Good ideas travel fast

As DSI celebrates the 25-year anniversary of its revolutionary AT Pipe Umbrella System, Karl Boehm, one of the system's originators, tells us its history.

Had Karl Boehm and Josef Mocivnik not invented the AT Pipe Umbrella System 25 years ago, the trajectory of DSI Austria – formerly Alwag - would certainly have been different. Good ideas travel fast in tunnelling, and this good idea helped grow the company from its home markets in and around Austria to a company that serves tunnelling and mining projects around the world.

At the age of 20, Karl Boehm began working in the family-owned business, following in the footsteps of his father, and was promoted to managing director at the tender age of 26. Mocivnik was managing director of Techmo which supplied accessories such as nuts, couplers and drill bits for self-drilling bolts to Alwag.

"Josef was a very experienced guy. He had been the managing director of Boehler, which produced drill rigs in Austria, and he knew a lot about drilling technology," recalls Boehm, a mechanical engineer by training.

The combination of Boehm's youthful inspiration and Mocivnik's experience produced a winning innovation, the AT Pipe Umbrella System. (The AT stands for Alwag Techmo). A forepoling system for supporting weak ground, this new approach had several advantages over the traditional one: it could be installed faster, it used drill rigs already on site and could be installed by the tunnelling contractors' crew rather than a specialist company. In short, it saved significantly on time and cost.

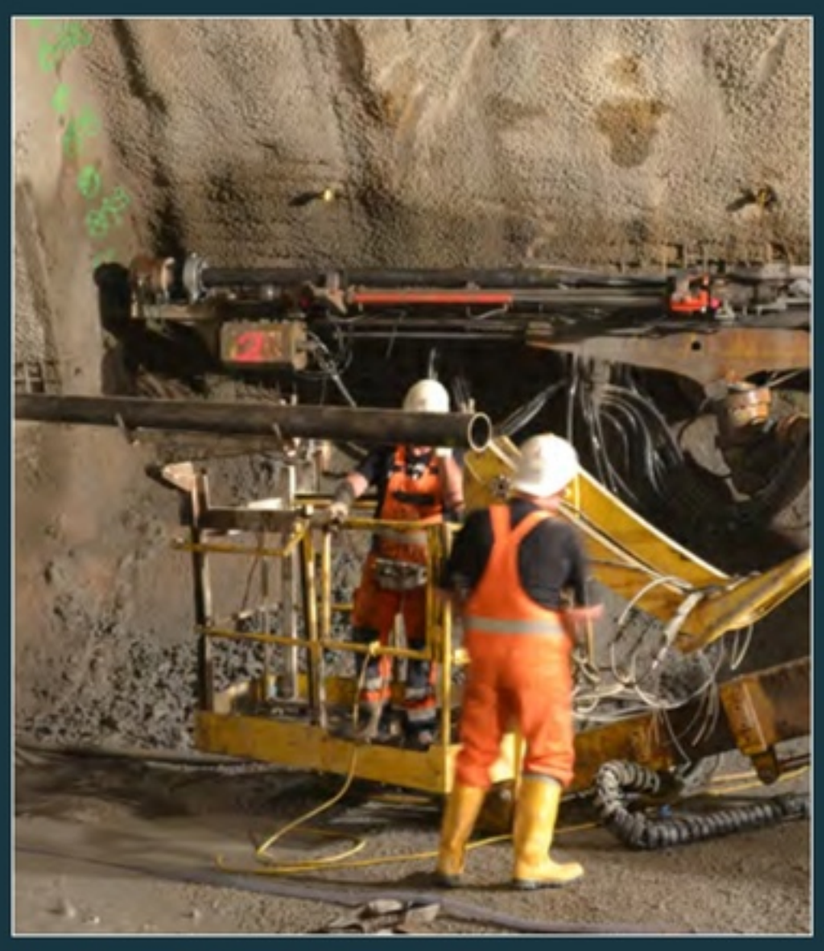
There have been several developments to the system over the years which have improved its efficiency and its safety. There have also been several changes of ownership for the company that Boehm heads up, the latest seeing global engineering company Sandvik acquire the whole of DSI Underground for €943m in July 2021.

