Rehabilitation of Klingenberg Dam – now fit for another 100 years

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Klingenberg Dam

Map showing Klingenberg Dam in Freestate of Saxony.
Klingenberg dam - technical details

- Catchment area: 89.4 km² (incl. Czech Republic 12.3 km²)
- Total storage: 17.5 Mio. m³
- Reservoir area at operation level: 1.16 km²
- Height above foundation level: 40 m
- Length of the dam crest: 310 m
- Width of the dam crest: 6.2 m
- Volume of the dam body: 118,000 m³
- Water supply: 1,000 l/s
- Design flood earlier (before 2002): 95 m³/s
- Normal design flood new: 145 m³/s
- Maximum design flood new: 225 m³/s

Type of the dam: Masonry gravity dam with upstream concrete cover and with curved axis (principle of Intze)

Time of erection: 1908-1914
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Klingenberg dam - facts

• ageing based problems after 90 years in operation
• flood-related damages (extreme flood 2002)
• dam rehabilitation 2006 - 2013
• drinking water supply & flood control for City of Dresden
Klingenberg Dam - Objectives of the rehabilitation

• Preservation of the structural substance of the 100 years old dam
• Safeguarding of the function of the dam at least over further 80 years
• Repair of the damages caused by the extreme flood in August 2002
• Adaptation to the state of the art and to German technical standards for dams
  – Modernisation of facilities for monitoring & control, ensuring safe operation of the dam
  – Improvement of dam safety against overflowing by means of increasing the capacity of existing spillway and additional spillway tunnel (by-pass tunnel from the upstream pre-dam to downstream of the main dam)
• Reconstruction of the water intake and outlet works in order to improve water management with respect to water quantity and water quality (limnology)
Klingenberg dam - Damages at the upstream face of (ageing)

unsuitable facilities for the water management
Klingenberg dam
Spillway cascade during extreme flood in August 2002
Klingenberg dam - Serious damages due to the extreme flood in August 2002

at the spillway, cascades and stilling basin

at the pre-dam
(destruction by overflooding)
Klingenberg dam - Special challenges of the rehabilitation

- To guarantee the raw water supply of the waterworks according to demand (average 1 m³/s, max. 1.28 m³/s) during the rehabilitation of the dam without interruption during empty reservoir over approx. two years

- Temporarily replacement of water supply from Klingenberg reservoir by a system of other existing reservoirs connected by pipelines and tunnels

- To ensure water quality sufficiently suitable for the conditions in the waterworks

- Maintain flood protection in the Weiβeritz river valley continously by retaining of 9 Mio. m³ water in the system consisting of Klingenberg dam and the upstream situated Lehnmuehle dam
Klingenberg dam - Rehabilitation measures from 2005 to 2013

Phase 1: 2005 – 2009
- Construction of a new by-pass tunnel (TBM)
- Removal of the destroyed old pre-dam and erection of the new pre-dam
- Installation of the facilities for replacement of the raw water of the Klingenberg reservoir
- Excavation (blasting) of the inspection gallery in the main dam (at impounded reservoir)
- Erection of appurtenant works (e.g. water-depth gauges)

Phase 2: 2009 – 2013 (empty reservoir 2010 -2011)
- Reconstruction of the upstream face, the crest and the downstream face of the main dam
- Rehabilitation of the spillway, the cascade and the stilling basin
- Installation of technical equipment (water intakes, outlet works, monitoring systems)
- Removal of parts of sediment from reservoir bottom
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By-pass tunnel (flood & raw water tunnel) under construction, 3.2 km
Klingenberg Dam - Cross section of new homogeneous pre-dam
New pre-dam of the Klingenberg reservoir after impounding
Temporary replacement of raw water from Klingenberg dam
New inspection gallery throughout the Klingenberg dam

gallery after completion
Klingenberg Dam - New Inspection Gallery

- excavation under full reservoir level
- 30 m head, min. distance to u/s face 3 - 5 m
- "drill and blast" method
- \( l = 245 \text{ m} \), \( A = 6 \text{ m}^2 \) (w/h 2.0 m / 2.90 m)
- 2 m / working day average advance rate
- 4 tons total explosive consumption
- state of stress calculation due to blast exposure
- measurement program
- excellent material properties - no liner required
- installation of dam instrumentation systems
Klingenberg Dam - Reconstruction of the dam body

