The impact of EXtreme weather events on MINing operations

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The role of groundwater on the stability of an abandoned shallow underground room and pillar coal mine

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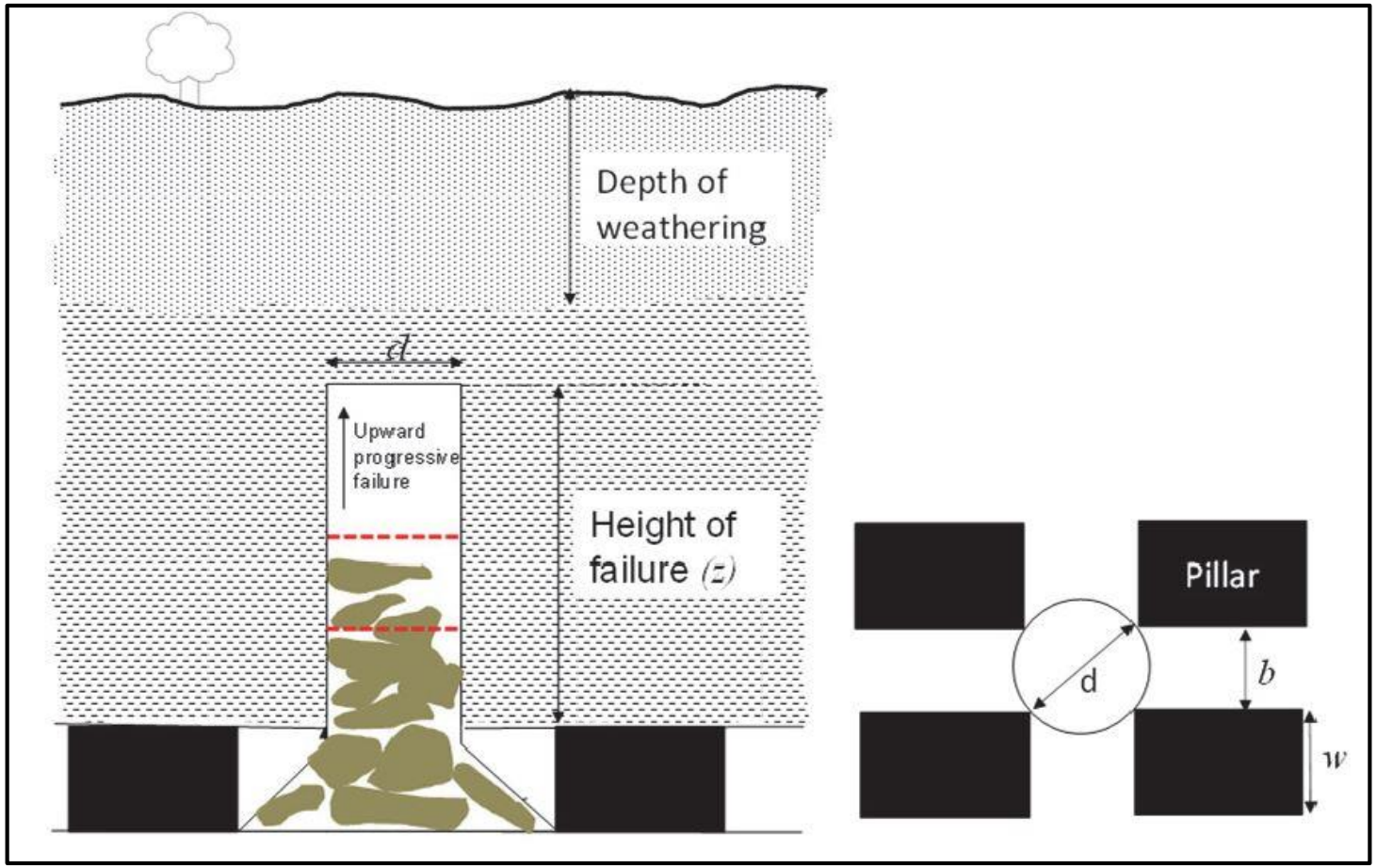
Sinkholes - general

- A surface depression occurring when an underground opening fails, and the overlying soil/rock flows into the opening.
- Physical processes: Chemical solution of natural underground cavities
- Artificial processes: Mechanical collapse of underground openings (tunnels, mines etc.)
- Major factors for the occurrence of sinkholes:
  - development of mining operations at small overburden heights
  - weak overburden strata
  - unfavorable geological structures
- Rainfall might trigger the formation of sinkholes.

