AMBERG MAKES THE CASE FOR BIM

With tunnelling just completed, TJ caught up with engineering company Amberg to find out about challenges on the new Bözberg rail tunnel – and how 3D design helped.

ON 29 NOVEMBER 2017 contractor Implenia broke through on the 2.7km-long Bözberg tunnel which runs between its southern portal at Schinznach-Dorf to a northern one near to Effingen in Switzerland. The trickiest element of the tunnel build, certainly in terms of design, came at the very start of the TBM-dug section where it took over from a 175m-long traditionally constructed section.

"There was an initial zone with shallow overburden at the south end of the tunnel, ranging from just a few metres up to 45m. The ground was very complex, a mixture of quaternary deposits and heavily-weathered loose rock," says Karl Grossauer, project manager on the Bözberg Tunnel for lead designer Amberg which is working in joint venture with Basler & Hofmann, F Preisig and Heierli. "We decided to excavate this first zone using conventional methods."

The single-shield, 12.36m-diameter, Herrenknecht hard rock TBM could not begin tunnelling until it had a certain depth of rock overhead. Amberg created a 3D model to determine where that point would be and to help communicate the complexity of the situation to Implenia's client SBB, the Swiss Railway Authority.

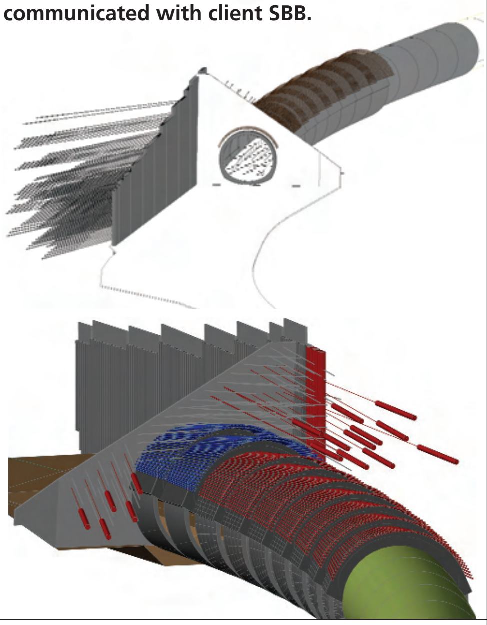
From road to rail

The new tunnel runs almost parallel to the existing Bözberg railway tunnel, which was built in 1875 and is too low to accommodate modern freight trains. The new tunnel will accommodate wagons up to 4m high, encouraging a modal shift from road to rail on the Gotthard line between Basle and Chiasso on the Swiss southern border. The project is part of a bigger SFr940M programme which will see upgrades to 20 other tunnels and alterations to platforms, traction current systems, signalling and overpasses.

SBB awarded the SFr150M contract to Implenia in November 2015, at which point Amberg and its joint-venture partners began the detailed design process. Implenia's contract includes besides the main tunnelling works the construction of both portals, including two short sections of cut-and-cover tunnel, dewatering and the installation of electrical equipment, and the installation of the rail system. Implenia will also convert the original

Above: The TBM waits to start its drive, taking over from a traditionally-dug section through soft ground and low cover.

Below: 3D modelling helped Implenia predict where the TBM could start tunnelling and to communicated with client SBB.



tunnel into a service and rescue tunnel, digging five cross passages between the old and new tunnels.

Work on site began in March 2016, with excavation of the traditionally dug section starting in September that year. Implenia supported the roof of the excavation with 16m-long pipe umbrella arches, each overlapping with the next by 4m, with shotcrete used as a temporary support.

The hard rock TBM started tunnelling in May 2017. The traditionally reinforced segments are made up of 5+1 segments with no bolts, no dowels and no gaskets, and the keystone always at the bottom. This facilitates an entire ring build in only 15 to 20 minutes.

Mostly the TBM had only to bore through the Jura zone, a mixture of limestone, marl, sandstone, claystone and Opalisus clay, which is very common in this area of Switzerland. However, there was a section of swelling

ground with claystone and anhydrite. "A nearby road tunnel, built in the 1990s had serious issues with heaving," says Grossauer. "That's why they chose a TBM to provide a closed ring which gives a stiff final lining system."

