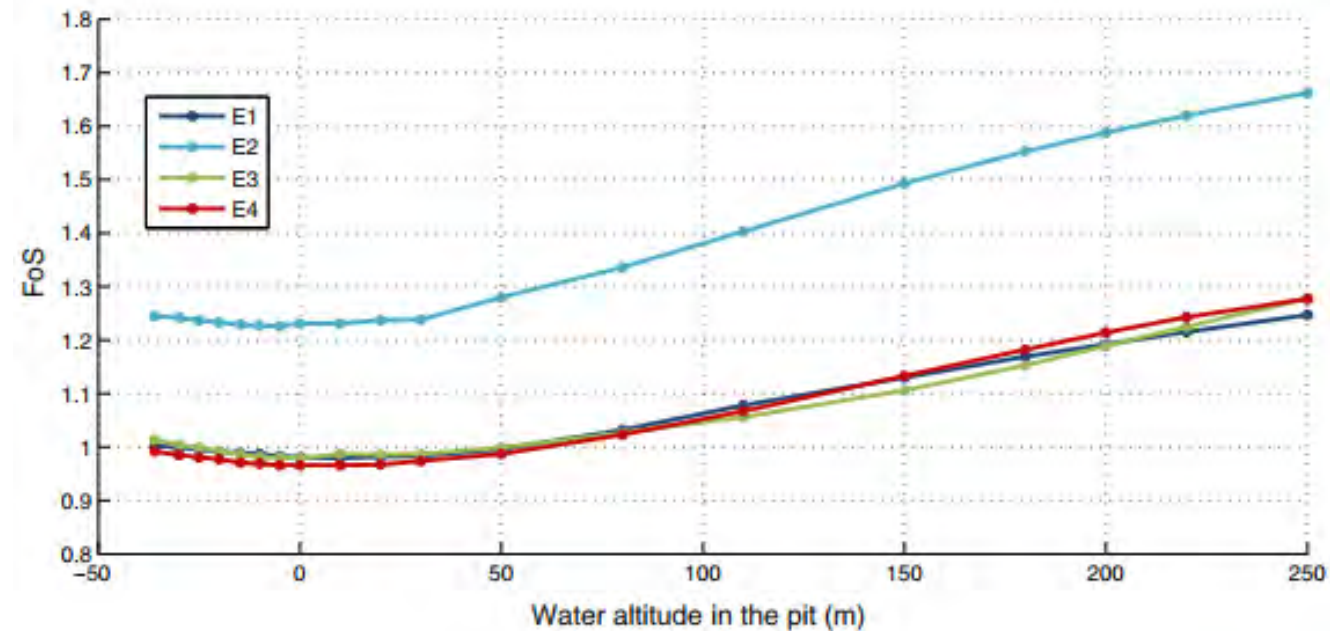
Stability of pit lakes

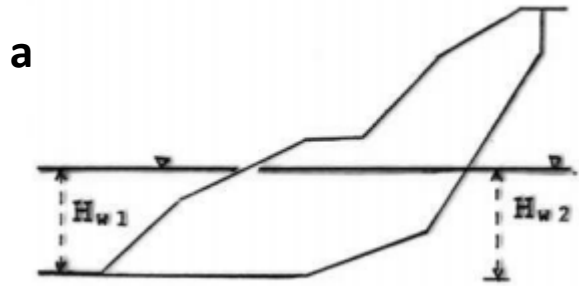
Grenon (2017) - *Rock Mechanics and Rock Engineering*



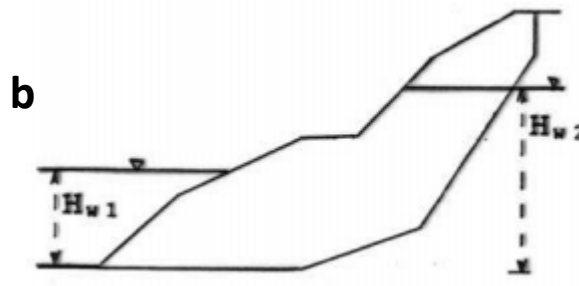
Radius of influence > 1km

Slide2 & RS2 (Monte Carlo)

