Pumped-Storage Power Plant
Modernization Waldeck I
Edertal, Germany

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Total order volume (net):
€45 million (total order)
€6 million (foundation engineering share)

Construction period:
April 2006 - January 2009
April 2006 - May 2007 (foundation engineering work)

Client:
e.on Wasserkraft GmbH (EWK)
Landshut

Services:
Shaft excavation, rock bolting and shotcrete, bored pile wall and rock grouting works
Sheet pile cofferdam
Roadheader driven rock tunnel

Execution:
Consortium of Implenia Infrastructure GmbH + Voit Siemens GmbH

Foundation engineering:
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E.ON Wasserkraft GmbH operates the Waldeck I pumped-storage power plant at the Eder river in Edertal. It has been in operation since 1932. The plant includes an artificial upper reservoir of 65,000 m³. The lower reservoir, known as the Affolderner lake, was created by damming the Eder river. The pressure ducts between the upper reservoir and the powerhouse at the lower reservoir negotiate a height difference of about 300 m over a length of about 960 m. After more than 70 years of operation, two of the four turbines in the powerhouse were reconstructed as part of the modernization. The other two turbines were replaced with a modern pump turbine as part of the construction of a pumped storage power plant.

The new power plant was built within the facilities next to the existing powerhouse while the plant remained in operation. The **shaft pit**, almost 40 m deep, 17 m wide and 22 m in length, represented the core of the construction work.

The underground conditions in the area of the shaft pit consisted of loose overburden, six to eight meters thick. The underlying rock layer was partially highly irregular interstratification of argillaceous shale and greywacke and was highly permeable to water (up to $k=2 \times 10^{-3}$ m/sec).

On top the shaft pit was built with a 90 cm diameter double-anchored secant bored pile wall. The rock was lined by rockbolting and shotcrete.
Due to the groundwater level just under the ground surface and the highly permeable rock layers, a grout curtain was installed within the rock layer prior to pit construction surrounding the shaft surface at a distance of six meters and to a depth of ten meters below the base of the shaft. From surface level, 100 drill holes reached to a depth of 50 meters. Another 30 m deep, three-row grout curtain was added to compact the rock within a geological fault zone. Excavation of the pit was carried out according to the observational method and was accompanied by an elaborate measuring program.

Upstream, a 5 m wide cofferdam was constructed in the Affolderner lake to seal the pit for the duration of construction and for the construction of the inlet/outlet structure. The sheet pile walls were driven 1.5 meters into the bed of the lake by vibration hammer on pontoon. After anchoring granular material was filled between the sheet pile walls. The rock layer beneath the cofferdam was grouted with a 20 m deep, single-row curtain to prevent water ingress.

The existing pressure ducts from the upper reservoir were connected to the new pump turbine by a tunnel. For this purpose, the existing pressure pipeline including intake and discharge pipes, as well as flow control units, had to be dismantled during operation of the existing plant. Within the existing power plant a 20 m long and 7 m deep starting pit was excavated. A 45 m long inclined rock tunnel (25°), followed by a 15 m long horizontal tunnel, was driven by roadheading technique with shotcrete and rock bolting.
The inclined section of the tunnel was grouted on top to avoid water ingress and stabilization. Ground water level was lowered within the fragmented rock by three wells.

**Key Quantities**

1) **Shaft construction pit**
- 125 piles (bored pile wall) \( D = 90 \text{ cm} \ L = 7.50 \text{ m} \)
- 53 ground anchors \( L = 14 \text{ m} \)

2) **Permanent waterside retaining wall**
- 35 piles (bored pile wall) \( D = 90 \text{ cm} \ L = 7.50 \text{ m} \)

3) **Jet grouted sealing**
- approx. 160 m³

4) **Foundation piles for power house**
- 17 piles \( D = 120 \text{ cm} \ L = 9.0 \text{ m} \)

5) **Rock grouting (sealing and compaction)**
- 99 grouting holes \( L = 50 \text{ m} \), grouting length \( L = 42 \text{ m} \) in rock, vertical, grouting through tip of pipe
- 15 grouting holes \( L = 30 \text{ m} \), grouting length \( L = 22 \text{ m} \) in rock, vertical, grouting through tip of pipe
- 14 grouting holes \( L = 51 \text{ m} \), grouting length \( L = 50 \text{ m} \) in rock, inclined, for tunnel top grouting

6) **Sheet piling for cofferdam construction**
- 260 double wall sheet piles L603, \( L = 7.40 \text{ m} \) driven by vibration hammer

7) **Shaft lining**
- 2,400 m² of shotcrete, 5,400 5.0 m rock bolts