Linking physical wall roughness of unlined tunnels to hydraulic resistance

Courtesy N.R. Olsen

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(30% of the budget)

BKK

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Collaborative partners

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- Leichtweiss-Institut fuer Wasserbau (Dr. Ing. Katinka Koll)
- University of Aberdeen (Prof. Vladimir Nikora)

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Project description

Primary objective: 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 tunnel roughness using **statistical analysis** 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

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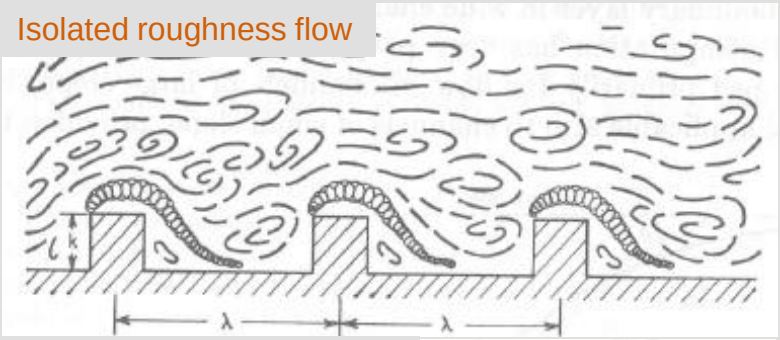
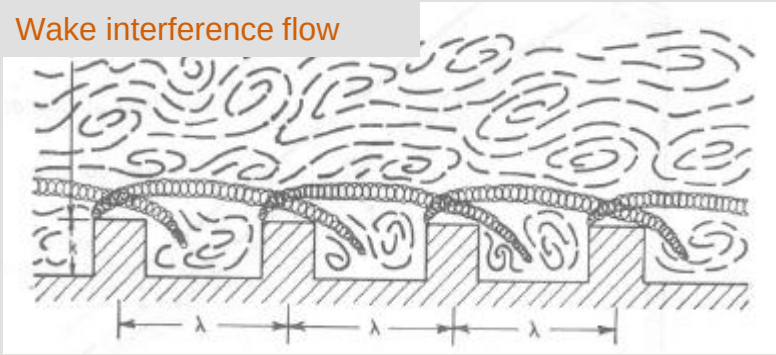
Why roughness is so important…?

Quasi smooth flow

Isolated roughness flow



Wake interference flow



From Chow (1959)

Head losses due to :

- Cross section variations
- Wall roughness
- Singularities (intakes, turns…)

Current status:

- Most previous research has been done with well defined roughness elements
- Type of roughness can vary, affecting flow patterns.
- How can we describe heterogeneous roughness and associated head loss?
- … and it's a 3D problem!

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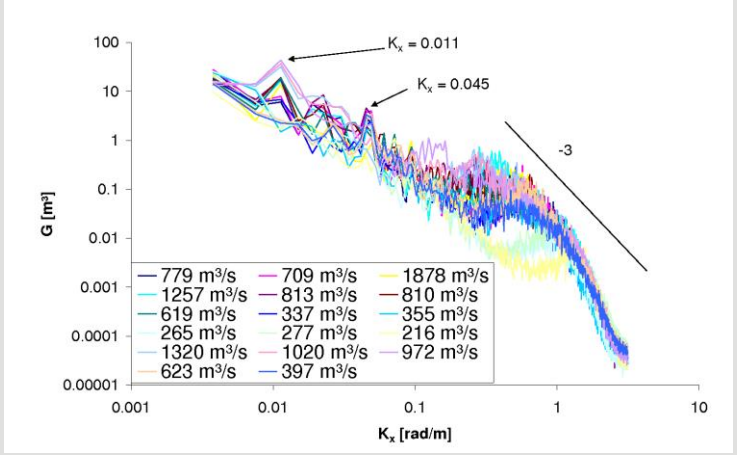
Roughness characterization



Roughness length scales of natural dune beds determined by FFT-analysis

- Calibration of the head-losses, regardless of the characteristics of the roughness
- Derivation friction coefficient and k_s based on statistics of a 1D profile (SD, skewness).
- Spectral analysis of the 1D profile (identification roughness scales)

=> None of these methods use the 3D information we get from tunnel scans!