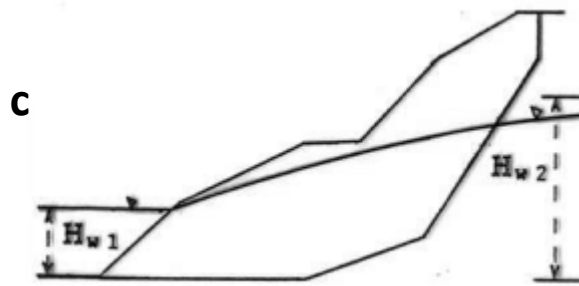




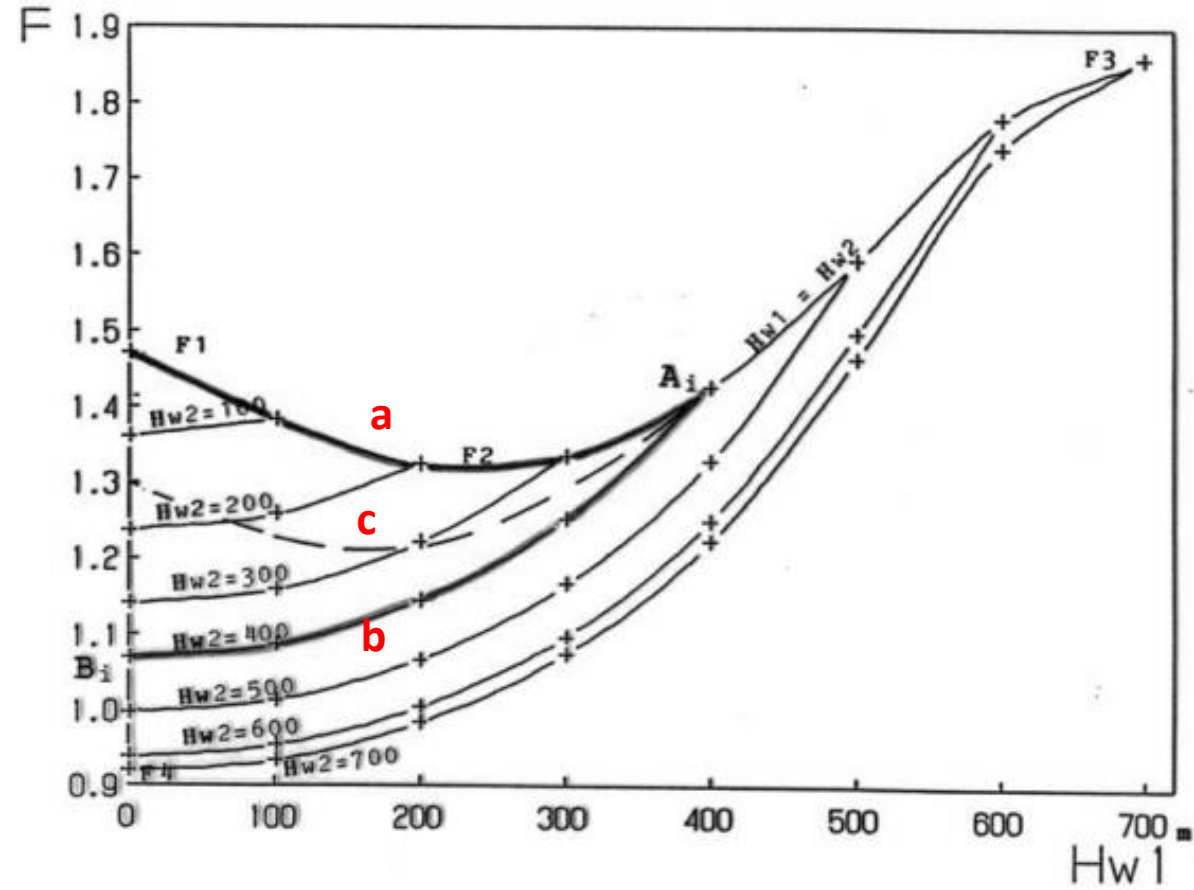
slow filling-perfect drainage of
($H_{w1} = H_{w2}$)



Rapid drawdown conditions
no drainage conditions in
the slope.

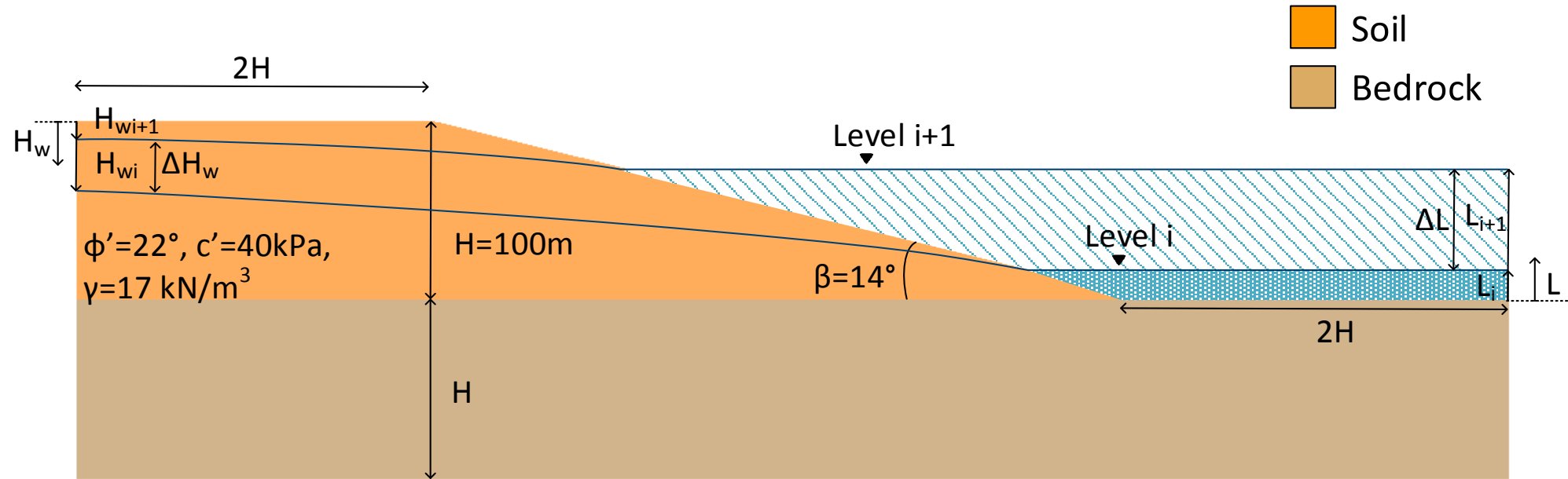


Intermediate drainage
conditions (between perfect
drainage and no drainage
conditions)



