Applicability of Unlined/Shotcrete Lined High Pressure Tunnels for Hydropower Projects in the Himalaya

Candidate: Chhatra B. Basnet

Main Supervisor: Dr. Krishna K. Panthi
(Department of Geology and Mineral Resources Engineering)

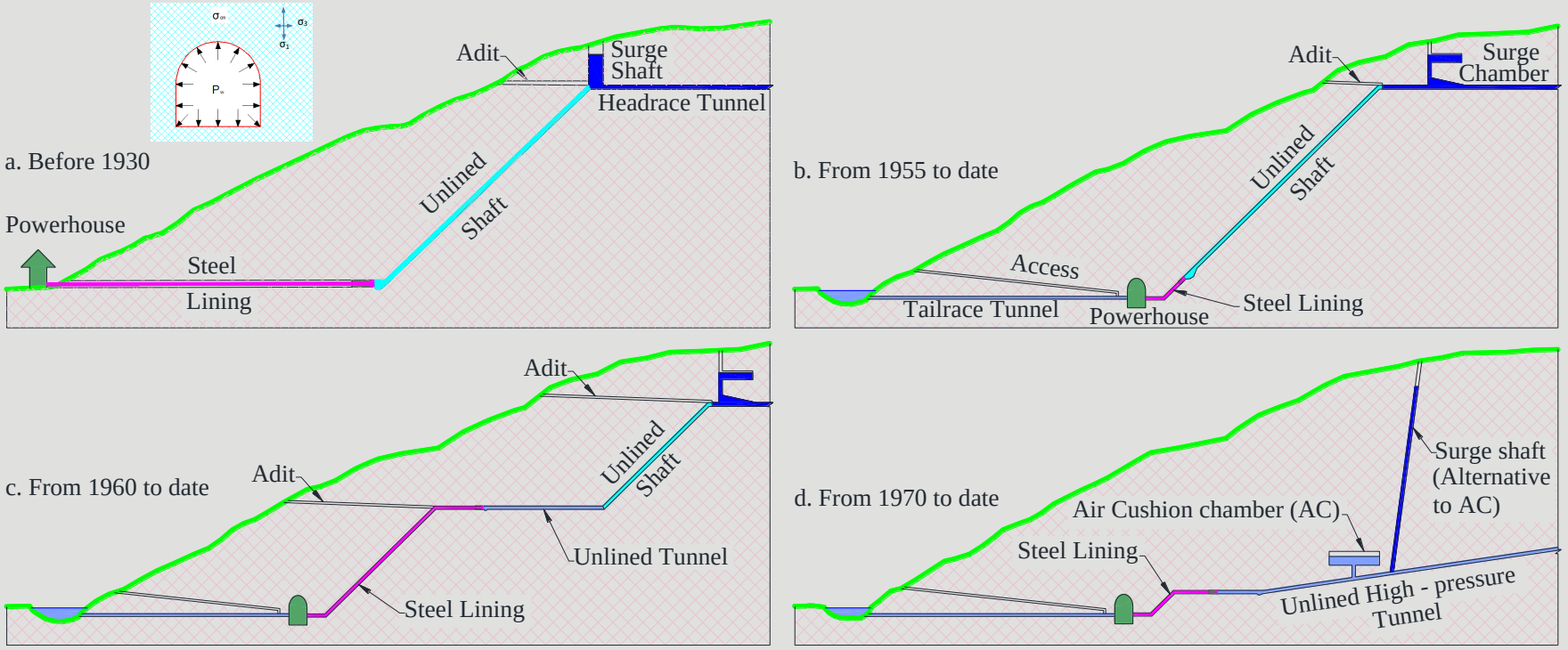
Contents

- Norwegian unlined pressure shaft / tunnel concept
- Research question of the PhD work
- Major issues for unlined shafts / tunnels
- Applicability in the Himalayan environment
- Conclusions

NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Norwegian unlined shaft / tunnel concept



NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Cases that helped to build and upgrade the concept

