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CIGB 2018 26 ^{ème} Congrès 86 ^{ème} Réunion Annuelle 1 - 7 JUILLET, VIENNE

Performance of PU-foam as anchoring for penstocks





PU-foam for penstocks - Background

- Motivation: Reduce costs and increase construction speed for small hydro penstocks
 - Transport of gravel for support as the most expensive part
- PU-foam is available for industrial use
- PU-foam is frequently used in civil works
- Research carried out in lab in 2015
- Co-authors:
 - Tor Oxhovd Svalesen (Statkraft), Guy Harris (inventor), Mathias Kullberg (Multiconsult), Stian Løbø Åker (NTNU/NGK Utbygging)





PU-foam for penstocks - Concept

- Placement on site
- Continuous process in the longitudinal direction
- Functions
 - Anchoring
 - Protection
 - Insulation
 - Retention in bends





PU-foam for penstocks – Construction work

- Placement in two main alternative processes
 - Spray foam
 - Pour foam

Properties

- Tensile strength $f_{PU,t} = 0,7$ MPa
- Compressive strength $f_{PU,c} = 0.5$ MPa
- Expantion rate 20:1
- Impervious (if properly applied)





PU-foam for penstocks – Construction site

- Lille Måsevann PSP in Finnmark (Norway), N71° 8' 2"
- Technical data
 - H_{max} = 39 m
 - P = 0,8 MW
 - L = 1100 m
 - D = 900 mm
- Main powerplant is Adamselv
- P = 50 MW, E = 200 GWh





Photos from construction work





PU-foam for penstocks – Monitoring system

- Fully equipped and monitored pump/plant
 - Power, flow, rpm, head etc.

Two 15° bends have displacement transducers

- Type HEP
- Resolution [mm]
- Ad hoc measurements

Monitoring program

- Total shut off, immedeate start
- Annually or ad hoc
- Logged externally









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PU-foam for penstocks – 'Long term' performance

- Estimated displacements in the bends
 - 1 mm

Monitored displacements during first filling (2017)

- 0,2 mm
- Resolution [mm]
- Ad hoc measurements
- Monitoring program
 - Total shut off, immedeate start
 - Annually or ad hoc
 - Logged externally





PU-foam for penstocks – First year displacement





PU-foam for penstocks – Second year displacement



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PU-foam for penstocks – 'Long term' performance

- Development in displacement in start/stops
 - In 2016: 0,2 mm
 - In 2018: 0,2 mm
- Permanent seasonal displ.
 - 2 mm (in operation)
- Material properties
 - Rely on accelarate tests
 - No sampling yet











PU-foam for penstocks – Conclusions

- No indication of increased displacements
- Displacements < 0,2 of estimated displ.
 → Forces in bends are distributed away from the foam
 > Forces is able to encharge bands
 - \rightarrow Foam is able to anchore bends



 Quality of foam and permanent displacement must be followed up