Water filling of pit lakes and hydraulic conditions

What happens with the water inside the slope?



$$\text{Water filling index: } I_{WF} = \frac{\Delta H_w}{\Delta L}$$

Water filling index definition

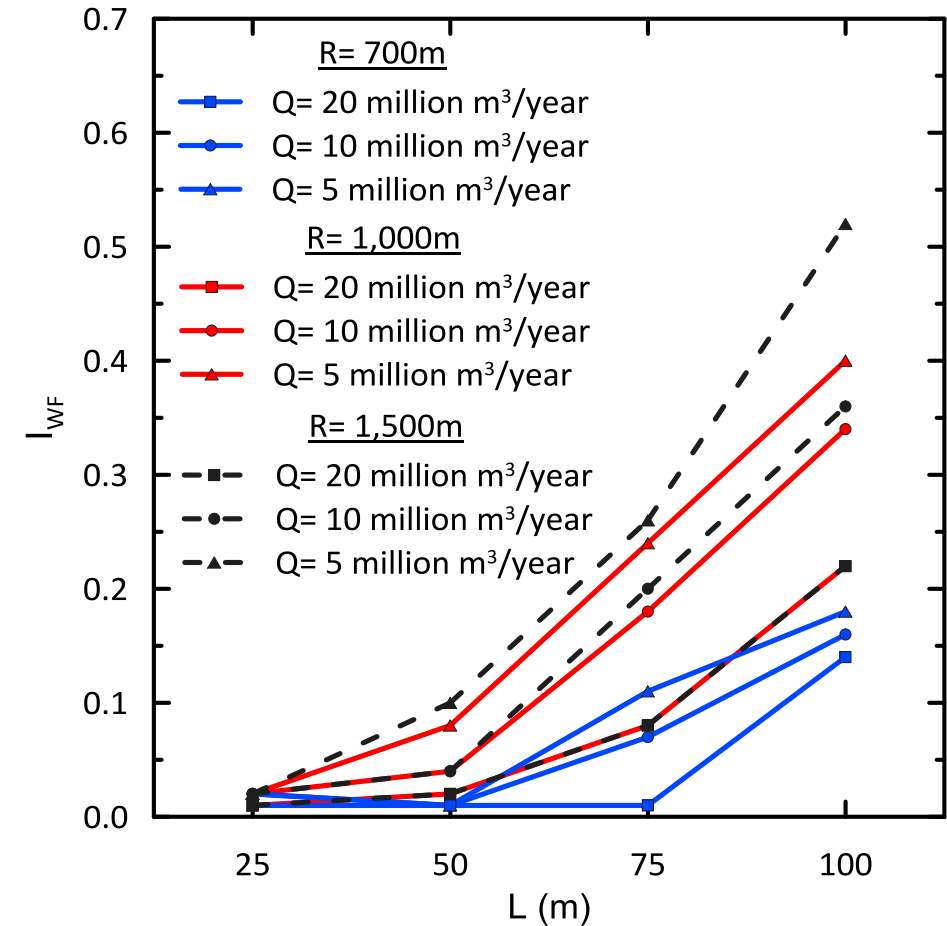
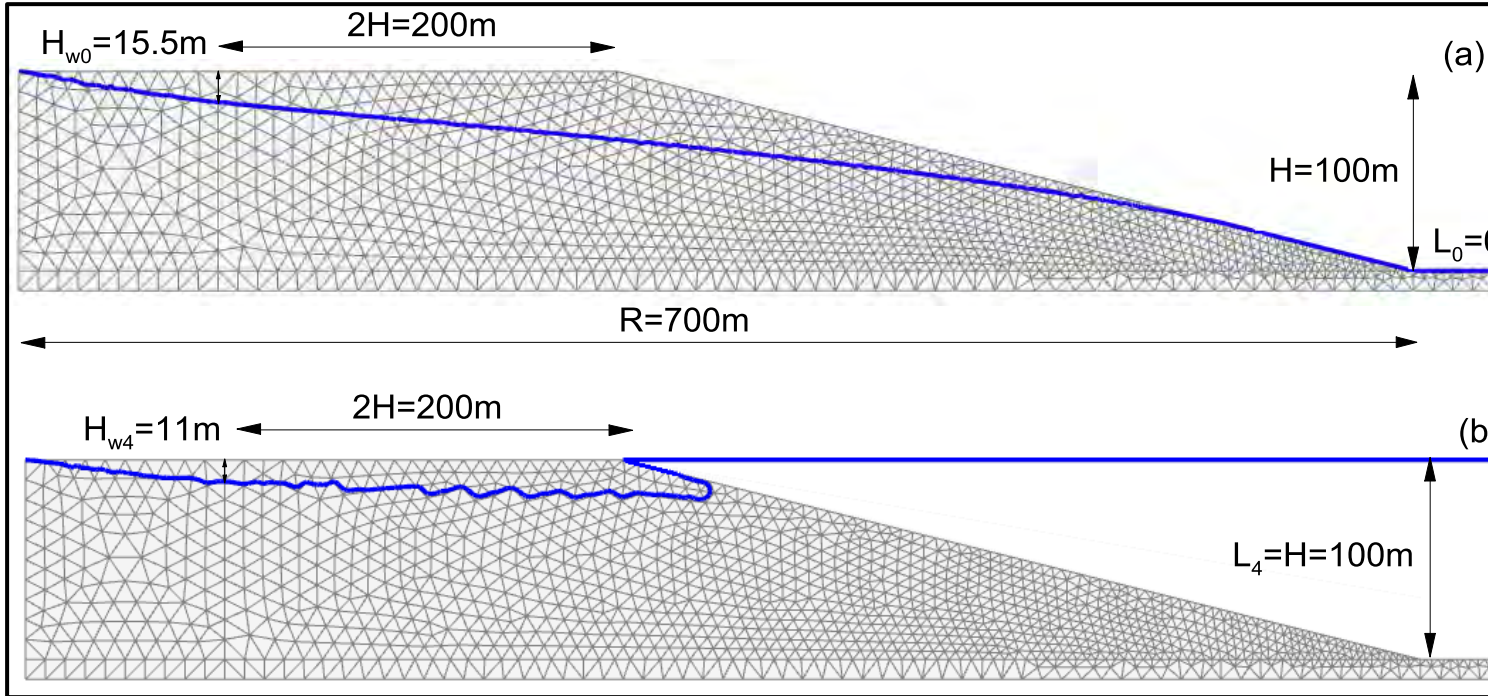
$$I_{WF} = \frac{\Delta H_w}{\Delta L} \geq 0$$

