Renesco GmbH

Belchenstrasse 2, 79539 Lörrach
Tel.: +49 (0) 7621 1681560, mobil, Fax: + 49 (0) 7621 1681568
Mail: per.koenig@martiag.ch URL: www.renesco.sk

Waterproofing Technology – Special Projects

Per König

Summary: The tunnel services provided by Renesco (former Schmutz/ThyssenKrupp Xervon) focus on the sealing/proofing of underground structures and systems to prevent the entry of (un)pressurized water. Here are a number of reference projects:

For the watertight lining of the Burgholz road tunnel in Wuppertal in November 2003, a ceiling-side partial proofing against unpressurized water was carried out while along an area of some 3,500 square meters, the tunnel was completely sealed at the invert, walls, and ceiling.
Similar work was required a year later on Switzerland's Lötschberg tunnel which was protected against seepage by a waterproof partial lining along a length of 6.4 km. This so-called "umbrella" lining consists of multilayered systems and is installed prior to the concreting of the inner shell.
The solution was different when sealing off the emergency exits at the Westerschelde road tunnel near Antwerp in April 2003. Situated 60 meters below sea-level, this transverse tunnel with a diameter of 3.20 meters had to be reliably proofed against water pressures of 6 bar. The system used had previously been employed for lining various underground stations and caverns, the emergency and access shafts when building the Copenhagen subway.
Included among the tunnel services are projects such as waterproofing the intermediate storage facility at the Neckarwestheim nuclear power plant. The challenge in this instance: water had to be kept out even at permanent temperatures of 80 °C.

An umbrella against seepage water
110,000 m² of watertight lining in Wuppertal's Burgholz road tunnel

WUPPERTAL, November 2003 The newly built Burgholz road tunnel near Wuppertal is currently being given an "umbrella". With a watertight lining on the walls and ceiling, the two roughly 2 km long tunnel tubes are to be protected mainly from surface water – a specialty of Renesco (former Schmutz/ThyssenKrupp Xervon), which has been awarded the contract for the large-scale waterproofing work (110,000 m²) on Burgholz Tunnel. It is one of the few European companies capable of protecting underground structures from water, unpressurized or pressurized.

The completion of Wuppertal's L418 southern expressway has taken several years. The plans date back to 1962. But construction of the missing and most controversial section through Burgholz forest didn't start until last year. In order to protect this area of woodland north of Wuppertal's district of Cronenberg, the City Council, responding to many protests from the local community, demanded in 1984 that this section be tunneled. The construction of the roughly 2 km long Burgholz Tunnel was officially sealed, finally, in 1999. Two, two-lane tunnels (1865 and 1787 m long) will now plug the gap in the L418.

On 22nd August, the tunnel consortium (G. Hinteregger & Söhne Bauges.m.b.H. and Baresel AG) announced the completion of the tunnels, and the waterproofing experts, who had been working in parallel with the tunnelers from July onward, then embarked on the most difficult part of the project – the complete waterproofing of both tunnel tubes beneath the Glasbach valley. Tunneling under this small, stream-carrying valley demanded the complete waterproofing of an estimated 3,500 m² of floor, walls and ceiling of the tunnel. This is supplemented by the installation of a repair system to enable any leaks to be quickly and easily eliminated. For the other sections of the tunnel, only so-called "umbrella" waterproofing is envisaged. The floor of the tunnel will not be sealed here because the tunnel tubes only have to be protected from unpressurized surface water. However, no one is entirely sure if the estimated 106,500 m² of "umbrella" waterproofing will be sufficient. Although tunneling through the Glasbach valley failed to yield any geological surprises and confirmed the expected ground conditions, the period of weeks between tunneling and the start of waterproofing work are being used to carefully watch out for the emergence of water in the delicate section beneath the Glasbach valley. Only on site will it then be possible to precisely determine how much all-round waterproofing is required. "So that the tunnel tubes are absolutely tight beneath the Glasbach valley, we are working in this area with 3 mm thick plastic waterproofing membranes made of flexible polyolefins," says Renesco waterproofing expert Per König, explaining how the Burgholz Tunnel is to be effectively sealed all-round against water at a pressure of 6 bar.