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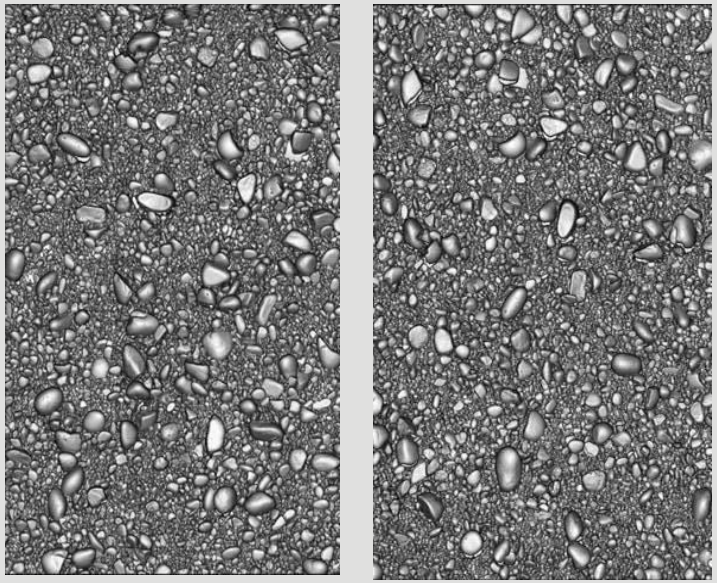
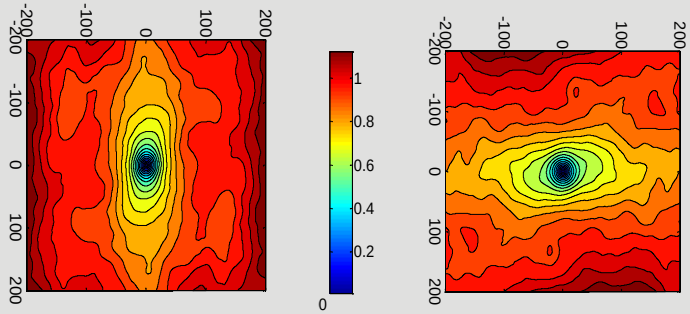
Roughness characterization





2D-Structure functions of gravel beds defining correlation lenghts and roughness structure

- The structure of heterogeneous roughness can be described with a technique called Random Field Approach (statistical method)
- The spatial velocity field is described by double-averaged Navier-Stokes equations
- This provides the theoretical background for coupling between roughness elements and the head losses

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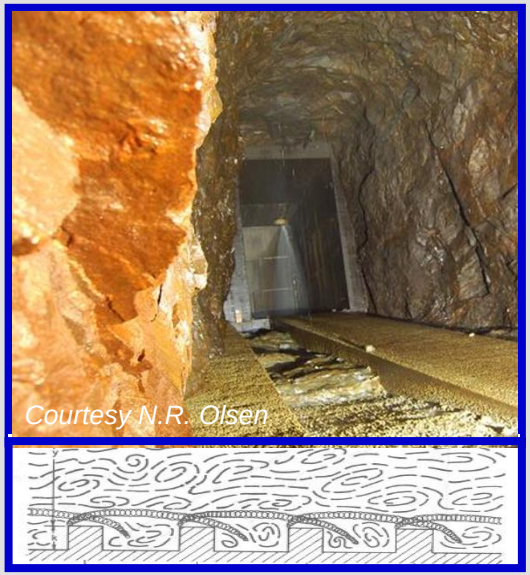
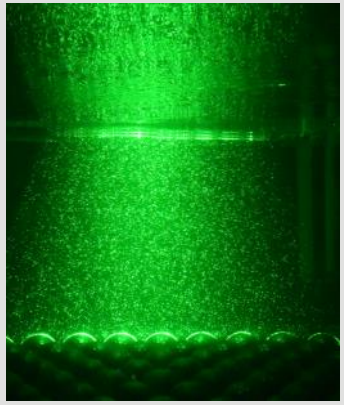
Model tests



- Scale devices from prototype with high precision (never used for tunnels): We can increase the accuracy of model studies, we set new standards for model studies
- Build laboratory models with various type of roughness (including former modelling mth)

- Investigate relationship between roughness, head loss and turbulence (piezometers, Stereo PIV,…)
- Provide recommendations that can be used to determine which tunneling techniques that are economically optimal
- Bonus: study the flow pattern using PIV in the model and validation of numerical calculations



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For summing up this presentation…

… that's what we do!

- **Quantification of head loss as a function of the tunnel roughness generated by different tunneling methods** *(Knowledge for the Industry)*

- **Turbulent flow of irregular roughness elements** *(Scientific knowledge)*

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Thanks for your attention ☺

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