Perfect concrete solution
The PAUS UNI 50 series offers a perfect match in combination of concrete mixer and shotcrete solutions

Visit us on BAUMA in Munich 24.10-30.10.2022

Hermann Paus Maschinenfabrik
Siemensstr. 1-9  48488 Emsbueren Germany
Tel.:+49 5903 707-0
info@paus.de
www.paus.de

For further underground mining equipments please visit our websites

ANY MINERAL. ANY GEOLOGY. ANYWHERE.

For more than 130 years we have safely and successfully sunk more than 500 shafts with a depth of over 230,000 m.

We are a member of The Redpath Group, operating on all five continents and belonging to the world market leaders in the field of mine contracting and construction.

We provide our customers with a complete range of services from design and engineering to construction, maintenance, reconstruction and rehabilitation. Contact us with your shaft-related inquiries.

LEADERS IN MECHANIZED (SBR) SHAFT SINKING

Shaft station level 700 m, Slawkaliy mine Nezhinsky, Belarus

REDPATH DEILMANN GmbH
Haustenbecke 1, 44319 Dortmund, Germany
Tel.: +49 231 2891 395/396

www.redpathdeilmann.com
Content

EDITORIAL

‘Focus on Technology’ or ‘Wonders of modern Technology’  6
Katrin Brummermann

The bauma trade fair will soon open its doors, about six months late – at a time of major changes and challenges. To coincide with the 33rd World’s Leading Trade Fair for Construction Machinery, Building Material Machines, Mining Machines, Construction Vehicles and Construction Equipment, the focus of this issue is on technology – an interesting special topic for all of us in the areas in which we work, not just for trade-fair visitors and exhibitors.

Geotechnics • Tunnelling • Mining • bauma • Technology • Innovation • Sustainability

A WORD ON ...

bauma 2022: five Key Themes for a better Future  7
Klaus Stöckmann

This year’s bauma trade fair will see five key topics for a better future presented on five theme days – each seeking to address the urgent problems of our time and to help find the solutions that are needed.

bauma • Technology • Innovation • Future • Key themes • Theme days

A WORD ON ....

How a Generation Change can succeed  9
Christoph Beumer and Rudolf Hausladen

The BEUMER Group has had a new CEO since June 1, 2022. The previous and the new CEO explain how a generation change like this can succeed.

Company • Generation change • CEO • Conveying technology • Quality • Sustainability

A WORD ON ...

The World stands at the eleventh Hour  11
Peter von Hartlieb

Mankind is facing enormous challenges that threaten to bring major changes in areas such as climate protection, raw materials security and supply chain reliability. By promoting an exchange of ideas and information the bauma 2022 can help to provide and develop practical solutions to these problems.

Mining • Raw materials • Geotechnics • bauma • Technology • Sustainability • Communication • Knowledge transfer

Geotechnics

Failures of self-drilling Hollow Bar Systems, and Lessons learned  13
Racquel Nottingham and Giorgio Severi

Threaded hollow bar systems have grown in popularity and the range of products has increased. The market is flooded with many commercial options comprising different material properties and surface treatments, and providing varying methods for corrosion protection. Often the question of effective corrosion protection is at the forefront of discussions, and according to the current codes and norms, guidelines are provided and applied as required. This paper highlights some examples where threaded hollow bar systems failed and examines the possible reasons and lessons learned from such unfortunate circumstances.

Geotechnics • Micropiles • Anchoring • Failure • Corrosion protection • Standards • Reinforcing

Tunnelling

World’s longest Railway Tunnel Project – supported by innovative Conveyor Digitalisation and reliable Engineering  16
Mattia Corna and Giancarlo Leombruno

The consortium BTC Brennero Tunnel Construction and the Hosch Group jointly delivered on a world-class tunnelling project by combining excellent engineering with the innovative remote monitoring system Hoschiris Discover. System integration in May 2021 has effectively prevented any instances of serious belt damage. Moreover, service missions have become more efficient and can be scheduled on-demand.

Tunnelling • Conveying • Belt cleaning • IIoT • Monitoring • Digitalisation • Brenner Base Tunnel

More than Monorails
SMT Scharf GmbH is best known for its monorail systems. But its portfolio of products goes well beyond this. The company is widely diversified has established a reasonable position on the global market. Read more on pages 49 to 51.

https://www.smtscharf.com

Focus on technology
Predictive Maintenance of Conveyor Belts: World Premiere for the E-PrimeTracker

Thorsten Koth
Scrapetec Trading GmbH presents at bauma a technical innovation for the preventive maintenance of belt conveyors, which reduces costs, avoids downtime and increases service life.

Mining • Tunnelling • Innovation • bauma • Conveyor technology • Predictive maintenance

Energy-efficient and environment-friendly Tunnel Logistics with Automated Service Vehicles

Christoph Müller
When it comes to supplying tunnel boring machines in drivages innovative Automated Service Vehicles (ASVs) can offer an effective alternative to conventional track-bound conveyances and Multi-Service Vehicles (MSVs). This article outlines the flexibility, efficiency and environment-friendly qualities of ASVs and describes how this has been put to good use at the Kerenzerberg safety tunnel in Switzerland and at the SKW2 Kühtai pumped storage plant in Austria.

Tunnelling • Mining • TBM • Logistics • Practical applications • Construction and mining machines • Automation • Innovation

Paus: New Technologies on Show at bauma 2022

Hermann Paus Maschinenfabrik GmbH
Paus presents new technologies at bauma 2022.

Mining • Tunnelling • Geotechnics • Machinery • Innovation • bauma

Sugar Cane sweetens the CO₂ Balance of Segment Gaskets

Franziska Kachel
Innovative profiles from Sealable Solutions GmbH for sealing between lining segments in mechanically excavated tunnels are more sustainable and improve the CO₂ balance. Other relevant product properties are not negatively affected by the avoidance of fossil raw materials.

Tunnelling • Waterproofing • Segments • EPDM • Innovation • Sustainability • Building materials

Hybrid Grouting – an innovative Technology

Adriano Fumagalli, Hansjürg Baumann and Sewerin Sabew
Standard grouting equipment is limited to cement-based or organic grouting gear. Recent developments in grouting technology allow cement-based or organic grouting on a single mobile grouting platform.

Tunnelling • Mining • Geotechnics • Injection • Grouting • Mixing • Technology • Innovation

Practical Experience and Findings relating to the Preparation of a BIM Model for the Subsoil Foundations of a Tunnel Construction Project

Jürgen Schmitt, Claudio Cortese, Joachim Michael and Simon Meißner
The paper describes the practical experience and findings acquired during the preparation of a BIM model for the foundations of a tunnel construction project.

Tunnelling • Geotechnics • BIM • Modelling • Foundation subsoil

An Alternative for Mineral Oil in Hydraulic Systems

Volker Bremer
Current developments pose a risk to our supply chains. Climate change, environment protection and occupational safety are increasingly taking centre stage. This paper presents one potential solution where mineral oil-based media can be replaced by water-based polymer fluids in hydraulic systems. This is one fairly simple way in which companies can contribute to workplace safety, environmental conservation and resource security.

Mining • Tunnelling • Geotechnics • Hydraulic fluid • Mining and construction machines • Product news
How an IIoT Solution for Mining Machines can be successfully introduced into a Quarry Operation

Michael Suciu

Many mining companies still do not know whether they are ready to implement IIoT projects for mobile mining machines – and things often stay this way until they try out digitalisation for themselves in an in-house pilot project. Sometimes it is enough simply to go for it and learn from the experience. But what is actually possible and how can ‘digital transformation’ be applied in-house? The conditions and measures needed for such a successful digital transformation are outlined below from the perspective of a tech company that supplies hardware and software solutions and also supports clients through the introduction and implementation process.

Mining • Pits and quarries • Digitalisation • Mining machines • IIoT • Change management

SMT Scharf – more than Monorails

Christian Rumpf

SMT Scharf GmbH is best known for its monorail systems. But its portfolio of products goes well beyond this. The following article looks at the company’s widely diversified product line and the position it has established on the global market.

Mining • Construction and mining machinery • Digitisation • Autonomous vehicles • Trackless technology • E-mobility

Environmental Social Governance (ESG) – the Future in Mining

Martin Wedig

A raw materials turnaround in the sense of uniformly higher international standards in terms of environmental protection, social and technological development (Environmental Social Governance) (ESG) will become the future guideline in mining. The most urgent task for the coming years is to implement both issues, raw material security and ESG conformity, at the same time. This requires above all investments in the exploration, production, processing and refining of raw materials. In addition, technical innovations are needed to expand existing mining capacities and make them as ESG-compliant as possible. At bauma 2022, technological solutions and specialist expertise will be presented.

Mining • Raw materials • ESG • Future • bauma • Investment

Imprint

GeoResources Journal

8. Year. Journal for Mining, Tunnelling, Geotechnics and Equipment
Date of publication: 20 October 2022
ISSN | Online 2364-8430 • Print 2364-8422

Publication:
GeoResources appears 4 times per year in German (GeoResources Zeitschrift) and 4 times in English (GeoResources Journal). GeoResources is released as online issues on the GeoResources Portal (www.georesources.net). Additional GeoResources Journals are available as printed copies.

Purchase Price:
Online issues are free of charge. Printed issues in one language for 100 €/a, the combined English and German package for 150 €/a. Student discount 50%, incl. shipping costs, shipping envelope, VAT in Germany included.
Contact: abo@georesources.net

Publisher:
GeoResources Portal Manfred König
Oleanderweg 12, 47228 Duisburg, Germany
mobile: +49 172 244 1616
email: press@georesources.net

Editors:
Dr.-Ing. M.A. Katrin Brummermann
mobile: +49 151 70 888 162
email: kb@georesources.net
Dipl.-Ing. Manfred König
mobile: +49 172 244 16 16
email: mk@georesources.net

Freelance Editor:
Peter von Hartlieb
email: pvh@georesources.net

Media and Advertising:
email: advertising@georesources.net
phone: +49 2841 60 789 67

Production/Layout/DTP:
Herbert Stimper
email: hs@georesources.net

Print Production:
Kiess und Makossa Mediengruppe GmbH, Gelsenkirchen, Germany

Copyright:
All rights reserved ©GeoResources Portal, Duisburg, Germany - www.georesources.net - No part of this journal may be reproduced in any form by photostatic copy, microfilm or another process without the permission of the copyright owner or utilized in a form resulting from machines or data processing systems. Science and non-commercial instruction represent exceptions. Notification of use is appreciated. The contents of the submitted manuscripts remain the property of the authors (writers) providing they were submitted free of charge. The writer is responsible for the content of signed contributions and supplied photos and diagrams.
‘Focus on Technology’ or ‘Wonders of modern Technology’
Dr.-Ing. M.A. Katrin Brummermann

Most of us are familiar with the expression ‘a wonder of modern technology’. Fascination by a machine, a device or a vehicle often generates the spontaneous, admiring remark: ‘That’s a wonder of modern technology!’ But there can be a flip side: the German expression ‘a blue wonder’ refers to a nasty surprise. Technology can hold nasty surprises in store, for example if the technology fails or was actually developed for a good purpose, but also has unexpected negative effects.

So technology is not a panacea, as sometimes promised. And it cannot replace human creativity. It often makes our work or life easier, but it sometimes also leads to problems that we would not have had without it. It is up to us to make responsible use of technology. A definition of the term technology in the German ‘Duden’ dictionary reads as follows: ‘The entirety of measures, facilities and procedures that serve to make scientific knowledge practically usable.’ This definition is of little help to me in everyday life when I reflect on responsible use in practice and sensible and useful developments of technical devices and systems.

Recently, a still amazingly spry 96-year-old told me what she had replied to a woman when asked what kept her fit: Singing in the choir, reading, her great-grandchild, housework and gardening, writing letters and emails on the computer, but also by hand without a spelling checker – as a mental challenge. When she added that she was 96 years old, her much younger neighbour on the park bench was totally taken aback. What impressed me about this story? It was clearly the decision to write using a computer and a word-processing program, but in parallel to write by hand again and again as a mental challenge, and to have to think more and to stay fit.

People can decide whether and how to use technical devices, and how and when not to use them. Very different individual motives can play a role here. Computers can of course make our work easier and give us new insights, but they can also prevent us from thinking ourselves and coming up with new, creative solutions.

I wish you an interesting read
Katrin Brummermann
bauma 2022: five Key Themes for a better Future

Klaus Stöckmann, VDMA Mining, Frankfurt, Germany

‘...for a better future’ may perhaps sound somewhat trite. Yet the key themes being highlighted at bauma 2022 may provide an effective response to many future challenges. bauma – the world’s leading trade fair – has rarely been accompanied by so many expectations as it does this year: psychologically, economically and politically.

Psychologically

Visitors and exhibitors are looking forward to meeting up again face to face, with an opportunity to hold private discussions in the conference room away from the hustle and bustle of the public exhibitions area.

Economically

It is important from an economic perspective that exhibitors in all categories – construction machines, material supply systems, construction equipment, vehicles, mineral winning and processing technology, tunnel construction, site supplies and fixtures and much more besides – should have an opportunity to present themselves as state-of-the-art suppliers and to be one step ahead of the competition when it comes to product innovation.

Politically

It is politically important that the event can serve as a platform where effective answers and solutions can be presented to all questions relating to the energy transition and climate change. Those who fail to use bauma to showcase concepts, ideas and technical solutions for carbon-free construction and manufacturing run the...
risk of being disregarded as suppliers to the construction and raw materials industries.

**Five Key Themes for a better Future – with Zero Emission the ultimate Goal**

Against this backdrop the Munich fair has opted to respond by staging five key themes (these being objectified on consecutive theme days held during the event):

- Construction methods and materials of tomorrow
- The pathway to autonomous machines
- Mining – sustainable, efficient, reliable
- Digital construction site
- The way to zero emission

While all these themes naturally have their own focal point they are also of cross-sectoral relevance. Autonomous vehicles, for example, are not only used on construction sites but in the mining industry too. Likewise, zero emission is now a declared target not just at building sites (especially in intra-urban settings) but also in the extractive industry (especially below ground). And in the middle of all of this we have raw materials – which are essentially the basis of everything. Photovoltaics or silicon? Wind farms or cobalt or rare earths? Batteries without lithium? Not to mention, for example, copper, nickel and all kinds of building materials. This is why raw materials production is one of the key themes at this year’s bauma.

**Mining – sustainable, efficient, reliable**

This includes driverless vehicles and autonomous operations that are now on the advance in the mining industry both above and below ground. The Roy Hill Mine in Australia, for example, has mainly been using remote-controlled vehicles for a number of years, while several hundred driverless dump trucks are currently in operation around the world. Germany too has been engaged in the development of manless coal winning systems – all this representing real technology milestones for a better future.

What is being presented and discussed at bauma Day Two therefore has real significance for raw materials extraction too. However it can be said with all modesty that one of the key aspects of autonomous operations is to be covered in Day Three.

Under the headline ‘Mining – sustainable, efficient, reliable’ the forum due to be held in Hall LAB0 will be presenting and offering up for discussion various innovative ideas and solutions for an autonomous, environment-friendly and reliable raw-materials production system. Here the main themes will be digitisation and automation, including a realignment of the entire process and materials chain, both horizontally and vertically. The key enabler for all this is ‘interoperability’. This allows machines from various manufacturers with different control systems to exchange signals and data with one another – in other words to communicate.

The different solutions being put forward by equipment suppliers, operators and the scientific community reveal the complexity of this undertaking. The key factor here is ‘interoperability’, this feature being used first to generate information models and then to produce companion specifications (CS). The latter define the details for the interface description so that machine-to-machine communication becomes possible. The more technically oriented contributions on this topic are supplemented by a submission written from the perspective of a mid-sized mine operator that also describes the future technical and regulatory challenges.

In the same context a number of startup ventures will be presenting their particular proposals for a sustainable, efficient and reliable mining industry. The Mining theme day will be rounded off with presentations from VDMA members and other exhibitors on the latest technology for raw materials production. VDMA Mining and the Institute for Advanced Mining Technologies at RWTH Aachen University will also be organising an OPC UA Walk during the fair. Registration information available at: **VDMA bauma**. And finally, on bauma Day Five, an attempt will be made to collate all the issues that have come up for discussion during the fair and to place them in a common context under the heading ‘The way to zero emission’.

You can find the programme for the bauma forum to be held in Hall LAB0 online [1]. I am really looking forward to meeting friends old and new and to all the stimulating conversations that await us in Munich.

Klaus Stöckmann


---

**Klaus Stöckmann**

is Deputy Managing Director of VDMA Mining, Frankfurt a. M., Germany.

**Contact:** klaus.stoeckmann@vdma.org
The BEUMER Group has had a new CEO since June 1, 2022. The previous and the new CEO explain how a generation change like this can succeed.

**Company • Generation change • CEO • Conveying technology • Quality • Sustainability**

---

**Dr. Christoph Beumer ...**

Well, I can count, and when my children were born, I realized that there would be no direct succession in the family unless I kept working until I was seventy-five. However, that was out of the question because it wouldn’t make sense for the company. So I’ve been able to plan this change for twenty years and set up our organization in such a way that it can also be led by a CEO who is not a family member. The selection process was quite complex and probably one of the most critical decisions in my professional career, if not the most important. It took quite some time. The important thing is to open up, talk about where you want to go, use your network and make no secret of it. This was the only way I could find people with the necessary qualities.

