Rowa Customers Day

Uetliberg Tunnel N4.1.5
Zurich West Bypass
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Follow-On System for Tunnel Bore Extender (TBE) with Undercutting Technology, Special Requirements and Selected Solutions
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1. Requirements and specifications for the installation builder

Special requirements
Owing to its large cross-section and the difficult geology, the Uetliberg Tunnel makes stringent requirements of the tunnel builders. Extensive measures for rock support are required using long rock bolts, fitted vaults, mesh reinforcement and shotcrete placement directly behind the cutterhead. The tunnel bore extender with undercutting technology also represents a technological innovation which has never before been used to this extent.

These boundary conditions necessitate specific measures as regards machine technology as well, a tailor-made concept and adapted equipment engineering.

The Uetli Joint Venture elaborated a comprehensive set of specifications with the followings points of emphasis for this purpose.

Construction-engineering and functional requirements
• The basis is the existing Aosta/Paracuellos follow-on, designed and constructed in 1998 by Rowa.
• Extensive rock support measures must be able to be used, i.e. rock bolts, mesh reinforcements, shotcrete and steel vaults.
• Invert extension with shotcrete, levelling concrete, insulation and reinforced invert vault in the follow-on.
• Disposal by means of belt conveyor systems
• Supply by means of pneumatic vehicles
• Corresponding material handling points in the follow-on
• The vault is concreted and the crosscuts and bays are excavated and concreted simultaneously with driving operations.

Rates of advance
The follow-on installation must be able to transport away the quantities excavated by the tunnel bore extender and to transport all constructions to the correct working point and process them. The target rates of advance are as follows:

- Drive rate of advance 2.4 m/h
- Average drive rate of advance 5-12 m/h – depending of class of excavated material
- Max. daily rate of advance 18 m/working day
- Max. spoil and borrow conveying 800 metric tons/h
- Drilling and placing rock bolts up to 135 m/h (rock bolt length 5-8 m)
- Vault shotcrete quantity, fixed 6.7 m³/m² of tunnel
- Vault shotcrete quantity, fixed 100 m³/working day

Work safety
Today, compliance with current work safety regulations is standard. Builder-owner, planning engineers and the company performing the work and its suppliers strive to avoid possible work accidents in all phases.

All technical equipment must be examined for possible vulnerabilities and injury potentials using a risk analysis. In the specific case of Uetliberg, the Joint Venture itself is the supplier of essential parts of the tunnel bore extender and the follow-on, i.e. it must, itself, verify work safety of its equipment by CE conformity.

Rowa has a study group which verifies this CE conformity and implements it in practice on behalf of the Uetli Joint Venture.
2. Rock support feasibility study

Owing to the high given installation quantities for the rock support and the requirement of installing the rock support equipment on the existing Paracuellos follow-on installation, Rowa was commissioned by the Uetli Joint Venture to conduct a rock support feasibility study. This feasibility study essentially covered the following points:
- Plotting the work areas for the drilling equipment
- Presenting the required kinematics of the drilling equipment
- Presenting the possible drilling cycle times
- Cycle study for the rock support equipment for indicating the dependences
- Presenting geometrical interfaces to the existing follow-on

Owing to the complex sequences of movement and restricted space conditions, the front section of the drive installation was recorded in a 3-D model. It is only this 3-D model which allowed us to review feasibility for set-up of three bolt drilling units and a working platform with a vault setting unit in an informative manner under greatly restricted geometrical conditions.

Rowa received the official contract for development, manufacture and delivery of the installations for the rock support on the existing follow-on installation from the Uetli Joint Venture on 16 May 2002. The installation, consisting of shotcrete robot L1, two system rock bolt drill units, a roof bolt drill unit, a mobile working platform with vault setting unit and a mobile shotcrete robot L2, was designed in accordance with the state of the art.

The highly mechanised rock support represents a crucial factor in respect of success of the drilling operation owing to the demanding geological conditions.
3. Rock support construction sequence

**Setting rock bolts:**
Two system rock bolt drill units are set up on follow-on 1 owing to the large number of rock bolts to be set.
These system rock bolt drill units drill the boreholes with a max. diameter of 51 mm for the cable bolts (length from 5 to max. 8 m). The units can also be used to set extensible Swellex rock bolts besides the cable bolts.

The roof bolt drilling unit allows subsequent bolt anchorings to be performed up to max. 13 m behind the face and it is also used to set the suspension bolts for the suspended platform. The roof bolt drilling unit is also able to drill boreholes up to a length of 8 m using a telescopic drilling cradle and automatic auger stem feeder.
The bolt holes can be drilled during driving operations (with cutterhead rotating).

