BAUER

Services for Dams and Dikes

Content

Center Hill Dam (USA), Rehabilitation
The Center Hill Dam is located at Caney Fork River approx. 96 km east of Nashville, Tennessee.

The project consisted of two major scopes of work:

- approximately 9,900 m² of encasement wall with nominal thickness of 2.25 m through the embankment, extending from the crest of the dam down to a minimum of 0.6 m into the foundation bedrock
- aprroximately 20,500 m² of barrier wall with an average thickness of 0.83 m. The barrier wall was constructed through the center of the encasement wall extending down into the foundation bedrock for total depth of up to 95 m

It is particularly noteworthy that the cut-off wall was successfully connected to the existing concrete dam and, for this purpose, the contractually required encasement wall was continued by grabbed monolith elements in the area along the concrete dam.

Applications - Dams and Dikes/Levees

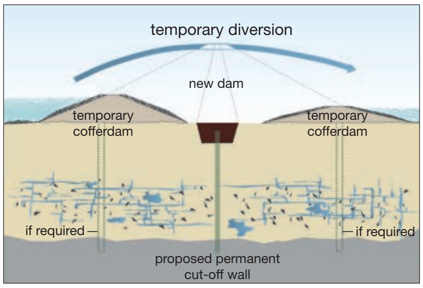
For more than 30 years, BAUER Spezialtiefbau GmbH, together with its subsidiaries, has been successful in the field of design and execution of special civil engineering services, including cut-off walls for dams, dikes and levees.

Aramon (France)
Rehabilitation
The project site is a dike along the Rhone river, close to the town of Aramon in the Provence. The works consisted of 12,500 m² Mixed-in-Place cut-off wall, with a thickness of 55 cm, up to 23 m deep. To reach the specified challenging depth and for the embedment into the weathered limestone, a modified drilling rig BAUER BG 40 was utilized for the works.

Dams

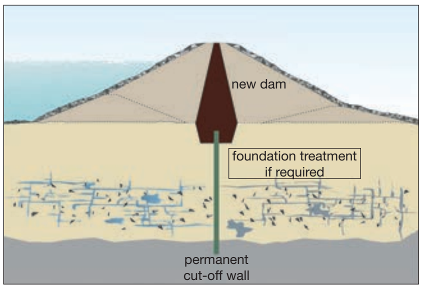
Greenfield Projects

Bauer cut-off walls provide new opportunities for investors and designers involved in Water Resource Development projects. When planning a new Water Resource Development project, one of the major obstacles is finding a location with suitable geological and hydrological formations for the project, including fulfilling the environmental and social expectations. Bauer cut-off walls can be installed in any type of ground condition to provide a reliable, durable and impermeable (approximately 1x10-8 m/sec.) system which ensures efficiency, durability, stability and safety for your project. Thus, the Bauer cut-off wall makes selection of the project site that bit easier. Bauer cut-off walls convert the existing ground conditions to meet your design requirements, at a location of your choice. The ability to install safe walls in remote areas enables you to meet the environmental and social requirements of dams, in line with public interests.

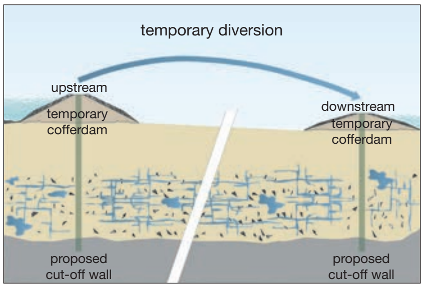


Cofferdams for New Embankment Dam founded on alluvium

Design and construction stage 1

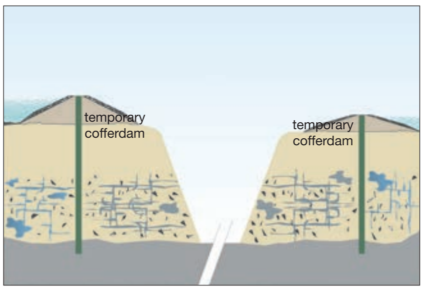


Cut-off wall in operation stage 2



Cofferdams for excavation pits for New Concrete Dam founded on rock

Design and construction stage 1

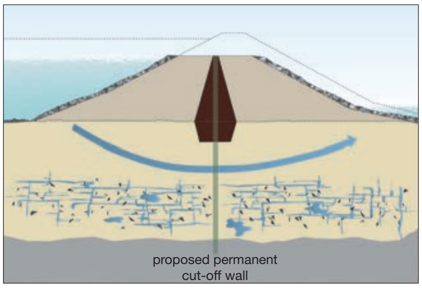


Excavation in operation stage 2

Existing Dams

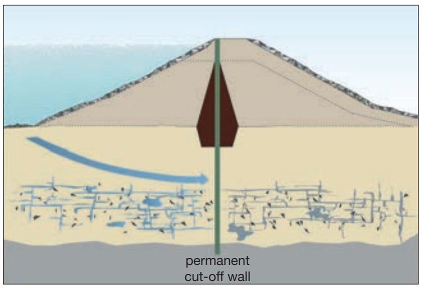
Upgrade, Rehabilitation and Repair Projects

As part of dam safety programs, dam owners, municipal and state authorities and private parties conduct regular reviews of all their dams. Although the condition of a dam has not changed since it was built, reviews of the purpose or the design identify a need for upgrades to increase capacity or to enhance life span and dam safety, which may be compromised due to hydraulic conditions or during major earthquakes. Other existing barrier systems, for example those constructed with conventional grouting methods, over time and in the particular geology like Karst or alluvial/colluvial sediments, often fail to meet the degree of efficiency and durability, as well as other performance specifications impairing the life span of the structure, as required by the design and intended purpose.

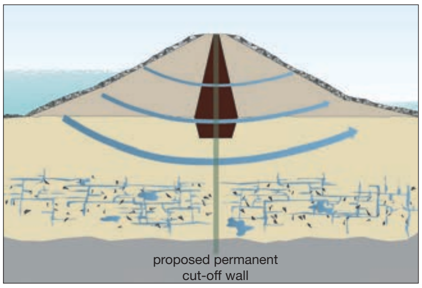


Upgrade of Existing Dam (heightening)

Upgrade design and construction stage 1

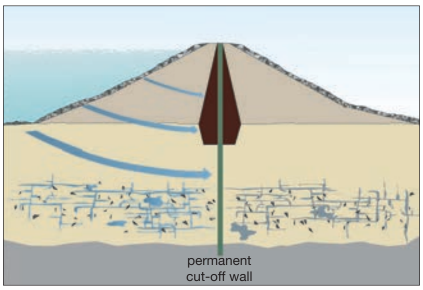


Upgrade in operation "increased dam safety and storage capacity" stage 2



Mitigate Seepages by durable Concrete Barriers

Rehabilitation design and construction stage 1



Rehabilitation in operation "increased dam safety and storage capacity" stage 2

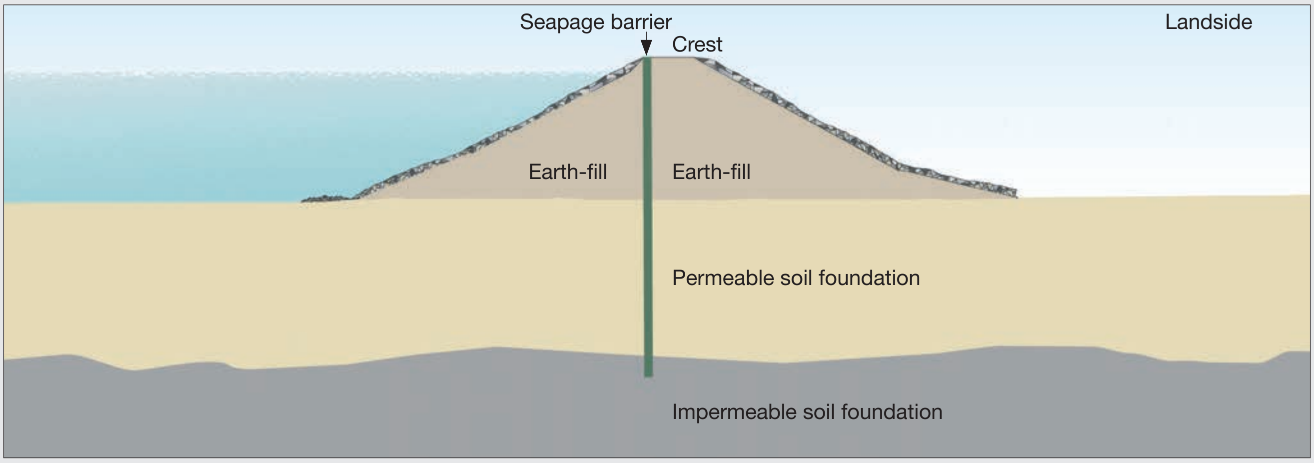
Dikes / Levees

Current situation
Dike and levee systems are an important component of flood management. Many of our towns and villages would not be habitable without them, and adjacent industrial areas rely on the protection provided by the surrounding artificial dike and levee systems.

Maintaining and strengthening these structures in preparation for flooding is an important task for the responsible flood control authorities. Existing structures must be maintained, improved or rehabilitated, and new ones must be built.

Risk events
Global warming leads - among other things - to:

- Heavy rainfall-induced flood events, which more frequently last for days, from mountainous headwaters to lower reaches of rivers
- Sea level rise and associated risks of extreme flooding for island nations (especially in the Pacific), coastal regions, and lower lying cities



Seepage, piping, partial liquefaction, surface erosion due to flooding or wave action, usually cause significant damage to the protection system. With the appropriate product, such as a cut-off wall, this can be prevented or significantly mitigated.

Our mission
Bauer has all relevant and proven technologies for the effective installation of cut-off walls.

The application of cut-off walls for seepage path extension (using construction methods such as Mixed-in-Place, Cutter-Soil Mixing, grab/cutter or even with grouting), are often considered as a solution against the risk of the above-mentioned causes of damage. The walls or individual elements can be reinforced if necessary and can thus be used to improve the stability of the dike.

The construction method to be selected and the wall geometry will depend on the available building area on the dike, the ground conditions, especially the properties of the permeable layer, and the depth and properties of the underlying impermeable layer. The thickness of the wall and the materials used for the seepage barrier can be adapted to meet the specific project requirements.

Whatever the boundary conditions of a project, we have a suitable technology that can be used.

Using in-situ soil mixing technologies for seepage barriers in dams, dikes and levee systems not only provides the low permeability required but is also a more sustainable, reliable, quality proven (and adaptable to most of the geological conditions) solution, than the more traditional excavate and replace technologies.

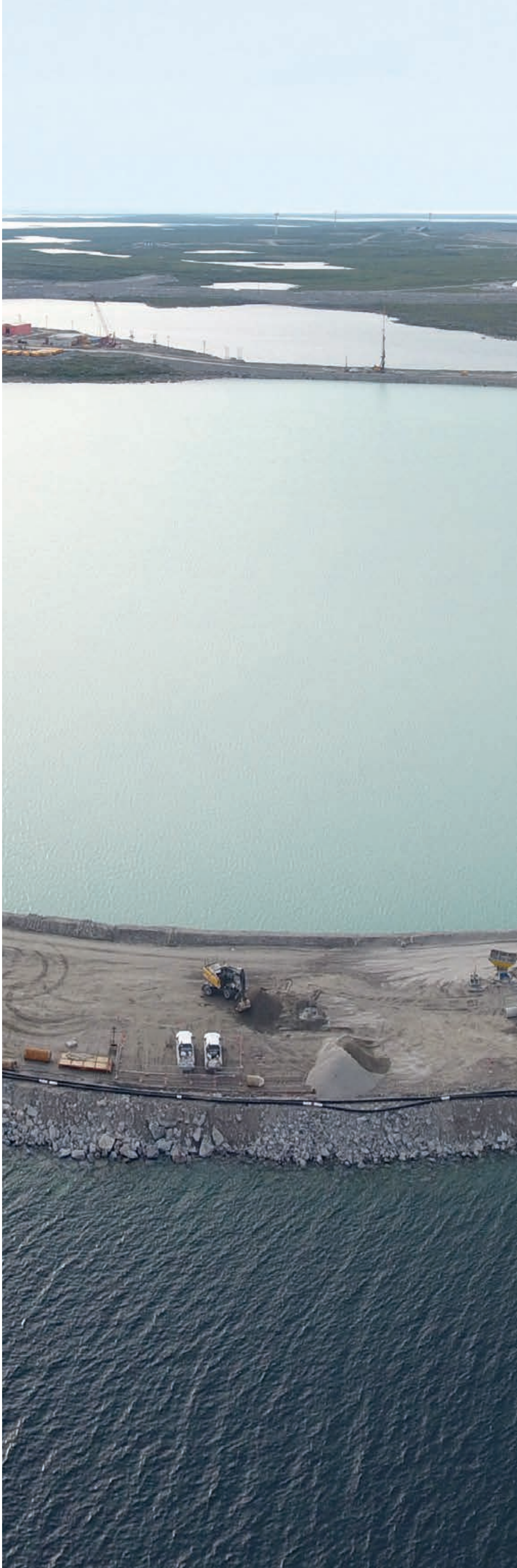
Gianfranco DiCicco,
President & CEO,
BAUER Foundation Corp.

Applications - Mining and Tailing Storage Facilities

The special civil engineering services are used for rehabilitations, upgrades of existing and new hydro structures, as well as for cofferdams and tailing dams in mines. Our track records and expertise speaks to our involvement already during the planning phase.

Diavik Mine A 21 Mine (Canada), Mining support
The Mine is located approximately 220 km south of the Arctic Circle and 300 km northeast of Yellowknife, capital of Canada's Northwest Territories. The objective of this project is the construction of a dike to enable open-pit mining, at the remote subarctic Diavik Diamond Mine in the Northwest Territories (NWT) of Canada. The location presented special challenges, enabling works only between May and October. Logistics were another major challenge, as large transports are only possible during an eight-week window during the winter, when the ice road to the mine is open. As a result, the project had to be completed in two stages in 2016 and 2017. In order to meet the specified construction schedule, some of the construction works had to be executed through the harsh winter months of Northern Canada. Temperatures during wall installation were as low as -30°C.

- Vibro densification (max. depth 23 m), total: 29,781 m
- Curtain grouting (max. depth 59 m), total drilling: 28,637 m, total grouting 13,791 m
- Pre-drilling CSM (max. depth 26 m), total: 23,636 m
- Cutter Soil Mixing (CSM) (max. depth 26 m), total: 19,226 m^2
- Jet grouting (max. depth 41 m), total: 8,546 m



Mining Support

With decades of experience in specialist foundation engineering, Bauer offers the mining industry worldwide to support them in project execution and in contributing to planning and design, to provide safe solutions for mining tasks.