When I took over the company, I was aware that a lot of things would have to change in the organization if we wanted to retain our employees and the size of our company here in Beckum. We started by defining our corporate strategy in five-year periods. We wanted more growth and more internationalization. However, growth alone must not be the goal and thus become an end in itself – in the end, it’s the result of our work. We are a family business, and we have to be profitable.

We’ve established and expanded subsidiaries worldwide. We’ve also opened and expanded plants in China and India, enabling us to produce for these regions in their respective countries. In this way, we’ve grown organically stable. There were also targeted acquisitions of international companies, such as FAM GmbH, one of the world’s leading full-service providers of bulk material handling and processing plants. This acquisition will strengthen our market position enormously. For us, it was always important to integrate the different mentalities and cultures. We are not a company with M&A divisions that systematically look for acquisition targets. When we see an opportunity, we carefully examine whether a company can dovetail with us or not. Of course, more growth also means more market visibility, which also increases our appeal to top-class executives.

**... and his successor Rudolf Hausladen**

As the new CEO, my primary goal is to continue the success of the Beumer Group. There will undoubtedly be no revolution – there’s no need for it. We’re currently in the process of preparing our strategy for the next five years – Strategy 2028. As a new member of the Beumer Group and the first external CEO, this is an essential step for me to close the link to Christoph Beumer and the family. It’s also crucial to prepare for the change to the fourth generation if a member of the Beumer family takes over the leadership again in the future. We also must ensure that a new generation of leaders and experts is established in the organization over the next ten to
Sustainability plays a significant role in everything we do. We also link this to the environment holistically, meaning to the economy and society. We introduced the Bumex Sustainability Index in 2008, a uniform validation system for all our products to measure sustainability. We believe that as a company, we must take responsibility. Sustainability is the most critical issue of our generation, and that’s why it’s been part of this company’s values for a long time. This approach, however, also requires a rethink, especially for manufacturers who are represented worldwide with several locations.

We should stop thinking only in a cost-optimized way; we must, above all, be more flexible. If a company manufactures a product at one location and then ships it to another location because another component is produced there or the customer is located there, this is not sustainable. Especially in these times of unstable supply chains, many customers are willing to pay a higher price for more reliability.

**BEUMER Group**

BEUMER Group is an international leader in the manufacture of intralogistics systems for conveying, loading, palletising, packaging, sortation, and distribution. With 5,100 employees worldwide, BEUMER Group has annual sales of about EUR 1.1 billion. BEUMER Group and its group companies and sales agencies provide their customers with high-quality system solutions and an extensive customer support network around the globe and across a wide range of industries, including bulk materials and piece goods, food/non-food, construction, mail order, post, and airport baggage handling.

For more information visit [www.beumer.com](http://www.beumer.com)

---

**Dr. Christoph Beumer**

Family member and majority shareholder of the BEUMER Group

**Rudolf Hausladen**

The new CEO of the BEUMER Group

---

**Discover the new GeoResources Portal and the Online Market Place 4.0**

[www.georesources.net](http://www.georesources.net)
The World stands at the eleventh Hour

Peter von Hartlieb, Dusseldorf, Germany

It’s high Noon and the Race is on

With negative reports every day about the disruptive effects of the war and its global consequences since March 2022 we seem to have become overstretched in all kinds of ways. The relationships involved are so complex that we normal citizens, and even the experts, lobbyists and politicians – including those at the very top – are incapable of providing a reliable assessment of the developments and their implications. Have governments even come up with an agreed path that can be understood and supported by the population at large? Are the aims realistically attainable and can the measures be afforded? Are we heading for a new kind of dependency as we again shy away from the risks of greater involvement in overseas mining projects? In its 26th edition published in June 2022 DER SPIEGEL wrote about the mistakes of the past in the following terms: ‘The gas industry has been driven by hope, poisoned by mistrust and viewed with suspicion.’ Accounts of the Federal Chancellor’s Africa trip in May and the G7 summit held at the German Schloss Elmau in June reported that in response to the question of whether they wanted to join an alliance with the West leading African politicians replied: ‘We are being invited for the first time to take part in discussions on issues that will affect the future of the planet. We now need time to consider who we want as partners in this venture.’

Railing against Change – it’s human Nature but it serves no useful Purpose

There will be changes to come. The entire world is in turmoil and there is real apprehension that the repercussions of this year’s events will have a personal impact on all of us. As we look back on what has happened in recent months many are now seeking and hoping for external guidance and clarification. We are looking for security to ease our growing sense of anxiety. And just as it was during the peak of the Covid pandemic we have quickly come to be dependent on the guidance of ‘experts’ – on their assurances and their confidence and on the supposed definitiveness of their judgment. Time and again we like to transfer our responsibility and exchange it for mere words. But this only means giving away something that lies within our control and swapping our uncertainty for an illusion of security that is being offered to us by others. And in the same breath we do not think and act ourselves. We listen to the judgment of others and are quick to block out the fact that in spite of everything we ourselves ultimately have to bear the consequences.

Mankind, Technology and the Future

It is against this backdrop that the bauma trade fair, which is to be held in Munich this coming October, provides us with an opportunity to take stock and to venture a look at the years ahead. I sincerely hope that man’s labours and the activities of companies will once again be characterised by qualities such as social interaction, empathy, creativity and skillfulness.

One of the key themes at bauma 2022 should probably be presented as a question: what kind of problems will arise and what kind of trends will develop when the world opens up again and work resumes in full? How can we ensure that fair and transparent supply chains are created across the entire spectrum for the raw materials that are needed for a transport and energy transition based on sustainable and environmentally-friendly methods of construction? What kind of technical innovations in the form of construction and mining machines and vehicles can usefully be brought to bear in this area? What sort of new and improved products are
available and/or desirable? How can those mainly mid-sized German companies that specialise in mining plant and machines and in the mine service sector preserve jobs at home and create an environment in which they can innovate and apply their wealth of know-how and their technical creativity and expertise, and where they can forge alliances with overseas partners? How can we prevent supply chain problems affecting our manufacturing companies, mine operators and construction companies and, ultimately, our societies?

And does the same not hold true for those companies operating outside our national borders – in the countries where we source our raw materials? In those places where our service personnel work, where our on-site storage facilities are located and which provide jobs for our locally-based colleagues. De-globalisation should not and will not happen. Here too the decision will be ours to take.

**Making the most of Opportunities**

One thing that will not be lacking in the world of tomorrow is opportunity. And there are options a plenty to be found. The children’s author Erich Kästner coined the phrase: ‘Nothing good happens unless you do it!’ Far-reaching changes will have to be made if we are to meet the challenges that face us and future generations. So let us do our bit to turn back the world clock. With this in mind let us change the way we live and the way we work and to this end let us apply the specialist skills that we have in the construction, mining and raw materials sectors, for this expertise will be vital for the tasks that lie ahead.

**Inspiration through Communication – both within our Homeland Industries and with the outside World**

Professionals from the relevant industries have joined with scientific bodies, institutes and organisations – this including colleagues at DERA within the BGR and at VDMA Mining, as well as at various neutral networks, the GTAI and the GMN – and have for years, and not without reason, been calling for greater headway to be made in digitisation, communication and knowledge transfer and have been working to ensure this.

We cannot let our motivation wane. We must take on a new identity through courage and confidence and make broad circles, like a stone dropped into water. The motive force behind this is communication and knowledge sharing, both within the industry and beyond it. Specialist portals like GeoResources can make a real contribution here in the form of digital transmissions and printed products.

With a modern digital marketplace 4.0 in the GeoResources portal www.georesources.net the website will in future be geared towards companies, institutions and specialist practitioners based within the relevant industries, but will also be search engine optimised so that external users will have access to suitable products, targeted services and expert advice from around the globe.

Find out more about the media that can support your work in the most effective way and make use of the tools and utilities that have become available. There is not an expert in the world who can make the decision for you or weigh up its implications.

Add to this the fact that events like the bauma are the ideal platform for face-to-face encounters, personal interaction and vibrant presentations that you can almost touch. The bauma will be a place for ideas, inspiration and sound solutions. Munich will once again be a meeting point for the whole world – just a few months later than originally planned. May I wish all showgoers and exhibitors a very successful bauma 2022 and the energy we need to turn that clock back.

With sincere best wishes

Peter von Hartlieb

---

**3D Components for BIM Models**

- Micropiles
- Anchors
- Soil nails

FRIEDR. ISCHEBECK GMBH
Loher Str. 31-79 | DE-58256 Ennepetal

All components and component groups available to import directly into Revit.
For further information: export@ischebeck.de

Peter von Hartlieb
Contact: pvh@georesources.net
Failures of self-drilling Hollow Bar Systems, and Lessons learned
Racquel Nottingham and Dott.Ing. Giorgio Severi, Friedr. Ischebeck GmbH, Ennepetal, Germany

1 Introduction

Over the years many failures involving threaded hollow bars have been observed and recorded but the reasons have not been truly investigated. Hollow bar systems in this study refer specifically to threaded hollow bar systems where the threads have been pressed into hollow steel tubes for the purpose of creating reinforcing elements. These elements are extended via coupled connections until the desired length is achieved (Fig. 1).

Self-drilling, hollow bar systems are three-in-one continuously threaded hollow bars that function as drilling rod, injection tube and reinforcement, and are installed through rotary percussive drilling. Whilst drilling, the elements are continuously grouted using dynamic injection, initially with a watery grout as flushing fluid, which forces the soil particles away from the drilling rod and generates a rough interlocking surface at the interface between the grout and ground. Once the designed length is achieved, the borehole is filled with high-strength grout, leaving the hollow threaded bar as the reinforcement.

Hollow bars can be applied to many geotechnical systems such as micropiles, soil nails, anchors, rock bolts, and roof bolts. They provide different solutions to problems including, but not limited to, slope stabilization, anti-heaving, tunnelling, mining, and retaining structures. Due to the size of these elements, they can be installed in different site conditions with the aid of appropriately sized equipment. Even in cramped spaces, with minimal headroom or lateral room, these hollow bar systems have proven their worth on the market.

Since these hollow bars have a wide range of applications, so too are the different codes and norms to which they can be designed. The European Standardization Committee has developed several standards that regulate the use of hollow bar systems according to their application. These standards provide specific guidelines – often by means of execution standards – on materials, design considerations, execution, testing, and record keeping. The material specifications summarised below are often overlooked in design.

2 Materials

Table 1 summarises the standards according to applications and type of load bearing elements. Table 1 includes not only the hollow bar guidelines but also the hot-rolled elements that are often used for similar applications. It gives the allowable grades as presented in the relevant standards.

The standards are very clear about which steel grades can be used and for which purposes. In the case of hollow bars, only grades which conform to the EN 10210 or EN 10219 may be used in the listed applications. The standards also state: “Other materials or grades for reinforcement and load bearing elements may only be used if their suitability has been proven (EN 14199 [2]).”

The EN 10210 [4] and EN 10219 [5] give the material classifications in accordance with the classification of EN 10020 [9], which categorizes steel elements based on their chemical properties. These categories include non-alloy steels, stainless steels, and other alloy steels.

Fig. 1: Section through a typical self-drilling hollow bar

<table>
<thead>
<tr>
<th>Application</th>
<th>Execution standard</th>
<th>Hollow bars</th>
<th>Hot rolled bars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground anchors</td>
<td>BS EN 1537 [3]</td>
<td>EN 10210 or EN 10219-1</td>
<td>EN 10025</td>
</tr>
</tbody>
</table>

Table 1: The material standards classified according to the applications and the allowable grades as given in the standards.
3 Failure Examples

3.1 Anchor Failure

A retaining wall was anchored using both Titan and rope thread elements (Fig. 2). The installation of both element types was carried out at the same time and the heads of all the bars were coated with the dark red oxide coating for corrosion protection. After some time, all the rope thread anchors appeared to protrude from the face of the wall as shown in Fig. 2 (left), but the Titan anchors, Fig. 2 (right), remained fixed as per the design requirement.

Further investigation showed that the rope thread elements were fully corroded and could be manually extracted from the grout. From initial investigation, the bond between the steel and grout was not sufficient.

Embedded steel structures within the ground are often susceptible to corrosion arising from an electro-mechanical reaction. Varying soil conditions behind the wall can easily recreate an anode and cathode situation, allowing electromagnetic currents to flow and induce corrosion.

The two load-bearing elements in this aforementioned project, have significantly different properties and characteristics that could explain the increased corrosion and subsequent debonding that was observed on site. The rope thread (ISO 10208 and ISO 1720), magnified in Fig. 3 (left), is characterised by the shallow rope-like threads pressed into the quenched and tempered welded steel tubes. The shape of the threads gives rise to much larger splitting forces which creates an uncontrollable cracking pattern in the grouted body. Titan’s thread according to 10080 [10], magnified in Fig. 3 (right), features a trapezium shaped thread with the groove removed from the ridge, emulating that of a rebar. This shape promotes smaller splitting forces to form at every crest. This controlled cracking pattern allows for much smaller cracks to form which do not reach the edge of the grout body thereby preventing the load-bearing elements from direct contact with hydrogen and oxygen from the surrounding soil. Such contact would disrupt the anodic and cathodic processes, thus advancing the corrosion.

In this particular example, further protection could have been provided by modifying the head construction to include a cap filled with grease. This would protect the exposed head of the anchor and could easily be removed for testing and restressing. A further method of corrosion protection is to apply coatings to the elements – either one coat of galvanizing, or duplex coating of the elements.

3.2 Soil Nail Failure during Installation

Slope stabilization works were ongoing along the slope shown in Fig. 4, when a part of the slope began to fail. An entire section of the slope experienced the typical circular slip failure and many of the soil nails were completely severed at the heads, bent or completely destroyed.

Upon investigation, several reasons for the failure were determined, the first and foremost being that design was inadequate. The soil nails were not designed with a length sufficient to intersect the critical slip surface and thus severely under-designed. With any change in the soil properties, the failure that should have been prevented by the nails was not because the nails were completely inefficient. In addition to the short elements, arguments were raised regarding the errors in the installation as sufficient grout (according to the standards) was not provided to ensure that a properly grouted element was formed.

The design is extremely important and so too the geotechnical investigation prior to the design phase, to ensure that the engineers have all the information necessary to reproduce an accurate model to design the reinforcement.

3.3 Pile Wall with Tieback Anchors

A pile wall was constructed along a new express route and featured Designed For Flysch (DFF) piles with H-beam struts and tension micropiles as tiebacks (Fig. 5). These DFF piles were designed specifically for the geological conditions of the Carpathian Flysch found
in Poland [11]. After the piles were installed, the tension micropiles were installed in rows as the excavation progressed. However after excavating below the second layer of tension tiebacks, the heads of some micropiles broke and others failed. The wall started to visibly displace, and a displacement of 87 cm was recorded before the works stopped.

The investigations into the failure were very extensive and tensile tests proved that the micropiles only reached 20% of their design loads. Further site investigation, post-failure, showed that the design lengths of the micropiles had not been achieved and the grout encapsulation was discontinuous and, in some cases, almost non-existent [12].

Similar to the previous example, both the design and also the material selected for the tension micropiles were inadequate.

4 Conclusion

This paper has presented some failed self-drilling hollow bars in practice. The reasons for the failures can be classified according to inadequacies in the design, material, installation, or a combination of all three. It is especially important that as designers, we meticulously consider the quality of products available on the market that claim to comply with a certain specification without providing proof of tests or test results to confirm these claims. The norms are also clear as to which materials that may be used, and for which specific application.

5 References


Fig. 5: Pile wall and two rows of tiebacks before the excavation proceeded and broken micropile heads (small photo) that littered the site post failure


Racquel Nottingham, M.Sc.
Geotechnical Design Engineer,
Friedr. Ischebeck GmbH,
Ennepetal, Germany
Contact: nottingham@ischebeck.de

Dott.Ing. Giorgio Severi
Area Manager of Friedr. Ischebeck GmbH in Italy.
Contact: severi@ischebeck.de
World’s longest Railway Tunnel Project – supported by innovative Conveyor Digitalisation and reliable Engineering

Mattia Corna, Brennero Tunnel Construction (BTC), Mules, Campo di Trens, Italy
Giancarlo Leombruno, Hosch Group, Recklinghausen, Germany

Introduction

When completed the Brenner Base Tunnel will be the longest underground railway connection in the world. Such complex tunnelling projects and massive underground constructions are a challenge to engineers and equipment alike. But the effort will be well worthwhile. Regional cross-border transport will become much more time and cost efficient. However, the construction work has to tackle a number of logistical challenges and the 230 km of tunnel drivage calls for enormous quantities of rock to be transported over long distances. As excavation works are driven from both ends of the tunnel each side has to maintain conveyor systems that are critical to the whole operation. With only limited pil-

The consortium BTC Brennero Tunnel Construction and the Hosch Group jointly delivered on a world-class tunnelling project by combining excellent engineering with the innovative remote monitoring system Hoschiris Discover. System integration in May 2021 has effectively prevented any instances of serious belt damage. Moreover, service missions have become more efficient and can be scheduled on-demand.

The consortium BTC Brennero Tunnel Construction and the Hosch Group jointly delivered on a world-class tunnelling project by combining excellent engineering with the innovative remote monitoring system Hoschiris Discover. System integration in May 2021 has effectively prevented any instances of serious belt damage. Moreover, service missions have become more efficient and can be scheduled on-demand.