Geschäftsführung: Ing. Per König
Sitz der Gesellschaft: Lörrach
USt-IdNr.: DE162535571
Steuernummer: 1109031298

Bankverbindung: Dt. Bank Lörrach (BLZ 683 700 34) Konto 0 400 440
IBAN-Code: DE22 6837 0034 0040 0440 00
BIC-Code: DEUTDE6F683

A watertight case

Although every project is different and demands the adaptation of the multi-layer waterproofing system to the local geological and hydrological conditions, the basic principle of the waterproof lining and the steps required in its creation are always the same. The first step involves attaching a protective nonwoven geotextile fabric to the shotcrete lining of the tunnel tubes. This 1200 g/m² thick layer of material protects the subsequently fitted plastic sheeting. "We use nothing but environmentally neutral sheeting of flexible polyolefins (PFO). Unlike PVC, it does not contain plasticizers and can be expected to last 100 years," König explains. So that the waterproofing clings without cavities like a skin to the shotcrete coating of the tunnel tubes, it is fastened to the substrate with the aid of previously anchored discs. These discs and the sheeting are welding together with hot air. Since they are both made of the same material, a strong and lasting joint is created.

Sheet welders then weld the overlaps together. Between the resultant, roughly 15 mm wide seams, an approximately 10 mm wide channel is created, which can be filled with compressed air to check the tightness of the seam. Informative statements about the quality of a weld seam can only be made when it has been tested with suitable methods. In addition to the demanded visual inspections and mechanical testing by the installer's own staff, the guidelines of the DVS (German Welding Association) specifying compressed air and vacuum tests must also be applied. In the compressed air test, for instance, a pressure of 2.5 bar is built up in the channel between the two parallel weld seams. If this pressure has not decreased by more than 20 percent after ten minutes, the seam is considered tight and of sufficient mechanical strength.

Easy repairs

Once all the required tests have been successfully completed and recorded, the fabric-and-sheeting waterproofing system is essentially complete. However, it is being followed by a further protective layer of plastic sheeting. Because the engineers want to err on the safe side on this sensitive Glasbach valley section of Burgholz Tunnel, a repair system is also being installed. Any leaks arising in the all-round seal can then be quickly and easily remedied. To this end, the engineers have integrated in the seal injection nozzles, whose hoses extend through the tunnel's concrete shell. Should a leak ever occur, a waterproofing gel can then be injected into the affected area. The last, 3 mm thick layer of protective sheeting is provided with 0.2 mm pimples to create a gap between the waterproofing membrane and the protective layer. It is into this gap that the repair gel is injected. It remains to be mentioned that the fully waterproofed section of Burgholz Tunnel has been fitted with about 750 m of joint strips to enable individual sections to be sealed off.

Umbrella protection

Rather than being fully waterproofed, the major part of Burgholz Tunnel is being protected from surface water with an umbrella-like seal on the walls and ceiling. Because the water here is not under pressure, a 2 mm thick plastic sheet is sufficient as the waterproofing membrane, which is sealed off every 30 m with joint strips. So that everyone can working flexibly on the project, Renesco's (former Schmutz/Thyssenkrupp Xervon) waterproofing experts have slightly modified the originally envisaged procedure. To start with, a 2 m wide waterproofing strip is fitted as a base strip along the sidewalls on either side of the road. This means that the side barrier can be poured without having to waterproof the ceiling first. Tunnelers and waterproofers can thus work independently of each other. Coordination has so far been excellent. Everyone is on schedule. All the same, waterproofing work is expected to take until the end of August next year.

Pictures:

Visual inspection of Wuppertal's Burgholz Tunnel: With a watertight lining on the walls and ceiling, the two roughly 2 km long tubes of the road tunnel will be protected from water.

During hot-air welding, working speed and temperature have to be absolutely right. Specially trained membrane welders seal two the overlapping membranes in a double seam.

