DUCTILE IRON PIPE SYSTEMS

The Annual Journal of the European Association for Ductile Iron Pipe Systems · EADIPS

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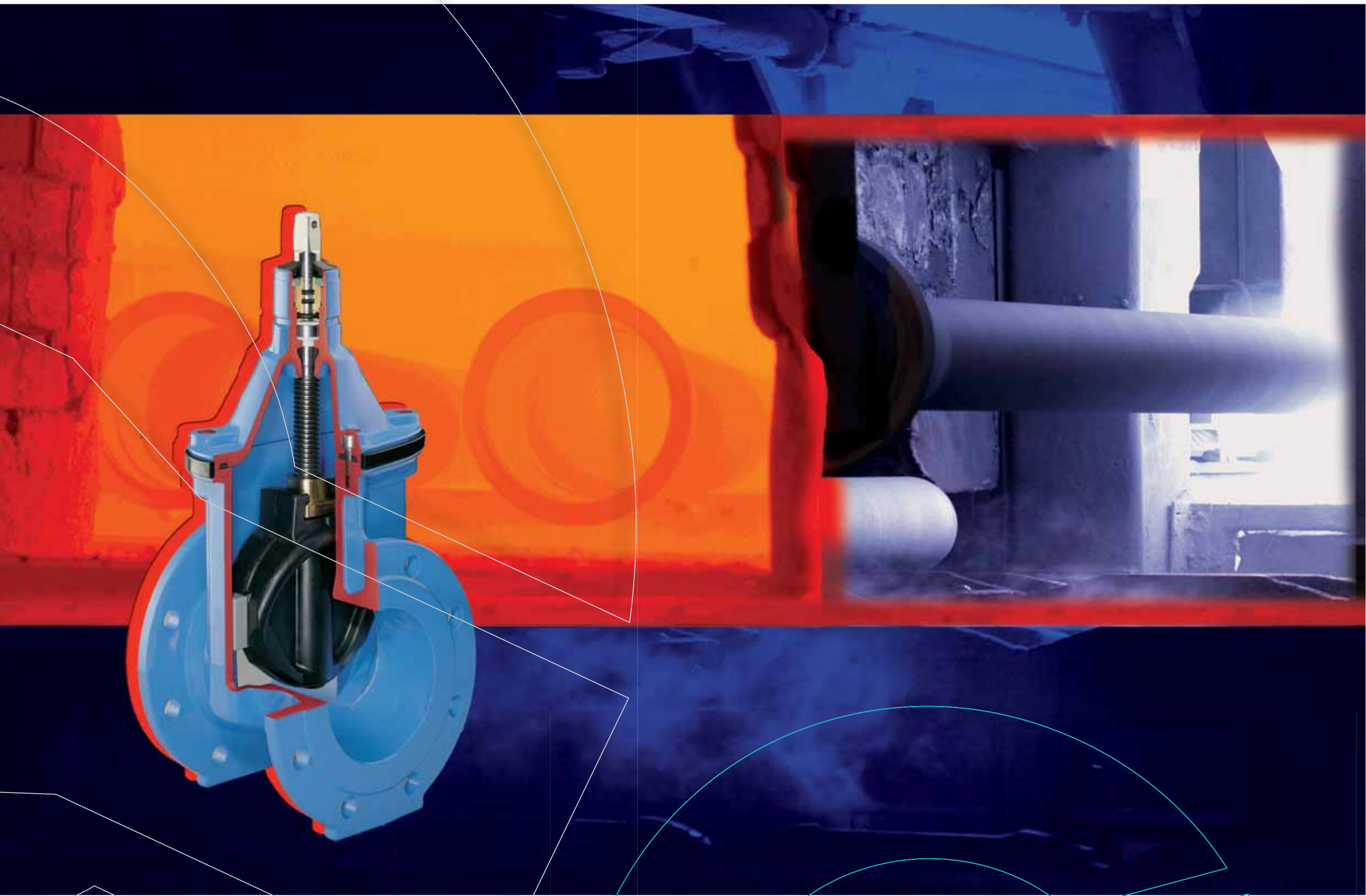

kolumne

Dear readers,

The new title may have given you a clue: after nearly 6 decades, the beginning of 2010 has seen the Fachgemeinschaft Guss-Rohrsysteme (FGR) e.V. develop into a European industrial association known in English as the **E**uropean **A**ssociation for **D**uctile **I**ron **P**ipe **S**ystems · **EADIPS**. From now on, the FGR/EADIPS association will be representing the interests of European manufacturers producing pipes, fittings and valves of ductile cast iron.

With its change of title from **GUSSROHR-TECHNIK** to **GUSS-ROHRSYSTEME**, the 44^{th} issue of our journal is indicative of the FGR/EADIPS's new focus. This 44^{th} issue of our journal is also the first edition available in English.

The articles in No. 44 are focused on pipeline systems (pipes, fittings and valves), namely pipeline systems whether for water distribution, for sewage disposal or for other technical applications. The reports from the practical field have been selected to spotlight the diversity of possible applications for ductile cast iron pipe systems.

Here is an up-to-date overview of what ductile cast iron pipe systems are capable of doing nowadays.

We trust you will find this new 44^{th} issue of **GUSS-ROHRSYSTEME** an enjoyable read!

Main connecting sewer in a former mining area in the Deuben municipality in the Burgenland district of Saxony-Anhalt

Heiko Schiemann and Hendrik Kahnt 9

Unstable soils, areas of mining subsidence and earthquake zones are just some of the conditions that ductile cast iron pipes have long been able to cope with, as they have again demonstrated at a sewer laid in the Burgenland district of Saxony-Anhalt in Germany. The only possible route for a gravity sewer ran through small subsidence troughs, but these troughs were successfully crossed by DN 250 pipes with restrained joints. Even the inspection chambers have restrained joints. Ductile cast iron pipes were the most economical solution under these difficult conditions.

The "Gämpi" sewer viaduct with walk-on maintenance access – a main sewer of DN 400 polyurethane-lined ductile cast iron pipes

Urs Lang 13

The DN 400 main sewer of a mountain village in Switzerland crosses a deep valley on a pipe viaduct. After 50 years, both the sewer and the viaduct needed to be replaced and the foundations of the viaduct needed to be moved to an area where the ground was more stable. The old sewer had to be kept in service during the replacement work and only one hour was available for the changeover. Due to the inaccessibility of the site, all of the material had to be brought in by helicopter. Ductile cast iron pipes with restrained joints and a polyurethane lining showed how suitable they are for difficult projects of this kind.

Replacement of the combined sewer and storm water pipeline in the town of Willingen (Upland)

Ingolf Bittermann and Karl-Wilhelm Römer 17

When sewer pipes have to be replaced in narrow old streets in towns in mountainous areas, this is often the right time for ductile cast iron pipes to be used. This was the situation in Willingen (Upland) in the German state of Hesse where there was a combination of the following problems: shallow top cover, an increase in diameter, existing buildings and existing pipes and cables for other services and the need to maintain drainage capacity and access to shops and for residents. It was only the ductile cast iron pipe that could solve these problems and it even did so four weeks earlier than scheduled.

Cast iron veins to carry some of the lifeblood of the new Berlin-Brandenburg International Airport (BBI)

Lutz Rau 22

Construction of the new Berlin International Airport BBI includes an extensive network of drinking water and waste water pipelines. This interim report shows that two years before completion of the airport more than 60 km of ductile cast iron pipelines ranging in size from DN 80 to DN 700 have been laid, most of them with restrained joints. The safety requirements of the designers and operators are extremely demanding but they can be met by pipelines of ductile cast iron.

Reconstruction of the Rietwis bridge in Wattwill an der Thur in Switzerland includes a thermally insulated DN 200 ductile cast iron water pipeline

Stefan Rüegg 27

A road bridge has been adapted to the increased payloads of vehicles and this called for a drinking water pipeline installed on the bridge to be replaced. Its cross-section was increased to DN 200. To meet state of the art standards, the pipes were provided with factory-applied thermal insulation with an electrical trace heating system.

Renovation of the water main running from the Nibelungenplatz to the Danziger Platz in Frankfurt am Main

Alexander Scholz and Christian Schmidt..........29

A more than 60 year old water main made of DN 500 grey cast iron pipes lay along a three-lane east-west arterial highway in Frankfurt am Main. Due to "spongiosis" (graphitization) it was prone to damage and needed to be renovated. Hydraulic calculations indicated that the cross-section could be reduced from DN 500 to DN 300. The final outcome of an exemplary multi-stage planning process including a feasibility study, a comparison of variant laying techniques and a study of the existing pipeline was the selection of relining with ductile cast iron pipes in two sections. Such thorough planning had to succeed!

Renovation of large trunk mains in Leipzig

Henry Simon and Wolfgang Rink.......................34

The development of a town is reflected in its infrastructure. While Leipzig was growing in the era of progressive industrialization, the system for supplying drinking water was constantly having to be extended. There was further growth too after the Second World War. Re-unification was followed by a drastic fall in consumption due to demographic change and the fact that there was now a charge for consumption.

As a result, the cross-sections of the pipelines have to be downsized to adjust the residence time of the drinking water in them to meet health requirements. Relining with ductile cast iron pipes has proved successful for the large trunk mains. Regardless of the condition of the old pipeline, the new pipeline that is pulled in or pushed in is equivalent to a newly laid one, with all that this means for useful life and depreciation. The installation costs are lower than for conventional laying in open trenches.

The development of valves for pipe networks in water supply

Oliver Jäger..40

For the safe and reliable distribution of good quality drinking water, the industry has always relied on durable products whose life cycles are measured in decades. Nevertheless, it is important for there to be a continuous and forward looking process of ongoing development. Some selected groups of products are taken as examples to show the stages by which certain features have developed in the field of valves.

Renovation of a drinking water pipeline intersection in Burgkunstadt in Bavaria

Udo Arrenberg..44

The successful development of valves and fittings is focused on customers' problems and requirements. Typical examples of this are the flangeless gate valve with restrained sockets and the adapter for fitting between old pipes of different materials and the restrained socketed gate valve. When a pipe cross with four integrated gate valves and a hydrant was replaced in a municipal water distribution system, the new valves and accessories cut the number of individual components from 546 to 47 and the installation time went down from four hours to less than one.

Valves of ductile cast iron – an investment in the future

Thomas F. Hammer..47

The principle of sustainability implies the holistic consideration of all the costs of producing, operating and disposing of a product. The reconditioning of a DN 2000 needle valve weighing 40 tonnes after 40 years in service was found to be more economical and sustainable than the production of a new valve. For such a project to succeed, the prerequisite is of course total know-how covering all the stages of stripping out, transporting and machining the old valve and re-installing the reconditioned one when it is, once again, as good as new.

Casting process simulation in valve and fitting production

The same applies to foundry management as to other areas of the economy: those who are quick to do something beat those who are slow. Formerly, castings were developed to production standard in single steps and trial runs by a laborious optimisation procedure. Patterns, runner gates and feeder systems were modified and trial casts made until the casting defects and dimensional errors were within acceptable limits. Depending on how complicated the casting was, optimisation of this kind could take weeks to months before volume production by a stable process was possible.
With the development of computer-aided casting and solidification simulation and given suitable experience, this optimisation phase has been shortened, on the computer, to a few days. Foundries who made use of this modern-day production tool in good time gained a significant competitive advantage. Casting process simulation is described by reference to a fitting for water distribution.

Ductile cast iron pipes – "Arteries" for the snow-making system

Around 20 million winter sports enthusiasts come to Germany's Sauerland mountains for a refreshing break or a holiday. Climate change is putting the region's economy at risk due to the lack of snow.
However, at heights below 1000 m the skiing season can be extended from 30 days to 80 days by the production of artificial snow. This is essential for the survival of the tourist industry. This article tells the impressive story of the design, planning and construction by the municipality of Willingen of a snow making system costing more than Euro 5 million, a process that never lost sight of the need for the environment to be respected and the natural landscape preserved. It is not only the authorities at federal state, district and municipality level who are bearing the financial burden. The ski-lift operators are paying a similar amount for snow canons and water intake points. Only ductile cast iron pipe systems could meet the requirements set by the internal pressure, ground conditions and laying technique.

Electricity generation by using the power of drinking water has a future

In alpine terrain, drinking water is collected at springs and fed to covered reservoirs serving local communities. There are considerable heads between the two points. Hydroelectric plants powered by drinking water kill two birds with one stone: a local water supply is combined with local electricity generation. Guaranteed tariffs for electricity fed onto the grid mean that the plant and the installation work soon pay for themselves. Ductile cast iron pipes with restrained push-in joints are equal to the high operating pressures and are easy to install and their robust material will withstand any external loads.

Parts of a turbine penstock pipeline slope at up to 80° – The Plankenbach (San Cassiano) small hydroelectric power plant

Governments try to achieve their CO_2 reduction targets by making guaranteed payments for electricity from renewable sources which is fed onto the grid. These same targets also have an important part to play in the economic success of a small hydroelectric power plant in South Tyrol. A spring, formerly used only for drinking water production, is being used to feed a 1.2 km long DN300 turbine pipe with a PFA of 63 bars. With extreme gradients of up to 80°, pipe laying in steeply sloping trenches blasted in rock and other acrobatic feats called for – ductile cast iron pipe systems provided an elegant solution to all these problems.

The CO_2 reduction programme, the feed-in tariff for electricity from renewable sources and favourable topographic conditions are factors that encourage the construction of small hydroelectric power plants. In Garmisch-Partenkirchen, an old line for drinking water has been increased in size to feed a small hydroelectric plant which mainly generates electricity but also provides a reserve supply of drinking water. In the steep mountainous terrain there were extreme difficulties that the pipeline layers had to overcome. Thanks to the rugged ductile cast iron pipes with restrained joints and heavy duty external protection, the project went off exactly as planned. The pressure test at 61 bars was passed at the first attempt and the small plant has been producing electricity for 700 4-person households for a year now. Over the next 10 years the community is looking to increase its proportion of renewable energy to 40 %.

For the past few years, the centrifugally cast ductile cast iron pipe has been used in a slightly modified form as a foundation pile in special purpose foundation engineering. It combines a number of technical and economic advantages such as its simple installation without the use of any special machinery. A simple excavator with a hydraulic pile driving hammer fitted is all that is needed. No scrap sections have to be cut off and any leftovers can always be used. More recently, there have been trials of its use as an energy pile in geothermal tubes and this gives it additional potential in these times of increasing promotion of renewable energies.

Main connecting sewer in a former mining area in the Deuben municipality in the Burgenland district of Saxony-Anhalt

by Heiko Schiemann and Hendrik Kahnt

1 Introduction

The municipality of Deuben is situated in the Burgenland district of Saxony-Anhalt and its salient feature is mine workings dating back as far as the end of the 19th century. The municipality consists of the villages of Naundorf, Deuben, Wildschütz and Nödlitz, in virtually of which brown coal has been mined to depths of around 25 m by underground and open-cast mining. The municipality's sewage facilities needed to be developed and for this a sewer pipe serving 1,100 inhabitants needed to be installed.

2 Planning

Right from the start it was considered important to minimise any ongoing costs which might arise in the future and to find a route for the sewer which met this demand.

The option of using a pressure pipeline plus a sewage lift/pump station was ruled out early on in the phase when the various options were examined.

Unfortunately, the heights and the ownership of the pieces of land concerned meant that there was only one route along which a gravity sewer could be laid. There were old mine workings along this route.

The LAGB, the Office of Geology and Mining of the state of Saxony-Anhalt, supplied documents which allowed the positions of the underground mine galleries to be located **(Figs. 1 and 2)**. These were underground galleries of the "Emilie" pit. Stabilisation work by stowing had been done from 1975 to 1976 and in 1995 in the galleries and shafts, which had formerly been shored with timber and masonry. It was known that the stowing was not com-

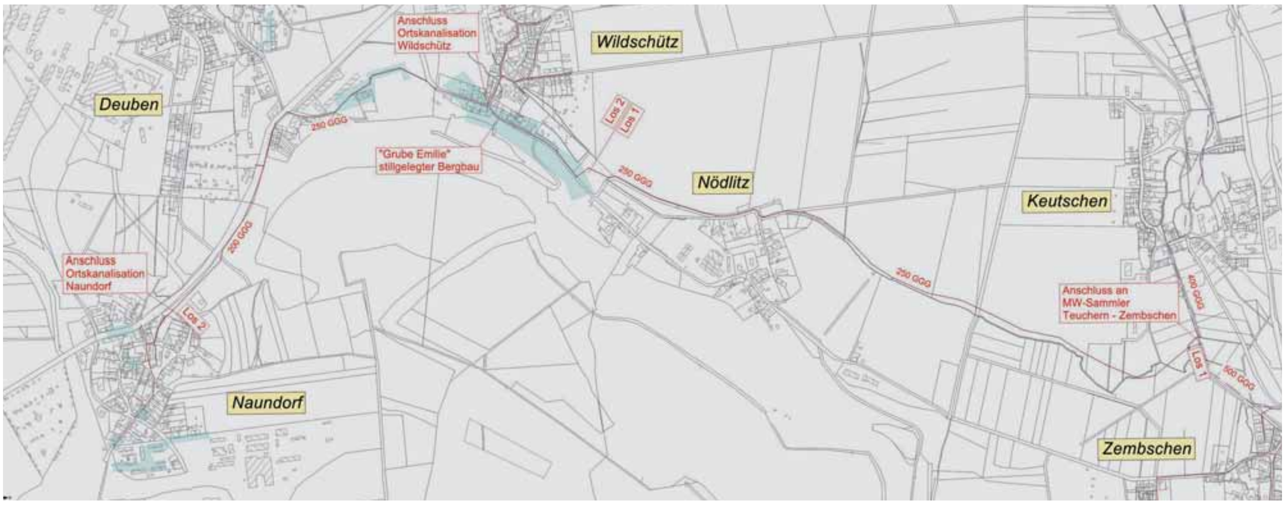

Fig. 1:
Overall plan of the sewer route from Naundorf to Zembschen
(Areas shown in blue = areas of mining subsidence)

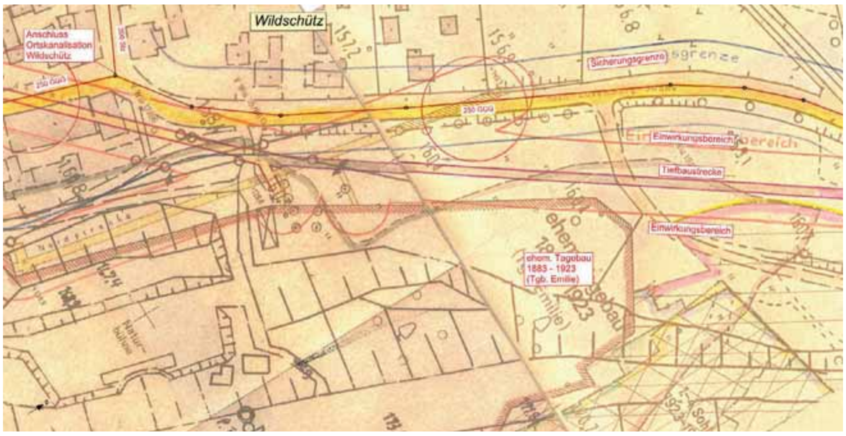

Fig. 2:
Detail view of a mine subsidence area – from the LAGB's plans

plete along the galleries and that, because of the varying water table, the stowing material could flow out in the parts of the galleries which had been left unstowed. The possibility of subsidence sinkholes could therefore not be ruled out. Sinkholes measuring approx. 3 m in diameter already existed above these parts.

The pipes selected therefore needed to be ones which would cross sinkholes of this kind without allowing the sewage to seep out into the mined area below. The Office of Mining feared that the infiltration of such sewage could trigger further subsidence.

3 Selection of the pipes

The pipes selected had to meet the requirement for high longitudinal bending strength. The funnel-shaped sink troughs expected were 3 m wide and the pipes needed to be capable of crossing these without any risk of fracture. Vitrified clay pipes are usually up to 2.5 m long so this ruled them out. Plastic pipes such as PVC and polyethylene pipes and PVC sewer connecting pipes were unable to meet the stress requirements.

A pipe of the right kind was found in the form of the ductile cast iron pipe. The pipe is supplied in lengths of 6 m and this enabled it to bridge the 3 m wide funnels expected. Stress analysis prior to the laying work verified that the pipes selected would be stable. The verification was carried out for two extreme situations, firstly as simply supported beams and secondly as cantilever beams.

There was one extra job that the pipeline had to do: even if a funnel occurred in the soil, drainage of the sewage and wastewater should continue until steps could be taken to stabilise the funnel that had appeared. The possibility of escaping sewage causing further subsidence had to be ruled out. This was the reason why restrained BLS® push-in joints were used. This type of push-in joint has the advantage that if subsidence occurs the resulting longitudinal forces can be transmitted to the pipes next in succession and to the area where the ground is stable without this causing a joint to be pulled apart and starting to leak.

4 Execution of the laying work

The main connecting sewer was laid in DN 200 and DN 250 ductile cast iron pipes to EN 598 with TYTON® push-in joints to DIN 28603. The ductile iron sewer pipes are lined with cement mortar and have a metallic zinc coating plus an epoxy top coat **(Fig. 3)**. DN 250 pipes of wall-thickness class K 9 with restrained BLS® push-in joints **(Fig. 4)** were installed in the area where there was mining subsidence.

Fig. 3:
Ductile iron pipes to EN 598 with TYTON® push-in joints

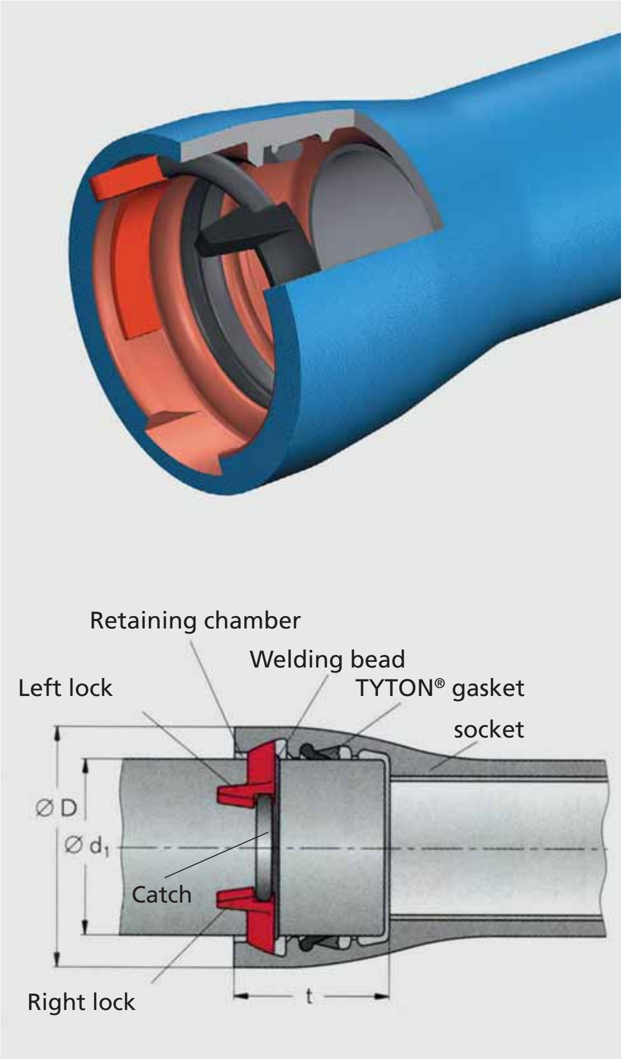

Fig. 4:
Structure of the
BLS® push-in joint

The ground water had to be drained away to outside the area which had been affected by mining. Because deposits of brown coal were encountered in the pipe trench itself, the floor of the trench had to be stabilised. As far as possible, the weak areas of brown coal were replaced with a compactable material. Even so, it cannot be ruled out that further strata of brown coal may cause some minor subsidence. With its restrained push-in joints, which can be deflected to up to 4°, the pipeline will even allow minor amounts of subsidence without ceasing to operate as a sewage-tight system.

Fig. 5:
Bottom section of concrete manhole
with restrained VRS manhole connector

The bottom sections of the manholes were produced as precast monoliths incorporating restrained VRS manhole connectors **(Fig. 5)**. A total of 62 manholes were installed. Ductile iron pipes were also used for the connecting pipes to the houses. These connecting pipes were connected to the main sewer itself with all socket tees.

In the course of the installation work, particular care was taken to shore the walls of the trench and to drain it. The company doing the laying work, Meliorations-, Strassen- und Tiefbau GmbH, used slide rail shoring to shore the trench **(Fig. 6)**. The trench was drained by drainage pipes laid in open trenches.