Tunnelling • Conveying • Belt cleaning • IIoT • Monitoring • Digitalisation • Brenner Base Tunnel

Hardware Reliability Improvement based on state-of-the-art Belt Cleaning Technology tailored to operational Requirements

To reduce component wear, carry-back material and unscheduled downtime, a combination of Hosch scrapers HD-PU-S2 and D2 scrapers was chosen and installed.
at the identified section (Fig. 3). This combined set-up was no coincidence, but was a result of Hosch Group experts working in close cooperation with the operating technicians. The tunnel advance rates being achieved means that the conveyed material and its physical properties are changing permanently. Predicting component wear by cohesiveness and abrasion rates was impossible and had to be solved in practice.

Partnering with the Hosch Group in this challenge produced an immediate impact. By deploying their unique experience in belt cleaning systems and ultra-resistant wear parts, the conveyor experts from Germany were able to design and integrate a reliable and low-maintenance solution. This includes the flexible adjustment and improvement of components during the first weeks of operation. To facilitate speedy implementation engineers from Hosch accompanied the service technicians at the construction site, the operation also being supported by R&D Experts from Hosch HQ, which tailored components to match the requirements.

Reducing Risks and operational Challenges with Remote Monitoring

While having a reliable belt cleaning solution is essential for improving belt lifetime and conveyor availability, several more risks occur when operating a conveyor system. Apart from rollers and drives, the most common down-time triggers are splice-failures. Furthermore, when operating a long-distance conveyor line, keeping an eye on the belt condition is usually associated with time and labour extensive service missions, or so called ‘belt-walks’. Such missions are an even more challenging endeavour in a tunnel where two conveyor lines and a heavily frequented train track are running side-by-side. Repairing a belt splice can take 10 to 40 hours, depending where in the tunnel the damage occurred and how heavy the load on the belt is at the moment of incident.

In order to enable a more efficient prioritisation and timing of maintenance efforts for the belt, the Hosch HD-PU-S2 scraper was equipped with the patented Hoschiris Discover Unit for continuous belt monitoring. An important part of the operating principle of Hosch belt scrapers is continuous contact with the belt surface. Due to advanced engineering and bearing design Hosch scraper blades can maintain seamless contact with the belt surface. This unique ability was primarily taken into account when developing and installing the Hoschiris Discover. This sophisticated remote monitoring system makes use of the privileged position and ability of the scraper, while magneto-inductive position sensors are able to detect even the slightest deflection of the scraper blades (Fig. 4).

The remote monitoring system provides immediate feedback about changes or damage to the belt surface. A straightforward and automated data analysis system was also included to support the operator’s decision
making process. Three-staged alarm thresholds are defined in conjunction with the individual data signature of the belt. Notifications about detected anomalies and their severity can therefore be transmitted without delay. Having such a reliable notification system in place, means that capacities can be focused on more urgent operational challenges.

The system also includes a camera at the belt head, to validate registered events and perform remote visual inspection. The camera stream and the sensor data and insights are both presented in real-time on a screen in the control room. The Hoschiris Discover Web provides information on operating times, scraper wear, registered scraper deflection and triggered alarms (Figs. 5 and 6).

**From digital Potential to operational Excellence**

It is a well-known fact that a digital application is just as capable as its user. The additional insights provided by Hoschiris Discover therefore had to be taken on board by site management and maintenance technicians. Apart from being notified about irregularities on the belt surface, engineers took advantage of the detailed data visualisation capability. By comparing observations during maintenance missions with correlating data patterns, the operating team grew in confidence in its ability to identify belt splices, belt sections and general belt conditions. Over time maintenance missions were scheduled according to data signatures rather than fixed in intervals. This innovation allowed capacities to be released for investment in other critical parts of the operation.

The Discover system was further utilised to identify and remove oversized material or metal objects that could cause serious belt damage along the whole conveyor line. Technicians experienced with the Hoschiris Discover system and the conveyor installation were able to identify potential events and developments, even before alarms were triggered. Thanks to the Discover System they can now pinpoint the indicated belt damage along the 20 km conveying system to an accuracy of about 10 m.

During the course of the project over 180 million metres of conveyor belt have been scanned and monitored by fully automatic means. Every month about 150 GB of data is recovered, analysed and visualised in order to generate operational benefits and insights for the maintenance management. These figures show that the need for digital applications to monitor conveyor belts can be met by deploying small but smart and pragmatic installations. Robust technology combined with sophisticated mechanical equipment transforms a high-performing belt-cleaning product into a digital remote monitoring solution that can help to keep the whole operation running.

**Efficient Operations driven by digital Solutions as the new Standard**

The application described in this article highlights the obvious benefits of introducing reliable digital monitoring solutions into operational planning. With the digitised society now becoming a reality, the tunnel-
Tunnelling sector and heavy industry in general are still struggling to close the gap. There are many reasons for this. Outmoded equipment and operating procedures, as well as a lack of industry-ready and sufficiently rugged technology are just some obstacles. On the other hand, future generations and the workforce of tomorrow will certainly have a challenge to cope with non-digital practices and processes. What is more, the costs incurred for skilled labour and manual operations will continue to increase. So the stakes are high. Combining of engineering expertise with operational ingenuity, as demonstrated here, can deliver real benefits when it comes to digital monitoring in practice – and this is possible right now.

BTC Brenner Tunnel Construction and the Hosch Group have shown how mutual cooperation and a readiness to accept new technology can improve plant maintenance efficiency. The direct impact of this is greater plant availability and reduced safety risks. The number of tunnelling projects without digital monitoring and predictive maintenance on-demand will fade. It is now set to decline as we go forwards. The future focus must therefore be on project-based experience and future-ready equipment.

**Mattia Corna**
Plant Manager, Brennero Tunnel Construction (BTC), Mules, Campo di Trens, Italy
*Contact: m.corna@btctunnel.com*

**Giancarlo Leombruno**
International Business Development, Hosch Group, Recklinghausen, Germany
*Contact: giancarlo.leombruno@hosch.de*
Predictive Maintenance of Conveyor Belts: World Premiere for the E-PrimeTracker

Thorsten Koth, Scrapetec Trading GmbH, Kamp-Lintfort, Germany

Scrapetec Trading GmbH presents at bauma a technical innovation for the preventive maintenance of belt conveyors, which reduces costs, avoids downtime and increases service life.

At bauma, ScrapTec Trading GmbH, a specialist in the optimization of bulk material conveyor systems, will be showing a system for the first time that will make the maintenance of belt conveyors much easier and significantly increases their availability and service life: the E-PrimeTracker.

As great as the benefits of this system are, its structure is just as simple. The tried-and-tested PrimeTracker is installed on the existing belt system (Fig. 1): a guide roller that detects belt misalignment and automatically corrects it. The developers at Scrapetec have integrated robust sensors into this roller, which record central and meaningful characteristic values – for example the belt position, the belt speed and the condition of the belt connection.

This world premiere thus creates the prerequisite for continuously and comprehensively recognizing and documenting the ‘health’ of a belt conveyor in the sense of condition monitoring and predictive maintenance – with the aim of reporting irregularities and eliminating them as quickly as possible. A compact industrial computer, which is mounted directly at the conveyor belt in a robust, dust-proof and splash-proof housing, performs the data evaluation required for this.

The compact computer sends the operating data relevant to the status via mobile communications or WLAN, e.g. to a control room or to the laptop or mobile phone of the service personnel. An on-site status display, e.g. with warning or indicator lights, can also and additionally be implemented. There will also be an app that will give on-site service technicians or maintenance planners mobile ‘remote’ access to every E-PrimeTracker at the company’s premises.

This transparency with regard to operating data and irregularities increases operational reliability significantly – and it reduces the risk of unplanned downtime. Wilfried Dunnwald, managing partner of ScrapTec: ‘With the E-PrimeTracker, the user can continuously monitor the critical operating data of the conveyor belt and easily integrate the belt into preventive maintenance systems. Service requirements can be derived from the transmitted data because the sensors reliably detect changes and issue a warning message at an early stage – before major damage or a belt downtime occurs.’

The system also collects and documents the recorded data. On the basis of this data, the user can, for example, optimize the belt’s driving style and thus extend its service life. Irrespective of this, the conveyor belt tracker continues to fulfill the task of detecting belt misalignment and automatically correcting it.

At the bauma, Scrap Tec is showing a first functional and series-ready prototype of the E-PrimeTracker. Wilfried Dunnwald: ‘We see this prototype and this presentation as a basis for talking to visitors about their specific requirements for condition monitoring and preventive maintenance of conveyor belts. We have many ideas on how to expand this first system – for example by integrating additional sensors, for monitoring the condition of the roller bearings, or by using artificial intelligence to evaluate the data. We are very excited to see what ideas and suggestions the bauma visitors will contribute.’

Thorsten Koth
Sales, ScrapTec Trading GmbH, Kamp-Lintfort, Germany
Contact: thkoth@scrapetec-trading.com
bauma 2022: Hall C2, booth 225/14

Fig. 1: Guide roller of the E-Prime Tracker for easy installation in existing belt conveyor systems - left photo and right sketch
Source: ScrapTec Trading GmbH
Energy-efficient and environment-friendly Tunnel Logistics with Automated Service Vehicles

Dr Christoph Müller, VirtuRail GmbH, Schruns, Austria

Background

Track-bound conveyances and diesel-powered Multi-Service Vehicles (MSVs) are the traditional solution when it comes to supplying tunnel boring machines with the materials they need for carrying out TBM drivage projects. Here logistics operations have often proved to be a source of holdups that impair the drivage performance, especially as the tunnel reaches its end. The choice of transport logistics is therefore crucial for the overall tunnelling performance and for the commercial success of the project. The latter is also dependent on primary energy costs and expenditure on the ventilation system, together with factors that are indirectly and/or not directly related to monetary aspects, such as the provision of a flat roadway surface without obstructive railtracks that is suitable for standard transport vehicles and the possibility of an unbroken transport route, which may even include steep ascents and descents.

[1] reports on a new transport system in which trains of rubber-tyred vehicles were deployed at the Ahrental construction site in order to supply a TBM operating in the Brenner Base Tunnel in Austria. The trains were electronically controlled in such a way that each vehicle axis exactly followed that of the first car as if running on a virtual track. This system ran successfully from 2016 to 2020 and remained accident-free throughout, including having to negotiate a 2.4 km-long section with an 11% descent.

This technology has now been further developed and commercialised by VirtuRail GmbH, which was set up some two years ago with its two partner companies: the Austrian tunnelling specialists Jäger Bau, based in Schruns, and the automation company MineTronics GmbH of Ladbergen in Germany. VirtuRail develops and produces electrically powered, highly automated Automated Service Vehicles (ASVs) that are specifically designed for delivering emission-free, energy-efficient and cost-effective transport logistics, primarily for the mining and tunnelling industries (Fig. 1). Dispensing with costly rail infrastructure greatly increases operational flexibility on-site as all the travelways can also be used by normal road vehicles – a factor that greatly simplifies the organisation of the entire construction site.

Fig. 1: ASV train operating in the tunnel

- Individual vehicles and train sets: Unlike conventional MSVs, ASV trains comprise fully functional individual vehicles with their own drive units and energy supply systems. These can be operated as stand-alone units or can be coupled together to form a train of cars, thereby providing a high degree of flexibility for construction site deployments.
- Electric drive: Every ASV is designed as an individual vehicle with its own electric-motor drive and the latest high-voltage battery with lithium-ion technology. Each ASV is therefore a fully functioning vehicle in its own right.
- Travel speeds: ASVs are provided with drive and automation systems that enable travel speeds of up to 30 km/h. This makes for efficient deployments, even in long tunnel drivages.
- Ascending and descending routes: An increasing number of infrastructure tunnels, and especially base tunnel drivages, can only be reached via access tunnels with declines of up to 12% and measuring several kilometres in length. Here the question that arises is whether to operate a transloading system or maintain an unbroken transport route. When run-
ning down gradient at speeds of up to 12 to 15 km/h ASV trains are able to convert the downhill force into electrical energy by using an energy recuperation process charging the batteries. This significantly reduces total primary energy consumption.

- **Automation:** As the vehicles are fitted with electronic controls and extensive sensor technology for environment recognition the ASV concept is already fitted out for all-automatic, autonomous operations.

- **Functional safety:** The redundant setup of the electronic control system provides for a level of functional safety that exceeds the minimum normative requirements. This built-in redundancy also ensures the highest possible failsafe performance along with additional emergency drive functions.

**Vehicle and System Concept**

The ASV concept uses the modular design principle whereby vehicles are divided into categories according to width: ASVs are currently available in widths of 120 and 160 cm, with a 180 cm-wide model now undergoing development. Each vehicle consists of a chassis with two or four individually steerable axles, one or two of these axles being fitted with an electric drive system.

**Drive Unit and Energy Supply**

The output of the electric drive system is adapted to suit the type of vehicle and the project in question. The motors fitted up to now have ranged in capacity from 50 to 95 kW.

Energy is supplied from Li-ion batteries that have a safety rating which allows them to be used in both industrial and road transport applications. There are currently battery systems available with capacities of between 64 and 185 kWh per individual ASV. This means that even longer tunnel drivages can be supplied using all-electric vehicle technology. In the event that this output still proves insufficient in a particular case it would in theory be possible to install a diesel hybrid generator on one of the ASV train units. This would also call for a high-voltage cable to be run the length of the train, though this can be completely dispensed with when battery technology is used exclusively on the individual vehicles.

The configuration of the powertrain can be adapted to suit the project in question. This means that the downhill energy can be fully recuperated on descending runs, a benefit that can result in huge energy-cost savings under certain conditions.

Normally the batteries can be kept charged using on-board charging systems. These only require a standard 380 VAC/63 A connection and a corresponding Wallbox unit per vehicle. DC charging stations can also be used if higher charging capacities are needed.

**Auxiliary Equipment**

A water-glycol cooling system is installed for the drive and high-voltage equipment and for the battery units. If required this system can also be provided with a heating facility so that in the winter months the batteries can be thermally conditioned prior to service.

The steering and brakes are supplied by an electrically operated hydraulic power pack and are electronically controlled for full redundancy. The steering and braking equipment meets all current vehicle technology requirements and is designed for immediate full functionality even in the event of a failure of one of the redundancy circuits.

**Functional Safety**

Vehicle safety, particularly in respect of the electronic functions that govern steering and braking, has been developed and validated from the ground up in accordance with EN 13849. The redundant design of the automation technology, and to some extent of the machine technology too, not only provides for a high level of PLd-based functional security but also means that tunnel blockages caused by individual failures can largely be avoided, as instead of simply switching off the vehicles can usually continue to operate, albeit at a reduced speed.

**Travel Configurations**

A remote control system is available for shunting and maintenance functions. This can be connected up to each individual vehicle or train section. In the normal regime individual vehicles are operated by remote control from freestanding control consoles. Complete train units are operated from a portal-side driver’s cab, the driver’s seat being turned about for travel towards the TBM so that the driver gets a full view of things with the aid of a video screen mounted on the back wall of the cab (Fig. 2). In manual mode the travel speed is limited to a figure that lies within the speed range of conventional MSVs and one that is specified and electrioni-
cally configured as part of the risk analysis carried out in conjunction with the worksite.

Automatic and Assistance Functions

For safety reasons full travel speeds are only enabled when the ASV train is operating in an assistance or automatic mode. To facilitate this, sensor carriers (SRCs) are fitted at each end of the train, these units also featuring standard-conforming vehicle lights (Fig. 3). The latter are already set up for status signalling with coloured LED strips, a system that is now being used on autonomous vehicles operating in the mining industry.

The sensor carriers are fitted with an environment sensor system that can see up to 80 m ahead of the vehicle. This system ensures that the travelway is free of obstacles and serves as an automatic navigation device for the ASV train: here predefined route segments are used to determine electronically exactly where the ‘virtual track’ is along which the vehicle should travel section by section – in other words along the centre line of the tunnel or 1.5 m from the right sidewall. The maximum travel speed is also configured, this being reached provided that there are no obstacles present that could restrict the travelway.

Obstacles lying within the clearance gauge result in an automatic reduction in the vehicle speed as a function of the available roadway width. When set in automatic mode vehicles are also able to respond automatically by driving around any obstructions and if the clearance gauge is not sufficient to allow the vehicle to pass through the ASV will automatically come to a stop. With the vehicle in automatic mode, as soon as the driver moves the joystick, thereby issuing a manual steering command, the ASV immediately switches to manual operation.

The roadway sections are also electronically marked with RFID tags on both sides of the tunnel and this ensures an automatic, tamper-proof switchover to the next travel segment.

With these functions already in place VirtuRail ASVs are systematically set up for autonomous operation.

Remote Connectivity

The ASVs are fitted with communication equipment that provides permanent remote connectivity via a WLAN system. This also makes the vehicles accessible for advanced diagnosis to be carried out remotely by technical specialists, while in the future it will also thereby be possible to implement online functions aimed at optimising operational and service-related performance.

Operational Experience to Date

VirtuRail ASVs are currently operating in two major construction projects: a 160 cm-wide ASV160 set of cars is working in a safety tunnel being constructed for the Kerenzerberg motorway tunnel that forms part of the A 12 Zurich to Chur link in Switzerland, while an ASV120 train is being used to support work under way at Tiwag’s SKW2 hydroelectric power plant at Kühtai in Austria. Unlike diesel vehicle projects, the planning required for every ASV operation mainly focuses on the energy availability factor and is designed to ensure that selected battery capacities are suitable for the routes in question and that battery charging can take place as necessary during the planned charging periods.

