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Geomechanical explanation of the Enguri power tunnel leakage

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The Enguri Dam (Georgia) is one of the highest arch dams in the world, located at Enguri river in the Greater Caucasus. A 15 km long pressure tunnel with a slope of 1.1 % connects the reservoir to the power station. The tunnel was initially flooded in 1978 and takes a flow rate of up to 450 m^3/s. Annual water level changes in the reservoir reach 100 m and generate variable internal water pressure, which places a considerable and dynamic strain on the structure. Water losses of more than 10 m^3/s required extensive rehabilitation work in 2021.

The pressure tunnel is lined by upper and lower concrete parts separated by longitudinal construction joints. During the rehabilitation in spring 2021, an approximately 40 m long section of a construction joint with a gaping fissure and several smaller cracks were located.

To explain why only one of the construction joints was leaking, we combined field observations with numerical modelling of the stress state around the pressure tunnel. To infer the regional tectonic stress field various stress indicators have been used like borehole observations (borehole televiewer data) in the field, hydraulic fracturing and earthquake focal mechanisms. These different methods provide mean values with standard deviations. This enabled the estimation of uncertainties in the model input data (field data).

Our approach is based on a static linear-elastic 2D model of the tunnel at km 13.7 within a limestone of homogeneous material properties. The orientation of the profile section is parallel to the regional maximum horizontal stress (SH), which corresponds to maximum principal stress in a thrust faulting regime. SV is the vertical stress. To account for uncertainties, the model was calculated for different stress state scenarios e.g. variation of SH/SV-ratio from 2 to 6 and internal pressure from 0 to 1.6 MPa.

The results show a symmetrical distribution of tensile and compressive stresses around the tunnel, with the axis of symmetry tilted by ca. 30° clockwise (in flow direction) for all scenarios. This is due to the high topography. Therefore, in some calculations, tangential tensile stresses are observed on the downslope side in the region of the construction joint, while compressive stresses are expected for the upslope construction joint.

Therefore, it can be concluded:

(A) the initial stress state is an important parameter for the positioning of underground installation like pressure tunnels especially in areas of high topography.

(B) geomechanical numerical modelling can help to design and dimension safe constructions.

These kinds of investigations can help to omit leakage which can lead to a reduction of the capacity of the power plant and to prolongate the integrity of the tunnel statics. Further investigations could consider the hydraulic situation of the karst rock in the surrounding of the tunnel.