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DAMAST DAMS AND INDUCED SEISMICITY TRANSFER FOR SUSTAINABILITY

2021 Inspection of Enguri Pressure Tunnel Reveals Unexpected Insights for the Seismicity after Reservoir Impoundment in 1978

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Introduction

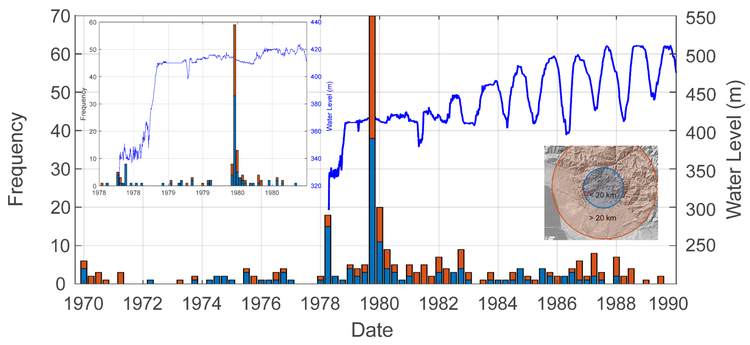
The 271-metre-high Enguri Arch Dam in NW Georgia which holds back water from the Jvari reservoir from the Enguri river and the Gali reservoir are the most important sections of a system-relevant hydropower (HP) infrastructure, the Vardnili Cascade. Enguri HP provides with 1300 MW approximately 40% to the Georgian and 100% to the Abkhazian electricity supply.

The study area is part of the southern Greater Caucasus Mountains, characterized by ongoing convergence of Eurasian and African-Arabian plates (Reilinger et al., 2006) with folding, thrusting and crustal shortening. It is a tectonically active area (Tsereteli et al., 2016).

Earlier interpretations of induced seismicity

The early seismic network (operative ca. 1972-1990) consisted of 11 stations.

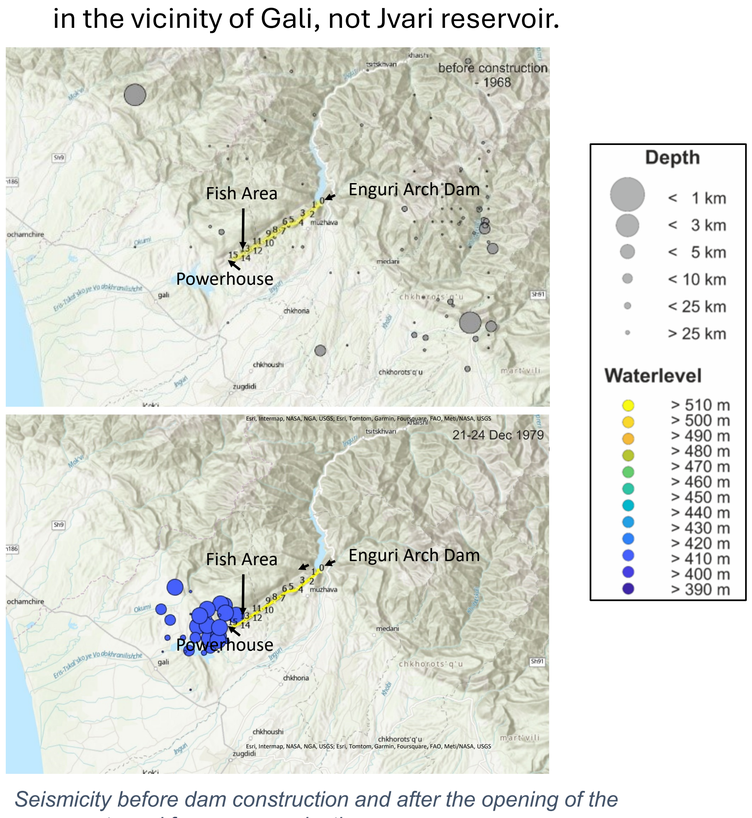
Earlier publications related seismicity to the increase of the water level in the Jvari reservoir during impoundment. However, most studies summarized all seismicity that occurred within a radius of 50 (Telesca (2024), 90 km (Peinke, 2006, Telesca, 2012) or even 100 km (Chelidze, 2019) around Enguri Arch Dam and included also deep and distant tectonic events.



Histogram of seismicity and water level around reservoir impoundment (with respect to m.s.l.) in the Jvari reservoir. Blue circle and histogram color denote 20 km radius, orange circle and histogram color 50 km radius around dam.

New display of seismicity and Water Level

- April 1978: start of impoundment.
- December 1978:
  - water level in Jvari reservoir reached 405m,
  - opening of pressure tunnel for power production.
- December 1979: Rechkhi earthquake series occurred in the vicinity of Gali, not Jvari reservoir.

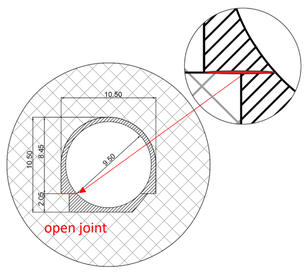


Seismicity before dam construction and after the opening of the pressure tunnel for power production.