Umbrella for the Lötschberg Tunnel: 130 000 m² of watertight lining

RAARON, December 2004 The fastest north-south railroad link through the Swiss Alps is taking shape. The 34.6 km long Lötschberg base tunnel from Frutigen in the Kandertal valley (Bernese Oberland) to Raron in the Rhône valley is scheduled to open in 2007.

The railroad engineering companies will start equipping the tunnel from the southern entrance (Raron) at the end of 2004. Beforehand, however, the excavated cross section is being given an overhead watertight lining as protection from seepage water for the first few kilometers into the mountain. This waterproofing work is a specialty of Renesco (former Schmutz/ThyssenKrupp Xervon). In two stages, Renesco (former Schmutz/ThyssenKrupp Xervon) will be attaching a socalled umbrella seal to the roof and sidewalls along a total 6.4 km of tunnel.

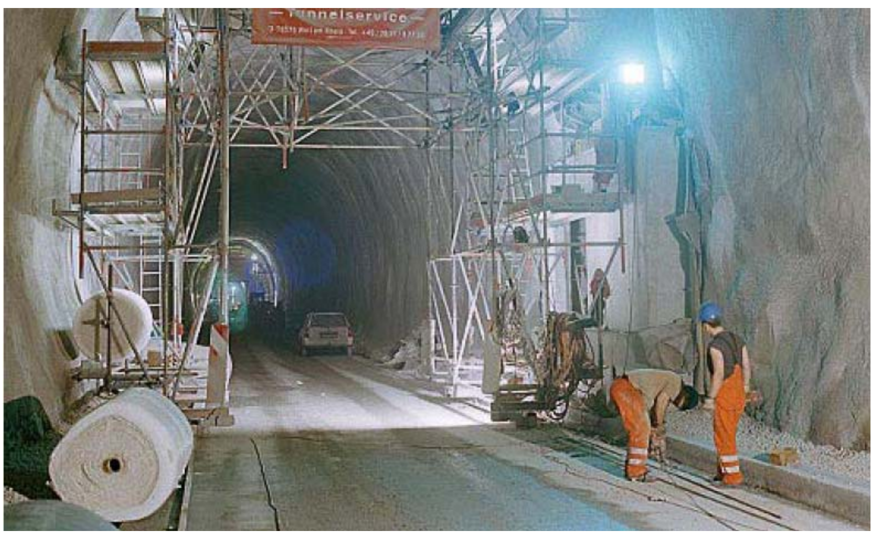
A specialty
Before the inner shell is concreted, the tunnel will be lined as required with a drainage sheet whose randomly oriented outer profiling allows seepage water to flow down the sides into the floor. The pipe installed there carries this clean water out of the tunnel. Because geologists expect a constant flow of seepage water in both tunnel tubes over the initial kilometers from the southern entrance, the tunnel is also being given a so-called umbrella seal in this area. This partial waterproofing extends along the tunnel ceiling and walls down to the floor and consists of a multi-layer waterproofing system. Waterproofing for the floor is not necessary because the tunnel tubes only have to be protected from unpressurized seepage water.

The Lötschberg project makes use of the waterproofing system 212 manufactured by Sika that Swiss Rail has approved for all NEAT (Neue Eisenbahn-Alpentransversalen = New Transalpine Railroad Links) tunnels. First of all, a 900 g/m² and roughly 16 mm thick drainage layer is fitted as the first protective layer. Like a tautly fitted carpet, it protects the subsequently installed, at least 2 mm thick PVC waterproofing membrane. So that the seal clings tightly to the tunnel tube without air pockets, it is fastened at intervals to the substrate with previously anchored discs. These discs are made of the same material as the sheeting and are welded to it in a special process. To this end they are heated with hot air, fuse with the sheeting and create a tight fit with the substrate.