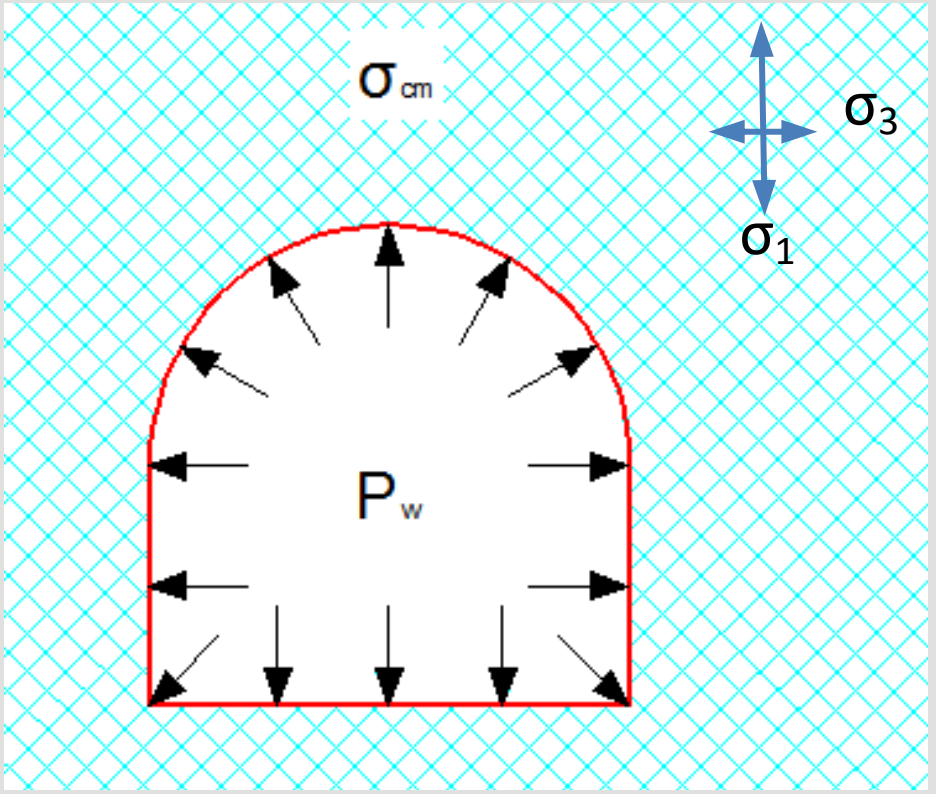
Project	Year	Water head (m)	Rock types	Cross-section Area (m^2)	Failure condition
Herlandsfoss	1919	136	Mica-schist	8.0 (Tunnel)	Partly failed
Skar	1920	129	Gneiss-granite	Tunnel	Completely failed
Svelgen	1921	152	Sandstone	4.5 (Shaft)	Minor leakage
Byrte	1968	303	Granite Gneiss	6.0 (Shaft)	Partly failed
Åskåra	1970	210	Devonian Sandstone	9.0 (Tunnel)	Partly failed
Bjerka	1971	72	Gneiss	10.0 (Tunnel)	Partly failed
Holsbru	2012	63	Dark Gneiss	18.0 (Tunnel)	Leakage

NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

The principle requirement

$$\sigma_3 > P_w$$



NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Research question of the PhD work

- What could be the requirement that helps to use unlined / shotcrete lined pressure shafts and tunnels in the Himalaya?

NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Major issues for unlined shaft / Tunnels

- **Hydraulic criteria**
- **Hydraulic spliting**
- **Long term stability of the waterway**

NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Hydraulic Criteria

- Rough tunnels will have higher roughness and higher headloss
- Unlined tunnels are rougher than lined one
- Trade off between the extra headloss due to rough surface and cost of lining – Optimization
- Optimized roughness depends upon energy price and cost of construction