Experienced in the rehabilitation and reinforcement of dams and dikes using a variety of techniques and methods, or the installation of seepage barriers and foundation improvement, Bauer is the partner for such tasks.

In addition, the BAUER Group has extensive experience with all types of equipment adaptations to perform these techniques in all variations, and a proven history in groundwater management and treatment, if required. Our experience in deep-water drilling operations enables us to operate almost all of our devices remotely, which can be of crucial importance on critical tailings piles and their dams.

Bauer is able to offer project and customer specific solutions for the mining industry - read more in our brochure Mining Solutions.

Tanami (Australia)
In the Tanami Desert (NT) a raisebore ventilation shaft from the gold seam, approximately 800 m below the surface, will be constructed. This will be a 5.7 m dia 800 m deep vertical ventilation shaft. The vent shaft ensures clean/fresh air can be supplied to the underground mine workers. Bauer was engaged to complete a ringed secant piled wall, using bored piles down to 52 m, to restrain the weathered rock conditions as the raise bore came up to the surface.

Raise bore shaft collars west Africa - using the secant wall circular shaft for the raise bore drilling collars has proved to be a most reliable method to get to the top of the bed rock for raise bore drilling. Raise bore drilling is a growing market in the gold mining industry, as the mines are now going underground and new shafts are required for ventilation of these underground mines. Bauer´s experience in drilling is making a difference in the mining industry by offering optimum solutions.

Emmanuel Dengu,
Senior Project Manager, Africa Division

Tailing Storage Facilities

With the demand for increased safety for existing tailings dams and the call to de-characterize inactive tailings storage facilities, methods to safely stabilize such dams - permanently or temporarily - are required.

Protection against liquefaction of the coarse and fine soils underlying sections of tailings storage facilities is particularly important for dams constructed using the upstream process. Vibration can cause de-stabilization of such dams, posing a hazard to people working in or living near such facilities.

The Mixed-in-Place method uses rotary drilling or milling methods, which already do not introduce significant vibration into the subsurface through the drilling and mixing process. The existing material is mixed with cement and additives to form a stable element. The objective of soil improvement is to improve the compressive and tensile strength, as well as the modulus of elasticity of the soils in and under the tailings facilities and the related dams. Construction work on dikes, dams and in mines has demonstrated the reliability of suitable project-specific Mixed-in-Place methods for the safe low-vibration stabilization of soils with a high liquefaction risk.

To prevent spontaneous failure due to liquefaction in existing upstream tailings dams, one of the three critical conditions (loose soils / presence of water / stimulation by vibration or load change) must be eliminated in a defined manner. Soil improvement measures in the subsurface, such as immobilization by a deep mixing method (DSM) and drainage, can significantly reduce the risk of failure. In addition, installation of a rigid grid of interconnected DSM elements can help stop the flow of liquefied material toward a critical tailings dam.

It is recommended to install a monitoring system that can be used before, during and after the subsurface improvement methods. This would be particularly useful for sensitive structures, to establish the necessary controls required ensuring their safety and integrity. Bauer has the know-how and technologies for such instrumentation and monitoring installation.

Tailings dams are often critical elements of a mine's processing facilities and hence their on-going safety and stability is essential. Whether such stability is potentially compromised by seepage or loose foundation soils, Bauer has the know-how and a vast number of ground improvement technologies to recommend and execute the most appropriate solution.

John Theos,
Regional Director Americas, BAUER Spezialtiefbau GmbH

Competencies

Bauer has great expertise in the design and execution of sealing and soil improvement solutions (for both new and rehabilitation projects for dams, dikes, levees, polders, mines and tailings facilities). Our core competencies include various technologies or a combination of techniques using different technologies. Project-specific requirements for special equipment are covered by solutions from the BAUER Group. The experience gained over many years with regard to the construction materials used and the integrative design solutions required for specific projects, ideally complements our overall competence in contributing to durable solutions.

Hinze Dam (Australia)
Rehabilitation and upgrade
The Hinze Dam is located on Nerang River in the southeastern part of Queensland. Bauer executed a cut-off wall of 227 m length, a depth of more than 50 m and a nominal thickness of 0.8 m. Cutting of rock with UCS up to 200 MPa was daily requirement to accomplish the task.

Construction Methods

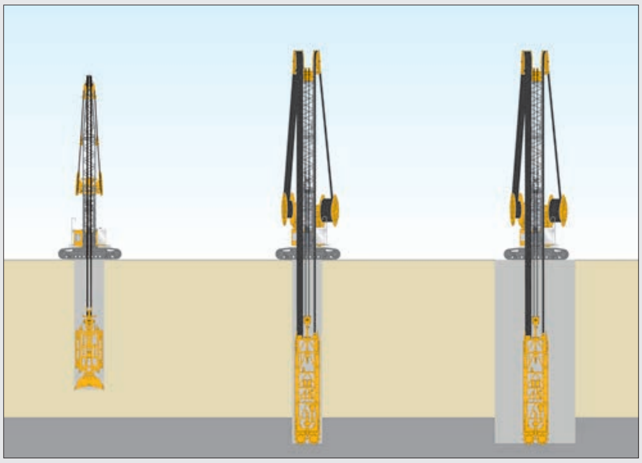
Diaphragm wall

The classical type of positive cut-off wall for deep barriers in all types of geology is excavated by grab and/or cutter to reach depths of more than 200 m and is typically embedded in bedrock as designed. The walls are constructed using primary and secondary elements, with element length depending on safety, trench stability of the slurry-supported excavations and given geology. The continuous walls are formed by overcut of primaries, while constructing the secondary elements. The limited number of joints are serrated and cleaned as required for optimum interlocking.

Single-phase-method

The construction of a 1-phase-wall comprises the following steps: The first step involves excavation work, optionally with a grab or cutter, whereby the stabilizing slurry consists of a self-hardening bentonite-cement slurry. Subsequently, sheet pile walls or beams can be installed as structural element in the not yet hardened slurry.

In this process the support fluid, which is pumped into the trench during the excavation stage, consists of a bentonite-cement slurry, that remains in the trench after completion of the excavation and forms a self-hardening barrier inside the trench.



Double-phase-method

The construction of a 2-phase-wall comprises the following steps: The first step involves excavating a defined sub area (panel) using suitable excavation equipment, such as a grab or cutter under stabilizing bentonite slurry and/or polymer. This is followed by the regeneration of the stabilizing bentonite slurry and/or polymer. The final step involves concreting using the tremie pipe. For sealing purposes using a two-phase cut-off wall, a placement of a reinforcement cage is not necessary. The support fluid is subsequently cleaned and then replaced in a second phase by the actual barrier material (e.g. plastic concrete) which is placed in the trench using the tremie method.

Slurry handling

In general: The required slurry is pumped through installed lines from the mixing area to the open trench. Using cutter: The mixture of soil material and slurry is pumped through permanently installed lines to the desanding plant. There, the soil material is separated from the slurry by means of vibrating screens and cyclones. The cleaned slurry is then returned to the excavation trench. During concreting the stabilizing slurry displaced from the trench is also pumped out and cleaned. Using grab: Each time the grab is pulled out of the open panel, the mixture of soil and slurry is usually unloaded onto skips and transported to an intermediate storage facility.

The rivers of the Himalayas have the potential to help achieve the global goals on renewable energy. However, in order to build Hydroelectric Power Plants in the alluvial and colluvial soil formations of these rivers a technology is required to enable cutting through boulder and into the underlying bed rock. With the Bauer Cutter Technology we have cut boulder of more than 10 m diameter and bedrock of more than 180 MPa UCS value. This is only possible with #BAUERPOWER.

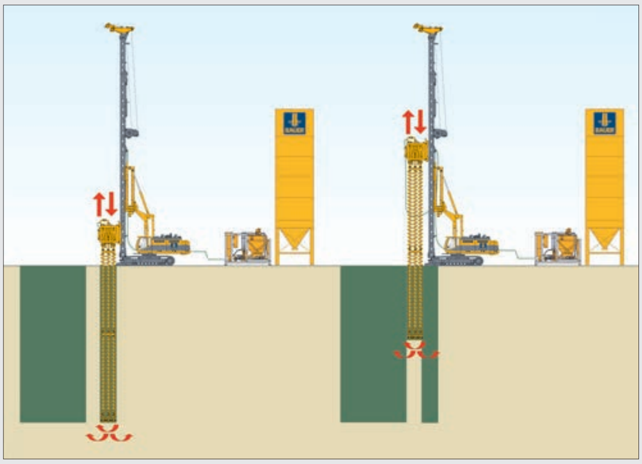
Mikko Gastager,
Regional Director Asia Pacific,
BAUER Spezialtiefbau GmbH

Mixed-in-Place

Mixed-in-Place (MIP) is an in-situ soil mixing technique. Triple continuous augers drill down to the final depth, under low pressure injection of cement slurry. Upon reaching the final depth, the homogenization process takes place. During the homogenization process, the soil along the whole depth is mixed with the cement slurry. The use of triple continuous flight augers enables a vertical material flow, along the whole depth of the MIP-element, which assures a homogenized mixed soil along the whole depth of the element. MIP walls can reach depths down to 23 m below working platform and are offered in two thicknesses, 370 mm and 550 mm.

Work procedure and sustainability

To achieve a continuous water barrier and to ensure the homogeneity of MIP walls, in the horizontal direction as well, MIP walls are constructed using the patented double pilgrim step method. This construction method is characterized by additionally mixing of the overlapping areas between primary and secondary cuts. This aims to ensure that along the MIP wall, each wall element has been mixed at least twice. MIP uses the existing natural soils as aggregates. Cement and bentonite are used as construction materials and the soil is not replaced. Therefore, it represents a sustainable solution for cut-off walls.



Applications

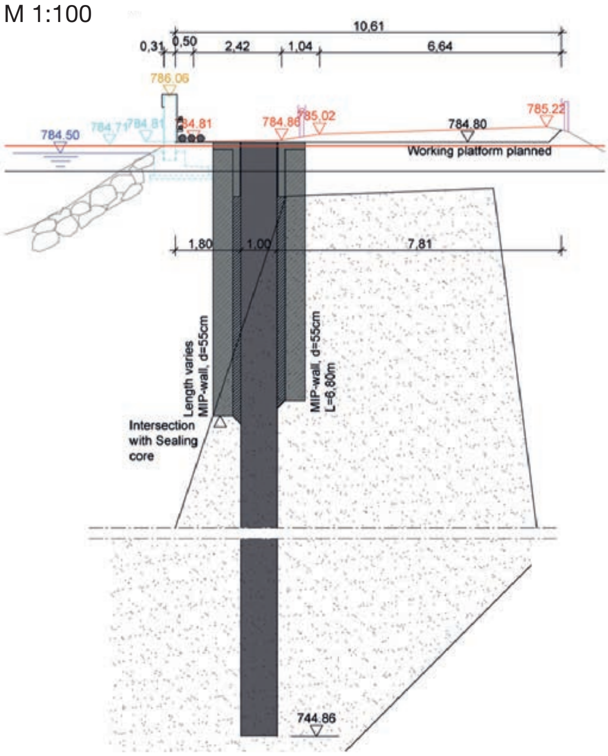
MIP cut-off walls reduce or prevent seepage through dikes and thus increase its stability. MIP cut-off walls can also serve with structural function when fitted by steel beams. MIP cut-off walls are constructed along the dike axis and are either embedded into an underlying impervious layer or serve as an extension of the seepage path. The hardened cut-off wall materials can withstand erosion.

INFO

Rosshaupten Dam (Germany):
To ensure the safety of the dam in the event of a rapid drop in the supporting fluid level within the trench, due to unknown features in the karstic rock below the dam foundation level, a Mixed-in-Place (MIP) wall was incorporated into the guide wall on both sides of the trench.

This is further evidence of Bauer's innovative approach, using its experience with different techniques and methods to suitably combine them for specific project requirements.

Standard cross section A-A
Construction condition
M 1:100



Construction Methods

Cutter Soil Mixing

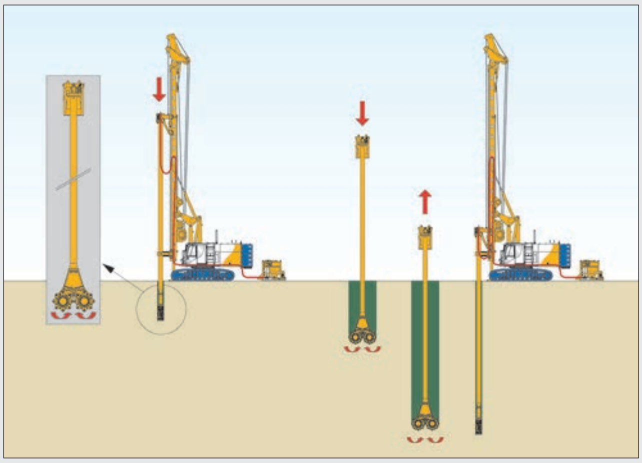
Mixing of self-hardening slurries with native soils by using a modified trench cutter technique, is an innovative and effective method for constructing cut-off walls, earth retaining walls, foundation elements, as well as for soil improvement. CSM is used mainly for stabilizing soft or loose soils (non-cohesive and cohesive). The equipment used is derived from Bauer's cutter technology. The applicability of the method is thus extended to much harder strata, when compared to other methods of soil mixing.

Main advantages of the method are:

- High productivity
- The in-situ soil is used as a construction material
- Little generation of spoil
- No vibrations induced during construction
- Extended depths (up to 80 m) can be reached – when using rope-suspended units

Construction sequence

Preparation: Excavation of a guide trench for collecting surplus slurry



Step 1:
Positioning of the cutter head in wall axis.

Step 2:
The mixing tool is driven into the ground. At the same time self-hardening slurry or bentonite slurry is added. The soil matrix is broken up by the cutting wheels and liquified by adding slurry. The rotating wheels and cutting teeth push the soil particles through vertically mounted shear plates that have the effect of a compulsory mixer.

Step 3:
After reaching the final depth the mixing tool is extracted while self-hardening slurry is added.

Step 4:
Reinforcing elements required for structural purposes can be inserted into the mixed wall. Therefore, steel beams (usually H-beams) can be installed into the not yet hardened fresh mixed panels. The spacing of the beams and beam cross sections are designed on the basis of the applied loads.