Kerenzerberg Safety Tunnel, Switzerland

As part of the Kerenzerberg Safety Tunnel project crosscuts to the main road tunnel, along with a number of connecting ventilation galleries, are to be driven to the rear of the main tunnelling operation by drilling and blasting, this being done concurrently with the TBM drive. This places enormous importance on the flexibility of the logistics system.

It was therefore originally planned to deploy an ASV train of four vehicles in order to supply the TBM operation and to use two ASV trains each comprising four cars to act as mucking units for the cross-cuts. In practice it was found that it was much more flexible to operate with individual vehicles for mucking-out behind the tunnel drivage, these subsequently being fitted with suitable operator’s platforms. The original plan was therefore modified to create a configuration comprising two ASV trains each of three cars for supplying the TBM. These consisted of two vehicles for the full-ring support system and one vehicle for bringing in the pea gravel. A further four individual cars were provided as follows:

- One vehicle for supplying the TBM with cement, pipes and other materials
- Two vehicles each fitted with two containers for mucking out the shotfired drivages
- One vehicle for supplying the roadway slabs and for placing gravel containers and personnel cabs
The second project involves supplying a TBM operating in the water diversion gallery for Tiwag’s Kühntai 2 hydroelectric power plant in Austria. This tunnel, which is only 4.2 m in diameter, is being driven by an open TBM. The ASVs that have only recently been introduced into the project are just 120 cm wide, but in view of the overall tunnel length of 25 km have been fitted out with a battery capacity of 140 kWh per vehicle (Fig. 5). It is planned that the automation level will be further extended for this project, the system technology on the vehicles already having been prepared with this in mind.

Outlook

A further ASV design series is currently being developed for larger tunnel diameters. This will have a system width over wheels of 180 cm and will then be available with different loading platform widths for tunnel face advances of 180 to 220 cm. The vehicles will be designed for maximum payload capacities.

The long-term objective of this initiative is to develop remote-controlled and driverless ASV operation from a central Remote Supervision Centre. The first steps in this direction will be displayed on the MobileTronics exhibition stand at the bauma 2022 trade fair.

Further developments are also under way in areas such as data-based services and diagnosis functions.

References


Dr. Christoph Müller
CEO, VirtuRail GmbH, Schruns, Austria

Contact:
office@virturail.com
www.virturail.com

The initial scepticism and concern that were present prior to the introduction of such highly developed and complex vehicles soon disappeared: after a short familiarisation period and a few test runs the drivers were ready to operate the ASV trains and individual vehicles in complete safety.

When manoeuvring into the TBM back-up system only a few centimetres of clearance are available on each side of the ASV (Fig. 4), which represents something of a technical challenge. Under these extremely cramped conditions each individual axle of the ASV train, which is 30 m and more in length, is steered in fully automatic mode. Such a situation would doubtless prove too much for a driver equipped only with a manual control system.

The energy efficiency of the VirtuRail ASVs has already been confirmed in ongoing operations. To give one example of this: a single vehicle with a full load configuration (total weight around 40 t) requires about 22 kWh to complete a circular route of approximately 7,600 m. For this project-specific travel profile this figure represents a consumption rate of 2.9 kWh per km or – in equivalent diesel terms – about 0.3 l of diesel fuel per km.
Paus: New Technologies on Show at bauma 2022

Hermann Paus Maschinenfabrik GmbH, Emsbüren, Germany

The rapid development of the underground mining and tunnelling industry has meant an increased demand for new solutions. These can be individual and customised configurations as well as advanced and forward-looking technologies such as BEV, IoT interfaces, remote operation and teleoperation, new safety features and many more. Paus is constantly expanding its underground portfolio and developing its expertise to provide inspiration as an innovative partner of choice.

After already showcasing BEV and the corresponding electric driveline concept in 2019, Paus will now be putting its latest developments on display at this year’s bauma 2022. As well as new designs and individual characteristics all the machines on display feature the latest technology as part of a general and forward-looking programme of product development.

Paus PScale 8-T Scaler – Experience a maximum Scaling Performance

Safety, performance, sensitivity and high durability are the design principles and values Paus has used for the development of the new scaler generation that delivers a unique scaling experience (Fig. 1). In the underground mining industry rock falls can potentially result in fatalities, injuries and damage to underground personnel and infrastructure. To ensure a safer working environment any loose rock therefore needs to be removed before the follow-up processes can begin. Paus now offers extremely efficient, high-precision and cost-effective scalers that can create a much safer workplace for machine operators.

Maximum performance is guaranteed thanks to a powerful motor unit, a 20° tiltable cabin, individual parameter adjustment of the hydraulic hammer and an operating and diagnostic display designed to ensure a reliable and high-quality of the scaling process. By utilising a high performance scaling regime the PScale series allows the operator to adjust and check hammer parameters directly at the face instead of having to made adjustments on the surface. The 20° tiltable cabin gives the operator an excellent view of the scaling tool and ensures fast and efficient gallery protection. The small envelope size in combination with a high boom reach provides fast operation without the need for frequent positional changes. The ergonomic and well proportioned operator’s cabin exceeds international ROPS/FOPS requirements while the use of additional configurations, such as plug-and-play for the remote control, 3P safety belts, a brake test button, hill start assistance and pressurised cabin further help to reduce individual risk levels.

Designed for versatility of use, the PScale series is available with an extensive package of optional equipment designed to meet the individual demands of the users, including a range of motor units with the latest exhaust stages and a CE declaration of conformity for deployment within the EU. Paus also offers the PScale 10-T for working heights up to 10 m.

Paus UNI 50 BM-TM – heavy-duty Concrete Mixer

In order to improve underground productivity and increase efficiency in logistics the remit was to provide a transport solution offering a higher payload together with a safe and comfortable driving experience, even on rough terrain. Paus responded by developing its UNI 50 machine and now offers a larger UNI 50-5 carrier with a payload of up to 17 t, increased ground clearance, a more powerful driveline and a spring-mounted fully suspended front axle (Fig. 2).

The UNI 50-5 BM-TM concrete transport mixer comes with a new UNI series chassis designed for a variety of superstructures and with front axle suspension as part of the basic configuration. With a payload volume of up to 7.5 m³, the Paus transport mixer is a reliable partner for successful concreting operations below ground. This compact and powerful vehicle is fast, comfortable and safe, and performance is not affected even by the worst road conditions, where the front axle suspension comes into its own. The UNI 50-5 carrier can also accommodate different superstructures, including a fuel tank, a lubricant service unit, a water tanker and fire tanker, a loading platform with crane and many other attachments. Moreover, Paus can provide various customised configurations and options tailored to the individual requirements imposed by different underground operations and conditions. In line with the economic fleet concept the carrier can also be further equipped with different types of change-over systems for carrying cassette mounted superstructures.
The Paus UNI 50-5 BM-TM has a rated motor output of up to 173 kW and can be supplied with Deutz or Mercedes Benz engines, though other variants are available on request. APC transmission control (automatic gear shift) ensures that long round-trip distances can easily be managed, even over routes with gradients of up to 35%. The UNI 50-5 can optionally be equipped with Stage V engines. These power units have lower emissions and therefore help reduce the ventilation requirements in the mine. The basic configuration and the improved cooling concept are designed for operation in an environmental temperature range of -20°C to +40°C. Paus is also offering a number of standard and customised options to complement this machine.

**Paus PMKM 8030 Dump Truck – compact in Size with a high-tonnage Payload**

The PMKM 8030 is designed specifically operating in confined workplaces and is one of the most compact and powerful machines in its class. Combining improved design and operating characteristics with the latest electronics and a preliminary setup for smart equipment the PMKM 8030 provides a future-oriented solution not only when it comes to operator comfort and safety but also in terms of efficiency, productivity and economy – the ideal solution for bulk conveying in a confined mining environment (Fig. 3).

While its well-established sister machine, the PMKM 8010 is narrower and longer and stands somewhat taller in height the new PMKM 8030 is broader and shorter in design with a reduced loading height and with improved driving characteristics due to a lowered centre of gravity, bigger tyres and new axles with integrated oscillation. With a payload of 16,000 kg the machine is fitted as standard configuration with an 8 m³ dump box as standard and can be further customised for carrying bulk materials with a higher or lower density value.

As well as the basic model, Paus also offers various customised configurations and options designed to meet the individual requirements imposed by different underground operations and conditions. The machine is also equipped with a number of smart systems, including a bird’s eye view camera, tyre pressure control and a load weighing system. All can be wirelessly monitored and displayed via Paus Connect.

The inclusion of an IoT interface means that this machine series is set-up for digitisation and automation in the underground mining industry – this including the communication and wireless transfer of machine data, interconnectivity between machines and/or operators, the teleoperation and fully automated mining processes.

The PMKM 8030 sets a new benchmark for the Paus dump truck series with a rotational driver’s seat for long distance trips and rearward driving backward at high speeds (bidirectional) and a more spacious, high-comfort driver’s cab.

As working depths continue to increase mine trucks are tasked with having to negotiate longer and steeper ramps – and in response the PMKM 8030 can now be equipped with a choice of different Cummins and Caterpillar diesel engines at different exhaust stages and with power outputs of up to 190 kW. This model also comes with latest exhaust stage EU Stage 5 Tier 4F exhaust system and is therefore certified for use within the EU. The machine includes the Paus standard safety package for underground mining machines, namely SAHR brakes, a ROPS/FOPS cabin, enhanced LED lighting, etc.

With the PMKM 8000 series Paus is offering a future-oriented solution with endless possibilities that is designed to match the individual needs of the company’s customers around the world.

With its technical design, new components and range of available options the new PMKM 8030 promises to be a more durable, more efficient and more maintenance friendly machine that will deliver real economies for operators in this mining sector.

**Paus Mining and Tunnelling**

‘The people who care’ maintain close contact with its customers. Thus, Paus is able to understand their needs and as a result can deliver a solution that best meets their individual requirements. All Paus mining and tunneling machines are ‘Made for Mining’ and are stamped with the ‘Made in Germany’ seal of quality.

With a wide-ranging portfolio of products and a huge variety of options and the customised features our machines can provide the basis for practically any task imaginable – no matter how individual and specific the solution. Through a global supply network, direct OEM German-based service backup, dedicated training programmes, online catalogues, digital support and the Paus Connect the mining and tunnelling specialists Paus have all the resources needed to close to their clients – no matter where they are in the world.

In addition to the continuous development of machines and technology solutions Paus is also working on new ideas, including like a special mine rescue vehicle that is currently being developed in cooperation with the company Dräger and a major European supplier of firefighting equipment. And the ‘Scale Sense’ project being worked on by RWTH Aachen university, which is close to being taken to the next level for extended field testing, is aimed at detecting loose rock and will provide an important tool for Paus scaling machines. The company also has a number of ‘classified’ projects involving new developments that will be the subject of further publications.

---

**About Hermann Paus Maschinenfabrik GmbH**

Hermann Paus Maschinenfabrik has a workforce of over 300 employees and is recognised around the world as a partner manufacturer of construction machinery and dumpers, mining and tunneling vehicles, inclined lifts, mobile elevated work platforms and cranes. With a company history that goes back 50 years, Paus has developed into a leading specialist in mechanical engineering equipment: from development to production and service backup.

**Contact:** bwilmes@paus.de

---

**Fig. 3:** Paus PMKM 8030 dump truck
Sugar Cane sweetens the CO₂ Balance of Segment Gaskets
Franziska Kachel, Sealable Solutions GmbH, Waltershausen, Germany

The Sustainable Future for Tunnel Segment Gaskets

In addition to the increasing technical challenges, the reduction of CO₂ is an even more important topic in the construction industry. Saving concrete in the segment design is only one way to reduce CO₂ emissions during the excavation of a tunnel project. The constant tightening of emission protection limits and the growing demand for sustainable products also require new, innovative materials and combinations in the production of sealing solutions for segments.

An approx. 5 km long tunnel section of the Paris Metro demands 2,500 segment rings which are equipped with approx. 218,000 m of sealing profile. Almost 28.75 t of EPDM are used inside. Actual emission values indicate that 100 t of CO₂ are emitted for the seals alone. For comparison: the per head emission of CO₂ in Germany in 2018 was 10.4 t.

Sealable Solutions GmbH has set itself the task of developing a sustainable sealing profile to counteract emissions. With an environmentally friendly EPDM rubber as an alternative component in the sealing profile, it is possible to significantly improve the CO₂ balance.

Sugar Cane instead of Crude Oil – the sustainable Difference

The special feature of the new rubber compound: instead of the commonly used fossil fuels, natural sugar cane (Fig. 1) is used as an alternative. EPDM (Ethylene-Propylene-Diene-(Monomer) rubber) is produced using ethylene and propylene. These are raw materials that are traditionally obtained from crude oil. With the new material, fossil fuels are not used for extraction and instead the bio-based ethylene is produced from sugar cane extract (Fig. 2). The properties of the material remain the same, but the production is carried out using a sustainable and resource-saving method and is independent of fossil fuels.

Conventional EPDM currently has a CO₂ balance of 3.5 t per tonne of rubber. Biobased EPDM with 0.6 t per tonne of rubber is almost 6 times lower than this value (Fig. 3). This significantly reduces the CO₂ footprint of the segment seals and therefore as well for the project it is used for. All previous advantages, whether physical properties such as relaxation, tightness and long-term relaxation or the easy handling of the profiles, remain unchanged.
In the development and manufacturing of the products, Sealable believes that ecology and economy are not contradictory – on the contrary, they are going hand in hand. Lean and energy-efficient processes are not only ecologically sound, but also the basis for high-quality products at Sealable. All our products are produced with 100% green electricity and consist of REACH-compliant ingredients. It is important to Sealable not to wait until it is legally required to work with REACH-compliant substances. For example, all profiles for tunnel construction are already nitrosamine-free and the adhesives are toluene-free.

Health as well as sustainability are equally important at Sealable and an essential pillar of the value-based company philosophy.

Franziska Kachel
Sealable Solutions GmbH, Waltershausen, Germany.
Contact: franziska.kachel@seal-able.com

**Fig. 3:** CO₂ balance of rubber made from sugar cane and from crude oil
Hybrid Grouting – an innovative Technology
Adriano Fumagalli and Hansjürg Baumann, Häny AG, Jona SG, Switzerland
Sewerin Sabew, Hochtief AG, Munich, Germany, former Häny AG, Jona SG, Switzerland

1 Introduction

Grouting has a long history in underground construction and emphasises sealing or consolidating weak or water-bearing ground conditions. Organic grouting is primarily carried out in complex ground conditions or areas of heavy water inflow. These circumstances place high demands on equipment and materials. For example, the grouting unit must be mobile due to the constantly changing sequences of excavation and grouting works. And the grouting unit must handle various types of grouting materials and additives to adapt to changing ground and site conditions and objectives.

Standard grouting equipment is limited to either cement-based or organic grouting gear. This limitation has made grouting in underground construction considerably more difficult until now. However, with recent developments in grouting technology, both the cement-based, and the organic grouting technology can be utilised on a single mobile grouting platform (Fig. 1). Because this grouting system can process both grouting materials individually or simultaneously with different mixing ratios, it is dubbed Hybrid Grouting [1].

The advantages of this unique system are apparent when it is used to stop water inflow. Extensive water flow paths can effectively and quickly be closed using a high proportion of PU resin in the hybrid grout mix. The PU resin proportion can then be lowered until the water inflow stops completely. Subsequently, the ground can be further sealed and consolidated with pure cement suspension without being washed out. [2,3]

Hybrid Grouting combines the advantages of economical, cement-based grouting and the advantages of highly reactive resin injections. Furthermore, with Häny Hybrid Grouting technology, processes are fully automated and enable controlled and efficient grouting operations.

2 Hybrid Grout Mixes

Hybrid Grout, as mentioned above, consists of two grout agents:

▶ Cement-based grout
▶ Organic grout

Cement-based grouts are essentially a mix of cement and water in a given ratio optionally combined with inert materials such as fly-ash, bentonite, and additives like calcium chloride or sodium silicate to increase stability or decrease the setting times. These mixtures create suspension grouts in which solid particles are more or less evenly distributed (floating). The cement reacts with the water (hydration), and the grout mix changes continuously from a liquid through stiffening, solidifying, and hardening into a solid cement paste. The start of solidification of cement-based grouts is usually a couple of hours and can be modified to as little as even a few seconds.

Organic grouts consist of two or more synthetic components (such as urethanes, sodium silicates, and acrylamides) in a given ratio that forms a gel, a solid precipitate, or a foam.

Hybrid Grouting mainly uses a combination of cement and polyurethane resins. However, projects are also known that have combined cement grout with sodium silicates or acrylic gels.