Sinkholes and mining

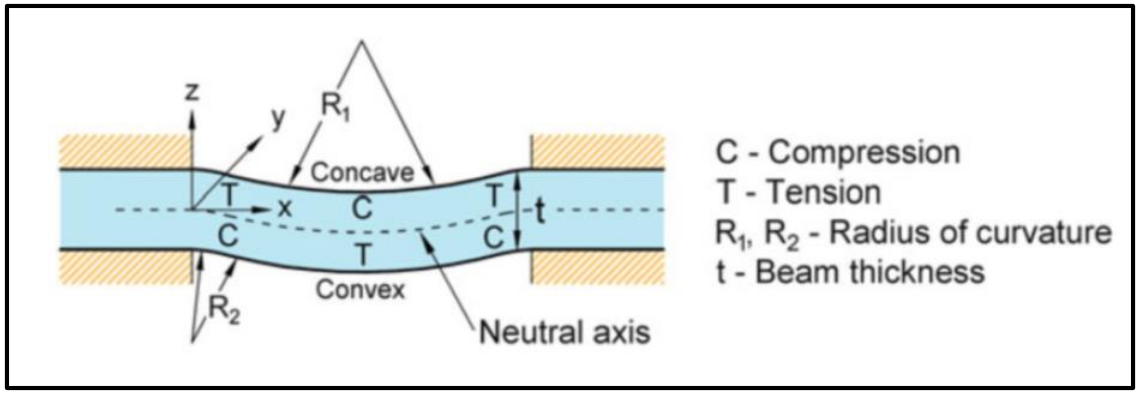
Mining-induced sinkholes are commonly associated with shallow underground mines (typically lower than 50m), operated by the room and pillar method.



Roof Stability methodology

Roof bending - Tensional failure of the immediate roof:

- most typical instability mechanism of the underground cavities
- directly associated with the occurrence of sinkholes providing appropriate geology and a shallow exploitation.