A continuous wall is formed in a series of overlapping primary and secondary panels. Overcutting into fresh adjacent panels is called the „fresh-in-fresh method".

The cutter technique also allows the "hard-in-hard method", whereby secondary panels are cut into the already hardened primary panels.

The cutting and mixing procedure can be executed in two ways - in the one-phase or the two-phase system.

One-phase system

With the one-phase system binder slurry is introduced during both the downstroke and upstroke processes. During the penetration (downstroke) phase, cutting, mixing, liquifying and homogenising is performed while pumping the binder slurry and compressed air into the soil.

In the upstroke phase the remaining volume of binder slurry is blended into the soil. The speed of extraction can be higher as the majority of the binder slurry has already been mixed with the soil in the downstroke phase.

Advantages of the one-phase system:

- No auxiliary desanding circuit required
- Higher speed of extraction
- Preferred application in easy and uniform soils, depth range < 20 m

Two-phase system
The soil is liquified and homogenised in the downstroke phase by pumping bentonite slurry or water (in case of clay) into the soil. The backflow can be pumped to a desanding plant, where the sand is separated from the slurry which is then pumped back to the rig.

After reaching the final depth, the injection of bentonite slurry or water is stopped and replaced by binder. During the upstroke process cement slurry is mixed thoroughly with the liquified soil. The speed of extraction and flow of binder are adjusted to ensure that the total calculated quantity of binder is blended with the soil.

Advantages of the two-phase system:
- No risk of getting stuck when working at extended depths or when the working process is interrupted, due to hardening bentonite slurry above the mixing tool
- Wear and tear on the cutting wheels is reduced by using binders
- Preferred application in difficult soil conditions and for extended depth

Bauer is proud to have been contracted to execute many cut-off wall projects as part of the Herbert Hoover Dike Rehabilitation in FL, USA. Working both as a General Contractor for the US Army Corps of Engineers or as a Subcontractor. Nearly 28 miles of CSM (over 5 million square feet!) have been installed, starting in 2008 with the Reach 1 task orders, continuing through 2019 with various new culverts and continues into 2022 with the multiple award task orders.

Bryn Harris,
Project Director,
BAUER Foundation Corp.

Construction Methods

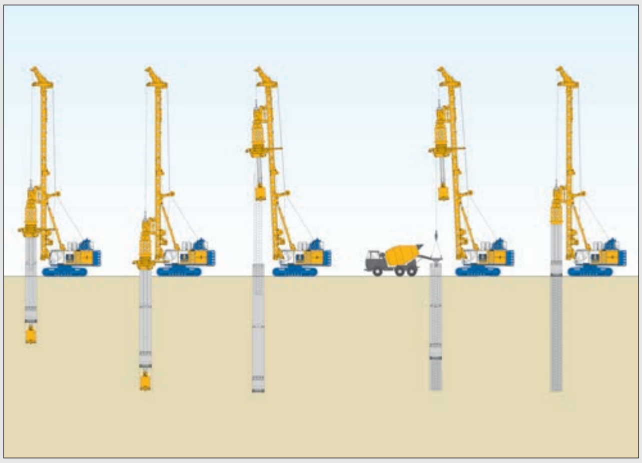
Secant Pile Wall

Positive cut-off walls constructed by overlapping/interlocking circular primary and secondary elements are being executed by hydraulic drilling rigs. The open boreholes are supported by either special segmental steel casings or by slurry.

The relatively small size of equipment is advantageous for smaller work platforms. The continuous walls are being installed in all types of geology, including embedment into rock.

Construction sequence

Prior to starting the construction of the pile wall, it is required to install a reinforced guide wall. The guide wall is necessary to ensure a correct positioning of the piles. It also acts as a guide for setting the casing and as guidance when drilling the first meters. The amount of overcutting depends on the pile diameter, the depth and the purpose of the wall (temporary or permanent use).



Casing installation with the rotary drive of the drill rig (pushing and rotation).

Drilling with bucket, auger or core barrel. Stabilization of the wall of the bore partially or completely with casings.

Concrete pour via tremie method.

Extract casing with the rotary drive (or alternatively with an oscillator) concurrent with rising concrete level inside the bore.

A series of primary piles are constructed first. After the primary piles have reached the necessary concrete strength the intermediate secondary piles are constructed. The construction of the secondary panel differs from the construction of a primary panel in so far as the casing and drilling tools cut into the adjacent concrete of primary piles.

The SPW method is suitable for both soil and rock conditions, with the use of casings to help ensure verticality and hence the desired overlap for a continuous barrier. The step-wise sequence of cased piling also enables minimal disturbance of existing (sensitive) earthern dams and maintenance of hole stability during construction. The SPW technique is also ideal for small working areas; such as those on existing dam/ levee sites. The SPW system for use on dam projects assures our Clients achieve maximum quality with minimum disruption …

Dr. Serhat Baycan, Managing Director,
BAUER Foundations Australia Pty. Ltd.

Grouting

Grouting is a technology used to improve the tightness of in-situ ground conditions and/or bearing capacity, using small diameter boring. The improvement can be achieved by filling pores, fissures or cavaties, using cement based or chemical based fluids.

GROUTING TECHNIQUES

In granular soil:

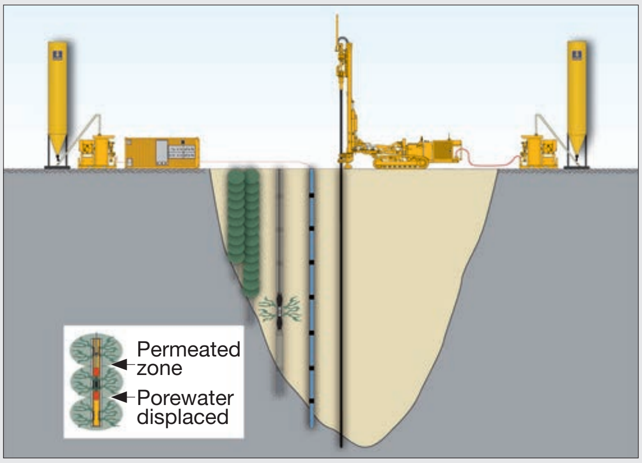
- Grouting with tubes-à-manchette (TaM) with annulus grout

Work sequence:

- Drilling with temporary casing (optional)
- Placement of annulus grout
- Installation of TaM
- Casing extraction (eventual)
- Additional annulus grouting
- Grouting of each manchette with double packer

In sound rock:

Upstage grouting: Procedure of drilling a hole to full (required) depth in one operation and grouting from the bottom of the hole towards the surface in successive stages, by setting a single packer at predetermined depths.



In weathered and unstable rock

Downstage grouting: Procedure of drilling a hole to a limited depth, setting a single packer and grouting the hole, permitting the grout injected around the hole to set sufficiently to prevent it from entering into the hole when the hole is cleaned.

- Re-drilling through the hardened grout
- Drilling the hole to the next deeper stage
- Setting the packer at the bottom of the previously grouted stage or as directed by the Engineer and grouting of the new stage

APPLICATIONS

Pre-Treatment

Grouting for piling and diaphragm walls: Backfilling of cavities and large voids, either by gravity or by low pressure grouting by means of sleeve pipe.

Consolidation grouting underneath dikes and dam foundations: Injection of the first ground layer underneath the foundation that might be impaired by excavation and blasting.

Tightening and seepage mitigation

Grouting underneath dam and dike foundations:
Granular soil

- Pore permeation grouting with tubes-à-manchette (TaM)
- Filling of soil pores in order to reduce the permeability and
- to provide a seepage barrier underneath the (coffer-) dam foundation

Curtain grouting underneath dam and dike foundations:
Rock

- Fissure grouting
- Grouting of fissures and cracks of the rock to provide a seepage barrier underneath the dam foundation

Ground Improvement

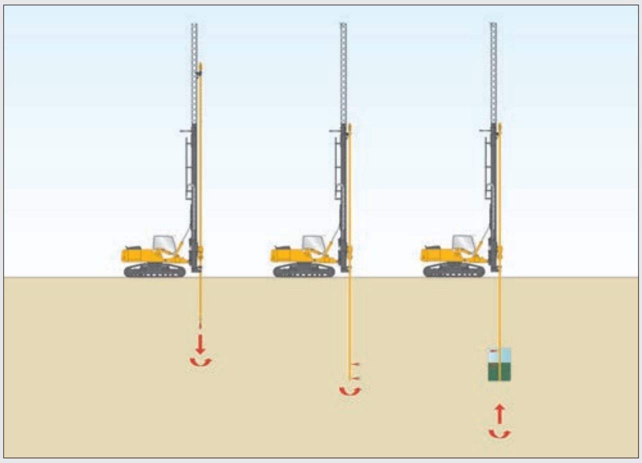
Compaction grouting: Compaction grouting is a way to consolidate foundation soil by injecting low mobility grout. This process is used to prevent settlements or to stabilize structures which have settled. Holes are installed by either drilling or a drive string, attached with a sacrificial point. Low mobility grout or mortar is injected in upwards stages with a low volume, using high pressure pumps. The injection rod is withdrawn at a controlled rate to give the grout a globular shape. The grout is injected until a predetermined pressure is reached or the ground begins to heave upward.

Construction Methods

Jet Grouting

The jet grouting process consists of the disaggregation of the soil or weak rock and its mixing with, and partial replacement by, a cementing agent; the disaggregation is achieved by means of a high energy jet of a fluid which can be the cementing agent itself. The main advantages of this process is that large solidified jet grout elements can be executed in the ground by relatively small drill rod (borehole diameter approx. 15 cm), and the method is applicable with limited working space, too.

Test columns
Before commencing jet grouting operations, it is essential to construct test columns, if comparable suitability tests are not available. The average diameter of each test column must be determined and compared with the diameter specified in the design. Based on the results of this comparison, the production parameters may have to be adjusted accordingly.



Construction sequence:
A string of jet grouting rods is drilled into the ground to the required depth by a rotary drilling rig. The lower end of the drill string is fi tted with a nozzle holder and a laterally mounted jet grouting nozzle.

A jetting fluid (usually a cement grout, depending on the type of jet grouting system) is pumped through the jet grouting nozzle at high pressure (400 - 600 bar). This produces a high-energy „cutting jet“, which erodes the soil from its natural position and mixes it with the grout. The diameter of the column is determined by the density and type of soil, as well as the jet grouting parameters.

By rotating and simultaneously retracting the jet grouting drill string, the cutting jet describes a tightly spaced helix in the soil, resulting in a column-shaped space filled with grout and soil. The cement grout causes this mixture to set and solidify, as a result of which load-bearing jet grouting columns are formed.

Jet grouting systems and sequences
Depending on site-specific circumstances, and the prevailing soil conditions (granular and/or cohesive) the system and sequence must be determined for each individual project, to ensure the required quality.

Jet grouting systems:
Single system: Process in which the disaggregation of the soil and its cementation are achieved by a high-energy jet of a single fluid, usually a cement grout. An adequate column diameter is already achieved with this system in homogeneous soils.

Double (air) system: Process in which the disaggregation of the soil and its cementation are achieved by one high-energy fluid (usually a cement grout), assisted by an air jet shroud as a second fluid to maintain the energy of the fluid jet over a longer distance. Wherever air support is advisable, larger column diameters can be achieved compared to the single system.

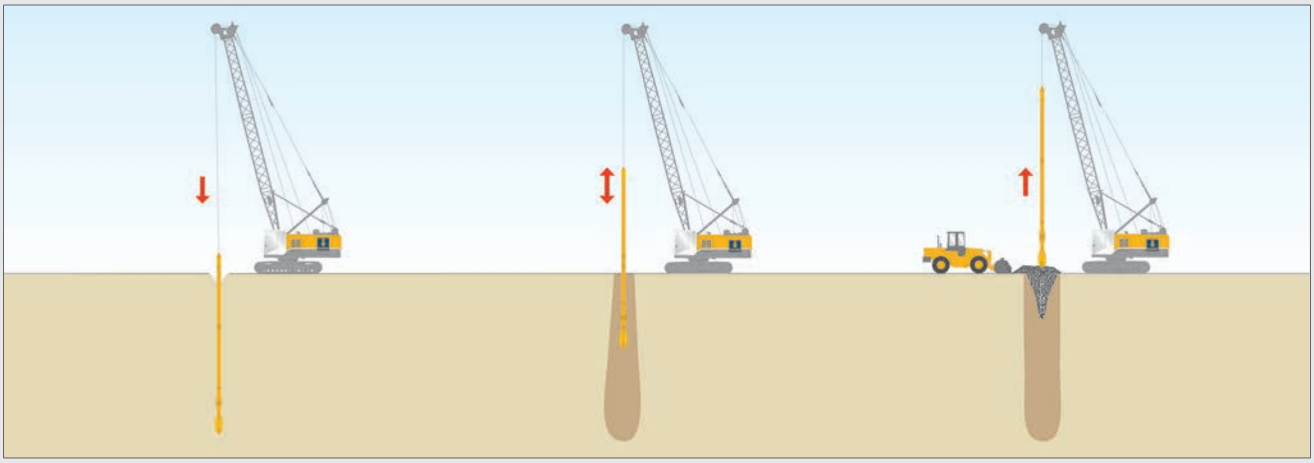
Triple system: Process in which the disaggregation of the soil is achieved by a high-energy water jet, assisted by an air shroud, both aimed to achieve a larger column diameter. Its cementing is simultaneously obtained by a separate noncutting grout jet.

Sequence:
The execution of continuous jet elements can be achieved by single columns executed in the runner sequence, or by single columns executed in the pilgrim step mode. A fresh-in-fresh sequence aims to further integrate the individual columns of the longer planar elements.

Soil Improvement

The use of soil improvement for Dams, Dikes/Levees, Mines and Tailing Storage Facilities follow the same necessity as soil improvement for other structures, namely settlement control, liquefaction mitigation, bearing capacity increase or the improvement of slope stability. Therefore the question of which technique is applicable will depend wholly upon: what is the aim of the treatment, what is the soil to be treated, what is the site access, and what is the most economically viable technique, then of course is it greenfield, new build or remediation?

Many Dams built in the first part of the 20th century have been found to be lacking in terms of stability for the current design levels for seismic loads and so typically compaction of the clean (possibly) alluvial sands is needed for liquefaction mitigation. However, sometimes the dams have been formed from old mine tailings and as such the dam structure itself (if not the core, then the surrounds) may also need treatment. In these situations, treatment outside the footprint of dam maybe possible, but for treatment under the dam, then grouting or soil mixing maybe the most beneficial step. At Bauer we have the tools to assess the needs, and the machines and techniques to provide the solution for the rehabilitation of the dam.



