

# Rock Erosion in Spillways – Norwegian perspective

Research approach, case studies and key findings

by

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Photo: Tafjord kraftproduksjon

# Current situation in Norway

2700 dams (class 1 – 4), 335 large dams

No dam failures or severe damages from erosion in spillways have been encountered

Not a major concern, few considerations are normally adopted

- Good rock conditions ( $f_{c, \text{unfrac.}} = 150 - 250$  MPa)
- Over 100 years of experience
- 'Common sense' technology
- 'Trial and error' is accepted
- When weak rock conditions are encountered, measures are normally taken



# Regulations and guidelines

Design flood  $Q_{1000}$ , Failure control:  $Q_{PMF}$

From the 1981 regulations:

*Erosion must be avoided by design of the chutes and downstream areas and exposed areas must be protected if required. Energy dissipaters must be constructed if necessary*

From the 2006 regulations:

*Erosion must be avoided by design of the chutes and downstream areas and exposed areas must be protected if required. Energy dissipaters must be constructed if necessary*

*For the outlet in the river:*

*Damages are normally not the issue in Norway where good rock conditions secure both quality and strength. Generally, spilled water is routed into the river without any measure*

# Current situation in Norway

Case studies – current practice and erosion

Dam Virdnejavri, tunnel spillway

Dam Sandvatnet, overflow spillway

Dam Fallforsen, gated spillway, run-of-the-river

Dam Sæterstivatnet, small chute, severe erosion

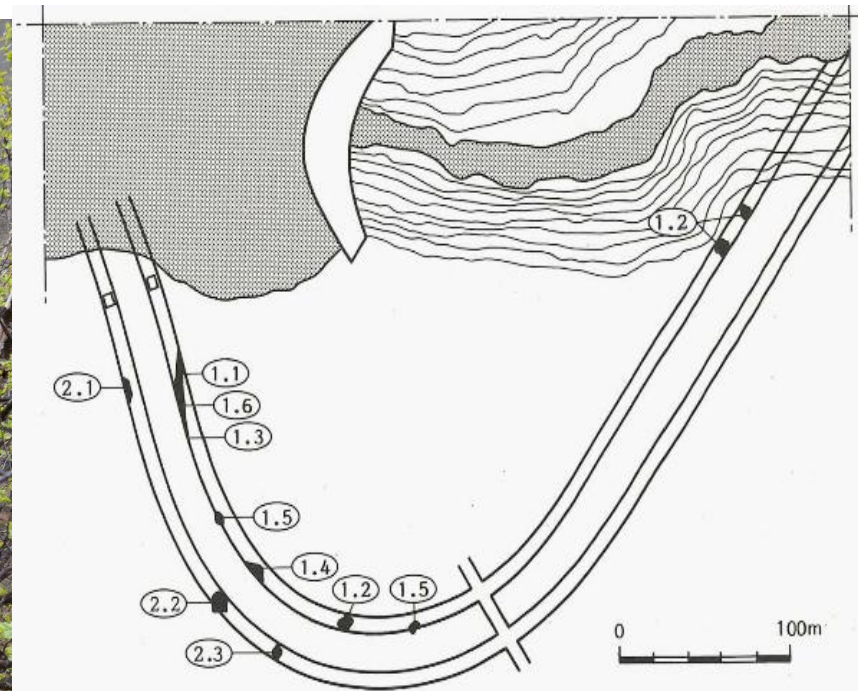


# Dam Virdnejavri, tunnel spillways

$Q = 650 \text{ m}^3/\text{s}$  in each tunnel,  $v = 30 - 20 \text{ m/s}$ ,  $\mathbf{F} = 3$

Severe erosion first year of operation

Maximum erosion discovered  $L = 40 \text{ m}$ , depth  $4 \text{ m}$ , >  
10 scouring pits



# Dam Sandvatnet

Free crest overfall spillway

Foliated rock, spilling during wintertime, erosion propagating towards the dam toe



Photo: Saudefaldene

# Dam Fallforsen, ROR, gated spillway

Minor erosion, scouring holes, composite geology

No measures, slow process



# Dam Sæterstivatnet, small is beautiful?

Small unlined chute, no initial measures

Severe erosion occurred in foliated rock

Lined chute constructed







DRIKKEVANN  
FØRINGS IKKE  
FERDIGT  
BEKKELOP  
ELLER VAV.