Test pressure of 2 bar
Membrane welders then weld the overlapping sheets together with a double seam. Between the resultant, roughly 15 mm wide seams, an approximately 10 mm wide channel is created, which can be filled with compressed air to check the tightness of the seam. To this end, the channel is subjected to an air pressure of 2 bar. Unless this pressure drops by more than 10 percent within ten minutes, the seam is considered tight and of sufficient mechanical strength. Once all the required tests have been successfully accomplished and recorded, the key element of the fabric/sheeting waterproofing system is installed. It is then followed by a further protective membrane of plastic sheeting.
The first 3.2 kilometers in the western Lötschberg base tunnel tube (excavated by blasting) have already been waterproofed.
From the beginning of March to the end of June, the waterproofers installed about three metric tons of material per day at an ambient temperature of around 32°C. "Per day, our 13 men managed 1,000 square meters, which is equivalent to 50 meters of tunnel," exclaims an impressed Renesco Project Manager Per König. Such temperatures are stressful not only for the men, but also for the materials. The higher the temperature, the softer the PVC membrane.
"Handling it properly takes real skill," König insists.

Pictures:

Much like a second skin, the taut plastic sealant sheeting envelops the walls of the tunnel tubes.



First of all, a 900 g/m² and roughly 16 mm thick drainage layer will be fitted, followed by the at least 2 mm thick PVC waterproofing membrane. The seal clings tightly to the tunnel tube without air pockets, thus creating a tight fit against the substrate.

Renesco (former Schmutz/ThyssenKrupp Xervon) employees have been specially trained and approved by the German Welding Association as plastic sheet welders. The company is a skilled practitioner of a special process for applying environmentally neutral plastic waterproofing membranes like a watertight skin to tunnel tubes

Westerschelde tunnel and the Copenhagen metro: sealed with thermoplastic sheeting

April 2003 They work around the world and you can count them on one hand in Europe: companies that take on tunnel projects such as sealing the ducts, caverns and shafts. Renesco (former Schmutz/ThyssenKrupp Xervon) is one of them. With its “tunnel service", the company offers sealing of “underground engineering works against water with or without pressure". This occurs with environment-friendly plastic sealant sheeting which is fastened to the tunnel walls using a special method. Among Renesco's (former Schmutz/ThyssenKrupp Xervon) most recently completed contracts are the sealing of all of the escape routes along the Westerschelde road tunnel close to Antwerp and the lining of various stations and caverns as well as emergency and access shafts during the construction of the Copenhagen metro.

“Really every one of our construction sites is an adventure", Per König, tunnel service expert, characterizes his field of activity. It’s true that the sealing methods are standardized and always go by the same rules and above all the same high quality standards. "We work either to the extremely strict 853 code of German Rail as applying to railway tunnels or the somewhat less rigid ZTV, which applies in Germany to road tunnels", is how tunneling expert König explains the quality specified. "But still, every construction site is different and requires the multi-layered sealing system to be adapted to onsite conditions", he continues. That’s why, particularly in large projects, five to ten years of practical experience and the execution of similar reference projects is a prerequisite for even having a chance in the bidding phase.

Westerschelde road tunnel: 60 meters below water level

Even though every tunnel construction site is preceded by lengthy geological surveys, surprises nonetheless repeatedly surface. In the construction of the 6.5-km road tunnel beneath the Westerschelde, this was evident right from the start in the first two of altogether 24 cross-cuts acting as links between the two parallel tunnel tubes and serving as escape routes. It was not possible to seal these against water pressure using the specified techniques of an internal concrete shell and injections. Only with the aid of a very expensive inner liner of steel could the first of the cross-cuts be repaired.

As a consequence, for the remaining cross-cuts, the Dutch government insisted on an alternative technique. In order to seal the cross tunnel (diameter of 3.20 m) against 6-bar water pressure, Renesco (former Schmutz/ThyssenKrupp Xervon) together with the tunnel builder developed in the course of a test and planning phase stretching over several months an alternative sheeting-based system. Convincing tests for tightness plus a visit to Copenhagen, where concurrently a new stretch of the metro was being sealed with a similar system, finally persuaded the client. "In the final resort, the new proposal saved us about six months of construction time and a lot of money. Our sheeting-based seal cost less than one half of what a subsequent repair to the cross-cuts would have entailed", is how Per König calculates the savings.