**Setting mesh reinforcements / fitted vaults:**
The cable bolts are set and grouted from the longitudinally travelling working platform. It is also used to lay the reinforcing meshing of Type K 188, K 283 or K 335, depending on type of excavated material.
Steel vaults of Type TH 29/58 are placed with the vault setting unit constructed on the working platform.
In addition, the shotcrete robot L2 has a working platform and lateral landings in order to ensure accessibility to the wall. This allows additional rock support work.

**Shotcrete:**
The shotcrete in area L1 is placed with the specially designed shotcrete robot L1. The peripheral range is 360° and the longitudinal travel is 1.5 m. This ensures optimum application to the tunnel circumference.
A self-propelled shotcrete robot which is independent of the follow-on is used in area L2. This large carriage has two cross-carrriages with complete shotcreting equipment, together covering a range of 250° in the tunnel cross-section.
4. Shotcrete robot L1

Shotcrete is applied in area L1 by the shotcrete robot L1 directly behind the rotating cutterhead.

In the case of geologically difficult conditions, the shotcrete robot arm can move between the drillings buckets of the tunnel bore extender, with the cutterhead stationary, and place the first support optimally, almost as far as the face. For this operation, the tunnel bore extender is locked to the shotcrete robot by means of a safety system.

The shotcrete robot can be telescoped 1.5 m beyond the tunnel cross-section and thus apply shotcrete at a spraying distance of approx. 1.5 m from 3 m to max. 4 m above the tunnel cross-section, thus giving it a radius of action of 9 m beyond the tunnel cross-section at a spray distance of 1.5 m.

Technical data:

- Longitudinal displacement: 1.5 m
- Spray range circumference: 360 °
- Spray nozzle nominal diameter: 80 mm
- Operation: with radio remote control for reasons relating to improving working conditions and work safety
5. System and roof bolt drills:

**Special features of the bolt drills:**
- Long drilling cradles 18 feet, for drilling shot holes with a drilling depth of 8 m
- Drilling diameter up to 51 mm
- Overhead drilling (normally, such long bore holes are drilled only horizontally in tunnel construction). This leads to more stringent requirements made of the drilling equipment:
  - Carrier equipment with drive unit and control stand must be solidly covered and thus protected against excavated material dropping down
  - Longitudinal displacement of the carrier equipment so that the drilling unit can be moved to parking position
  - Option for advance drilling
  - Self-propelled hydraulic supply
- Unusually high forces and torques acting on the carrier equipment
- Control system CAN bus with moveable control stand

The roof bolt drill for the roof / subsequent bolt anchoring and for the bolt suspension of the suspended platform is located at the centre on the follow-on 1.

There are two system bolt drills, one at the left and one at the right, on the follow-on. The left-hand drill covers the 9 o’clock to 12 o’clock range of the tunnel cross-section and the right-hand drill covers the 12 o’clock to 3 o’clock range.

6. Working platform and vault setting unit

The movable working platform serves as an erection platform for setting fitted vaults and mesh reinforcements and as a workplace for the rock support work in the tunnel roof. Moving the working platform to the rear frees up the required space for the bolt drills. In addition, the bolt drills are protected against rebound while attaching the shotcrete robot.
7. Shotcrete robot L2

**Special features of the shotcrete robot L2:**
- Self-propelling and, thus, independent of the follow-on with a longitudinal travel of approx. 18 m
- Two spray nozzle carriages with a longitudinal displacement of 3 m
- Semi-automation: the two nozzle carriages can be controlled in semi-automatic mode and in conventional manual mode by radio remote control. In semi-automatic mode, the nozzle carriages move independently in longitudinal and transversal direction. The speeds can be controlled by means of potentiometers.
- Working platform and lateral landings for accessibility to the wall, for any additional rock support work such as mesh reinforcement etc.
- Weight approx. 47 metric tons
8. Strengths of Rowa Tunnelling Logistics in the Uetliberg project

The installations which Rowa Tunnelling Logistics AG was able to supply to the Uetli Joint Venture are an excellent example of our achievement potential and high performance in the sector of special installations. They originated subject to the following influences:

**Early inclusion of Rowa**
It is a generally known fact that good ideas at an *early* project phase are able to influence success on a more sustained basis than such ideas at a late point. Rowa already conducted initial feasibility studies for various variants for the Uetliberg project as early as the project phase and prior to the invitation to tender.

**General development**
Good ideas may be incorporated from all sides. It is important that it is possible to implement these ideas jointly with the installation builder and operator optimally in a product. We constantly endeavour to find the most efficient and economical solution project specifically together with our customers.

**Required competence**
Rowa Tunnelling Logistics AG consists of 22 motivated construction and mechanical engineers, technicians, designers and businesspeople. We avail of many years of experience and are able to cover the important interfaces between plant construction and tunnel construction in a special way.

Wangen, July 2003