For newly built dams, or even the treatment of tailings, then a similar approach follows to that described previously. What are the targets or needs of the client/consultant in terms of slope stability (for dynamic and static cases), does the existing ground need to be treated to allow the construction of the dam (for settlement control, or liquefaction or slope stability)? Does the available material (sand, clays, tailings, silts) need treatment (by soil mixing or other mechanical treatment methods)? Bauer can offer the use of vibrocompaction or dynamic compaction for the treatment of sands or silty sands for liquefaction and settlement control, with these being effective to 50 m or 15 m respectively, in case of more silts or fine contents then techniques such as soil mixing, full displacement columns or stone columns may be used to provide not only settlement control, but slope stability and liquefaction mitigation methods.

DSM (Deep Soil Mixing)

The Single Column Mixing (SCM) method is a well-known deep soil mixing method, whereby a self-hardening slurry is added and mixed to the in-situ soil in order to improve its original hydro-mechanical properties. The SCM technique is an economical process for the construction of columns, walls and blocks of improved soil. One advantage of the treatment of greenfield sites and the treatment of the dam itself can then be steeper side slopes, resulting in less land take, often a huge cost in the building process, especially if greater heights are being considered. As such Bauer can offer a solution to your needs.

Equipment

Cutter and grab
Bauer trench cutters and Bauer hydraulic grabs are equipment for the panel excavation for the execution of cut-off walls. The centerpiece of the Bauer trench cutter system consists of a steel frame with two gearboxes attached at its base, which rotate in opposite direction around their horizontal axis. Cutter wheels suitable for the prevailing ground conditions are mounted on the gearboxes. Selecting the most suitable type of cutter wheels (equipped with flat teeth, round shank chisels or roller bits) is essential for cutter progress, which mainly depends on the geological conditions (particle size, density, abrasiveness, compressive strength, etc.). The accurate determination on the trench cutter for your project depends on the project ground conditions, the required trench width and wall depth. The ideal base carriers for Bauer trench cutter and mechanical or hydraulic grab equipment are BAUER MC 76, MC 86, MC 96 and MC 128 duty-cycle cranes. The entire hydraulic power supply of the attached cutter/hydraulic grab is provided by the hydraulic systems of the MC duty-cycle cranes, which have been specially designed for those applications. Cutter and grab are available for a nominal width of 640 mm, 800 mm, 1.000 mm, 1.200 mm, 1.800 mm and 2.200 mm, and panel length of 2800 mm and 3.200 mm, however also special measures for width can be manufactured, if required.

Rotary drilling rig
Bauer rotary drilling rigs are used to construct a single pile or (secant) pile wall or – in combination with diaphragm wall elements – a hybrid wall. The BG hydraulic drilling rigs like BG 30 or BG 45 are ideally suited for drilling cased or slurry-supported boreholes, with the kelly-system and special drilling tools demanded by the individual geology on the project. The segmental steel casings for cased boreholes are installed by rotary drive or optionally by hydraulic oscillator, powered by the drilling rig or additional powerpack. Drilling tools are available for diameters from 600 mm to 3500 mm.

Small diameter drilling rig
The main equipment for the drilling and grouting method are the Bauer hydraulic drilling rigs of the KLEMM KR 800-series. These modern and extremely compact rigs are particularly suitable for the different drilling applications:

- Rotary drilling with down-the-hole hammer,
- Rotary percussion-,
- Overburden-,
- Double head drilling rotary/rotary and
- Double head drilling rotary/rotary percussion.

The drilling rigs will be fitted with hydraulic drifters from the Eurodrill HD-series, with different types of drill rods and drill tools to suit the geology and depth required for the individual project. After extensive checks over borehole deviation the grouting process will be executed. The accurate determination on grouting equipment (pump type, mixer, packer type, etc.) depends inter alia on soil conditions and the required grouting material.

Mixed-in-Place
Bauer Mixed-in-Place (MIP) equipment is developed specifically for use in the overburden (granular, slightly cohesive soils). The entire hydraulic power for the rotary drives of the attached triple augers is provided by the hydraulic system of the base carrier, which has been specially modified for those applications. Base carriers like BAUER RG 19 T, RG 25/27 S or modified BG are chosen according to final depth and the required nominal width to be achieved. Triple augers are available for a nominal width of 370 mm, 550 mm and 750 mm.

Cutter Soil Mixing
Cutter Soil Mixing (CSM) equipment derived from Bauer trench cutter technique. Depending on the required depth of the cut-off wall, the cutter-mixing unit is held and guided by round Kelly bar or by a Mono Kelly, with rectangular cross-section. Cutter wheels break up the soil matrix and mix it with cement slurry to a homogeneous soil-cement mortar. The system is applicable in various soil conditions – even in hard or layered strata. Cutting and mixing head are available for a nominal width of 600 - 1,200 mm.

Jet grouting

Attaching the required jet grouting equipment, the universal Bauer BG base carrier and KLEMM hydraulic drilling rigs can be converted for the jet grouting works. Additional equipment, like jet grouting drill rods, high pressure jetting pump and a mixing plant are necessary.

Mixing and desanding unit

The open trenches of diaphragm wall elements and possibly piles are supported by slurry. During the preparation of bentonite slurry, the bentonite powder has to be mixed intensively with water. This is achieved by pump mixers or colloidal mixers. Single-phase slurry mixes for cut-off slurry walls, consisting of multiple components, such as rock powder, cement, bentonite and water, are produced by Bauer MAT mixers as well. Bauer MAT desanding plants are developed specifically for the use with trench cutters, to separate the cuttings from the slurry used to support the open trench and to transport the cuttings. The plants are characterized by the following features: Modular construction throughout the entire plant unit and, therefore, the ability to match treatment capacity to soil type and cutter output capacity. Advantages: secondary circulation with desilter or centrifuge possible, short set-up and dismantling times and containerized transport dimensions.

Soil improvement

The ideal base carriers for Bauer soil improvement are duty- cycle cranes, like BAUER MC 96 and MC 128, and BG 28 and BG 40 for Deep-Soil Mixing (DSM). The entire hydraulic power supply of the attached soil improvement equipment is provided by the hydraulic systems of the MC duty-cycle cranes, and BG drilling rigs. Depending on the required technique (stone columns, vibro compaction, dynamic compaction, DSM) the additional equipment (vibro probe, pounder/weight, drilling / mixing tool) will be connected with the base carrier.

The max. DSM depth that can be executed with a single stroke can be up to 31 m, the diameter of the mixing tool can be designed individually (ø 600 - ø 2,000 mm).

The advantages for the owner and consultant/designer using soil improvement measures is that it gives the flexibility to use it whenever and wherever required. Improvement of existing grounds can offer a cost-effective solution to improve non-compliant material at any stage of a project. You start from scratch on a green field or structures are already in place on a brown field, Bauer has proven its ability to work in both environments. DSM columns and wet stone columns improved the soil conditions in a damproject in southeast India, which was a green field project.

Max Trombitas,
Regional Director South Asia,
BAUER Spezialtiefbau GmbH

Construction Materials

Bauer´s **Competency** regarding Construction Materials is established and has been constantly progressing, as a result of:

- In-house scientific research supported through academic cooperation with partner universities, investigating and assessing materials’ influence on the installation process and their influence on the final, integral quality of the wall or pile
- BAUER Spezialtiefbau GmbH cooperates worldwide with various organisations to specify standards and regulations. Amongst others we participate in the following groups
- We are a member of the German delegation for the Technical Committee TC288 of CEN, in charge of European Standards for Execution of Special Geotechnical Works (EN 1538 Diaphragm walls). We were also a member of the tremie concrete task group of the Piling and Foundation Specialists Federation (which compiled the “Guideline on Tremie Concrete for Deep Foundations”, published in 2012, by the Concrete Institute of Australia)
- Furthermore we have been chairing the joint Concrete Task Group of the EFFC, the European Foundation Contractors, and of the DFI, the Deep Foundation Institute (USA), established in January 2014. In 2018

  the 2nd edition of the Guide to Tremie Concrete for Deep Foundation was released. It recommends to adjust the design and quality control of tremie concrete in accordance with to latest developments and introduces these results to the European and international market, applicable for the revision of the concrete specifications for the next generation of CEN standards
- Consulting in operational works, hence giving project-specific advice in concrete design, raw materials and concrete testing, as well as quality assessment, in all construction phases, from planning, calculating or finally executing the dam rehabilitation project
- Bauer aims to support own projects in all matters and steps of materials’ use for deep foundation works. Regarding concrete for dam rehabilitation, principal demands have to be specified in order to proof both sufficient fresh and hardened concrete properties
- Permeability and erodibility, both must, within defined ranges, ensure the demanded serviceability of the wall
- According to Bauer’s experiences gathered in own research, standards and consulting works, the concrete, prior to its application in a project, must be properly designed, specifically tested and optimized. For placing concrete in deep excavations, the fresh concrete behavior must be understood and required properties must consequently be controlled throughout the concreting process
- It is Bauer’s experience that the cut-off wall construction safety for both the ultimate and service limit state, in terms of its function as a water barrier, should not be based on the strength of the plastic concrete used, but on its deformation capacity in order to gain from the material‘s plastic properties.

Construction materials
The materials used for dam construction and remediation have to meet the demands arising from the design and functionality aspects, as well as to fulfil the specific requirements imposed by the used construction methods and the project’s boundary conditions. The following section describes the most common water cut-off materials and their application respectively.

Plastic concrete
Plastic concrete is used preferably for permanent D-wall installation under main dams and for temporary approaches at cofferdams. Compared to structural concrete, plastic concrete is characterized by lower strength, below 5 MPa, lower cement content, the use of a clayey component, such as bentonite and lower young modulus. It is most suitable for dams which need to sustain higher hydraulic gradient, but still exposed to deformations due to upcoming loads. Besides the design strength level, the durability of the plastic concrete with respect to erosion is supported

by suitable grading curve. Cement content and bentonite dosage can be set and adjusted, depending on the required strength and maximum allowable permeability. Workability properties and duration of plastic concrete can be set to site requirements with available admixtures.

Lean concrete
The Lean concrete is an intermediate option between the highly deformable plastic concrete and the conventional structural concrete, with higher resistance towards mechanical and hydraulic impacts. Compared to plastic concrete, this concrete has a higher strength, with up to 15 MPa and a higher cement content. The stability of such concrete is enhanced by a higher fines content, achieved, where required, with inert, pozzolanic and/or clayey additions, such as fly ash, selected stone powders and/or adding calcium or sodium bentonite. Similar to plastic or structural concrete, lean concrete contains sand and gravel, composed to a well adjusted grading curve, together with a required design strength to guaranty erosion stability. Flowability and workability duration are controlled similarly to other concretes with available admixtures.

Bentonite-cement slurry
In application fields with less existing water pressure, like construction pits or dikes and lower dams, the use of hardening bentonite-cement slurry is a practicable option. Here the well-retarded slurry, produced on-site by slurry plants, is pumped to the trench with remotely controlled pumps. Compared to plastic concrete, the major advantage is the significantly increased productivity and the higher independency from on-time concrete deliveries. The hardened bentonite-cement mix does not have a stiff grain structure like concrete, which gives such materials higher plasticity and allow better accommodation of introduced strains. Cement content and bentonite dosage can be set and adjusted depending on the required strength and maximum allowable permeability or required elasticity. Required open working time of slurry can be set to site requirements up to 36 hrs with suitable admixtures

Soil-slurry mix
Soil-slurry mixing is favourable due to its lower ecological impact. It uses major parts of the existing ground and therefore requires less transportation for materials and spoil, as well as a smaller mixing plant. By preparing a bentonite-cement slurry and mixing it into the ground, strength and permeability properties of the soil-slurry-mix can be set similar to plastic concrete by adjustment of cement and bentonite content. Workability of slurry and the liquefied soil mix can be fit to required working conditions with suitable admixtures.

Grout
Grouting works on dams require custom-made grout compositions, depending on the application conditions and purpose. Whilst in granular deposits grouts of pronounced filtration stability are a must, weakly stabilized mixes are not uncommon for closure of fissure cracks in rocks. In the last decades however, the increased application of the GIN method in rock grouting, has raised the importance of stabilized grouts for sealing of rock cracks and apertures as well. In fine-granular soil chemical grouting with resin and gel solutions is usually a better choice. Depending on the required mechanical properties, the durability and exposure conditions, choice can be made between soft, hard gels and polyurethan resins. Meanwhile, chemical grout control agents, such as polymers, have found application in conventional rock grouting as well. One of the main advantages of the grouting methods, besides the preservation of soil in place, just sealing the cracks and voids with wide-spread grouts, are the limited dimensions of utilized equipment. The lower portion of material demand is a further decisive factor, making grouts an economically attractive solution.

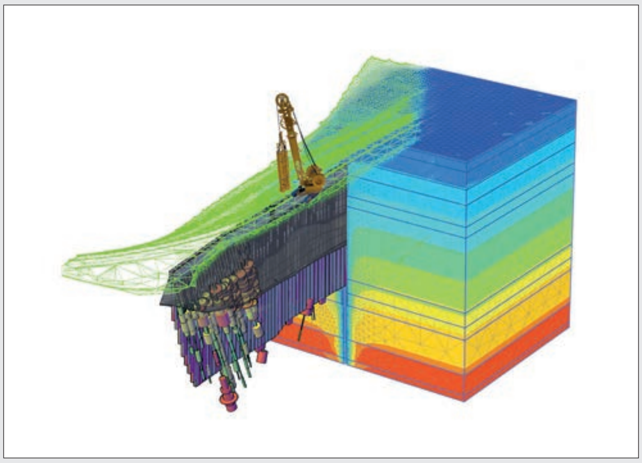
Integrated Design

Finding the most efficient way of applicating and processing data is crucial in a changing world. Integrated design bring all relevant information together. Starting with a geometrical survey and geological data, a model of the proposed structure is developed, which fits exactly into each individual situation.