Polyurethane grouts come in two forms, single component and plural component, with variations in reaction time, reaction with water, expansion characteristic, and flexibility. Two-component grouts commonly used in underground construction are mixed with a fixed ratio of 1:1. "The polyurethane is formed by an exothermic polyaddition reaction of polyol (A-component) and isocy-
the combined cement-polyurethane grout at the same time. The polyurethane is embedded in the cement grouting mix and forms during the hydration phase an initial structure due to the progressive polyaddition reaction, which stabilizes the grouting mix’s wash-out effects. The quality of the combined products is the adequate dispersion and homogenization of the initial products during the mixing process. Fig. 2 schematically shows the emplacement of PU within the cement paste.” [4]

3 Hybrid Grouting Mixing Technology

Hybrid Grout is created by mixing polyurethane A-component and B-component, and in the second step, by combining the polyurethane with the cement-based grout. The scheme of the mixing gear is shown in Fig. 3. “The PU is formed by mixing the A-component [yellow] of polyol and B-component [blue] of isocyanate through a static mixer [PU mixer], which is fed downstream through a bypass to the cement line [orange]. The final cement-polyurethane grout mix [black] is generated by a second static mixer [Hybrid Grout mixer].” [4]

4 Hybrid Grouting Unit

The Häny Hybrid Grouting unit consists of a cement grouting unit and an organic grouting unit. The equipment is installed on a mobile platform as shown in Fig. 1. The unique feature of the Hybrid Grouting unit is the pump control system. This enables fully automated cement-based and organic grouting on a single platform.

The cement-based grouting unit consists of a high-shear mixer, an agitator, two cement pumps, mixing and pump control unit, and a cement silo with an inclined auger. In addition, an integrated measuring station in-
A flow rate and pressure sensor is built into each grout line. All devices are operated via a control panel (see Chapter 5).

The stability of the grout mix depends on the mixer’s effectiveness in ensuring the cement particles’ complete hydration and preventing lump formation. The Häny high shear mixers meet these requirements. As shown in Fig. 4, a turbo mixing pump with reverse vortex-type propellers achieves high hydraulic turbulence by circulating the entire tank content several times per minute. As a result, each particle is separated and individually wetted, creating a homogeneous and fully hydrated stable grout mix which resists intermixing with free water resp. groundwater.

Two-cylinder (Duplex) plunger pumps, as shown in Fig. 5, are commonly used for cement-based grouting operations in underground constructions. These pumps are synchronized so that the second plunger starts to displace the grout just before the first plunger has completed its stroke. Thus, the change of plungers creates only a minimal fluctuation of flow rate and pressure. The pumps must be equipped with precise pressure and flow control valves to allow stepless control and regulation of the injection process.

The grouting gear for organic resin processing consists of two polyurethane pumps and a resin storage unit. The polyurethane pumps are 2-component pumps and deliver both components at a fixed mixing ratio of 1:1. Double-acting reciprocating pumps are commonly used for organic grouting in underground constructions and are air driven. A double-acting reciprocating pump discharges on both the piston’s forward and return stroke, and the flowrate can be considered constant with slight pulsation. These pumps must be equipped with precise flow control valves to control the injection process automatically.

5 Automation and Digitalisation of Hybrid Grouting

Another critical element of modern grouting technology is automation. Digital measurement and state-of-the-art control technology are required to control all essential parameters, record them digitally and enable rapid, accurate data evaluation.

With Hybrid Grouting, measuring the flow rate and pressure for each flow line of the material components is required. A magneto-inductive flow meter registers the flow rate of the cement grout mix – the flow rate of each polyurethane resin component is registered via an impeller flow meter. In order to exclude the pressure losses from the line and mixing system, a pressure gauge must be installed in the hybrid line. However, placing the pressure gauge in the hybrid line is not recommended. And the flow meter should not be installed in the hybrid grout line, since due to the high reactivity of polyurethane resin, there is a risk that deposits in the flow meter and may falsify the measured values. Instead, the grouting pressure should be measured in the cement line. The pressure losses can be determined using flow tests and free-discharge tests, and can be considered to determine the pressure criteria. In addition, pressure gauges are installed in each polyurethane component line to identify any pressure increases, e.g., due to blockages in the mixing system.

The measuring sensors and the individual pumps are connected to a control unit. Fig. 6 shows the input parameters for the automatic control of the Hybrid Grouting process. For example, the flow rate of polyurethane can be set as a percentage of the cement flow rate (Additiv). Moreover, the grouting process can be automatically stopped via various stop criteria, e.g., a volume criterion (Menge), pressure criterion (Maximaldruck), and/or minimum flow rate criterion (Min. Durchfluss).
Pressure and flow rate are recorded and displayed on the control panel. The pressure in the cement line (P) and the flow rate of the hybrid grout (Q), as well as the cumulative amount (Menge) and injection time (Dauer) are displayed for one pump (Fig. 7 left) or for up to 4 pumps (Fig. 7 right). The flow rates of each component of the hybrid grout are shown in a single view only (flow rate cement grout QP, flow rate component A, flow rate component B).

The consistent and repeatable production of grout mixes can be ensured through automatic control and recording systems, as shown in Fig. 8. The mixing components can be entered and stored in different recipes through the touch screen. In addition, the control automatically optimizes the dosing procedure and achieves optimum accuracy after three mixing cycles. The mixing process is shown in real time on the panels’ display, and a batch record of each component of every mixing cycle is stored and available for further documentation.

The data is available for further documentation on a USB memory stick or via a wifi/cellular transfer on an FTP server.

6 Conclusions

Recent developments in grouting technology allow cement-based or organic grouting on a single mobile grouting platform. The new technology offers significant advantages resulting from the simplified change between injection components during the construction process. This contributes to solutions which are technically optimal and reduce costs.

7 References


Adriano Fumagalli
is Head of Mixing and Injection Technology Division, Häny, Jona, Switzerland.
Contact: adriano.fumagalli@haeny.com

Hansjürg Baumann
is Sales Manager MIT Division, Häny, Jona, Switzerland.
Contact: hansjuerg.baumann@haeny.com

Dipl.-Ing. Sewerin Sabew
is Oberbauleiter Spezialtiefbau, HOCHTIEF Infra-structure, Munich, Germany, since August 2022 and former Product Manager Mixing and Injection Technologies (MIT), Häny, Jona, Switzerland.
Contact: sewerin.sabew@hochtief.de
1 Introduction

Building Information Modelling (BIM) is a model-based process aimed at optimising the planning and execution of a building project and its various operations. This is achieved using a digital whole model in which various sub-models and subject models are integratively processed with the aid of special BIM software solutions. While BIM technology has already become well-established in the field of structural engineering or building construction there are still a number of challenges to be faced before the BIM method can be fully applied in the civil engineering and underground construction sector.

This paper will seek to show to what extent it is possible, on the basis of the current technology and software development status, to deal with the subsoil modelling process and manage the interfaces between the static-constructional constraints of the tunnel structure and the geotechnical and structural engineering parameters and attributes. Particular attention is paid here to the data exchange formats, as these play a key role in maintaining the transparency and consistency of the digital data during the BIM process.

With reference to a tunnel survey project based on conventional planning methods and its derived geotechnical assessment a study was also carried out with a view to using the software solutions currently available to produce a subsoil model with all the necessary geotechnical and tunnel-engineering parameters and attributes.

2 Multidimensional Planning of 2D to xD

The BIM method introduces new planning dimensions to the already standard 2D and 3D planning techniques. The 3D model of a building, of the kind that is currently the norm today, can be extended by factors such as ‘build time’ and ‘construction costs’ (Fig. 1). Introducing the build time into an existing 3D model means designating the latter as a 4D model. Factoring-in the build time and the construction costs then generates a 5D model.

However a BIM model is created not merely by extending its dimensions. In fact there is a much more important step involved when building the 3D model itself. The aim here is to develop an overall model (OM) based on different subject models (SMs) that in turn are composed of various component models (CMs). The overall model then contains all the relevant factual data, comprising parameters, attributes and relationships. The parameters primarily feature the geometric properties of each individual physical object (PO). The attributes describe all the characteristics of a physical object. These can for example comprise material properties (concrete quality, exposure class, steel grade etc.), soil properties, manufacturer specifications, installation instructions, etc. The relations describe the relational connection between the individual physical objects (POs) as well as the connections between the individual subject models (SMs), which can be mutually interdependent. The relations between the SMs are only represented in the overall model (OM).

3 Model Structure

In order to execute a tunnel construction project using the BIM method it is first vital to obtain the funda-
mentals by digitally processing the data that have been gathered during the exploration and survey phase. The challenge here is to develop a model structure for the foundation subsoil and to establish this in normative terms and in open and neutral data exchange formats. This is essential if the digital data is to be made compatible for use in a BIM model, in this case for tunnel construction work.

For a BIM geotechnics model it is therefore expedient according to [1] to divide the ‘foundation subsoil’ subject model up into the following component models:

- Digital terrain model (DTM)
- Soil layer model/homogeneous area model/drilling profile
- Groundwater level models
- Unexplored ordnance survey model (and separate subject model if necessary)
- Model showing areas suspected of contamination
- Model showing structural elements present in the subsoil/identified obstacles

### 4 Model Granularity

Model granularity [2] describes the maturity level of the planning and/or development stage in various developmental stages for geometric and semantic data in the BIM model. The internationally accepted terms Level of Geometry (LoG), Level of Information (LoI), Level of Detail (LoD) and Level of Development (LOD) have been established for this purpose. In the structural engineering industry LOD is applied with five stages ranging from 100 to 500.

#### 4.1 Model Granularity LoX Foundation Subsoil

As far as the foundation subsoil is concerned there are currently no recommendations for determining the completion status with the granularities LoG, LoI, LoD and LOD, as is shown in section 4.2 for tunnel construction under [2].

Furthermore, the established model granularities from the structural engineering field cannot be directly adapted for the BIM subsoil model. According to [3] geotechnics involves a ‘relatively high degree of uncertainty’ and taking the LOD definition in structural engineering as an example it is apparent that this very much based on the planning phases. Such a definition cannot be directly applied in the case of the BIM subsoil model.

In [3] a LODgeo is presented that makes a statement about the level of detail of the BIM subsoil model using existing prospection data and archived drill logs in a certain grid pattern. However it remains questionable whether and how the model granularities that are familiar to the structural engineering industry can be applied for a BIM subsoil model and whether it is possible in simplified terms to start on one level from a LOD 100 for a BIM subsoil model or even a ‘stock model’.

#### 4.2 Model Granularity LoX Tunnel Construction

The DAUB working group [2, 4] has submitted recommendations for subsurface construction that seek to define the completion status with the granularities LoG, LoI, LoD and LOD.

The level of detail in the parametrisation, i.e. the depth of geometric information on the components of a BIM model, is designated as the Level of Geometry (LoG) according to the recommendations of the DAUB working group.

For subsurface construction work the DAUB recommendation specifies LoGs for ‘conventional excavation and support methods’ and for ‘tunnels with full-face extraction and tubbing supports’. The level of detail is subdivided into four main stages of 100 to 400. These relate to the relevant methods used in subsurface construction, such as extraction, roof support (outer shell and other support measures), sealing, inner shell and internal support system.

The project concept design must specify in the client information requirements (EIR) and BIM execution plan (BEP) exactly which applications correspond to which LoG in certain phases of the project.

In its annex 1 ‘Proposal for using a Level of Geometry (LoG) in conventional tunnelling’ and annex 2 ‘Proposal for using a Level of Geometry (LoG) in mechanised tunnelling’ the DAUB working group provides help and advice on determining the level of detail in the individual LoG stages. The DAUB working group points out that these should be seen as a recommendation and not as a rule. Fig. 2 presents an example of a LoG 400 in the form of a tubbing support system with its associated reinforcement.

The Level of Detail (LoD) describes the level of detail of the attribution of a component in the BIM model. As well as providing semantic information on the component in question it is essential to retain a unique ID of the specialist object in the form of a GUID (Globally Unique Identifier) or a simulation code that is generated uniquely for every object in the BIM model.

The Level of Detail (LoD) describes the amalgamation of the LoG and LoI according to [2]. By contrast with the structural engineering sector this does not

---

*Fig. 2: Example of tubbing support/reinforcement in LoG 400 [5]*
generate a new definition as the original use of the LoG from structural engineering can be transferred to the subsurface construction field. In the LoD stage, according to [2], the allocation of the attributes (LoI) and geometric detail level (LoG) is documented with reference to the respective application for each component in the modelling guidelines. Unlike the structural engineering sector, however, there is here no need to use an LoD 500 (as built), as the maturity level can be described in the Level of Development (LOD).

The Level of Development (LOD) describes the maturity level of a BIM model. The LODs are recorded and fixed in the EIR and in the BEP. A life-cycle assessment for the structure is carried out early in the project design stage and from this it is possible to define the requirements of the individual project phases. In the Level of Development it is possible, among other things, to create views of choice of routing, the removal of excavated material and collisions with existing structures.

In [2] the DAUB working group proposes the following models for an advanced planning status:

- Concept model (overviews prior to execution)
- Execution model (maturity level for 2D plan derivation)
- Production model (incorporation of actual performances, e.g. geology and tunnel drivage classes)
- ‘As-built’ model (model for handover to the operators as the basis for a stock model or operator model)

5 State of the Art and Data Exchange Formats

Certain tools, in the form of software solutions, have to be developed and applied for the practical execution of the BIM method. High-grade, user-friendly software solutions already exist for the structural engineering industry that enable integrative working in the BIM environment. As well as the existing range of software it is the software-spanning data exchange that is of particular importance for practical work. However, consistent standards are still needed in order to exchange interdisciplinary and software-spanning data between the different technical planners. According to the BIM guidelines for Germany [6] the Open BIM Standard should eventually be established with the introduction of the BIM method for the planning and building of structures. In the field of structural engineering the Industry Foundation Classes (IFC) format is increasingly becoming mainstream. The buildingSMART forum supports open interfaces for the BIM method and makes great efforts to find and establish standards and solutions for technical tasks.

5.1 Open BIM Standard

The Open BIM standard describes open and neutral interfaces for an effective and transparent exchange of data between all parties involved a project planned using the BIM method. In Germany efforts are under way to ensure that the data exchange formats will not be exploited as a means for gaining monopoly status by a software manufacturer. There are already a number of proprietary data exchange formats that have their merits for certain specialist applications [7].

For public sector infrastructure projects the phased plan that was put forward by the Federal Ministry of Transport and Digital Infrastructure (BMVI) [8] in 2020 calls for the use of the Open BIM Standard for projects being planned with the BIM method. As several proprietary data exchange formats have already established themselves, as mentioned above, further data packages besides the data in the Open BIM Standard can be supplied to the client as add-on applications in the form of proprietary exchange formats. The provision of the digital data must however be based on the Open BIM Standard and be fully in keeping with the phased plan of the BMVI as the use of proprietary data exchange formats can lead to overly close ties to certain software manufacturers, which can result in a lock-in effect [7]. This system then prevents public-sector clients having to prescribe the use of certain software products, possibly even in the EIR. Such a stipulation would affect the general trading and competition conditions and would force public-sector clients into being excessively tied to the most internationally active software manufacturers [6].

Another benefit of the Open BIM method is that major infrastructure projects often take decades to plan and execute and may then have an operating lifetime of as much as 100 years. In situations requiring the long-term storage of digital data as submitted by the contractor it is not possible to guarantee that a proprietary data exchange format will continue to be developed and maintained over the years. The use of the Open BIM Standard prevents any loss of digital data as the open data exchange formats can continue to be developed independently of the software manufacturers.

One of the greatest challenges for the implementation of the Open BIM Standard is the programming of error-free interfaces, which have to be tested at an early stage and must output to the export data in such a way that the import side can reload them along with all the export data. In order to be able to export and import the complex digital BIM data error-free the user also has to manually configure the export and import process [6].

5.2 Industry Foundation Classes – IFC

The IFC specification is an open, standardised data exchange format in which a BIM model with all its physical objects and their factual data (parameters, attributes and relationships) can be interchanged across different software systems in a specified data schema. This has now been updated in other versions since the IFC4 standard was published in 2013 [6].
The IFC structures are being updated for the aforementioned data exchange formats on the basis of the requirements laid down for the individual specialist areas, an operation that is being carried out in association with various countries, universities and companies that are involved in the development of the BIM method.

The data exchange format IFC Tunnel, for example, has for some time been the focus of two research projects being carried out at German universities. These are primarily concerned with definitions for the tunnel construction operation and the tunnelling machines and with the level of detail for BIM tunnel models. It is essential that all project members always have access to the digital data for the BIM project the CDE is often centrally administered within this data environment that can be accessed by all participants working within a project being planned using the BIM method. All project information is filed and released centrally to everyone involved when a specified maturity level has been reached and a quality assurance procedure completed [11].

6 Modelling the Foundation Subsoil

The subsoil modelling work carried out for the project study used Hole-Base SI standard software from Bentley (formerly Keynetix) for creating the drilling database and Autodesk Civil 3D software from Autodesk for generating the subsoil model. A future paper will examine the practical experience acquired with other types of software (e.g. Leapfrog Works) for the foundations modelling work.

6.1 HoleBase SI Drilling Database

A large portion of the data only existed on paper or in PDF format. The bore logs were also available in proprietary bop format, which is the data format of the iDat WinBohr program. The next step was to select and compile specific prospection data on tunnel construction. This selection was summarised in an Excel file and provided with the following parameters, which would subsequently be stored in HoleBase SI:

- Location ID – definitive borehole name
- Location type
- Easting [m] according to Gauss-Krüger Zone 3
- Northing [m] according to Gauss-Krüger Zone 3
- Ground level [m] – height above mean sea-level
- Final depth [m] – metres drilled per entry point
- Routing distance [km]

As well as the parameters, which were essentially the descriptive geometrical data, various attributes were also saved in HoleBase SI. Here it has to be noted that the attributes are in some instances dependent on parameters, especially when building geological objects in the BIM project. Attributes are directly related to parameters in the BIM object ‘drilling profile’. This fact relates in particular to the lithologies and soil properties, which are related to the parameter ‘metres drilled’.

