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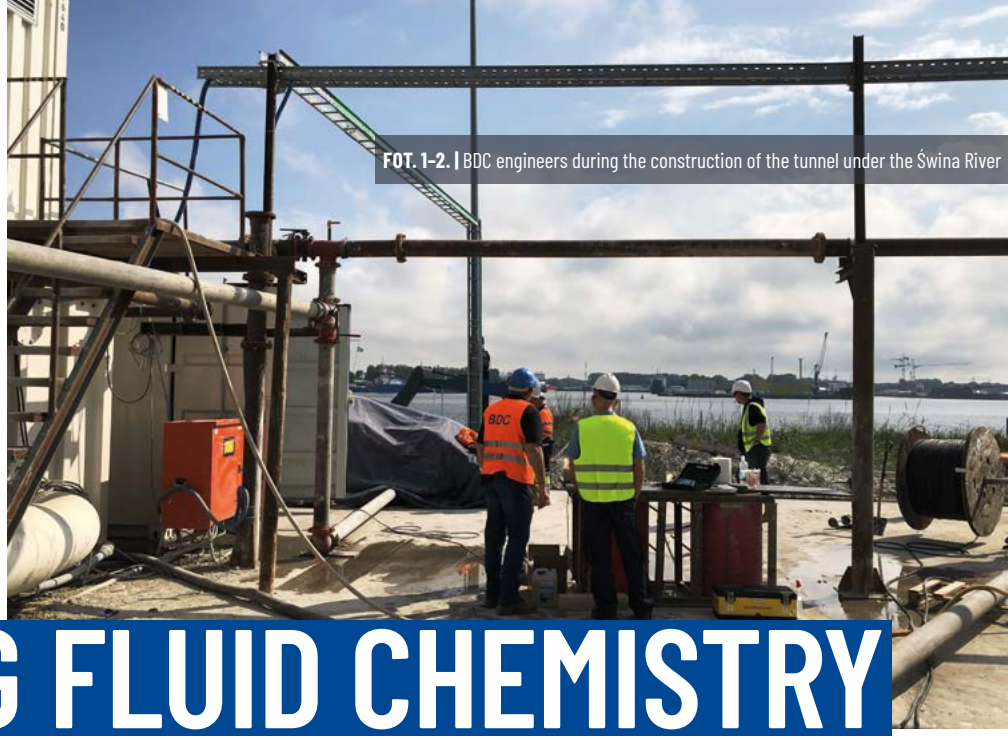

**FOT. 1–2.** | BDC engineers during the construction of the tunnel under the Świna River

# DRILLING FLUID CHEMISTRY
## AT THE CONSTRUCTION OF THE SWINOUJŚCIE TUNNEL
### AN INVESTMENT FULL OF CHALLENGES

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## YOU WILL LEARN:

- ☑ **What tasks were undertaken by BDC Poland,**
- ☑ **Which flushing system was implemented,**
- ☑ **Which specialized agents were required to resolve the TBM servicing issue.**

BDC International has been servicing engineering projects worldwide since 1976. Not only as a producer of drilling fluids, but also as a provider of comprehensive technical solutions. In 2021, representatives of its subsidiary, BDC Poland, supported the road connection project beneath the Świna, known as the SWINOUJŚCIE TUNNEL The primary goal of this endeavor was to connect the territories of the islands of Uznam and Wolin. This task was accompanied by a series of engineering challenges where the expertise, experience, and measures applied by BDC proved crucial.

Our activities focused on the following areas:

1. Determining the parameters and supplying the flushing system for the TBM,
2. Selecting flocculants for the drilling fluid treatment system,
3. Employing specialized agents to address the engineering challenges arising during the project.

## FLUSHING SYSTEM

The proper drilling fluid must be selected in accordance with the geological conditions and technical parameters of the project. However, we often encounter various constraints that must be taken into account so that the designed fluid not only meets drilling requirements but can also be processed with the available equipment—such as mixers, flocculation stations, existing screens, etc. Another factor is the drilling crew's established practices, which can frequently become a challenge and force a compromise between seemingly irreconcilable conditions.

The proposed system, based on the bentonite product Swellgel MA was modified not only on-site during operations but also at the production level. It was characterized by low viscosity—al-

lowing an increased solid phase—and by a flat flow curve.

An additional component was the product EM35®. This unique liquid polymer blend offers a wide range of applications. In appropriate doses, it acts as a flocculant, prevents the hydration of clayey formations, and significantly reduces friction. This material has repeatedly proven effective in even the most challenging engineering works. As a component of the drilling fluid, it is an indispensable "rescue" additive in cases of stuck drill pipes. EM35® is a liquid additive for drilling fluids based on a multi-molecular polymer emulsion. It is easily soluble in water and exhibits multifunctional properties.