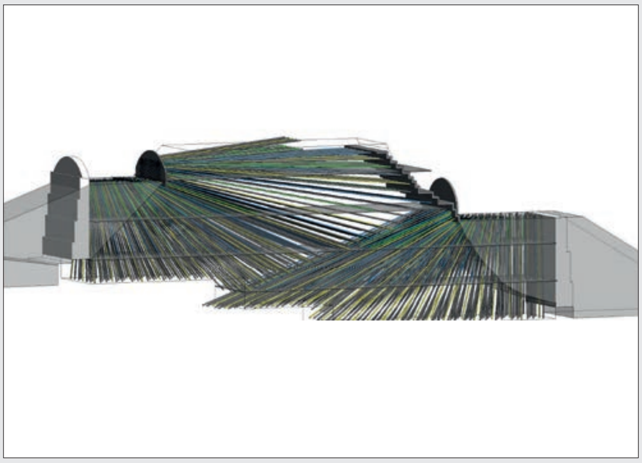
With our vast experience in construction methods the sequencing of production is optimized, combining equipment and material in the most effective way.

During construction production data is collected and merged, proving compliance between built and designed reality and providing experience for the next project. Integrated design requires the cooperation of all parties involved and good confidence into the realized design solution.

For the Punatsangchhu-II project, long injection bores for stabilization of a rockfall mass were executed within a tunnel. The number and exact position of each drill was planned, so that the drilling rig can approach the places with ease and execute them accordingly.



Construction model comprising data of different sources, Rosshaupten Dam, Germany.



Drilling and grouting in downstream surge gallery, Punatsangchhu-II HEP, Bhutan

Ahead of the pre-treatment grouting works, seven exploratory boreholes were drilled, to a depth of up to 85 m, in order to take cores, and to obtain supplementary information about the unconfined compressive strength, the fracturing degree and the permeability of the existing rock. The permeability was determined using the Lugeon packer test.

The data, which was monitored during all drilling works, also gave valuable information for the later grab and cutter excavation for the trenching. The data were digitalized and a 3D model and was produced step by step in real time, documentation and vizualization using Bauer's specialist digitization B-project model.

Design is always the first step to quality and reliability - this is particularly true for complex dam projects.

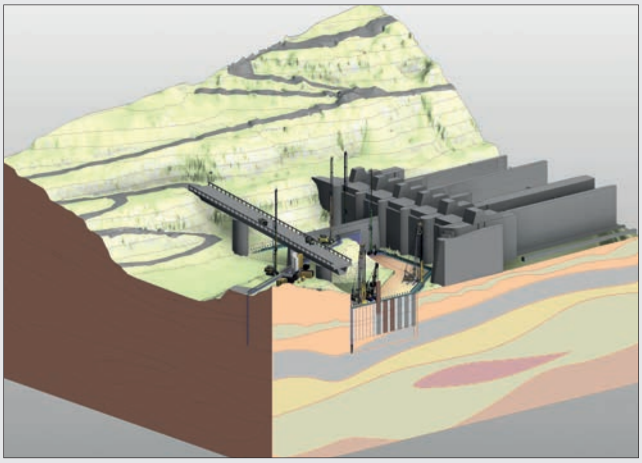
Dr. Klaus Idda,
Head of Design Department,
BAUER Spezialtiefbau GmbH

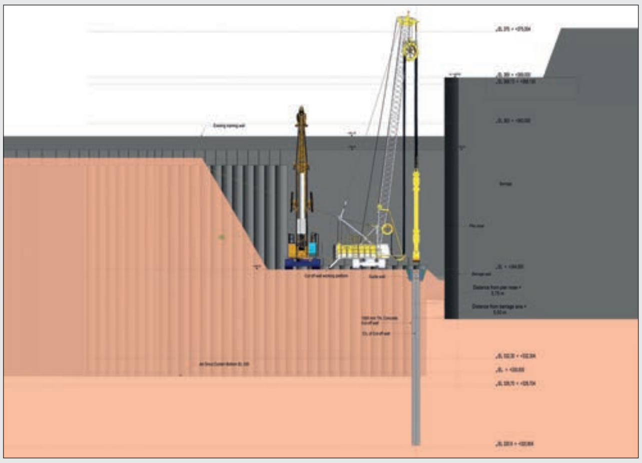
Teesta VI hydroelectric power project is located in the Himalayan mountains in India. The multidimensional project model, includes topograhy, geology, existing and planned structures and the machinery for execution. Individual sections, showing the necessary detailing, are derived from the model. Typically a cut-of wall is installed in the subsoil below the barrage. This wall ties into impermeable layers and prevents an underflow of the structure.

BAUER´s scope of work:

- Jet grouted cut-off of about 4700 m² along the U/S Coffer Dam
- Diaphragm wall of about 4,600 m² on the upstream side of the barrage, incl. pre-treatment
- Pile wall consisting of about 10,000 lin.m. of 800 mm diameter piles and
- Anchors of about 60,000 lin.m., to enable excavation for intake structure on the right bank

The left figure shows a project model with jet-grouting, trench cutter and reinforcing of diaphragm wall in process. The right figure and the section through the barrage shows the cut-off wall with trench cutter in action. In the background aspect on the jet grout curtain in execution.

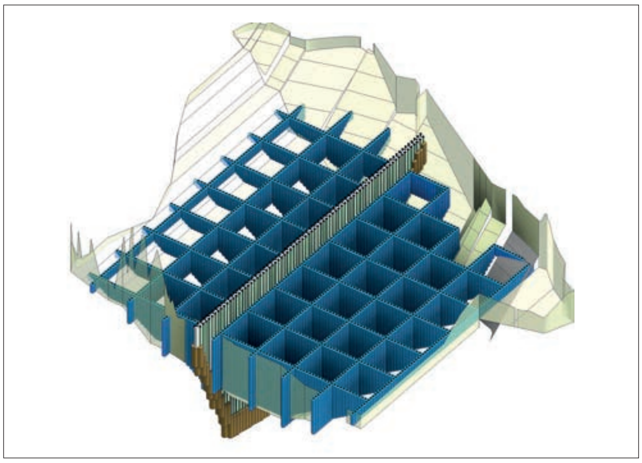




For the Pakal Dul HEP in India, a mighty earth dam is to be filled in a mountain valley. Upstream a cut-off wall is planned in the river sediments of sand and boulder masses down into the unweathered fresh rock. The contact zone between soil and fresh rock is sealed by grouting.

The total area is at risk of earthquakes. In consequence soil liquefaction of the sand layers with a complete failure of the earth dam can potentially occur.

Discussed alternative to large volume soil replacement: a massive grid executed by jet grouting could mitigate this effect. The individual components are developed in drawings integrated into the subsoil model and planned in detail.



Responsibility

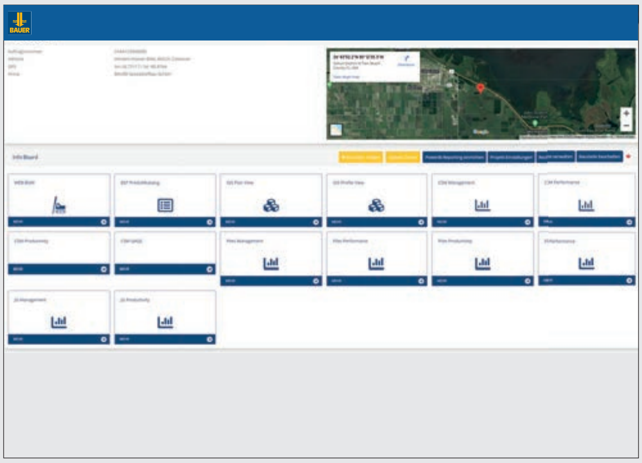
The successful completion of our work as a contribution to customer satisfaction is based on our leading knowledge of digitalization in civil engineering, the ISO 9001 standard, and the associated standards and norms. Likewise, our quality management is based on a project-specific quality management plan, to ensure the agreed quality of our work. Supporting this quality assurance are our digitization tools and monitoring capabilities, all aimed at improving our services. A carefully planned, certified and implemented HSE management system accompanies the planning and production processes. Our responsibility contributes to durable projects and includes, on a project basis, our contribution to sustainability in construction.

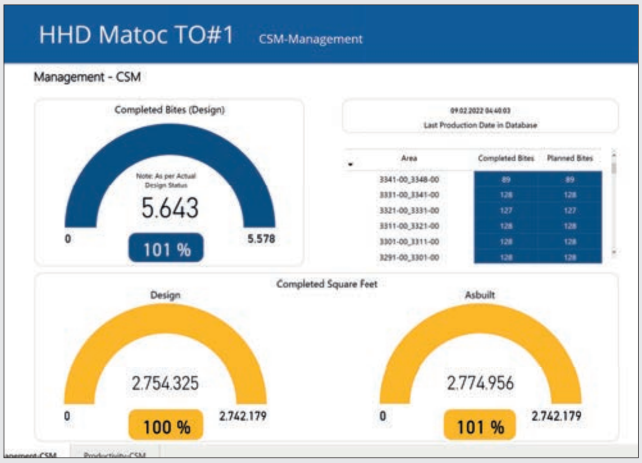
Punatsangchhu I (Bhutan)
New dam
The project is located in the Southern Himalayas, about 80 km east of Bhutan's capital Thimphu. The scope of works included soil pre-treatment with gravity and tubes-à-manchette (TaM) grouting and 8,062 m² cut-off wall, with a nominal thickness of 1,200 mm. Boulders in sizes up to few meters frequently occur in cut-off wall alignment. Bedrock reaches from exposed surface, down to as deep as 93 m below actual working platform elevation, with a UCS strength of occasionally more than 100 MPa.

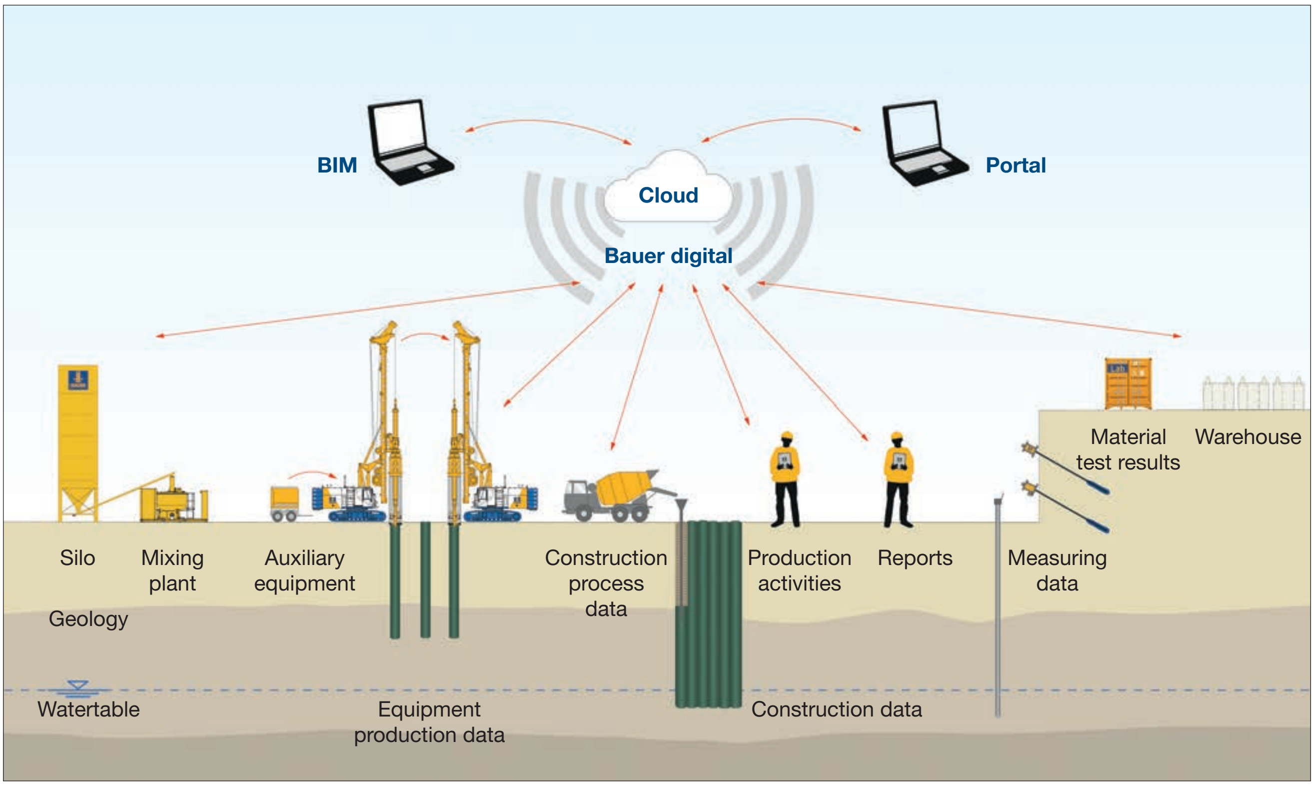
Digitalization and Monitoring

Goal
All digitalization efforts and innovations are intended to improve our services and products by simplifying the daily work of all employees and promoting a partnership-based collaboration with our customer / client. To attain this goal and under the guiding principle of "Bauer digital", the BAUER Group follows a holistic approach covering all aspects of project management. Project-specific digital monitoring, during execution of the required work and after implementation, is an important element in digital construction to achieve and secure productivity and quality results.

In addition to the digitalization of business processes in administration, the focus is also on digitalization of plant production, as well as site processes. Digital work processes assist in the quick and effective processing of all types of projects to save time, reduce cost and ensure that quality is achieved. The addition of digital services and products to the product range and the improvement of products through digital methods and technologies are also being driven forward. Digitalization of the delivery chain is another component, as well as securing all digital activities with a relevant IT infrastructure and data protection.





