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The application of several construction methods at dam projects in Asia

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Intro

The construction of dams in Asian countries include different tasks considering the geological conditions of the sites like terrain, overburden, bedrock, etc. which demand a tailor-made solution for the foundation works. Considering the individual site/project specific technical solutions would vary from maximum depth of the seepage barrier, access roads to the site for equipment movement, etc. This paper discusses the most sustainable foundation techniques or construction methods or geotechnical works a specialist foundation contractor with global experience can offer to ensure the long-term safety of existing and/or new dams gathered from experience of executed projects. The paper outlines various technologies and construction methods adopted at Semantok Dam (Indonesia) for the execution of a cut-off wall by means of secant pile wall; Diaphragm wall and jet grouting at Teesta VI HEP (India), Grout curtain by means of permeation/TAM grouting at Arun 3 (Nepal), and finally Jannah Dam (Lebanon) constructing the Cut-off wall and bulkhead by means of diaphragm wall and drilling and grouting at Jannah Dam (Lebanon).

1. Background

For investors and designers involved in Water Resource Development projects cut-off walls provide several opportunities. During the planning of a new Water Resource Development project, one of the major obstacles is finding a location with suitable geological and hydrological formations, including fulfilling the environmental and social expectations. Due to the current equipment available and the several construction methods, cut-off walls can be installed in any type of ground condition and up to 150 m to provide a reliable, durable and impermeable system which ensures efficiency, durability, stability and safety for the project. Thus, the cut-off wall makes selection of the project site that bit easier. 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 - efficiency and durability, as well as other performance specifications impairing the life span of the structure, as required by the design and intended purpose.
As part of dam safety programs worldwide, 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 particular geology like Karst or alluvial/colluvial sediments, often fail to meet the degree. 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 and tailings facilities). Our core competencies include various technologies or a combination of techniques. 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. The successful completion of our work as a contribution to client satisfaction is based on our knowledge of digitalization in civil engineering, the ISO 9001 standard, and the associated standards and norms.
Likewise, the quality management is based on a project-specific quality management plan, to ensure the agreed quality of the work. Our digitization tools and monitoring capabilities are supporting this quality assurance, all aimed at improving our services. A carefully planned, certified and implemented HSE management system accompanies the planning and production processes.

2. Southeast Asia

Based on relevant news, new dams will be constructed, and existing dams will be rehabilitated and upgraded during the next 10 years in several East Asian countries. A project we were recently involved in is described below.

2.1 Semantok Dam, Indonesia

Semantok Dam is located in East Java province, in the district of Nganjuk. Approximately 670 km east-south-east of Jakarta, the capital of Indonesia. The dam will be the longest in Southeast Asia with a dam crest length of 3,100 meters. The dam with a zonal type random fill and clay core will have a height of 31.56 meters. Later, this dam can accommodate water with a total capacity of 32.67 million cubic meters, so that during the dry seasons this dam can supply water (Fig. 2). It is also expected to irrigate 1554 Ha land and generate 1.01 MW electrical power. The employer is the Directorate General of Water Resources, Ministry of Public Works and Housing of Indonesia. PT BAUER Pratama Indonesia was appointed to construct the cut-off wall by means of secant pile wall for the Semantok Dam by Hutama–Bangunnusa KSO as main contractor.