The addition of Polymer EM35® to the flushing fluid results in:

- Formation of encapsulating sheaths and reduction of hydration in the drilled clayey rocks,
- Stabilization of the wellbore wall,
- Increase in the viscosity of the flushing fluid,
- Improvement in the flushing fluid's ability to clean the drilling tool and transport cuttings from the wellbore,
- Reduction of torque and friction forces during the retrieval of drilling rods through improved lubricating properties,
- At low concentrations (10–100 g/m$^3$), promotion of fines flocculation and prevention of the dispersion of the solid phase within the fluid.

These characteristics—specifically the flat flow curve and reduced friction coefficient—directly influenced many aspects of the drilling process, including cuttings transport, wellbore wall protection, and prevention of drilling fluid migration into rock formations. The achieved lubricity reduced friction between the cutting tool and the formation, ensuring more efficient drilling and extending the service life of wear parts—an aspect often overlooked. The applied flushing system maintained a constant fluid viscosity despite increasing shear rates and proved effective in transporting cuttings. As a lubricating liquid delivered via nozzles, it provided adequate lubrication, significantly reducing forces during excavation (see Table 1).

An extremely important element of large-scale drilling operations is ensuring a continuous supply and readiness to respond immediately to material requirements. Logistics becomes a challenge when high consumption of material is combined with limited capacities for receiving and storage (e.g., the number of silos and spatial limitations at the construction site). Timely deliveries, material readiness, and the availability of engineers ready to respond immediately were key aspects of BDC's service. The production team, collaborating companies, drivers, and coordinators all contributed to maintaining continuous operations, eliminating potentially costly downtimes, and ultimately ensuring timely project completion, as confirmed by the main contractor's official reports and correspondence.

## DRILLING FLUID TREATMENT

BDC supplies flocculants to numerous industrial sectors. One of the strongest product groups in our portfolio is specialized polymers. In the project under discussion, the drilling fluid treatment system was based on a flocculation station.

The selection of flocculants is a key process in many fields. Flocculation is a technique that aggregates small suspended particles into larger clusters that are easier to remove. This process is therefore crucial in fluid treatment, including in drilling and engineering applications.

The choice of the appropriate flocculant depends on several factors, such as the type and size of the particles, process conditions, the pH of the environment, temperature, and the presence of other chemical substances. There are many types of flocculants available, including salts, polyelectrolytes, and organic polymers.

## LABORATORY TESTS

BDC has extensive experience in selecting flocculants. To properly choose a flocculant, it is recommended to perform laboratory tests or small-scale trials to assess the effectiveness of various chemical agents under specific process conditions. It should be remembered that selecting the proper solution is crucial, as it significantly impacts both process efficiency and production or treatment costs.

Samples of the processed drilling fluid were delivered to the BDC laboratory for optimal flocculant selection. The laboratory report indicated that the supplied material was a heterogeneous mixture with a dry mass concentration of approximately 0.7% SOM. Due to its specific gravity, it naturally sediments; the separated supernatant water has a whitish tint. After 120 minutes of drilling, the water becomes turbid and contains numerous suspended particles, so BDC's objective was to select the best agents to obtain clear water suitable for discharge.

The treated water should exhibit low turbidity (NTU), and the additives must act quickly—the rate of sedimentation is a key indicator. The selection of the appropriate agent for a given project is a painstaking process. In this article, we will limit ourselves to demonstrating the effects of using the optimal preparation. The most efficient product in physicochemical terms enables the overall process of drilling fluid treatment to be more economical. In summary, the optimal agent among those tested turned out to be „P-Floc 23".

The flocculation process proceeded efficiently so that the separated supernatant water could be pumped out without issues, and the sedimented fluid could be processed—either by feeding it to dewatering equipment

| Composition | Fann 600/300 reading | plastic viscosity [cP] | yield point [lb/100sqft] | structural strength [lb/100sqft] 10" i 10' | friction coefficient [-] |
|---|---|---|---|---|---|
| EM35® - 5 kg/m$^3$ | 23/16 | 7 | 9 | 0"/4' | 0,18 |
| EM35® - 6 kg/m$^3$ | 31/22 | 9 | 13 | 4"/5' | 0,15 |
| EM35® - 7 kg/m$^3$ | 34/24 | 10 | 14 | 5"/7' | 0,13 |
| EM35® - 8 kg/m$^3$ | 36/27 | 7 | 20 | 7"/9' | 0,1 |

