SAFETY CORRIDOR IN GEOTECHNICAL DESIGN OF CONVENTIONAL TUNNELLING”

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In tunnel design and construction there is intensive and complex interaction. Advanced tunnelling technology is featured by flexible response to ground reactions. The concept of structural design for underground structures is of increasing importance. There is a different approach in modelling underground structures when taking into account cross section geometry, geotechnical conditions and overburden.

The size of tunnels is of essential importance. To provide re-produceable conditions it is a challenge both to the designers, public authorities and builders. It need to be differenciated whether a tunnel is situated shallow (up to approx. 30 m), medium deep (approx. 100 m) and deep (acceding 100 m up to approx. 2000m) conditions of overburden.

For shallow tunnels the structural design will require considerations of taking greater number of different loading conditions resulting in rather stiff and rigid lining support concepts. Medium deep tunnels do need very specific structural analysis which will relate to loading conditions on the lining showing extended deformation capabilities. Deep tunnels have an essential need for implementation of flexible lining responses due to observations.

All 3 tunnel categories could be faced with failures and collapses of the tunnel lining interacting with the surrounding ground. In the past such failures have offered the chance to study the failure mechanism and to learn for the future in order to improve control of risk through advanced risk management. Medium deep tunnels could show benefits in design and construction both for shallow tunnelling and deep tunnelling technology. They are designed to use as a minimum requirement standard support measures. Depending on the ground, medium deep tunnels need to be supplemented by additional support measures as provided for in the design under the requirements of standard safety needs during all construction stages. Such additional support measures are forming the safety corridor.

PREFACE

In conventional tunnelling the ground surrounding the tunnel is considered to be a load bearing structure of support whereas in former times the ground has been considered as a load on top of the tunnel. During tunnel excavation the ground reactions result in deformations of the rock respectively of the lining. The pressure in the lining is measured in order to monitor sufficient stability of the excavation. Structural requirements could result in either rigid support or in deformable support mostly consisting of shotcrete.

In order to achieve best economy and safe support installation respective contractual arrangements have to be implemented. Originally conventional tunnel construction has used a rock classification system being related to stand-up time of unsupported excavation. It has to be agreed between the contractor and the engineer what type of rock class needs to be applied. Such judgement should be made at the tunnel face and should include all experiences available. The development of a conventional tunnel project should be viewed in several phases.

CONCEPTUAL DESIGN PHASE

The conceptual design phase being the start phase of a conventional planned tunnel projecet will be followed by the preliminary design phase. Thereafter comes the tender design phase followed by the construction design phase.

The alignment of the tunnel will be selected and later confirmed during conceptual design. It provides the client with information for the first rough idea of budget. The design documents and drawings in the conceptual design phase should include the following.

- Scope and verification of conceptual design
- Selection of preferred alignment from several alignment studies
- Geological and hydrological information to develop geotechnical characteristics
- Validation of anticipated tunnel construction including environmental aspects
- Conceptual cost estimate
- Conceptual construction schedule
- Conceptual ventilation scheme

PRELIMINARY DESIGN PHASE

In the preliminary design phase the target is to receive the owners approval for the construction of the project. This phase is therefore focusing legal aspects e.g. water resources, forestry and environmental protection. The preliminary design phase includes

- Contribution to the site investigation programme by the tunnel designer
- Evaluation of site investigation and laboratory testing results
- Identification of portal locations, design of portal structures and slope design for portal cut
- Development of typical cross sections based on the geotechnical requirements
- Decision on tunnel advance methods
- Tunnel waterproofing and drainage concepts
- Design of particular requirements regarding the operation and tunnel safety concept (e.g. ventilation, fire fighting, lighting, telecommunication etc.)
- Definition of construction concepts, water and power supply, location of construction roads and muck depots
- Documentation regarding land acquisition, inventory checking and building restrictions
- Detailed construction programme

