Characterization and Modelling of Hard Soil/Soft Rock considering Anisotropy and Swelling Capacity (ChaMod-HSSR)

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Introduction

Transitional stratum, also termed hard soil/soft rock (HSSR), is geomechanically a challenge. It's behaviour strongly depends on the state of stress, it alters rapidly in contact with water, and often conventional characterization and classification methods from rock and soil mechanics as well as numerical material models are often inadequate. HSSR can feature an inherent anisotropy and may be prone to swelling. Not only the numerical modelling of the swelling behaviour according to the state-of-the-art has deficits, but above all those of the anisotropic rock mass and system behaviour. The construction of the Angath adit tunnel in Tyrol, Austria through the rock mass of the Unterangerberg formation began in 2023. This rock mass comprises a large variety of HSSR. The ChaMod-HSSR research project seizes this rare opportunity and aims at a detailed characterization of HSSR as well as the further development and calibration of material models. In the Angath adit tunnel, observations are carried out and relevant information and data from experimental (in-situ, laboratory) and measurement campaigns are included in the evaluations and modelling work. The project shall contribute to a clear and meaningful approach differentiating between rock, HSSR, and soil. The research project is funded by the Austrian Research Promotion Agency (FFG) and supported by the Austrian Federal Railways (ÖBB-Infrastruktur AG).

Alignment of the Angerberg tunnel with the accompanying Angath rescue tunnel.

Hard Soil/Soft Rock

HSSR exhibits a complex ground behaviour characterized by variations in hardening, softening, and strength. Unlike in classical soil and rock mechanics, HSSR responses are influenced by their composition, which may contain a mixture of soil-like and rock-like properties, as well as environmental factors such as moisture content, temperature variations, and geological processes.

The interlayered marl, claystone, and sandstone layers cause inherent anisotropy. The stratification further contributes to the heterogeneous nature of HSSR, necessitating careful consideration in engineering analyses.

HSSR is prone to weathering and variability when exposed to water. When samples of the lithology are stored for extended periods of time before lab testing, test results also yield different results than when tested immediately after sampling.

Research objectives

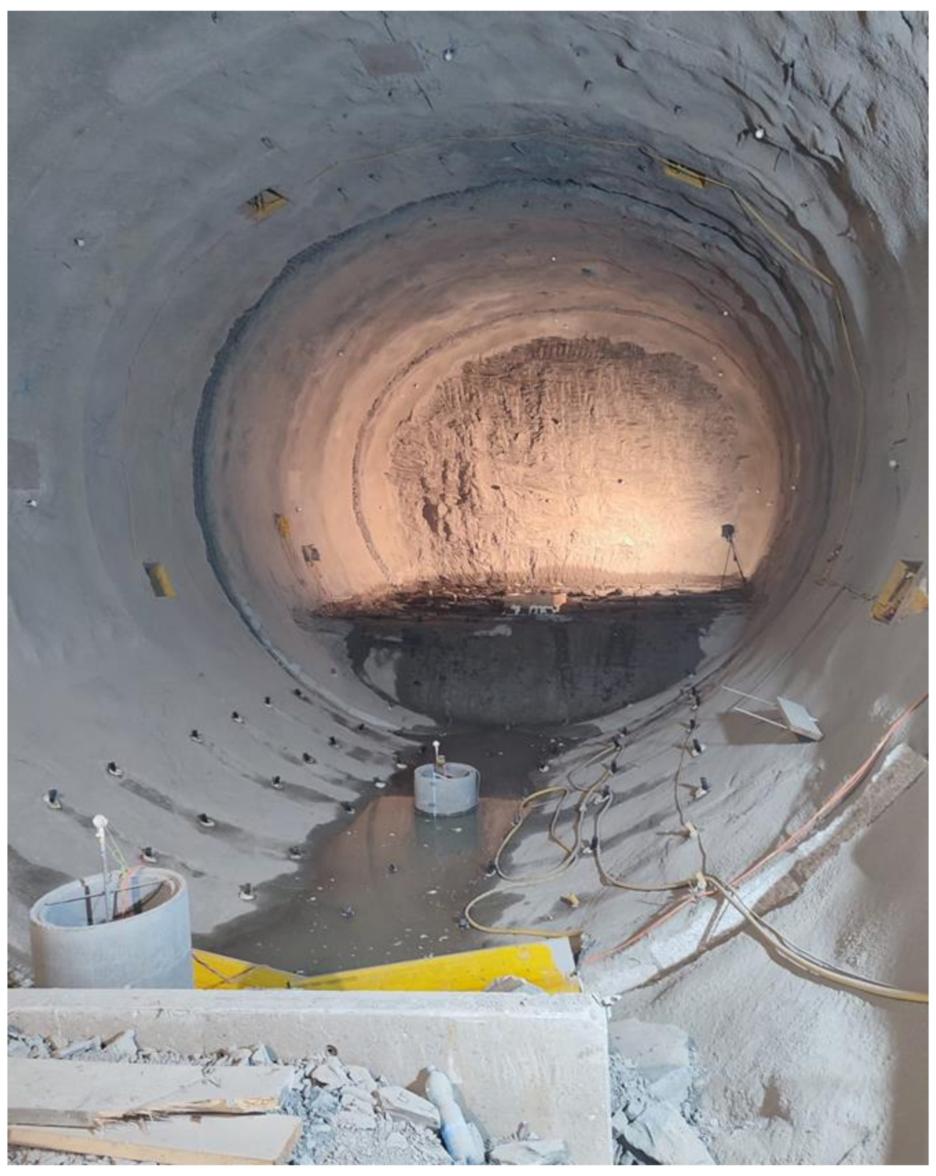
In the course of the research project, the focus lies upon achieving the following goals:

- Material testing by means of in-situ and laboratory tests to aid in the rock mass characterization of the HSSR lithology on-site
- Characterization and classification of the lithology with respect to HSSR, anisotropy, clay mineral swelling
- Creation of a geotechnical database by collecting, correlating and processing relevant data
- Numerical modelling on laboratory scale and of selected tunnel sections by researching, adapting, and implementing current numerical material models

Testing strategies

Both, small-scale laboratory tests as well as large-scale in-situ tests in a cross-passage of the tunnel are conducted.

A cross-passage of the tunnel serves as our in-situ test gallery. It is separated into three adjoining blocks, whereas the first block is still connected to the system and comparatively stiff support of the adjacent Angath adit tunnel, and mechanically decoupled from blocks 2 and 3 via radial shotcrete slots. These slots only contain the preliminary spraying instead of the 20 cm design thickness and only one of the two mesh layers. A horizontal chain inclinometer at the crown elevation is installed next to the cross-cut before the beginning of the excavation to be able to detect the pre-displacements caused by the tunneling works. Two measuring cross-sections are installed in the middle of blocks 2 and 3 and feature extensometers in four directions, measuring anchors, stress strain meters, as well as 3D monitoring targets. The end face of the test gallery is left open in the long-term as an enlarged shotcrete window during the construction works of the construction lot and is observed using 3D monitoring targets in combination with photogrammetry.



Test gallery in cross-passage of the Angath adit tunnel.

Sample before and after a uniaxial compression test in directions A and B.

To preserve the original geotechnical properties of the lithology for laboratory testing, large drill cores are intricately handled and packed as well as transported to the lab in a timely manner. Contact with water is minimized and avoided where possible in all work steps. The lithology is tested using

- Uniaxial, triaxial compressive tests
- Splitting tensile tests (normal and parallel to bedding planes)
- Density determination
- Slake durability tests, Hollmann/Thewes sieve drum test
- Cerchar abrasivity, x-ray diffractometry, thin section, clay mineral analysis
- Swelling tests (powder, free, pressure, Huder-Amberg)

The comprehensive in-situ as well as laboratory tests aid in characterizing and classify the HSSR lithology and identify the extents of anisotropy and clay mineral swelling. The parameters derived from the tests serve as input parameters for numerical models and are stored in the parallelly created database.

Outlook

We expect to collect long-term monitoring results until the end of the Angath adit tunnel excavation towards the end of 2025. In particular, the long-term irrigation-swelling test in the invert of the designated test gallery yields valuable results in terms of swelling pressure expectation. The comprehensive data and information pool will be completed accompanying the ongoing laboratory tests. The lessons learned from the research project will assist in creating a more detailed material characterization and in turn, the planning of the Angerberg tunnel with fewer uncertainties.

References

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