Fig. 6:
Installation trench with slide rail shoring

Table 1:
Key pipeline-related data on the operation

Pipeline	Nominal size	Length
Ductile iron pipeline with TYTON® push-in joints	DN 250	2,400 m
	DN 200	700 m
Ductile iron pipeline with BLS® push-in joints	DN 250	800 m

To prevent any drainage effect from occurring in the longitudinal direction of the pipeline, the backfilled trench was interrupted every 25 m by transverse barriers of concrete or cohesive material.

Table 1 gives the key pipeline-related data on the operation.

The total planning and installation costs amounted to a gross figure of 910,000 Euros.

5 Summing-up

In spite of the difficult constraints caused by the old mine workings, the installation operation, involving 3,900 m of DN 250 ductile iron pipes, was completed within only four months. Capable installers and thorough monitoring of the work and checking of invoices allowed an all-in price per metre of pipe installed of 196 Euros to be achieved. This price per metre is not particularly high, especially when compared with pipeline installation operations where there were fewer problems with the ground. The ductile iron pipe system used did its bit to ensure the economic success of this demanding operation.

Authors

Dipl.-Ing. (FH) Heiko Schiemann
Walter + Partner GbR
VBI Consultant Engineers
Kleingärtnerstrasse 10
06682 Teuchern, Germany
phone: +49 (0)3 44 43/50-1 13
E-mail: walter.partner@wup-te.de

Dipl.-Ing. (BA) Hendrik Kahnt
Walter + Partner GbR
VBI Consultant Engineers
Kleingärtnerstrasse 10
06682 Teuchern, Germany
phone: +49 (0)3 44 43/50-1 19
E-mail: walter.partner@wup-te.de

Clients

AZV (Special-Purpose Sewage Association)
Oberes Rippachtal
Krautbrückenweg 1
06679 Hohenmölsen OT Zembschen, Germany
phone: +49 (0)3 44 41/3 31 44

ZWA (Special-Purpose Water Supply and Sewage Disposal Association) Bad Dürrenberg
Thomas-Müntzer-Strasse 11
06231 Bad Dürrenberg, Germany
phone: +49 (0)34 62/54 25-0
E-mail: info@zwa-badduerrenberg.de

Planning and installation monitoring

WALTER + PARTNER GbR
VBI Consultant Engineers
Kleingärtnerstrasse 10
06682 Teuchern, Germany
phone: +49 (0)3 44 43/50-0
E-mail: walter.partner@wup-te.de

Installation work

Meliorations-, Strassen- und Tiefbau GmbH
Nebraer Strasse 103
06636 Laucha, Unstrut, Germany
phone: +49 (0)3 44 62/31-3
E-mail: info@mst-laucha.de

HIESTRO-Bau GmbH
Pegauer Strasse 50
06682 Nessa, Germany
phone: +49 (0)3 44 43/6 00-0
E-mail: info@hiestro.de

The "Gämpi" sewer viaduct with walk-on maintenance access – a main sewer of DN 400 polyurethane-lined ductile cast iron pipes

by Urs Lang

1 Introduction

The old main sewer (DN 400, fibre cement pipes) of the Swiss village of Adligenswil crossed the stream called the Würzenbach on a slope subject to erosion and slippage. After 50 years of service, it has been replaced by DN 400 polyurethane-lined ductile cast iron pipes.

2 The "Gämpi" viaduct

The main sewer of the village of Adligenswil goes from Adligenswil towards the Würzenbach district of Lucerne. In the "Gämpi" region, the sewer pipeline, of DN 400 fibre cement pipes, ran above the ground on steel girders (forming a viaduct) for a length of some 80 m. The pipeline ran through the forest and over the Würzenbach stream across a steep, impassable slope which is very subject to erosion and slippage **(Fig. 1)**.

The viaduct was just as old as the pipeline and just as much in need of renovation. Some of its foundations had slipped and been damaged **(Fig. 2)**. There was a danger that the old viaduct and the pipeline might suffer further damage from erosion and slippage of the slope and that sewage might get into the Würzenbach as a result. The pipeline was difficult to access and hence to maintain.

3 The renovation project

After a study of the variant options, it was decided in June 2008 that a new main sewer pipeline would be installed on a viaduct situated away from the slope which was subject to erosion and slippage. The following requirements had to be met:

- a substantial improvement in the safety, protection and accessibility of the sewer pipeline,
- protection for the sewer pipeline from falling trees,
- foundations for the viaduct away from the slipping slope,
- walk-on access to the new viaduct to facilitate maintenance work and
- improvement of the small longitudinal gradient as compared with the old pipeline.

Fig. 1:
The old "Gämpi" viaduct

Fig. 2:
Destabilised foundations which had slipped

The new “Gämpi” viaduct was constructed to the east of the old one, away from the slope which was subject to erosion and slippage. This also allowed the pipeline to be shortened and the new gradient to be optimised at around 0.6 %. In the north a new inspection manhole was constructed at the transition to the existing pipeline and in the south the existing manhole was used. The overall length of the viaduct constructed is 67 m, its width is 1.5 m and its maximum height above ground level is approximately 9.0 m. Seen in plan, it contains a 30° angle and was constructed in 3 spans (23 m/24 m/20 m) with two intermediate supports. A summary of the main structural dimensions of the new viaduct can be seen in **Table 1**.

The steel structure of the viaduct consists of two lateral longitudinal girders, transverse girders and a floor of walk-on steel gratings for maintenance work. The abutments and the foundations of the two intermediate supports are of concrete and are carried on moraine. In the region of the banks of the Würzenbach, the foundations are protected by flow-channelling blocks (block stones) to improve their hydrodynamic profile. The intermediate supports are constructed from galvanized steel tubes strutted in three directions. Because of the difficult, impassable terrain, the entire project was planned for transport by helicopter as far as the components were concerned.

The sewer pipeline is positioned between the steel longitudinal girders of the viaduct (Fig. 3) and thus has the maximum possible protection against being hit by trees. The following were the factors which decided the material selected for the ductile sewer pipeline:

- very high transport capacity for suspended material due to low frictional drag (k < 0.01 mm),
- high strength of ductile cast iron as a material and hence a low weight for the pipeline,
- very high resistance to abrasion, and a simple, fast and safe connecting technique.

The best way of meeting these requirements was with a polyurethane-lined DN 400 sewer pipe and with the hydrotight restrained joint.

4 The execution phase

Because of the difficult conditions posed by the terrain, building a suitable access route would have been too expensive. The entire project from the construction of the concrete foundations to the installation of the pipes therefore had to be planned around the use of transport helicopters **(Figs. 4, 5 and 6)**. The completion on schedule will live in the memory of all those involved as an impressive event and an example of ideal co-operation between clients, engineers, constructors, installers and suppliers.

Table 1:
Structural dimensions of the new “Gämpi” viaduct

Structure	Dimension
Viaduct – Length	67 m (3 spans of 23, 24 and 20 m)
Viaduct – Width	1,5 m
Viaduct – Height	Max. of 9 m above ground
Pipeline – Length	80 m
Pipeline – Gradient	0.6 %

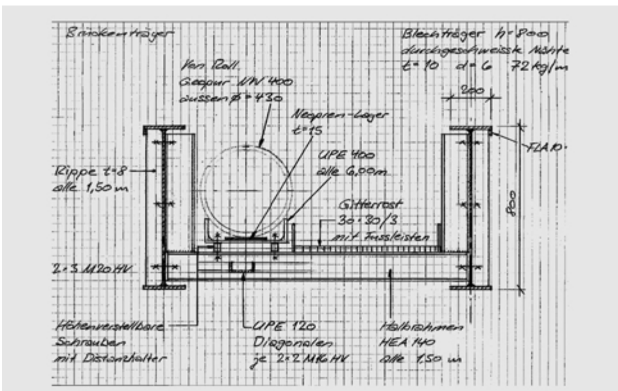

Fig. 3:
Drawing of the viaduct in cross-section

Fig. 4:
Transport helicopter

Fig. 6:
The "Gämpi" walk-on sewer viaduct showing the DN 400 geopur pipes and their transport

Fig. 5:
The ductile sewer pipes being swayed in

Fig. 7:
A ductile iron pipe with a polyurethane lining and an external zinc coat plus bituminous top coating

The eastward shift in position allowed the new viaduct to be constructed without regard to the old one and without temporary provisions. This was essential because the existing sewer carried a great deal of sewage. The connection of the old pipeline to the new section therefore had to take place within a very short time. The new 80 m long sewer pipeline was installed within an hour – which included the transport of the ductile sewer pipes for 500 m by helicopter and the connection of the restrained push-in joints.

The pipeline uses a 30° bend with restrained push-in joints to follow the angle in the viaduct. Because of the pressure of time, the bend was pre-assembled to the geopur pipe **(Fig. 7)** by the exterior hydrotight restrained joint at the intermediate storage point. In this way, at the point of use, it was able to be connected immediately to the ductile iron pipe already in place.

Following the successful construction and pipe installation work and the entry into operation of the new pipeline in 2009, the old pipeline was broken up, flown out by helicopter, and properly disposed of.

Author

Urs Lang
Bucher + Dillier
Ingenieur-Unternehmung AG
Industriestrasse 6
6000 Lucerne, Switzerland
phone: +41 (0)41/3 68 07 64
E-mail: u.lang@bucher-dillier.ch

Client

Einwohnergemeinde Adligenswil
(Adligenswil residents' council)
Chairman of council Markus Sigrist
Dorfstrasse 4
6043 Adligenswil, Switzerland
phone: +41 (0)41/3 75 77 22
E-mail: markus.sigrist@adligenswil.ch

Project and construction management

Bucher + Dillier
Ingenieur-Unternehmung AG
Urs Lang
Industriestrasse 6
6000 Lucerne, Switzerland
phone: +41 (0)41/3 68 07 64
E-mail: u.lang@bucher-dillier.ch

Constructors

Schmid Bauunternehmung AG
René Schurtenberger
Neuhaltenring 1
6030 Ebikon, Switzerland
phone: +41 (0)41/4 44 40 27
E-mail: rene.schurtenberger@schmid.lu

Steelwork

Mauchle Metallbau AG
Pfrundmatte 4
6210 Sursee, Switzerland
phone: +41 (0)41/9 25 12 51
E-mail: info@mauchleag.ch

Pipe installation

Schacher Sanitär
Gido Schacher
Dottenbergstrasse 15
6043 Adligenswil, Switzerland
phone: +41 (0)41/3 70 30 30
E-mail: info@.schacher-sanitaer.ch

Cast iron sewer pipes – and big ones too

Replacement of the combined sewer and storm water pipeline in the town of Willingen (Upland)

by Ingolf Bittermann and Karl-Wilhelm Römer

1 Introduction

The municipality of Willingen (Upland) has 3,500 inhabitants. It lies at an altitude of 584.10 m above sea level in the south-western part of the Upland region, between Hesse's Westerwald mountain range and the Rothaargebirge range. The wide range of leisure activities it offers has made the municipality a favourite holiday resort. It is famous for the annual return of top events such as the FIS Ski-Jumping World Cup, the Mountain Bike Festival and the Alpenhorn Fair.

Willingen, the main town of the municipality, is drained mainly by a combined system and the sewage is treated in a treatment plant situated at a lower level. The supervisory authorities called for refurbishment work to be done and laid down deadlines for the conversion or replacement of sewer systems including the associated structures. The refurbishment of the main sewer running along the Schwalefelder Strasse was part of the refurbishment of the sewer network as a whole.

2 The initial situation

Hydrodynamic calculations were done for the entire drainage network of the town of Willingen and these gave the pipe diameters and the overflow and flood frequencies. They showed that the main sewer in the Schwalefelder Strasse needed to be completely revised. The old rainwater overflow structure situated in the Schwalefelder Strasse was no longer of the right hydraulic dimensions and, in structural terms, no longer measured up to current standards of good engineering practice. Because of the sizes of the existing pipes it was not possible for the existing network to be refurbished; the main sewer had to be re-laid. The ground was rocky and because of this the re-laying could only be carried out by conventional open-trench techniques. The council of the municipality of Willingen (Upland) entrusted the duties of planning, overall management for the client and installation management to the Oppermann GmbH civil engineering company of Vellmar **(Fig. 1)**.

During the installation work, runoff capability had to be maintained in the Schwalefelder Strasse all the way along the main sewer. Also, access for people and deliveries had to be maintained throughout the installation period for the shops, businesses and boarding houses fronting on the street, which meant that arrangements had to be made for intermediate stages of completion in the course of the installation work.

Added difficulties were the demolition of the old rainwater overflow structure and the building of a new rainwater relief system at the point where a multi-storeyed post-and-beam house carried on columns running into pointed arches was situated. As mentioned above, the existing combined sewer running to the treatment plant had to be increased in cross-section, as also did the relief sewer running from the rainwater overflow structure to the receiving watercourse, the stream known as the Itterbach. Because of the installation work, parts of the existing cable network and the gas pipeline also had to be converted or re-laid and this meant further difficulties.

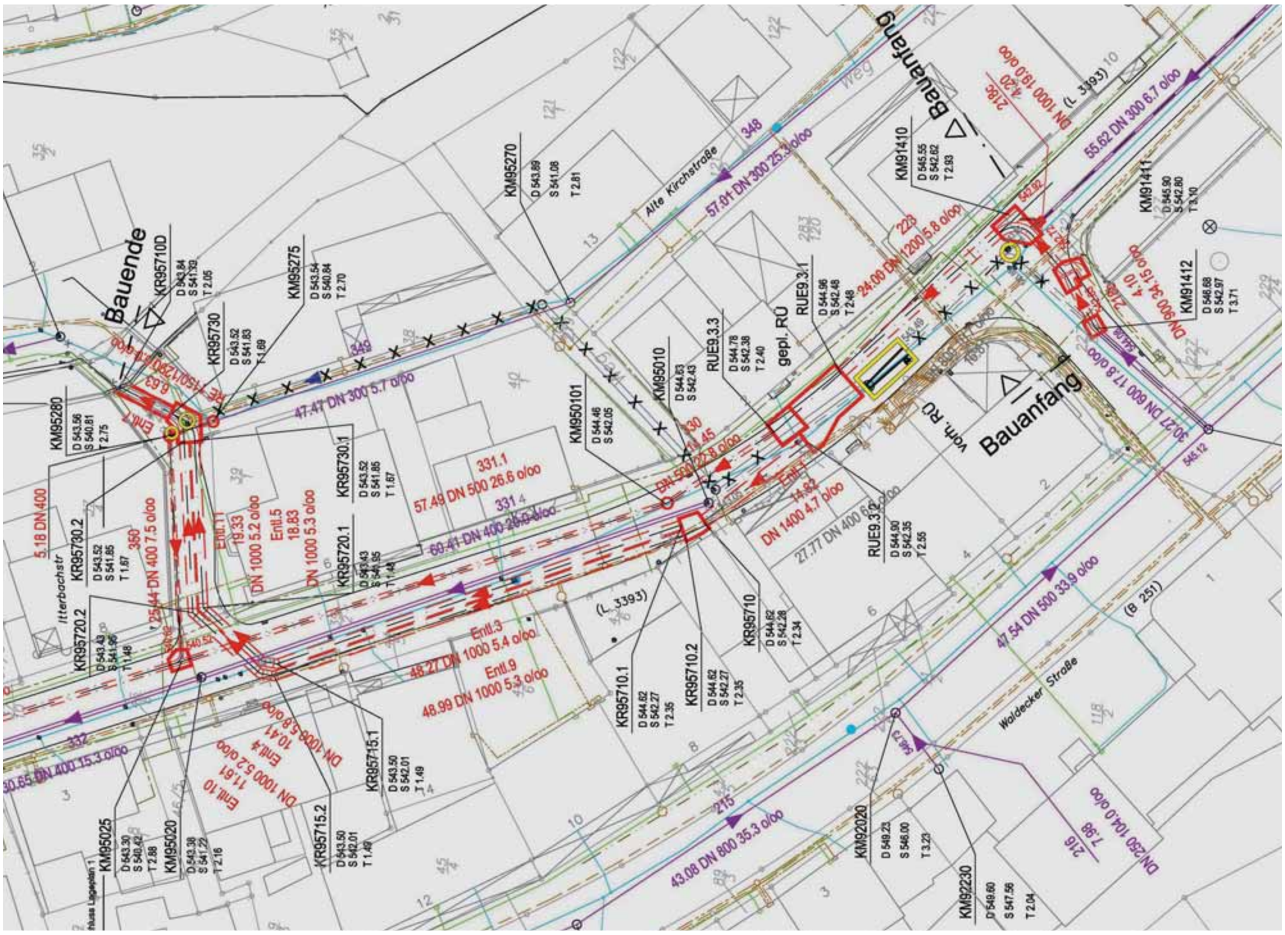

Fig. 1:
Location plan for the work on the main sewer on the Schwalefelder Strasse in Willingen (Upland)

3 Selecting the pipes

Because there would be only a small height of cover over the relief sewer and because the pipe cross-section required was DN 1400, careful overall planning was needed.
A concrete-framed rectangular sewer could not be laid due to lack of space and the excessively small height of cover and this was why the client, together with the civil engineering company, decided to use ductile cast iron pipes to EN 598 for the entire sewer system that had to be replaced **(Fig. 2)**. These pipes are lined with high-alumina cement mortar as standard and are protected externally by a zinc coat and a top coating **(Fig. 3)**.

Fig. 2:
Ductile sewer pipes lined with high-alumina cement mortar for internal protection and with a zinc coat and a top coating as external protection

Fig. 3:
A DN 500 ductile iron sewer pipe to EN 598

Fig. 4:
The post-and-beam house shored up by a wall of secant bored piles

Fig. 6:
Twin DN 1000 ductile iron pipelines forming the relief sewer from the overflow structure

Fig. 5:
The DN 1400 outer sewer from the rainwater overflow tank

Fig. 7:
The relief sewer (twin DN 1000 pipelines) covered with earth

The TYTON® push-in joint to DIN 28603 has been proving its worth in pipeline systems for drinking water and sewage for decades now. The sewage pipes of ductile cast iron are capable of carrying high loads, are secure against fracture and are suitable for carrying high earth loadings and traffic loads with only small height of cover.

4 Execution of the installation work

There were the following major difficulties affecting the installation work planned:

- rocky ground,
- position of the old sewer,
- runoff capability had to be maintained,
- existing supply pipelines and cables,
- existing buildings
- access had to be maintained for people and deliveries
- installation time had to be short.

An open, competitive pre-qualification procedure therefore took place to enable the expertise and performance of the potential bidders to be checked in advance. This was followed by a restricted call for bids which was won by the expert, high-performing Rohde/Wachenfeld consortium from the Waldeck-Frankenberg district. The existing combined main sewer remained in operation throughout the entire installation time and the new main of DN 500 ductile iron pipes was laid in parallel on the left and right hand sides to the new rainwater overflow structure.

A wall of bored secant piles anchored at the rear was set up to safeguard the multi-storeyed post-and-beam house **(Fig. 4)**. It should be mentioned that no damage whatever occurred to buildings during the sewer installation and the subsequent road-building work.

Fig. 8:
Twin DN 1000 socket bends of ductile iron

Fig. 10:
Pre-cast reinforced concrete component with pre-fitted DN 500 ductile iron connector

Fig. 9:
Twin DN 1000 socket bends when installed

Fig. 11:
Pre-cast reinforced concrete manhole with ductile iron manhole connections

The existing rainwater overflow structure was demolished section by section and replaced by a new one. Because of the shallow depth at which it lays and the intersection with the combined main sewer, the relief pipeline from the new overflow structure could not be laid throughout in a nominal size of DN 1400 **(Fig. 5)**.
Therefore, to take the water at the relief flow rate (Q_{out} = 3,059 L/s), twin pipelines of DN 1000 ductile iron sewer pipes **(Figs. 6 and 7)** were installed as a continuation of the initial outlet sewer. Here the small wall-thickness of the ductile cast iron pipes proved to be a considerable advantage over reinforced concrete pipes.

The direction of the relief sewer was changed from the Schwalefelder Strasse onto the Itterbachstrasse by means of twin DN 1000 bends (six in all) **(Figs. 8 and 9)**. Before the outfall into the Itterbach, the two relief sewers installed in parallel were combined at a single structure and were tied into the wing wall of the structure

Fig. 12:
House connections being made from the sewer with ductile iron saddles

of a bridge by means of rectangular-section framing profiles. In the region of the two relief pipelines, the pipes were sheathed in Dämmer filling material.

Ductile iron manhole connections to EN 598 were used to tie the pipelines into the pre-cast reinforced concrete manholes **(Figs. 10 and 11)** and into the structures of cast-in-situ concrete. The house connections from the sewer were made with ductile iron saddles **(Fig. 12)**. The inlet main to the new rainwater overflow structure likewise consists of ductile iron pipes, of sizes from DN 900 to DN 1200.

Despite their overall length of 6 m, the ductile iron pipes were always easy to handle. When adapting pipes were required, it was also easy to make cuts in the pipes to produce them. Whenever there were questions about pipe installation or the successive deliveries of pipes, the pipe manufacturer's field staff could always be contacted and there was always somebody on site, meaning that there were no downtimes during the installation work.

5 Final review

The right choice was made when ductile iron sewer pipes were selected for the re-laying of the main sewer on the Schwalefeder Strasse in Willingen (Upland). Even where there was only small height of cover, loads could be applied to the sewer pipeline immediately following installation without any additional structural provisions. This and the expert way in which the installation was carried out enabled the operation to be completed in 2006 as much as four weeks ahead of the scheduled final deadline. Thanks are once again extended here to all those who contributed to this fine success.

Authors

Dipl.-Ing. Ingolf Bittermann
Oppermann GmbH
Civil Engineers and Engineering Consultants
Adalbert-Stifter-Strasse 19
34246 Vellmar, Germany
phone: +49 (0)5 61 / 8 29 07-63
E-mail:
ingolf.bittermann@oppermann-ingenieure.de

Karl-Wilhelm Römer
Duktus Rohrsysteme Wetzlar GmbH
Kassel Sales Office
Schweinsbühl, Kerbelweg 6
34519 Diemelsee, Germany
phone: +49 (0)56 32 / 92 22 52
E-mail: karl-wilhelm.roemer@duktus.com

Client

Gemeinde Willingen (Upland)
Dipl.-Ing. Walter Frosch
Waldecker Strasse 12
34508 Willingen, Germany
phone: +49 (0)56 32 / 40 10
E-mail: post@gemeinde-willingen.de

Planning and installation management

Oppermann GmbH
Civil Engineers and Engineering Consultants
Dipl.-Ing. Ingolf Bittermann
Adalbert-Stifter-Strasse 19
34246 Vellmar, Germany
phone: +49 (0)5 61 / 8 29 07-63
E-mail:
ingolf.bittermann@oppermann-ingenieure.de

Installers

Rohde/WACHENFELD Consortium

Heinrich Rohde
Tief- und Strassenbau GmbH
Jahnstrasse 18
34497 Korbach, Germany
phone: +49 (0)56 31 / 56 03-0
E-mail: info@rohde-bau.de

JOS. WACHENFELD GMBH & Co. KG
Frankenberger Landstrasse 8
34497 Korbach, Germany
phone: +49 (0)56 31 / 9 50-0
E-mail: info@wachenfeld-bau.de

An interim report

Cast iron veins to carry some of the lifeblood of the new Berlin-Brandenburg International Airport (BBI)

by Lutz Rau

1 Description of the giant construction site

The construction site is a gigantic one. It is situated on the south-eastern edge of Berlin and incorporates the existing Schönefeld airport **(Fig. 1)**. The BBI International Airport project combines not only the construction of the new airport itself while normal flying services are maintained but also a complete re-organisation of the transport connections to the capital and its urban field. Access to the future airport is being opened up by the Schönefeld autobahn interchange and its connecting road to the capital, Berlin, and by the railway links including the S-Bahn network.

A vast range of supply and disposal pipelines are needed for this largest German transport project. Because of the demanding requirements for long life and safety which the drinking water supply and sewage and wastewater disposal systems have to meet in operation, the client and the planners are putting their trust in ductile iron pipes to EN 545 or EN 598 and the TYTON®-BRS® and TYTON®-BLS® restraint systems.

Extensive pipeline re-laying work **(Fig. 2)** and a drainage pipeline for rainwater prepared the way for the construction work in the years from 2004 to 2007. Altogether, this involved the installation of some 25 km of ductile iron pipes of nominal sizes ranging between DN 150 and DN 700 for conveying drinking water, sewage and wastewater.

