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Tunnel Roughness

Linking physical wall roughness of unlined tunnels to hydraulic resistance

Spillway tunnel, Strandevatnet dam (Leif Lia - 2018)

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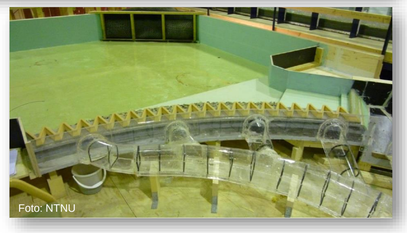
Background

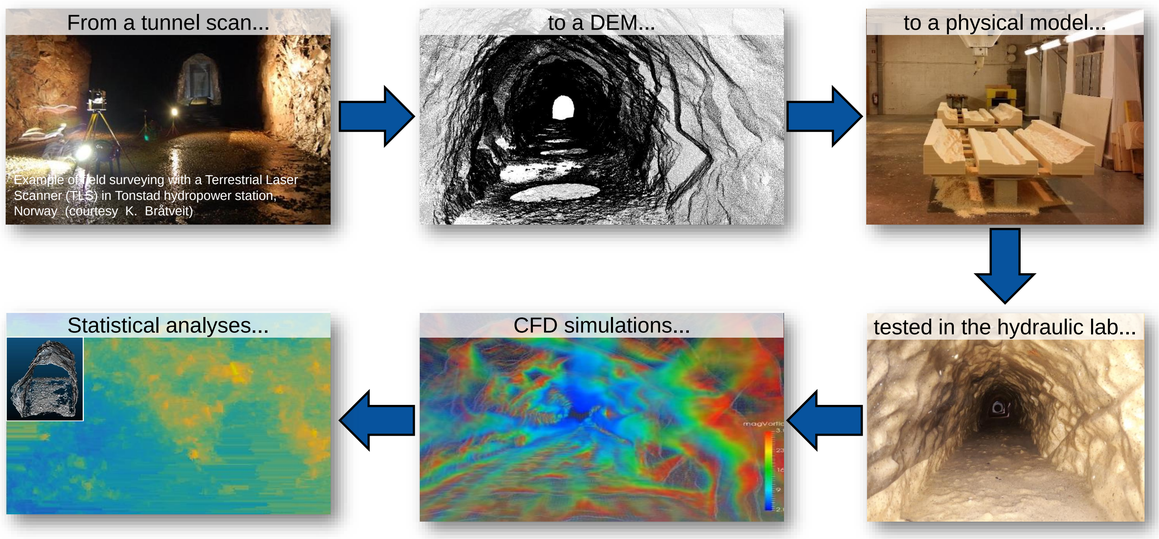
- ***Hydropower tunnels*** are an important feature in Norwegian hydropower systems and are used for
  - the transport of water from reservoirs for energy production
  - the controlled release of flood flows from reservoirs
- How much water can be conveyed in a tunnel depends on its friction, and many of the Norwegian hydropower tunnels are generally unlined, i.e. the tunnel walls are left rough after excavation
- The friction caused by such tunnel walls is generally quantified using empirical approaches, tabulated values, or photographic methods

The spillway at the Gravann-Valevann-Kilen reservoir in Norway and the physical model tests for its design in the NTNU hydraulic laboratory



Research Methodology (1)

- Combination of physical scale model studies, computer (numerical) simulations, and analytical considerations
- Terrestrial Laser Scanning of hydropower tunnels to obtain the topography of unlined hydropower tunnels
- Digital Elevation Models derived from the point clouds are used to
  - mill scaled models of tunnel sections with high accuracy which are used in innovative laboratory experiments
  - perform high resolution numerical simulations
  - determine roughness patterns



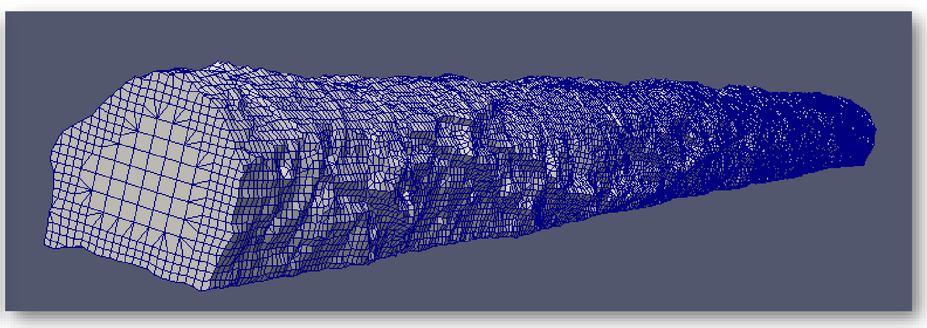
TunnelRoughness project

- ***Primary objective***
  - To improve the accuracy of analytical, experimental and numerical methods for the determination of energy-losses through friction in unlined hydropower tunnels
- ***Secondary objectives***
  - Assessment of the roughness characteristics of unlined tunnels based on statistical analyses of tunnel topography and relating geometrical roughness characteristics to spatial scales and tunnel construction methods
  - Development of an advanced approach to link geometrical surface properties to hydraulic roughness and hence friction losses
  - Linking near-wall turbulent flow field features to tunnel roughness characteristics using innovative analytical methods
  - Assessment of the performance of numerical models for capacity calculations in tunnels
  - Improvement of physical scale modelling techniques for the simulation of unlined tunnels

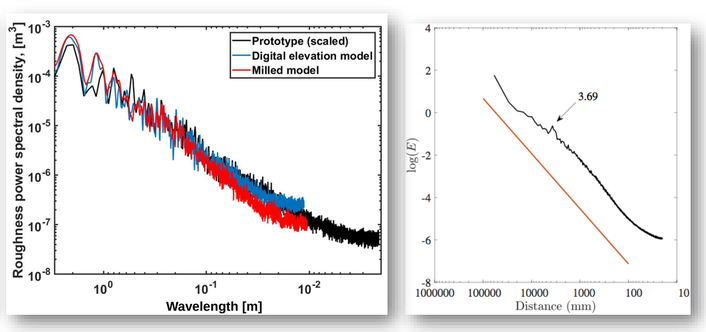
Research Methodology (2)

- Measurement of hydrodynamic variables and the turbulent flow field in scale model experiments using advanced instrumentation to determine energy losses and investigate hydrodynamics
- Statistical analyses of roughness patterns by treating the tunnel surface as a random field of elevations to assess the roughness structure and determine characteristic length scales of unlined tunnels
- Determination of friction losses and hydrodynamics in high resolution computer simulations using the same bathymetry as in the laboratory experiments
- Comparison of the results from the physical and numerical experiments to validate the results
- Linking energy losses and hydrodynamic characteristics with roughness characteristics to derive novel approaches for the determination of energy losses
- **The final results** will be of high relevance for end-users as they will allow for the direct assessment of energy losses in unlined tunnels based on laser-scanning data

A classical model of an unlined tunnel and a view into a milled tunnel with access windows for optical flow measurements with Particle-Image Velocimetry (Potos: NTNU)



A computational mesh for the numerical simulations generated from a laser scan



Spectral analyses of longitudinal elevation profiles of selected DEM-regions, the milled tunnel model, and prototype tunnel (left plot) and spectral analysis of the prototype tunnel section (right plot)

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