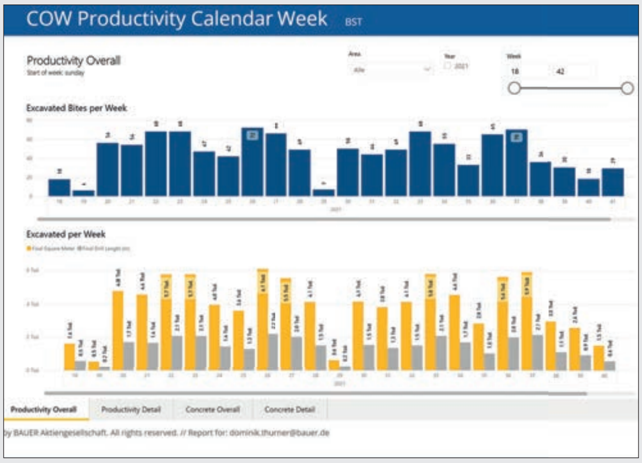


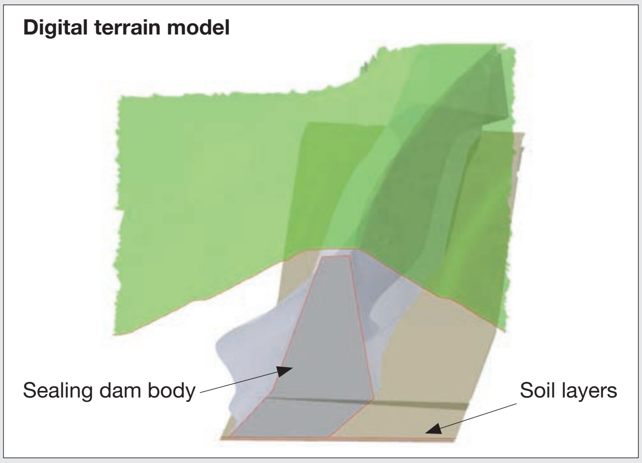
Bauer Construction Process (BCP)
The system facilitates coordinated processes, collaboration as a team, and effective operation. All project participants are kept up to date, all work is synchronized and completed on time.

Building Information Modeling (BIM)
The goal of BIM is to visualize the entire life cycle of a building at all times, from design to construction and maintenance measures at a later stage. Bauer uses the model in the execution phase and adds information for the subsequent operation of the building to the model.

b-project – the Bauer data management software
The effort for capturing, linking, and evaluating different data can be reduced with b-project. In this way, you can make reliable and quick decisions on possible optimizations.

The b-project data management software comprises various applications. At the beginning of the construction project, design data from the construction office is recorded digitally and transferred directly to the site. Machine production data generated during the construction works is read into b-project, analyzed, and also made available to the site manager as prefilled reports. In addition, sample





lists and technical progress reports are automatically derived from the data. And digital machine data generated by drilling equipment form the basis for the production reports created in b-project.

The automated feedback of the actual production data into the quality documentation and performance reporting forms the central interface of the system. The target data from the planning phase can be linked directly with the data from the actual construction and then analyzed, using b-project. Automating this process significantly reduces the documentation and testing effort and supports a standardized, automated, and effective site optimization process for the project. In addition, the software can be used to view various visualizations, including via dashboards, as well as an overview of the current status of the work.

By providing analyses for process control, process optimization, and accounting through b-project, virtually the entire site process can be digitally recorded and visualized.

Digitalization provides automated evaluations and 3D Models, which enables our engineers to optimize the production and to guarantee a product which fulfills the specified quality.

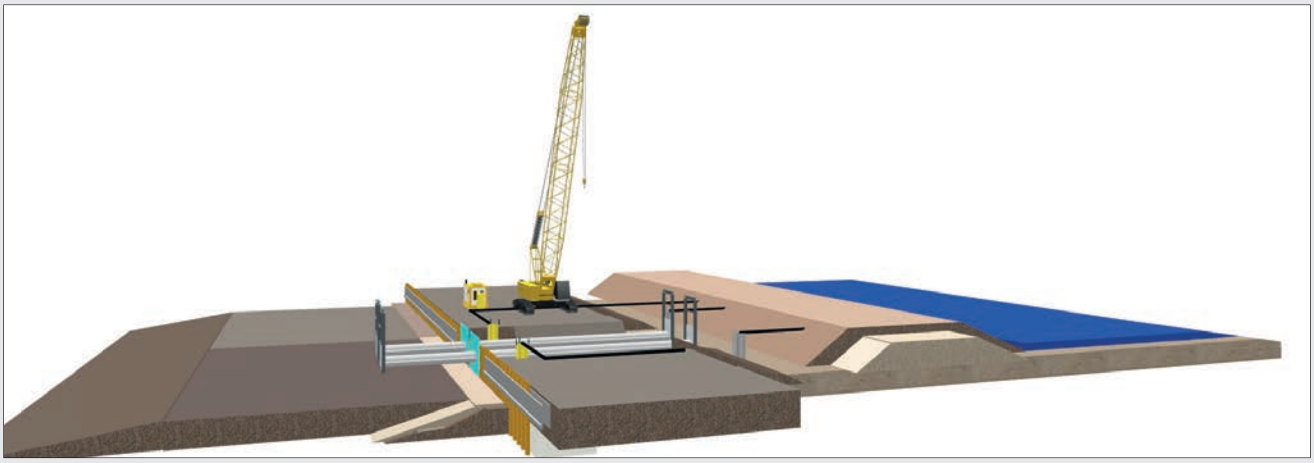
Marcus Daubner,
Head of Digitalization, BAUER Spezialtiefbau GmbH

Quality Management

“Verified quality is our most effectual product. It is the key to success, today and tomorrow.”

Construction Quality Control (CQC) System Commitment - Bauer is committed to delivering high quality products for all our projects. For each project, we implement a project-specific Construction Quality Control (CQC) system, aimed at ensuring a consistently high standard of quality throughout all phases of work. Our CQC system, which is designed to control and verify the work performed, is based on the following fundamental quality principles, among others:

- Ensuring the highest quality of work by establishing, monitoring, maintaining and updating quality control procedures. This is accomplished by providing written instructions governing quality control procedures and practices to establish clearly defined responsibilities and authorities at the beginning of the project, to ensure quality is maintained
- Compiling accurate records of test results, certifications, and other required documentation that meet project-specific contractual requirements and standards



- Notifying the customer‘s representative of any quality deficiencies and proposed corrective actions and ensure that agreed upon corrective actions are properly implemented
- Providing qualified individuals responsible for managing and implementing an agreed CQC program
- Ensuring high quality execution and project management by implementing strong, transparent documentation procedures

Quality is the basis for the BAUER Group‘s global success and is therefore one of the company‘s key priorities. The trust in the quality of our products, services and equipment, which has developed over many years, is to be maintained and optimally expanded.

System
Our quality management system is based on ISO 9001 and the relevant legal and industrial norms.

All relevant processes of our company are methodically analyzed and documented. The processes are designed to increase product quality, for the continuous improvement process and thus increase customer and employee satisfaction. We use key performance indicators to regularly check whether the planned quality targets have been achieved. Deviations are analyzed and remedied in a timely manner.

Quality strategy
The quality strategy includes measures for quality assurance and quality control. All these steps are agreed on a project-specific basis and serve to minimize the construction risk and ensure the function of the final product. The steps are listed below as standard measures applied by Bauer for construction processes.

Quality assurance
Constructability
- Evaluation of soil conditions
- Selection of the construction method
- Selection of the (wall) geometry based on the Engineer requirements (i.e. width and depth and overlapping of elements)
- Definition of a sequence of execution
- Prediction of wear

Integrity of materials used
- Trial mixes to ensure that their properties fulfill the requirements
- Selection of an applicable mixing procedure for each mixed material – if required

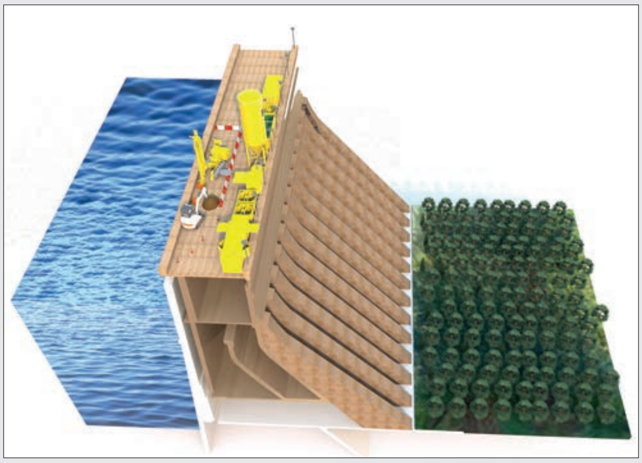
Quality control
Monitoring while execution
- Monitoring of materials before use, during operation and after (… reaching the final depth)
- Monitoring of equipment set-up
- Monitoring of excavated soil type and any anomalies
- Monitoring of used backfill materials with regard to fresh and hardened properties

Measurement of the (wall) geometry
- Position of the center points of the individual wall elements
- Inclination of individual (wall) elements
- Rotation of individual (wall) elements – if required

Reports (in-time documentation)
- Individual element: execution reports
- As-built report for individual elements

Production analysis

As-built visualization



Quality management the way we perceive it, does not begin when we commence execution on site. For us, quality management already begins in the tender phase and continues - in case of being awarded - in the preparation phase. Quality in a service or product is not what Bauer put into it, it is what our valued client gets out of it.

Michael Baltruschat,
Senior Project Manager,
Growth Fields Dams and Dikes,
BAUER Spezialtiefbau GmbH

HSE Management System

Safety based on sound foundations
Our health safety and environmental (HSE) management system is founded upon the ISO 45001 requirements and sets out in detail our plan and concept for managing project-specific HSE measures in the international construction world.

This methodology of HSE management across the BAUER subsidiaries provides continuity of best practice and delivers to the project a wealth of experience from lessons learned.

New ideas, opportunities and methods are identified, evaluated and shared with the group, these lessons and experiences are implemented across the globe continuing the cycle of HSE improvement.

Health and safety
Safety on construction sites is vital in order to maintain high levels of concentration and efficiency. Bauer Spezialtiefbau´s staff are highly trained, undergo regular refresher courses to keep their skills and knowledge up to date and use equipment that is serviced regularly and thoroughly. The health and safety management system employed by Bauer Spezialtiefbau is routinely certified to OHRIS standard.

Environmental management
The construction industry inevitably has an impact on the environment. The challenge faced by all construction companies is to keep such impact to a minimum. BAUER Spezialtiefbau GmbH operates an EMAS-certified environmental management system and submits itself to environmental auditing procedures. Bauer Spezialtiefbau is also committed to collaborative, efficient working practices in the execution of its projects, which further helps to conserve resources.

Ethics Management System
BAUER Spezialtiefbau GmbH has established a binding programme of values. As a founding member of the German construction industry‘s ethical management association EMB Wertemanagement Bau e.V., it requires its employees to act in a manner conforming to the highest ethical standards. The ethical management practices of BAUER Spezialtiefbau GmbH are routinely audited and regularly recertified.

At Bauer workplace safety is more than an objective to be noted in a manual. It's a personal conscious commitment by Bauer and its employees who choose to except responsibility for safety.

John Holland,
HSE Director International Projects,
BAUER Spezialtiefbau GmbH

Sustainable Construction

In line with the international approach of various industries, Bauer contributes to achieving the “17 Sustainability Goals“ presented by the United Nations in its AGENDA 2030 with a selection of technologies and construction methods with minimal environmental impact and carbon footprint.

At Bauer, product sustainability is implemented in the design phase, continues in the execution phase and culminates in long-lasting products of the best possible quality, with low maintenance requirements. Real added value is achieved in the activation of geothermal energy, by installing suitable elements in walls and foundations. The digitalization of project construction sites, e.g., to optimize the construction process, and the development of electrified equipment further support the goal.

The selection of processes and materials in the planning phase are two important aspects to pave the way to product sustainability. Bauer has already proven with various DSM processes that the number of transports to and from the construction site can be significantly reduced. A reduction factor of well over 80% is achievable.

B sustainable

The use of the EFFC/DFI carbon calculator to compare the product carbon footprint of a retaining wall, constructed with standard diaphragm wall technology, according to EN 1538 with Mixed-in-Place (MIP) technology, is described in more detail by Hursit Ibuk, in the paper ‘Dry excavation pits installed with smaller carbon footprint by soil mixing, Deep Mixing Conference, DFI, Gdansk, Poland, 2020/2021’. Bauer has been executing permanent MIP walls as barrier walls in dikes for decades and recently also in dams with suitable geology.

INFO

Sustainable products in foundation engineering are no longer a pipedream. Such ideas are already being implemented at project sites, to take responsibility for future generations.

Geotechnical products need adequate building materials – simple. The complexity of the material behavior and in particular the challenge to meet all specific requirements for execution and across the product’s service life, involves six engineers and six technicians in BT dedicated purely to materials. Beside the worldwide support in technical optimization of materials – known for their major impact on carbon emissions of a construction – Bauer has always and will further continue to step up our efforts to high-ambitious sustainability goals.

Dr. Karsten Beckhaus,
Head of Technical Services Department, BAUER Spezialtiefbau GmbH

Projects

The many years of experience and the successful implementation of the existing innovative know-how are impressively demonstrated by the work carried out by our dedicated employees, the successfully implemented projects and satisfied customers. The benchmarks of quality and time are as essential for our clients, as they are for Bauer.

Bagatelle Dam (Mauritius)
New dam
The Bagatelle Dam project is located on the Terre Rouge River, circa 20 km southeast of Port Louise. The installed plastic concrete cut-off wall below the actual earthfill dam extends over a length of 2.4 km. Approximately 57,000 m² cut-off wall, with an average excavation depth of 24 m, and with the maximum depth reaching up to 44 m. Within the Central Area up to 28 m, basalt layers (UCS values up to 220 MPa) had to be excavated.


BAUER
BAUER MC 64
BAUER

The World is our Market

2002, 2017
Diavik, Canada

2006
Peribonka, Canada

2004
Kebir Dam, Tunisia

2019
Rosshaupten Dam, Germany

2020
Teller Dam, USA

2014
Center Hill Dam, USA

2007 – 2022
Herbert Hoover Dike, USA

2020
Monte Grande, Dominican Republic

2013
Daula Vince, Ecuador

2013
New Assiut Barrage, Egypt

2004
Naga Hammadi Barrage, Egypt

2012
Sylvenstein Dam, Germany

2017
Skhalta Dam, Georgia

2017
Mseilha Dam, Lebanon

2017, 2019
Jannah Dam, Lebanon

2004
Yeleh, China

2014
Mangdechhu, Bhutan

2012, 2015
Punatsangchhu-I and -II, Bhutan

2012
Matala Dam, Angola

2015
Bagatelle Dam, Mauritius

2019 – 2022
APC Dike 1, Jordan

2008
Hinze Dam, Australia

● A selection of key global projects

Jannah Dam (Lebanon)

The Jannah Dam, located on the Nahr Ibrahim River, approx. 30 km north-east of Beirut, is designed as a massive arch gravity dam, to store 38 million m^3 of water to feed the areas of Byblos, Beirut and its suburbs. The maximum height of the dam above the foundation level is 162 m. Reaching the dam foundation level at sound rock requires an excavation to some 65 m below the original ground level and river elevation.

