A COMPARISON OF TRENCHER METHOD VS. SLURRY TRENCHING AND SOIL MIXING FOR CUTOFF WALLS IN DAMS

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ABSTRACT

In recent years, the chain-style trencher has been proven a valuable tool for installing vertical walls on challenging sites where conventional methods may be less desirable. Like many tools, trenchers are most effective when used with the right application. Trenchers are commonly used for applications that could also be completed with conventional slurry trenching; low-permeability cutoff walls, collection trenches and permeable reactive barriers (PRBs). Drawing from a wealth of experience with conventional slurry trenching and the trencher, this paper compares and contrasts the technical considerations, treatability, installation, performance, and lessons learned for recent projects.

INTRODUCTION

Slurry trenching is a method of construction that is widely used for the installation of cutoff walls. Details and overviews of slurry trenching are the subject of many other publications, as a start Ryan (1987) and Evans (1993). Recently the Chain-Mixing-Method (CMM), often referred to as the trencher-method, has been gaining popularity in the United States (US). Early versions of trenchers were used to install subsurface drains in the US dating back to the 1950’s (Bureau of Reclamation, 2008). These early trenchers used a variety of cutting implements such as wheels, buckets, etc. The more common bar and cutter chain style trenchers that are used today for soil mixing came into use in the mid 1980’s in Europe and Australia (Boersma, 2020). Since the early 2000’s specialty contractors in North America have innovated upon and retrofitted bar and cutter trenchers to handle installations of cutoff walls, collection trenches and permeable reactive barriers (PRB) on specialty civil and environmental projects.

The Japanese developed a similar bar and chain style cutter called the Trench Remiking Deep (TRD) method. The notable difference between this technique and the trencher is that the TRD bar is segmented whereas the trencher bar is fixed. While this technology is widely accepted for installation of cutoff walls, it has been excluded from this paper as the intent is to compare conventional slurry trenching methods with trencher style methods for cutoff walls, collection trenches and PRBs.

The CMM has been making its way into specifications for a variety of projects in the public and private sectors. In fact, the private sector has widely accepted the trencher, in some cases specifying the method, seeking the advantages that come with it.

In order to determine effective uses of the trencher it’s important to first review the advantages and disadvantages. First and foremost is the understanding that not all sites, equipment, and conditions are equal. Understanding the site constraints and equipment capabilities will always help determine the best method.

TRENCHER VS. SLURRY TRENCHING

The trencher is essentially a large mixing chain mounted on a tracked chassis, even more simplistically described as an excavator with the front end replaced with a chainsaw blade. The chain rotates around a
steel bar at a high rate of speed in a fixed position while the tracked chassis advances along the alignment. As the chain is moved through the subsurface, the soil is sheared or excavated. In contrast to slurry trenching, trencher installations can ascend and descend grades (generally 10% or less) as well as maneuver along curves. Cutoff walls installed using the trencher are mixed in-place and reagent addition can be adjusted along the length of the cutoff wall over short distances. Collection trenches and PRBs are constructed by excavating the soils while simultaneously emplacing the specified backfill through a narrow trench box fixed to the trencher’s arm. Conversely to low permeability cutoff walls, collection trenches and PRBs are designed to pass water and fluids (high permeability).

**Advantages of the Trencher vs. Slurry Trenching:**

- Can operate safely in tight spaces
- Eliminates the “open” trench reducing the risk of trench cave-in and falling/drowning hazards. Another safety advantage is less equipment operating on site as the trencher completes the work.
- Installations can be completed independent of the water table location or consideration of groundwater flow
- Potentially lower cost and shorter schedule
- High efficiency mixing is performed in situ and vertical blending is improved
- Less handling of contaminated materials
- Can accommodate low headroom once in the ground (~20-ft.)
- Contact between adjacent constructed elements (Stare et. al. 2017)

**Disadvantages or Limitations of the Trencher:**

- The bar and chain are designed for shearing soil, not rock, which makes excavation of large objects such as cobbles and boulders impossible.
- Trencher depth is generally limited to 50-ft. or less. A very limited number of trenchers exist that can handle depths greater than 50-ft. Depth is a function of the trencher chain bar whereas other in-situ mixing techniques are more readily available beyond 50-ft. deep, excavator slurry trenching methods can easily obtain 90-ft, and clamshell slurry trenching methods can be used beyond 90-ft.
- There is no “key” verification as the in-situ cutting and mixing eliminates the ability to retrieve key materials at depth.
- Underground utilities are somewhat challenging
- Full volume mixing and vertical homogenization makes it impossible to segregate excavation spoils from undesirable layers, like peat, or for potential reuse.

