Safe, sustainable and aesthetic design of Norwegian hydropower plant caverns

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In the design of underground hydropower caverns, safety regarding rock mass stability is priority number one. To achieve the required safety, high quality pre-construction ground investigations of sufficient extent are required, and a systematic design procedure focusing on optimization of the following four important factors: 1) Location, 2) Orientation, 3) Shaping/geometry and 4) Dimensioning.

Long term behavior and durability of rock support and lining for ensuring stability and operational requirements are of course always important factors to consider, and one factor which has become increasingly important is sustainability, particularly regarding CO_2 footprint. For conventional drill & blast excavation concrete lining for rock support is the largest potential contributor to emission causing climate change (around 40% of the total emission for drill and blast excavation of railway tunnel according to study published by NFF (2014), and believed to be of the same order of magnitude for powerhouse excavation). When concrete lining can be replaced by thinner layer of sprayed concrete and rock bolting, this may reduce the CO_2 footprint considerably (by 50% or more).

Aesthetics is always a main concern in powerhouse design and excavation, and there are many examples of excellent architectural design of powerhouse caverns, with exposed rock in the walls of the cavern as eye catcher. In some cases, one is shown in Fig. 1, such caverns due to Their excellent acoustics even have been used for concerts.

Fig. 1. Example of powerhouse cavern design with exposed rock at end wall and between pillars at side walls (from Norwegian Tunnelling Society, NFF 2013).

For Norwegian hydropower projects, it has been possible in most cases to find locations of good rock quality for the excavation of powerhouse caverns. To achieve the best possible excavation result, the upper part of the cavern (which is normally between 15 and 20 m wide) most commonly is excavated as two top headings and the bottom by benching, which gives a very smooth contour when properly designed and executed. Normally, no continuous concrete lining is applied in the walls, only pillars if required, supplemented by rock bolts as required for stability reasons (see example in Fig. 1). If the rock conditions are more difficult, a 8-10 cm thick layer of sprayed concrete and rock bolting is normally used in the walls, as illustrated in Fig.2. A basic philosophy is that the self-supporting capability of good quality rock mass should be taken full advantage of, and that good quality rock should not be replaced by support of poorer quality. Similar design philosophy is believed to be realistic also for many international projects.

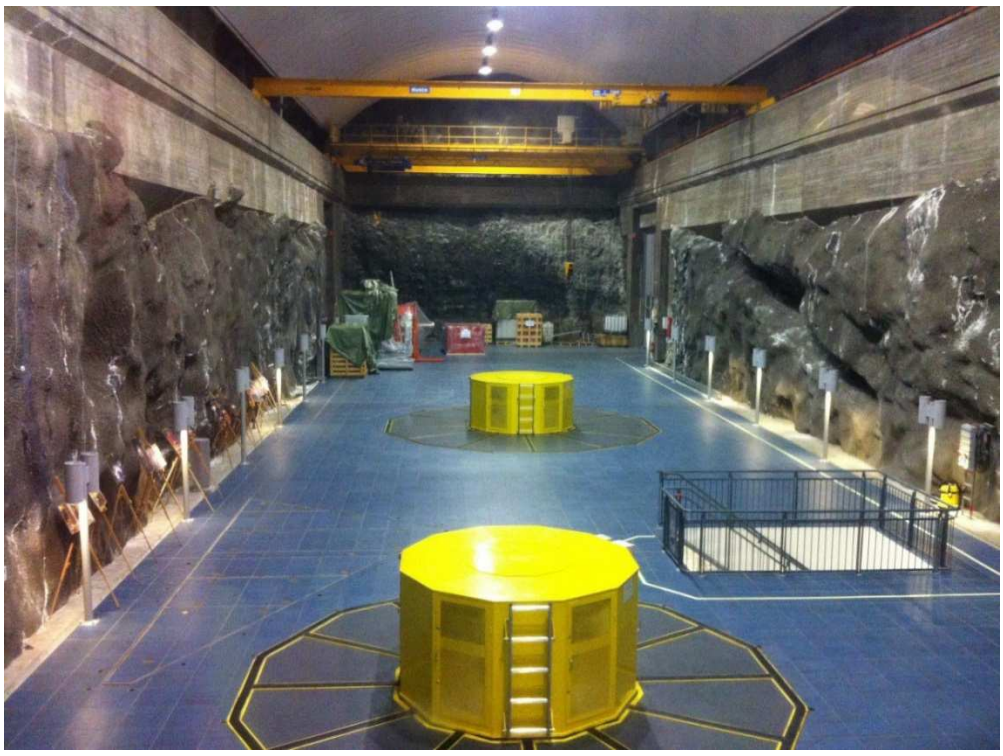

Fig. 2. Example of design of recent Norwegian powerhouse cavern with exposed rock at end walls and thin layer of sprayed concrete combined with spot bolting at the sidewalls.

Issues related to hydropower projects are presently in great focus at NTNU, in cooperation with the industry, as result of hydropower technology having been selected one of the national research focus areas connected to renewable energy.

Information about the research centre related to hydropower; HydroCen can be found on: https://www.ntnu.edu/hydrocen

References:

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