Sub-ice sealing

This is what the tunnel experts came up with: the seabed was first of all iced and then the tunnel sectionwise cut out. In the course of this process, the tunnel walls were given their water-proof linings. An identical procedure was followed in all instances: first of all a protective layer, a 1200 g/m² geotextile to safeguard much as a tightened carpet the 3-mm sheeting, is applied. This environment-neutral sheeting made of FPO (flexible polyolefin) contains – in contrast to PVC– no plasticizers and has a 100-year life. The sealing material is attached to the foundation at specific points with previously mounted, so-called rondels, so that it stretches over the shot-concrete covered tunnel like a skin. These rondels are made of the same basic material as the sheeting and are sealed to it using a special technique: they are heated with hot air, which bonds them to the sheeting, fastening it to the foundation. This ensures that the sheeting is not perforated in the course of being affixed, and so it remains completely leakproof.

Welders then bond – double seamed – the overlapping sheets with one another. In the process of fixing the two individual seams, each around 15 mm wide, an approximately 10 mm wide test-channel is created between them. This can be filled with compressed air to check that the seams are tight. Once the sealant layer is installed, another protective layer of plastic sheeting follows. In the case of the Westerschelde tunnel, this is 3.5 mm thick and has knobs enabling gel to be injected between the seal and the protective layer. This is finally followed by a concrete shell including reinforcement, often several meters thick. In both the Copenhagen and Westerschelde applications, the customer had the foresight to install repair systems. Injection channels leading through the concrete shell were built into the sealing. In the event that damage actually occurs, a repair gel can be specifically injected into the right areas through these ducts, without having to first drill through the meter-thick concrete with an uncertain outcome.

Sheet welders examined once a year
Only specially trained welders are allowed to carry out this sealing process and the related tests for tightness. They require a license as sheeting welder from the German Association for Welding and, moreover, each year their theoretical and practical skills are re-examined. At present, Renesco employs 16 such highly skilled welders on construction sites around the world. The Westerschelde tunnel, for instance, employed four welders for a period of 16 months sealing a total tunnel surface of about 6,000 m².

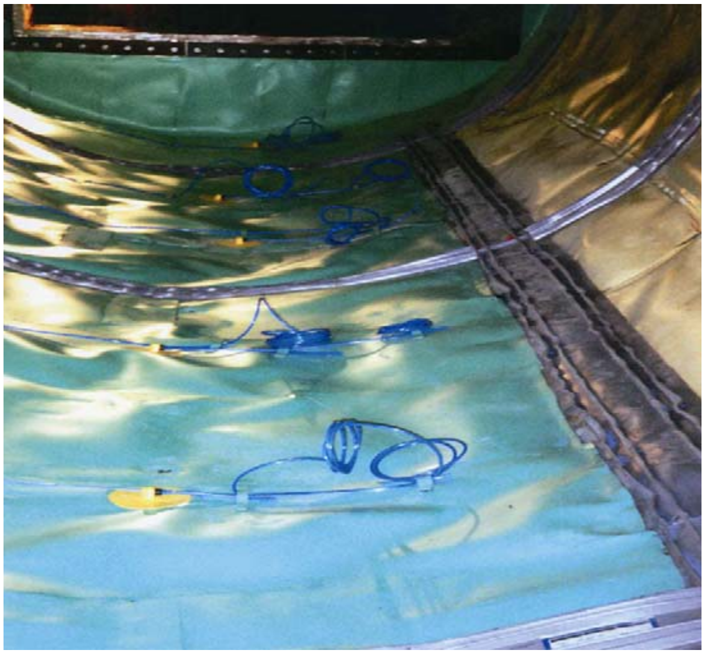
Three years in the Copenhagen underground
Twenty more Renesco (former Schmutz/ThyssenKrupp Xervon) specialists were at work on building the new Copenhagen metro from 1999 to 2002. What's often lovingly called the "mini-metro" has been running on its first nine kilometers of track under Denmark's capital since October 19 of last year. In the northern metropolis' underground, everything is a bit smaller than is usual for subways: the cars, the trains and even the diameter of the tunnel. Exactly matching a city with a good 600,000 inhabitants. But then the fully automatic mini-metro is truly a new development. Each of the driverless trains consists of only three cars, is 39 meters long, 2.65 meters wide and carries up to 300 passengers at a maximum speed of 80 km/h.