- Dimensionless and non-negative.
- Very low I_{WF} values (close to zero) → rapid filling process, the **reservoir's** level increases so rapidly that the groundwater remains practically constant
Small void volumes, high discharge rates, low aquifer permeability
- High I_{WF} values → slow filling process, the groundwater has adequate time to adjust to the **reservoir's** level changes
Large void volumes, low discharge rates, high aquifer permeability
- Horizontal groundwater $I_{WF}=1$ → prolonged filling process ($\Delta L = \Delta H_w$).
- Higher values are unrealistic except for specific scenarios.

Water filling index range

Groundwater flow analysis – Finite Element Method

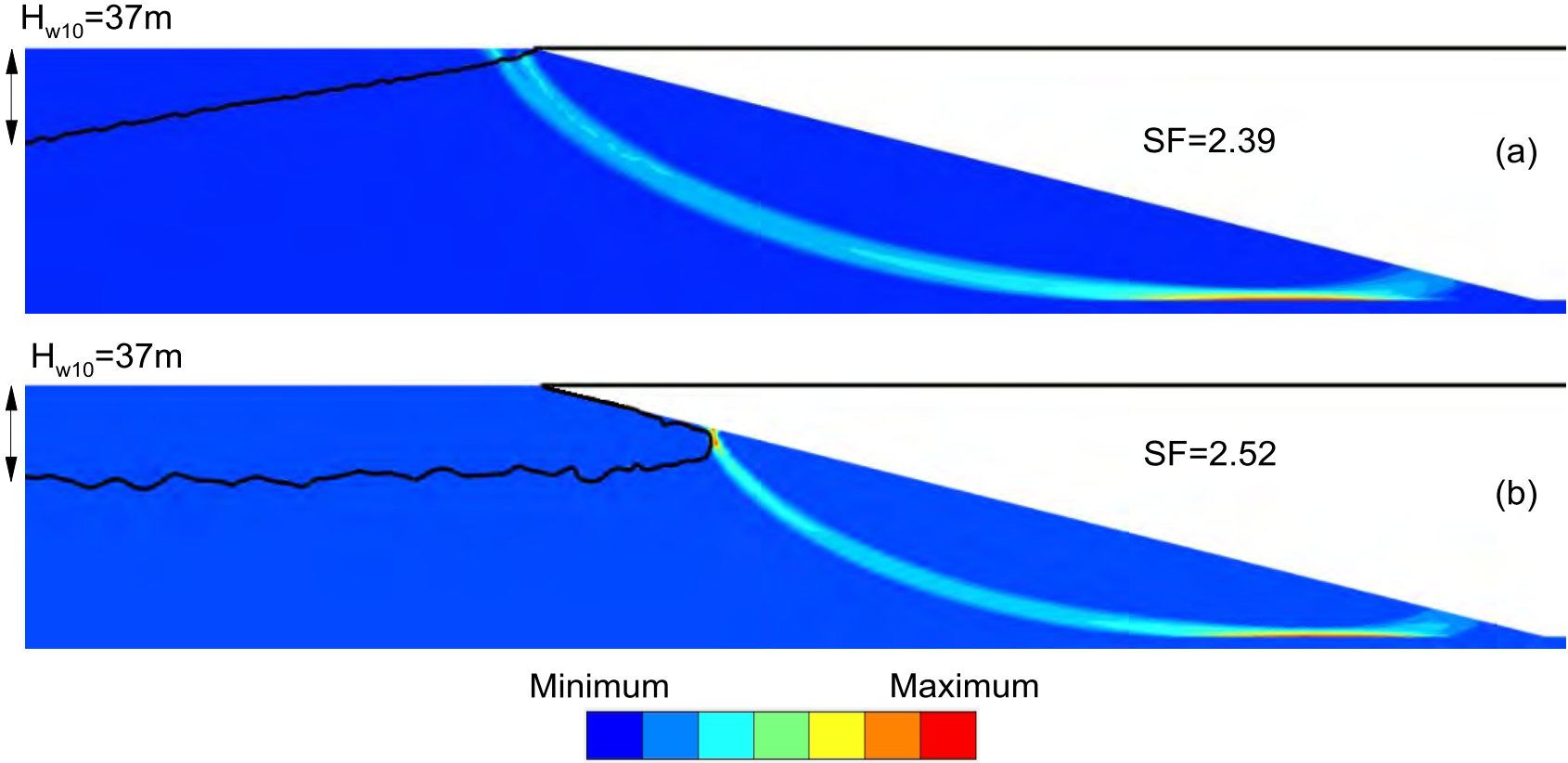
$$I_{WF} = \frac{\Delta H_w}{\Delta L} \geq 0$$