Fig. 1:
Flying services are maintained in spite of the giant BBI construction site

Fig. 2:
Pipeline re-laying to prepare the construction site

Fig. 3:
DN 300 drinking water and sewer pipes laid out along the route where they will be installed in parallel

Fig. 5:
A DN 600 drinking water pipeline in the Kienberg area

Fig. 4:
Ductile iron drinking water and sewer pipes being installed in parallel

Fig. 6:
A DN 300 ductile drinking water pipeline being connected and pushed in by special attachment

2 Off-airport development for sewage

The sewage conveying pipeline between the airport site and the Wassmanndorf sewage treatment plant, comprising around 4,000 m of DN 600 ductile iron sewer pipes and around 1,500 m of DN 400 pipes, is currently being commissioned. An old drinking water pipeline of Hume pipes had to be re-laid for this purpose and this too was done with DN 600 ductile iron pipes of wall thickness class K10 with the BRS® restraint system **(Figs. 3 and 4)**.

The work of pipe laying on the grounds of the treatment plant itself (a length of pipeline of around 1,000 m of various nominal sizes) was done by Berliner Wasserbetriebe (BWB), the plant operators, once again using ductile iron pipes.

3 Off-airport development for drinking water

From the new, re-laid, DN 600 pipeline of ductile iron pipes, Märkische Abwasser- und Wasserverband, the supply company, supplies the airport with some 2,000 m³ of fresh drinking water every day via a further DN 400 ductile iron pipeline. This is equivalent to the demand from a small town populated by some 20,000 people. At peak times this volume can be increased to 5,500 m³. The connecting pipeline mentioned went into operation in October 2009. A further pipeline is being added to ensure security of supply. At the moment installation work is going on in what was the little settlement of Kienberg to lay two DN 300 and DN 600 drinking water pipelines **(Fig. 5)**, which once again use ductile iron pipes with the TYTON® BRS® system.

Fig. 7:
A section of DN 300 pipeline retrospectively diverted sideways for a hydrant to be fitted

Fig. 8:
Culverting under a structure to be erected later using DN 400 ductile pressure pipes

4 On-airport development

The contract for the development of the on-airport pipelines was given to the "BBI GU XI Ver- und Entsorgung" (BBI General Contractor: Supply & Disposal) consortium formed by two well-known Berlin construction companies. As well as a large number of other supply pipelines and cables the consortium has, since January 2008, been installing amongst others 26 km of drinking water, sewage and wastewater pipelines of nominal sizes from DN 80 to DN 400 with BLS® or BRS® restrained joints **(Fig. 6)**. After 22 months, the consortium is on schedule with 80 % of the volume of work completed. The challenges faced include not only the changing soil conditions and the weather but also the site conditions, which change almost every day, and the beginning of the above-ground construction. This calls for the installation work to be done in a flexible way, sometimes "on call" as it were when sections have to be completed at short notice **(Figs. 7 and 8)**. Runs of casing tube have to be pre-stretched and fitted with pipes to carry media **(Fig. 9)**. Most of the pipes currently being installed are part of the DN 300 and DN 400 main pipeline systems. Smaller networks of pipes will follow as part of the final development. The completed sections of pipeline are pressure-tested and disinfected but the pipelines have to be disinfected again before they actually go into operation for reason of drinking water hygiene.

5 Tunnel for the railway link

To drain the railway tunnel and the station below the airport terminal building, a Berlin consortium is installing around 5,200 m of ductile sewer pipes of DN 150/DN 200 (30 %) and DN 300 (70 %) nominal sizes in the reinforcement of the railway tunnel.

6 Thermally insulated drinking water pipes at a track crossing

Along the continuation of the route followed by the tracks, DN 150 thermally insulated ductile iron pipes fitted with the TYTON® BLS® restraint system have been installed on I profiles to cross above the tracks.

Fig. 9:
BLS® socket-jointed DN 400 ductile iron sewer pipes being pushed into a run of casing tubes

7 Rainwater drainage

Due to structural requirements, a 160 m long DN 600 pipeline for rainwater drainage has been installed using ductile iron pipes.

8 Planning

The planning engineers took particular note of the requirement for the linings of the sewer pipes and fittings and the TYTON® NBR gaskets to be resistant to wastewater from de-icing. Oil-resistance was required in the area of the railway.

To ensure safety at the planning stage, the pipe manufacturer verified these characteristics in advance with the help of the relevant testing bodies.

Total impermeability to the diffusion of phenols was required for the drinking water pipes even in the event of an accident (to fuel lines or sewer pipelines). The socket joints were fitted with sleeves to provide additional protection.

The tremendous requirement for safety can be seen from the fact that all the drinking water pipes being installed are of the K 10 wall-thickness class. All the pressure pipelines are being laid with restrained joints, the frictional TYTON® BRS® system being used for the buried pipelines and the positive locking TYTON® BLS® system for the casing tube runs.

9 The installation work

Having been called up from the supplier by the installing companies over the internet, all the deliveries of pipes to the airport are notified to BBI's appointed security partner KÖTTER Services, i.e. the truck and driver on the notification are given a time slot for entry and are assigned to the appropriate unloading point. This co-ordination is essential firstly for the smooth flow of site traffic and secondly because it enables the frequent changes in the access points to the site to be allowed for.

Certain pipelines have to be installed with relatively small height of cover (e. g. parts where there are hydrants) and therefore need safety provisions during the installation phase **(Fig. 7)**. Other sections by contrast have to serve as culverts deep down because they are going to be crossed by media-carrying pipelines to be installed at a later stage **(Fig. 8)**. The use of restrained joints means that thrust blocks are not needed, that the installation times are shorter, and the space available is used only for the actual pipeline installation.

Where there are long parts of routes over open land, it may also be advantageous to use a special attachment. The attachment, which is fitted to an excavator, takes hold of and carries pipe of different nominal sizes safely and securely and is also able to insert the spigot end into the pipe socket precisely. The reverse movement required for locking after the push-in joint, e. g. the BLS® system, has been assembled, is also performed. Installation in a run of casing tube can be seen in **Fig. 6**. The installation attachment pushes the complete string of pipes into the casing tube in this case, and a traction is applied to the pipeline to stretch it on completion of the overall installation work.

As a comparison with this, **Fig. 9** shows DN 400 ductile iron sewer pipes with BLS® push-in joints being pushed into a run of casing tube. The individual pipes are each guided by steel profiles when this is done and are pushed forward by the boom of a hydraulic excavator.

10 Concluding review

On the giant BBI airport construction site, rugged ductile iron pipe systems have once again been able to give a number of installing companies and consortiums a convincing demonstration of how reliable and easy to connect and install they are in a variety of applications. Speed and good solutions can both be achieved with the complete and exactly matched systems of fittings not only at final completion but also at intermediate stages of installation. Anyone can see for himself how smoothly this giant project is progressing by visiting the BBI Info Tower at the airport or making a site inspection guided by BBI employees.

Author

Dipl.-Ing. Lutz Rau
Duktus Rohrsysteme Wetzlar GmbH
Berlin Sales Office
Hangelsberger Gang 30
12589 Berlin, Germany
phone: +49 (0) 30/64 84 90 70
E-mail: lutz.rau@duktus.com

Reconstruction of the Rietwis bridge in Wattwill an der Thur in Switzerland includes a thermally insulated DN 200 ductile cast iron water pipeline

by Stefan Rüegg

1 Introduction

To the west of the Heberlein area in Wattwil an der Thur in the Swiss canton of St. Gallen lies the aesthetically appealing reconstructed Rietwis bridge, which links the Ebnater Strasse to Wattwill railway station.

The existing bridge, dating from 1910, was an over-deck steel truss bridge and needed to be replaced because in November 2001 the St. Gallen cantonal council decided now to include the section of road from the square in front of the railway station to the turn-off to the Löwen restaurant in the cantonal road-planning map. The municipality of Wattwil needed to bring the vehicle payloads of 28 t for the old Rietwis bridge into line with the current payloads of 40 t. Investigation by the planning engineers showed that this could only be achieved by building a new bridge.

2 Planning and design

The project by Schällibaum Ingenieure AG which in 2004 won the project competition organised by the municipality of Wattwill complied with the requirements for safe load-bearing capacity and fitness for purpose. At the same time the new bridge also allowed a larger free passage for the river Thur. The new bridge also had to meet the criteria for a structure worthy of protection because it lies in an area which is critical for Swiss heritage protection. This was another constraint which the Roads and Roadway Structures Department of the St. Gallen Cantonal Office of Civil Engineering found that the new bridge **(Fig. 1)** met.

3 A frost-proof water supply

A new reference reservoir had been built on one side of the valley and provided the main infeed to the network of water pipes and because of this the water pipeline of DN 125 grey cast iron pipes which was installed on the old bridge was no longer up to the performance requirements. When the new bridge was built, a new and larger, 48 m long, DN 200 thermally insulated pipeline (of ecopur pipes) **(Fig. 2)** was therefore incorporated in the bridge and, to protect it from freezing up, was provided with trace heating.

For this special application, thermally insulated (ecopur) ductile iron pipes were needed. The pipes were first cut to the exact size (lengths of 5 x 6 m, 2 x 5 m and 2 x 4 m) in the manufacturer's works in Choindez and the cut edges were then re-coated. The thermal insulation intended to keep the water in the pipeline at a constant temperature was then applied in the shops of HWT Haus- und Wassertechnik AG of Au in the canton of St. Gallen. For this purpose, a DN 315 HDPE casing tube with a wall-thickness of 9.7 mm (a sewer pipe) was slid over the ductile iron pipes, a duct of galvanized steel for pulling in the trace heating cable was inserted (trace heating cable supplied by Energie Wattwil AG) and the gap was filled with polyurethane foam (foam density 50 to 55 kg/m^3).

For the DN 200 ecopur pipeline to be installed, openings were made in the abutments and the steel girders of the structure of the new bridge through which the pipes could be introduced and connected together. To enable the pipes to move freely without any external restraints, pipe bearings were welded to both sides of the openings in the steel girders and the push-in joints were designed to be locked against longitudinal forces by a hydrotight internal thrust resistance system **(Figs. 3 and 4)**. After the assembly of the push-in joints, the polyethylene casing tubes were connected by means of electrofusion couplers. The personnel of Dorfkorporation Wattwil (Wattwil Municipal Water Supply Association) installed the pipes. The pipeline carried on the Rietwis ridge was completed in August 2008.

Author

Stefan Rüegg
vonRoll hydro (suisse) ag
vonRoll-Strasse 24
4702 Oensingen, Switzerland
phone: +41 (0)62/3 88 11 11
E-mail: stefan.rueegg@vonroll-hydro.ch

Client

Dorfkorporation Wattwil
Erich Eberhard
Bahnhofstrasse 1
9630 Wattwil, Switzerland
phone: +41 (0)71/9 88 59 33
E-mail: e.eberhard@thurweb.ch

Pipe insulation

HWT Haus- und Wassertechnik AG
Magnus Hugentobler
Industriegasse 26
9434 Au, St. Gallen, Switzerland
phone: +41 (0)71/7 44 15 59
E-mail: info@hwt.ch

Fig. 1:
The Rietwis bridge under construction

Fig. 2:
An ecopur ductile iron pipe

Fig. 3:
Internal thrust resistance of the hydrotight system

Fig. 4:
The ecopur ductile iron pipe and its internal thrust resistance being prepared for the connection of the push-in joint.

Renovation of the water main running from the Nibelungenplatz to the Danziger Platz in Frankfurt am Main

by Alexandra Scholz and Christian Schmidt

1 Introduction

The installation operation which forms the subject of this article was the renovation of the DN 500 drinking water pipeline running between the Nibelungenplatz and the Danziger Platz in Frankfurt am Main. The drinking water pipeline needing renovation runs along the Alleenring ring road in Frankfurt am Main. The Alleenring is an important east-west arterial highway in the town's road network.

The section of the pipeline which was at risk from fractures was 2,300 m long and was laid in the years from 1904 to 1939 in grey cast iron pipes. Because of selective damage/corrosion ("spongiosis" or graphitisation) to its grey cast iron material, there was a increased frequency of damages in the existing pipeline. The pipeline which had to be renovated conveys drinking water mainly from the extraction areas in the south of Frankfurt to the northern regions of the town.

2 Planning and routeing

Before the planning phase for the renovation of the drinking water pipeline, a comparison of the variant renovation techniques which were possible was made as part of a feasibility study. The study examined five variant renovation techniques, looking at their economic, technical and operational aspects. Also examined were constraints relevant to the project such for example as traffic and environmental requirements. An important basic consideration in the feasibility study was to decide the cross-section needed for the pipeline, which belongs to the NRM Netzdienste Rhein-Main GmbH supply company, when replaced.

The cross-section required from the hydraulic point of view was calculated with due allowance for the constraints and the contractual requirements. As a result, the size decided on for the pipeline was DN 300.

Following this, it became increasingly clear from the feasibility study that, for economic reasons amongst others, the renovation should be carried out by a trenchless technique. On the shortlist of suitable largely trenchless techniques were pipe relining using butt-welded steel pipes and pipe relining using ductile iron pipes with BLR® push-in joints. A cost estimate for pipe relining using butt-welded steel pipes showed the costs to be roughly comparable with those of pipe relining using ductile iron pipes. However, when the time and the quality assurance required for the making of the welds when using steel pipes were compared with the making of the BLS® push-in joints when using ductile cast iron pipes (time of approx. 20 min per joint), the former were assessed as taking more time. Also considered a positive point was the fact that the BLS® push-in joint could be deflected by up to 3°.

In conclusion, the feasibility study decided that pipe relining using ductile iron pipes should be used. As well as the technique being decided, the pipes were also selected, namely DN 300, K 9, PN 10 pipes of ductile cast iron with a cement mortar lining (ZMA), cement mortar coating (ZMU) and BLS® push-in joints to EN 545 [1]. For various reasons, the annular space left between the old pipe and the new one was not to be filled so a cement mortar coating to EN 15542 [2] was selected as external protection. For the pulling-in process, the 6 m long ductile iron pipes were fitted with sheet-metal cones in the region of the socket joints.

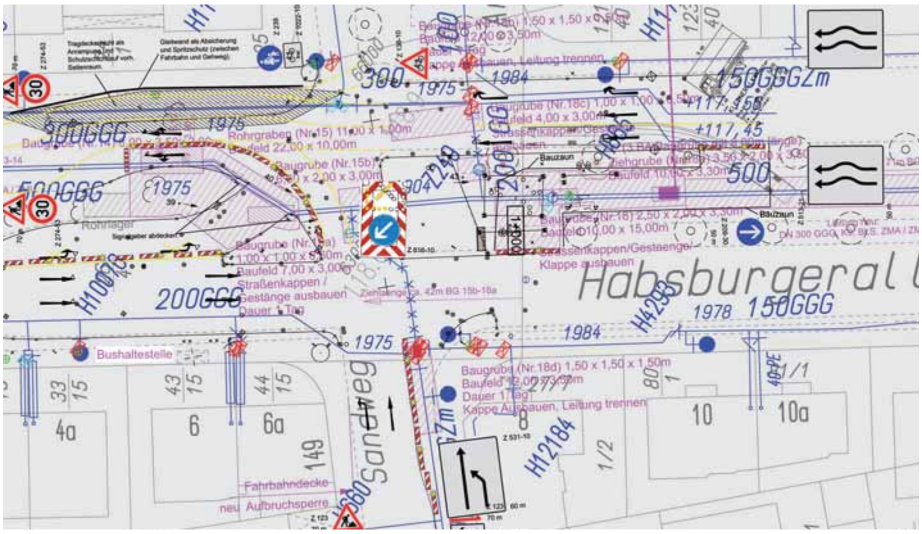

Fig. 1:
Plan of traffic signs

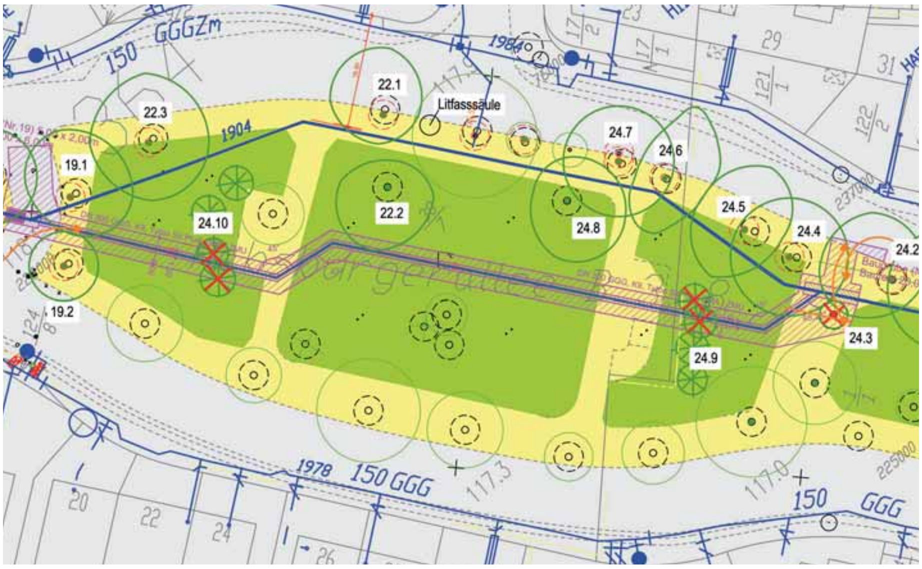

Fig. 2:
Plan of green spaces

The cones were intended to protect the socket joints from damage while the pipes were being pulled in.

During the planning phase, the constraints relevant to the project were examined in detail. Particular consideration was given in this case to the traffic-related constraints (a two- to three-lane main traffic artery, very heavy traffic load) and to the existing trees needing to be preserved along the Alleenring. As part of the planning phase, geotechnical and environmental studies were made, a special plan was worked out for construction site signs and barricades and for the directing of traffic **(Fig. 1)** during the installation operation, and so too was an environmental impact and compensation plan (a special green plan) for the areas to be used during the installation period **(Fig. 2)**.

The planning work was done in close collaboration with the offices and approving authorities of the city of Frankfurt am Main which were involved and it was approved for the execution of the installation work.

The route selected for the drinking water pipeline being renovated was finally decided as part of the planning. A very high proportion (approximately 90 %) of the route of the existing DN 500 pipeline was used for the route of the future pipeline. Only in certain sections where the local constraints permitted was it planned that the renovation would be done in open trenches. In these sections the top cover over the pipes of the drinking water pipeline was reduced from between 2.20 m and 2.40 m to between approximately 1.20 m and 1.40 m.

Due to the changes in the direction of the existing pipeline and to the valves fitted in it, 35 trenches (insertion and pulling-in trenches) had to be planned in the area occupied by the roadway and green spaces along Frankfurt's Alleenring. The dimensions of the insertion trenches, in which the units of pipe were fed in and the BLS® push-in joints were connected, were as follows:

- width: 2.00 m,
- length: 8.00 m,
- depth: 3.50 m to 3.70 m.

To enable the planners' assumptions to be confirmed, the first section of pipeline, between the Nibelungenplatz and Höhenstrasse, was examined early on with a camera in the phase when the execution of the work was being planned. The results showed incrustations of a thickness from 10 to 30 mm and a path which matched what was shown in the documentation on the existing pipeline (no angular deflections). The inspection by camera thus confirmed the correctness of the renovation technique selected in the feasibility study.

3 Installation of the pipeline

Once the installation site signs and barricades been set up and the traffic temporarily redirected to allow it to travel round the sites, the trenches were dug. Because of the special traffic situation, the shoring in the first section of the installation work took the form of bore joist sheeting **(Fig. 3)** with wood plug (trench depth up to 3.70 m). Using the documentation on their locations, the other existing utility lines (cables and pipelines) were safeguarded by means of locating slots; the shoring system selected enabled them to be included in the auxiliary provisions for installation.

Within the trenches, the pipeline was cut and a segment removed. Before the lining pipes were pulled in, the pipeline was cleaned mechanically section by section, was inspected with a camera and was checked for free passage by calibration (the pulling through of one 6 m DN 300 pipe). Having been called up by the installing company, the pipes to be installed were delivered by the manufacturer straight to the site in bundles of four. The DN 300 ductile iron pipes were connected together in the insertion trenches **(Fig. 4)** and pulled in, following the handling and installation instructions for the pull-in pipe relining technique, once the installing company's personnel had been instructed by the manufacturer's applications engineering division. The maximum permitted tractive forces of 380 kN (from the manufacturer's figures for the DN 300 BLS® push-in joint) were not reached. The longest section of the relining operation extended for 350 m.

Fig. 3:
Putting in the bore joist sheeting on the Nibelungenplatz

On the basis of the experience gained in the first section of the installation work, in the second section the trenches were shored with double-slide-rail shoring in conjunction with pile chamber shoring **(Fig. 5)**. Even when there was only restricted space available, it was possible for the 6 m long pipes to be introduced into the trenches without any problems.

The ends of the old DN 500 pipeline were walled off in their respective insertion trenches. Sections of the pipeline which were not to be renovated were closed off with a filling material of high fluidity.

The flushing and pressure-testing/disinfection of the pipeline of DN 300 ductile iron pipes were carried out in a number of stages in line with the connections (cross-connections) to the existing pipeline. With the agreement of the Frankfurt Civic Water Drainage authority, the flushing water was passed into the sewers through existing inlets along the roadway.

Fig. 4:
Connecting a BLS® push-in joint

Fig. 5:
Inserting the DN 300 ductile iron pipes

The internal pressure-testing was governed by EN 805 [3] and DVGW Arbeitsblatt W 400-2 [4]. The disinfection was carried under the rules given in DVGW Arbeitsblatt W 291 [5].

4 To sum up

The project known as "Renovation of DN 500 drinking water pipeline between Nibelungenplatz and Danziger Platz" was launched with the drawing up of the feasibility study in August 2006. The results of the examination of the variant techniques taken from the feasibility study became available to NRM Netzdienste Rhein-Main GmbH in January 2007. The detailed planning work for the renovation of the pipeline lasted until July 2007.

The execution of the first section of the installing work began in September 2007. The work on this section, which was around 600 m long, was completed in December 2007. The second section of the installing work began in June 2008 and was completed with the entry into service of the water pipeline in October 2008.

Thanks to the smoothly functioning way in which all the parties involved worked together, the handling of this renovation project can be seen as a total success for NRM Netzdienste Rhein Main GmbH. The renovation technique which was selected in the feasibility study took on a more tangible form in the planning phase and was successfully put into practice when the installation work was carried out.

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[2] EN 15542
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Authors

Dipl.-Ing. Alexander Scholz
NRM Netzdienste Rhein Main GmbH
Solmstrasse 38
60486 Frankfurt am Main, Germany
phone: +49 (0)69/2 13-01
E-mail: A.Scholz@nrm-netzdienste.de

Dipl.-Ing. Christian Schmidt
UNGER Ingenieure
Ingenieurgesellschaft mbH
Julius-Reiber-Strasse 19
64293 Darmstadt, Germany
phone: +49 (0)61 51 /6 03-0
E-mail: c.schmidt@unger-ingenieure.de

Planning

UNGER Ingenieure
Ingenieurgesellschaft mbH
Dipl.-Ing. Christian Schmidt
Julius-Reiber-Strasse 19
64293 Darmstadt, Germany
phone: +49 (0)61 51/6 03-0
E-mail: da@unger-ingenieure.de

Client

NRM Netzdienste Rhein Main GmbH
Dipl.-Ing. Alexander Scholz
Solmstrasse 38
60486 Frankfurt am Main, Germany
phone: +49 (0)69/2 13-01
E-mail: info@nrm-netzdiesnte.de

Installation work

First section of installation work:
Kessler Rohrleitungsbau Hirsch GmbH
Friesstrasse 8-10
60388 Frankfurt am Main, Germany
phone: +49 (0)69/90 47 52-0
E-mail: info@kessler-hirsch.de

Second section of installation work:
Brochier Aschaffenburg GmbH
Haselmühlweg 50
63741 Aschaffenburg, Germany
phone: + 49 (0) 60 21/3 44-0
E-mail: katzlinger@ brochier-ab.de

Renovation of large trunk water mains in Leipzig

by Henry Simon and Wolfgang Rink

1 Water supply yesterday and today

In 1905, Adolf Thiem was commissioned by the civic authorities of Leipzig to undertake some preliminary hydrological investigations for a new waterworks which was to be built.