Renesco (former Schmutz/ThyssenKrupp Xervon) had to seal three metro stations and 14 emergency shafts, which on an average extend down vertically 30 meters, against water pressure to 3 bar. They had three years to line – watertight – a total surface of 40,000 m² with 240,000 kilograms of material. Similar to the Westerschelde tunnel, a geotextile layer weighing 500 g/m² was used, followed by a 3 mm layer of FPO, and a final 4 mm protective layer.
Yet installing the sealing in Copenhagen presented some exceptional challenges – above as well as below ground. Per König: "Sometimes we worked at six installation sites at a time. That wasn't that easy logistically, for the city hardly permits any construction areas for traffic reasons – not even for its own subway."

Logistics challenge
Getting through big-city traffic was a constant torment and brought the city lots of parking-fine revenues by the time all materials where brought below ground in the places they were needed. "But we knew beforehand that a logistic challenge was in store for us", König says. But what they didn't know: Copenhagen's underground is spotted with irregularly placed groundwater-bearing ravines and their water levels – although far from the sea – react to the tides. "Sometimes the water came, sometimes it didn't. The first shaft was flooded three times. Sometimes we had to work in there with a raft", Per König tells of the unpredictable conditions. But with suitably extended pump capacity, in the end one was able to get the massive entry of water under control and seal everything on schedule.

And this despite the fact that there were certain stretches of tunnel that needed subsequent repair and re-sealing since they could not be sealed with the concrete originally specified by the construction site. In contrast to the double-shell shafts and stations, a less expensive single-shell mode of construction had been selected for the actual road traffic tunnel. The tubes were cut in full section and then lined with concrete segments. Wherever water still entered, concrete had to be injected. But since this was not possible in all cases, the Renesco (former Schmutz/ThyssenKrupp Xervon) experts had additional sealing work to carry out.

Pictures:



Even while the sea bed was iced, all the escape routes of the Westerschelde road tunnel were watertight sealed with ecofriendly FPO sheeting. So that the sealing stays skin-tight to the tunnel tubes, it is secured to the subsurface using socalled rondels.

In the construction of the Copenhagen metro, 3 stations and 14 vertical emergency shafts were lined with sheeting to withstand 3-bar water pressure. Altogether, 40,000 m² were lined with 240,000 kg of sheeting. The system used was similar to that on the Westerschelde tunnel: here a 500 g/m² geotextile lining followed by 3-mm FPO sheeting, and a final 4-mm layer.

Watertight at 80 degrees - Nuclear storage site in Neckarwestheim given a new watertight inner lining

NECKARWESTHEIM, August 2005 The new nuclear temporary storage site at the Neckarwestheim power plant is being given a watertight inner lining. The two big caverns, all of the connecting tunnels and shafts are being completely sealed against groundwater and precipitation along the walls and ceilings with the aid of multilayered proofing. A precondition for the project is that even at permanent temperatures of 80 °C, the geotextile/plastic sheet acting as waterproofing retains its watertight properties.

“Proofing underground structures against pressurized and unpressurized water” is the specialized task that just a handful of companies in Europe are capable of performing. Renesco (former Schmutz/ThyssenKrupp Xervon) is among them. It commands a special technique whereby the environmentally neutral plastic waterproofing sheet clings to the tunnel tubes much like a watertight skin. And because this technique outperforms in terms of safety and reliability the solution originally proposed for the Neckarwestheim power plant, the specialists were able to secure the contract for themselves. Says Renesco sealing expert Per König: "The originally planned full-surface proofing of bitumen and PVC cannot be securely enough when installed overhead in the dome. So this was our opportunity.” Various tests and sample bondings underscored both the technical competence of our alternative proposal plus its cost efficiency. Impressed by the proposals were EnBW, (the power plant operator), the Swiss Gähler und Partner engineering consultants and the contractor in charge Baresel AG.