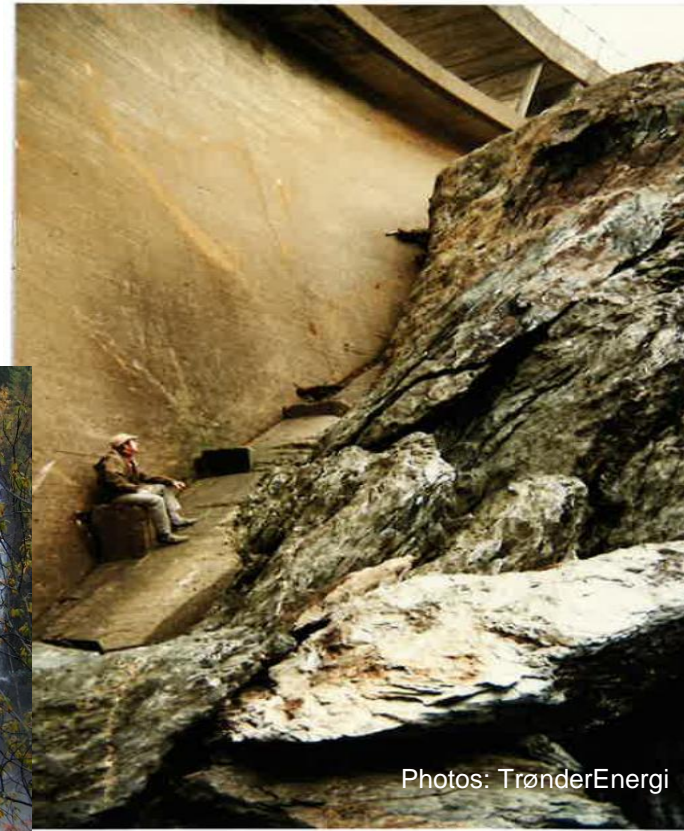
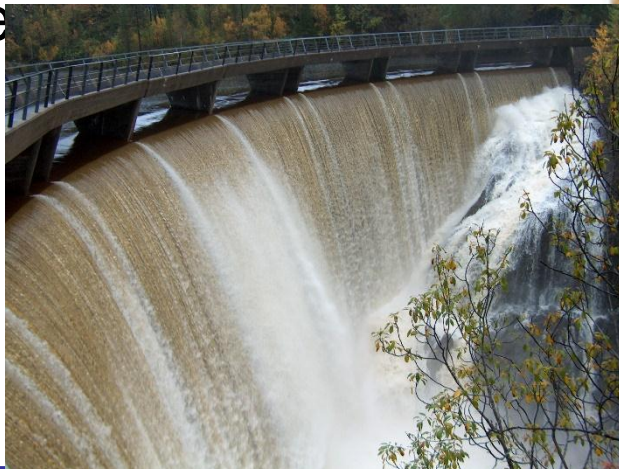
# Research done

Urgent situation at Dam Sokna and Dam Storfossen

Two large concrete dams experienced severe rock erosion after the 1983 spring flood

Measures had to be taken

Pulsating forces from the water jet recognized as the main problem source



Photos: TrønderEnergi

# Research done – Laboratory tests

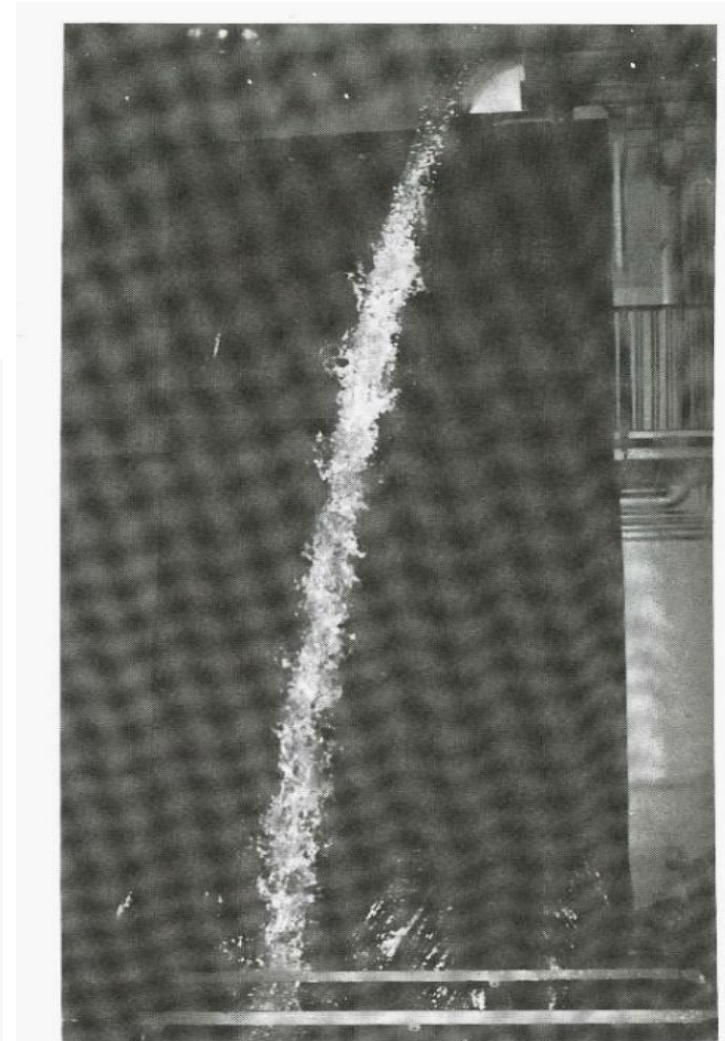
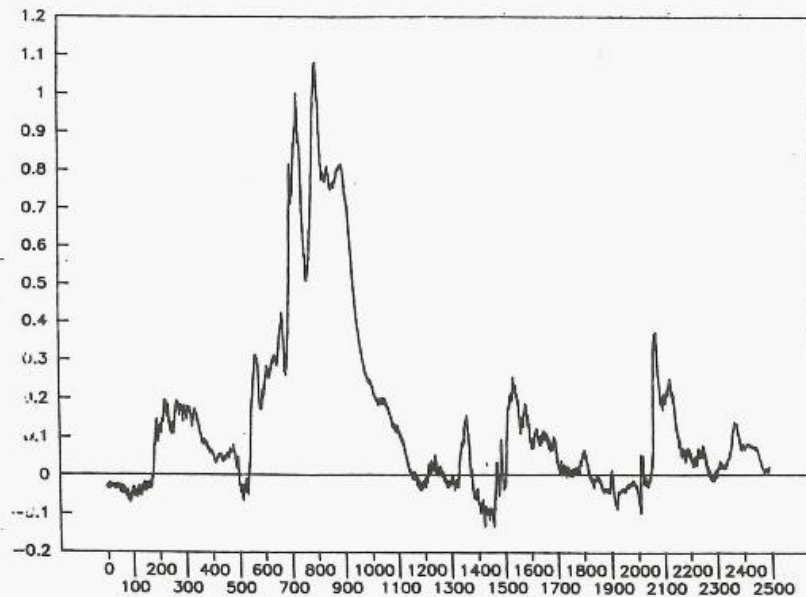
## Test setup