Geology:
Heterogeneous soil condition, consisting of fill, cobbles and boulders of limestone, basalt and chert, sand, clayey sand, sandy clay, gravel rock. Moderately weathered and slightly weathered limestone (dolostone/dolomite), with UCS values up to 60 MPa.

Scope of work:
Cut-off wall: The installed cut-off walls are below the upstream and downstream cofferdams and extend over a length of 128 m (U/S) and 161 m (D/S). Approximately 9,500 m^2 cut-off wall, with a nominal thickness of 1.0 m (U/S) and 0.8 m (D/S). The maximum excavation depth is 42 m for the upstream cut-off wall and 50 m for the downstream cut-off wall.

Diaphragm wall (Bulkhead): The deep excavation to the dam foundation level is supported by an arch-shaped bulkhead, composed of three parallel diaphragm walls, each 1,200 mm thick, connected by a capping beam. The installed diaphragm walls with a total area of about 3,610 m^2, with maximum excavation depth of 38 m. The diaphragm walls extends over a length of approx. 80 m. The design concept comes from Bauer.

Along the dam foundation and in the abutments, consolidation grouting of the rock is performed, below highly stressed parts of the foundation. The grout curtain, consisting of drilling and grouting in several galleries and on the steep slopes, is to be executed in order to control seepage in the rock foundation of the dam. The maximum drilling depth currently reached is 94 m. Special rails with a mobile platform are constructed on the slopes, in order to drill and grout the slopes ahead of the RCC dam construction.

INFO

Construction Methods: Diaphragm wall, grout curtain, piles

Construction Materials: Plastic concrete, structural concrete, grout

Main Equipment: Cutter, small drilling rigs, BG

Construction Period:
Cut-off wall: August 2017 - December 2017
Diaphragm wall: October 2018 - February 2019
Grout curtain: 2020 - ongoing

A bulkhead arch-gravity diaphragm type shoring wall as a three-layer, each layer 1.20 m thick, which is to support the 38 m deep excavation to reach the dam foundation level, was executed for the first time at a large dam.

Georges Abdo, Managing Director,
BAUER Lebanon Foundation Specialists S.a.r.l.

Skhalta Dam (Georgia)

The Shuakhevi Hydro Power Plant (Skuakhevi HPP) is a run-off-the-river plant in Adjara, Georgia. It will have an installed capacity of 185 megawatts. The plant will have the capacity for diurnal storage in two reservoirs. The 22 m high Skhalta dam, with a 19.4-hectare reservoir and the 39 m high Didachara dam, with a 16.9 ha reservoir, allows Shuakhevi HPP to store water for up to 12 hours. Three main tunnels are to be constructed on the Shuakhevi project: the 5.8 km Chirukhistsqali to Skhalta transfer tunnel, the 9.1 km, Skhalta to Didachara transfer tunnel and the 17.8 km Shuakhevi head-race and pressure tunnel. The Shuakhevi HPP in the Adjara Autonomous Republic is part of a three-step cascade on the River Adjaristskali.

Geology:
Heterogeneous soil conditions with fill (0 - 35 mm), gravel, sand, silt and clay and bedrock (Andesite Basalt).

Scope of works:
133 nos. secant piles, with a nominal diameter of 1,500 mm, were executed with 500 mm intersecting between adjacent piles. Average depth amounted to 26.5 m; the longest pile depth was 34.3 m. A total of 3,526 lin. m. of piling was

installed as specified, piles at the abutments had to be embedded at least 1 m into the competent rock. Other piles were designed to be embedded into the coarse alluvium, a stratum below a 2 m thick clay layer. All pile depths and rock/alluvium levels were checked and confirmed by inspectors from the Consultant.

Miscellaneous:
Harsh winter conditions – temperatures during pile construction were as low as -20° C (-25° C when considering the wind chill).

INFO

Construction Methods: Secant pile wall

Construction Materials: Plastic concrete

Main Equipment: BG 28 with oscillator

Construction Period: October 2016 - Febuary 2017

Shkalta Dam project required tailormade solutions for a remote COW. Geometric and weight restrictions for mobilization of equipment prohibited the economic use of a trench cutter – a secant pile wall was the solution. A huge temperature variation between summer and winter proposed a challenge for our in-house mix design experts #BAUERPOWER.

Knut Pielsticker,
Business Development,
BAUER Spezialtiefbau GmbH

New Assiut Barrage (Egypt)

The Assiut Barrage is a dam structure across the river Nile in the vicinity of the city of Assiut in Upper Egypt (400 km south of Cairo). The Assiut Barrage was constructed between 1898 and 1903 across the Nile, approx. 560 km downstream of the Aswan Dam. Along with the old Aswan Dam, the Assiut Barrage today remains in service as the oldest barrier on the Nile in Upper Egypt. Following the results of a feasibility study, the decision was taken to proceed with the project of constructing the New Assiut Barrage and Hydropower Plant approx. 200 - 300 m downstream of the existing dam.

INFO

Construction Method: Diaphragm wall, piles, barrettes, wells

Construction Materials: Self-hardening cement-bentonite slurry, structural concrete

Main Equipment: Cutter, BG

Construction Period: November 2012 - December 2016

Scope of works:

- 60,000 m² of temporary single-phase cut-off wall with a depth 38.2 m (November 2012 - February 2013)
- 57 Dewatering wells (42 offshore + 15 onshore) with average depth of 45 m (March - May 2013)
- Permanent double-phase cut-off wall: 12,000 m² (July - September 2014)
- Foundation barrettes: 18,000 m² (September - December 2014)
- Pile wall: 450 piles with a diameter of 1 m and a depth of 30 m (September - November 2015)
- Permanent double-phase cut-off wall for the closure dam: 20,900 m² (October - December 2016)
- Diaphragm wall: 19,000 m² with a depth of 15 m

Miscellaneous:
Cut-off wall for a ring dam in the river Nile, harsh weather conditions, temperatures of over 50 °C.

For the implementation of the project, the installation of a temporary cut-of wall was required within the ring cofferdam, which is constructed to encapsulate the later excavation pit. Bauer used self-hardening slurry (single phase cut-off wall), instead of ordinary double phase cut-off wall. In addition to overcoming a tight time schedule and hard geological conditions, the project gains cost optimisation and low permeability due to wet-to-wet technique which decreases cold joints to minimum.

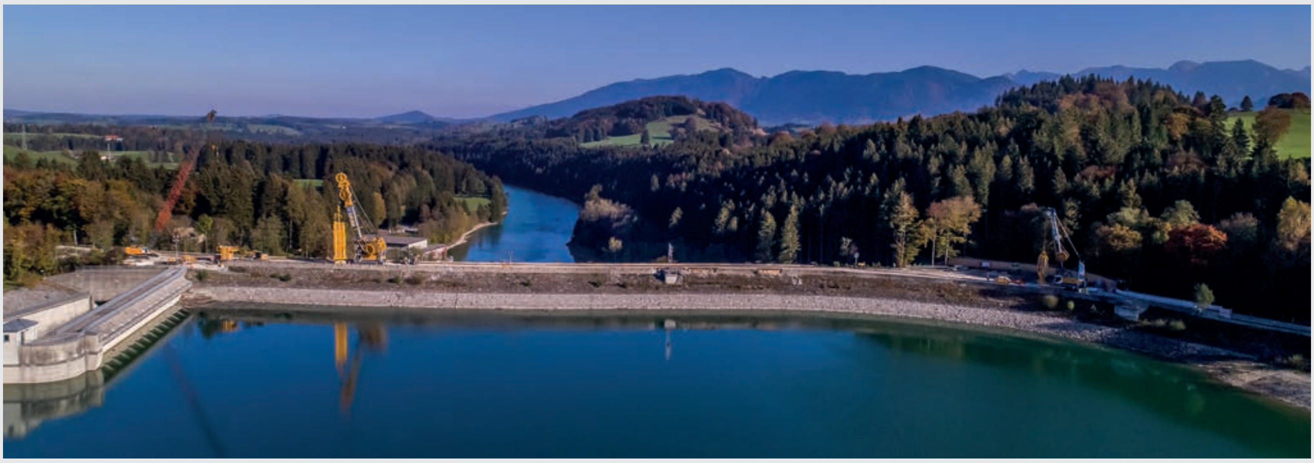
Ashraf Wahby,
Technical Manager,
BAUER EGYPT S.A.E. Specialised Foundation Contractors

Rosshaupten Dam (Germany)

The Rosshaupten Dam is located in the South of Germany, close to the famous Neuschwanstein Castle. The dam is forming the Forggensee, which is the largest reservoir in Germany in terms of surface area.

Scope of works:
Bauer was awarded the construction of the plastic concrete cut-off wall, including additional exploratory holes and the implementation of a soil stabilization work package, which was executed ahead of the actual cut-off wall installation.

A drilling and grouting campaign was executed to seal specific areas of the dam body, to a maximum depth of 85 m. In order to protect the core of the dam structure, i.e. to avoid a cracking risk as far as possible, drilling in the dam body was carried out by sonic drilling. The Wassara percussion drilling method was used for the bedrock. Grouting in bedrock was carried out according to the GIN method. In total, a grout curtain with an area of 3,300 m² and approximately 275 m³ cement slurry was grouted above, in and below the interface between the dam body and the competent rock. A unique application was the installation of a MIP retaining wall (pls. to page 15).



Another element of the preparatory work was the removal of buried existing reinforced concrete structures, up to 48 m deep. All obstructions within the cut-off wall alignment were removed with a drilling rig BAUER BG 40.

Geology:
The dam structure is an approximately 40 m high, earth-filled dam. The bedrock consists of alternating claystone and marlstone layers, permeated by bands of sandstone, as well as coal in some places.. The undecomposed bedrock on the Rosshaupten Dam shows compressive strengths up to 85 MPa.

INFO

Construction Method: Diaphragm wall, grouting, Mixed-in-Place and coring

Construction Material: Plastic concrete, grout, soil slurry mix

Main Equipment: Cutter, grab, small drilling rigs, MIP rig, BG

Construction Period: September 2017 - April 2019

Miscellaneous:
In order to meet the specifi ed construction schedule, the cut-off wall works had to be executed through the winter months facing the harsh winter conditions. Temperatures during wall installation were as low as -10° Celsius and this required special winter set-up for the mixing plants, as well as the slurry lines.

Six years after the successful completion of works on the Sylvenstein dam, Bauer was awarded another contract to install a cut-off wall in an existing dam body in the south of Germany. Widening the dam crest could be avoided, due to Bauer´s turnable hose drum system, which additionally saves on time and costs.

Stefan Jäger, Tender Engineer,
BAUER Spezialtiefbau GmbH

Monte Grande Dam (Dominican Republic)

The Monte Grande Dam, in the southwestern province of Barahona in the Dominican Republic, is an important infrastructure project for the country. In addition to controlling water levels in the Yaque del Sur River, the 55 m tall dam will also be used for flood protection and generation of hydroelectric power. Other aspects include tourism and the use of the water from the reservoir, for irrigation of agricultural land. A zoned earth-filled dam, with asphaltic core and an impermeable plastic concrete base foundation cut-off wall was constructed.

Scope of works:
In total Bauer built approx. 26,000 m^2 of cut-off wall over a length of 1,350 m. The average excavation depth was 20 m with a maximum depth reaching up to 31 m.

Geology:
Heterogeneous soil conditions with horizontal and inclined layering and variable thicknesses of generally three groups of soils and rocks. Aquifer made of loose granular materials. They are continuous and of variable extension, made of unconsolidated clastic sediments, like silts, sands, gravels and boulders. The recent quaternary alluviums and alluvial terraces are up to 14 m thick.

Miscellaneous:
A particularly challenging aspect were the extremely variable working platform elevations, which ranged between 152 m and 197 m above sea level and which occurred over the entire length of the cut-off wall alignment. To cope with these differences, in total 17 different working platforms were created, from which the cut-off wall was constructed.

Bauer was involved at early design stage with the client in the project preparation phase, mix design and technical assessment and later mobilized on time the most avanced equipment to the site and executed the works within the agreed schedule.

INFO

Construction Method: Diaphragm wall

Construction Material: Plastic concrete

Main Equipment: Cutter and grab

Construction Period: May 2019 - May 2020

Monte Grande was a challenge that finally became a success. Further to the method, mix and set-up optimization, the client experienced the Bauer added-value when we adapted to the specific requirements, project constraints, re-designs and executed took fast decision, due to unforeseen events.

Jaime Sobrino,
Technical Manager, BAUER Fundaciones Panamá, S.A.

Teller Dam (USA)

The Teller Dam at the Turkey Creek River is located within the U.S. army post Fort Carson, south of Colorado Springs in Colorado. The remediation works are coordinated by the U.S. Army Corps of Engineers (USACE). The prime contractor, Komada LLC, commissioned BAUER Foundation Corp.

The intent of the cut-off wall is to intercept potential seepage pathways that could contribute to internal erosion of dam material along the dam and abutment contact. The cut-off wall consists of two sections, a secant pile wall through the left end of the dam and abutment and at the abutment contact, and a grout curtain to further extend the interception of seepage pathways at the left abutment.

The secant pile wall and grout curtain´s total length in plan view is approximately 106 m, reaching a maximum depth of 36.5 m.

Geology:
The encountered bedrock during the cut-off wall installation is a mixture of Glencarin shale and Dakota sandstone, with rock strength (UCS) exceeding 100 MPa.

Scope of works:
- 1,189 m² of secant pile wall
- 1,175 m² of grout curtain

Miscellaneous:
The pile execution had to follow tight verticality requirements and a minimum pile overlap and minimum continuous cut-off wall thickness had to be guaranteed throughout the entire pile length, despite the challenge of a very steeply angled soil-rock interface. According to the specification, three different methods for verticality measurements (DIS, RIS, PRAD) had to be executed, to confirm the required cut-off wall parameters. In addition, verification holes were cored between two adjacent piles and CCTV and OPTV surveyed.

The grout curtain installation included drilling of the embankment soil and bedrock, with specific core drilling in combination with packer grouting. The Klemm 806 drill rig was used supported by an automated grout plant and a grout buggy.

Grouting works included real-time computer monitored single and double packer grouting, considering the upstage grouting method, but also the downstage grouting method in specific cases. Lugeon testing and OPTV surveys were executed, to identify potential rock fissures.

INFO

Construction Method: Secant pile wall, grout curtain

Construction Materials: Concrete, grout

Main Equipment: BAUER BG 39 with oscillator and Klemm drilling rig

Construction Period: August 2019 - October 2020

The project was planned, executed and completed successfully according to the Quality Control requirements. The most challenging part was executing the secant pile wall between the Dam Embankment and the Dakota Sandstone Foundation interphase slope.