**DESIGN CONSIDERATIONS**

The design considerations generally relate to the collection of pre-construction data such as geotechnical data, chemistry, and site characteristics. This data is essential when considering what type of installation method to choose. When scarce or insufficient geotechnical data is provided, the method has to be selected using extrapolated data. As the data gaps increase, the risk of a change-of-condition increases which raises the potential for claims; an undesirable situation for all parties. Data gathering is often highly driven by cost, often to the detriment of the project. For instance, the cost of change orders from material differences will easily outweigh the cost of the right data collected at the onset of the project.

Understanding the groundwater level and groundwater flow characteristics is specifically important. One of the key features of the trencher is that it can effectively excavate or mix below the groundwater table, and mostly independent of the groundwater flow. Sites with high groundwater levels can be problematic for slurry trenching or require costly ancillary tasks, such as dewatering or work platform modification. As
such, trenchers have a strong history in countries like the Netherlands and Belgium where the groundwater table is generally near the surface.

Another consideration in the design should be the need for and extent of a “key”. One of the main disadvantages of CMM is the inability to verify the “key” soils. Thus, when the trencher is used, more extensive geotechnical investigation is required to pre-determine the depth and makeup of the “key” strata.

In relation to gathering geotechnical data in the design phase, obstructions must be on the list. Understanding the presence or likely presence and severity of underground obstructions is critical. Obstructions can be the detriment of even the best subsurface wall design. Obstructions can be boulders, bedrock outcroppings, debris, or prior site features such as foundations, building slabs, etc. Not all obstructions are encountered underground, however. Above grade obstructions can be anything that would impede the construction equipment used to install the designed remedial system.

Stability of the work area should also be considered during design. For example, an unstable dam or levee that requires a barrier may be restricted to mix-in-place installation methods such as the CMM.

Treatability studies are a complex and important part of the design. For cutoff walls, the CMM incorporates the below-grade materials with appropriate binders to create the barrier wall product with vertical mixing being a significant feature of the CMM. While binder content and mixing energy cannot be varied with depth, the mixed materials are exceptionally homogenous due to the mixing energy imparted by the speed of the chain coupled with the prevalence of teeth on the chain (Stare, et. al.). The soil and groundwater that will be incorporated in the final mix must be considered for CMM and its full vertical mixing action. Collection trenches and PRBs require a different type of treatability study, but this is still an important piece of the design. In addition to determining cost-effective reagents, a treatability study should also consider that certain products may not be compatible with the site constituents. This could be an important factor for method selection if compatibility issues preclude the use of slurry – as in a slurry filled excavation. Furthermore, for high permeability barriers, the retention time may dictate a minimum width that may not be achievable with all methods.

**INSTALLATION**

There are considerations for equipment selections in the industry today. The use and availability of the designated primary and support equipment should be considered during the method selection. Is there enough workspace available to operate the equipment? Will construction traffic cause unstable or unsafe conditions? These are just some examples of things to consider. Vibrations, swing radius, overhead clearance and headroom are a few of the characteristics that vary between the methods.

Responsibility for the spoils or waste materials should also be considered. On many remedial sites, there is not space to incorporate the spoils elsewhere onsite. Thus, a spoils management and/or disposal plan should be vetted and incorporated into the overall project plan. The spoils volume and makeup also varies by method. For example, a self-hardening slurry trench will generate a full volume spoils quantity whereas a soil-mixed option would result in less spoils, on the order of 10% to 40% of the mixed volume.

**CASE STUDIES**

The following case studies demonstrate the evaluation potential of the information presented herein. In order to condition the reader to understand method selection, the facts of each case are outlined and then the reasons for the selected method are described.
CASE STUDY 1 – PERIMETER CUTOFF WALL

On this site a cutoff wall was installed around the perimeter of a large site for the purpose of reducing offsite migration of water. The cutoff wall was designed as a hanging wall, i.e. the bottom of the wall was not tied into a lower permeability layer, with relatively shallow depth of 25-ft. The site was a vast, flat landscape with the only operational constraint a deep perimeter drainage channel for the control of surface water runoff located approximately 10-ft to 15-ft off the cutoff wall alignment. Soil explorations encountered mostly sandy soils with underlying silty sand layers at depth. Stumps were also encountered in several borings and even more commonly in shallow test pits. Groundwater was encountered at about 6-ft. below ground surface.