Enguri Arch Dam

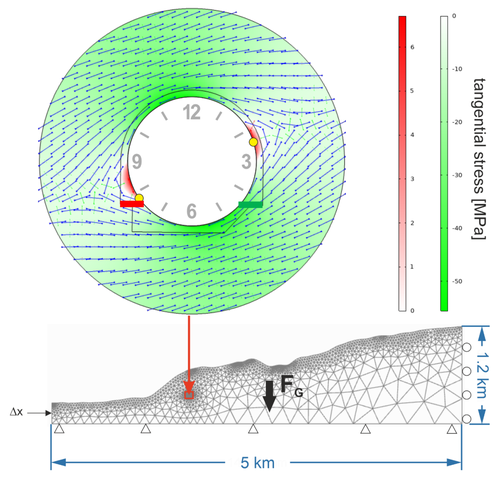
Technical Description of the Pressure Tunnel

- The Jvari reservoir is linked via the pressure tunnel (hydro plant diversion tunnel) to the powerhouse at the Gali reservoir (Abkhazia), which is situated approximately 15 km to the SW of the Enguri high dam.
- The pressure tunnel is located in a SW-NE striking, foothill of the Greater Caucasus and is surrounded by highly karstified rock.
- Tunnel diameter is 9.50 m. It enables up to 450 m^3/s of water flow.
- The elevation difference between the reservoir inlet and the powerhouse is ca. 160 meters.
- Despite numerous rehabilitation works the water loss in 2021 was still ca. 10 m^3/s (Kalabegishvili, 2013)



In most sections, the lining of the pressure tunnel consists of an upper and lower concrete shell with a thickness of ca. 0.5 m. Shells are separated by construction joints. There is a 6m grouting zone in highly carstified rock around the lining.

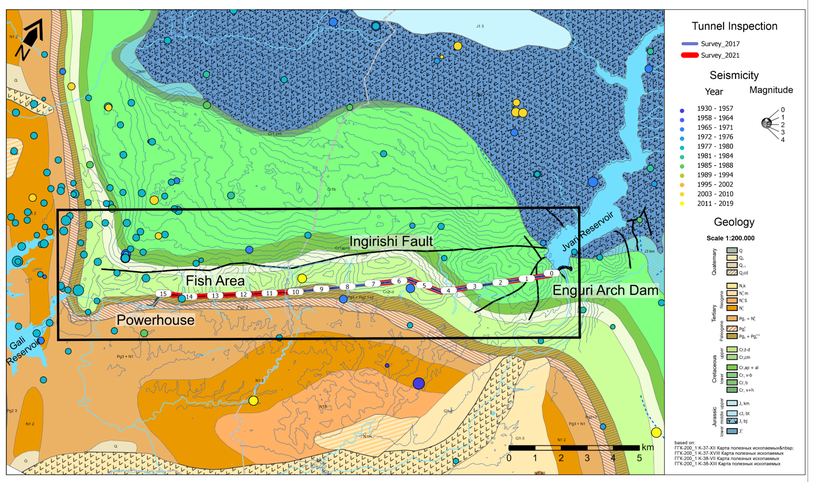
Geomechanical Observation for Joint Opening



Numerically modelled stress orientations and magnitudes in a cross section around the pressure tunnel in the area of the open construction joint (km 13.7). The left (in direction of water flow) construction joint and found fractures within inspected tunnel sections (yellow dots) are in the tensile zone around the pressure tunnel (Aberle 2023, Niederhuber et al. in prep.).

Conclusions

1. Opening of construction joint can be interpreted to result from tensile stress concentration (especially when combined with internal pressure during HPP operation)
2. Loss of fluid at the construction joint could increase pore pressure on the nearby Ingirishi fault and enable fault reactivation.



Geological and geographical overview map of the study area including Jvari and Gali reservoirs and Enguri Arch Dam. Shown are the trajectories of the Ingirishi and branch faults and the pressure tunnel. The numbers along the pressure tunnel are km from entrance at the Arch Dam. The colors indicate the tunnel sections inspected for damages in 2017 and 2021 before rehabilitation works. Locations of seismic events from historical and instrumental records are shown.

Observations in the Pressure Tunnel

Independent investigations during the DAMAST projects (2019-2024) included:

- Determination of tectonic stress orientation and magnitudes in the study area.
- Relocalization of seismic events before and after the opening of the pressure tunnel.
- Identification of a 40 m long open construction joint at a distance of 13.7 km from the Arch Dam during geotechnical inspections in 2021.
- Only the left (direction water flow) construction joint was open.
- Sizes of found fish in the joint suggest that internal tunnel pressure widens the joint more than the 3 mm observed in empty tunnel conditions.
- Inspection of 8 km of the pressure tunnel for faults in the tunnel lining.

Part of a 40 m long open construction joint found at km 13.7 in the pressure tunnel. In this tunnel section, mud, larger fish and pieces of wood and plastic got stuck (Photo B. Aberle).

A 40 cm long core of 64 mm bit size had been drilled into the joint and the surrounding concrete. Inside the joint fish (8 cm long), pieces of wood and plastic had been found. (Photo: B. Aberle).

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