Cyril Bou-Sleiman, Project Manager,
BAUER Foundation Corporation

SITE C (Canada)

British Columbia Hydro and Power Authority (BC Hydro) is building the third hydro-electric power plant on the Peace River in northern British Columbia. The dam is being constructed nearby Fort St John. The Peace River is a 1,923 km-long river, that originates in the Rocky Mountains of northern British Columbia and flows to the northeast through northern Alberta.

The objective of the dam is the creation of a third hydro-electric power plant on the Peace River in northeast British Columbia (B.C.). B.C. is the westernmost province in Canada, located between the Rocky Mountains and the Pacific Ocean. The dam will be a source of clean, renewable and affordable electricity in B.C. It will provide enough energy to power the equivalent of approx. 450,000 homes per year in B.C.

Geology:
Dike fill material (thickness between 4 to 6 m, with a grain size of 3 inch down) and heterogeneous soil condition: clay, silt, sand, gravel and cobbles, weak sandstone and mudstone.

Scope of works:
80,000 m² cut-off wall, with a wall thickness varied between 600 mm to a maximum of 1,800 mm, over a total length of approx. 3.7 km. The wall had to be embedded into the weak sandstone / mudstone rock. In places up to 3.8 m rock embedment was achieved to reach the designed wall toe levels. The panel excavation reached a maximum installation depth of approx. 25 m.

Miscellaneous:
In order to meet the specified construction schedule, the cut-off wall works had to be executed during the harsh winter months of Northern Canada. Temperatures during wall installation were as low as -25° C. The main cut-off wall construction works were carried out in multiple shifts 24 hours a day, 7 days a week.

INFO

Construction Method: Diaphragm wall

Construction Materials: Selfhardening CB slurry

Main Equipment: Grab

Construction Period: August 2016 - November 2017

Once built, Site C will be a source of clean, reliable and affordable electricity in British Columbia for more than 100 years. Bauer has constructed cut-off walls along the Peace River, using self-hardening slurry through the man-made dikes and original overburden with a key into the underlying bedrock. These cut-off walls enabled very deep excavations behind the Peace River in the dry.

Endre Balogh,
Vice President of Estimating,
BAUER Foundations Canada Inc.

APC Dike 1 (Jordan)

The Arab Potash Company's (APC) site is located at the southern end of the Dead Sea in Jordan. Dike 1 is approx. 11.5 km long, forming the perimeter for several salt pans. The potash salt, being the basis for Carnallite production, is obtained in several solar ponds, with an area of 112 km², where the coveted raw material is concentrated by evaporation. What is interesting about this is that the basins are located around 400 m below mean sea level and therefore at the lowest point on earth (above water). The main purpose of this project is to rehabilitate the existing dikes, to improve their stability, mitigating the development of sink holes/cavities and interception of leakages from the ponds with associated losses of carnallite.

Scope of works:
Approx. 311,000 m² cut-off wall over a length of 11.2 km with a width of 640 mm. The actual wall set-up was varied between various sections. One stretch of the wall was excavated down to 18 m in combination with sheet piles driven by vibro equipment, some 4 meters into the soil below the bottom of excavated panels. Other stretches of the cut-off wall were constructed down to maximum 30 m, with installation of suspended sheet piles.

Miscellaneous:
Harsh weather conditions, temperatures approaching 50 °C and an extremely salty environment were just part of the challenges.

The subsoil presented a special challenge: The hard crystalline salt layers required the use of two Bauer cutter units, in combination with one grab unit. Also, the tremendously critical effect of the high salt content on the support fluid had to be addressed by developing innovative custom-made compositions.

The detailed production tracking with Bauer's b-project software provided, besides the web-based visualization of the progress, an effective instrument for the management and control of high-quality level of the construction works The completed sections of the wall, extending over several kilometres, have proven total efficiency. Measurements of the unambiguously significant raise of the differential hydraulic head on both sides of the cut-off wall, besides the completely disappeared water flow stretches on the downstream side, provided clear evidence for the success of the executed works to the stakeholders.

INFO

Construction method: Diaphragm wall, earthworks

Construction Materials: Plastic concrete, sheet piles

Main Equipment: Cutter, grab

Construction Period: January 2019 - December 2021 (ongoing)

Bauer brought its technology and expertise to one of the worlds harshest and extremely saline environments to construct a cut-off wall, using salt-resistant clay fluid to support the open trenches, allowing the novum of instrumentation-controlled placement of continuously interlocked sheet piles and back-filling with plastic concrete.

Khalil Daher,
Senior Project Manager,
BAUER International FZE

Aquila Mine (Australia)

A major mining company situated in Australia has recently re-opened a previously worked mine, which was in the Bowen Basin mining area in central Queensland, approximately 900 km north of Brisbane. In line with expansion plans for this seam, a new ventilation shaft was required. This vent shaft ensures clean/fresh air can be supplied to the underground mine workers.

Geology:
Tertiary clayey/sandy material from construction level down to 13 m. From 13 m down to 68 m, Permian coal measures consisting of sandstone/siltstone material were encountered. The Sandstone / Siltstone UCS strength ranged from 30 MPa, up to 90 MPa.

Scope of works:
- Installation of concrete collar slab for position and pressure tolerance
- 2.5 m dia drilled down to 13 m bgl; 2.4 m dia tertiary liner installed with rig to 13 m bgl; 2.2 m dia drilled down using 6 m long core barrel to 68 m depth
- Installation of 2.1 m OD liner to 68 m depth. Installed as 12 m sections and bolted together
- Drilling of 2 m dia through concrete plug and into top of working coal seam roof at 71 m

- Drilling of 2 m dia through concrete plug and into top of working coal seam roof at 71 m

Miscellaneous:
The verticality of the drilled hole had to be nearly perfect (i.e. 1:200) verticality – to ensure the full length liner was fully installed. To assist with ensuring this was achieved, Bauer utilised the specially adapted 6 m long core barrel tooling. To monitor the actual verticality of the hole as it progressed with depth, a special 3D laser surveyor was used. Sources of ignition are a major item when working with mines and as BFA were holing into a working coal seam with inherent, potential flammable gases present, therefore there could be no hot works carried out with the liners. So to join the liner sections (12 m) together BFA designed the connection points using the Bauer double wall casing locks.

INFO

Construction Method: Large dia vertical shaft

Construction Materials: Concrete, steel liners, grout

Main Equipment: BAUER BG 40

Construction Period: January 2020 - February 2020

One of our key mining clients in Australia engaged BFA to construct a near vertical ventilation shaft, from the surface, down to the working coal seam below, using conventional piling drill methods. The timeframe and quality of work completed by BFA was extremely valued & recognized by the client and ensured BFA was the market leader for this mining industry requirement.

Matthew Barber,
Senior Project Manger,
BAUER Foundations Australia

Subika Mine (Ghana)

The mine is located along the Sefwi Volcanic Belt, a north-east-southwest trending volcanic belt in Ghana. The mine is in the Ahafo region, approximately 307 km northwest from the national capital Accra.

Bauer was commissioned to construct the guide walls and subsequently install three shafts.

These ranged in diameter from 4.1 to 5.1 m. Two of the shafts were intended for the ventilation (Return Air Raise and Fresh Air Raise) and one for waste extraction for the Subika underground mine extension.

Geology:
Overburden soil in the upper 31 m followed by hard Gabbro rock with a strength up to 293 MPa.

Scope of works:
- Guide walls
- RAR shaft: 29 nos 1,180/1,060 mm Ø piles
- Waste Pass shaft: 25 nos 1,180/1,060 mm Ø piles
- FAR shaft: 24 nos 1,180/1,060 mm Ø piles

The piles had to have a rock socket of between 1.0 and 2.0 m, to ensure the piles were embedded in the solid rock and not the weathered rock.

Miscellaneous:
For RAR shaft having a diameter of 5.1 m, 24 secant wall piles, 4 bearing piles and 1 centre pile were installed. The maximum depth reached here was 21 m. On Waste Pass shaft, for recovering mine waste, fibre reinforced concrete plus standard reinforcement was used, with a 45 MPa concrete, to enable a higher abrasion resistance of the piles once the shaft was completed. The maximum depth of the 25 piles (20 secant wall piles, 4 bearing piles, 1 centre pile) reached 18 m. For RAR shaft, the diameter was 5.2 m. The 29 piles (24 secant wall piles, 4 bearing piles, 1 centre pile) installed reached a maximum depth of 31 m.

INFO

Construction Method: Secant pile wall

Construction Materials: Concrete, steel

Main Equipment: BAUER BG 28

Construction Period: August 2020 - February 2021

The mining industry has very high quality and safety standards. The choice of Bauer as contractor by all the mines in Ghana, relies on the guarantee that we provide on performing the works with high quality and precision, on respecting the environment, on avoiding all the hazards and using only experienced skilled people for each task.

Giuseppe Canducci PhD, Managing Director,
BAUER Engineering Ghana

Woodsmith Mine (England)

Woodsmith Mine, located near Whitby in North Yorkshire, is a deep potash and polyhalite mine.

The project involves Anglo American constructing the UK's deepest mine, which will see the company extract large quantities of Polyhalite for global distribution. The mine is the biggest mining project in Britain for decades; its twin shafts will be the deepest commercial mineshafts in Britain. A sensitive project, having attracted many objections along the way, developing the mine to extract the material from 1.5 km below the moors with minimal impact, was always going to require complex ground engineering solutions.

To comply with planning, the mine had to be low impact, which restricted it to having only two 60 m deep chambers, to house the headgear for the production and service shafts and a 37 km long tunnel, to take the material directly to port facilities at Wilton in Teeside. Three shafts were required from ground level for production, services and one for launching the 5 m diameter tunnel boring machines (TBM), that will drive the first section of the 37 km material transport system (MTS) tunnel at 360 m depth to Teeside.

Geology:
Mudstone and Sandstone; classed as weak to medium-strong.

Scope of works:
- Service shaft headgear chamber to 60 m depth, 35 m dia; 48 no. 2.8 m wide and 1.2 m thick panels
- Production shaft headgear chamber to 60 m depth, 32 m dia; 44 no. 2.8 m wide and 1.2 m thick panels
- Production shaft main shaft to 120 m depth, 8 m dia; 14 no. 2.8 m wide and 1.2 m thick panels

Miscellaneous:
To guarantee the specified vertical tolerance of 200 mm, various survey methods had to be combined, which were documented in a 3D BIM model. In addition, a large quantity of bentonite slurry had to be reconditioned in a complex desanding plant and by use of specially designed polymer-based additives. Notwithstanding the often extreme weather conditions, such as high winds and heavy snow, which were also challenging.

The intermittent nature of the geological lamination made the cutting process technically challenging and required the deployment of a number of combinations of cutter wheel configurations to optimise performance.

INFO

Construction Method: Diaphragm wall

Construction Material: Structural concrete

Main Equipment: Three BAUER BC 40 cutters on MC 96 and MC 128 duty-cycle cranes, and complex desanding plants.

Construction Period: October 2017 - December 2018

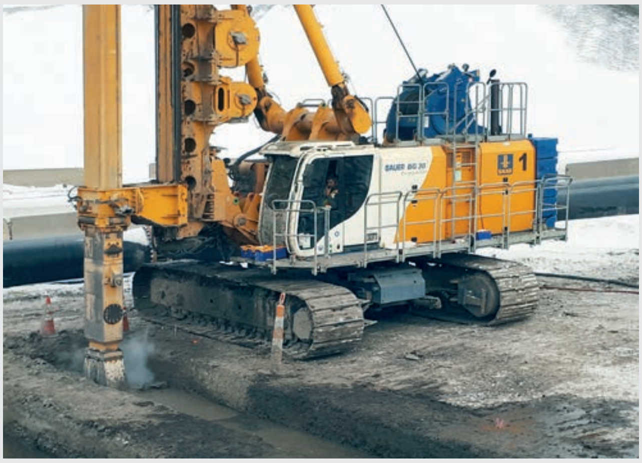
Our diverse team of diaphragm wall specialists implemented a rigorous H&S and quality control system, which allowed us to install Europe's deepest diaphgram wall shaft within extremely tight tolerances and to the full satisfaction of the client.

Gustav Jahnert,
Senior Project Manager,
BAUER Technologies Limited

Red Dog Mine (USA)

Red Dog Mine, one of the world's largest zinc mines, is located in the northwest of Alaska, around 170 km north of the Arctic Circle and nearly 1,000 km to the northwest of Anchorage. A ground improvement program was implemented as a practical risk reduction strategy, to counteract strength reductions and settlement, which could be expected if the frozen,ice-rich native coarse warm permafrost soils, which underlie a tailings dam, were to thaw and be subjected to a seismic event, inducing liquefaction. Due to the unique nature of the soils and to confirm the achievable treatment parameters, prior to planning the full-scale ground improvement program, a ground improvement field trial program was carried out, before the final design of the liquefaction mitigation system. The two ground improvement techniques selected for the field trial, were CSM and jet grouting. The results of the field trail identified the CSM method as the most suitable choice for the main scope.

Scope of works:
Field Trial: CSM panels 5 no, (2 of which were pre-drilled using Kelly pre-drill methods), jet grouting 18 no, and verification coring



Main Scope:

- Pre-drill piles 660 no., 1,000 mm diam
- CSM panels 462 no., 1,000 mm width

Geology:
Fill, native soil (that requires treatment), bedrock.

Miscellaneous:
One of the main challenges was the mobilization of equipment. Some equipment was transported by plane and then by ship from Seattle Harbor, across the Bering Sea, to a dock just over 80 km from the mine. Other equipment was transported via Hercules aircraft, from Anchorage airport to the airport on the mine site.

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Construction Method: Cutter Soil Mixing, jet grouting, verification coring

Construction Materials: Soil-slurry-mix

Main Equipment: BAUER BG 30 for pre-drilling and CSM, small drilling rig for jet grouting and verification coring

Construction Period: Trials in 2019, and main scope of works in 2020 and 2021

This project demonstrated Bauer's ability to find optimum solutions for our clients and, even when working in remote locations, showcased that we can undertake challenging projects in terms of operations, engineering and logistics; all to the satisfaction of the client and the engineer.

Bryn Harris,
Project Director,
BAUER Foundation Corporation

BAUER Spezialtiefbau GmbH
BAUER-Strasse 1
86529 Schrobenhausen, Germany
Tel.: +49 8252 97-0
bst@bauer.de
www.bauer.de

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