Revised cost estimate based on a detailed calculation of quantities

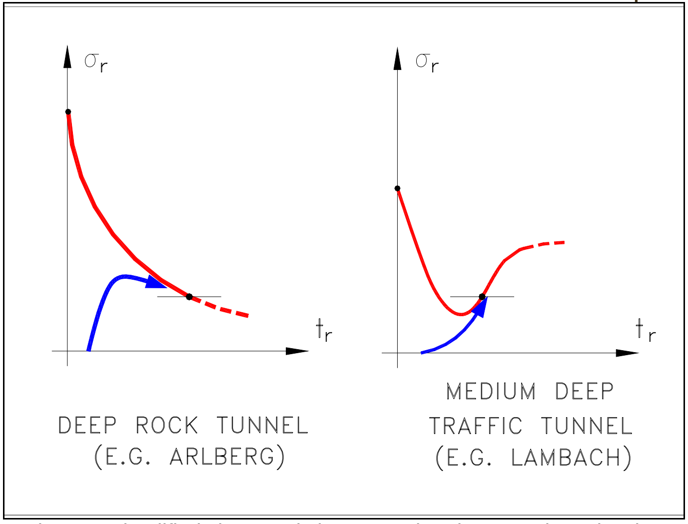

Figure 1 Simplified characteristic curve related to tunnel overburden

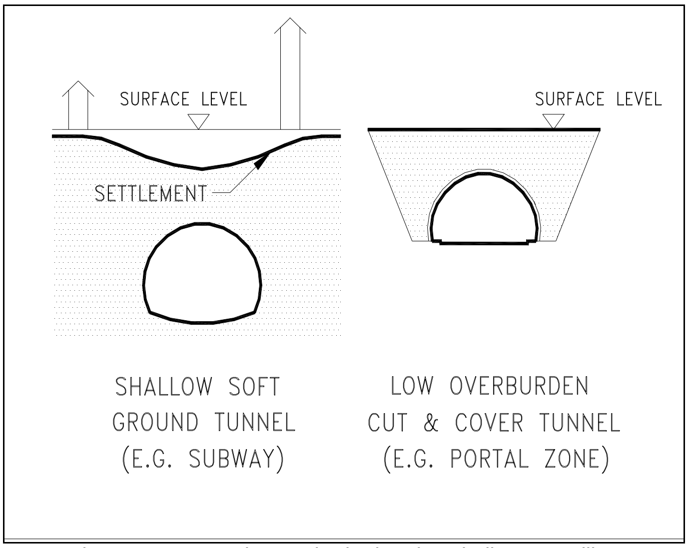

Figure 2 Construction Method related to shallow tunnelling

TENDER DESIGN PHASE

The target of the tender design is to define the works in order to make exact pricing of each work item feasible. The tender design phase should include

- Detail design of all structures and incorporation of latest project developments, results of additional site investigations and requirements by the authority.
- Update of geotechnical prognosis, support measures drawings, distribution of support classes, detailing of auxiliary construction methods and provision of information as required by the national standards and guidelines

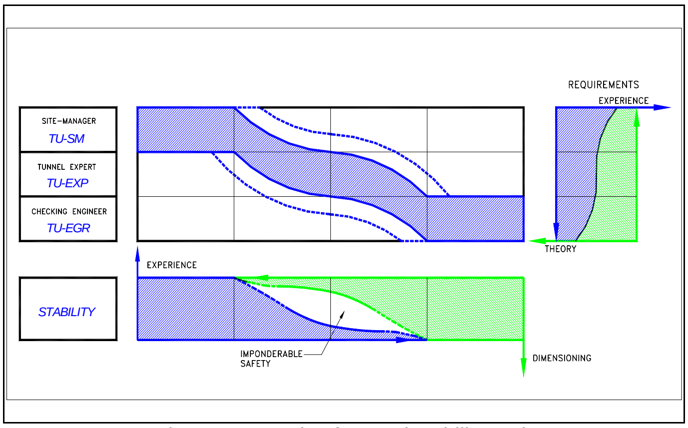

Figure 3 Tunnel safety and stability path

FINAL DESIGN PHASE

The target of the final design for conventional construction is to prove constructability. This will be achieved by detailed work descriptions in the tender design phase. The final design in construction includes