"Sandvik acquiring us is very positive because we can now bring together the machinery and the ground support products," says Boehm. "That interface is very important and now we can remove it for our customers."

Rethinking support

Like many of the best ideas, Boehm and Mocivnik's AT Pipe Umbrella System took an existing system and rethought it.

Forepoling is used to support weak or blocky ground before traditional tunnelling can advance, creating an umbrella-like supporting canopy of fanned-out pipes above the crown of the tunnel profile. With traditional installation, a specialist rig drills holes into the ground, the drill bit



DSI's AT Pipe Umbrella System has evolved over its 25 years. On the right is an early iteration at work in the Hirschhaggen Tunnel, Germany in 2015. On the left, the latest version combining umbrella system and jumbo is seen in action at Sandvik's mine test facility in Tampere, Finland.

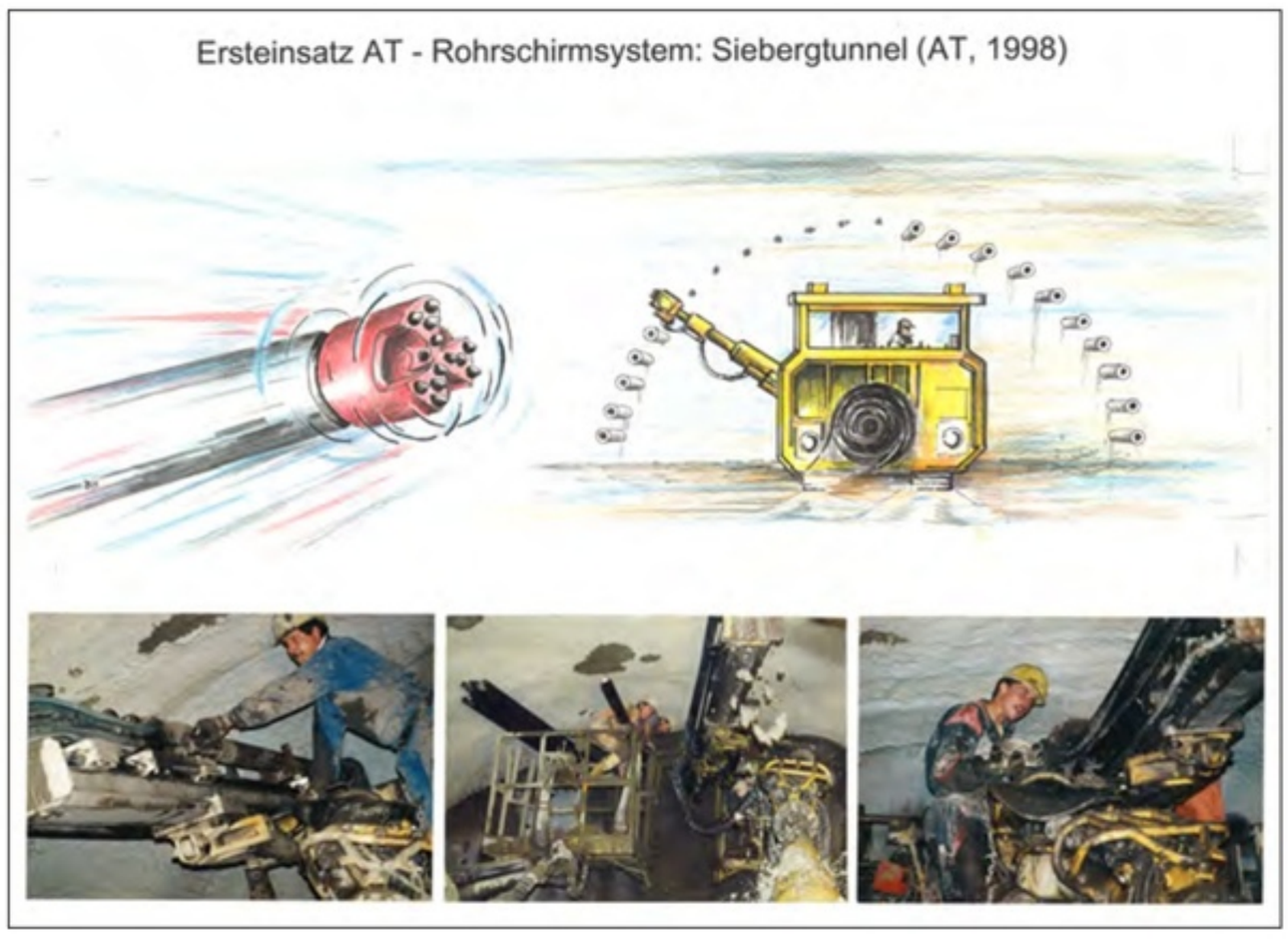
Hirschhaggen Tunnel Germany 2015

is withdrawn, a steel tube inserted and then grout injected into the tube. Back then, the tubes would typically be around 12m long, with overlaps between each successive installation.

With the AT Pipe Umbrella System, the drill bit is sacrificial, remaining in the ground for grout or resin to be pumped into it. This speeds up the whole process and removes the risk of the ground falling into the drill hole before the steel casing can be inserted. Additionally, since the self-drilled steel tubes support the drill hole, the risk of subsidence above the tunnel is removed - a significant benefit for urban projects. The first iteration of the AT system saw a two-part boring head consisting of a pilot head, which was detached and withdrawn at the bottom of the bore, with a ring head which was left in the ground.

The first project to exploit this speedy new system was the Sieberg tunnel on the Vienna-to-Salzburg high-speed rail line, in 1998. "We did the first test installations there, which were very successful, and we were rewarded with the supply of 100,000 metres of pipe," says Boehm.

The contractor was very willing to try out this new approach, says Boehm, because they could see how much time and money it could save: "They recognized they could do it themselves with their existing drilling machine from the tunnel and instead of one week it took them two days for one umbrella. That meant there were huge time and manpower savings."



The first ever project to use the AT Pipe Umbrella System was the Sieberg Tunnel in 1998.