- I_{WF} is largely non-constant
- The water inflow (and thus, the filling speed) is rarely constant in practice
- Thus, a constant value was assumed
- $I_{WF} = 0.1, 0.3, \text{ and } 0.5.$

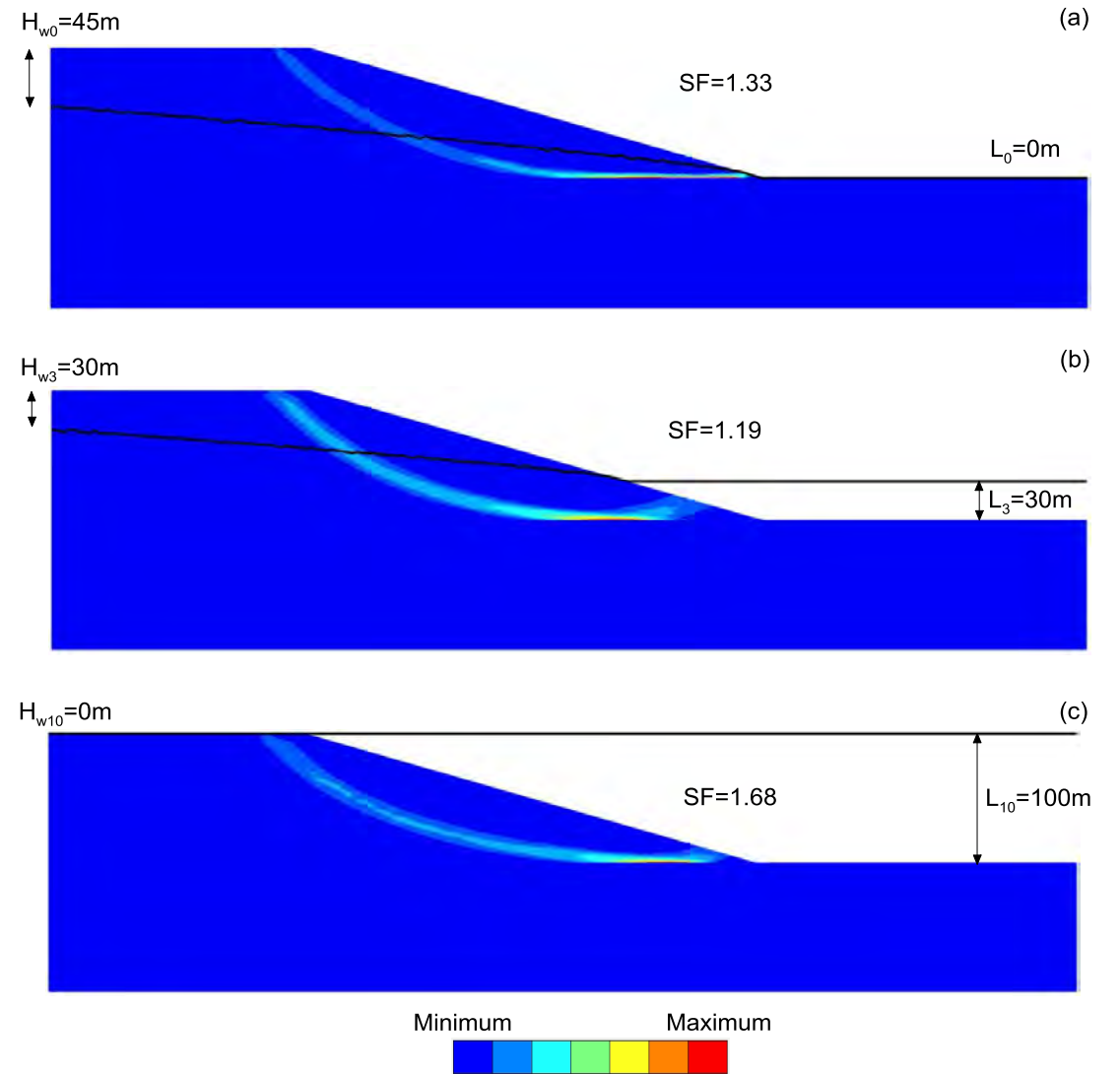
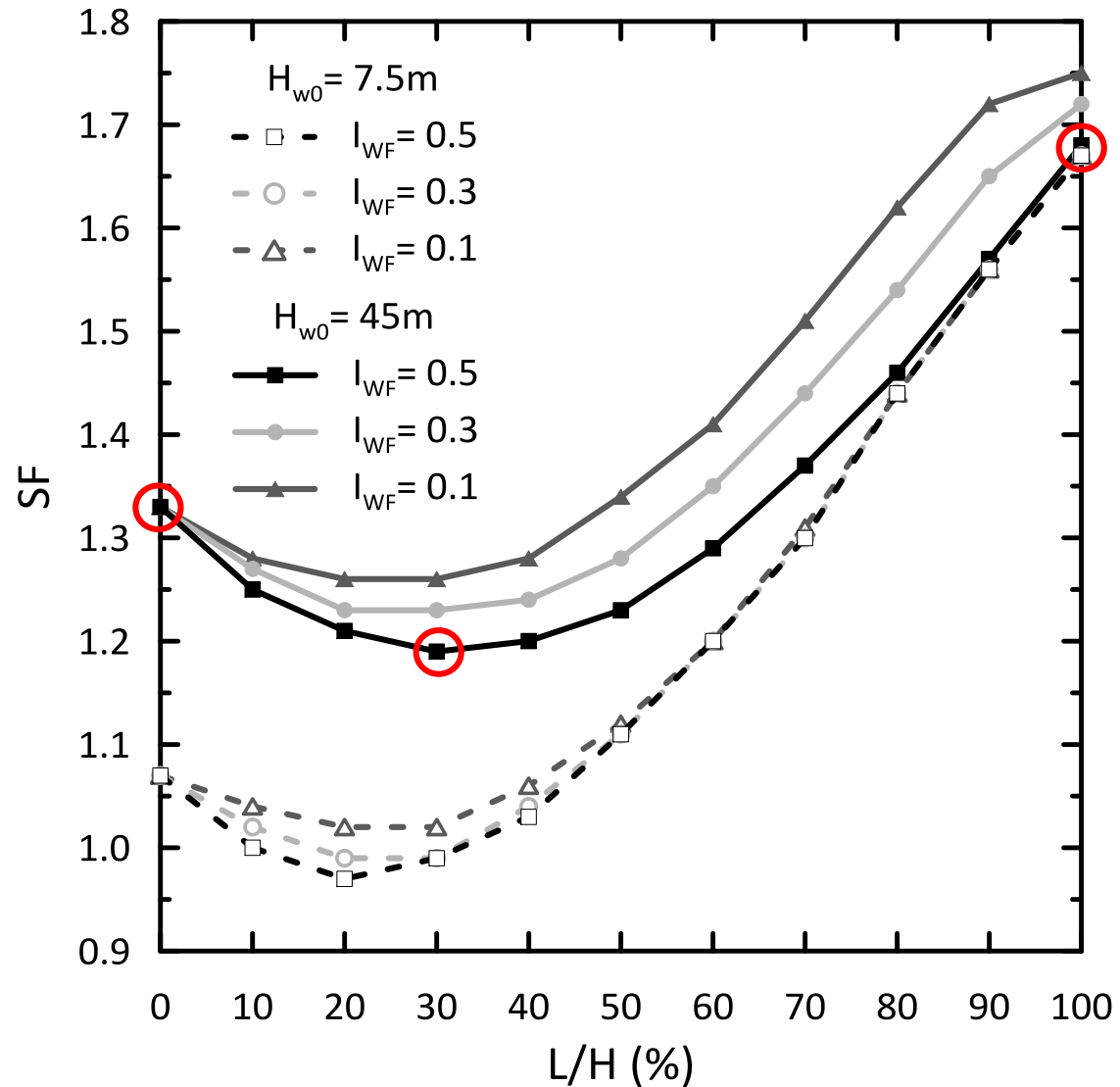
Water filling effect on stability – hydraulic conditions