After 1870, Leipzig experienced a headlong rise in its population. By the beginning of the 20th century the town already had around 600,000 inhabitants. There was thus a massive rise too in the requirements which the water supply had to meet. With the existing Naunhofer waterworks it would no longer be possible for the increased demand for water from the metropolis of Leipzig to be met in the short or medium terms. Calculations showed that a new and larger waterworks had to go into operation to supply Leipzig by no later than 1912. Adolf Thiem, who was then almost seventy, made more than 100 bores to investigate the area of the banks of the river Mulde in the Eilenburg/Wurzen region and came to the conclusion that the requisite volumes of groundwater were available in the catchment area of the Mulde between the villages of Nischwitz and Wasewitz.

Once the hydrological investigations were available the Leipzig council decided as early as 1907 to buy the pieces of land, of a total area of more than 700 hectares, which would be needed for the construction of the waterworks.
The construction of the waterworks and the intake system and the laying of the supply main to Leipzig were pressed ahead with and the supply of water was thus able to begin as from 1912. To increase the security of supply, a second trunk main, long sections of which ran parallel to the first trunk main, was laid in the years that followed. These two pressure pipelines consisted of pipes which were, with few exceptions, grey cast iron pipes of nominal sizes of DN 1000/DN 1100. They have been doing their duty since 1912. Almost 60 years later the Fair town once again underwent a radical change. Because of the perpetual housing shortage and because of the open-cast mining of brown coal which was going on on a large scale in the area around Leipzig and the "swallowing" of whole villages which went hand in hand with this, the need arose for new residential areas to be built and for these to be developed from the point of view of the supply of water and so on. It was in this way that an area of newly built housing for almost 100,000 inhabitants sprang up in the early 70's in the Leipzig-Grünau district of the town. A steel DN 1000 trunk main was laid as a main artery for supplying drinking water.

The two trunk mains mentioned and the above trunk main are part of the 3,200 km long pipe network belonging to KWL Kommunale Wasserwerke Leipzig GmbH. Today, more than 600,000 inhabitants are supplied with fresh drinking water through this close knit network of pipes. In the first place this extensive network requires renovating at steady rates and in the second the local authority of Leipzig, like so many others in Eastern Germany, is faced with the task of responding to demographic change.

Since 1993, the figures for water consumption have been showing a downward trend; in 2008 they were only 89 L per inhabitant per day. What this also means for water supply in Leipzig is that many of the pipelines need to have their cross-sections reduced so that the quality and quantity of the drinking water will remain at a high level.

Over the past few years, renovation schemes based on preliminary hydraulic investigations together with prospective developments the need for which is becoming clear have been worked out for all the main supply pipelines and trunk mains in the greater Leipzig area. The renovation technique is determined mainly by the minimum nominal sizes required and when it was being selected in the past, it was renovation with ductile iron pipes which was preferred in a number of cases and which had, in the end, been successfully performed. In the following study, some light will be shed on both the **pulling-in** and the **pushing-in** of pipes of nominal sizes of DN 600 and DN 900 by looking at two examples.

2 Installation work on the Thallwitz-Canitz trunk main

As part of the implementation of the project, the following constraints had to be heeded and observed:

- To ensure security of supply, one of the two trunk mains always had to be in operation.
- To optimise the installation times and hence to minimise the times out of operation, work had to be done in two shifts.
- The installer had to give the trunk main which was in operation particular protection, especially in the section where laying had been in parallel

Fig. 1:
Shoring of a trench with sheet pile shoring

- The new butterfly-valve-equipped cross and connecting pipeline which had to be installed needed to be installed in two stages.

To suit the local conditions and the "push-in" renovation technique, three pushing trenches and four arrival trenches were dug. To meet the stress analysis requirements, the trenches were shored throughout with sheet piles **(Fig. 1)**. The DN 900 ductile iron pipes were pushed into the old pipeline from the different pushing trenches in four separate sections. The lengths pushed in in this case were approximately 50 m, 125 m and 232 m plus the longest section, which was 289 m long.

Because of the smaller outside diameter of the TYTON® push-in joint as compared with the restrained BLS® push-in joint, what was selected as the renovation technique was the **pushing-in** of the pipes while sliding on their sockets. The pipes which were used in this case were ductile iron pipes to EN 545 [1] equipped with the TYTON® push-in joint. The pipes are lined with cement mortar. Because the annular space left between the old pipe and the new one was closed off with an alkaline filler after the pressure testing, the external protection selected for the pipes was a zinc coat (200 g/m^2) plus an epoxy top coating.

The pipe manufacturer's manual entitled "Trenchless Installation of Ductile Cast Iron Pipes" [3] gives 4,330 kN (433 t) as the permitted pushing-in force for DN 900, K 9, ductile iron pipes equipped with the TYTON® push-in joint. No allowance is made for a safety factor here. The safety factor has to be determined to suit the local conditions, i.e. above all to suit the radiuses of any curves and the angular deflections. It has to be agreed with the manufacturer's applications engineering division **(Table 1)**.

To prepare it for the renovation, the old DN 1100 pipeline was cleaned throughout with water at a very high pressure of 1,000 bars. This technique proved to be very effective and time-saving as compared with cleaning with chain cutters. Although no appreciable differences in the position of the old pipeline were apparent in the section to be renovated, the cleaned pipeline was inspected and the free passage through it was checked with a length of pipe of the same outside dimensions as the ductile cast iron pipes to be pushed in. The results were not at all bad. All the incrustations had been removed and the length of pipe could be passed through all the

Table 1:
Push-in forces for ductile iron pipes
(These are independent on the socket-type and do not include a safety factor – this has to be matched to the local conditions, i. e. above all to the radiuses of curves and to deflections and has to be agreed with the Applications Engineering Division of BGW)

Nominal size DN	Outside diameter d_o in mm	Wall-thickness class	Wall-thickness s_{min} in mm	Permitted compressive stress σ_{perm} in N/mm²	ermitted push-in force F_{perm} in kN
80	98	K 10	4.7	550	138
100	118	K 10	4.7	550	168
125	144	K 9	4.7	550	206
150	170	K 9	4.7	550	244
200	222	K 9	4.8	550	339
250	274	K 9	5.2	550	513
300	326	K 9	5.6	550	723
350	378	K 9	6.0	550	968
400	429	K 9	6.4	550	1,246
500	532	K 9	7.2	550	1,912
600	635	K 9	8.0	550	2,750
700	738	K 9	8.8	550	2,425
800	842	K 9	9.6	550	3,350
900	945	K 9	10.4	550	4,330
1000	1,048	K 9	11.2	550	5,500

sections to be renovated without any problems. The old pipeline was bright metal, ready for renovation with DN 900 ductile iron pipes.

To optimise the push-in process and reduce the push-in forces, certain quite large gaps and steps within the sockets were compensated for in the pipe bottom. The actual pushing-in the pipes did not take long. The average assembling and pushing-in times for each 6 m long TYTON®-pipe were less than 10 min **(Fig. 2)**. Because the pipes slide on the socket when being pushed in, all the sockets needed mechanical protection against abrasion in the form of sheet metal cones. At the longest push-in of almost 290 m, when the weight of the string of pipes was 93 t, forces of 558 kN (55.8 t) were measured at the pusher.

Once all the sections of pipeline had been pushed in, they were connected together in the individual trenches with appropriate fittings including, in pressing trench 2, with an adapting and removal fitting as an aid to installation.

Fig. 2:
A DN 900 TYTON®-pipe being pushed in

Fig. 3:
Installation of a butterfly-valve-equipped cross

In the region where the trunk mains run in parallel, a complete butterfly-valve-equipped cross which had four DN 800 butterfly valves with bypasses and a DN 600 connecting valve was installed to optimise operation **(Fig. 3)**. Because one trunk main always needed to be in operation, this installation was carried out in two stages.

The pipeline was secured in position with thrust blocks and with the client's agreement these were sized to allow for a maximum operating pressure of 6 bars. The pressure testing of the renovated section of the Thallwitz–Leipzig trunk main was successfully completed on 5 October 2009. Having been released from the point of view of drinking water hygiene, it could be connected into the existing pipe system. In this way the preconditions were met for the rest of the work on the second trunk main.

3 Installation work on the DN 1000 Leipzig-Grünau trunk main

The section to be renovated was situated in Leipzig-Grünau between Brünner Strasse and Schönauer Strasse and was approximately 1,200 m long. Because of the decline in water consumption and demographic change and also the local urban redevelopment measures, the nominal size could, and indeed needed to be, reduced to DN 600 to meet hydraulic requirements. The renovation technique was determined by a wide range of influencing factors and constraints. Important among these were the following:

- A large number of differences in position was a characteristic of the route followed.
- The space available for installation was very limited; the dimensions of any installation trenches required needed to be minimised.
- The existing trees needed to be largely preserved.

Table 2:
Pull-in forces for ductile iron pipes
Permitted tractive forces, deflectability and radiuses of curves for ductile iron pipes with BLS® push-in joints

Nominal size DN	Wall-thickness class	Component operating pressure PFA in bars 1)	Permitted tractive force Z_{perm} 2) in kN		Deflectability of joints 3) in °	Minimum radius of curves in m
			DVGW	BGW		
80	K 10	110	70	115	5	69
100	K 10	100	100	150	5	69
125	K 9	100	140	225	5	69
150	K 9	75	165	200	5	69
200	K 9	63	230	350	4	86
250	K 9	44	308	375	4	86
300	K 9	40	380	380	4	86
400	K 9	30	558	650	3	115
500	K 9	30	860	860	3	115
600	K 9	32	1,200	1,525	2	172
700	K 9	25	1,400	1,650	1.5	230
800	K 9	16	1,350	1,460	1.5	230
900	K 9	16	1,700	1,845	1.5	230
1000	K 9	10	1,440	1,560	1.5	230

1) Basis for calculation was wall-thickness class K 9. Higher pressure and tractive forces are possible in some cases but must be agreed with the pipe manufacturer.
2) When pipelines follow straight paths (max. deflection of 0.5° per pipe joint), the tractive forces can be raised by 50 kN. High-pressure locks are required for DN 80–DN 250.
3) When of the nominal dimensions

In view of these requirements, it was worked out in the planning process that relining with ductile iron pipes under DVGW Arbeitsblatt GW 320-1 [2] would be the most economical option.

Because the exact route followed by the existing pipeline could not be established with absolute certainty, the client decided in favour of the **pulling-in** of DN 600 pipes with restrained BLS® push-in joints to EN 545 [1]. The pipes were lined with cement mortar. Their external protection consisted of a zinc coat (200 g/m²) and an epoxy top coating. The old pipeline was prepared for renovation under the requirements of DVGW Arbeitsblatt GW 320-1 [2] by the operation described above. The manual entitled "Trenchless Installation of Ductile Cast Iron Pipes" [3] gives 1,525 kN (152.5 t) as the permitted tractive force for the DN 600 BLS® push-in joint. **Table 2** shows the permitted pull-in forces for ductile iron pipes.

Thanks to the overall length of the pipes of 6 m, it was possible for the trenches needed for installing the pipes to be shortened and hence the costs of excavation reduced. What proved to be another major advantage was the short assembling time of the BLS® joint, which was generally less than 20 min once the site personnel had familiarised themselves with the operation **(Fig. 4)**.

18 trenches were dug for this entire section of renovation. In 17 pulling-in operations, the installing company connected a total length of 1,070 m of ductile iron pipes with BLS® restrained joints and pulled it into the previously cleaned and calibrated pipeline. With the relatively complicated paths followed – many changes of direction, inserted items, lateral connections – the operation made stringent demands on everybody involved **(Fig. 5)**.

To enable the supply to be maintained, the installation of the pipeline was carried out in two sections. After pressure testing and flushing out, the section which had been renovated was put back into operation and the outgoing supply pipes were then connected in. The annular space between the old pipeline and the new DN 600 pipeline was filled. In the final stage of the operation, the trenches were filled back again and the road infrastructure restored.
The entire operation was completed within the scheduled installed time of April to September 2009.

Fig. 4:
Assembling of a DN 600 BLS® pipe

Fig. 5:
Relatively complicated paths were followed

4 To sum up

Two renovation operations have been described in this article. However, these were not renovations in the true sense of the word but trenchless replacements using the pipe relining technique. Regardless of the state of the old pipelines and the way in which they were behaving, the replacement pipelines can be considered equally as good as new pipelines installed in the conventional way in open trenches as far as their technical working life and their depreciation assumed for costing purpose are concerned.

However, in comparison with replacement in open trenches some considerable cost savings were achieved. In both these installation operations, ductile iron pipes of different types once again showed how very well suited they are to trenchless replacements. In both cases, the excellent way in which all those involved worked together resulted in the installation going off without any trouble. The scheduled installation times were met.

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Authors

Dipl.-Ing. Henry Simon
Bau + Service Leipzig GmbH
Berliner Strasse 25 · 04105 Leipzig, Germany
phone: +49 (0)3 41/9 69-34 80
E-mail: henry.simon@bs-l.de

Wolfgang Rink
Duktus Rohrsysteme Wetzlar GmbH
Sophienstrasse 52–54 · 35576 Wetzlar, Germany
phone: +49 (0)64 41/49-29 23
E-mail: wolfgang.rink@duktus.com

Client

Kommunale Wasserwerke Leipzig GmbH
Dipl.-Ing. Andrea Bauer
Berliner Strasse 25
04105 Leipzig, Germany
phone: +49 (0)3 41/9 69-15 38
E-mail: andrea.bauer@wasser-leipzig.de

Planning

H. P. Gauff Ingenieure & Co. KG
Dipl.-Ing. Andreas Meyer
Rudolf-Breitschied-Strasse 63-64
14482 Potsdam, Germany
phone: +49 (0)3 31/7 48 68-0
E-mail: ameyer@gauff.com

Gruner & Partner GmbH
Dipl.-Ing. Gert Jakob
Dufourstrasse 28
04107 Leipzig, Germany
phone: +49 (0)3 41/2 17 26 60
E-mail: gert.jakob@gruner-partner.de

Installation work

Josef Pfaffer Baugesellschaft mbH
Dipl.-Ing. Sven Fischer
Föpplstrasse 10a
04347 Leipzig, Germany
phone: +49 (0)3 41/2 45 42-0
E-mail: leipzig@pfaffinger.com

Diringer & Scheidel GmbH & Co. KG
Dipl.-Ing. Jörg Öhmigen
Zschortauer Strasse 46
04129 Leipzig, Germany
phone: +49 (0)3 41/9 04 70-24
E-mail: Joerg.Oehmigen@dus.de

Project control

Bau + Service Leipzig GmbH
Dipl.-Ing. Olaf Schröpfer
Berliner Strasse 25
04105 Leipzig, Germany
phone: +49 (0)3 41/9 69-34 80
E-mail: olaf.schroepfer@bs-l.de

The development of valves for pipe networks in water supply

by Oliver Jäger

1 Introduction

In water supply, valves have, for centuries now, been a vital part of the safe transportation of drinking water. Without reliable components, security of supply and the quality of drinking water would not be as good as they are. Breakdowns of water supply systems are in fact rather rare events. Under the aegis of the DVGW (the German Technical and Scientific Association on Gas and Water), the water supply companies and the producing industry have made continuous improvements in the components. These improvements have been reflected in the requirements and tests laid down in the sets of rules. The sets of rules give a picture of the state of the art and are an assurance for users of a high standard of quality when selecting the components. This is equally true of the use of ductile cast iron materials.

2 Valves

If today's valves are compared with those of around 25 years ago, it can be seen that there have been few changes in their basic functions. Nevertheless, valves of the current generations have little in common with their predecessors.

The efforts that are made to constantly improve the quality of our drinking water and to reduce the costs of maintaining and renovating the pipeline systems have been reflected in a wide variety of changes made to the valves. In this way, the lamellar graphite (grey) cast iron material used mainly for those body parts of valves which have to withstand pressure has given way to high-grade ductile cast iron. In this connection, there have also been further developments in the corrosion protection of these body parts. Epoxy-resin-based paint finishes with film thicknesses of around 80 µm were originally used but these were of only limited suitability when in long-lasting contact with drinking water and development has progressed from these to materials specifically designed for drinking water. Epoxy-resin-based powder coatings with a film thickness of at least 250 µm are currently being used. In working with the coatings, the leading valve manufacturers follow the rules laid down by the "Gütegemeinschaft Schwerer Korrosionsschutz (GSK)" (GSK Quality Association for Heavy Duty Corrosion Protection) [1]. As an alternative, an enamel finish specifically designed for use on valves in contact with drinking water has been developed.

Also with corrosion protection and drinking water hygiene in mind, the materials used for connecting components, such as bolts for connecting valve bodies, have been changed from carbon steel to stainless steel, of a minimum of A2 grade.

In the field of sealing components, development has advanced from fibrous materials to elastomers. As well as the requirements which they have to meet in respect of their operation, modern-day elastomers also have to meet the German Federal Environment Agency's KTW recommendations [2] in respect of toxicology and drinking water hygiene and the requirements laid down in DVGW Arbeitsblatt W 270 [3] in respect of microbiology. The same is, by the way, also true of coating materials of epoxy resin.

In the field of connections to other pipeline components, what have established themselves as the connections of choice are, as well as the original flange connections, push-in joints suitable for the particular pipe material concerned.

Fig. 1:
Soft-sealing gate valve of the Multamed 2 Plus type

2.1 Gate valves

As well as the changes to the materials which were described above, there have also been changes in principles of design which can be seen in the gate valves used in drinking water supply **(Fig. 1)**. In this way, the gate valves with metal seats which were used in earlier days have given way to resilient seated gate valves. The first step in this respect was to provide part of the shut-off wedge with a coating of rubber in the area where it sealed against the seat, thus making it possible for the floor of the "tube" through the body of the valve to be smooth. This ruled out the possibility of deposits building up in the so-called "Schiebersack" or gate-valve seat trough and causing leaks. The seal between the body and the shut-off wedge thus became unaffected by solids in the pipeline.

Another significant step in the development process was the introduction of maintenance-free stem sealing by means of O-rings mounted in non-corroding materials. For the material of the stem, brass was replaced by stainless steel.

2.2 Butterfly valves

Butterfly valves **(Figs. 2 and 3)** have followed a similar pattern of development to gate valves. The original metal seat in the body was found to be very expensive to produce and sensitive in use. The obvious step was therefore for its place to be taken by a resilient structure. Via the intermediate stage of so-called O-ring butterfly valves, development continued to today's profiled sealing rings. In these designs, the resilient sealing member is positioned on the disc and can be adapted in a variable way to the conditions at the seat in the body. There have also been further developments in the valve disc and in the mounting of the shafts in the body. The original lip seal has changed to O-ring seals held in cages of non-corroding material in this way. Also, the seals and shafts are now mounted in such a way as to be "blow-out-proof".

2.3 Hydrants

As well as the changes to high-grade ductile materials for the bodies and to coatings preservative of both economic and operational value, there have also been changes in design as hydrants have developed. In hydrants of the old type, the valve cone providing the main shut-off was moved upwards, away from the pipe system, when the hydrant was opened. With a

Fig. 2:
Butterfly valve of the ROCO Premium type

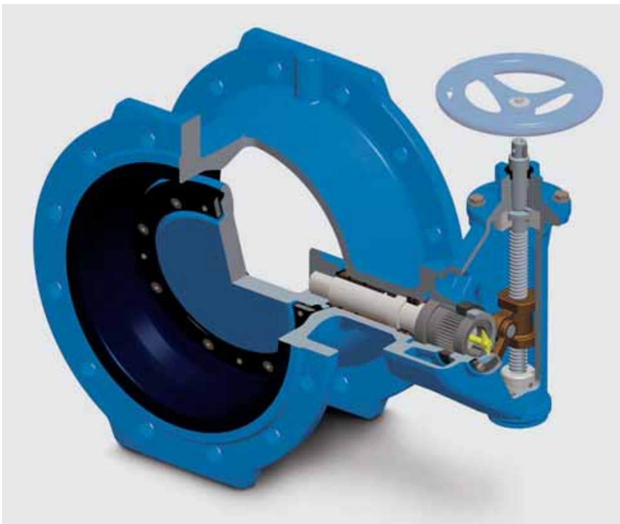

Fig. 3:
Cut-away view of a butterfly valve

Fig. 4:
Cutaway view of an underground hydrant

Fig. 5:
Post hydrant – version with a drop mantle

change in the direction of movement to "downward-opening", towards the pipe system, it was possible for the "double shut-off" function to be introduced. At the same time the material of the seal on the valve cones was changed from hide to elastomers.

In the field of underground hydrants, there was then a further innovation in the form of the introduction of one-piece bodies **(Fig. 4)**. What had been used up to that point had been a flanged connection, in the ground, between the inlet piece to the body (which might have a double shut-off for example) and the body itself and the one-piece body meant that this was done away with. In the field of post hydrants **(Fig. 5)**, the so-called "breakage point" was also introduced and the colour of the above-ground section was changed from gray to red.

2.4 Air-release and air-admission valves

Air-release and air-admission valves **(Figs. 6 and 7)** have followed the general trend that was apparent in engineering towards "smaller, lighter and higher performing". Air-releasing and air-admitting performance was increased and at the same time the dimensions of the bodies, and hence their weights, were reduced thanks to high-grade ductile iron materials.

The latest development has produced what are known as "air-release and air-admission valve sets". In these, the valve is supplied in a small pillar which is part of the valve. At the top end, the pillar ends in a street cap and thus even enables the valve itself to be stripped out for maintenance purposes by taking off the street cap.

2.5 Pressure and flow control valves

The broad class of pressure and flow control valves can be divided into the sub-class of needle valves **(Figs. 8 and 9)** and that of pressure reducing valves. In the sub-class of needle valves what can be considered a far-reaching innovation is the development that led to a piston, including the piston bearing, of stain-

Fig. 6:
Air-release and air-admission valve of the Twin-Air type

Fig. 7:
Cut-away view of an air-release and air-admission valve

Fig. 8:
Needle valve of the RKV Premium type

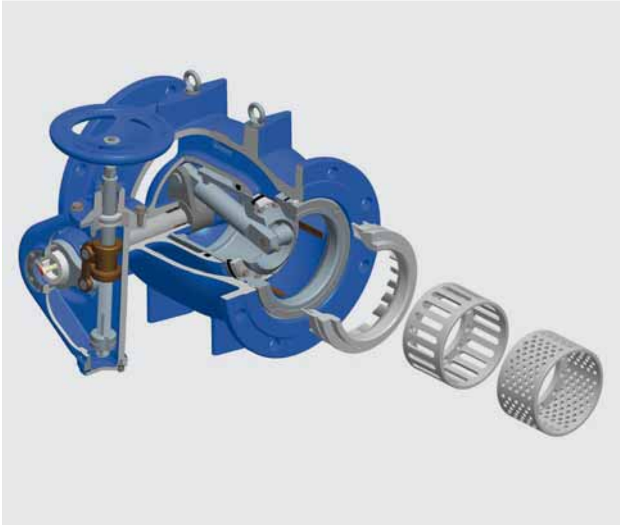

Fig. 9:
Cutaway view of a needle valve

less steel. The piston bearing is welded into the piston in this case. The purpose of this development was to ensure the long-term durability of the piston – even when operating with cavitation in the seat region.

Following the introduction of valves pilot-controlled by the medium itself, there was a shift in the sub-class of pressure reducing valves away from the spring-loaded valve to the pilot-controlled valve.

3 Resumé

There is a constant and continuous rise in the level of the requirements which components are called upon to meet in water supply. What components are mainly affected by in technical terms are the requirements arising from the construction of pipelines and the requirements arising from the operation of pipelines, particularly with regard to the quality of drinking water. Added to these nowadays are also more requirements for efficient and economical operation. There is a continuous increase in the pressure from outside for the efficiency of systems to be improved. Even though the proportion which components represent of the production costs of a pipeline system is at most 15 %, they do have an effect on the overall costs if these are looked at holistically, i.e. in both technical and economic terms, which they do above all by ensuring long and damage-free use. The materials and components selected have to be matched to the particular field of use and the conditions which apply locally.

It is precisely in the case of large valves that the advantages of high-grade cast iron materials can be seen. After being in use for decades, needle valves of larger nominal widths can be remachined in the area of the seals and bearings. The cast iron body is preserved and in this way can achieve lifetimes of more than 50 years (see also the article beginning on page 49 of this issue of the journal).

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Author

Oliver Jäger
ERHARD GmbH & Co. KG
Meeboldstrasse 22
89522 Heidenheim, Germany
phone: +49 (0)73 21/3 20 0
E-mail: oliver.jaeger@erhard.de

Renovation of a drinking water pipeline intersection in Burgkunstadt in Bavaria

by Udo Arrenberg

1 Introduction

The BAIO® system is a non-bolted, restrained connecting system for drinking water and gas pipelines which is protected against corrosion [1]. The system was developed in the early 80's by Hawle Armaturen GmbH with the aim of providing pipe layers with

- a system for easy pipe installation,
- an integral restraint system between fittings and gate valves,
- a nonconducting restraint system between fittings/gate valves and pipes,
- a system for all current pipe materials (cast iron, PE, PVC, steel) in sizes from DN 80 to DN 300,
- a non-bolted coupling system offering no points of attack for corrosion,
- a socket end/spigot end joint able to be angled by approximately 3°
- a system providing heavy duty corrosion protection by powder coating to GSK requirements
- an opportunity to hold only small stocks.