Another advantage of the AT Pipe Umbrella System is that it can be installed at a shallower angle than traditional pipe umbrella arches. This means that the excavation cross section is smaller and hence less shotcrete is required.

Word about this great new idea soon got around and contractors tendering for the new high-speed line between Frankfurt and Cologne came calling: "The contractors heard of the first installation of our system and everyone came to the job site: the owner, designer, contractors and DB, Germany's national rail company," says Boehm. "It was accepted as an alternative to the tendered system. In the early 2000s we had huge orders from all those projects."

The AT Pipe Umbrella System – also known as a canopy system or long forepoling system outside Europe – was soon being used on other continents too. In early 2000 German contractor B&B used it on a pre-Olympics project in Sydney, Australia which was followed by a tunnelling project in Hong Kong for Bouygues in 2002.

Jobs in the US and UK followed. "Tunnelling is a 'family business' and designers work all around the world," says Boehm. "Austrian designers took our technology with them and introduced it onto other projects."

There have been multiple

The Austrian invention has spread to North America. Here is Eglinton Line Toronto, which used DSI's AT Pipe Umbrella System 2019.

refinements or improvements to the system over the years. One of the first moves was to automate the joining of two tube pieces on the drill arm. These weighed 100kg and so could be difficult to handle manually. The automated system used a rotating motor to screw two lengths of pipe together and was developed during the Sieberg Tunnel, ready to deploy for the Frankfurt-to-Cologne project.

A further development saw the removal of the pilot bit. This development came because feedback from sites revealed that the pilot bit was sometimes lost because it could not be disconnected from the ring bit. So, in 2008, DSI Underground made changes so that there was just one drill bit.

"With this solution, the entire drill bit is lost but the big advantage is that there are improved drilling speeds which meant that we could drill 25% faster," explains Boehm. "The material costs are higher but the time saving more than compensated for that higher cost."

The next improvement removed the need to thread the inside and outside of the tubes so that they could be connected. These were often damaged during transportation to or around site, says Boehm, leading to waste. DSI developed a squeezing joint consisting of a male pipe end which is force-fitted into a female end, using a hydraulic clamping system. This was first used on the Hirschhagen Tunnel on Germany's A44 motorway in 2013.

