FEATURE ARTICLE

OUTSTANDING PROJECT AWARD RUNNER UP

Partnering for Cutoff Wall Project Success

The East St. Louis Deep Cutoff Wall project is located in the area of East St. Louis, Illinois, across the Mississippi River from the city of St. Louis, Missouri, along the left descending bank of the river. The project is a fundamental part of the U.S. Army Corps of Engineers' (USACE) effort to rehabilitate and secure the aging East St. Louis levee system that provides flood protection to approximately 250,000 residents and more than $4.5 billion in economic value.

The project was devised and designed by USACE as a cutoff wall to be installed in the Metro East Sanitary District levee segment, one of the levee segments that form the East St. Louis system. The contract for the construction of the cutoff wall was awarded in November 2019 to Bauer Foundation, the American subsidiary of the Bauer Group.

Project Design

The design provided for the installation of an approximately 4,440 ft (1,350 m) long cutoff wall, with a minimum 24 in (610 mm) thickness and a maximum design depth of more than 140 ft (43 m). The cutoff wall extends through alluvial and outwash soils, which include a highly permeable gravel and cobbles layer, and is embedded by a minimum of 2 ft (0.6 m) in hard limestone with an unconfined compressive strength up to 25,000 psi (172,370 kPA). The wall was excavated by the panel method, comprising overlapping primary and secondary panels, each no more than 30 ft (9 m) in length. The maximum allowed vertical deviation of each panel was 0.5% of its full depth.

The cutoff wall was installed following the single-phase process. This process requires that a self-hardening slurry be used as the excavation fluid. Once panel excavation is complete, the slurry is left in place to cure and thus becomes the cutoff wall's final backfill material. The slurry, designed by the contractor, meets the following specified stringent requirements: unconfined compressive strength between 50–250 psi (345–1,725 kPA) and maximum hydraulic conductivity of $1x10^{-6}$ cm/s.

Two 80 ft (24 m) long openings or "windows" were located along the cutoff wall alignment. The windows were due to the presence of vital underground utilities, passing through the wall alignment. One of the utilities serves the purpose of flood control, while the other one supplies water to the surrounding areas.

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Several other major utilities crossed — and in some cases ran parallel to — the cutoff wall. Among the many utilities, it is worth mentioning the following: A high-voltage transmission line and a gas pipeline, which ran parallel to the cutoff wall along its entire length and crossed it at the upstream end; a conveyor belt that crossed the cutoff wall to transport grains from storage silos located on the land side of the wall to barges stationed along the Mississippi's shore. Also, a bridge crossed the river, to connect Missouri and Illinois, close to the north end of the cutoff wall.

The project design included the installation of nine inclinometers in sets of three. Two sets were installed at the location of a cutoff wall demonstration section while the third set was installed around 3,000 ft (915 m) downstream. The purpose of the inclinometers was to monitor any movement of the surrounding soils that could signal any potential collapse of the excavation trench. A series of increasing movement thresholds and alarm triggers were set so that the onsite personnel would be immediately notified once any of the thresholds were surpassed, so that appropriate, and preplanned, emergency actions could be taken immediately.

Cutoff Wall Construction Equipment

The contractor determined that the installation of this cutoff wall required the use of a hydraulic clamshell grab (Bauer DHGV) combined with a cutter (Bauer BC-40), both mounted on Bauer MC-96 cranes. The cutter was equipped with a portable desanding unit.

The batching plant, where the self-hardening slurry was produced, was equipped with five mixers (three Bauer CMS-45 dedicated to the preparation of the self-hardening slurry and two Bauer SKC-30 for the batching of bentonite slurry), tanks for water storage and bentonite hydration, vertical and horizontal silos for bentonite and binder powders, insulated and heated containers where additives were stored, and two trailer mounted 500 kW generators. Due to the winter conditions in the area, the batching plant complex was enclosed in an insulating structure.