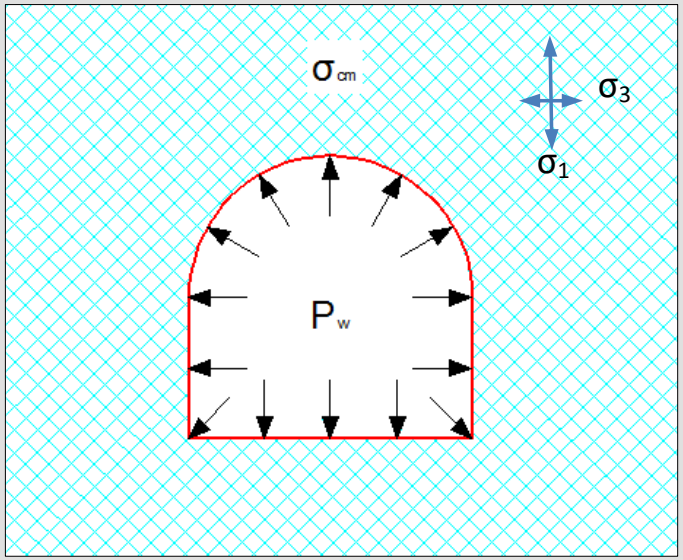
Field work completed and analysis underway

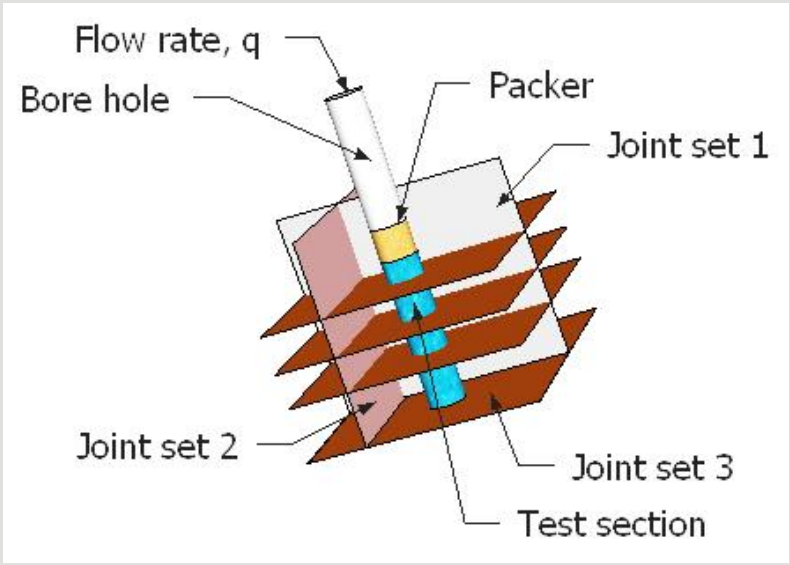
NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Hydraulic splitting

- Fracture initiation in rockmass or opening of existing fractures
- In-situ (field) test is necessary to build the criterion