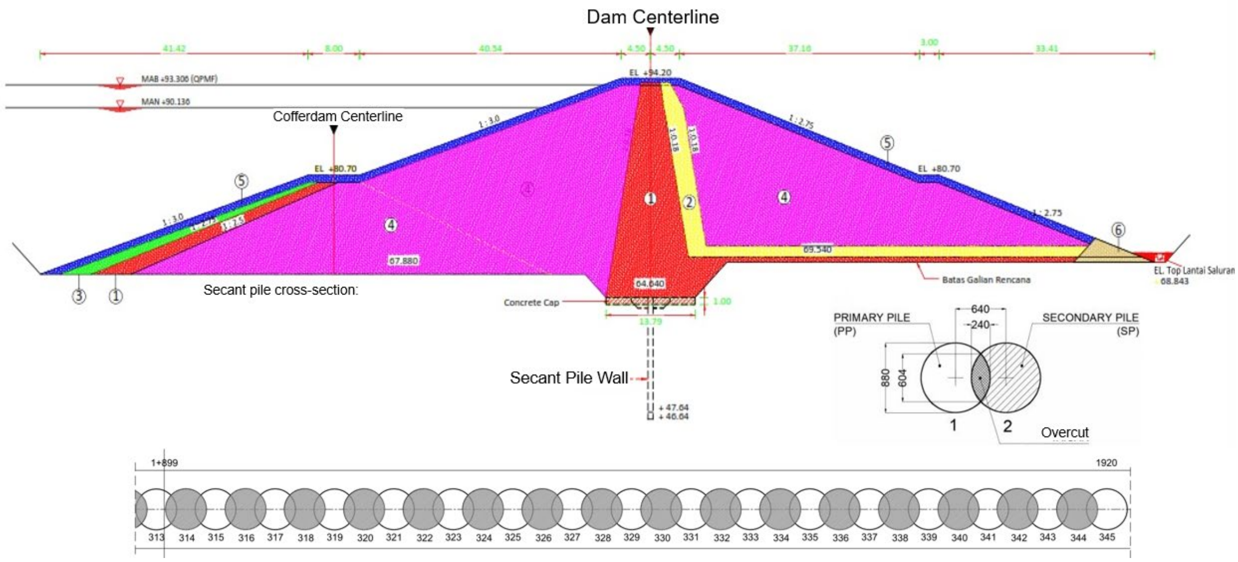

Fig. 1. Typical cross section showing the secant pile wall beneath the main dam, and pile layout

An unreinforced secant pile wall (Fig. 1), diameter 880 mm with a depth up to 25 m cast with plastic concrete, was constructed for a cut-off wall. Spacing 640 mm c/c to have a minimum wall thickness of 600 mm after overcutting. The specification of this wall is to have a cut-off wall with an elasticity modulus equal to maximum 5 times of the surrounding ground material. Permeability test was mandatory for this wall, and the coring position is on the overcutting area (in between the primary & secondary). Works were carried out from various working platform levels which follow the cut-off trench level that is equal to the pile cut off level. Due to the low plastic concrete strength, special attention was paid to the secondary pile drilling process to avoid cracking the primary pile. Two units BAUER BG 28 were deployed. In total 1104 nos. Secant piles were executed to create a cut-off wall alignment with a total length of 703 m.

The geological conditions in the cut-off wall alignment were heterogeneous. Between the top and the toe of each pile the following layers were encountered: clay, tuff rock, sandy clay, tuff rock, sandstone, siltstone, sandstone.

The requirement of verticality of the drilled holes is 1:100, each of the piles must be checked by ultrasonic verticality tests. There are several cases of flooding throughout the construction period. To prevent our equipment from being trapped in flood, an escape route (evacuation ramp) was identified, and flood sensors installed. Monitoring staff also standby to monitor the upstream area 24/7.

All falling head permeability tests, which are the key to the success of this project, produced results much higher than the requirement. The cut-off wall by means of secant piles was constructed between November 2019 and June 2020.

Fig. 2. Execution of secant pile wall (left), and picture showing the current status of the project

3. South Asia

The main rivers in South Asia originate from the Himalayan Mountain Range, which are young mountains with highly fractured rock formations. The construction of foundations for hydro power projects in the mountains has many challenges which have to be addressed. The below subsections describe two projects from India and Nepal and the foundation works executed.

3.1 Teesta VI Hydroelectric Power, India

The Teesta-VI hydroelectric power project is a 500-MW-run-of-river project under construction in Sikkim, India, by Lanco Teesta Hydro Power (LTHPL), a subsidiary of National Hydroelectric Power Corporation (NHPC). The power plant is expected to be commissioned in March 2024. The Teesta-VI hydroelectric power project is part of six hydroelectric projects being developed on the Teesta River. It is located near the village of Subin Khore in southern Sikkim. The contract for the foundation engineering and geotechnical works for the Teesta-VI hydropower project was awarded to BAUER Engineering India. The company is responsible for the construction of an anchored pile wall, a grout curtain along the upstream cofferdam and a diaphragm wall on the upstream side of the barrage (Fig. 3).