Again, the contractors were willing to work with a new system because they saw the potential benefit: "To be honest the system was not finalised by then, but the contractors and project owners were willing to use it even knowing that we had to fine tune it. In the end it was very successful, 120,000 metres of installation and it saved half a year of excavation time," says Boehm.

The squeezing joint has structural benefits too: with a threaded connection, the joint becomes a weak point whereas with the squeezing connection the joint is just as strong as the rest of the pipe. Using this connection rather than a threaded one also means that the walls of the pipe can be thinner, requiring less metal and hence less cost and a lower carbon footprint.

To scientifically verify the design and application of the AT-Pipe Umbrella system, Alwag worked with Graz University of Technology, Austria for decades. DSI Underground's R&D director Dr. Guenther Volkmann, who was working at the university at that time, determined analytical rules for designers by evaluating recorded tunnel deformation data and using numerical models. He then created a so-called 'geometry calculator', an Excel tool which helps define the saw-tooth-shaped geometry needed which can then be used in design drawings. The tool has evolved since then, allowing DSI to assist its customers with temporary support design.

The AT Pipe Umbrella System is also deployed in mines. The El Teniente copper mine in Chile was the first to use it in 2004. More recently, it was used in 2021 on Anglo American's Woodsmith Mine, a new polyhalite mine currently under construction in the North of England.

The success of the AT Pipe Umbrella System helped turn Alwag into an international business which made it an attractive proposition for would-be acquisitions. In 2006, it was acquired by Dywidag-Systems International and the global tunnelling and mining business was split off and renamed DSI Underground.

DSI Underground's recent move to Sandvik, where it is now Sandvik's ground support division, is helping to propel the AT Pipe Umbrella System into yet another overseas tunnelling market, this time Japan. Sandvik can now supply the entire system: drilling rig, squeezing tube connections and chemicals with a good degree of automation. The first jumbos with their integrated pipe umbrella installation capability will arrive in Japan this year.

As well as reducing risk for its customers because Sandvik is responsible for the whole system,

Germany's Hirschhaggen Tunnel was the first to use squeezing joints in 2015.

In 2016, the system was used for the tunnel portal for part of the Dulles Corridor Metrorail Project in the US.

Full-scale demonstration at Montan University Leoben's Zentrum am Berg.

the union of jumbo and umbrella system supplier means that the best technical solution can be selected. When different firms are involved, explains Boehm, there is always negotiation and compromise because each company does not want to make too many changes to their product. "We have brought the technical departments from Sandvik and DSI together and we look at what's most efficient," he says. "There is no quarrel."

Appetite for more

Although Boehm has been at the helm of DSI Austria for 37 years, he still has a strong appetite for new ideas and for change.

DSI Austria retains is 'family business' ethos, which helps when it comes to identifying problems out in the industry and then working to create solutions. "When people have problems, that's when we really see what we need to develop," says Boehm. "You have to be on the site to do that. I always tell my staff that if they visit a project, they must go inside the tunnel to watch and to listen. That is very important for us."