Various analyses comparing steady-state flow vs transient conditions.

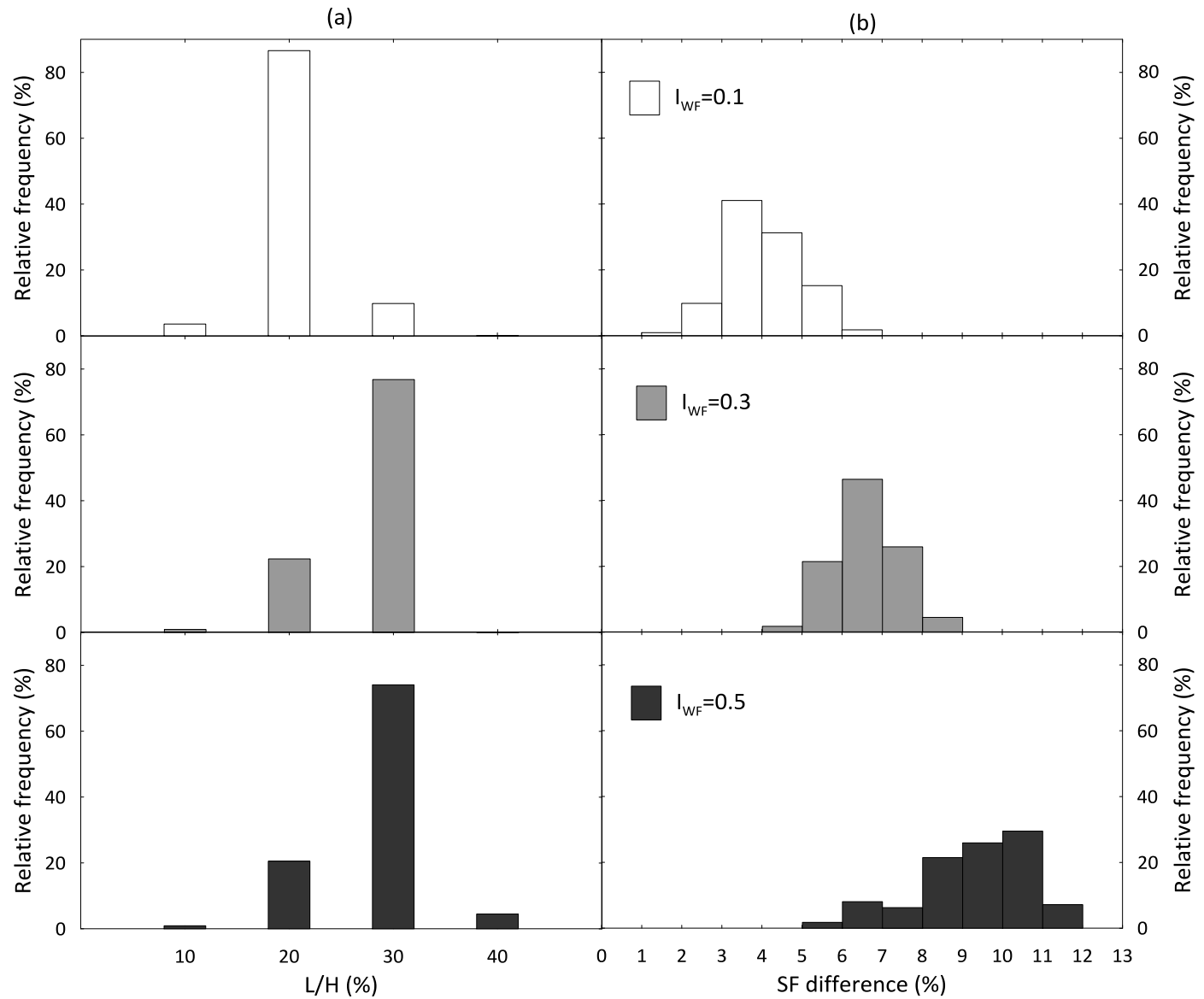


The steady-state flow case is always conservative with less than 5% error ! 11

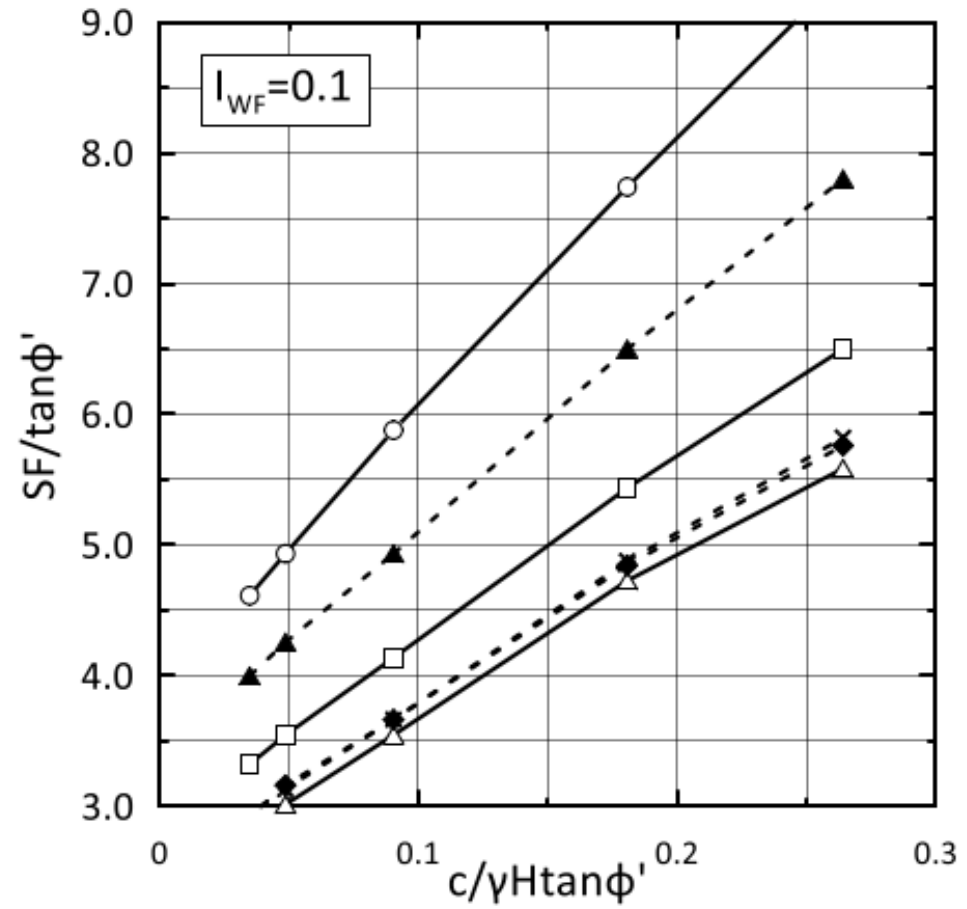
Water filling effect on slope stability



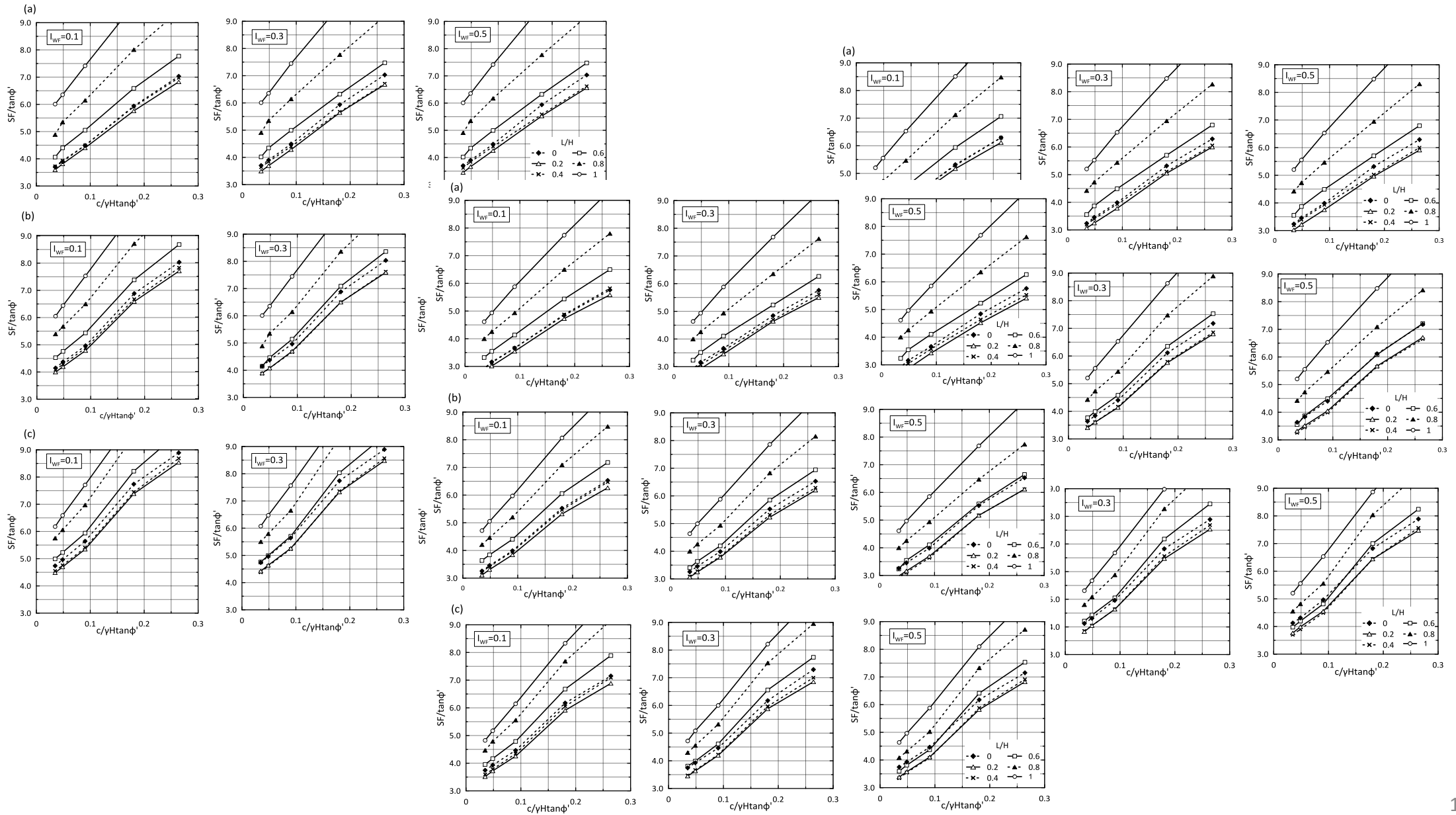
Water filling effect on critical level



Stability charts



Stability charts for various angles



Conclusions

- The water filling index can consider the filling speed within a general framework that does not depend on case-specific parameters.
- It can also indirectly consider the factors affecting the water filling and quantitatively assess their effect on stability.
- I_{WF} is a dimensionless, non-negative number that practically varies for the stability problem of pit lakes 0.1-0.5; 0.1 → very fast filling process, 0.5 → slow filling process.
- Numerical analysis : as the water filling evolves, SF decreases to a minimum at a certain value of the ratio L/H, then rises to high values, higher than the initial SF.
- The maximum SF reduction was between L=10%H and 40%H.
- These results agree with the few previous works on pit flooding.

Conclusions

- The water **filling's** effect on stability is also similar to drawdown, where the critical level is reported to be around $L=H/3$.
- Moreover, the critical **levels'** position is significantly affected by I_{WF} ; the faster the water filling rises within the pit, the lower their position is encountered.
- The minimum SF at the critical levels depends on the I_{WF} ; $I_{WF}=0.1$ reduces SF by 1% to 7%, while $I_{WF}=0.5$ causes a maximum SF drop equal to 5%-12%.
- This reduction might be crucial for mine slopes close to 1.10 - 1.20.
- In such cases, the rapid filling of the lake can improve the stability of the pit during flooding, while a slower filling process might lead to failure.

Thank you!