Summary of Site Criteria:

- Ample room to work – site was large and flat
- Soils – sand and silty sands with frequent stumps
- Groundwater – 6-ft. bgs.
- Key requirement – none.
- Treatability/Mix – bentonite was the only reagent required to lower permeability.
- Cutoff wall size: 7,000 lineal feet, 25-ft deep, 2-ft wide.
- Cutoff wall type: soil-bentonite (SB)

Originally the Owner pursued a conventional slurry excavation method for the purposes of lowest cost. This is a completely valid selection for this site as there is plenty of room for ex-situ mixing adjacent to the cutoff wall, the excavator method can be used to easily remove any stumps from the cutoff wall alignment, and the groundwater was low enough to accommodate proper stability of the trench during excavation and backfilling operations.

Despite the applicability of slurry trenching to this site, the method was changed to the Trencher/ CMM (Figure 1) prior to construction. This change was made to improve the site logistics and reduce site disturbance. The trencher method was able to reduce the site disturbance to only a narrow band along the perimeter of the site which allowed the General Contractor (GC) to simultaneously work on other critical site tasks. This change resulted in a schedule pickup for the Owner which also resulted in a lower overall cost to the project. The disadvantages of the trencher method for this site were the risk of stumps/obstructions causing damages, refusal and possibly schedule delay or claims to the Owner. Through pre-construction planning discussions, all parties, Owner, GC, and specialty cutoff wall contractor, agreed that the lower overall cost and schedule decrease associated with the CMM outweighed the risks.

Lessons Learned:

- Workspace availability – while there was enough space available for ex-situ mixing, the site disturbance was greatly reduced by CMM enabling the GC to decrease the overall schedule by utilizing the available workspace to advance the schedule of other tasks simultaneously.
- Stumps – possible obstructions – overcome by trencher. This obstruction risk was worth it due to the relatively weak nature of the stumps compared to the robust mixing chain and cutting teeth of the trencher. Furthermore, the depth of the stumps was relatively shallow, which could be extracted
from the cutoff wall with other methods if the stumps caused a refusal of the trencher. The stumps did not ultimately cause any problems and were passed without causing damage, refusal, or claims.

- Treatability/Mix Design – The mix design was initiated during the early phases of the project when conventional slurry methods were proposed. The slurry method and CMM have different mixing techniques which should be considered during bench scale tests. The bench scale results dictated the need for a relatively high dosage of bentonite. While slurry/grout mixing can be used with CMM, adding large amounts of bentonite via slurry is less practical than dry addition. While dry reagents are delivered via this specific system, it should not be considered a dry mixing method given the simultaneous delivery of water and aggressive mixing action of the chain (Stare, et al.).

**CASE STUDY 2 – CIVIL DEWATERING**

At this site a cutoff wall was installed around a new commercial building site for the purposes of reducing the influx of water to eliminate an expensive dewatering effort during basement excavation. The cutoff wall was designed to extend just below a porous water-bearing gravel zone near the basement slab elevations. A clay layer underlying the gravel strata served as an aquitard “key”. Depths to the aquitard varied between 8-ft. and 20-ft. bgs. Although long term water intrusion into the basement will be reduced by the cutoff wall, the primary intent was to cutoff flow during the basement excavations for the new construction. The cutoff wall was designed as a soil-cement-bentonite (SCB) type due to the need for excavation equipment and utility pipes to cross the cutoff wall during construction. The available geotechnical data revealed sandy clay above a gravel layer, underlain by fine grained silty clay at the terminating depths.

*Summary of Site Criteria:*

- Ample room to work – site is large and flat
- Soils – sandy clay, above a gravel layer, underlain by fine grained silty clay at the terminating depths.
- Groundwater – 5 to 10-ft. bgs. in gravel layer.
- Key requirement – 2-ft into clay.
- Treatability/Mix – mix design for slurry method using bentonite and Portland cement.
- Cutoff wall size: 3,300 lineal feet, up to 20-ft deep, 2.5-ft wide.
- Cutoff wall type: soil-cement-bentonite (SCB)

Given the available data and bids, the Owner pursued a trencher/CMM method for the purposes of lowest cost. The CMM method could accomplish many of the main criteria with specific advantages in the rate of installation and lower cost. Another advantage of CMM at this site is the full vertical mixing which uniformly mixes the porous gravel soils with the sandy clay above. During method selection, the disadvantage of the CMM was the inability to verify key soils. Despite its disadvantage, the proposed lower costs were enough for the GC to award the contract. When it was clear that the trencher was the selected method, the Owner conducted a more extensive geotechnical investigation to determine more precise bottom elevations for the trencher to follow.

