Rock mass behavior during excavations in the Mont Terri Underground Rock Laboratory

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The Mont Terri rock laboratory was constructed during several stages between 1996 and 2012. At present, a total length of 650 m of galleries and niches in Opalinus Clay are available for experiments. The rock laboratory is located at a depth between 280 and 320 m below the surface.

Excavation techniques: Different excavation techniques were applied and tested: 1) blasting, 2) excavation of niches using a hydraulic hammer and 3) excavation with road header techniques. The first 2 techniques resulted in horseshoe-shaped profiles, whereas the latter created circular profiles. Excavations involving horizontal raise boring and steel auger techniques with circular profiles were locally applied.

Lining: It consists mainly of a shotcrete layer with a mean thickness of 15 cm. The shotcrete can be reinforced with metal (about 30 kg/m3) or synthetic fibres (about 6 kg/m3). In sections of reduced strength, such as tectonic faults, or in sections excavated parallel to bedding strike, where buckling and breaking apart of bedding planes often occurs, steel meshes were fixed onto an initially thin shotcrete layer. Different types of rock bolts (metallic or fiberglass bolts sealed with cementitious grout or resin cartridge) were used. They typically have a length of 2 to 3.5 m. At particular locations, self-drilling bolts 6 meters long were implemented. Certain sections required the installation of steel arches (full or triangular) in order to allow transfer of the load to the invert or to close the profile.

Rock mass behaviour during and after excavation: The orientation of galleries relative to the stress field and the bedding anisotropy, as well as the heterogeneity such as the facies and tectonic faults, have a great impact on the tunnel stability. Enhanced deformations were observed not only when galleries where excavated parallel to bedding, in the shaly facies or in the foot- and hanging walls of tectonic thrusts, but also when excavation progressed too quickly or when shotcrete was applied too late. The least deformations were observed in the sandy facies normal to bedding strike with rapid implementation of lining. An example of a major breakdown, which occurred in the shaly facies parallel to bedding strike, is presented.

Of special interest is the excavation damaged zone (EDZ), which develops in the tunnel walls during and shortly after the excavation. Stress redistribution leads to changes in pore water pressures. Extensile fracturing and bedding parallel slip were confirmed by several mine-by tests. The EDZ can be limited in extent when rounded or even circular profiles are obtained (e.g. with road headers). Blasting results in higher fracture frequencies in the EDZ. Several experiments were carried out in order to characterise the dynamic formation and the final geometry of the EDZ [1, 2, 3].

Key experiences gained during excavations in the Mont Terri rock laboratory. No use of water: major wet excavation and drilling cause deformation due to swelling phenomena. Thus the use of water in the Opalinus Clay should be avoided. Dry excavation and rapid coverage of the Opalinus Clay are recommended. Dust evacuation: dry excavation causes huge dust clouds. A powerful air circulation combined with a dust extraction system is required to keep dust concentrations minimal and to obey SUVA norms. Drying-out of the Opalinus Clay: the strong air circulation causes partial desaturation of the claystone and, at the same time, a significant increase in the uniaxial compressive strength. These changes may result in slower excavation progress than initially planned.

References:

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