Demolition of the upstream concrete cover and dam crest
Reconstruction of the dam crest

- problem: no seal, seepage, lime mortar outbreak, discharged on d/s face
  - leach flags
  - decay due to frost
  - leaching of the masonry
- solution: removal, new construction
- crest plate = toe of the parapet wall = top end of the upstream sealing layer
- sealing layer + 40 cm (wave action safety - DIN 19700)
- partial demolition of crest building – enlarged modestly
- rehabilitation in compliance with German monument preservation order
Reconstruction of upstream sealing

• damage of old cement mantle (compressed concrete)
• dismantling of ‘Intze’-wedge, protective facing, foundation
• new sealing (h = 34 m)
• grouting at u/s dam toe
• sealing wall:
  – sealing layer (reinf. concrete 40 cm, w/h 8/4 m)
  – drainage layer (bricks, seepage detection)
  – sliding layer (bitumen sheet)
  – compensation layer
• elastomeric water stop (joint tape and plates)
• 570 rock bolts anchored in the dam
Klingenberg Dam  - New intake tower

• problem 1: decay, massive leaching
  – high hydraulic gradient in the tower wall
  – relatively high permeability of the concrete
  – mix-formula of used binder
• problem 2: increased space required for the new pipelines
• solution: demolition and new construction (increased semi-cylindrical ground-plan)
• 8 Stories, freight elevator, stairway
• 3-D FEM-analysis
• connection with the sealing wall by sealed expansion joints
Klingenberg Dam - Repair of downstream face of the dam

• damage of old joints with partly heavy vegetation
• danger of falling stones
• joints and stones cleaned with high pressure water jet and grouted
• rehab of joints in compliance with monument preservation order
• renovated downstream dam face stands out visually
Klingenberg Dam – Cascade Spillway

- flood 2002: hydraulic overload, massive damage
- new design flood inflows HQ1,000 = 145 m³/s, HQ10,000 = 224 m³/s
- completely new inlet design, cascades and stilling basin in compliance with monument preservation order
- hydraulic model tests (scale 1:30)
- new side channel l = 50 m, flap gate w = 6.3 m
- cascade: guidance wall, side walls partially increased, first step omitted, steps edged with concrete frame
- deepening of stilling basin t = 0.4 m
- new end sill h = 2.4 m
- new bridge
- deepening of collection channel
- removing of existing end sill
Klingenberg Dam - Spillway cascade after rehabilitation
New upstream face consisting of a watertight reinforced concrete wall
Klingenberg Dam - Modernisation of technical equipment

- 5 raw water intakes
- new bottom outlet
Klingenberg Dam - Bottom Outlet and Raw Water System

- construction required a temporary water supply
- raw water supply: highest standards (quality / quantity)
- former structure: 3 raw water intakes (old intake tower on right side)
- problem: limited abstraction of good water quality due to allocation of intake horizons
- new: 6 intake horizons in new intake tower
- parallel raw water supply and discharge of water with poor quality
- subsurface valve chamber
DEUTSCHES TALSPERRENKOMITEE e.V. (DTK)

Klingenberg Dam - Bottom Outlet and Raw Water System
Klingenberg Dam - Bottom Outlet

- separation of systems
- new bottom outlets in former diversion tunnel (now operated as pressure tunnel $l = 160 \text{ m}$, $A = 5 \text{ m}^2$, reinforced shotcrete lining 30 cm thick)
- discharge control by combination of vertical lift and radial gate $(w / h = 0.90 \text{ m} / 1.20 \text{ m})$
- stilling chamber
Klingenber Dam - New intake tower with 5 raw water intakes
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Klingenberg Dam - Monitoring facilities

- designed and installed in close consultation with the client
- based on the German code of practice
- components added in several stages or structurally installed
- installation of automatic measuring station
  - water level
  - seepage and leakage
  - uplift pressure
  - seal monitoring
  - inclinometer
  - joint displacement
  - crest and surface alignment
  - pendulums
Klingenberger Dam - Removal of sediments nearby the dam

Empty reservoir with relatively minor sedimentation
Reimpoundment of the Klingenberg reservoir (blue line) according to the test programm
Klingenberg Dam - Conclusions

- Rehab. completed in 2013, all tests successfully, regular dam performance
- Safe dam operation at least for the next 80 years
- Enhanced flexibility of raw water management
- Very successful planning, construction and supervision
Thank you very much for your kind attention!