The drilling profile attributes from the existing bore logs in PDF format were taken over and manually transferred into HoleBase SI. This particularly included the downhole information and its long-text description.

HoleBase SI operates with a linked SQL database. As no CDE existed in this particular case the data from the drilling database were stored in a local SQL environment. HoleBase SI was developed specifically for the UK market and already contains adaptations for other areas, especially the American one. For this reason a number of presets are still required before the program can be employed in the German market.

As it is also possible in HoleBase SI to store the results of laboratory tests the contact data of those labs that the engineering team worked with during the course of the project can also be lodged here. This
means that the laboratory results can be allocated to the particular lab that did the work.

The Borehole Log profile was used to input the borehole data. This allows the following data to be stored in eight steps:

1 Locations
2 Drilling details
3/4 Wells and water strikes
5 Samples
6 Results - in situ
7 Results - environmental
8 Geology

In the first step (locations) the parameters are defined for each borehole. This mainly includes the location ID, the location type, the final depth [m], the ground level [m], the northing [m] and the easting [m]. It is also possible to store a date for the beginning and end of the drilling work. This allows each hole to be clearly identified in the BIM process.

In the second step (drilling details) information can be entered on the drilling process and on the spatial position of the hole. This is of an advantage for boreholes that cannot be drilled down vertically due, for example, to geological reasons such as faults or the spatial location of the joint structure. Moreover, corrections for boreholes that were originally planned as vertical can in theory be carried out in respect of deviations from the nominal position of the hole.

In the third step (wells and water strikes) information can be supplied on the optional development of the groundwater monitoring station. This includes, for example, data such as the diameter of the standpipe, the date of the development and the filling of the cavity between the standpipe and the hole.

In step four, also wells and water strikes, information can be provided on the groundwater that has been encountered.

In step five (samples) information is stored on the collected samples. This provides an opportunity to allocate each sample a clear ID and to define the sampling method. Data can also be stored on the depth positions (depth top [m] and depth base [m]) and on the number of blows.

In step six (results - in situ) the results of any in situ tests carried out are updated.

In step seven (results - environmental) environmental burden values, such as the results from the FID (flame ionisation detector) and PID (photo ionisation detector) tests, can be entered with the current pre-settings. Here it would also be appropriate to check whether environmental lab results, such as LAGA categorisations, could be inserted instead.

Step number eight (geology) is very important for the subsequent preparation of a BIM subsoil model. This is where the geological data from the drill core survey can be stored with the help of stratigraphic boundaries and lithology. The ‘legend code’ makes it possible to display the characters for the different soil types in accordance with DIN EN ISO 14688-1 or DIN 4023 and DIN 21920.

These saved legend codes later make it possible to use automatically created bore logs in HoleBase SI. In addition, when the drilling profiles are subsequently being compiled in a BIM-capable CAD program, such as AutoDesk Civil 3D, it is possible to choose between two different displays, i.e. legend codes or geology codes.

Geology codes play a key role during the subsequent modelling of the foundation subsoil. Like legend codes they can be individually created and edited in HoleBase SI. It is absolutely essential that the geology codes are laid down by an experienced geologist or geotechnical engineer who can professionally collate the downhole information in idealised soil layers.

As well as enabling the manual input of data HoleBase SI can also import prospection data. The following data formats can be imported using HoleBase SI:

- AGS files
- Key Logbook
- gINT
- pLog Tablet
- Geodasy
- CSV (comma-separated values).

The import that most closely matches the Open BIM Standard is that which is based on CSV files.

The datasets entered in HoleBase SI or imported using CSV files can also be exported. Alternatively it is possible to export AGS formats in the file versions 3.1, 4 and 4 NZ. Data exported in this way can be used for subsequent processing with the BIM method. HoleBase CONNECT Civil 3D Extension is a special tool available from HoleBase SI that is able to integrate HoleBase SI in AutoDesk Civil 3D. It is therefore appropriate to develop the subsoil model with this program as it enables a loss-free transfer of data.

As well as outputting drilling data as CSV files HoleBase SI is also able to produce DIN-compliant protocols under the mantle of a preset document template. The data stored in HoleBase SI can therefore be output very quickly and easily as bore logs, for example, which will be compatible with the preset document templates and so meet UK standards. Updating the document templates for the European rulebook and the various national annexes would be both useful and desirable.

6.2 Subsoil Model AutoDesk Civil 3D

The subsoil model was constructed using the BIM-capable CAD program Civil 3D. This is especially suitable for linear construction projects and contains many useful tools for the rail and road construction sector along with functions for the integration of all kinds of geodetic information. The HoleBase CONNECT Civil 3D tool was used to transfer the information stored in the drilling database to the CAD software. This involved
using the tool to establish a direct link to the SQL database, from which it was then possible to read out digital data in the drilling database.

When establishing this connection and taking over the digital data from the SQL database the main focus is on the parameters with all their embedded geometric properties and the attribute information on the lithological and petrographic characteristics. The moment the link to the SQL database is made the desired project is selected (this having already been created in HoleBase SI Standard) and the digital data from the drilling database are automatically inserted in the CAD drawing.

The exploration results and the soil layers stored in HoleBase SI can be viewed in 3D (Fig. 3). The standard setting provides for the soil series to be represented using the geology codes that were previously defined in HoleBase SI. By selecting the setting ‘locations’ there is also the option of switching the display to Legend Codes, BGS Lexicon, Boundary or Geology Code. Using Geology Code 2 is especially beneficial when a second interpretation is required. This means that HoleBase SI can be used to specify other geology codes and the compilation of similar soil layers can be interpreted in different ways and multiple times.

The drilling profiles are automatically inserted as blocks. The drilling points in the 3D CAD space are determined by the coordinate parameters defined in HoleBase SI (easting, northing) and by the ground level. The correct colour representation for the geology codes has to be preset via the layers in Civil 3D. HoleBase SI automatically generates layers for each soil bed and other shapes and drawing elements. The layers established by HoleBase SI are identified by the abbreviation KNX, which is displayed before each layer name.

When it comes to further processing in particular it is important to remember that the drilling profiles are automatically represented with a five-fold height exaggeration. This factor is of special relevance if additional elements that have not been generated by HoleBase SI, such as a digital terrain model, are to be loaded into the 3D drawing.

The displayed drilling profiles of relevance can be selected in Civil 3D via the HoleBase SI Location Manager. By this means it is possible, for example, to create sub-subject models for a planning segment or to exclude inconclusive or archived boreholes from the modelling exercise.

In conformity with the geology codes laid down in HoleBase SI it is possible initially to generate the stratigraphic boundaries automatically using the HoleBase CONNECT Civil 3D tool (Fig. 4). As can be seen in Fig. 4 the HoleBase CONNECT Civil 3D tool generates stratigraphic boundaries between the existing drilling profiles using linear interpolation in 3D space. These boundaries and any lenses present have to be reprocessed and professionally interpreted.

The digital terrain model (DTM) is inserted into the model as an additional stratigraphic boundary in the upper soil layer. The automatically created upper boundary does not correspond to the actual ground surface. This plays an important role for subsequent direct volume calculations from the 3D model, as this allows the accuracy of the calculations to be increased. The automatically generated stratigraphic model, with the DTM as the uppermost stratigraphic boundary, can be seen in Fig. 5. The digital terrain model and the drilling points are represented with a five-fold height exaggeration. This greatly facilitates the visual understanding of
the subsoil situation and allows a precise interpretation to be made.

The adjustment and interpretation of the 3D subsoil model is achieved by way of cross sections in the interpretation and profile tools. This allows sections to be placed anywhere in the 3D space and created as a 2D section along with the actual 3D model (Fig. 6). The cross sections are in relation to the 3D model and any change in this model has a direct effect on the 2D section and vice versa. After the stratigraphic boundaries have been adapted in Civil 3D the result is an approximate 3D model of the foundation subsoil (Fig. 7).

However, with the improved representation of the 3D strata model one also arrives at the limits of what is technically possible with the programs in use. It is apparent that the stratigraphic boundaries cannot all be fully recognised and processed using the HoleBase CONNECT Civil 3D tool. Freehand editing of the boundaries is only possible to a limited extent. This is in part due to the fact that the prospection data for the underlying project were not planned for a BIM project. The body of data is therefore insufficient to create a meaningful 3D subsoil model, as is evident in Fig. 8.

7 Conclusions

As outlined above, HoleBase SI Standard software can be used to store and manage the results of a drilling campaign in a centralised database. The idea behind the program consistently follows the BIM method and allows digital data to be imported and exported, even using Open BIM. The open data exchange interface is restricted here to the CSV format (CSV = comma-separated values). The advantage of this is that the data can be opened and edited software independently, though it does have the disadvantage that they can only be read in and out in a format prescribed by the program.

Another point of discussion concerns the control of the input data. Bore logs are recorded in situ or at the drill core storage facility and are compiled manually. This does not entail mechanically generated digital data, such as that provided by survey instruments for example, that can be input directly by the computer. There is a certain error susceptibility attached to this as the datasets for each prospection have to be digitised again manually after each drill core recovery. If this is not done immediately in a BIM-capable drilling database, such as HoleBase SI, but in a standard bore log program of the kind commonly used in the industry, such as iDat WinBohr or WinSchi, the data will have to be transferred again manually into the BIM-compatible drilling database. This increases error susceptibility and in fact runs counter to the BIM principle. On the other hand, when reconditioning the data from the subsoil exploration stage it is customary that the geotechnical information from the drill returns has to be reassessed on site on the basis of further direct (laboratory and field tests) and indirect (e.g. geophysical findings) results when the geotechnical/tunnel engineering report is being prepared. It is at this point at the very latest that the BIM-compliant data preparation work can begin.

When creating a drilling database that is fully in keeping with the BIM concept the aim must be to store and manage the data in an interface-neutral way as possible. Here the aforementioned experience has shown that error susceptibility can be reduced when the amount of manual data processing required is kept to a minimum.

In order to be able to maintain centralised drilling databases in accordance with the BIM method it is also important that the tunnel construction parameters established by the geologists and geotechnical engineers can be directly stored in the drilling database. These parameters must also be definable as attributes in relation to the idealised soil layers and/or homogeneous areas. As regards the further course of the project in the BIM process the geotechnical and tunnel engineering attributes that are related to the lithology and stratigraphic
boundary parameters can be used as a calculation basis for the constructional/static BIM tunnel model when the BIM subsoil model is being generated and put to use. However this is not technically possible at the moment. The relevant tunnel construction attributes have to be entered manually in the BIM subsoil model or must be taken from the subsoil report and transferred manually to the structural calculation program by the support design engineers.

The options provided for interpreting the natural ground layers in the HoleBase CONNECT Civil 3D tool are basically well thought-out, though they do limit the user somewhat, even when there is a relatively small exposure density and fairly minimal ground complexity, as in this particular case. It remains to be established whether the concept being proposed at [3] represents a method by which the arrangement of the proposed drilling points can result in a meaningful BIM subsoil model.

Of course the ability to create lines, surfaces and solid bodies with the Civil 3D standard tools is still there. It would therefore also be possible to extrapolate a BIM subsoil model from linearly arranged prospection data. However this would not be in keeping with the BIM concept of open and neutral data continuity, as the drawing elements produced in this way would no longer have a direct link to the digital data stored in the drilling database. An alternative option would be to go back to the drilling archives, which can be integrated into the BIM process provided the database is well maintained. The data from the drilling archives can be digitised in the drilling database and linked to the BIM subsoil model using the HoleBase Civil 3D tool. However as the drilling archives are not always readily available or are some distance away this is not really a reliable way to go about developing the model boundaries of a BIM subsoil model. Moreover, it would be beneficial for future operations if the drilling archives were to be available from the regional authorities in open and neutral data exchange formats so that these could be used for further projects of this type.

It can therefore be concluded that, subject to the aforementioned restrictions, a BIM subsoil model is now realisable using the HoleBase SI, Civil 3D and HoleBase CONNECT Civil 3D Tool programs. It should be noted, however, that introducing the BIM method into company operations means a huge outlay in terms of time and cost for staff training and learning sessions and for the acquisition of the programs themselves. Even configuring HoleBase SI, involving as it will all manner of adaptation and customising to meet the needs of the company concerned and to comply with German norms and standards, requires a period of familiarisation that should not be underestimated. This is the point where the benefit-cost ratio has to be properly looked at. Similarly, extensive knowledge and experience in dealing with the CAD-BIM software AutoDesk Civil 3D will also be required. The BIM method will however prevail in the end, as is being stipulated for German transport infrastructure projects by the phased plan being proposed by the BMVI (Federal Ministry for Transport and Digital Infrastructure). While a lot of spadework still has to be done in this area, this will all pay off in the long run and will deliver improvements in the quality, openness and transparency required for the planning, execution and operation of infrastructure works.

8 Acknowledgements

The authors would like to thank Bentley Systems for providing the Hole-Base SI Standard software.

9 References

Practical Experience and Findings relating to the Preparation of a BIM Model for the Subsoil Foundations of a Tunnel Construction Project

Schmitt, Cortese, Michael and Meißner:

Prof. Dr.-Ing. Jürgen Schmitt
is responsible for the research and teaching of geotechnics, tunnelling, CAD and environmental geotechnics in the Department of Civil and Environmental Engineering at Darmstadt University of Applied Sciences.

Contact: juergen.schmitt@h-da.de

Claudio Cortese, M.Eng.
Project engineer at Prof. Quick und Kollegen – Ingenieure und Geologen GmbH, Darmstadt, Germany

Contact: claudio.cortese@quick-ig.de

Dr. rer. nat. Joachim Michael
has since 2014 been partner and managing director of Prof. Quick und Kollegen – Ingenieure und Geologen GmbH, Darmstadt, Germany. He lectures in tunnel construction and pipe jacking at the Technical University of Central Hesse. Dr Michael graduated in rock fracture mechanics and tunnelling from Phillips University in Marburg and is a publicly appointed and sworn expert for foundation engineering and geotechnics in tunnelling (IHK Darmstadt).

Contact: joachim.michael@quick.de

Dr.-Ing. Simon Meißner
is partner and managing director at Prof. Quick und Kollegen – Ingenieure und Geologen GmbH, Darmstadt, Germany. He lectures at the Technical Universities of Kaiserslautern and Darmstadt and is a publicly appointed and sworn expert for earthworks, foundation engineering and rock construction (IHK Darmstadt). He is also a registered inspector of earthworks and foundation engineering and a member of the DGGE working group 1.6 - Numerics in Geotechnical Engineering.

Contact: simon.meissner@quick-ig.de

GeoResources Portal – Reloaded!
News • Professional Journals • Events & more. Get that new look-and-feel!

www.georesources.net
Current developments pose a risk to our supply chains. Climate change, environment protection and occupational safety are increasingly taking centre stage. This paper presents one potential solution where mineral oil-based media can be replaced by water-based polymer fluids in hydraulic systems. This is one fairly simple way in which companies can contribute to workplace safety, environmental conservation and resource security.

An Alternative for Mineral Oil in Hydraulic Systems

Mineral oil-free Hydraulic Fluids proving a national and international Success

Dipl.-Betriebswirt Volker Bremer, Fluid Competence GmbH, Kamen, Germany

The corona pandemic and the Ukraine war have unsettled our economy and our society. Climate protection has now become an ongoing issue. Supply chains have been partly disrupted and container ships are waiting to be unloaded all over the world, including in Germany. Procurement has become a matter of concern for many companies and the question now is: How can we become less dependent? Can we as a company use product substitution to make a positive contribution to environment and climate protection and can this be done without losing sight of our own business objectives? This report uses several practical examples of hydraulic systems in operation to illustrate the reasons why companies have been replacing their mineral oil products.

And the operating medium they have been focusing on is hydraulic fluid.

Experiences with Mining and Tunnelling Machines

SaarGrundbau – Microtunnelling

As a plant operator in the mining and tunnelling sector SaarGrundbau GmbH & Co. KG has been on the lookout for a suitable alternative product for hydraulic systems that can be used safely and efficiently on its own equipment, including microtunnelling machines. Given the need to take account of environment protection and the general conditions prevailing at working sites that are often situated in semi-natural locations environmental performance was a major factor when it came to selecting the hydraulic medium. And here rapid biodegradability was central to the deliberations.

The first practical deployment of the new fluids, and one that also presented a significant engineering challenge, entailed using a Herrenknecht AVN 1200 C tunnelling system for the excavation and casing of a 100m-long small-bore utility tunnel (Fig. 1) [1]. The machine’s hydraulic system was filled with Lubesave, a mineral and bio oil-free, water and polymer based product supplied by Fluid Competence of Kamen in Germany. Other successful applications then followed on from this first commission.

The positive results achieved with this initial project persuaded the Saarbrücken-based engineering contractors SaarGrundbau to convert more of their machines to operate with mineral oil-free hydraulic fluids and the company personnel have now built up considerable practical experience in running their hydraulic systems on this alternative to mineral oil-based media. The substitution has worked very well and the firm has also been delighted with the improvement in employee protection levels.