The idea of the BAIO® system, which is restrained under DVGW Arbeitsblatt GW 368 [2], is based on a spigot end/socket end joint whose dimensions are taken from those of ductile iron pipes [3, 4, 5].
With ductile iron pipes, this makes it possible for standard commercially available seals for ductile iron pipes to be used, such for example as the TYTON® seal or the newly developed BAIO® BLD® lip seal. Originally developed for the laying of new pipelines, the BAIO® system is being used to an increasing degree for the renovation of old pipe networks. A special fitting, the EMS cut-in sleeve, was developed for this purpose. This fitting comprises a BAIO® spigot end, a collar section and a Multi/Joint® socket **(Fig. 1)**.

2 The renovation operation at Burgkunstadt

In October 2009, an old, flanged, pipeline intersection fitted with gate valves **(Fig. 2)** was renovated quickly and without any problems using the BAIO® system. The first step was to expose the existing intersection. This consisted of a DN 150 main pipeline of PVC which continued into a DN 100 pipeline of cast iron. There were also two, offset, DN 100 lateral connections, one of PVC and one of cast iron.

Due to corrosion, it was now impossible for the bolted connections at the flanges to be undone by hand. Consequently, the entire intersection was cut free of the pipes, at points back from the valves and fittings, and was lifted out of the trench and disposed off as a complete unit. The new pipe intersection was then assembled out of the trench and this was followed by the cut-in sleeves, with their BAIO® spigot ends, collar sections and Multi/Joint® socket, being slid onto

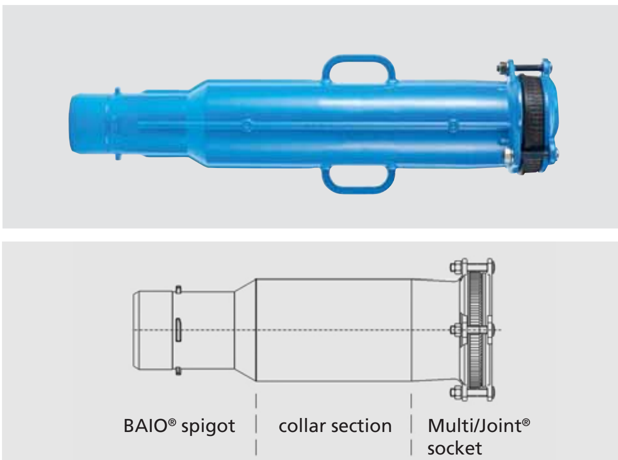

Fig. 1:
EMS cut-in sleeve with BAIO® spigot end, collar section and Multi/Joint® socket

Fig. 2:
The existing pipeline intersection

Fig. 4:
A restrained connection to a pipe end

Fig. 3:
Positioning the new gate-valve equipped intersection

Fig. 5:
The gate-valve equipped intersection after renovation

the pipe ends as far as they would go. After this, the pre-assembled intersection was lowered into the trench, positioned and lined up **(Fig. 3)**. The EMS sleeves were then slid back with the BAIO® spigot ends leading and were locked in the BAIO® sockets and were thus connected to their respective pipe ends by restrained joints **(Figs. 4 and 5)**.

Finally, a newly developed height-adjustable underground hydrant and the telescopic extension spindles were fitted. The time required for the entire process, i.e. from the assembly out of the trench to completion, was only 50 min. What were required for it were four gate valves, nine fittings, one underground hydrant, thirteen seals and ten connecting components, i.e. a total of 47 items.

As a comparison, a total of 546 items would have been needed for a conventional flanged intersection. The installation time would have been 3 to 4 hours in the latter case.

3 Concluding remarks

As well as the simplified installation and connection, which benefits mainly the personnel working in the trench itself, there is also a reduction in costs due to the time saved. In the case of the BAIO® system, there are also cost savings from the reduction in expenditure on valves, fittings and installing accessories. However, it too is a case where the greatest reduction in costs is achieved by shorter installation times. If the overall picture is considered, it is important in this case that movable spigot end/

socket end joints are used to install the BAIO® system. These spigot end/socket end joints are less sensitive to settlement than rigid flanged joints.

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Author

Udo Arrenberg
Hawle Armaturen GmbH
Liegnitzer Strasse 6
83395 Freilassing, Germany
phone: +49 (0)86 54/63 03-2 13
E-mail: udo.arrenberg@hawle.de

Ductile cast iron valves – an investment in the future

by Thomas F. Hammer

1 Introduction

Whether the right materials have been chosen is what, to a considerable degree, determines the costs of a product throughout its entire life cycle from manufacture through operation to its final disposal.
A needle valve of the DN 2000 size installed in the Wendefurth dam in Saxony-Anhalt, which went into service in 1967, can be taken as an example. After four decades of use, it was stripped out, reconditioned and then handed back to the dam operator, Talsperrenbetrieb Sachsen-Anhalt, for some more decades of use.

2 The Wendefurth dam

The Wendefurth dam, which is situated in the Harz Mountains, is one of a number of dams downstream of the Rappbode dam; it forms part of the flood protection system. **Fig. 1** is an overview of the whole of the Rappbode dam system.
The Wendefurth dam is a 43.5 m high gravity dam and it consists of 16 segments, which are 30 m thick at the floor of the valley and 3 m thick at the crest of the dam. On the upstream side, the individual segments are sealed by copper plates inset into the concrete. The joints are also sealed with tar and hemp.

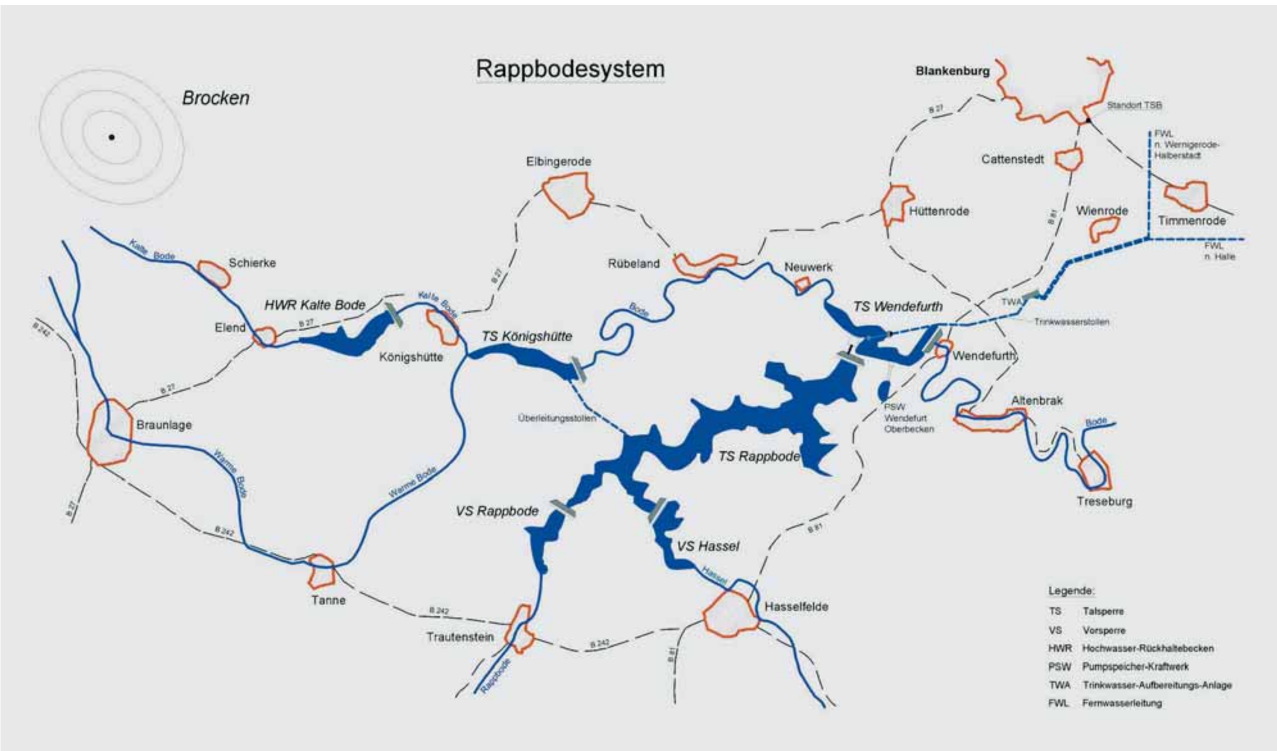

Fig. 1:
An overview of the Rappbode dam system (picture credit: Archive of Talsperrenbetrieb Sachsen-Anhalt)

Fig. 2:
The two needle valves and the turbine inside the dam (picture credit: Archive of Talsperrenbetrieb Sachsen-Anhalt)

For inspection purposes, there are a number of inspection galleries passing through the dam. At the bottom of the dam there are two outlet sluices fitted with needle valves and a turbine for generating electricity **(Fig. 2)**. The valves are capable of discharging up to 75 m^3 of water a second. They are the biggest needle valves used in any German dam.

3 Replace or refurbish

What has absolute priority for a dam is an assurance of normal operation. Once irregularities had occurred in operation in one of the two valves, action had to be taken immediately. A check made by engineers from a large firm of valve manufacturers in Germany showed that the valve could no longer continue operating safely in its current state. Tenders for the overhaul of the DN 2000 needle valve and for the cost of investing in a new one were analysed and their pros and cons considered and this showed that overhauling the valve would be the more economical solution – 40 t of cast iron was worth too much money.

The primary concern was the reconditioning of the valve. Despite their age, the body and the most important components of the valve were still in excellent condition. It was the guides and sealing components that needed to be revised and/or replaced. More than 40 years of use in day-in day-out operation had left their marks. There could not be any question of the valve undergoing a general overhaul on site so it had to be stripped out and transported to the valve manufacturer's works in the south of Germany. The scope of the contract also included all the logistics services which formed part of the project.

Fig. 3:
The DN 2000 needle valve, weighing 40 t,
has been removed from the dam and is being loaded.

Fig. 4:
The inner circumference of the valve being machined on a vertical turret lathe

4 The project took six weeks and not a day more

The project, from the hydraulic isolation of the valve to its re-installation, had to be squeezed into a very short period of time of 40 days. The needle valve having been stripped out **(Fig. 3)**, two days of transport as a heavy load took it from Saxony-Anhalt to the manufacturer's works in Swabia.

Following dismantling and appraisal, not only were the guiding and sealing components replaced but there was also a technical conversion of the design. Thanks to the outstanding quality of cast iron, it was possible for extensive work to be done on the structure of the valve. This was something that was needed if the valve was to operate accurately for decades more. The conversion operation was followed by machining of the guiding inner circumference of the valve, a strong-man act which was on a scale of its own.

Clamping a weight of 40 t exactly in position on a vertical turret lathe **(Fig. 4)** and machining it to tolerances of a tenth of a millimetre calls for some very special production knowhow.

The final assembly and the transport back went off on schedule **(Fig. 5)** and the manufacturer's service engineers were able to complete the commissioning within the time laid down.

Fig. 5:
Transport of the valve back from Heidenheim to the Harz Mountains

Author

Dipl.-Ing. (FH) Thomas F. Hammer
Tyco Waterworks GmbH & Co. KG
Meeboldstrasse 22
89522 Heidenheim, Germany
phone: +49 (0)73 21/3 20-0
E-mail: thammer@tyco-valves.com

Casting process simulation in valve and fitting production

by André Mähnert

1 Introduction

At the beginning of 2008, MAGMASOFT® simulation software was introduced at Duktil Guss Fürstenwalde GmbH. The aim was to enable the process of developing castings for production purposes to be optimised. Nowadays it is essential for companies to introduce tools of this kind if they are to survive in a competitive world, because the tools enable many steps on the path to optimisation to be simulated on the computer rather than on actual castings, which results in substantial savings in time and money. As so often happens when innovations are introduced, it was chiefly the old, dyed in the wool foundrymen with their long experience who were sceptical as to whether this software would work in the way that the publicity claimed it would.

Resistance had to be overcome, existing knowledge had to be added to and new approaches to finding solutions had to be advocated with some force.

It is true that there are still frequent differences of opinion but a majority of the workforce now see casting simulation as a useful tool. It is not easy to master, because the things that are shown on screen have to be interpreted correctly. However, the visualisation of the flow and solidification processes in the mould enables possible flaws in the casting to be recognised and eliminated back at the design phase. Casting process simulation leads to close collaboration between the designer, the foundryman and the pattern maker.

2 Casting simulation by reference to a practical example

The general procedure followed in casting simulation is always the same, regardless of whether it is a question of optimising an existing casting or designing a new one. Once the casting has been designed in the form it needs to take in use **(Fig. 1)**, the next step is for the solidification process to be simulated **(Fig. 2)**. What is shown in this case is the sequence in which the individual parts of the casting solidify. From this, the size and optimum position of risers is deduced. Areas where there are concentrations of material solidify last and as they cool cavities or porosities occur in them. Risers are a casting aid which provide a supply of molten iron to fill these cavities or porosities.

All that any simulation can do is to display and visualise the ideas of users but it is the user who actually decides what further steps are taken.

On the basis of the initial results from the simulation, the risers and their positions on the casting are then decided and if necessary corrections to the casting are agreed with the customer **(Fig. 3)**. If possible, the gating system (sprue, runners and gates) is not looked at in this phase because, if it is, this can often mean that the computing time goes up by a factor of three.

Fig. 1:
The casting
(the core is hidden)

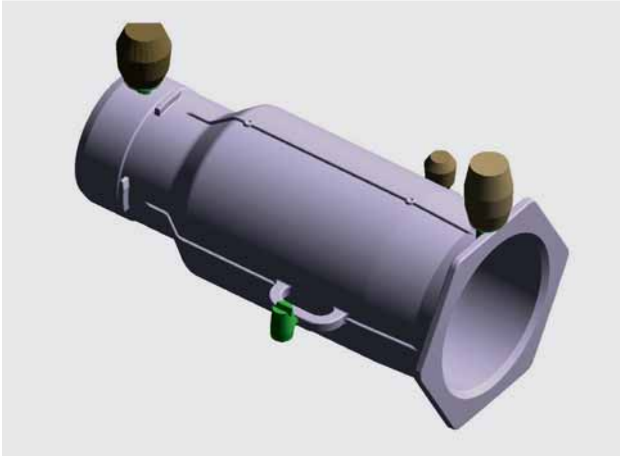

Fig. 3:
Casting + risers (three top risers and one non-sleeved riser)

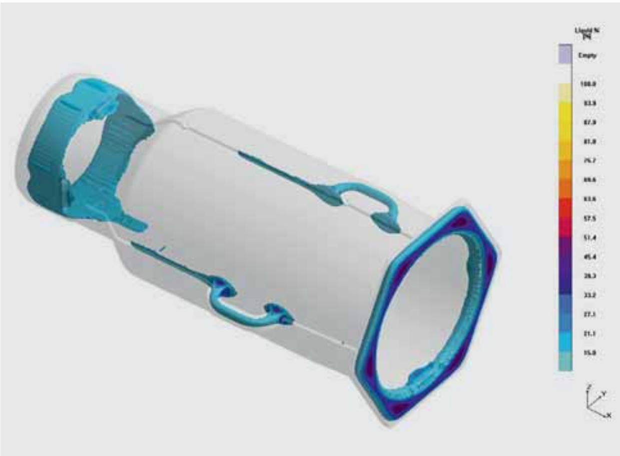

Fig. 2:
Solidification 1, molten metal and the slowly increasing parts of it which are solid, shortly before complete solidification (everything in see-through form)

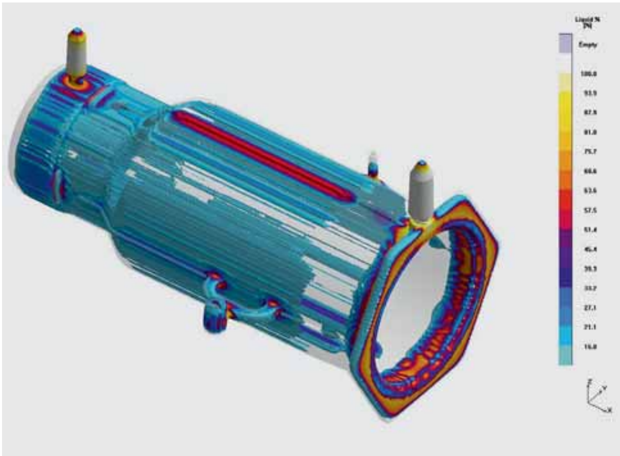

Fig. 4:
Solidification (beginning)

In **Fig. 4** it can be seen how the casting gradually solidifies. The aim is for the solidification to progress in such a way that the risers are the final items which remain liquid **(Fig. 5)**, which produces a casting free of porosities. There is no break in the solidification fronts between the casting and the risers. If there were, a porosity would occur downstream of the riser.

On the basis of the best variant type of risering, the gating system, consisting of the inlet (the stream of molten metal from the casting ladle), the sprue, the runners, the filters and the gates leading from the runners to the casting **(Fig. 6)**, is added to enable the mould filling process to be simulated **(Fig. 7)**.

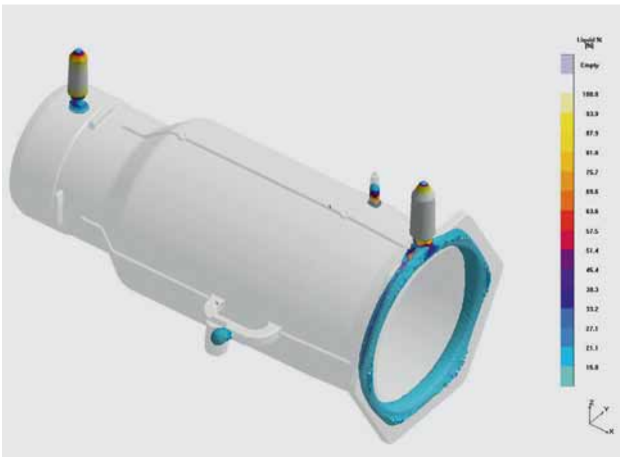

Fig. 5:
Solidification (concluding phase)

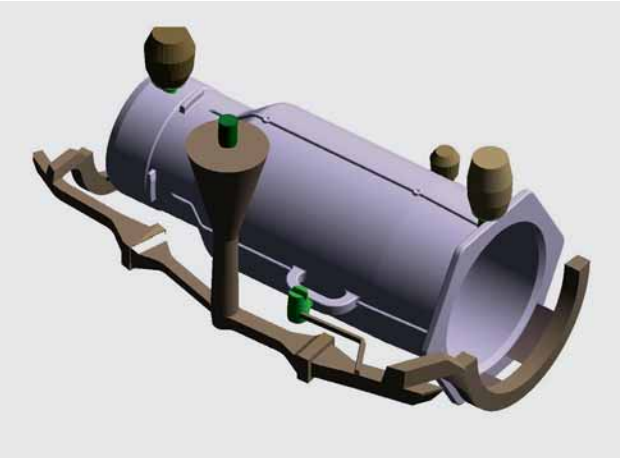

Fig. 6:
The complete casting + gating system, with the venting passages (generally situated at the highest points) hidden

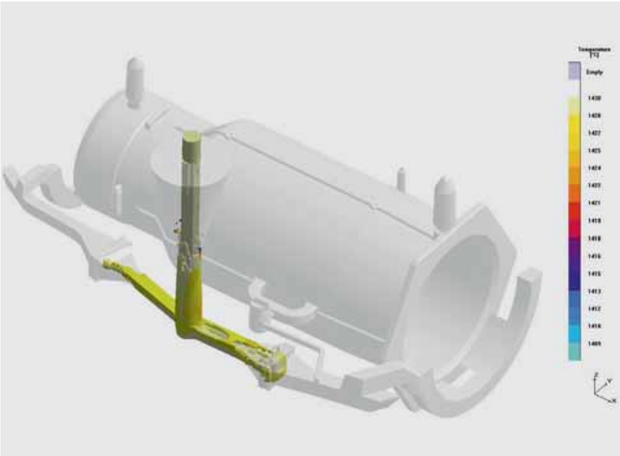

Fig. 7:
The beginning of casting; as it flows in, the molten metal is slowed at the filters, has contaminants filtered out of it, and is calmed.

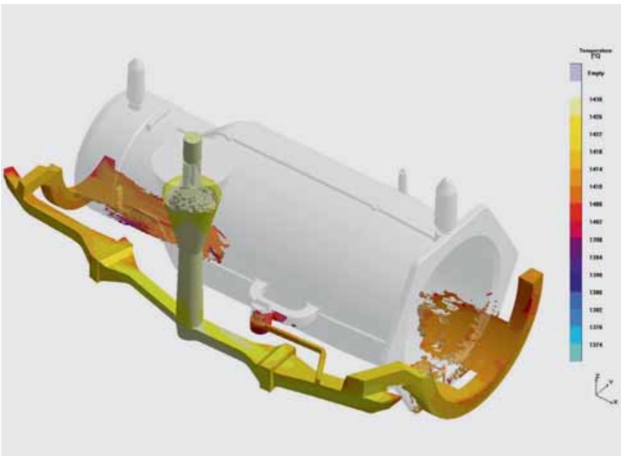

Fig. 8:
The melt enters the casting

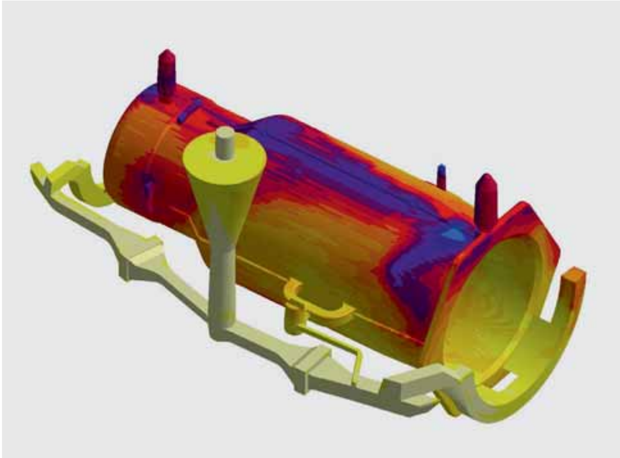

Fig. 9:
End of solidification

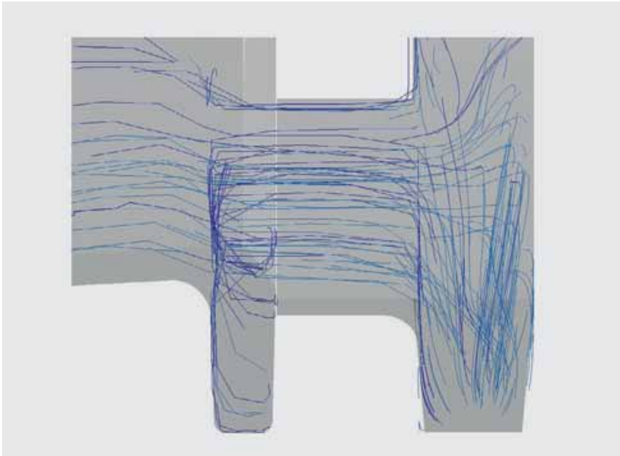

Fig. 10:
Tracers showing turbulence at the rear side of the flange

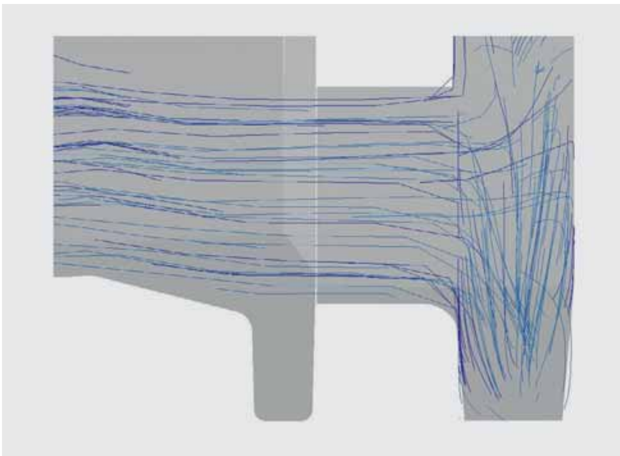

Fig. 11:
Revised section with no turbulence

Turbulence in the filling process should be avoided and the risers should be fed with molten metal which is as hot, i.e. "fresh", as possible so that they are completely effective in performing their action.