Self-Hardening Slurry Mix Design Program

The self-hardening slurry is a combination of water, hydrated bentonite slurry, binder and additives. The slurry has the property of solidifying after a curing period that varies based on the ratios between its ingredients. The contractor performed an extensive mix design program to identify a mix that best suited the geotechnical properties of the excavated soils and guaranteed the desired workability life of up to 40 hours, rendered necessary by the need to excavate triple-bite panels with a minimum 2 ft (0.9 m) embedment in the hard bedrock layer.

Cutoff Wall Installation

The installation of the cutoff wall was carried out in two stages: a demonstration section stage and a production stage. The scope of the demonstration section phase was to verify that the construction method provides a cutoff wall that meets the specified requirements. This stage was followed by a quality control testing period at the end of which, the contractor was required to prepare and submit a comprehensive construction report for USACE's review and approval. Once approved the demonstration section would become part of the final cutoff wall.

The contractor received the notice to proceed in January 2020 and, after a mobilization that proved unusually challenging due to the effects of the COVID-19 pandemic, proceeded with the installation of the demonstration section, which was successfully completed in May of the same year. Upon USACE's approval of the construction report, the production stage started at the end of July 2020. The installation of the first production panel saw a series of adverse occurrences manifesting themselves all at the same time (severe weather, including violent lightning storms, and a wall section with extremely hard bedrock, to mention a few) to create the proverbial "perfect storm" that resulted in the cutter getting trapped at the bottom of the panel at a depth of approximately 140 ft (43 m). In response to the issue, and to ensure that the project schedule was not affected, the contractor flew in a second cutter unit that was never utilized since the original cutter was retrieved from the excavation 17 days later. In the months that followed, crews installed the remaining 260 panels to successfully complete the cutoff wall construction. The major issues experienced during the production stage were the presence of obstructions, consisting mostly of industrial remnants; and a high slurry overconsumption that reached peaks of almost 130% and averaged at about 90%, due to the higher than anticipated permeability of the gravel layer.

Additional Work at the Cutoff Wall Windows

In early 2021, USACE consulted with the contractor regarding its intention to reduce the untreated area at each one of the two windows. Expressing interest to pursue USACE's goal and, after a request for proposal was issued by USACE, the two teams partnered to achieve a design that would meet the necessary hydraulic requirements, while being constructible. The final design comprised a combination of additional single-phase cutoff wall panels and jet grout columns to be installed at each one of the two locations. The cutoff wall was to be installed above and to the sides of each utility while the jet grout columns would provide as much closure below the utilities as possible. Most of the columns installed under the utilities were angled between 15–30 degrees from the vertical to form a fan-shaped jet grout curtain. A few vertical columns were installed to the sides of one of the

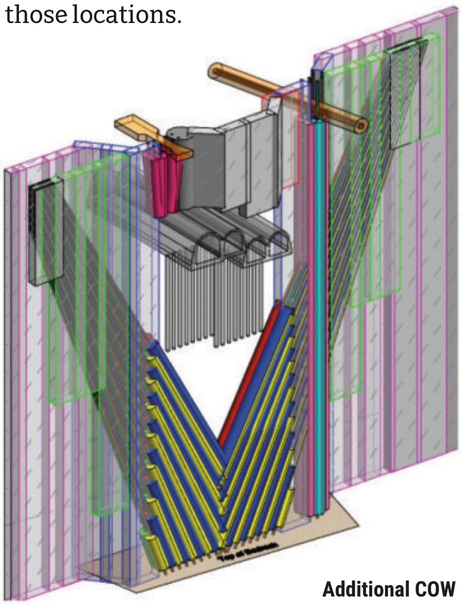
Completed panel excavation at the downstream end of the project

Cutter working in close proximity to a conveyor belt

Cutter excavating bedrock at the upstream end of the project (Stan Musial Bridge in the background)

A few vertical columns were installed to the sides of one of the utilities as an alternative to cutoff wall panels

utilities as an alternative to cutoff wall panels. Due to the presence of other utilities that ran across the cutoff wall alignment and that could neither be relocated nor interrupted, the installation of panels was not feasible in those locations.