Gasser Felstechnik – Swiss Tunnelling Project

An MK-A20 dump truck supplied by GHH was put into service at a Gasser Felstechnik construction site in Switzerland (Fig. 2). In this particular case environmental protection joined site productivity as key factors in the decision making process.
Gelsenkirchen-based GHH, which supplies machines for the mining and civil engineering industries, has committed to replacing mineral oil-based hydraulic fluids in its vehicle fleet [2]. In the run-up to the testing work the company was able to draw on more than ten years of experience in operating mineral oil-free fluids in the German coal industry. Investigations were carried out, for example, into the type of pump and other components that could be used in the machines. It was found that the MK-A20 dump truck could be run on Lubesave hydraulic fluid.

The operating experience that sister company Hazemag has acquired with fire-resistant fluids – including in association with the Schmidt Kranz Group – also played a key role. Hazemag additionally highlighted the excellent lubricating qualities, thermal stability and high level of corrosion protection offered by mineral oil-free hydraulic fluids.

Following the positive tests that had taken place with the replacement hydraulic fluid the MK-A20 underground dump truck was selected for service in a tunnelling project in Switzerland. The project contractors, Gasser Felstechnik of Switzerland, were extremely pleased with this choice of substitute hydraulic medium, given its technical and environmental properties and the reduced risk potential it presents. As the project progressed Gasser felt encouraged to adopt a similar course of action in future.

Dump truck manufacturers GHH were also very satisfied with the choice of fire-retardent and biodegradable hydraulic fluid from the Kamen-based firm. This decision was taken for environmental and safety reasons and was made prior to the invasion of Ukraine and the supply chain problems.

GTA – Motorway Tunnel Construction Project

The German equipment manufacturers GTA Maschinen­systeme of Hamminkeln also operate on the principle of ‘less is more’, in the words of their managing director Torsten Hußon. By foregoing mineral oil in the machine hydraulics customers have an opportunity to do their bit for climate protection [3]. GTA’s client base lies in the national and international mining and tunnelling sectors and, given the difficult conditions in general, customers are now confronted with issues such as fire resistance and the biological degradability of operating materials.

Lubesave hydraulic fluid from the Kamen company was successfully tested in a Lifter 750D twin-boom elevating work platform, which is designed for installing lattice girders and steel mesh in tunnel construction projects. The product was successfully field tested in a tunnel being built for a new section of German motorway (Fig. 3).

As well as conducting its own tests GTA also uses the operating experience acquired by the German hard coal industry in the design of support setting platforms, for instance. GTA also offers customers the option of having its machines filled with safe and environment-friendly mineral oil-free hydraulic fluids. Almost every manufacturer of machinery, including tunnel boring machines, dumpers and elevating platforms, operates on a leasing system, as does GTA. This involves the hiring out of equipment for a limited period of time. It is therefore important to be able to respond to the wishes of customers and when requested to provide machines that run on hydraulic fluids supplied by Fluid Competence of North Rhine-Westphalia.

Retrospective on Germany – future Opportunities in Overseas Markets

It is especially remarkable to see the leading role that the German coal mining industry has played in association with well-known machine manufacturers when it comes to the technical development of water-polymer fluids. It was a partnership that enabled this technology to develop internationally and to diversify into other branches of industry.

The origins of substituting hydraulic fluids in underground mining machines go back to the changes that were applied to the statutory requirements. Fire protection was very much at the forefront of concerns and replacing mineral oil with other products was an inevitable part of this development. This led to individual machines being converted as part of a gradual process. Specific industry standards were drawn up for the German coal industry (then RAG) and special product lines were developed for the hydraulic systems. All this
took place more than ten years ago and marked the advent of the Lubesave and Corsave range of lubricants. This substitution process was applied equally to mobile hydraulics and to stationary hydraulic systems.

Underground mining machines, such as drum shearer loaders, shield supports and boom-type roaders, were operated successfully for years without the use of mineral oil-based hydraulic fluids (Fig. 4). Everyone engaged in this project, including manufacturers and personnel involved with hydraulic equipment, was called upon to monitor the process with all the components and competencies they could bring to bear. This operation included pumps, cylinders, valves, tanks, control units and the servicing of entire production units. The comprehensive practical experience that was acquired with water and polymer based hydraulic fluids therefore dates back to this period.

This initiative actively contributed to the introduction of substitute products for mineral oil and bio-oil. The relevant licences were issued for machines from the mining equipment suppliers (OEMs) Caterpillar, Eickhoff and Hauhinco and all this was documented in the manufacturer’s user manuals.

The fluid development process included extensive biodegradability tests that were carried out in accordance with recognised methods (OECD) by the Ruhr District Institute of Hygiene/Institute for Environmental Toxicology in Gelsenkirchen. Tests were also conducted by the TÜV Nord Group and by companies such as Bosch-Rexroth and the relevant approvals were issued. All the official tests carried out at manufacturers’ facilities were supplemented by the practical experience that had been acquired by the different plant and machine operators. This ‘operators group’ also had wide-ranging experience of the fluid lifetime figures for the various machines and this meant that the fluid change intervals could be greatly extended.

Diversifying to the international Mining Market

Fluid Competence has used the current economic challenges to establish itself in new markets and positive references from Germany have resulted in international mining companies adopting the firm’s products. Fluid Competence now supplies markets on three continents.

As well as delivering for the German mining sector the company is also selling its products to mine operators on the Bosphorus and in Asia.

Tunnelling still a Key Activity Factor

In the tunnel construction industry hydraulic machines are regularly operating close to the ground and in the immediate vicinity of the groundwater. The use of environment-friendly hydraulic products is therefore especially relevant under such conditions. Here too fire protection is just as important as it is in the mining sector. Early successes in the field of utility tunnel construction have been described above.

Metallurgical Industry

When it comes to stationary hydraulics the focus is on industries such as steel, copper and aluminium production. Fluid Competence can count among its customers, some now of long standing, a number of well-known companies operating in these areas. Here too the process of replacing mineral oil-based fluids in hydraulic systems has already begun.

Fire protection has been a major reason for the uptake of the new fluids. However, freedom from reliance on mineral oil supply chains and environmental protection are now also perceived as two important objectives. The substitution process is gathering pace.

Literature


Dipl.-Betriebswirt
Volker Bremer

is Head of Marketing at Fluid Competence in Kamen, Germany.

Contact:
vbremer@fluid-competence.de
How an IIoT Solution for Mining Machines can be successfully introduced into a Quarry Operation

Dr.-Ing. Michael Suciu, Talpasolutions GmbH, Essen, Germany

1 Key Challenges

The ongoing process of digitalisation in the mining industry has meant that IIoT solutions can be increasingly employed not just for stationary equipment but for mobile machines too. This involves software solutions that can display information on mining machines and production processes in a clear and user-related manner and by means of data analytics can provide ‘insights’ that are the basis for practical recommendations for action.

The key feature of this system is that it provides permanent access to, and automatic capture and transmission of, real-time data streams using dedicated, rugged data loggers that are installed on-board the machines (Fig. 1). This generates what the data world calls ‘big data’. However, in order to use these big data efficiently they have to be intelligently processed, which means that they must be filtered and the relevant data analysed so that ‘smart data’ can be produced. Assuming that these smart machine data are interpreted and visualised in an appropriate and practical way by an experienced technology and data analysis partner there is another factor to be taken into account, namely that the employees of the mining company are ready to engage with the new solutions that have been introduced to help with their work and decision making and are prepared to maintain and use them accordingly. This is where the chosen technology partner can and indeed should provide support in the form of expertise and competence.

Mining companies are now fully aware of the fact that digitalisation is crucial for them if they are to use their machines efficiently and sustainably, especially when it comes to increasing operating times and productivity, reducing downtime and making decisions more rapidly and effectively. But many of them possibly do not know whether or not they are ‘digital ready’ – and they never will until they try out the new technology for themselves.

The provision of support for the decision-making process, which is described below, is driven by two key factors:

▶ Man and motivation
▶ Technology, infrastructure and processes

2 Man and Motivation

One thing is clear: the motivation for introducing something new begins at the top. Motivation is an important factor, and perhaps the decisive one. New technologies in general, and digitalisation projects in particular, can only prove successful when they are really wanted by the company management and are also driven and supported by them.

Some clarification is needed at this level as to what exactly ‘digitalisation’ (of mobile equipment) can bring...
What kind of operational objectives are to be achieved?

- What kind of faults and warning messages occur on a short-, medium- and long-term basis?
- Can these result in damage and downtimes?

Or should maintenance and repair also be the focus of attention?

- What quantity level can I produce?
- Where and when do idle times occur and how can they be reduced?
- Can I optimise my loading and transport cycles?

Finding answers to these questions will first and foremost be the responsibility of the company management and the managerial team, this comprising the operations manager, the production manager, the maintenance manager and the supervisors. Here it is vital to identify and appoint a management team that have developed a sense of togetherness and a mutual awareness of the urgency of the project. This team should then be capable of explaining to all stakeholders in the company what kind of pressing problems can and should be solved with the digitalisation project.

The decision-making process involved is a fairly complex one when it comes to choosing the solution to be adopted and/or the working partner to be used – this being due to the large number of providers on the market. Established software manufacturers are now offering expensive hardware and software solutions that are also time-consuming to install, the various vehicle manufacturers are providing software systems specifically developed for their telematics, while startup companies offer marketing solutions that are data analysis-oriented, focused on selected sensor technology and often manufacturer independent.

When it comes to the visualisation of the smart data there are a number of systems available, ranging from preset displays through to freely configurable dashboards with widgets where key figures can be chosen at will and collated for specified users or user-groups.

To what extent the provider is able to supply a service that is appropriate for the company will be reflected in the sector expertise of the vendor in question and in his overall approach during the bidding phase and during the transposition process.

Talpasolutions, an Essen-based startup for data analytics in the mining industry, has developed a structured procedure for just such a situation. During the bidding phase, and prior to the actual start of the project, Talpasolutions conducts interviews with several ‘persons of interest’, that is to say selected individuals with different functions and from different hierarchy levels, with a view to making a joint evaluation of the timeline and job content along with all the data and indicators required. It also carries out an analysis of the operational circumstances, e.g. whether the vehicles being integrated are ‘data capable’, whether GPS localisation is available at the quarry and whether interference-free data transmission can be guaranteed. An early workshop also marks out the expectations situation and the achievable results and jointly defines the kind of technical and organisational measures that have to be adopted for validation, for example.

This approach helps mining companies to formulate and expound their perception and expectations for the digital project.

3 Technology Infrastructure and Processes

3.1 Technical Assurances for the Data Collection Process

Collecting data is fairly unspectacular from a technology point of view.

The acquisition and transmission of machine data in a quarry environment involves the use of the Talpasolutions-developed talpacortex S data logger system, which operates with an antenna mounted on or in the vehicle and is connected to the latter via CAN bus interfaces. The data loggers feature an internal data storage unit that can hold up to three months of data and a computing unit for data compression so that a 10-minute data upload of log files is sufficient to transmit the machine data into the cloud-based data analytics platform. GPS positions and sensor data from an installed triaxial accelerometer are also transmitted alongside the original telemetric data. The actual data evaluation process is undertaken by the Essen-based data analytics company Talpasolutions using a web-based data analytics platform. The company specialises in IoT solutions for the mining industry and its expert team of mining and mechanical engineers and data analysts have built a platform and analytics algorithms based on the latest IT technology. The data logger can even be fitted and commissioned by mining company service engineers operating under instructions.

In response to the disruption caused by the corona pandemic Talpasolutions also developed an instruction guide that provides companies with brief and clear directions on the installation and functional testing of the data logger (Fig. 2) and enables them to fit the device independently. This has also made the new technology more readily acceptable to the operating personnel.

Having said that, the mining company needs to take steps to ensure that the new technology also runs
smoothly, i.e. that the machine data can be collected fully and continuously and as interference-free as possible and can be matched to the relevant production and machine processes for subsequent analysis purposes.

An efficient routine has been adopted to the effect that when the vehicle is being commissioned the operating personnel have to test the condition and functionality of the data logger using the illuminated display and if necessary check to ensure that any sensors fitted additionally or subsequently are working properly. As transmission takes place via the antenna the latter and its associated cables also have to be regularly inspected for damage. While the software could also be used to indicate whether the machine data are being sent out or not, it is important not to overlook the visual checks as a redundant procedure. Talpasolutions has drawn up appropriate guidelines for dealing with this.

3.2 Infrastructure Assurances for the Data Collection Process

The machine data must be collected in full and in an assignable way if a high level of analysis quality is to be achieved every time.

In order to ensure full data transmission in ‘batch packages’ the data loggers, and hence the machines, need to have sufficient time for the transmission process and so must be positioned in areas with sufficient coverage. Talpasolutions therefore examines these requirements when assessing the project at the bidding phase and if necessary decides on the technological provision of a machine-to-machine data transmission system in the data logger. Any technical and organisational measures that are deemed necessary are also communicated with the operational project team.

A significant share of the assessment work also requires a degree of spatial allocation, whether this be in relation to the absolute spatial situation based on GPS positioning or to the spatial situation relative to other vehicles, e.g. loader and transport vehicle during the loading phase or transport vehicle and crusher during the unloading phase. One particular challenge arises for the data analysis process when vehicles are temporarily or permanently parked at specified (workshops, parking area, fuelling station) or unspecified points. Subsequent logistic analysis may find it difficult or impossible to identify these vehicles in data algorithmic terms and this can result in incorrect interpretation.

From a data analytics perspective, for example, a vehicle that is parked up at the workshops is undergoing repair and is therefore not available for deployment. Parking a vehicle in this area should therefore only be possible when the operating personnel have been properly informed – if necessary using structurally defined demarcation lines.

In this particular case the parking areas were clearly visible and were marked off by solid perimeter lines and the operators were kept regularly updated as to the situation – similar to the procedure used for safety training and signage.

3.3 Procedural Assurances for Data Collection and Evaluation

Established processes and behaviour patterns have to be adapted and altered whenever new technologies are introduced. The different motives behind the introduction and launch of the digitalisation project have been set out above.

In the case of the projects being handled by Talpasolutions the project team prepared themselves in good
time for adapting to and implementing the organisational processes. In this the aims and measures laid down in the team remit were communicated to all the stakeholders in an open and transparent manner, with a special focus on evaluating the data and indicators that had been collected, analysed and presented.

Key performance indicators are particularly suitable for allocation to certain persons and person groups. Data protection concerns are to be taken seriously and addressed openly.

In order to involve the workforce right from the very start Talpasolutions arranged for a series of workshops to be held where solutions were presented, this involving the collection, analysis and presentation of the data, and the new practices and procedures introduced. Talpasolutions also established a communications framework and frequency rate with the core team and set up project meetings that were to be jointly headed by the project operations representative and a project manager from Talpasolutions.

3.4 Focus on rapid and lasting Success

It was found that one way to achieve success quickly and sustainably was to deliver short-term project successes, or ‘quick wins’. The experience from previous projects undertaken by Talpasolutions showed that short-term success depended on having key performance indicators generated automatically and permanently. The laborious and costly process of raw data gathering, which at best was selective and time limited, could be considered as superfluous. Instead, the data could be allowed to grow steadily with analyses continuously being brought up to date.

Automatic data collection and analysis alone could save one or two hours of engineers’ time each week as the daily and weekly figures were available at the click of a mouse along with the downloadable tabular and graphic displays. These could regularly be used for in-house meetings and also filed for documentation purposes.

Continuous data acquisition and analysis also enables an ongoing review to be made of the operational improvements achieved. At an operating site in the USA, for example, the target loading of the transport vehicles was permanently improved by 5% and the transport cycles also optimised, a result that meant a real reduction in vehicle waiting times.

The positive successes recorded in connection with the data collection and analysis process and with the measures jointly derived from it were also regularly communicated to and assessed by the operations team and the members of staff. At the same time, safety-relevant factors, such as excessive speeds at critical points, overloading of transport vehicles and dangerous tyre pressures, were kept in focus at all times. All this meant that the new system was quickly accepted by the workforce in general – and not just by the younger ‘digital natives’.

4 Summary and Outlook

Pilot projects undertaken by Talpasolutions at a number of stone quarries show that good short-term results generally bring rapid acceptance of this new technology. They also indicate that smart machine data can contribute to an efficient and sustainable mining operation in the medium to long term. Here it is essential that signal data from telemetry and sensor systems are continuously recorded and transmitted to a data platform where a needs-based, target- and user-oriented analysis can take place.

As with any new technology certain established organisational processes and behavioural measures have to be introduced in order to obtain the greatest possible and most sustainable benefits. Open and transparent communication and a common understanding of the motivation behind the digitalisation process and its ultimate objectives are a prime guarantor of success.

It has been found that when it comes to digital initiative projects small successes, or quick wins, are preferable to complex results. In the initial phase in particular it is important to focus on short-term successes and to invest in them. Digitalisation can no longer be ignored but rather is something that has to be confronted head on. It is now a question of how data is to be used rather than whether we should use it. Digitalisation based on data analytics platforms and machine learning algorithms is an ‘enabler’, not a substitute, for a sustainable and future-proof mining industry.

References


Dr.-Ing. Michael Suciu
is responsible for business development at talpasolutions GmbH, Essen, Germany.