The splashing of the molten metal at the end of the casting where there are twin gates **(Fig. 8)** indicates a problem to which further attention needs to be given. Otherwise, there are no problems with the filling process, even though the risers do not get the "freshest" molten metal. On the basis of the final filling temperature, the computation then continues to cover the solidification process **(Fig. 9)**.

Fig. 10 shows how the problematic area at the twin-gated flange is tracked in a more exact way by means of so-called tracers. These are virtual particles of no mass or volume which are carried along in the molten metal and thus indicate the direction of flow and any changes in this direction.

When it flows in from the gate, the molten metal strikes the mould sand at an adverse angle at the rear side of the flange and causes scouring there. This is something that was also seen to happen in practice.

With the help of the simulation, it was comparatively easy for this problem to be solved: at the rear side of the flange, the wall of the casting was made slightly thicker in a wedge shape and the molten metal thus struck the outline at a considerably more shallow angle **(Fig. 11)**. No erosion was now found after the casting – and that is how the casting has been produced every since.

3 To sum up

The difference from the conventional way of designing risers and the gating system is that with casting and solidification simulation it is possible to watch the casting on screen as it fills and as it solidifies. One sees the processes right in front of one's eyes and there is no need to draw conclusions as to how flaws can be avoided by looking at the flaws in a finished casting. The more accurate calculation either allows risers to be reduced in size or even allows some of them to be done away with completely. It is also possible for many filling problems to be detected and cleared up in advance. The number of trial casts is cut to a minimum and this in turn reduces the cost of materials and salary and labour costs.

Casting simulation is subject to a process of constant ongoing development so that further realistic results can be obtained. This makes the differences between the simulation and the actual casting smaller and the accuracy of the predictions is increased

Author

Dipl.-Ing. André Mähnert
Duktil Guss Fürstenwalde GmbH
Saarower Chaussee 34
15517 Fürstenwalde, Germany
phone: +49 (0)33 61/77 22-7 61
E-mail: a.maehnert@duktil-guss.de

Willingen ski resort

Ductile iron pipes – "Arteries" for the snow-making system

by Karl-Wilhelm Römer and Martin Schulte

1 Introduction

For the winter 2007/2008 season, a massive organisational and economic feat was performed at the winter sports centre of Willingen in northern Hesse **(Fig. 1)**. This is a winter sports centre steeped in tradition but not only was one of Germany's most up-to-date ski lift systems built there but it was also ensured that there would be a certainty of snow for the next few decades by installing a powerful snow-making system. To get an impression of the artificial snow-making "scene", it is a good idea to look beyond the horizon of the central area formed by the Alps from time to time because there are interesting developments outside this central area which, occasionally, may even serve as a model for the entire industry.

The Hochsauerland is one example of this: Willingen, together with Winterberg, is the most important main town in the Hochsauerland and is not only one of the most northerly winter sports centres in central Europe but also one of those with the greatest tradition in Germany. This is true not only of Nordic skiing, which every year reaches its pre-ordained climax at the Ski-Jumping World Cup (5–7 February 2010, for information go to: www.weltcup-willingen.de) but also of Alpine skiing; in Willingen alone there are 16 ski-lifts giving lifts of different lengths to runs of different difficulties for practising and learning the Alpine discipline. In all, the length of the ski runs at Willingen is 8 km. At the same time as the snow-making system was put in, one of Germany's most up-to-date 8-person gondola ski-lifts was also installed.

This makes Willingen and the Hochsauerland one of the most important "outposts" of the Alpine winter sports and tourism industry – but

Fig. 1:
Panoramic view of the Willingen ski runs

an "outpost" which, in the Ruhr region and the 20 million people who live there, has one of the most important catchment areas in the entire industry on its doorstep. And there are too the vast numbers of yellow Dutch number plates on the cars of the winter sports visitors that have even earned the Sauerland the paradoxical title of the "Dutch Alps".

But no-one can have everything: yes, there is a catchment area for which the people of Willingen may well be envied by many of the winter sports centres in the Alps, but on the other hand the town is at an altitude above sea level which, of course, classifies it as being in a low mountain range.

And at altitudes of less than 1000 m, the snow situation has, as expected, become the number one existential question for winter sports tourism. This is because there is a clear link between the snow situation and the number of beds that have guests sleeping in them, as the mayor, Thomas Trachte, confirmed in conversation: "The more snow, the more guests". And because the important thing in Willingen is to fill 12,000 beds for guests – which makes the little town, with its 6,000 souls, one of Germany's top ten tourist resorts – the matter of ensuring the certainty of snow and thus of artificial snow-making became a public task. The aim of the project entitled "Artificial snow-making" was to produce artificial snow and by so doing to improve the opportunities for winter sports in Willingen and to maintain them in a lasting way in order to safeguard the resort's winter season for tourists and expand it. With artificial snow the season can, after all, be lengthened from some 30 days for skiing to around 80.

Mayor Thomas Trachte: "This decision to invest was of course preceded by some extensive work done to inform and convince people. However, it was a study by the German Sport University Cologne (the master plan) that confirmed for us that, even at our altitudes and even with all the possible climate change scenarios, suitable winter sports business could be guaranteed for at least the next 20 to 30 years with artificial snow-making."

It is thus the municipality – and this is typical of the entire snow-making industry – which considers artificial snow-making to be a public/local authority task and which provides an infrastructure for it. Jointly with the operators of the ski runs, a "division of labour" was agreed under which the municipality would make water and energy available at the take-off points, i.e. would see to the procurement of water, the storage of water and the underground infrastructure. The provision of the take-off points and the procurement of the snow-makers was a matter for the operators. It was thus the municipality of Willingen which designed the following as technical components for the snow-making system: a reservoir for water, pipelines, pumping stations and a suitable supply of electricity. This is how Walter Frosch, the manager of the construction department at the municipality of Willingen who was responsible, summed things up: "The first thing needed was a central reservoir for water. The entire snow-making system had to be so designed that basic snow cover for the skiing area was possible in 60 h. This was the only way of achieving the number of days of operation of 80 that was being aimed for."

2 Preparation and planning

A high proportion of the ski runs are situated in the region of the Willinger Hochheide, a European Flora and Fauna Habitat which has special protection. The remainder are situated close to or even within the residential areas. The entire operation thus required planning permission. One of the planners' principal tasks was to find technical solutions which, in the sensitive FFH area, would allow the field pipelines to be laid and the take-off points constructed in the first place. By close collaboration with the environmental chaperoning section specifically assigned to the project, it was possible to work out solutions which made allowance for the question of nature protection.

The project could go ahead if the following constraints were observed:

- "quiet" snow guns or lances to be used in the area where residential buildings would be affected
- extremely small incursions in the FFH area, diversions to be made around particularly sensitive areas, the width of the pipeline route to be cut to an absolute minimum, work to be done section by section and the surface to be restored immediately sections were finished,
- pipelines to be concentrated in a trench which was as narrow as possible,
- laying roads would not be permitted and bulk material could not be transported to the laying route,
- chemically neutral building materials to be used and no sand or pre-screened materials,
- concrete components to be given an encapsulating coating of neutral pH.

2.1 The aims laid down

Understandably, all the ski run operators at the ski resort want to, and indeed need to, carry out the snow-making operation successfully at the same time, because the cold spells when temperatures are in the range from –2 to –6 °C and below are generally very short. The snow-making system therefore requires a suitably large number of snow-makers to be used and large amounts of water and energy to be consumed in short periods. In a large area of terrain like this, "punch" of this kind for the system as a whole means that some 50 snow-makers have to be used.

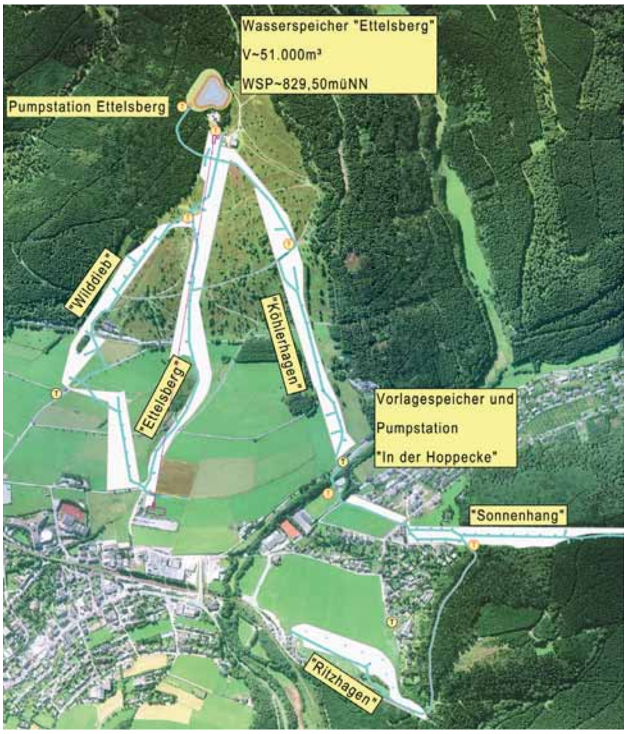

Fig. 2:
The Ettelsberg reservoir for water

For an initial snow-making operation it was expected that a volume of snow of 80,000 m^3 would be needed, i. e. 40,000 m^3 of water. The total water demand for the region would be around 90,000 m^3 for a winter season. The only way of providing these large volumes of water required in such a short time was to build a reservoir. This reservoir was at the heart of the entire design of the snow-making system and was to be designed to look at natural as possible so that in summer too it would operate as a landscaping feature.
All the ski runs are connected to the reservoir **(Fig. 2)** by transporting pipelines. Two central pumping stations (Ettelsberg and Hoppecke) provide the operating pressure for the snow-makers. Over the wide area covered by the ski runs, there are 114 take-off points for snow-makers.

2.2. The reservoir for water

40,000 to 45,000 m^3 of water in 50 to 60 h cannot be supplied from the normal flow of a small stream in a low mountain range. There therefore had to be an intervening reservoir. The water carried by watercourses in the area of low mountain ranges is very much dependent on the weather and in particular on the occurrences of rainfall. The amount of water carried rises quickly when the rain begins and declines again quickly once it has faded away. In the Willingen area, only the stream known as the "Hoppecke" is capable of supplying enough water for extraction for and filling of the reservoir on the Ettelsberg mountain.

In preparation for the planning of the reservoir **(Figs. 3 and 4)**, a thorough check was made on possible sites. The important thing was to find a site which would firstly be as eco-friendly as possible and which secondly, and at the same time, would enable the snow-making system to be operated economically. The site selected was situated in an area of forest near the Hochheide viewing tower. The surface of the water is at an altitude of approx. 830 m and is thus only some 7 m below the peak of the mountain.
The entire structure was so designed that a balance was struck between the masses of the material excavated and that used as fill. This avoided the need for any unnecessary transpor-

Fig. 3:
The central reservoir being excavated

Fig. 4:
The reservoir shortly before completion

tation of material in the sensitive area. A small shortage of material was made good with the excess material excavated from the trenches for the field pipelines. The capacity of the reservoir is about 52,000 m³ at a depth of water of 8 m and the surface covers an area of 10,000 m². The reservoir is sealed with a plastic sealing membrane. The slope of the embankments is 1 : 2.25 and 1 : 2.

2.3 The pumping stations

Via a preliminary reservoir – capacity around 1,200 m³ – the water is extracted in the valley of the Hoppecke by a filling pumping station. Three submerged pumps pump a maximum of 75 L/s of water over a height of 250 m through the DN 250, PN 40, ductile iron transporting pipeline to the central reservoir on the Ettelsberg. The 10 m high earth embankments of the central reservoir enabled the main pumping station **(Fig. 5)** to be connected into the embankment structure at low cost and in a way which was ideal from the technical point of view. The shared pump system pumps 210 L/s of water at a pressure of 30 bars into the field pipelines and to the individual ski runs. Including the compressor for pond aeration, the power consumption is 700 kW.

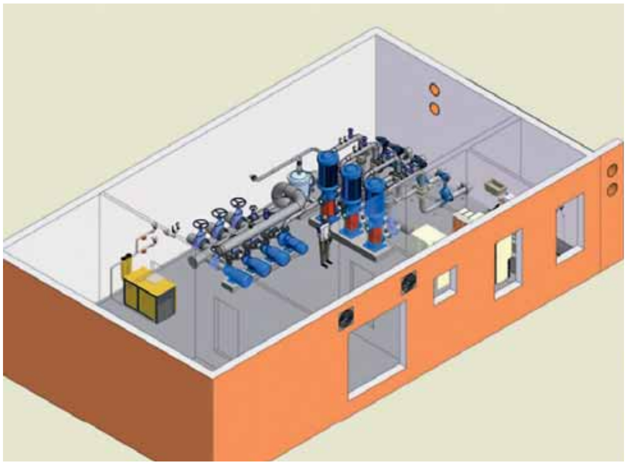

Fig. 5:
The main pumping station

The long transporting pipelines to supply the skiing areas of Sonnenhang and Ritzhagen required a further intermediate pumping station. At this station the supply pressure is raised to more than 55 bars so that even the snow-makers at the upper terminals of the respective ski lifts receive an adequate supply pressure. Including the compressor for pond aeration, the power consumption is 1,300 kW.

3 Installation work on the field pipelines

From the reservoir, the water is transported through field pipelines to the skiing areas. Being "arteries" for the snow-making system, there were certain requirements, relating to pressure and the environment for example, which the pipelines had to meet. A check on the possible variant pipes and techniques showed ductile iron pipes with restrained push-in joints to have clear advantages. In all, more than 13 km of ductile iron pipelines with BLS® push-in joints and a cement mortar lining (ZMA) based on sulphate-resistant cement were laid. The crucial advantages which the ductile iron pipe system selected has are that there is no welding work that has to be done out on the terrain and there is a full range of fittings matched to the system available. Compared with welded pipe systems, this brings the installation costs down considerably. With their allowable component operating pressure of at least 64 bars, the nominal sizes of DN 80 to DN 250 which were laid in this case give a level of safety sufficiently high to ensure that the snow-making operation will always proceed smoothly. The angular deflections of up to 4° which are possible with the BLS® push-in joint enabled the path followed by the route to be optimised. For the external coating, the choice fell on a pipe with a 200 g/m² coat of zinc and a 5 mm thick cement mortar coating. This latter allows the pipe to be used in stony ground without any special protective or bedding materials.

The individual snow-making sections along the runs are each supplied with energy via a low-voltage supply system and energy cables running from the seven transformer stations and feed points. The energy cables for supplying electricity to the individual multiple connection boxes were installed parallel to the main water pipelines, in the same trench. Each take-off point along a run is connected to one of the boxes.

Also installed in the trench are the medium-voltage cables to the transformer stations, the lighting cables for lighting the ski runs and the optical fibres for controlling and monitoring the systems. In the Ettelsberg trench there are also cables for the safety lighting and control cables for the new cable car. The total length of the cables in the main trenches is approximately 70 km.

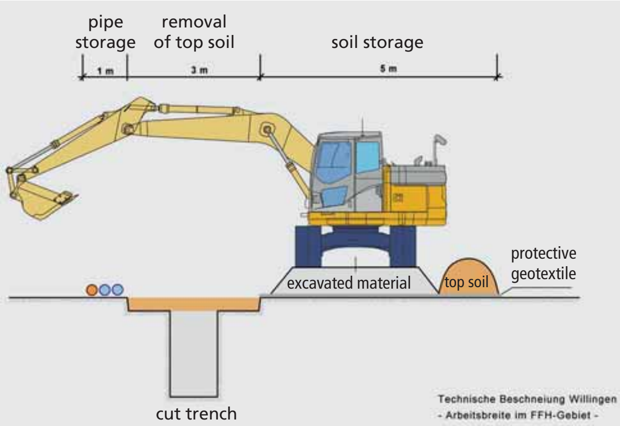

Fig. 6:
Dimensions in the region of the pipeline route – as specified

Fig. 7:
The region of the route in practice

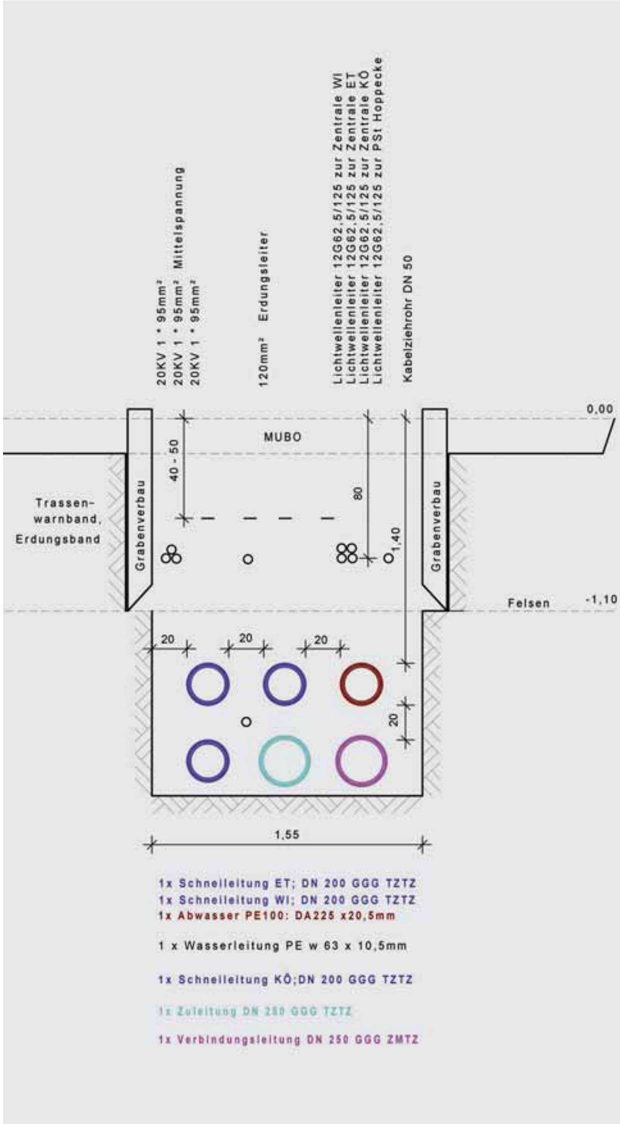

Fig. 8:
The trench profile

Due to the constructional restrictions on pipeline installation in the area of the Willinger Hochheide, unusual solutions has to be found. The width of the laying route was limited to 9 m **(Fig. 6)**, which meant that the pipes, the trench for the pipeline, the separate store of trench spoil and top soil and a laying road all had to be crammed into a width of 9 m.

The direct invasive action, the removal of the top soil, took place only over a width of 3 m. The rest of the area was covered with a protective geotextile. Because of the shortage of space, the laying road was situated on the stockpile of excavated material **(Fig. 7)** and only track-laying equipment was able to use it. Because of the large number of water pipelines, energy cables and data cables, they had to be installed one above the other in layers **(Fig. 8)**. Material from outside such as sand, crushed stone or concrete was not permitted. This meant that any possibility of making repairs or remedying defects in the course of the installation was virtually ruled out. All the items used therefore had to meet particularly demanding requirements.

In the course of the installation work, there was repeated evidence that the right choices had been made.

- Water pipelines – ductile iron pipes with BLS® push-in joints,
- Energy cables – aluminium cables in a protective sheath of rock-shielding material
- Control cables – in a protective pipe or in a protective sheath of rock-shielding material
- Installation took place in two to four layers one above the other.

4 To sum up

All in all, the Willingen project can be considered the largest snow-making project of the 2007/2008 season in Germany. The cost of installing the infrastructure for artificial snow-making amounted to some 5.5 million Euros. The federal state of Hesse funded the operations to the tune of around 3 million Euros and the district of Waldeck-Frankenberg did so to the tune of 500,000 Euros. Further sums were paid out by the private ski lift operators, who had to finance the water take-off points and the snow canons (5 million Euros). Despite the very bad weather during the entire installation phase from July to November 2007, which produced a great deal of rain and mist, the installing companies involved were able to complete the work on time. Because of the time available there was only one pressure test on the complete pipeline system of ductile cast iron. More than 12 km of DN 100 to DN 250 main pipelines with 114 DN 80 supply pipelines to take-off points were found not to leak at the first go.

Authors

Karl-Wilhelm Römer
Duktus Rohrsysteme Wetzlar GmbH
Kassel Sales Office
Schweinsbühl, Kerbelweg 6
34519 Diemelsee, Germany
phone: +49 (0)56 32 / 92 22 52
E-mail: karl-wilhelm.roemer@duktus.com

Dipl.-Ing. Martin Schulte
Ingenieurbüro
Dipl.-Ing Gröticke & Partner GmbH
Bahnhofstrasse 15
34477 Twistetal-Berndorf, Germany
phone: +49 (0)56 31 / 97 55 97
E-mail: info@groeticke.com

Client

Gemeinde Willingen (Upland)
Dipl.-Ing. Walter Frosch
Waldecker Strasse 12 · 34508 Willingen, Germany
phone: +49 (0)56 32/40 10
E-mail: post@gemeinde-willingen.de

Technical planning and monitoring of installation

Ingenieurbüro Gröticke & Partner GmbH
Dipl.-Ing. (TU) Martin Schulte
Bahnhofstrasse 15
34477 Twistetal-Berndorf, Germany
phone: +49 (0)56 31 / 97 55 97
E-mail: info@groeticke.com

INGENIEURBÜRO Arno Schweiger
Dipl.-Ing. (FH) Arno Schweiger
Vordere Burgauffahrt 25
87527 Sonthofen, Germany
phone: +49 (0)83 21/72 13 51
E-mail: info@seilbahnprofi.de

Environmental planning and monitoring of installation

Bioline Planungsbüro
Orketalstrasse 19 · 35104 Lichtenfels, Germany
phone: +49 (0)64 54/9 119 79
E-mail: planungsbuero.bioline@t-online.de

Installers

Bauunternehmung Erich Wenzel
Am Sportplatz 19
35104 Lichtenfels-Goddelsheim, Germany

Fr. Fisseler GmbH & Co. KG
Am Ziegelgrund 25 · 34497 Korbach, Germany
phone: +49 (0)56 31/97 97-97
E-mail: info@fisseler-korbach.de

G. Jordan KG
Tiefbau, Wasserwirtschaft, Kulturbau
Landstrasse 40
34454 Bad Arolsen-Mengeringhausen, Germany
phone: +49 (0)56 91/37 85
E-mail: g.jordankg@t-online.de

Bauunternehmung Eickmann GmbH
Am Hagenblech 63 · 59955 Winterberg, Germany
phone: +49 (0)29 81/92 70 - 0
E-mail: info@eickmann-bau.de

E. Grell GmbH & Co. KG
Strassen- und Tiefbau
Hünegräben 21 · 57392 Schmallenberg, Germany
phone: +49 (0)29 72/50 95
E-mail: l.grell@e-grell.de

SUFAG
Sport- und Freizeitanlagen GmbH
Hermann Felder
Bregenzer Strasse 5 · 6921 Kennelbach, Austria
phone: +43 (0)55 74/68 44-0
E-mail: office@sufag.com

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Electricity generation by using the power of drinking water has a future

by Roger Aebi

1 Introduction

If climate change is to be combated effectively, there has to be a considerable fall in the emissions of carbon dioxide (CO_2). There are three foundations on which Switzerland's energy strategy for achieving this is based:

- increases in efficiency,
- renewable energies, and
- electrification.

The future energy mix which includes electricity generated by CO_2-free or CO_2-neutral means will be playing an increasingly important role in this strategy. The generation of electricity by hydroelectric power stations powered by drinking water is a particular technique for this which shows an excellent CO_2 balance sheet, because the drinking water pipelines, as well as serving their main purpose of supply drinking water, also produce eco-electricity.

There is a long tradition of hydroelectric power stations powered by drinking water in Switzerland. 100 or so of them have been built since 1990 and today they generate around 100 million kWh a year of electricity, enough for about 12,000 households. The advantages for the operator are obvious. The electricity generated in drinking-water driven power stations is produced locally, nature and the water cycle are virtually unaffected and at relatively low cost an important contribution can be made to achieving the aims of Swiss energy and climate policy.