- The adaptation of the detail design to the particular requirements of the excavation and support methods selected for construction and to the geological/geotechnical conditions encountered in-situ is a particular aim of conventional tunnelling contracts conditions found on site
- The production of design drawings used for the construction (e.g. formwork drawings, reinforcement drawings and schedules, fabrication drawings etc.)
- The consideration of geological/geotechnical conditions encountered in-situ is a particular aim of conventional tunnelling contracts in Austria

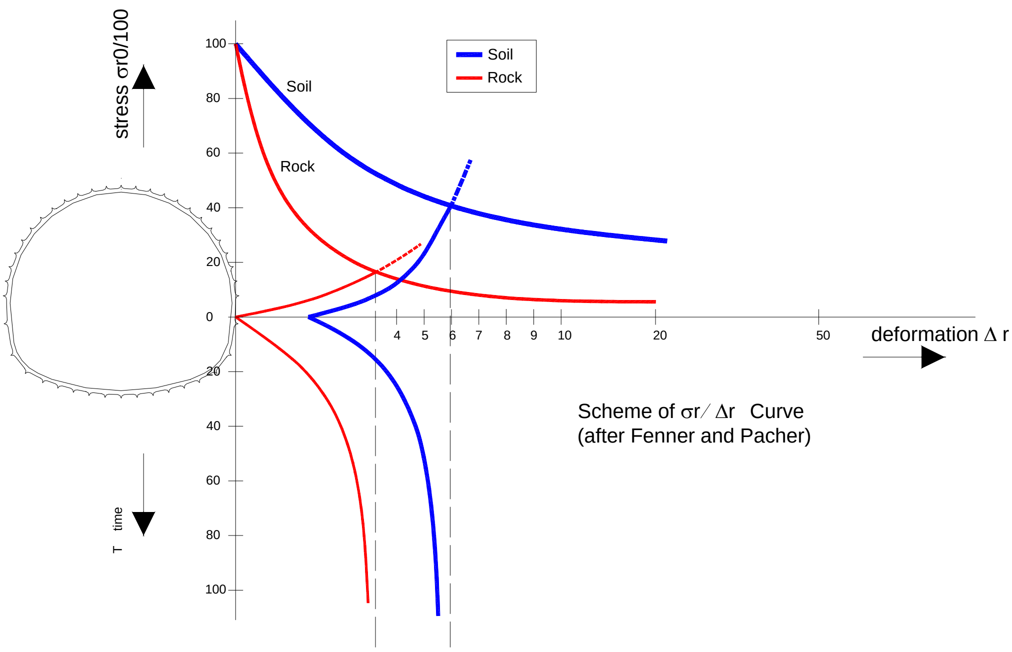

Figure 4 Radial deformation governing size of excavation section (Literature: Fenna/Pacher – Curve)

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GEOLOGICAL / GEOTECHNICAL EVALUATION

Two different phases have to be considered in this evaluation.

DESIGN PHASE

This phase involves determining the expected

- Rock Mass Types (RMT) and
- Rock Mass Behaviour, categorized into Rock Mass Behaviour Types (BT),
- Excavation classes are then determined based on the behaviour types and the excavation and support methods.

The design should also contain

- A baseline construction plan. This plan describes the expected rock mass conditions, assumptions, and the boundary conditions the design was based on. The plan also has to contain clear statements describing which measures cannot be modified during construction, as well as the criteria for possible modifications and adjustments during construction.
- The results of all phases of the geotechnical design have to be summarized in a geotechnical report.