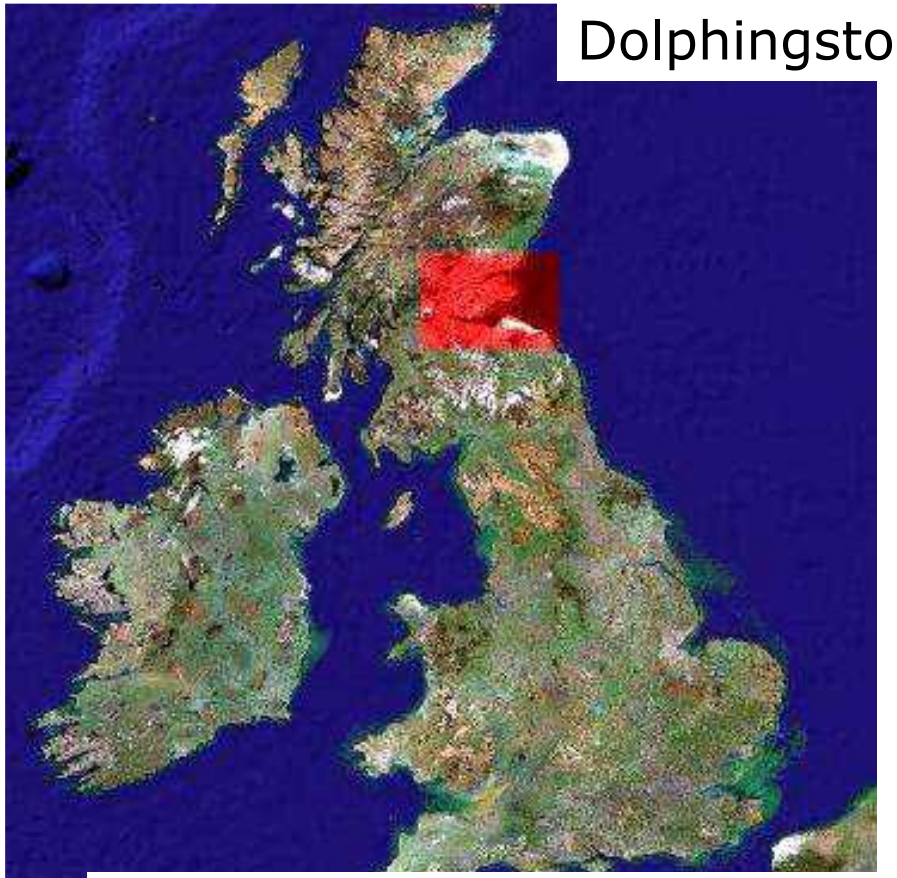


Roof stability is assessed by comparing

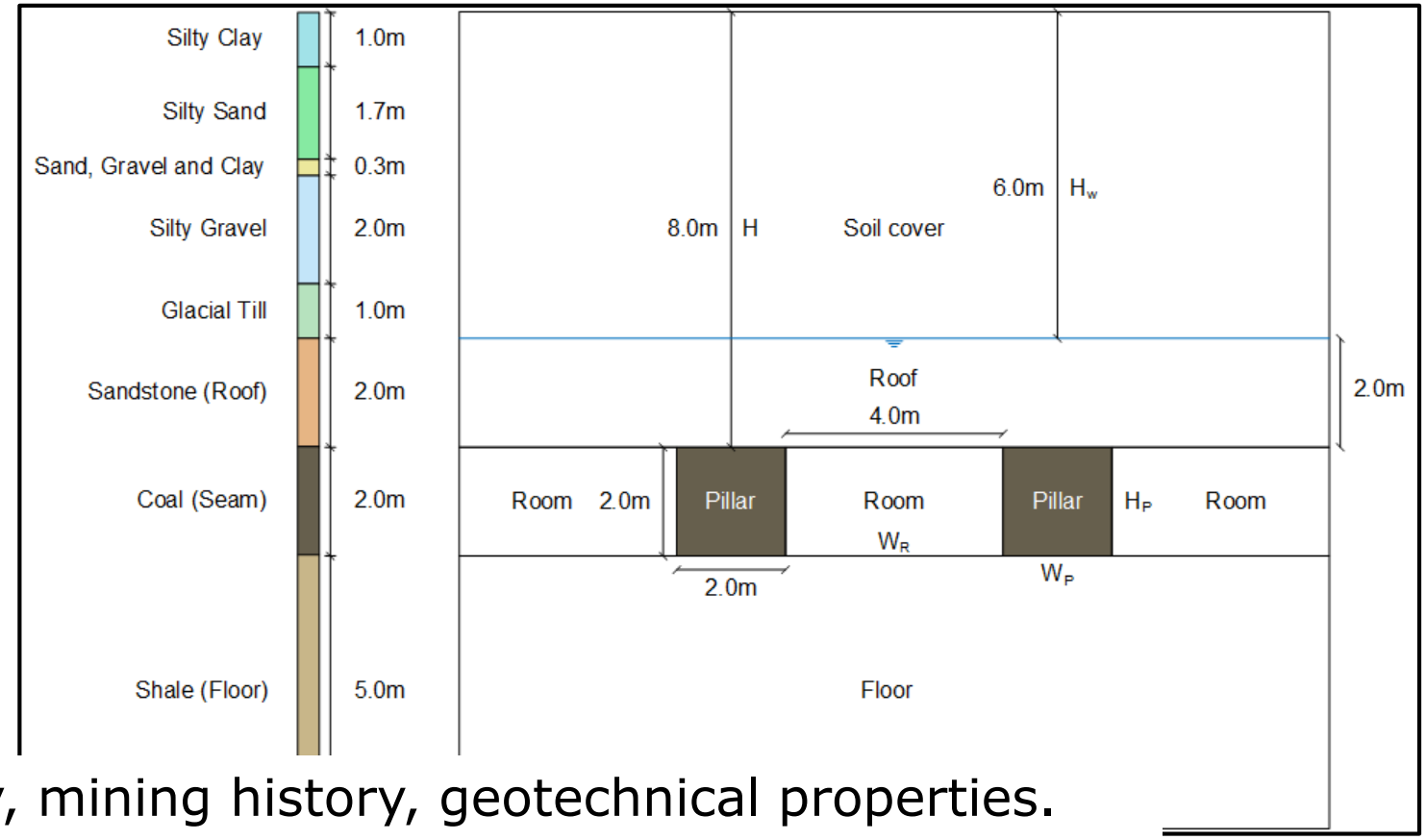
- the maximum principal effective stress on the middle point of the roof beam - σ'_3
- the tensile strength of the sandstone material σ_t

Then, the roof safety factor is **SF = σ_t / σ'_3**

Abandoned shallow underground coal mine – case study



Dolphingstone village, UK, located 4km East of Edinburgh, Scotland.