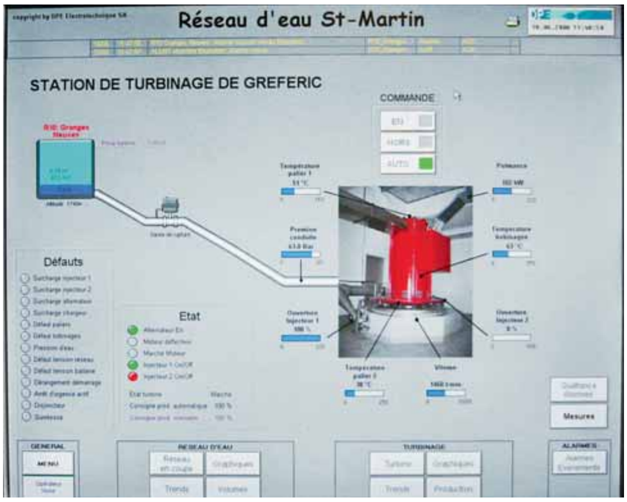


Fig. 1:
On-screen monitoring of the drinking-water power station

2 Unused potential for drinking-water power stations

According to surveys conducted by the Swiss Federal Office of Energy, there is still some unused potential. There are suitable sites for drinking-water power stations both in the mountainous regions and on the central plateau.

The municipality of Saint-Martin is situated some 20 km from Sion in the heart of the Val d'Hérens and in the 80's it drew up a scheme for the sustainable development of its region. The area of 36 hectares around Ossona had been unused since the 60's and it provided ideal conditions for regionally orientated agriculture developable for soft tourism. Ossona therefore also became an important part of Switzerland's pilot project for the development of its rural regions.

The supply of drinking water to Ossona was carried by a new, 1,702 m long, DN 150 water pipeline which branched off from the existing main pipeline which supplied water to Saint-Martin. The new pipeline descended for a vertical distance of 679 m and the tremendous head of water this produced enable a drinking-water-powered hydroelectric station to be built at the same time. The output of this station is an average of 825,000 kWh a year, which is equivalent to the energy value of 70 t of fuel oil or to a saving of 233 t of CO_2. A twin-jet Pelton turbine was installed in the drinking-water-powered hydroelectric station. The maximum pressure at the inlet to the turbine is 63 bars at a maximum water flowrate of 5 L/s. **Fig. 1** shows the control system for the station.

3 Easy pipeline installation

For the laying of a power station pipeline subject to high pressures, the factors which are crucial in deciding the pipe material selected are, we are told by the project engineer Monsieur Laurent Pitelloud who was responsible, great safety and reliability in operation, economical operation, easy installation of pipelines in steep terrain and a long life for the pipeline. The ductile iron pipe system **(Fig. 2)**, with a polyurethane (PUR) lining for combined drinking water and power station pipelines and a zinc coat plus a bitumen top coating, (the ducpur pipe system) was a component that the client found convincing. Thanks to the high strength of the material and the reliable and proven hydrotight connecting technology **(Fig. 3)**, these pipes are almost predestined for use in demanding areas of application.

4 Appreciably better profitability

Ductile iron pipes with a polyurethane lining have very good characteristics for the unimpeded flow of water and contribute to low head losses in the pipe network. The push-in joints can be deflected by up to 3°. This enables a pipeline of ductile iron pipes to be adapted to slight curves without the need for extra fittings, which gives a further optimisation of the energy properties of a network: for the operator, lower head losses produce a higher output from the turbine and hence appreciably better profitability for the power station.

Fig. 2:
A ductile iron pipe with a polyurethane lining and a zinc coat plus bitumen top coating

Fig. 3:
The hydrotight restrained push-in joint (external)

5 Demanding requirements for the pipes

The Saint Martin power station pipeline (the project data can be seen in **Table 1**) also sets demanding requirements for the lining of the pipes. The lining has to meet the requirements for drinking water hygiene, has to stand up to soft water, and at the same time has to be very stable and strong mechanically. The PUR lining to EN 15655 satisfies these requirements.

Table 1:
Project data for the new power station pipeline

1 ducpur ductile iron pipes		
DN	Wall-thickness class	Length of pipeline
150	K 9	870 m
150	K 10	700 m
150	K 12	132 m
2 Thrust resistance		
Type	Layout	Pressure class
hydrotight	External	100 bar

Fig. 4:
Hygienically satisfactory drinking water as it reaches the consumer

Security of supply in the areas of drinking water and energy has always been a precondition for the prosperity and progress of a society.

The generation of energy by drinking-water power stations combines opportunities for achieving the following:

- security of supply, looking towards the future, for the local population and industries **(Fig. 4)**,
- improvement of the results achieved by the industrial concerns run by municipalities and municipal associations,
- meeting of the concern for the environment to be protected.

This is a win-win situation and things that played no small part in achieving it in the present case were the experience and expertise of the engineers working for the manufacturers of the pipes and the power station equipment.

6 Water power is being funded by Switzerland

Technical innovations and measures to reduce CO_2 emissions are turning small hydroelectric power stations into beneficial energy sources which provide electricity generated in a de-centralised and environment-friendly way.

The new Swiss Federal Electricity Supply Act has been in force since 1 January 2008. It includes a cost-covering remuneration for electricity from renewable energy sources for new production facilities and this very much improves the economic conditions for the construction of drinking-water power stations **(Fig. 5)**.

The remuneration which is set for hydroelectric power station pipelines, arising from the sale and feed-in to the grid of the electricity generated in the power stations, helps to pay off the sums invested quickly and improves the economics of the business of supplying water. Eco-electricity from drinking water also makes an important contribution to environmental protection.

Water suppliers receive a remuneration ranging from approximately 15 to a maximum of 34 centimes/kWh which is guaranteed for a period of 25 years. A total of around 320 million Swiss francs is available every year and up to half of this is intended for small hydroelectric power stations and hence for drinking-water power stations.

Drinking-water power stations are secondary-use facilities because the main purpose in this case is the transportation of drinking water. The output of these power stations is normally in the range from 10 to 100 kW.

For further information, go to:

- www.infrastrukturanlagen.ch
- www.saint-martin.ch
- www.ossona.ch, and
- www.valdherens.ch.

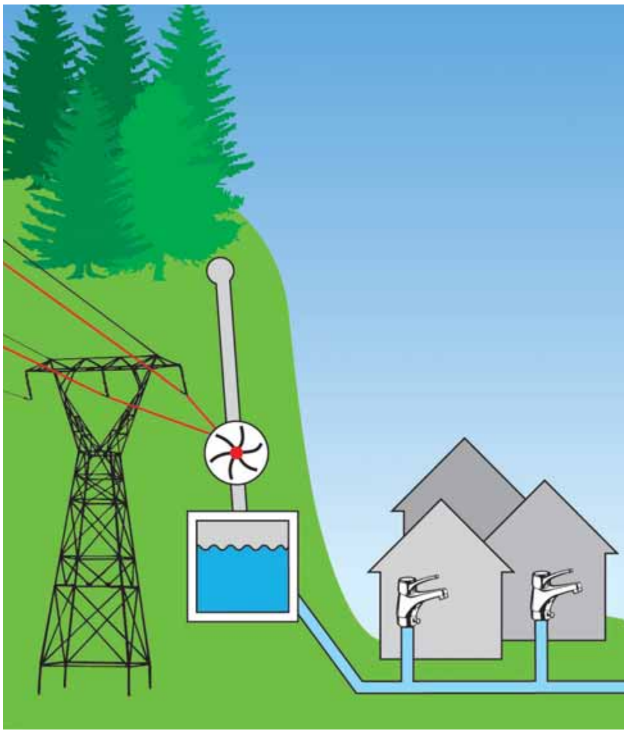


Fig. 5:
A schematic representation of a hydroelectric power station (using combined drinking water and power station pipelines)

Author

Roger Aebi
Wynigenstrasse 8A
3400 Burgdorf, Switzerland
phone: +41 (0)34/4 23 29 66
E-mail: roger-aebi@bluewin.ch

Client

Administration communale de Saint-Martin
Pierre Zermatten
Case Postale 64
1969 St-Martin, Switzerland
phone: +41 (0)27/2 82 50 10
E-mail: commune@saint-martin.ch

Project and installation and construction management

PRA Ingénieurs Conseils SA
Laurent Pitelloud
Rue de la Majorie 9
1950 Sion, Switzerland
phone: +41 (0)27/3 29 60 30
E-mail: prasa@praing.ch

Construction company

Dumas SA
Philippe Dumas
Rte du Manège 63
1950 Sion, Switzerland
phone: +41 (0)27/2 05 88 80
E-mail: info@dumas-construction.ch

Pipe laying

Guy Genolet
Case Postale 25
1987 Hérémence, Switzerland
phone: +41 (0)27/2 81 11 79

Parts of a turbine penstock pipeline slope at up to 80° – The Plankenbach (San Cassanio) small hydroelectric power plant

by Andreas Moser

1 Introduction

Against the background of the latest rises in the price of electricity in South Tyrol, the municipality of Klausen decided to build a small hydroelectric power station.
Since 1 January 2009, there have been a limited number of what are called "green certificates". These are entitlements to remunerations of 22 cents/kWh for energy fed onto the grid which are guaranteed for the next 15 years. However, certain criteria have to be met to obtain them.

In the case of the Plankenbach power station, one of these was the revitalisation of the Wieser power station. This had existed for quite some time and it was incorporated in the new station by taking over the existing penstock pipeline which it had and lengthening this pipeline by 1.2 km. The old Wieser power station would be demolished and a new Plankenbach generator building would be built; the head would be increased to 450 m.

2 The implementation phase – special topographic conditions

Work on the Plankenbach power station began in mid-May and when it is completed in April 2010 it will supply the 1,400 inhabitants of the village of Latzfons, the largest village in the municipality of Klausen, with ecologically clean energy.

The generator building of the Wieser power station was demolished in May 2009; the water which used to arrive at it to power the turbine had to be fed in a special duct to the new turbine pipeline for the Plankenbach hydroelectric

Fig. 1:
Extremely difficult laying conditions at the Plankenbach power station with slopes of up to 80°

power station. Even during the invitation-to-tender phase it was clear that there would be long stretches of the laying of the turbine pipeline where both man and pipe would have to show a degree of acrobatic skill.

Due to the topographic conditions, the work on the new turbine pipeline of DN 300, PN 63, ductile iron pipes which needed to be installed was very difficult in places. In the final section at the bottom of the ductile iron pipeline (just upstream of the generator building), the pipe trench sloped at up to 80°, i.e. the pipeline was almost vertical **(Fig. 1)**.

Only specially trained layers who have had experience of laying pipes in high Alpine terrain can be used for work of this kind. In this area, there were places where explosives had to be used to drive the trench for the pipes through the rock **(Figs. 2 and 3)**. In extreme sections of the pipeline like these, there are technical and economic reasons why only a restrained ductile iron pipe system is the optimum thing to install. What the layers stressed above all as something they liked was the very simple way in which the VRS-T®/BLS® joint is connected. In terrain of this kind the fitting of the locking components of the BLS® push-in joint had to be very quick and easy to perform and very safe and secure.

Upstream of the connection to the generator building there is a 90° bend for the inlet to the turbine and this section needed to be made particularly secure. There is a sideways thrust of 750 kN acting at this point, and this is absorbed by a special concrete thrust block with a volume of 150 m³. The operating pressure in the 1.2 km long ductile iron turbine pipeline is 45 bars (the difference in height between the water intake structure and the generator building is about 450 m) and the diameter of the pipes is 300 mm. In terms of stress analysis an operating pressure of this kind is no problem for the ductile iron pipe system that was used; it is capable of withstanding even higher pressures.

Nor was the remaining section of the pipeline easy to install. In the central section of the route, where the gradient was 100 % – equivalent to a slope of 45° – the pipes had to be moved to their destination on a goods-carrying cable car whose cable had been specially installed for the purpose.

Fig. 2:
The pipe trench being dug on a steep slope

Fig. 3:
A ZMU pipe being used in high Alpine terrain

Fig. 4:
Work being done on the turbine pipeline

Fig. 4 shows that even in terrain like this it is still possible to work with heavy equipment (a 20 t track-laying excavator). A great deal of excavated material can be moved with an excavator of this size and this is reflected in the speed of working and the success of the economics.
Even under these adverse conditions, the installation of the pipes was completed in a record time of five weeks.

Fig. 5:
Use of a cement mortar coated pipe in extremely difficult laying conditions

3 Special conditions – the ideal place for using cast iron pipes with a cement mortar coating

When the conditions of use are especially demanding, as they are for example when turbine pipelines are being installed, use is very often made of ductile iron pipes with a cement mortar coating to EN 15542. They are notable for the particular high corrosion protection they have with, at the same time, the ability to carry very high mechanical loads. When the pipes are being laid in stony ground and when the grain sizes are up to 100 mm, the excavated material from the trench can be used directly for backfilling **(Figs. 4 and 5)**.

Other areas where ductile iron pipes with this coating can be used are in highly corrosive soils (the pipes have increased corrosion protection) and when trenchless installation techniques are being used (the pipes have extra mechanical protection). The ruggedness of the cement mortar coating is a result of the process by which it is produced: as the zinc-coated ductile iron pipe rotates, plastic-modified cement mortar based on blast furnace cement is applied to it in a helix of uniform thickness from a fishtail nozzle. At the same time, the 5 mm thick layer is bandaged with an additional net-like knitted material.

4 To sum up

An overview of the advantages of ductile iron pipes with a cement mortar coating and of what they are used for is shown in **Table 1**.

There were several reasons why the decision was made to use ductile cast iron as the material for the new turbine pipeline. While the properties of the materials remain constant, the useful life of ductile iron pipes with a cement mortar coating is more than 100 years. As a material, ductile cast iron is capable of carrying heavy loads and will allow both deep and shallow height of cover. It has wide safety margins to allow for undesigned loads.

Table 1:
An overview of the advantages of the cement mortar coating and its use with trenchless laying techniques

High resistance to chemicals	■ Under EN 545, EN 15542 and DIN 30675-2, ductile iron pipes with a cement mortar coating can be used in any soils
Mechanical protection	■ Pipes with a cement mortar coating can be laid in bedding materials with a maximum grain size of 100 mm. ■ Because of the high impact resistance of the cement mortar coating, ductile pipes are particularly well suited to the usual rough treatment they can expect on building sites. ■ When trenchless laying techniques are used, the cement mortar coating helps to prevent damage during pulling-in.
Economic advantages	■ No need for exchanges of soil or for additional bedding for the pipes, and the soil excavated can be re-used. ■ Major savings of time and money, because the soil excavated does not have to be taken away and dumped. ■ Long-term corrosion protection (lasting for up to 140 years to DVGW [German Technical Association for Gas and Water] requirements) is obtained for the pipes.
Use with trenchless laying techniques	■ Ement mortar coated pipes can be used with the push/pull, auxiliary pipe, burst lining, horizontal directional drilling (HDD), pipe ploughing and pipe relining techniques.

The thicknesses of the pipe wall, the coatings on the pipes and the linings in the pipes can be adjusted to suit an enormously wide variety of different areas of use. There is a complete, modular, ductile system, consisting of pipes, fittings and valves, which is available for all the areas of application – including for turbine pipelines.

A prerequisite for the installation of the new pipeline was that it had to be possible for use to be made of restrained BLS® push-in joints and of the cement mortar lining, with its safe nature from the point of view of water hygiene. Also needing to be exploited was the possibility of angular deflections at the socket joints. The possibility of moving a pipeline string out of straight at the sockets can be taken advantage of to save on fittings – an economic benefit.

In laying the turbine pipeline for the Plankenbach hydroelectric power station, the client ensured that environment-friendly pipes (sustainable, recyclable, and using inorganic materials) were installed and that the needs for both groundwater and the soil to be protected were respected.

Author

Ing. Andreas Moser
Duktus Tiroler Rohrsysteme GmbH
Innsbrucker Strasse 51
6060 Hall in Tirol, Austria
phone: +43 (0)52 23/5 03-4 53
E-mail: andreas.moser@duktus.com

Installing company

Falserbau des Josef Fasler & Co. KG
Karl Weissensteiner
Gewerbezone Bodner 2
39050 Karneid-Blumau, Italy
phone: +39 (0)4 71/3 53 46-0
E-mail: info@falserbau.it

Using ductile cast iron pipes to combat climate change

by Stephan Hobohm

1 Introduction

Garmisch-Partenkirchen is a market town and, at the same time, the administrative centre of the district of Garmisch-Partenkirchen in the centre of the Werdenfelser Land in south Germany. With more than 26,000 inhabitants, Garmisch-Partenkirchen is one of 13 so-called empowered district-affiliated municipalities in the Free State of Bavaria to which the State has transferred the functions of the lower building supervisory authority and the lower water authority. Garmisch-Partenkirchen is situated in the centre of a wide valley basin at the confluence of the river Loisach, which comes from the Tyrol, and the river Partnach, whose source is in the Wettersteingebirge mountain range **(Fig. 1)**. It lies between the Ammergebirge range in the north-west, the Estergebirge range in the east and the Wettersteingebirge range, which has Germany's highest mountain, the Zugspitze, in the south. These topographical features are not simply an attraction for the more than 300,000 guests seeking rest and relaxation that the town welcomes every year. They also provide excellent prerequisites for the generation of eco-friendly energy. Against the background of the promotion of renewable energy, it is an obvious step for the many mountain streams, with the large amounts of water they deliver and the large heads they provide, to be used to generate electricity and thus to make a contribution to a clean environment.

Fig. 1:
Ductile iron pipes with BLS® push-in joints in the Wettersteingebirge mountain range –
with the 2,628 m high Zugspitze in the background

Once, these mountain streams, such as the Esterberg springs **(Fig. 2)**, supplied the whole of Garmisch-Partenkirchen with drinking water, but only until they lost their importance with the expansion of the main Degernlahne waterworks, after which they only operated as an emergency supply **(Fig. 3)**. Although this is a function they still perform today, an additional use has now been found for them. For a short time now the water from the Esterberg springs has also served to generate electricity.

2 From mountain stream to energy source

In the year 2000, experts from the Department of Hydraulic and Water Resources Engineering of Technological University Munich (TUM) visited, amongst others, the municipality of Garmisch-Partenkirchen. The task they had been assigned by the Bavaria State Ministry for Economic Affairs, Infrastructure, Transport and Technology was to examine existing water pipelines for their suitability for electricity generation. It was found that the Esterberg springs, a source of drinking water which had existed for many decades, was suitable for this purpose. The two existing DN 100 drinking water pipelines could become part of two small electricity

Fig. 2:
An Esterberg spring

Fig. 4:
The turbine house

Fig. 3:
The old water supply pipeline – two DN 100 drinking water pipelines of grey cast iron

Fig. 5:
The turbine and generator

plants. Given as an alternative to this was also the laying of a new, larger, pressure pipeline for one large electricity generating plant. Initially, both these proposals disappeared into the files, until the boosting of self-sufficiency became a matter of greater importance and someone remembered the investigations which had already been done. After a detailed check on the two options, the decision was made to go for the large, single-stage option, which promised a many times greater energy yield.

3 The construction and laying phase

The construction of the plant began in August 2007. The project was divided essentially into three parts: the construction of the turbine house, the construction of the intake structures at the springs, and the laying of the turbine pipeline itself.

3.1 The turbine house

The limited amount of space available made it necessary for a very compact turbine house to be erected in the town (at Am Steinbruch and Münchner Strasse) **(Fig. 4)**.

It is situated right on the main access road to Garmisch-Partenkirchen and its architecture needed to fit in well visually with its small-town surroundings. Hence there will be very few tourists who ever become aware of which is going on behind the walls of this little building. The Geppert company of Hall in Tirol was given the job of fitting out the power station. For the machinery, the ideal solution was found to be a twin-jet Pelton turbine because the delivery of water from the springs fluctuates relatively sharply between a minimum of 44 L/s and a maximum of 154 L/s. With a head of 502 m, the largest in Bavaria, the pressure at rest is around

50 bars. The water thus shoots out of the nozzles at about 360 km/h, which makes severe demands on the material and all the rotating parts of the machinery. It was only logical that what was wanted for the plant to operate safely was not only a strong turbine but also a strong generator **(Fig. 5)**. At 1,500 rpm, the Geppert Pelton turbine drives a brushless revolving-field synchronous generator with integral exciter, supplied by the Hitzinger company. The generator has a weight of 3.15 t and its rated output is 830 kVA.

Being water-cooled, the Hitzinger generator generates very little noise even at the speed in this high range. There was also no need for ventilation openings for this reason. Noise was a concern for the municipality of Garmisch-Partenkirchen in that the turbine house is situated close to a residential area. As a further noise abatement measure, the entire basement of the building was lined with mats of Sylomer® damping material and the concrete foundation for the machinery was then laid on top of this. From the acoustic point of view, this totally decoupled the machinery from the building and prevented any transmission of sound to the building. There is also a compensator which keeps the vibrations away from the penstock pipeline. In addition, the building was given a highly sound-absorbent door. But there was one more source of noise that had to be allowed for. Having done its work, the driving water is taken away by a rainwater relief sewer, with the result that appreciable amounts of noise were generated by the manhole covers. Together with the Geppert company, the Garmisch Municipal Utilities Authority developed a highly practicable solution to this problem. Through a sort of dip pipe, the water is now discharged, via a duct, under water, which very largely prevents it from generating any noise.

3.2 Construction of the spring tapping structures

In the course of the laying of the new turbine pipeline that was planned, there were also two new spring tapping structures that had to be built for the three existing Esterberg springs. These were constructed about 100 m apart at altitudes of some 1,205 and 1,190 m above sea level. With the inlet to the turbine building at an altitude of 691 m above sea level, this gives a geodetic difference in height of around 500 m or a pressure in the rest state of 50 bars. The existing spring tapping structures dating from the first half of the last century were not designed for today's requirements. They were used to collect the drinking water needed for the town and merely fed two DN 100 drinking water pipelines. To operate the new turbine, a DN 400 pipeline was needed, and the appropriate changes had to be made to the existing installation.

3.3 Laying of the pipeline

Even when the operation was being planned, it was clear that it would set very demanding requirements both for the material of the pipeline and for the skills of the laying team. This was due above all to the terrain, parts of which were very steep and rocky, to the complicated route followed **(Fig. 6)**, and to the high pressures and pressure surges expected.

When selecting the material of the pipeline, the Garmisch-Partenkirchen Municipal Utilities Authority basically decided to go for ductile cast iron and hence for ductile iron pipes to EN 545 [1] with the BLS® restrained push-in joint **(Figs. 7 and 8)** to DVGW Arbeitsblatt GW 368 [2]. A thrust-resistant joint of this kind has the advantage not only that thrust blocks can be very largely dispensed with but also that there are great advantages in using it when installing pipes in steep terrain.

Approximately 3,600 m of DN 400 ductile iron pipes were ordered, with different external coatings and of different wall-thickness classes to suit the pressure in the given zone and the conditions of installation. A PUR Longlife coating, an active protective system comprising a 200 g/m² coat of zinc and a 120 µm top coating of polyurethane, was provided on pipes which were to be laid under traffic-carrying surfaces

Fig. 6:
Ductile iron pipes being laid on the ski slope at Kuhweide

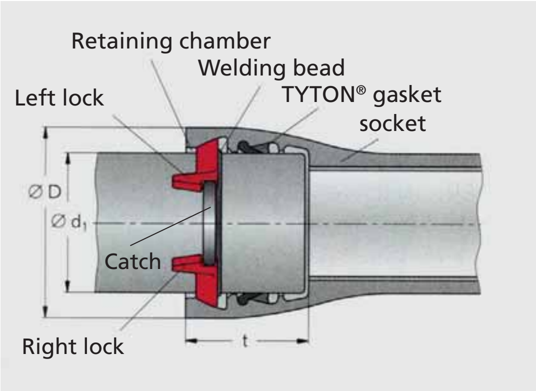
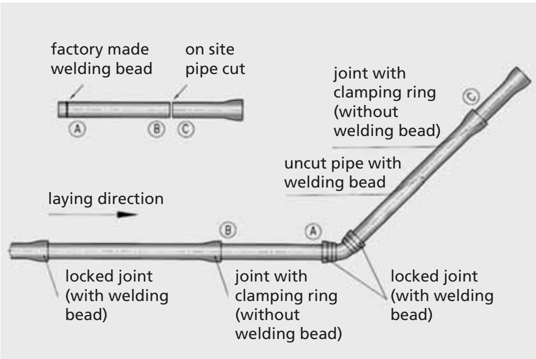


Fig. 7 (on the left):
The BLS® push-in joint

Fig. 8 (on the right):
Set of BLS® locks,
DN 300 to DN 500



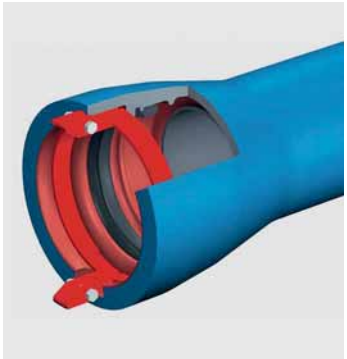


Fig. 9 (on the left):
Use of clamping rings
in the region of a bend

Fig. 10 (on the right):
The clamping ring in detail

(around 1,700 m). These pipes were laid with an infill of 0/16 mm grain size chippings. It was an advantage that the pipe manufacturer's works were situated close to the laying site. Because of the short haulage routes between Hall in Tirol and Garmisch-Partenkirchen – just on 70 km – not only could deliveries take place close to the laying time but it was also possible to save on quite a number of kilometres of lorry travel and hence on CO_2, which further emphasises the environment-friendly nature of this power station project. The remaining 1,900 m were covered by pipes with a cement mortar coating to EN 15 542 [3]. Under EN 545 [1], soils of any corrosiveness with grain sizes of up to 100 mm are suitable as bedding material for pipes with a cement mortar coating. In Alpine regions the transport and laying of gravel or fine chippings present considerable problems and they are thus the very place where there are compelling reasons for such a coating to be used.