Additional COW and jet grouting columns design

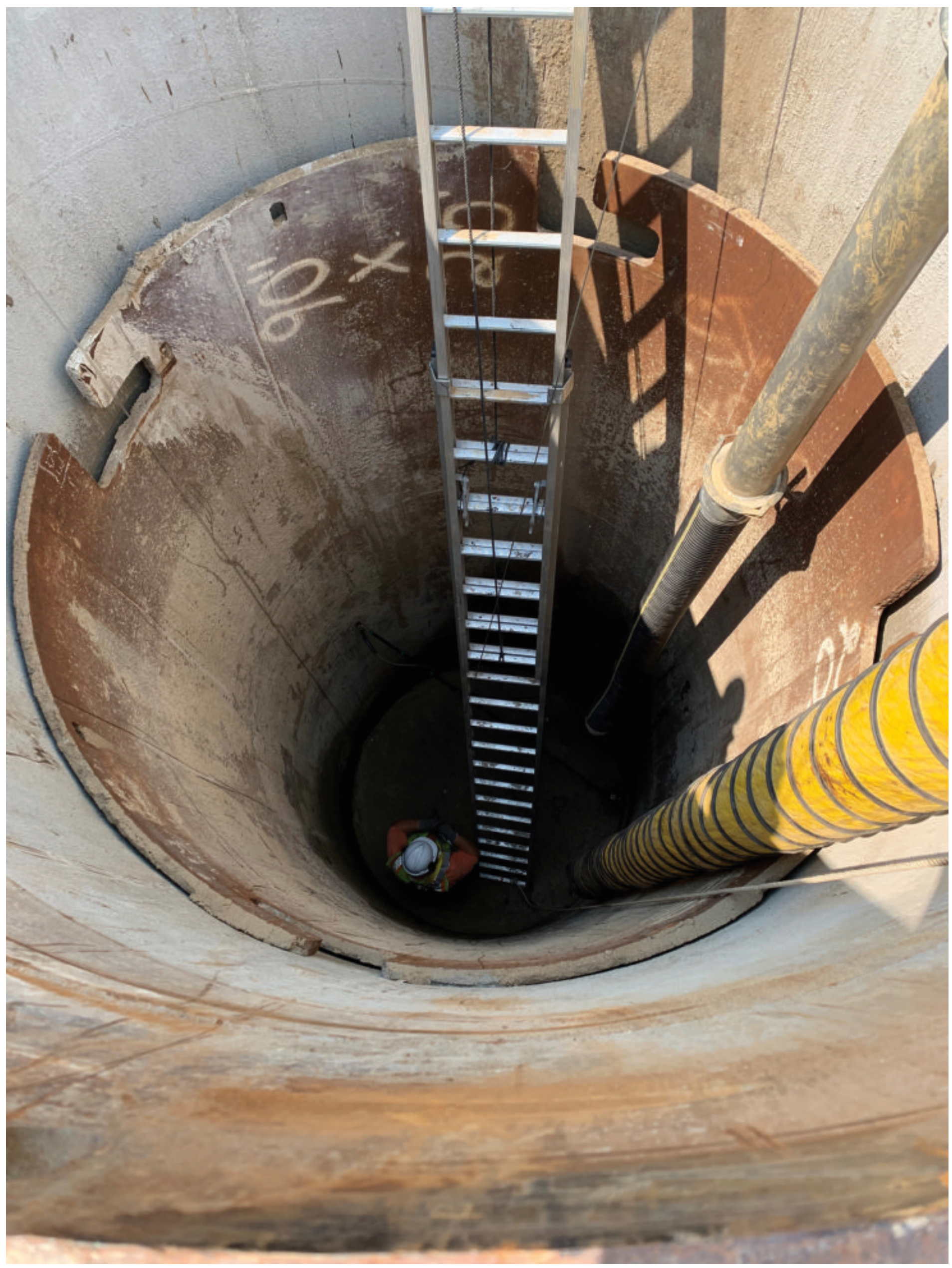
The specification required that the jet grout curtain be a minimum 30 in (760 mm) wide. In order to confirm the continuity and minimum thickness of the curtain continuity, all columns were surveyed for verticality.