Several details on stratigraphy, mining history, geotechnical properties.

Helm (2011). Analysis of the stability of shallow abandoned colliery workings, PhD Dissertation, School of Civil Engineering and Geosciences, Newcastle University.

Modeling approaches for groundwater effects on stability

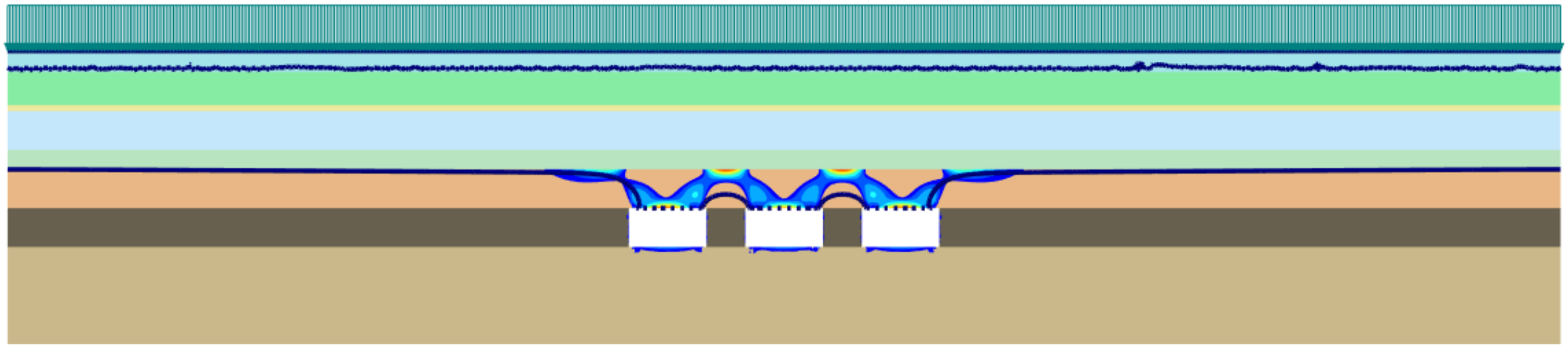
Fully-coupled flow-deformation: Time-variant pore-water pressures are computed from transient seepage flow analysis

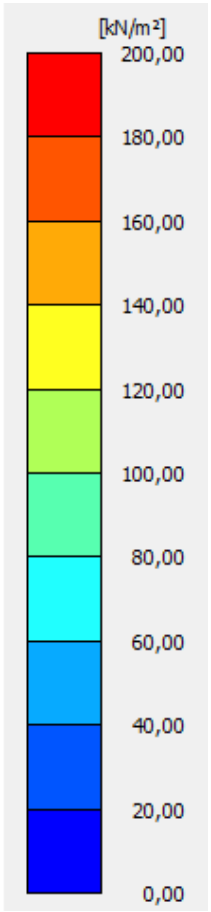
Static groundwater table: Static pore-water pressures are computed from the position of the phreatic surface

Steady-state flow: Constant pore-water pressures are computed from steady-state seepage flow analysis