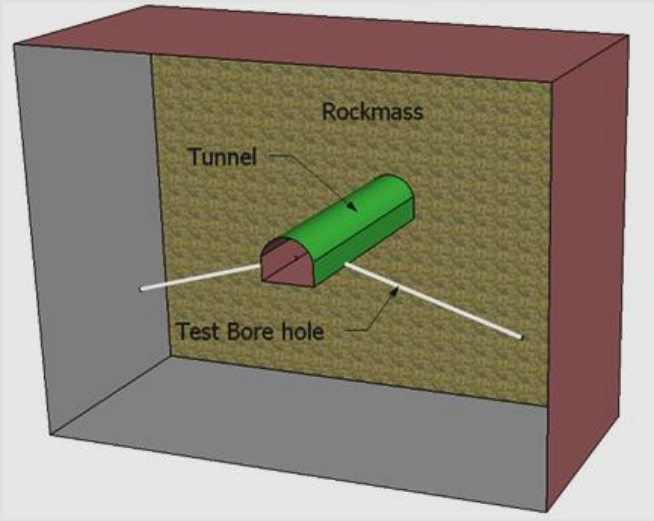


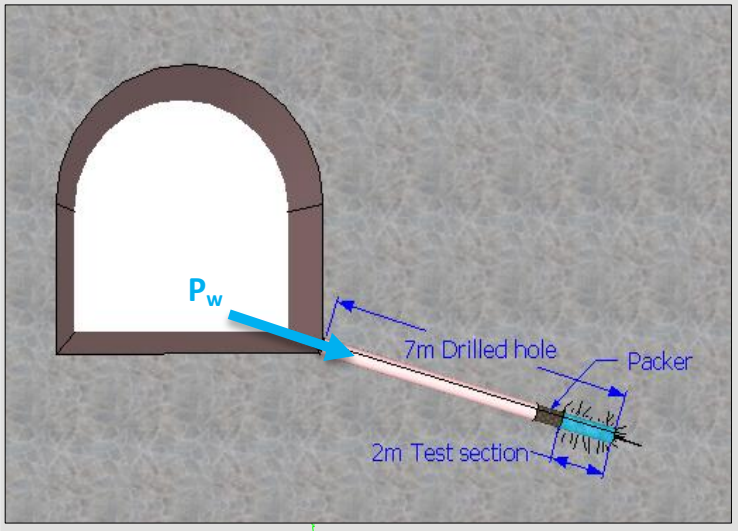


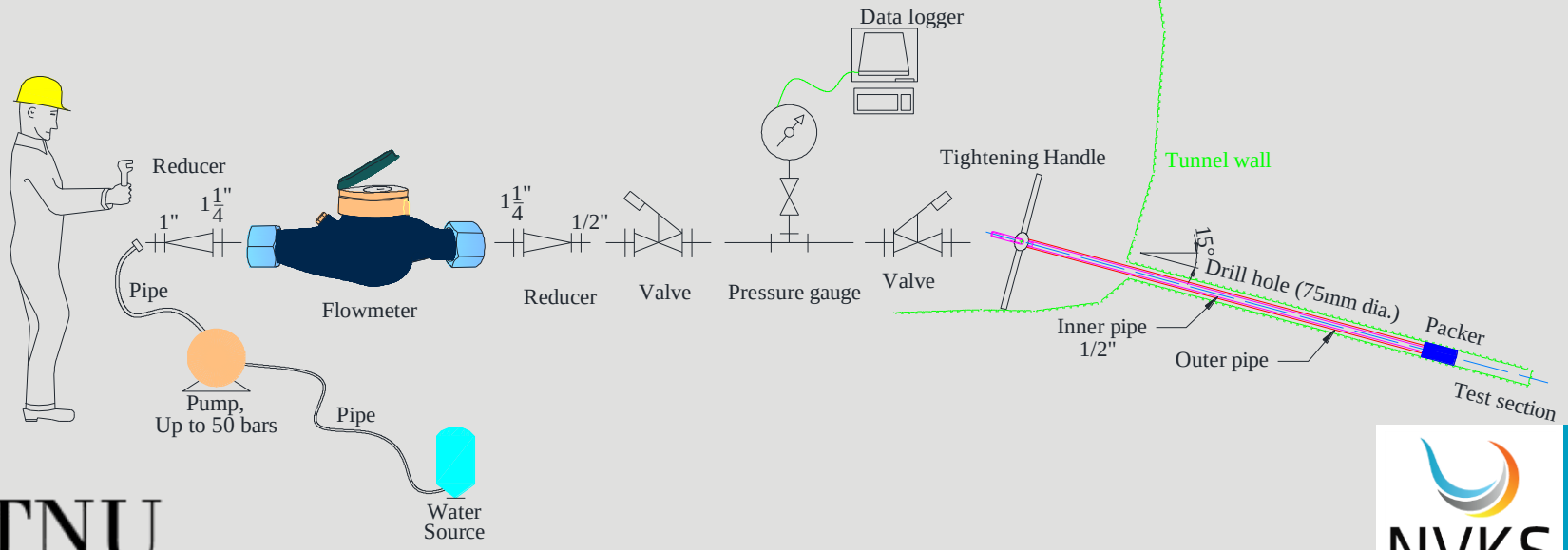
NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Field test







NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Field test

Flow Meter

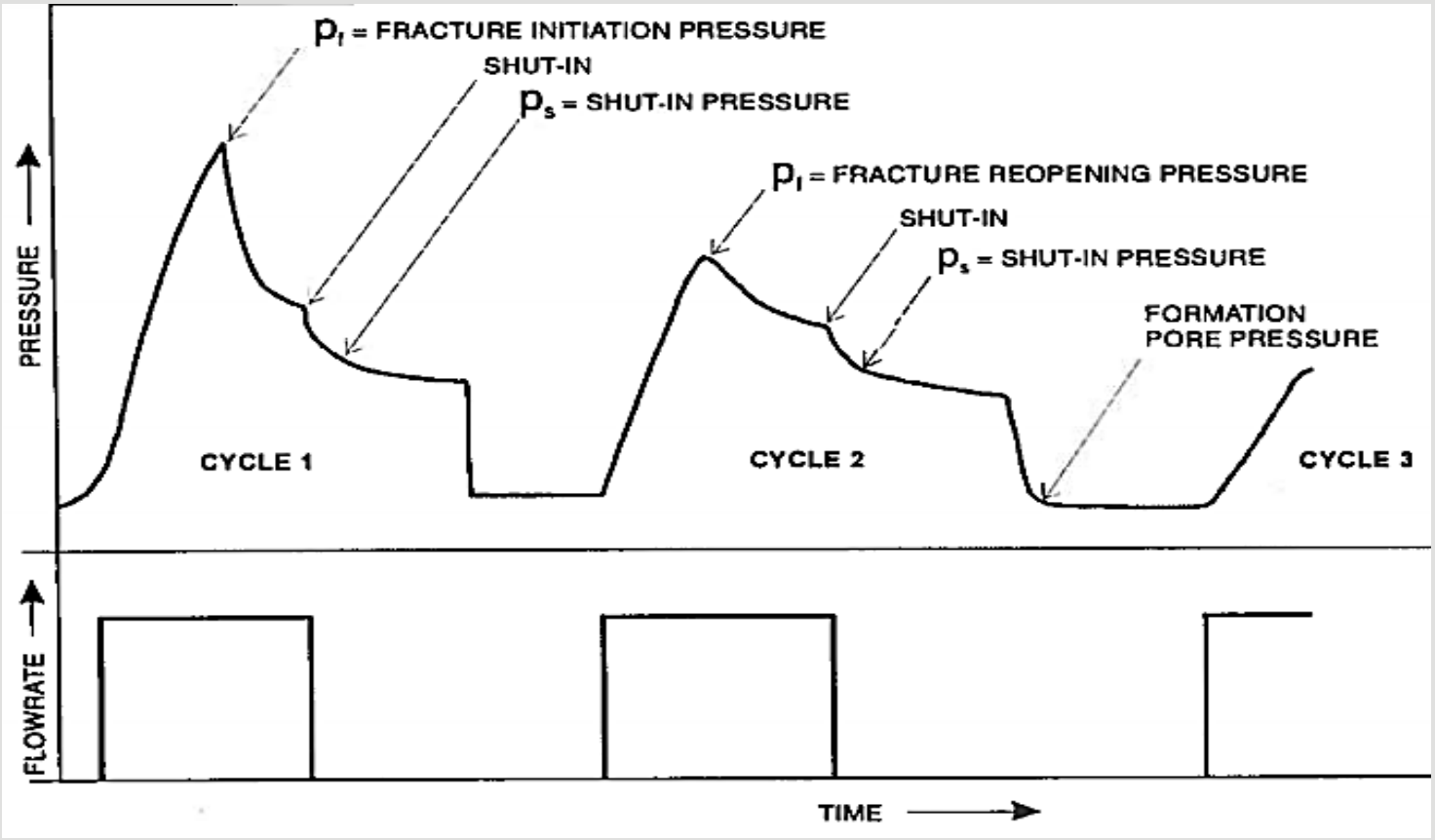
Pressure Gauge
0-40 Bars
0-60 Bars

Inner and outer pipes

NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Test output



Idealized hydraulic fracturing pressure record (ISRM, 1987*)

* Suggested methods for rock stress determination

NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Long term stability of tunnel

- Stress induced instability (rock spalling, rock burst etc)
- Rock mass should be strong enough to sustain the insitu stress
- Rock mass strength to be determined

NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Rock mechanical properties

Cores, extracted from the samples collected from field and ready for UCS Test

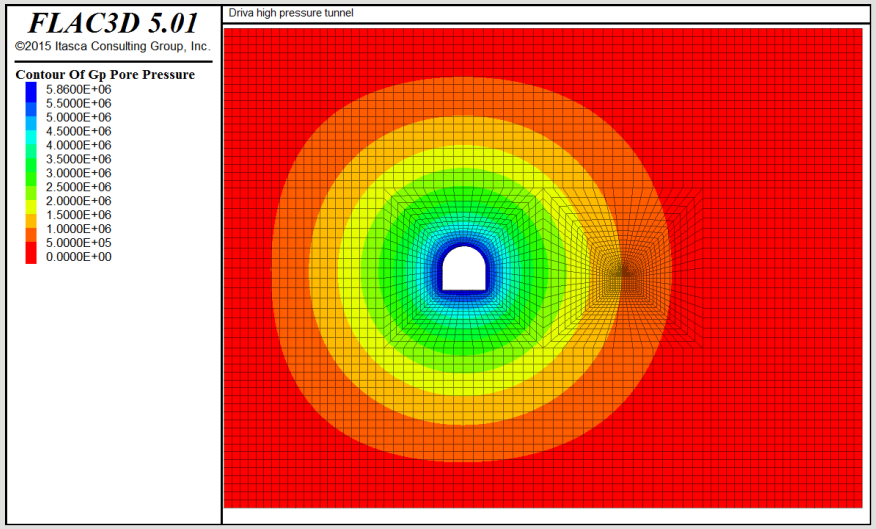
State-of-art Triaxial Press installed at IGB (NTNU) laboratory in 2013 (*Photo: Basnet, C.B.*)

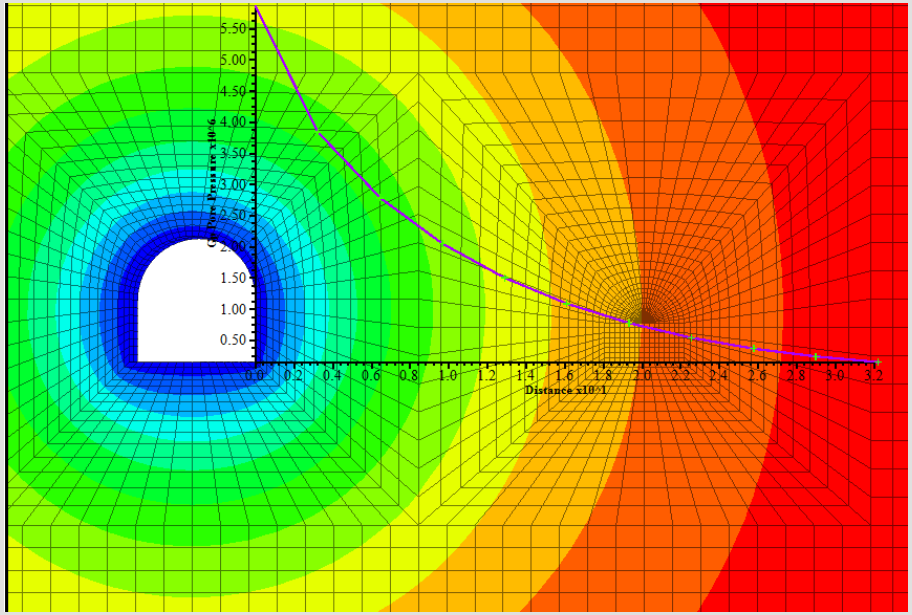
NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Numerial modeling

- Modelling of hydraulic splitting phenomenon in the rock mass around pressure tunnel
- Use of FLAC^{3D}/3DEC





- Stability analysis

NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Conclusions

- Headloss measurement has been carried out in the field and roughness of shotcrete lined tunnels is back calculated
- Field test arrangement for hydraulic splitting is underway
- This field test is simple and easy to use (Hope). Once it is applied in this research work, it can be implemented and used later on
- Unlined pressure shafts and tunnels are the economical solution in hydropower projects

NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE

Thank you!!

NTNU

NVKS
NORWEGIAN HYDROPOWER CENTRE