Water jet  $H = 8\text{ m}$

Discharge  $Q = 10 - 86\text{ l/s}$

Pressure cell high resolution

Monitoring [kHz]



# Research done – Field tests

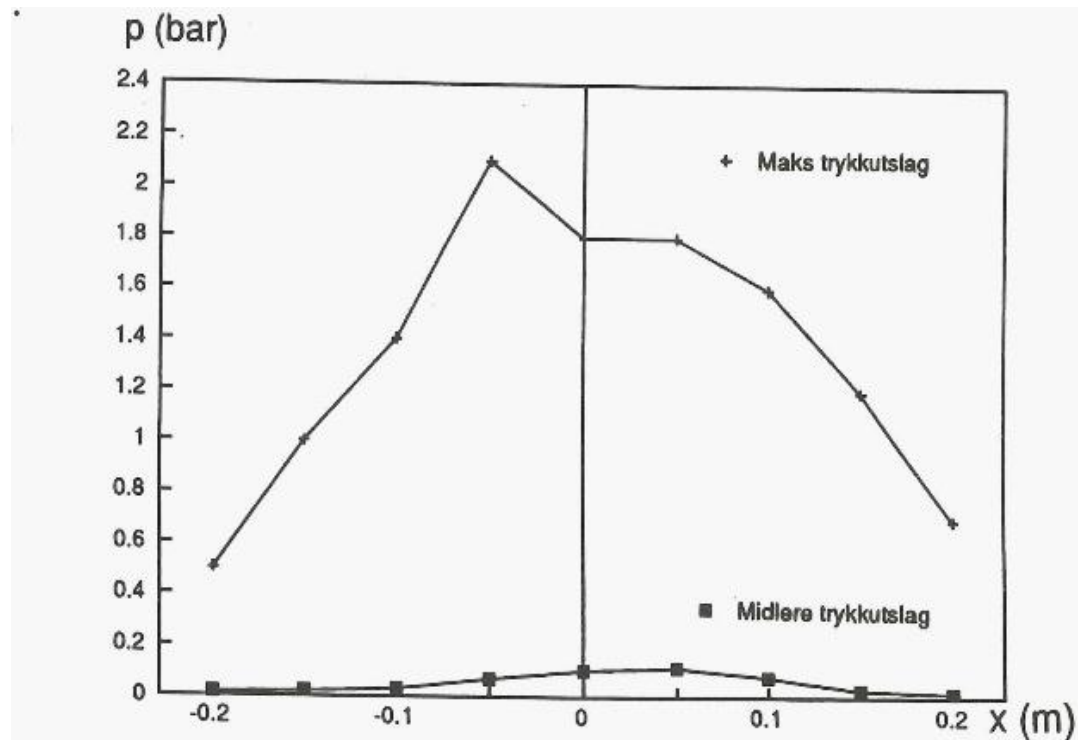
Field tests at Dam Sokna

Water jet  $H = 7,2 - 21,2$  m

Discharge  $Q = 10 - 86$  l/s

Pressure cell high resolution monitoring

Movable cell



# Measures available

- a) Concrete lining/reinforced concrete slabs
- b) Chutes, changes in geometry
- c) Downstream pool, depth  $> 0,1 \cdot H$





# Concluding remarks

Rock erosion is not a major problem in Norway

Exposed rock is of good quality in most spillway chutes and dam toes

Research done in the 80<sup>ties</sup> and 90<sup>ties</sup>

Measures taken on some spillways

- Concrete slabs

- Chutes, changes in geometry

- Skijumps

- Downstream pool, depth  $> 0,1 \cdot H$



But few spillways have so far experienced the

$Q_{\text{design}}$ ?