Fully-coupled flow-deformation – extreme rainfall

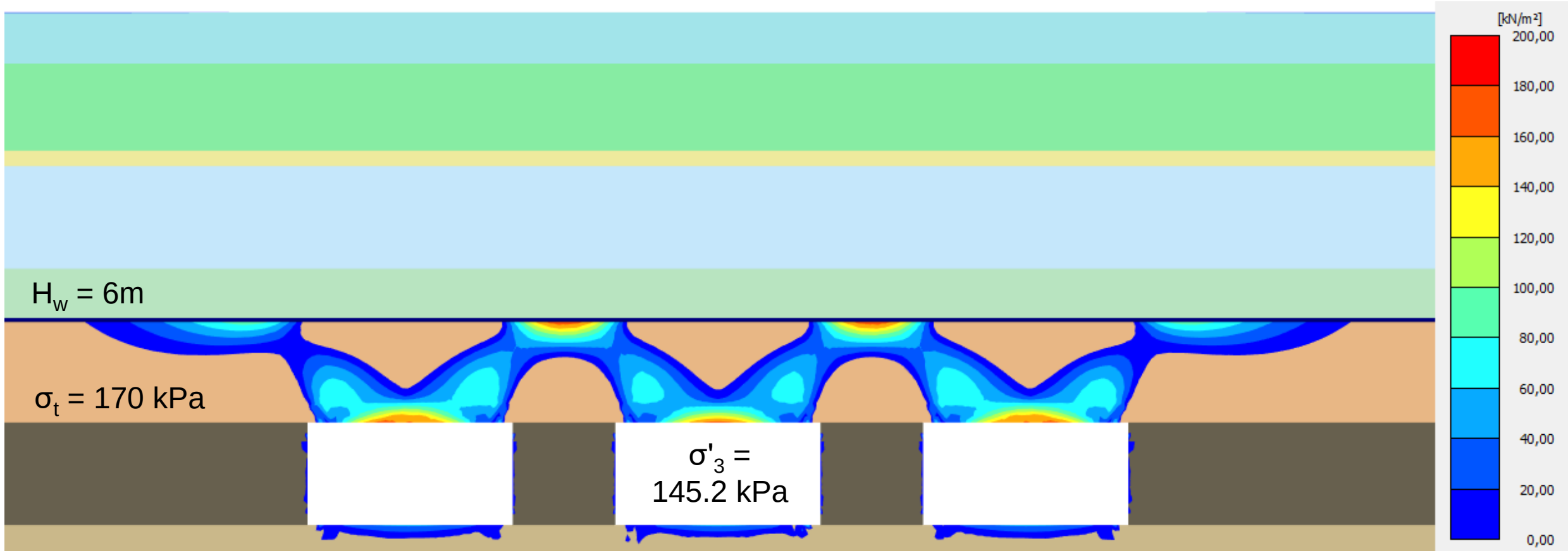
Extreme rainfall 2 days-3.6 mm/h
The upper soil layer (silty clay) inhibits the infiltration of rainwater, due to its permeability





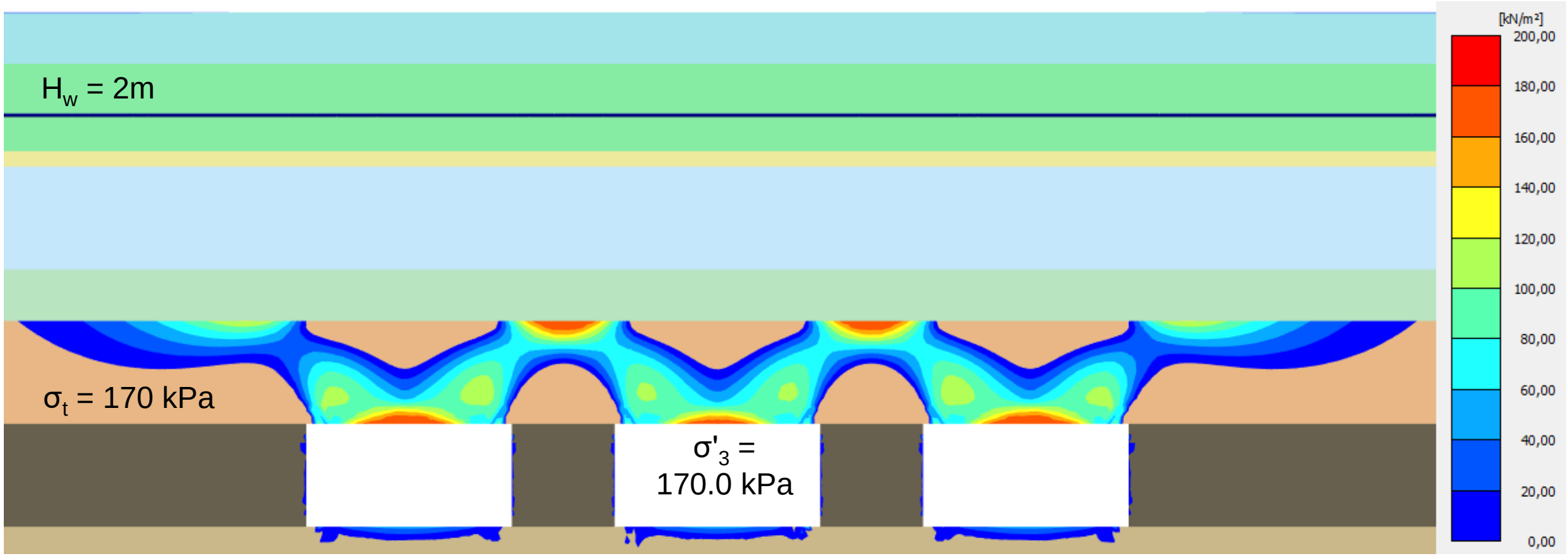
Instability is associated with **long-term processes of groundwater recharge**, and is **not attributed to individual rainfall incidents**