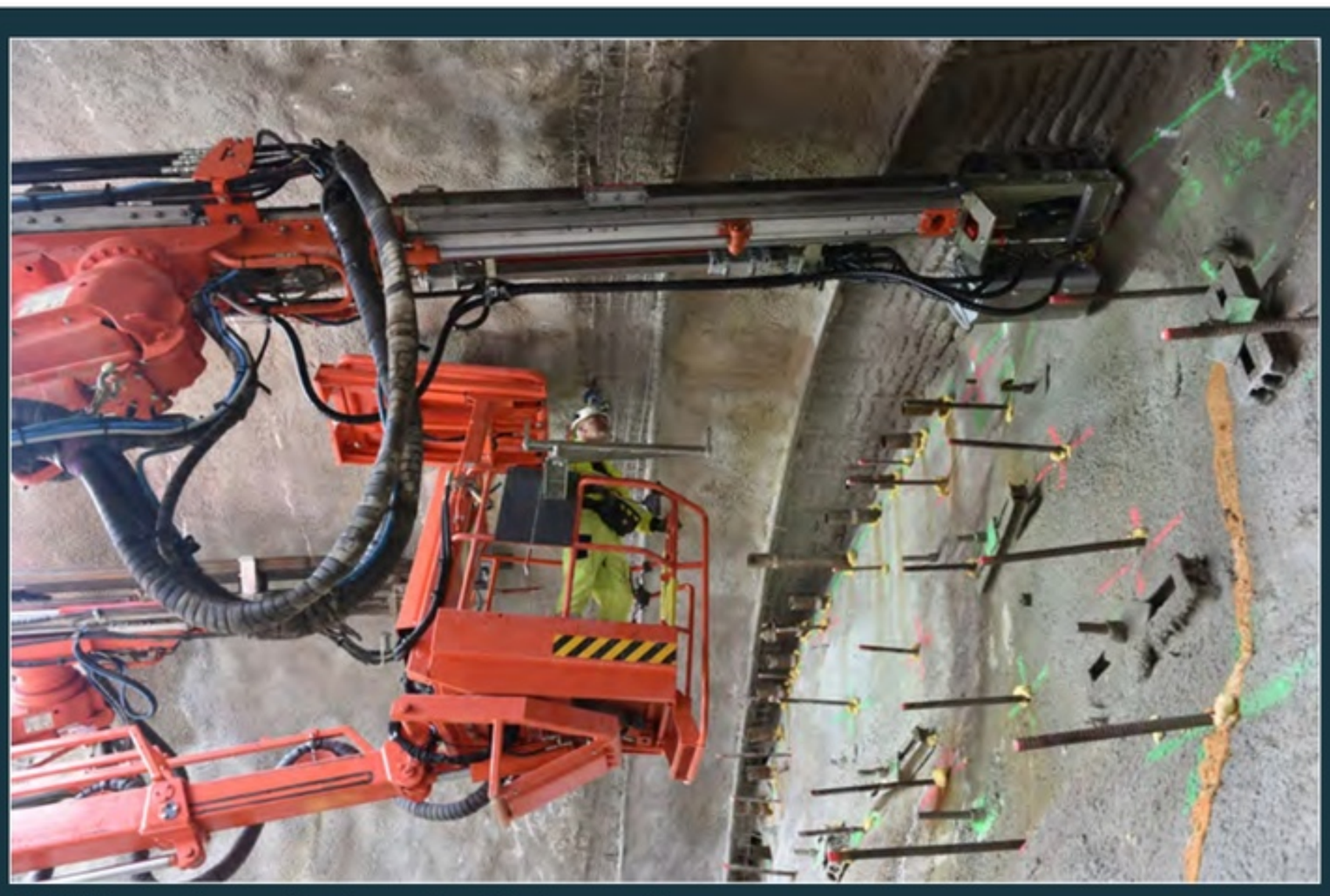
DSI's research and development efforts are centred on Austria. Recently it has started to carry out full-scale tests at the outdoor Zentrum am Berg facility, opened by Montan University Leoben in 2021. The underground facility boasts two road tunnels, two rail tunnels and a test gallery.

When seeking out future innovations, it's important to keep an eye on smaller supply chain companies too, says Boehm. "The real innovations come from the small and medium sized companies who really have the heart and the will to develop new things," he says.

One such smaller player is virtual reality training company Edvirt with whom DSI worked to create a simulation package which can be used to train people in how to use the umbrella system remotely. This development paid dividends during the Covid pandemic when DSI was able to train operatives remotely so that projects could proceed without delays while the contractors waited for trainers to make it to site.

In early 2021, DSI acquired Edvirt. Boehm now has ambitions to establish its pipe umbrella simulator tool as a global standard for training jumbo operators.

A quarter of a century after that first good idea that transformed the company's fortunes, with millions of metres of pipe installed using the AT Pipe Umbrella System, DSI is yet again looking to innovate with another forepoling system. Boehm isn't ready to say much about it, other than that testing is underway at Zentrum am Berg, Styria, Austria. Who knows where this next step will lead?



DSI trialling next-generation forepoling at Zentrum am Berg.

DSI has developed a VR package to train people remotely.