**TAB. 1. |** EM35 Additive in the TBM Flushing System. Source: Own elaboration

| Coagulant | Flocculant | Dosage | Mixing Time | Flocculation Value at 4 cm | Turbidity after 5 Minutes | Sedimentation Rate $v_{sed.}$ | Remarks |
|---|---|---|---|---|---|---|---|
| | | [g/m$^3$] | [s] | [s] | [NTU] | [m/h] | |
| P93 10% r-r | P21 0.1% r-r | 04 / 1 | 60 + 30 | 8 | 6 | 18 | |
| P93 10% r-r | P21 0.1% r-r | 04 / 1 | 60 + 30 | 6 | 4 | 24 | |
| P93 10% r-r | P22 0.1% r-r | 04 / 1 | 60 + 30 | 16 | 6 | 9,0 | |
| P93 10% r-r | P23 0.1% r-r | 0,4 / 0,5 | 60 + 30 | 9 | 5 | 16,0 | pH 6,0 |

**TAB. 2. |** Flocculant Selection. Source: Own elaboration

(such as a filter press or centrifuge) or by removing it with mechanical devices.

## SPECIAL AGENTS

Special agents and tailored solutions have been, and continue to be, an integral element of many operations. There arises a problem that requires a coordinated response from the entire team and all cooperating entities. Such a situation occurred during the Swinoujście Tunnel project—specifically, the need to service the cutting elements of the cutter head.

Drilling tunnels using a TBM (Tunnel Boring Machine) is an advanced method of tunnel construction that employs a specialized machine equipped with a cutter head. TBM cutter head servicing refers to the maintenance, repair, or overall servicing of the machine during tunnel excavation. This is a critical aspect to ensure that the TBM operates efficiently and safely throughout the project.

Servicing TBM cutter heads is a comprehensive process that requires precision and a strong focus on safety. Key steps in TBM cutter head servicing include:

1. Air Injection.
   During TBM tunnel excavation, ensuring proper ventilation is essential—especially in underwater tunnels. Special equipment and ventilation systems are used to inject air into the tunnel.
2. Entry of Service Personnel.
   The engineering team undertakes tasks such as checking the condition of the cutter head, removing deposits, and addressing faults.
3. Replacement of Cutter Head Elements and Repairs.
   TBM components are replaceable, with wear rates depending on the type of ground being excavated. During servicing, it may be necessary to replace cutter head elements—for example, the cutting roller—and perform all necessary repairs or adjustments to ensure proper machine operation.
4. Inspection and Maintenance.
   Regular inspections are crucial for the early detection of potential problems. Service technicians check the condition of the cutter head, mechanical and electrical systems, and carry out maintenance to ensure optimal TBM performance.

**FIG. 3. |** Mixture before and after the application of P-Floc 23

It is important to emphasize that servicing TBM cutter heads requires specialized knowledge and experience, and all actions must adhere to safety standards and procedures. In the initial stage, specialists encountered a challenge: the service chamber was not maintaining the required pressure. Consequently, the procedures outlined above could not be executed. The service personnel were unable to perform their tasks, and the machine could not continue operation. In an emergency intervention, BDC Poland engineers arrived on-site carrying specialized polymers from the LCM group.

Polymer Modisorb was chosen for application. The active substance in this product is used as a component of drilling fluids due to its thickening and stabilizing properties. This polymer is capable of absorbing and retaining large quantities of water, leading to swelling. This water absorption ability enables the formation of a polymer network that increases viscosity and reduces fluid permeability. During drilling, the drilling fluid can penetrate rock formations—especially if they are highly porous. Modisorb helps form a barrier on the borehole walls, reducing the likelihood of fluid migration into the formations. As a component of the drilling fluid, the material forms a polymer network that effectively stabilizes the borehole walls, preventing collapse or erosion. Notably, this material features a short polymer chain—a characteristic of significant importance in this application. Polymer substances with varying molecular weights and degrees of hydrophilicity can be tailored to the specific needs of drilling applications. For example, short-chain polymers may be more effective at preventing drilling fluid losses, while long-chain polymers might better thicken the fluid.

Upon application to the drilling fluid, the special agent penetrated the rock fissures and expanded several times in volume. Modisorb, used to seal losses of the flushing fluid, performed excellently by maintaining the pressure required for servicing operations.

The solutions selected on-site, the choice of the appropriate system and products, and the application of practical knowledge of the phenomena occurring in the excavated formations—all based on accumulated hands-on experience—helped meet the contractor's requirements and address the challenges encountered during the work. The proper selection of products and the commitment of the entire team enabled improved drilling efficiency and minimized potential issues related to technological downtimes, thereby contributing to the overall success of the project. We are proud to have been part of this endeavor, marking a positive chapter in the history of completed projects. |

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