Static groundwater table – initial conditions



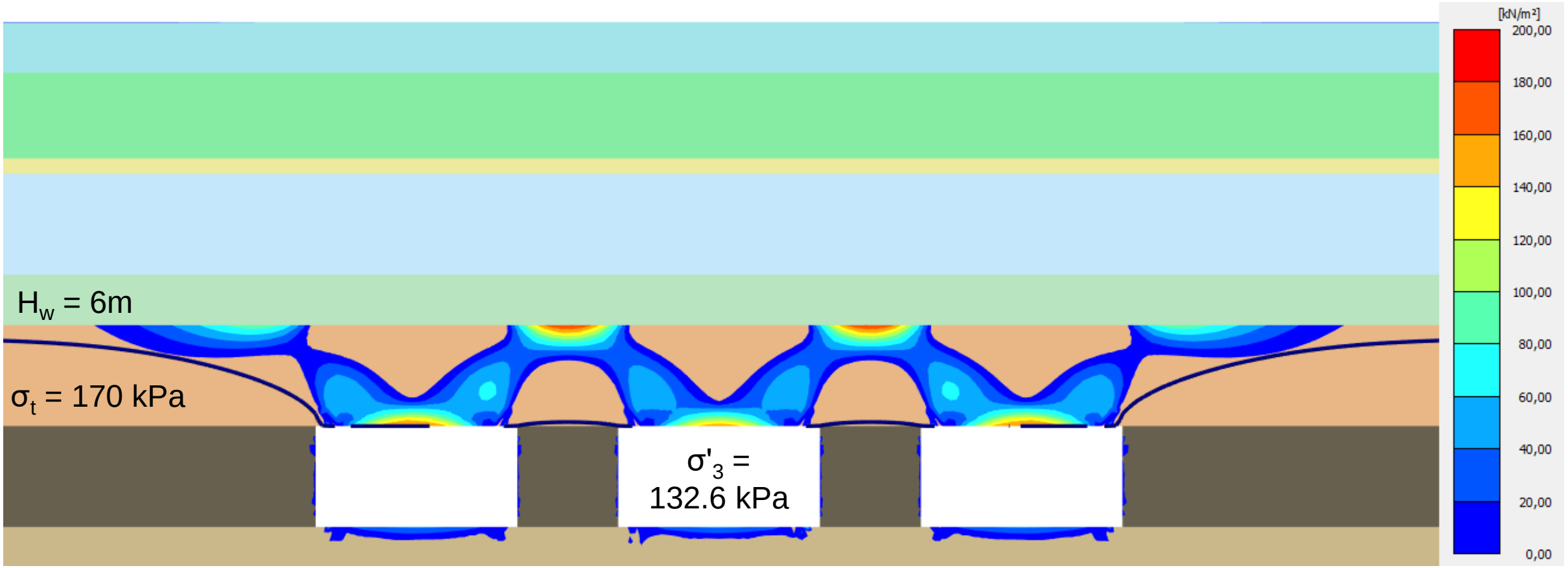
SF = 1.17

Static groundwater table – worst conditions



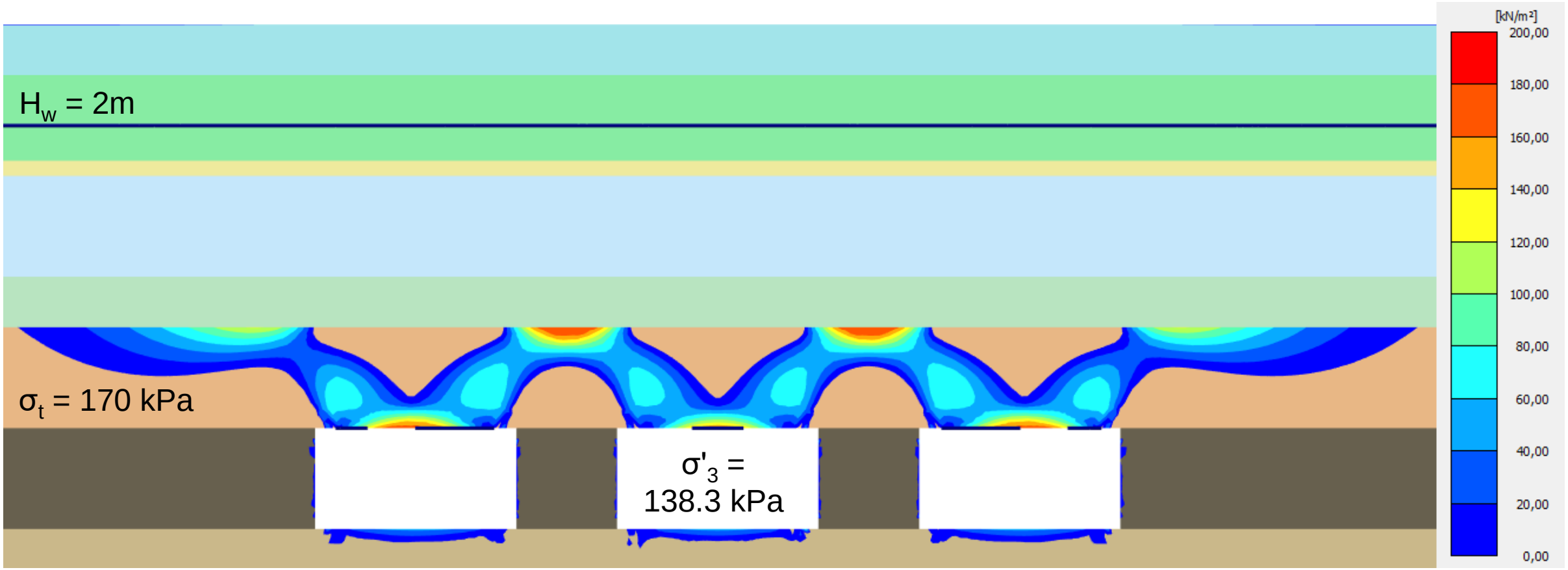
SF = 1.00

Steady-state flow - initial conditions



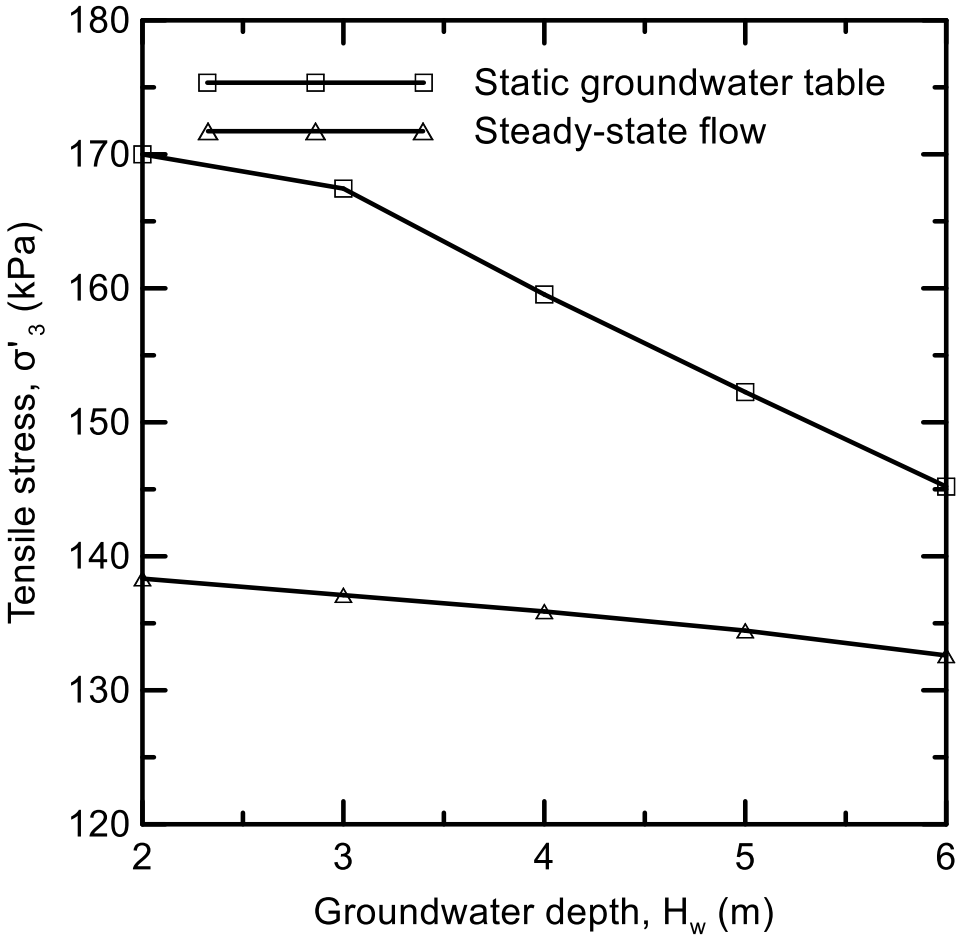
SF = 1.28

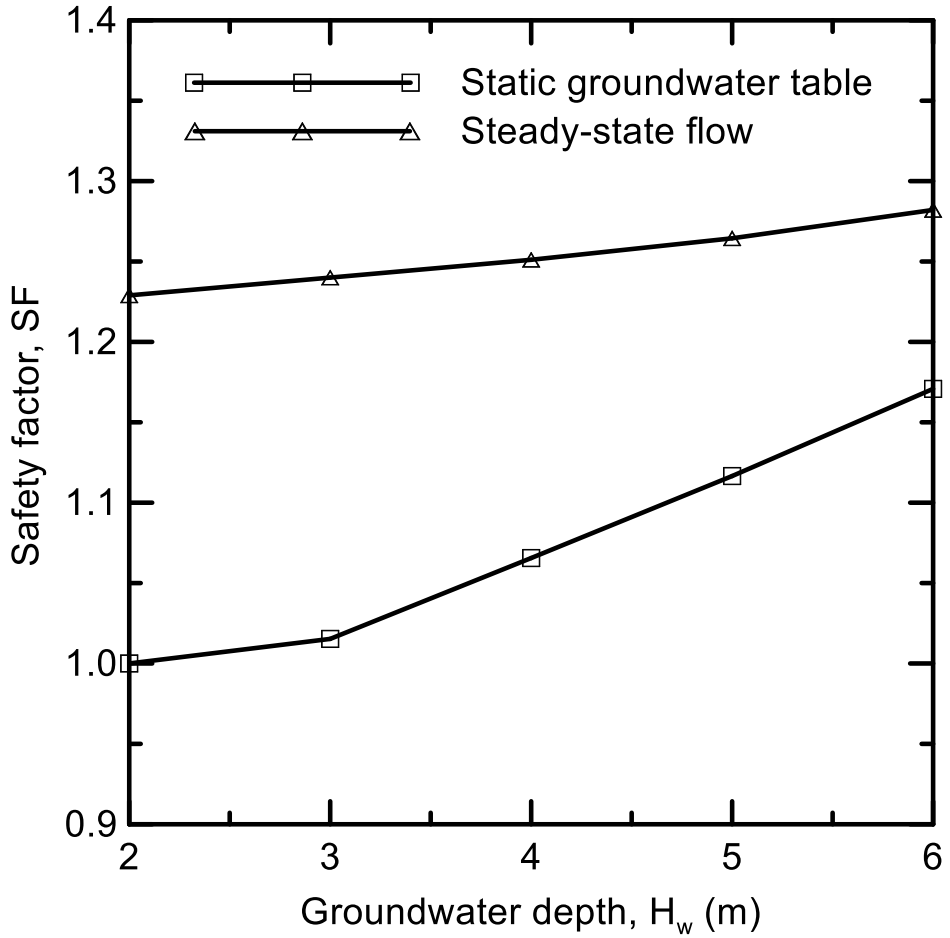
Steady-state flow - worst conditions



SF = 1.23

Phreatic table vs steady-state flow





Conclusions

- Sinkholes are localized surface depressions strongly related to the abrupt collapse of underground cavities.
- The triggering of roof instability in shallow underground coal mines due to water effects was investigated. This is directly related to the sinkhole potential.
- A well-documented case study was employed in 2D plane strain finite element analysis.
- Three approaches were simulated: extreme rainfall event, long-term recharge with phreatic table, long-term recharge with steady-state flow.
- Roof safety remains unaffected by a single rainfall event because a silty clay layer with low permeability limits the infiltration.
- For long term recharge the stability deteriorates in both cases
- The sinkhole formation potential is higher for static groundwater table reaching instability for very high water table.

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Thank you for your attention!

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