Fig. 3. Overview showing the scope of works consisting of several construction methods

The section details on the construction of the jet grouting works in the boulder strata of the river borne material to depths of 35m below bed level. The construction of the upstream coffer dam at Teesta VI HEP requires the installation of Jet Grouting Columns. The river born material are mainly cobbles and boulders to depths of 35-45 m below the existing bed level of the river. Among the various ground improvement solutions proposed jet grouted columns were selected as the most preferred technique to seal the ground under the site-specific conditions.

However, to establish the efficiency of jet grout columns in such soil conditions the execution of a trial shaft is mandatory. It is essential that the same parameters are used during the trials as subsequently for the main jet grouting works, i.e. overlap between adjacent columns, grid, and jetting-parameters. A total of 12 nos. of jet grout columns distributed at a circle with an equal spacing were executed (Fig.4). Toe elevation of these columns was at 327 MSL, top elevation was at 342 MSL. Additionally in the middle portion of shaft a plug consisting of 7 nos. jet grout columns have been executed from 326.5 MSL to 331.5 MSL.
Pre-drilling in designated column locations was executed, thereafter the jetting in the same pre-drilled hole with the same jetting parameters as the main jet grout curtain. The first 12 nos. of columns in the periphery of the shaft were jetted and after finishing all outer columns, the inner plug columns were jetted. After completion of all columns, (the shaft was left for) a period of 15-20 days was allowed for the strengthening of the jet grout columns installed. Thereafter excavation started from EL 343.0 m level (Fig. 5). After the completion of jet grouting in shaft, 2 nos. of observation holes were drilled up to the same bottom level of the shaft i.e., EL 327.0 m at 4 m and 8 m from the edge of the shaft respectively in one alignment for the monitoring of the ground water level. After the completion of drilling activity, perforated pipes were installed in the drill hole for ground water monitoring.

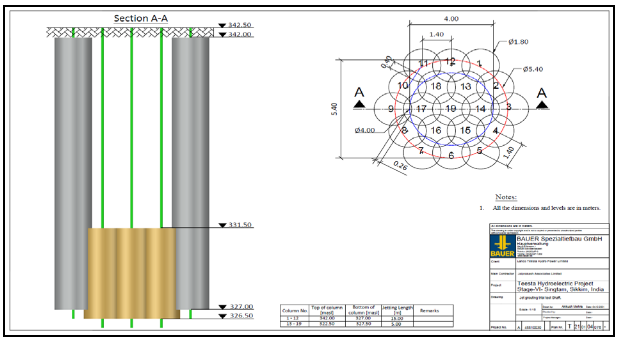

Fig. 4. Showing the jetting sequence and jetting depth of trial shaft

Fig. 5. Excavation of shaft

As per visual inspection during excavation of the shaft it was found that there was no seepage of ground water through jet grout columns even the excavation of the shaft up to EL 336.0 m that means the grout columns are properly overlapped and the curtain is acting - as seepage barrier structure. After the installation of the jet grouted columns and observing the seepage conditions the columns for the main works are installed.
The selection of the technique depends on the prevailing soil conditions, the scope of work and technical specifications. The chosen method for this project is the high pressure cutting with cement slurry and air assistance (Double Air system).

3.1.1 Procedure of installation of jet grouting works

Along the alignment there were different existing ground levels, which had to be taken into account with regard to the jet grouting works. As a result, the works have to executed in 4 phases to ensure proper bonding between the jet grouted columns. The coordinates of JG column points will be calculated from setting out data provided in the construction drawing. The JG column points will be fixed using Total Station. Due to the difficult nature of the soils to be drilled, separate per-drilling with an air driven DTH hammer was required. Predrilling was performed using a Symmetrix system with an air driven DTH hammer, with outer casing D 152 mm and inner rods D 90 mm. The casing diameter was 152 mm, pilot bit (hole) diameter 164 mm. Redrilling and jetting of production columns involve rotary drilling which will be done inside the predrilled hole with 114 mm jet grouting rods equipped with a 160 mm reamer. Water or a thin cement grout is used as flushing means for redrilling (Fig. 6). The quality assurance for the controls during predrilling works, jetting works, testing of bentonite and grout slurry, sampling and testing of grout cubes are carried out and recorded. Any unexpected drilling condition encountered is noted briefly in the records and brought to the attention immediately.

