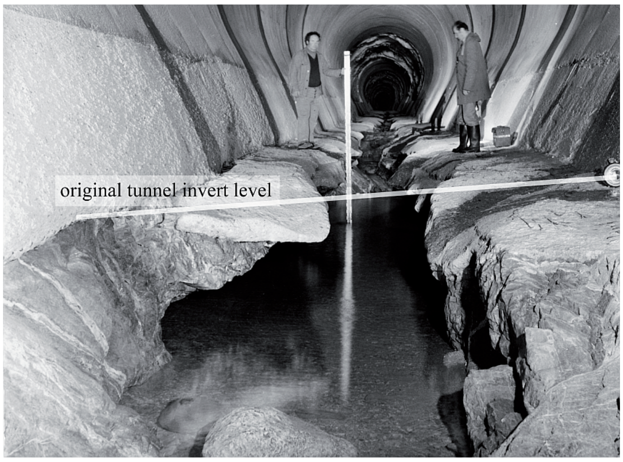
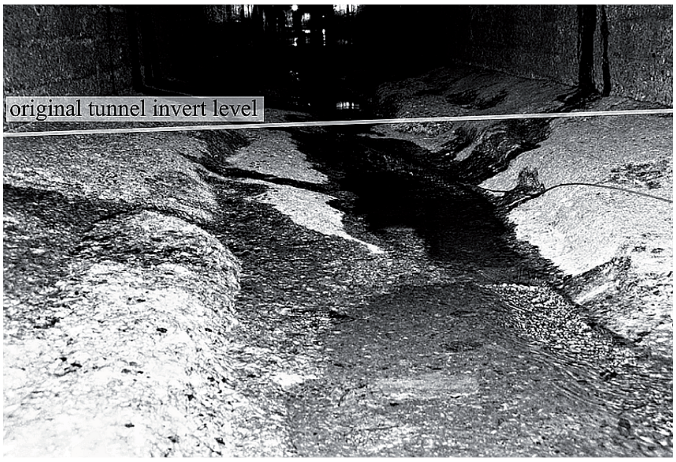
PhD - Layout and Design of Sediment Bypass Tunnels

Reservoir sedimentation is increasingly affecting the majority of reservoirs all over the world. As many dams are more than 50 years of age, this problem is becoming more and more serious nowadays. Reservoir sedimentation leads to various severe problems such as a decisive decrease of the active reservoir volume leading to both loss of energy production and water available for water supply and irrigation. These problems will intensify in the very next future, because sediment supply tends to increase due to climate change. Therefore countermeasures have to be developed. They can be divided into the three main categories sediment yield reduction, sediment routing and sediment removal. This research project focuses on sediment routing by means of sediment bypass tunnels. Sediment bypass tunnels are an effective measure to stop or at least decrease the reservoir sedimentation process. By routing the sediments around the reservoir into the tailwater in case of flood events sediment accumulation of both bed load and suspended load is reduced significantly. However, the number of sediment bypass tunnels in the world is limited primarily due to high investment and above all maintenance costs.



invert abrasion in Palagnedra sediment bypass tunnel, Ticino, Switzerland



invert abrasion in Runcahez sediment bypass tunnel, Grisons, Switzerland

Due to severe abrasion damages at the bypass tunnel invert the dam owners face, besides the construction costs, high investments for maintenance of the tunnel after almost every major flood event. One effective approach to reduce hydroabrasive wear is the optimization of the hydraulic conditions in the sediment bypass tunnel. The basic hydraulic design neglecting the influence of sediment transport can be determined by analytical calculations or numerical simulations, respectively, but there is a major lack of knowledge when sediment transport and abrasion are taken into account. This research project studies these processes and its decisive parameters by means of systematical hydraulic laboratory model tests.

The main goals of this PhD research project are to investigate (1) the mean and turbulence characteristics of supercritical open-channel flows, (2) the sediment motion and transport mode, i.e. rolling, saltating, or suspension under different flow conditions; and (3) the relationship between the transport modes and rates, and the invert abrasion depth. All experiments are conducted in a laboratory steel flume. Parameters such as the discharge, flow depth, bed slope, sediment transport rate and particle size were varied in a wide range to model all possible hydraulic conditions present in sediment bypass tunnels.

In test series (1) streamwise and vertical flow velocities were measured over the entire flume width using a 2D-Laser-Doppler Anemometry system, to determine turbulence intensities, bed and Reynolds shear stresses. In test series (2) single particle motion was recorded using a scientificCMOS - High Speed Camera system with a frame rate of 240 Hz. Particle saltation trajectories, and impact energies on the bed are determined and analyzed. The (3) test series deals with the abrasion pattern caused by high sediment flux at supercritical flow conditions. A part of the model flume was lined with brittle mortar to allow for small scale abrasion in short time scale. Patterns were scanned after every test and parameter such as mean abrasion depths, mean slope and abrasion pattern are analyzed.

The overall goal of this project is to establish general design criteria for optimal flow conditions where both sediment deposition in the tunnel is avoided and resulting abrasion damages are kept at a minimum.

Keywords: Reservoir sedimentation, sediment bypass tunnel, invert abrasion, sediment transport, hydraulic model test

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