The limited information regarding the exact location and structural conditions of one of the two utilities required that preventative measures be set in place prior to the commencement of construction operations. The contractor, in collaboration with USACE, determined that it was vital to first locate the utility and then devise a system to monitor it for potential movement during construction. The solution envisioned by the project team provided for probing of the utility from the bottom of cased drilled shafts. After the probing was completed, a movement monitoring system designed by the contractor was installed inside the shafts, which were then backfilled with self-hardening slurry.

The contractor ran a pump test at each window before the installation of the jet grout curtain took place. During the pump test, water flow and piezometric levels at several nearby piezometers were recorded documenting the hydraulic conditions prior to installation of the curtain. At each window, the collected data provided a baseline that was used later to compare to the data recorded after completion of the curtain.

Additional Cutoff Wall Panels and Jet Grout Columns

The contractor decided to make no changes to the cutoff wall installation procedure, given the excellent results previously achieved, and to install the jet grout columns using the single fluid method. The additional cutoff wall panels were installed using the same rigs and batch plant as utilized before. For the installation of the jet grout columns the team mobilized a Klemm KR 720 drill rig and a smaller batch plant that included high-pressure



Cased drilled shaft for utility location at a window

Jet grouting rig installing a column

pumps, slurry mixers, and vertical and horizontal silos. Crews installed a total of 167 columns between October 2021 and April 2022.

Upon completion of the jet grout curtain, the columns were left to cure. Subsequently, the contractor ran a second pump test, measuring the same parameters as before. The pump test data was analyzed and USACE expressed its satisfaction with the hydraulic conditions after curtain installation as documented by the test results.

Project Construction Results

Construction reached completion in April 2022 to the full satisfaction of the owner and none of the 265 panels comprising the original cutoff wall required any remediation work, nor did any of the additional panels installed at the two windows. The cutoff wall far exceeded the required minimum thickness set by USACE at 24 in (610 mm). The average hydraulic conductivity of the cutoff wall, tested on wet grab samples, was two orders of magnitude lower than

Jet grouting plant

Cutoff wall completion

the required hydraulic conductivity of $1x10^{-6}$ cm/s. The average unconfined compressive strength was within the 50–250 psi (345–1,725 kPA) range, and no specimen was either below 30 psi (207 kPA) or above 275 psi (1,896 kPA), as required by the specifications. Horizontal elevation cuts of the wall generated in 10 ft (3 m) vertical intervals demonstrated the continuity of the cutoff wall. All 22 verification borings drilled along the wall confirmed the continuity of the wall and proved its homogeneity.

The jet grouting barrier met all specification requirements, too. The total of just over 160 overlapping columns produced a curtain that reached the minimum required width of 30 in (760 mm). All wet grab samples tested at least one order of magnitude lower than the required hydraulic conductivity of $1x10^{-5}$ cm/s. A 3D model of the installed columns proved the continuity of the jet grouting barrier, confirmed in the field by 11 verification borings, each one drilled at the center of a cluster of three columns. The integrity of the utilities was maintained throughout the whole process and no significant movement was recorded.

Conclusion

The project faced several challenges throughout its whole duration. Some challenges were expected such as the technical complexity, due to several factors such as the depth of the wall, the hardness of the bedrock and the design of the jet grout curtain; or the logistical complexity, due to the presence of many utilities. Some challenges were due to worse than anticipated conditions, like the high slurry overconsumption caused by the higher-than-expected permeability of the gravel layer. Other ones were unforeseeable, like the COVID-19 pandemic that directly affected the lives of millions of people, disrupted supply chains and transportation, and made planning extremely difficult; or like the anomalous severe weather events that impacted project operations. Nevertheless, the contractor was able to produce a high-quality final product and the project was completed on time and within budget, to the satisfaction of USACE.

Col. Kevin Golinghorst visits the jobsite during the COVID-19 pandemic

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