Fig. 6. Redrilling for jet grouting and predrilling of the holes in the boulder strata along the alignment

3.2 Arun III Hydroelectric Power Project, Nepal

Arun-III Hydroelectric Project is a Run-of-River scheme, located on the River Arun in Sankhuwasabha District in the eastern development region of Nepal. The Arun River is one of the major tributaries of the Koshi River in the Sapta Koshi basin. BAUER was awarded the execution of a grout curtain consisting of three rows on the upstream cofferdam.

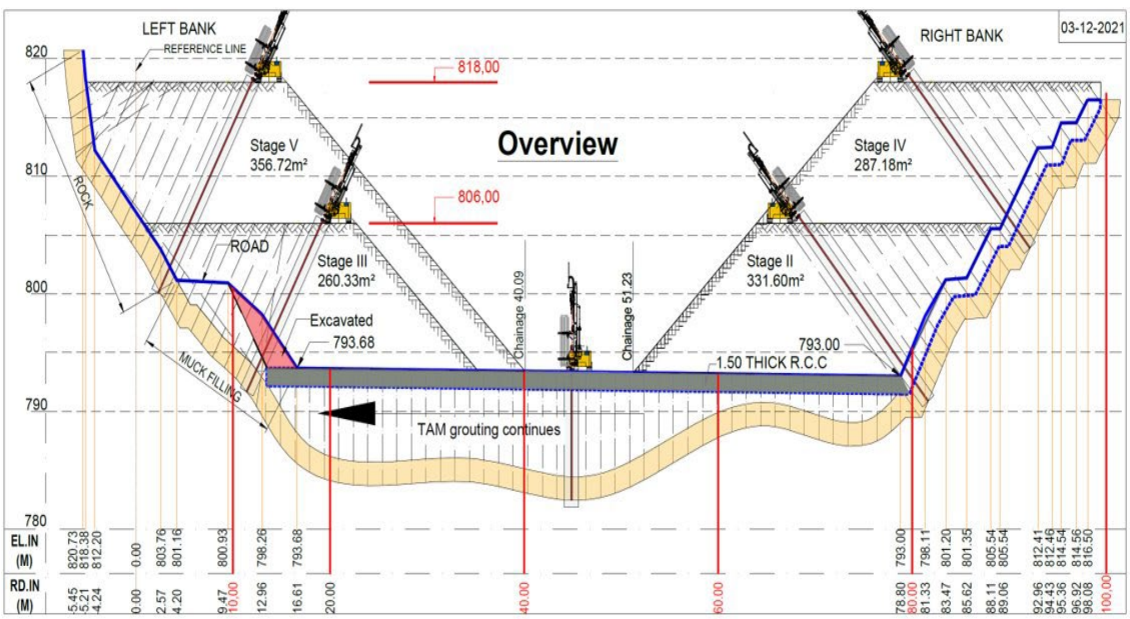

Fig. 7. Typical cross section of upstream coffer dam with grouting scheme geological condition

Drilling works consisted of drilling 3439 m, executed by means of a double head rotary drilling rig of Klemm 909-02 D model with 1100 CFM compressor unit and the drilling system adopted is symmetrix drilling by casing advance method (Fig. 8). Grouting works were executed with 4 nos. of DP-63 Obermann Pumps with complete mixing plant setup and data logging arrangement. The length of grouting in overburden by Tube-à-manchette was 3128 m, while in fresh rock it was 319 m (Fig. 7). The soil profile mainly consisted of alluvium and colluvium, consisting of sand, gravel, pebbles and boulders, followed by bedrock (gneiss and schist). UCS values of bedrock and boulders in the river valley vary in a range of 30 to 110 MPa.