CONSTRUCTION PHASE

This phase involves the following activities

- Geotechnical relevant rock mass parameters have to be collected on site, recorded, and evaluated to determine the rock mass type.
- Monitoring data together with the rock mass type allows the behaviour type to be determined.
- Excavation and support measures have to be chosen based on the criteria laid out in the baseline construction plan and the safety management plan.

The geotechnical design and the baseline construction plan have to be continuously updated based on the findings on site.

GEOTECHNICAL REPORT

The geotechnical report should contain the following information.

- Summary of the results of geological and geotechnical investigations, and the interpretation of the results
- Description of the Rock Mass Types and the associated key parameters
- Description of the Rock Mass Behaviour Types, the relevant influencing factors, the analyses performed, and the geotechnical model on which the BT is based
- A report on the determination of excavation and support, relevant scenarios considered, analyses applied, and results
- The baseline construction plan
- Detailed specifications to the Baseline construction plan (system behaviour, measures to be determined on site, warning criteria and limits, etc.)
- Report on the determination of excavation classes, their distribution along the alignment

BASELINE CONSTRUCTION PLAN

The baseline construction plan summarizes the geotechnical design and should contain following information:

- Geological model with distribution of Rock Mass Types and Behaviour Types in a longitudinal section
- Sections, where specific requirements for construction have to be observed
- Fixed excavation and support types (round length, excavation sequence, over-excavation, invert distance, support quality and quantity, ground improvements, etc.)
- List of measures to be determined on site (support ahead of the face, face support, ground improvement, drainage, etc.)
- Description of System Behaviour (behaviour during excavation, deformation characteristics, utilization of supports, etc.)
  Warning criteria and levels, as well as remedial measures according to the safety management plan

SAFETY MANAGEMENT PLAN

The safety management system has to cover following topics:

- A design concept for the determination of excavation and support
- Criteria for the assessment of the stability based on the knowledge of the ground conditions during design
- A monitoring concept with all technical and organizational provisions to allow a continuous comparison between the expected and actual conditions

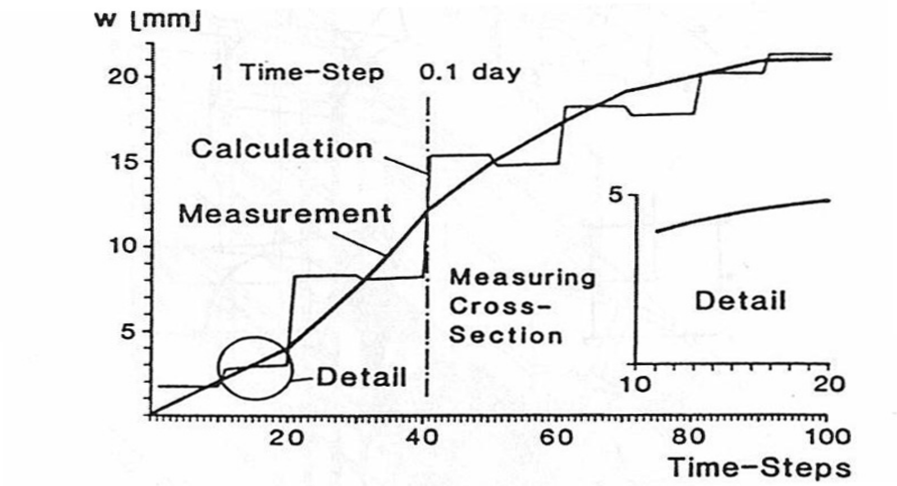

Fig. 5 Compatibility between measurements and numerical analysis

MONITORING - STATE OF THE ART DATA EVALUATION

The state of the art of geomechanical data evaluation is as follows.

- The problems experienced when tunnelling through poor rock and fault zones are well known all over the world.
- Besides proper modelling during the design, continuous and adequate monitoring of the behaviour of the rock mass support structure forms the basis for on site decisions.