There was a further sub-division in respect of the wall-thickness classes of the pipes. In this way, some 1,500 m were laid in wall-thickness class K 11 and some 2,100 m in class K 9. With the K 9 wall-thickness class, the BLS® push-in joint permits an allowable operating pressure (PFA) of 30 bars and with the K 11 class it allows one of 35 bars. Consequently, of the total of 500 metres in height, the top 350 metres were laid entirely with restrained joints and with no concrete thrust blocks. As well as this, the clever BLS® system meant that there was virtually no need for welding beads to be applied to cut ductile pipes by the layers, to allow socket bends to be fitted for example. This was possible by the use of what are called clamping rings **(Fig. 9)** from the BLS® range. There are only a few exceptional cases where the clamping ring **(Fig. 10)**, which is available in nominal sizes of DN 80 to DN 500, cannot be used in place of welded beads applied on site. A measure which goes even farther is the use of BLS® plain ended pipes and these were used to almost completely avoid any welding on the site from then on.

Although the bottom 150 metres in height (operating pressure of 35 to 50 bars) were likewise laid with restrained joints, they had to be given the additional safeguard of concrete thrust blocks at points where this was essential, such as at branches **(Fig. 11)** and bends. The reason for this was the need for the pipeline to be secured in position in the steep and impassable terrain.
As was only to be expected in the Alps, rock was encountered along large parts of the route planned for the pipeline. Hence, no less than 1,600 m^3 of rock had to be dug out or cut out in the course of the laying work.

Fig. 11:
Branch to a high level service reservoir

So that the pipeline can drain itself completely if any inspections are needed, a steady gradient of at least 1 % was set in the direction of the turbine house. The laying work was made more difficult by the fact that it was not always possible to follow the existing road **(Figs. 12 and 13)**, which runs from the springs almost directly to the outlet of the pipeline. In the way of the path to be followed by the pipeline were, amongst others, a ski slope, an unusually steep slope and some forested terrain which sloped down very steeply at an angle to the direction of laying.

In the latter area, the thinking initially inclined towards laying and transportation by helicopter but this was rejected by the company (Messrs. Hohenrainer of Ohlstadt) entrusted with the laying work. The company's laying skills and the use of its laying crew enabled even this section to be dealt with by the conventional open-trench technique **(Fig. 14)**. This job was certainly only one for laying companies that had had some experience in the field of work in the high Alps. The unusually steep slope, which followed on directly from the ski run below the little chapel called the Daxkapelle which had already been crossed, also called for all the skills and indeed the courage of the layers. With a maximum gradient of no less than 80 % (just on 38°) at the steepest point, it was essential for special-purpose equipment to be used and for plans to be made for additional securing provisions in the form of rock anchors and concrete thrust blocks. Concrete thrust blocks **(Fig. 15)** had to be positioned at the top and bottom ends of the slope while on the slope itself every second socket was fixed in place with a rock anchor and a concrete cross-bar and the infill in the trench was stabilised at the same time.

Due to seasonal constraints, the laying work was divided into a number of phases. The starting signal was given in August 2007 at a point above the unusually steep slope which has already been described. The ski slope, which had to be usable again by skiers in the winter, was crossed first. Having got past the Daxkapelle, the route of the road was followed towards the Esterberg springs, as far as the preset specifications and the weather permitted. With the onset of winter, which arrives very early in these regions, no further work could be done "way out on the mountain", and the site had to be left to rest temporarily in this area until the next spring. Hence it was only in the valley, between the edge of the town and the foot of the steep slope, that work could continue for a while until winter set in here as well. Because of the very severe and unusually long winter of 2007/2008, the laying company could not resume work until April 2008. At this time the pipeline was extended in the upper area to the spring intake struc-

Fig. 12:
Line followed by the route in the very steep area

Fig. 13:
The route followed by the pipes across the slope

Fig. 14:
A walking excavator in use

Fig. 15:
A concrete thrust block to fix the top end of the pipeline in place on the steep slope

tures which were being built, partly along the road and partly across a steep forested slope **(Fig. 16)**. At the same time the pipeline began to be laid down the steep slope and within the town.

Because of the division as described into three phases, two connections had to be made between the individual sections of the pipeline. In view of the high pressures expected of 35 bars and 50 bars respectively, this could not be done with the usual fittings (e. g. collars or flanged sockets). The decision was therefore made to join the ends of the pipeline without using fittings. For this purpose, the trench was left open on the left and right of the planned points of connection at certain lengths of pipe. One length of pipe was cut to a suitable length in each case and provided with a welding bead. The two ends of the sections to be connected were then swung out of line, the prepared piece of pipe was inserted and the pipe string was then swung back into line and the gap was closed at the same time **(Fig. 17)**. All the sections laid were connected together in this way without any problems and without any fittings being used. The two welding beads which were applied for the connections **(Fig. 18)** were then the only ones which had to be welded retrospectively by the layers throughout the whole of the project.

Fig. 16:
DN 400 ductile iron pipes –
on the cleared route across the slope

Fig. 17:
Pipe ends being swung together

Fig. 18:
A shortened ductile iron pipe with
a welded bead applied by the layers

3.4 The pressure test

The laying of the complete 3,600 m long pipeline was followed by an internal pressure test. In view of the pressure surge which had previously been calculated, the test pressure was set at 61 bars. At a pressure of 61 bars, a thrust of around 900 kN was exerted on the end closure, a PN 63 blank flange. For the bottom end of the pipeline, i. e. the part which enters the turbine house, a special steel fitting was used. This fitting was produced in the form of a DN 400, PN 63, flanged spigot about 2 m long, with three puddle flanges and a BLS® welding bead. A blank flange with a 2″ internally threaded bore was fitted to this flanged spigot and for subsequent drainage it was provided with a remotely controllable valve and a high-pressure pipe. The pressure was applied at the top end. After a successful test following the standard procedure laid down in EN 805 [4], the pipeline was accepted as free of leaks.
This was followed by recultivation work and the completion of the intake structures at the springs.

4 Experience in operation

Since January 2009, a period of trial operation has been going on and there have been no faults.

With the given head of 502 m and a water flowrate on completion of 154 L/s, the output on completion is 636 kW. The electricity generated is fed onto the grid that Garmisch-Partenkirchen's Municipal Utilities Authority itself operates. The intention is for around 3.1 GWh of electricity, obtained in an eco-friendly way from the power of the Esterberg springs, to be produced every year. The plant at the foot of the Wank mountain is thus showing itself to be highly economical.

Finally, the municipality, with its new power station able to generate electricity for around 700 four-person households, can reap the benefit of the new feed-in tariff of 12.67 cents/kWh which came into force on 1 January 2009. With this stipulated tariff the plant is going to pay back the entire sum of 1.73 million Euros that was invested in it in less than ten years. Also, the new power station will be saving the atmosphere from about 2,960 t of carbon dioxide a year. It will still perform its function as an emergency water supply. There is a branch pipe fitted into the pressure pipeline, thus enabling a switch to be made back from the supply of electricity to the supply of drinking water at any time.

For this ski-sports center in the Werdenfelser Land, the power station is one more way of boosting its energy self-sufficiency. The intention is that in ten years the municipality, which has 26,000 inhabitants, will itself be producing around 40 % of the energy it uses.

5 To sum up

Although the laying of a DN 400 pressure pipeline with a test pressure of 61 bars in difficult terrain was a challenge for everyone involved, the "Esterberg" power station project in Garmisch-Partenkirchen was completed without any unscheduled delays.

Quite a substantial contribution to this was made by the BLS® push-in joint, which is easy to connect but, at the same time, capable of carrying high loads. Together with the rugged cement mortar coating, it enabled the work to be done swiftly and at lost cost. A very large share in the success of the operation was of course also taken by the Garmish-Partenkirchen Municipality Utilities Authority, which laid the foundation with its independent and sophisticated planning and at the same time saw to the supervision of construction and laying. The good co-operation with Hohenrainer, the laying company, and the technical assistance with the operation provided on site by the pipe manufacturer helped as well.

That the Garmish-Partenkirchen Municipality Utilities Authority was very happy with the BLS® system, which it was using for the first time on this operation, is shown by the follow-up order which was placed almost immediately for a transporting pipeline from the Authority to Grainau.

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Author

Dipl.-Ing. (FH) Stephan Hobohm
Duktus Rohrsysteme Wetzlar GmbH
Sophienstrasse 52–54
35576 Wetzlar, Germany
phone: +49 (0)64 41 / 49-12 48
E-mail: stephan.hobohm@duktus.com

Client and planner

Gemeindewerke Garmisch-Partenkirchen
Josef Grasegger
Peter Klier
Adlerstrasse 25
82468 Garmisch-Partenkirchen, Germany
phone: +49 (0)88 21 / 7 53-0
Telefax: +49 (0)88 21 / 7 53-2 28
E-mail: info@gw-gap.de

Laying company

Franz Hohenrainer GmbH
Kanal - Erdbau - Transporte - Abbruch
Florian Weber
Heubergstrasse 20
82441 Ohlstadt, Germany
phone: +49 (0)88 41 / 67 30-0
E-mail: info@hohenrainer.com

The driven cast iron pile system – operation, use and advantages as illustrated by the Lebrija solar energy park in Spain

by Thomas Aumueller

1 Introduction

Applications of high-grade ductile cast iron pipe systems in water supply and wastewater and sewage disposal have long been known and such systems have proved themselves all over the world. Applications involving particularly high stresses and pressures such as fire-extinguishing pipelines, snow-making systems and turbine pipelines are likewise nothing new. What is less well known is that the driven ductile iron pile has been winning more and more of a place for itself in the field of special-purpose foundation engineering.

What is a driven pile and what function does it perform?

A driven pile is sunk into the ground by driving and transmits forces from structures situated above it into the ground (a process known as load transmission).
In actual fact, this procedure is a very old one; one has only to think of the lake dwellings of the Neolithic period and the Bronze Age of 4000 years ago, where wooden piles were driven into the shores or beds of lakes for the construction of dwellings.

With other materials (concrete or steel), different methods (driven piles, cast-in-situ concrete piles, bored piles) are used to transmit forces into the ground. These methods are not very flexible and also have the disadvantages that heavy and expensive equipment has to be used and the output per day is not very high. The construction industry was therefore looking for a simple and safe pile system capable of a wide range of uses. The driven cast iron pile has been meeting this demand for some 25 years now to excellent effect.

2 The driven cast iron pile system

The cast iron pile system is shown in **Fig. 1**. Spheroidal graphite (ductile) cast iron is a material which will carry tremendous mechanical loads – loads such as occur in a dynamic form in the driving process. The pipes are produced as centrifugally cast pipes of two sizes (diameters of 118 mm and 170 mm) and different wall thicknesses – to suit the load transmission required. The load which can be transmitted, and hence the static load, is between 50 and 140 t [1]. A pile pipe is 5 m long and at the top it has a socket with a conical inside surface and at the bottom

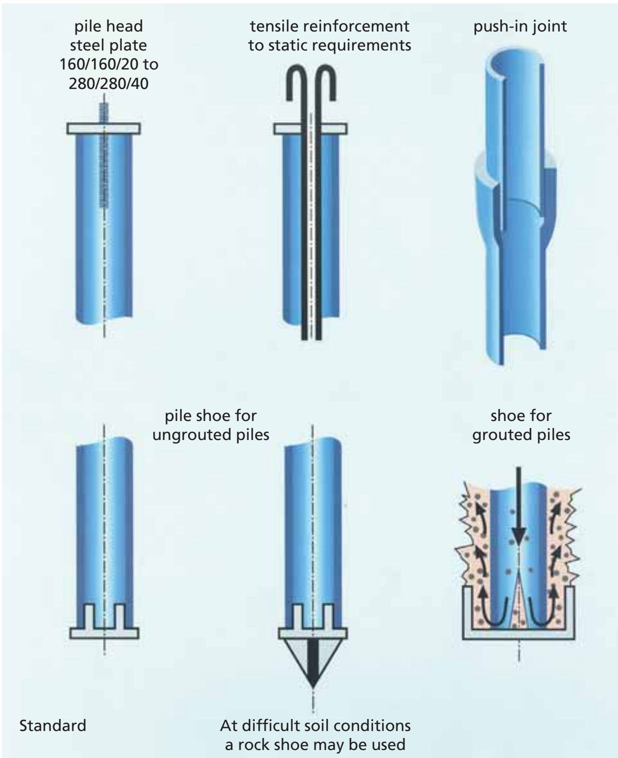

Fig. 1:
Components of the ductile pile system

a conical spigot end. Piles of any desired overall length can be obtained by plugging the individual lengths of pipe together.

No heavy driving equipment is needed for driving the piles; all that is needed is a light and widely used excavator. Instead of a bucket it is fitted with a hydraulic hammer with an adapter for the socket of the pile. Almost every construction company has equipment of this kind in use. The first pipe in the pile is fitted with a pile shoe which prevents earth from being forced into the pipe. The next pipe in the pile is inserted in the socket of the first pipe which has already been driven and is driven itself.

This process continues either until the pile is of the requisite length or the pile becomes set in firm ground. The very high impact energy in the driving process produces a rigid frictional connection as a result of friction welding. When the pile as a whole has reached the final depth, the section projecting above ground is cut off with an angle grinder **(Fig. 2)**. The piece that is cut off is at once re-used as the first section of pile in the next driving operation – hence there are no off-cuts and no waste.

Fig. 2:
Cutting off the projecting section of the pile

Driven cast iron piles can be sunk as ungrouted end-bearing piles or as pressure-grouted piles which transmit their load by skin friction. That sounds complicated but is in fact pretty simple.

In the case of a pressure-grouted pile, liquid concrete (grout) is forced into the interior of the pile at high pressure during the driving process. The concrete escapes though an opening at the bottom, climbs upwards, and wraps itself round the outside of the pile as the pile is being rammed. It thus forms an outer sheath of grout several centimetres thick. The concrete distributed around the outside of the pile thus enlarges the surface area of the pile, and in this way increases the friction with the soil **(Fig. 3)**. An ordinary concrete pump is used for this grouting process. This too is part of the inventory of virtually any construction company and can be found on almost any construction site. **Figs. 4 and 5** show the sinking of a pressure-grouted pile.

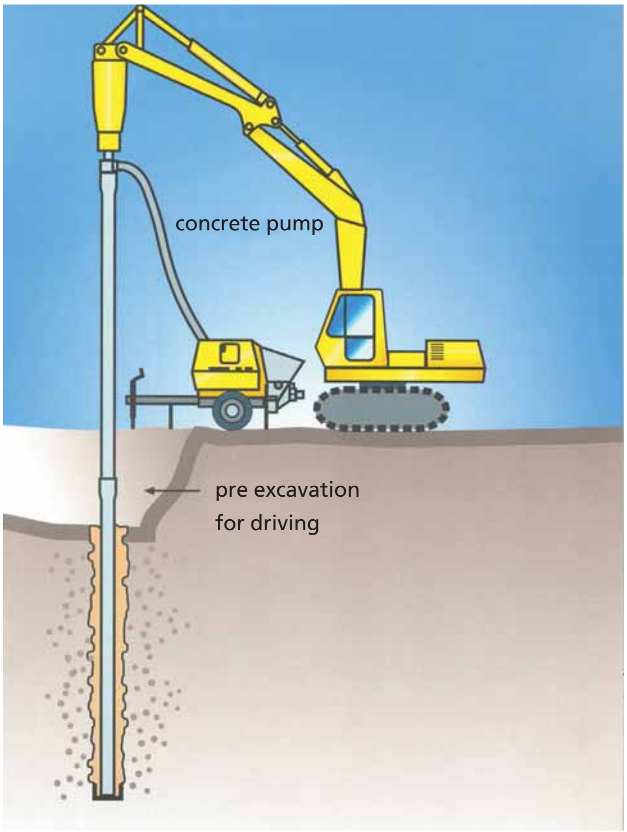

Fig. 3:
Driving of a pressure-grouted ductile pile

Ungrouted end-bearing piles are filled with concrete after they have been driven. A pressure-distributing plate is mounted on top of the fully driven pile and this gets it ready to transmit loads **(Fig. 6)**.

Fig. 4:
Driving of a pressure-grouted ductile pile in practice, the example shown being a foundation for a wind power plant

Fig. 5:
A driven ductile pile pressure-grouted with concrete and its top pressure distributing plate

Fig. 6:
The pressure distributing plate being fitted

3 Advantages of the driven ductile pile

1. The driven ductile pile manages with the simplest of site equipment, namely light and manoeuvrable excavators such as exist in virtually any construction company and on almost any construction site. For the companies doing the work this means low capital costs for the tools and equipment and simple and inexpensive handling on site.
2. With the system, a pile can be driven safely and securely, i. e. safe and secure foundations can be sunk for structures with it. As the driving proceeds a record is kept of the penetration into the soil per unit of time and in this way each pile is documented in a driving record.
3. Because of the simplicity of the system and the fact that simple excavators and equipment are used, piles can be sunk into the ground at output rates of up to more than 400 running metres a day. Because the pipes are small, a single 24 t articulated lorry can deliver up to 900 running metres of piles at a time to the site.
4. The use of quite small excavators and pile-driving hammers make it possible for piles to be sunk with almost no vibration. Hence driving can take place close to existing buildings. Distances of less than a metre from existing buildings and other structure are no problem in this case.
5. When working with these driven piles there are no off-cuts and the sections of pipe which are cut off can be used as the first pipe for the next driving operation.
6. No post-driving work has to be done on the heads of the piles and the installing work can continue without no delays.

4 Areas of use for the driven cast iron pile

Driven cast iron piles are used in the following areas **(Fig. 7)**:

- foundations for:
  - houses and blocks of flats,
  - industrial buildings and sheds,
  - water and sewer pipelines in unstable soils [2, 3]
  - bridges (even motorway bridges have already been given cast iron pile foundations),
- slope stabilisation,
- building of roads and footways.

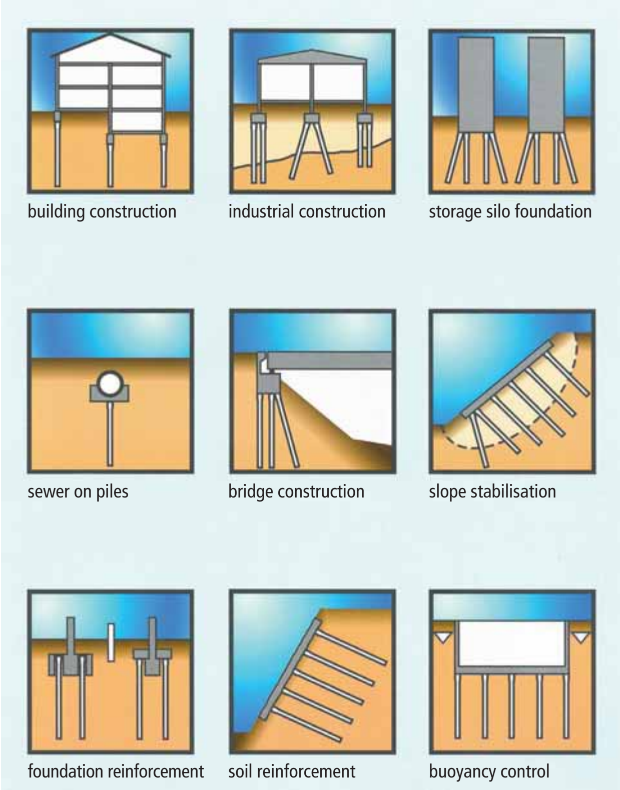

Fig. 7:
Areas of application for the driven ductile pile

5 Alternative applications, present-day developments

In these days of soaring energy prices, there is evidence of yet another interesting possible use for the driven cast iron pile and one that has nothing to do with load transmission, namely as an energy pile.

More and more consumers are putting their money on obtaining geothermal energy with heat pumps and thus on not being dependent on oil and gas. For geothermal energy to be obtained, a medium has to withdraw heat from the ground. For this purpose the medium has to penetrate into the ground over as large an area as possible and has to be brought back to the surface.

Given the high thermal conductivity of cast iron, this is a function for which the driven cast iron pile was almost predestined. These are early days for the driven cast iron pile in this application, but its future is promising because the only way of achieving the CO_2 reduction targets which are being aimed for will, in the future, be by the increasing use of renewable energy sources in the field of building heating.

6 Lebrija solar energy park in Spain – piles ensure reliable solar energy

Near the Andalusian town of Lebrija on the fruitful plain of the Guadalquivir, one of Spain's biggest solar energy parks, which will occupy an area of 20,000 m² and will produce an output of 6,500 MWh, is being built **(Figs. 8 to 10)**.

What was selected as the system used for implementation was the „Mover" system developed by Solon Hilber Technologie GmbH.

These are prefabricated modular units for generating solar electricity which track the sun as it moves. Because of this tracking movement by the modules, it is possible to obtain up to 40 % more electricity than is the case with modules which are held fixed. The Mover stands on a small pedestal and the ground below it can thus continue to be used for other purposes, e. g. for raising cattle. Also, because the large modular panels move, there is no fear either of the soil being eroded below the edges from which rain drips off or of its drying out below the Movers.
The structural design and the control system of the Movers are such that the panels will pivot to a position in which their aerodynamics are good if the wind speed rises to more than about 80 km/h and they will survive winds speeds of up to 150 km/h without any damage.

To stop any irregular settlement of the modules panels and hence any adverse effects on the pivoting mechanism, the pedestals were designed to be carried on pressure-grouted ductile iron piles as their foundations. Skin friction distributed over the optimised length of the piles allows the loads which occur to be transmitted without any problems into the soft soil present. The use of these piles was the least expensive way of obtaining a foundation. By the use of lightweight equipment, any adverse effects on the environment when sinking the piles have also been minimised because of the small areas for access and for doing the work which have needed to be surfaced. Hence, to allow an environment-friendly energy generating system to be produced, what has also been done is to install the deep foundation which is kindest to the environment.

7 To sum up

The construction industry is increasing coming to appreciate the value of the simple, fast and economical use of the driven cast iron pile and there has been a continuous rise in the share of the market held by it over the past few years. What can also be seen is an ongoing rise in the requirements which the driven cast iron pile is being asked to meet plus alternative areas of use such as that as an energy pile which has been described here.

Fig. 8:
Construction of the solar energy park in Lebrija

Fig 9:
The last pile being driven at the Lebrija solar energy park

Fig. 10:
A solar module being installed – this gives some idea of the size of an individual module, and hence of that of the solar energy park itself

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Author

Ing. Thomas Aumuller
Duktus Tiroler Rohrsystemen GmbH
Austrian branch
Innsbrucker Strasse 51
6060 Hall in Tirol, Austria
phone: +43 (0)52 23/5 03-4 43
E-mail: thomas.aumueller@duktus.com

Client

SOLON HILBER Technologie GmbH
Erlach 165
6150 Steinach am Brenner, Austria
phone: +43 (0)52 72/5 05-0
E-mail: solon.at@solon.com

Driving work

Grund-, Pfahl- und Sonderbau
Industriestrasse 27a
2325 Himberg bei Wien, Austria
phone: +43 (0)22 35/8 77 77-0
E-mail: office@gps-bau.com

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Fachgemeinschaft Guss-Rohrsysteme (FGR) e. V.
European Association for
Ductile Iron Pipe Systems · EADIPS

Im Leuschnerpark 4
64347 Griesheim
Germany
phone: +49 (0)61 55/6 05-2 25
telefax: +49 (0)61 55/6 05-2 26
E-mail: r.moisa@eadips.org
www.eadips.org

Editor:
Dipl.-Ing. Raimund Moisa

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