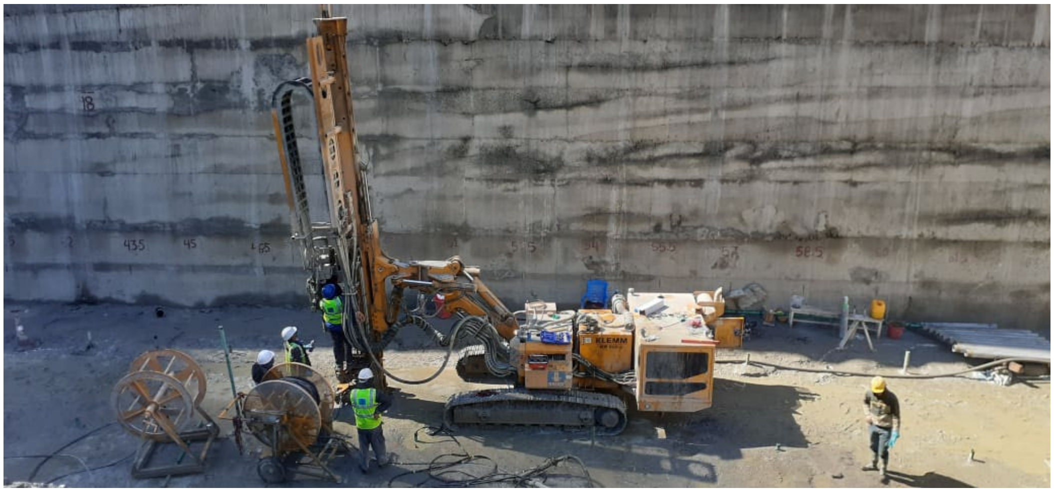

Fig. 8. Drilling and grouting works in progress

4. Western Asia

During the last years several hydro-projects were planned and executed in the Republic of Lebanon. Mainly to store water and to prevent potable water for the cities of Beirut, Byblos and suburbs and for irrigation purposes.

4.1 Jannah Dam, Lebanon

The Jannah Dam, located on the Nahr Ibrahim River, approx. 30 km north-east of Beirut (capitol of Lebanon), is designed as a massive arch gravity dam, to store 38 million m^3 of water. 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.
The soil condition at dam site can be described as very heterogeneous, consisting of fill, cobbles and boulders of limestone, basalt and chert, sand, clayey sand, sandy clay, gravel rock. Lab trials, performed in advance, showed UCS values up to 60 MPa for the moderately and slightly weathered limestone (dolostone/dolomite).
Since 2017, Bauer has been contracted several times by the main contractor. The scope of works included along others the following (Fig. 9).

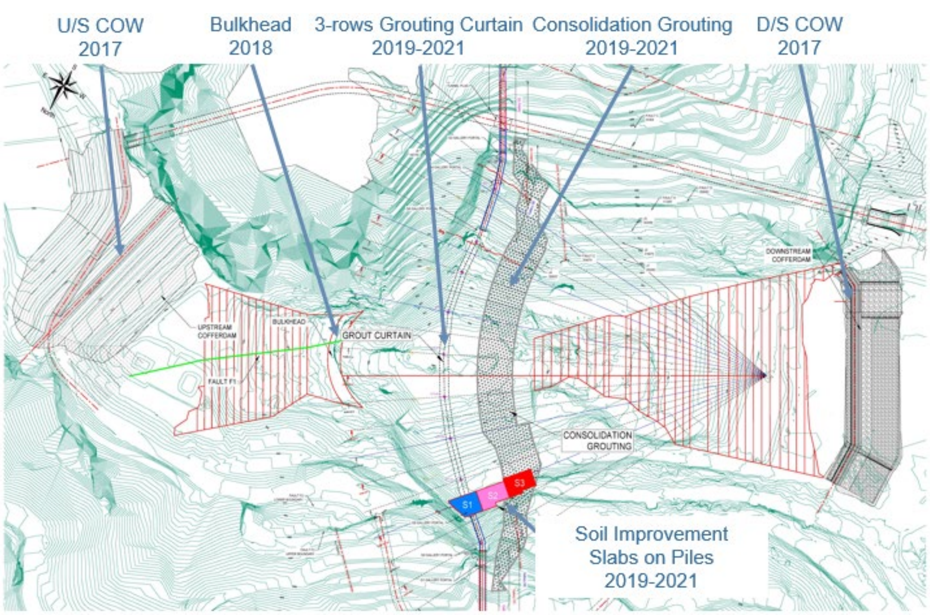

Fig. 9. The foundation engineering measures executed - general layout [1]