Contact:
michael@talpa-solutions.com
SMT Scharf – more than Monorails

Christian Rumpf, SMT Scharf GmbH, Hamm, Germany

The SMT Scharf Group located in Hamm, Germany, and its worldwide subsidiaries can look back on a long history. For more than 80 years these transport and logistics specialists have been developing and building series products and customised solutions that have created a link between the transport and automotive sector and the traditional mechanical engineering industry. While the company’s 400-strong workforce, which includes some 100 engineering staff, is proud of their past record and of the wealth of experience that has been built up, nevertheless their efforts are now very much focused on looking ahead to help shape the future – a future that lies beyond the underground mining industry.

The company’s product range is too broad-based for easy categorisation and overhead monorail installations are just one of the many items on offer, as the firm’s slogan ‘More than monorails’ is quick to point out. Yet the most widely recognised of all the company’s products are its rail-bound transport systems for the underground mining industry. SMT Scharf subsidiaries are based primarily in the world’s major coal producing countries where they provide services and spare parts supplies for customers that have to operate around the clock. And China is now the main driver of technical innovation and equipment development in this sector. The company was quick to react to this new customer base and in 2019 became the first Western supplier of the MA III-approved DZK 3500 machine series, which meets the stringent emission standards in the Chinese market (Fig. 1).

In China too there is now an ongoing demand for more automation and autonomous technology. While the shortage of microchips and electronic components for this sector in particular has also been felt by SMT, the company acted with far-sightedness a number of years ago by buying a controlling interest in the German-based hardware suppliers ser Elektronik of Möhnesee. ser Elektronik has its own development department and uses in-house SMD pick-and-place robots to manufacture specific products for complex industrial tasks and individual, custom-designed solutions. The products that SMT Scharf subsidiaries are able to procure from this source include electronic controls, intrinsically-safe power supply units, explosion-proof control panels, LED lights and power source systems.

ser Elektronik is also active outside its own corporate group and the company is a global supplier of acoustic signalling devices, instruments for architectural acoustics, controls for medical equipment and the food processing industry and products for traffic management systems, to name a few. The automation engineers at SMT’s Hamm-based plant in Germany and at Xuzhou in China have certainly been making the most of this key asset when it comes to developing complex automated and part-automated transport systems.

Doing other Things too

The company’s latest business unit, namely the Hamm-based tunnel logistics division, has also profited from this supply source. The new unit was formed by merger with the former NOWILAN company of Dinslaken and its engineers develop solutions for applications that present the same kind of challenges as those being faced by their colleagues in the monorail division:

- Confined working space
- High payloads
- Steep gradients
- Low fuel/energy consumption
- Low or ‘zero’ emissions

The company workforce has already demonstrated that it can achieve real synergies within the corporate family environment. The Snowy 2.0 pumped-storage hydroelectric power project under way in Australia has already opted to use the ‘Made in Germany’ reliability and quality that SMT can provide. The personnel transport system leading to the TBM, which has to climb a
rational development and production sites at Sudbury in Canada and Johannesburg in South Africa. There is also a sales and service centre in Santiago de Chile. At the three main production plants everything quite literally revolves around wheels – and in this case we are talking about the rubber-tyred wheels that keep the mineral mining industry moving.

So it is quite obvious that Germany’s ‘hidden champion’ can do more than monorails. A few years ago SMT Scharf acquired the know-how and the manufacturing facilities of the RDH in Sudbury, Canada. The Canadian company had already pioneered the electrification of underground loaders ahead of the big three LHD manufacturers based in Sweden and the USA. With their straightforward hands-on mentality the engineers at the newly branded Canadian subsidiary RDH-Scharf Mining Equipment lost no time in converting their own diesel loaders, scissor-lift platforms, trucks, drilling machines and other support vehicles to battery operation and in so doing soon acquired their own technical expertise in this technology. SMT Scharf can now cover the Americas market from its Sudbury base near Toronto, while the North Americans get support from Santiago de Chile – at the centre of the Chilean copper industry – for their South American operations.

Flexibility, customer focus and the willingness to respond quickly and readily to requests are attributes that are very much appreciated by customers in the hard-rock mining industry worldwide. The South African subsidiary SMT Scharf Africa has taken customer focus to new heights in that it not only serves the African continent but also uses first level support from other SMT companies to cover requests from the rest of the world.

The South Africans have been part of the corporate group for some time. With their electric drives the locally-used EMTS installations (Electric Monorails Transport System) mainly transport materials such as pipe sections and tunnel supports to where they are required in the deepest gold mines in the world. Though they are classed as monorails these systems are nothing like their diesel-powered German counterparts. But the real core business is chairlifts and this is the product that made SMT Scharf Africa what it is today. The chairlift has proved a massive benefit for the miners. The chairlift circuits are up to 3,000 m in length and the seats are more like those found on a bicycle than those you would see on similarly named installations at a winter sports centre. However, like ski lifts they are in continuous movement and have the capacity for carrying large numbers of people – in fact they can transport nearly one thousand miners every hour. The miners are always keen to point out that SMT Scharf can claim credit for building and operating the world’s deepest chairlift system, more than 4,000 m below ground.

Yet the company’s engineers and technicians are even more highly regarded for their developments in the field of battery power. In South Africa the group

**International Arena**

As well as maintaining production facilities in Tychy (Poland), Xuzhou (China) and Novokuznetsk (Russia) the German parent company also operates additional...
has put battery technology at the centre of all its development activities. Prior to this the parent company in Hamm had been developing its own solutions for underground electromobility in association with various West European suppliers. However, quality, reliability and that willingness to respond quickly and readily to customer requests seem to be in short supply in Germany and in Europe in general – but were much easier to come by within the group’s own ranks in Africa. And when it came to electric drive systems even the Canadians had a valuable contribution to make.

Something that is particularly worthy of mention – certainly in comparison with other electrified underground vehicles being supplied by the competition – is the safety philosophy that has been adopted by SMT Scharf. The batteries that are produced in-house use cells from reputable manufacturers, while all other components are products from the company’s own design and production line. What makes SMT Scharf batteries so special is that all the cells are immersed in a non-conductive dielectric fluid that under normal conditions prevents thermal work-through. In the event of such an incident, which can be caused by mechanical damage or electrical overload, one or several battery cells would catch fire and trigger a chain reaction or running fire – this being referred to as a thermal work-through. Obviously the high thermal load and smoke emissions associated with such an event, though serious enough above ground, would have even more disastrous consequences in an underground mining environment. And it is for this reason that the SMT Scharf team uses ‘wet’ battery technology and no other.

The company’s portfolio of rubber-tyred vehicles is an extensive one and the mid-sized model range, which comprises loaders with a 10 t payload capacity, trucks of 30 t capacity and various service vehicles, covers the whole spectrum of roadheading and mineral winning machinery. SMT Scharf also sells a lightweight electric transport vehicle, the Scharf LEV, which is based around the industry-proven Toyota Land Cruiser (Fig. 3).

As well as highlighting unique selling points like the very safe battery system and exceptional service backup the South African and Canadian teams are quick to point out that the vehicles are now available in remote control mode for all their key functions. Open interfaces are now provided for remote control as well as collision warning and emergency braking function, the latter having been mandatory in South Africa for several years. As SMT says, things are now ‘future ready’. There is no desire to force customers into adopting the company’s own OEM system but rather to maintain an open system approach that allows integration into the architecture and infrastructure of the client’s existing systems.

As well as running future-oriented electric drive technology all the vehicles in the range can also be fitted with diesel motors – and here too it is for the customer to decide what is the best option so that parts commonality along the powertrain matches that of the existing fleet.

And if there are readers out there who have ever tried out a pit bicycle they should know that this too was a product of the SMT Scharf factory. The pit bike is still available to this day, though delivery may take a while. And it’s definitely no monorail.

**Fig. 3:** The Scharf LEV: an electrically driven transport vehicle – with the SMT Scharf ultrasafe battery system fitted as standard

---

**Christian Rumpf**  
Sales Director,  
SMT Scharf GmbH, Hamm, Germany

**Contact:**  
christian.rumpf@smtscharf.com
Environmental Social Governance (ESG) – the Future in Mining
Dr.-Ing. Martin Wedig, Association of Foreign Mining and International Raw Materials Activities (FAB) in the VRB e.V., Berlin, Germany

A raw materials turnaround in the sense of uniformly higher international standards in terms of environmental protection, social and technological development (Environmental Social Governance – ESG) will become the future guideline in mining. The most urgent task for the coming years is to implement both issues, raw material security and ESG conformity, at the same time. This requires above all investments in the exploration, production, processing and refining of raw materials. In addition, technical innovations are needed to expand existing mining capacities and make them as ESG-compliant as possible. At bauma 2022, technological solutions and specialist expertise will be presented.

The demand for critical minerals is expected to increase over the next three decades, with some estimates suggesting that demand for clean energy technologies could reach more than €400 billion per year by 2050. The energy transition and the race towards net-zero emissions will therefore lead to a surge in demand for ‘critical raw materials’ (Fig. 1). Forecasts therefore foresee rising revenues for mining companies, but at the same time rising costs will put pressure on their margins. This is because the global economy is at the beginning of a megatrend with the ‘transition to a low-carbon, sustainable economy’. Environmental, social and governance (ESG) issues are therefore increasingly becoming the core of mining companies’ strategies and, along with the increased demand for certain raw materials, are the initiators of the raw materials turnaround.

It is primarily raw materials such as lithium, nickel, cobalt that are needed for the production of low-emission energy elements and graphite for energy storage, copper and aluminium for energy transmission, and silicon, uranium and rare earths for solar, wind and nuclear energy production. From today’s perspective, the supply of such minerals will hardly be sufficient to meet demand. In addition, there is currently a considerable investment backlog in the mining sector (Fig. 2). This is because although investment in exploration increased last year, it fell short of expectations as supply chain bottlenecks, Covid-19 restrictions and the consequences of war in Ukraine delayed important projects. As the top 40 mining companies need to increase spending at the same time due to ESG, they will carefully consider their investments in the face of rising inflationary pressures and ongoing supply chain issues.

The world will therefore only be able to achieve its net zero targets if the mining industry can increase its production. In this respect, not only increased investment in the exploration, production, processing and refining of raw materials is now required, but also technical innovations that lead to the expansion of existing mining capacities and make them more ESG-compliant as quickly as possible.

ESG Requirements

ESG – environmental, social and governance – and related issues are not new to the mining industry, even if the term is still not well practised. Mining companies have a history of addressing environmental issues in...
their production and have environmental management, reclamation and sustainability on their agendas. ESG now brings all these issues together in a broader framework:

- With regard to the **environment**, biodiversity, ecosystem services, water management, mining waste and tailings, air, noise, energy, climate change (carbon footprint, greenhouse gas), hazardous substances, mine closure and sustainability of mining raw material extraction are mentioned here as being particularly relevant to the goals.

- In terms of **social**, issues related to human rights and the vulnerability of people, land use, resettlement, gender equity, labour practices, health and safety for the workforce and communities, and sustainability issues – especially after-use of former mine sites – are prioritised.

- And in terms of **corporate governance**, the focus is on legal compliance, ethics, transparency and combating bribery and corruption, which are already being addressed by, among others, the international Extractive Industry Transparency Initiative (EITI) of currently 57 countries.

Investments in mining and the management of mining companies will therefore become much more difficult in the future. This is because mining companies will already have to check whether their planned investment is ESG-compliant when raising capital.

### Technological Solutions

Certainly at the **bauma 2022** the main technological solutions will be discussed such as ‘digitalisation and mining 4.0’. For the raw materials sector, Mining 4.0 means the further development of automation in extraction, transport and processing. The goal is to combine automation of surface and underground extraction and resource-conserving and sustainable raw material extraction through maximum selective production with the effect of cost savings. In recent years, the efforts of German mining companies have been focused on making mining even more efficient, economical, environmentally friendly, socially responsible and, indeed, transparent. **bauma 2022** will therefore focus on further new topics, such as data management and digital interaction.

In contrast to three years ago, the industry has already made a quantum leap, with companies across the sector already using automated technologies that now need to be intelligently networked in the next stage. For example, according to recent reports from GlobalData, diamond mining company Alrosa recently installed automated wireless monitoring to control its operations remotely and unmanned. Mining companies and mining equipment manufacturers such as Vale, Rio Tinto and Komatsu, meanwhile, have begun to use autonomous transport vehicles. In terms of bringing e-mobility to mining, ABB has recently developed a new ‘eMine FastCharge technology’ that enables autonomous charging of electric vehicles remotely to facilitate the green electrification of mining (Fig. 3). In addition to automation itself, ESG-related initiatives intend to increase the use of the Internet of Things (IoT) and artificial intelligence (AI). Other use cases include the use of intelligent video surveillance and predictive maintenance technologies that increase safety by reducing the risk of accidents. By using AI in prospecting, companies can identify areas of high resource concentration before mining and model blasting operations using machine learning (ML) to minimise environmental impact while maximising efficiency. The combination of AI, ML and IoT will make the mines of the future smarter, greener, safer and more cost-effective. Various German exhibitors – especially mining machinery manufacturers – will present such innovative developments to solve the aforementioned challenges to the international trade audience at **bauma 2022**.
FAB as Contact Partner at bauma 2022

For this reason, the Fachvereinigung Auslandsbergbau und internationale Rohstoffaktivitäten (FAB) will be answering the questions of visitors to bauma 2022 together with its many medium-sized companies. The FAB is not only committed to proactive raw materials security, but is also a network of various service providers in the raw materials sector. These include exploration companies such as ILV-Fernerkundung, Delta, Terratec and BEAK as well as technology companies DMT, Sandvik, Bochumer Eisenhütte, CFT Filtertechnik, Herrenknecht, WEG, Dorfner Anzaplan and many others that are organised at FAB and drive developments in the sector. The renewed interest in foreign mining is reflected by the influx of a number of start-up companies to the FAB, such as Caracal Gold PLC, Saxore Bergbau AG, ECM Lithium AT GmbH, Deutsche E-Metalle AG, and Neolit Minerals. These companies are developing new projects on various raw materials and should become interesting for German large-scale consumers to re-enter active raw material extraction. The FAB supports the projects of its member companies through a variety of association activities. In addition to pure committee work in advisory boards, multi-stakeholder groups and committees (BDI Committees on Raw Materials, Development, Export Credit and Foreign Trade Policy, NamiRo, Country Networks Mining and Energy and others), regular lectures and information events are offered. This year, bauma Mining is now prominently taking place in Munich. Here, FAB is represented with its own stand in cooperation with the VDMA and is the contact point and point of contact for institutions in Germany, for foreign mining delegations and companies, in order to establish contacts between different trade fair visitors and FAB members, to promote exchange and to stimulate international cooperation for raw material projects and foreign mining.

Dr.-Ing. Martin Wedig
Managing Director of the Association of Foreign Mining and International Raw Materials Activities (FAB) in the VRB e.V., Berlin, Germany

Contact:
martin.wedig@v-r-b.de

Beak Consultants GmbH - your partner for applied geology, environmental services, customised software development and advanced e-government solutions.

advangeo® software solutions cover the entire of geo-scientific data life cycle: capture, storage, processing, beneficiation, presentation:

Geodata management
- Observations/measurements
- Maps, documents, literature
- Cadastral data
- Bore holes, samples, analytics
- Mine sites...

Mobile data capture
- Orientation/navigation
- Documentation
- Mobile analytics

AI based predictive mapping
- Mineral Exploration
- Geohazard prevention
- Infrastructure protection
- From point data to aerial data
- Raster data interpretation
- 2D and 3D

Features
- Scalable
- Adjustable
- Multilingual
- Windows and web based
The Institute of Mining at the Clausthal University of Technology is organising the 23rd Colloquium: Drilling and Blasting Technology on 01 and 02 February 2023. The first blasting operations in mining in the Upper Harz Mountains date back to the year 1632. The rapid spread of the new extraction and excavation technology is considered one of the epochal milestones in the development of mining technology. The continuous further development of explosives in the Harz Mountains and the invention of dynamite in 1866 extends to the ultra-modern applications in surface and underground mining operations of today. Even in past centuries, the exchange of information on the current state of the art was of particular importance to disseminate further developments and advance innovations. The Colloquium was founded following this guiding principle.

In the past years, we were pleased to welcome more than 300 national and international participants to the colloquia of this series in Clausthal. The speakers presented internationally implemented solutions and innovative projects from the fields of drilling and blasting technology.

Organiser
Institut of Mining
Department of Underground Mining Methods and Machinery
Univ.-Prof. Dr.-Ing. Oliver Langefeld
Erzstraße 20
DE-38678 Clausthal-Zellerfeld
Tel.: 05323/72-3180
Email: info@bus2023.de

Further information on the event is available on the website:
www.bus2023.de

Best Regards and Glückauf
Oliver Langefeld

Discover the new GeoResources Portal and the Online Market Place 4.0

Fresh, new + up to date.

- Personnel News
- Events
- Journals
- Market Place 4.0
- Registration: Market Place 4.0 & Who is Who
- Mediapool
- www.georesources.net
EiControl ADVANCED STATE BASED AUTOMATION

The next level in longwall and remote mining face operation by utilizing highly advanced automation features.

Operation beyond the boundaries of the machine with smart sensor systems like vibration, sound and infrared supporting assistive automation.

Visibility of the operation by means of customer specific real-time data leading to faster decision making.

Better and safer work environment, higher repeatability, accuracy and enhanced reliability of operation.