There is also a section of around 400m in the tunnel with geothermal water. "There are quite complex hydrogeological conditions: geothermal ground water with an existing spa area very close to the site," says Grossauer.

This required a special waterproofing design consisting of two layers of plastic membrane with welded compartments which can be individually grouted up if a leak occurs in a specific location. The system has a protective layer between the segments and the plastic waterproofing membrane and another between the sheets and the invert of

Breakthrough! Implenia's Herrenknecht hard rock TBM finishes its drive on the Bözberg tunnel in Switzerland.

the final lining as well as where the final lining is reinforced.

Most of the inner lining is 300mm thick and unreinforced. Where there is the threat of ground swelling, the lining is between 400 to 600mm thick, with heavy reinforcement. The designers considered fibre reinforcement for the final lining, but it would not have been sufficient in these areas – and wasn't needed elsewhere. Polypropylene fibres will be part of the mix, for fire protection against spalling.

Removing the spoil from site presented some challenges. The initial plan had been to take it to a gravel pit in a neighbouring town, but this would have required 57,000 lorry movements so the local government refused permission. Instead a two-way conveyor system takes the spoil to a temporary storage location around 2km from the tunnel portal until it can be moved by rail.

Early BIM

Implenia and Amberg's use of 3D modelling cannot truly be called BIM, it is rather the early stages of BIM. A full BIM model would link the model elements with additional information such as schedule, cost and maintenance-related data to be used over the structure's whole life. However, the 3D approach does demonstrate some of the benefits that BIM could eventually bring.

Amberg used Leapfrog, a 3D geological modelling tool to model the ground conditions and then imported that into a Revit model of the civil structures. "We updated the model frequently on the basis of face mappings," says Grossauer.

So how accurately did it predict the location where the rock overburden was sufficient for the TBM to start? To within 1 or 2 metres, says Grossauer.

Amberg also used 3D models for the design of the five cross passages "We have a lot of installations there: piping for dewatering, and up to 22 cable ducts in each cross passage," says Grossauer. With a diameter of 5.8m, space is limited, so a 3D model should help prevent clashes later on.

The 3D models also helped explain the situation far more easily than 2D drawings would have done. "Using the model, Implenia was able to convince the client, the railway authority, to do certain things. We used it for meetings and explanations which helped a lot. We realised that it was so complex to appreciate the intersection between tubes and geological features. With the model, we could make live cross sections during the meeting to show them the geometrical situation and which issues we needed to discuss."

Amberg uses BIM – or at least the 3D model element of it – on around half of its projects, mainly within the project team. It helps improve communication and collaboration between the firm's offices in Switzerland, Spain, Czech Republic and Austria, says Grossauer. "It makes communication much more direct and efficient and facilitates interdisciplinary collaboration as all sub-models are united in single coordination model," he explains.

"Some clients are still not sure yet whether they should fully support BIM on their projects. They ask whether there is any benefit for the final project. It can be quite difficult to explain."

Amberg is convinced that there are benefits, and is working to make the technology familiar to more companies and clients, says Grossauer. For instance, the company created a 3D as-built model of a complex underground situation in St. Gallen for the famous Swiss exhibition Olma where a highway is being covered over in order to construct a foundation for the new exhibition hall on top.

"We scanned the whole area to create an accurate as-built picture because the as-built drawings we had were not accurate enough," says Grossauer. The surroundings contain many services and underground structures, and it is only possible to plan with precision where the new structures can be fitted into the complex and dense underground geometries by using BIM.

One of the barriers to wider uptake of BIM is the huge number of software platforms out there, says Grossauer. Designers may be reluctant to invest because the software may not be appropriate for the next projects.

Five more years

The TBM's breakthrough on 29 November was bang on schedule, says Grossauer. In fact, it was one hour ahead of the targeted 3pm timing.

"From a technical point of view, the breakthrough was very challenging," he says. "It was very close to the existing tunnel and railway line. We made a detailed design with additional measures, lots of monitoring and a very comprehensive risk management plan."

The next activity will be to mine the cross passages starting in January 2018. Implenia will not complete the 40m-long cross passages initially, leaving the last 8m intact, since trains are still running in the old tunnel.

Once the new tunnel has been fitted out and handed over in August 2020, the cross passages can be completed. Implenia will also remove the rails in the old tunnel to replace them with a paved road surface. The whole project is schedules to complete in 2022.