- Cut-off wall by means of diaphragm 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 m² 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, composing of three parallel diaphragm walls, each 1,200 mm thick, connected by a capping beam. The installed diaphragm walls have a total area of about 3,610 m², and a maximum excavation depth of 38 m. The diaphragm walls extend over a length of approx. 80 m. The design concept comes from Bauer (Fig. 10 & 11)

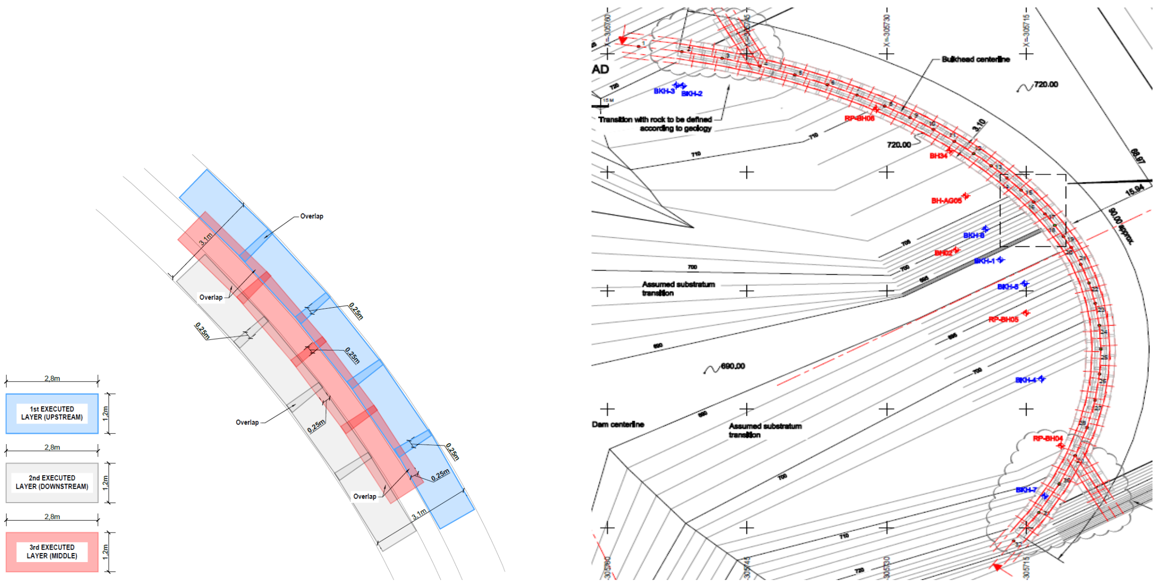

Fig. 10. Bulkhead executed as overlapped diaphragm walls

Fig. 11 Execution of diaphragm walls to create a bulkhead

- 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 (Fig. 12). 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.

Fig. 12 Mobile platforms on special rails for drilling and grouting works on slopes, exposed bulkhead in the background (left) [1], and working in galleries using electrical drilling rig (right)

5. Summary and Conclusion

For more than 30 years, BAUER Spezialtiefbau GmbH, together with its subsidiaries, has been successful in the field of design and execution of specialist foundation services, including cut-off walls for dams, dikes and levees. 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 valued employees, the successfully implemented projects and satisfied clients. The benchmarks of quality and time are as essential for our clients, as they are for us.

References

1. **Adnan, M., Baltruschat, M., Abdo, G., Daher K.** „Jannah Dam in Lebanon – a remarkably broad range of applied geotechnical works" Proceedings, Indian Geotechnical Conference 2022

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