15,000 m² of proofing

With its new temporary storage site for spent fuel rods, EnBW address the insistence by politicians on having local sites in proximity to the plants themselves. Neckarwestheim has two tunnel tubes driven into the rock located beneath the office building. These accommodate 150 Castor casks, albeit actual storage is confined to a maximum of five per year. Until the two parallel 90-meter long caverns (height: 18 m, width: 14 m) and all the related shafts and connecting tunnels are complete mid-2006, around 75,000 cubic meters of excavator ground will have to be removed and replaced by 33,000 cubic meters of concrete. Other work includes the sealing of around 15,000 square meters against groundwater and so-called meteorwater (resulting from all kinds of precipitation) at a continuous operating temperature of 80 °C. All parts of the new site, except for the tunnel invert, are being proofed. The invert itself comprises a watertight concrete slab secured to the proofing with joint tapes.

“Every waterproofing task is different and demands the adaptation of our multi-layer process to the specific geological and hydrological conditions,” explains Per König. In Neckarwestheim, the high required temperature resistance is particularly demanding. In contrast, the careful installation of the sealing is a chore that his specialists are confronted with most every day. What makes the new temporary storage site a genuine showcase assignment are the extremely confined space and tight deadlines for the individual work steps. “We have to stay constantly in step with the bar setters and concrete pourers, as we don't have the usual continuous work process as on most tunnel construction sites," adds König. Once the caverns have been excavated, a first layer of shotcrete is applied, then a 20 mm thick drainage followed by the shotcrete shell and another some 30 mm thick layer of fine shotcrete to support the following proofing of nonwovens and plastic sheet.

Simple principle: geotextile, PVC sheet, laminating layer

The principle of the watertight lining and the work steps required for this, on the other hand, is always the same. First of all a protective layer of geotextile (1,000 g/m²) is applied to the tunnel tubes lined with shotcrete in order to protect the subsequently fitted plastic waterproofing membrane, a 2 mm PVC sheet able to withstand temperatures of 80 °C (guaranteed temperature resistance) . So that the waterproofing clings without cavities like a skin to the walls and ceiling of the tunnel tubes, it is fastened to the substrate with the aid of previously anchored discs. In a special process, these discs and the sheeting are welding together with hot air to create a perfect fit. Then the overlapping plastic membranes are welded absolutely tightly together - various tests confirm the quality of the welds. Only specially trained sheet welders conforming to DVS Guideline 2225 (German Welding Association) are permitted to carry out this waterproofing process and the associated tests of tightness. Only when the quality testing has been successfully accomplished is a protective layer of self-adhesive sheeting installed as the final step. This laminated layer comes with a releasable marker film and is bonded over its entire surface to the PVC waterproofing. This way any damage to the waterproofing system is easily spotted. To complete the tunnel carcass, the only task that’s left is the construction of the reinforced concrete inner shell.

Background: Neckarwestheim power plant

This power plant generates annually over 17 billion kilowatt hours of electricity for the public grid and German Rail - equivalent to around a third of the annual consumption of the German state of Baden-Württemberg. Two pressurizedwater reactors located on the right-hand bank of the river Neckar between Heilbronn and Ludwigsburg generate the energy. Unit I dating back to 1976 has an output of 840 MW, unit II with an output of 1,395 MW came on stream in 1989 and is Germany's youngest and most modern power plant reactor.

Pictures:

The plastic membrane is applied like a waterproof skin to the tunnel tubes.

So that the waterproofing clings without cavities like a skin to the walls and ceiling of the tunnel tubes, it is fastened to the substrate with the aid of previously anchored discs.

Geschäftsführung: Ing. Per König
Sitz der Gesellschaft: Lörrach
USt-IdNr.: DE162535571
Steuernummer: 1109031298

Bankverbindung: Dt. Bank Lörrach (BLZ 683 700 34) Konto 0 400 440
IBAN-Code: DE22 6837 0034 0040 0440 00
BIC-Code: DEUTDE6F683