The soil borings and test pits did not reveal obstructions and were carried out adequately across the site. However, signs of boulders were present during the cutoff wall installer’s pre-mobilization site investigation. Signs of potential boulders were found in remnants of backfill piles from previous test pits conducted by the GC. As part of the cutoff wall installer’s due diligence, subcontractor test pits were conducted prior to mobilization to further investigate the soils for the presence of boulders since boulders present a significant disadvantage to CMM and can cause costly repairs and schedule delays. During this additional test pitting, numerous boulders were encountered at different locations across the site.

Due to the findings of these additional test pits, the method was changed prior to construction to conventional slurry mixing (Figure 2). This proved to be a wise choice as large boulders were frequently encountered along the entire alignment, approximately every 25 to 50 lineal feet. The boulders would have undoubtedly caused refusal of the trencher and significant project delays. In contrast the boulders were easily removed during the conventional slurry excavation without any project delays or claims for damages.

**Lessons Learned:**

- Collaborative Method Selection – site investigations including test pits were carried out by the Owner’s team without any understanding of the types of soils that are problematic to different methods. Select data was chosen to include in the bid documents, but early collaboration with cutoff wall installers could have eliminated additional investigations that lead to confusion, a delayed project start, and renegotiation of the contract at the onset of construction.
- Obstructions – frequent large boulders encountered in gravel, would have resulted in damage and delays for the trencher/CMM method. Impacts associated with these obstructions were eliminated.
through proper selection of the conventional slurry trenching method which was able to extract all obstructions and achieve the designed bottom elevations without additional cost or delay.

**CASE STUDY 3 – DIKE REPAIR**

For this site, a seepage barrier was designed to prevent the retained waters from seeping in an earthen embankment dike with a leak. Due to the limited width of the berm (Figure 3), the trencher was quickly identified for installation of a SB wall for the emergency repair. The existing workspace available was only the dike crest which was not much wider than the trencher tracks.

![Figure 3. Trencher with soil-mixing blade visible halfway out of trench](image)

**Summary of Site Criteria:**

- Limited room to work – cutoff wall installed from dike crest
- Soils – typical earthen embankment dam materials, various silts, clays and sands.
- Groundwater – 5-ft. bgs.
- Key Requirement – none.
- Treatability/Mix – soil-bentonite mix.
- Cutoff wall size: 100 lineal feet, up to 16 ft deep, 1.5 ft wide.
- Cutoff wall type: soil-bentonite (SB)

Due to the limited width of the berm, the trencher/CMM was the obvious choice for this installation. The soils did not present any obstructions, key requirements, or need to segregate the excavation spoils which could have precluded the trencher. Similarly, limited site access challenges were overcome by the in-situ mixing method since the trencher could track onto the alignment easily. By comparison, a slurry trenching method would not have had enough space to excavate the soil and mix and place the backfill, nor would support equipment be able to assist the primary excavator. Mobilizing other in-situ mixing methods for a small quantity of work and setting up a grout plant are not typically cost effective which is why the trencher was the selected in-situ mixing method.

**Lessons Learned:**

- Limited workspace and access – these are key advantages where the trencher excels.
- Mobilization, setup, and demobilization – these were carried out in short succession allowing swift repair of the leaking dike. The entire project was completed in 1 week, including mobilization and demobilization.

**CASE STUDY 4 – COLLECTION TRENCH**

On this project a collection trench was installed for LNAPL recovery. The site consisted of known coarse soils with boulders within the lithology. Groundwater was encountered near the surface. There was ample room to conduct either slurry methods or trencher methods. Due to the presence of boulders, pre-trenching was prepared in the budget and scope of work.
Summary of Site Criteria:

- Coarse soils with boulders.
- Groundwater – near ground surface.
- Collection Trench size: 1,275 lineal feet, up to 16-ft deep, 2.5-ft wide.

Due to the high groundwater and levels of LNAPL, the trencher/CMM was the desired option. The inability to overcome boulders was one of the main disadvantages of the trencher. However, the cost of the trencher was significantly cheaper than a bio-polymer slurry trench method. With the cost savings, the GC was able to remove the boulders, some of which were up to 6-ft in diameter (Figure 4), from the trench alignment through pre-clearing.

Lessons Learned:

- Pre-clearing obstructions can be an asset for the trencher, while still being cost-effective.
- Precision, quality control and record keeping with pre-clearing and collection trench alignment is critical.
- Backfill selection, control of water and existing soil conditions need to be well understood, for cost considerations.

Figure 4. Obstruction pile

CASE STUDY 5 – GAP CLOSURE CUTOFF WALL

At this site, a cutoff wall was installed to close a gap between previously installed sections of cutoff walls. The Owner solicited bids allowing multiple methods to create a cutoff wall in a tight site. The primary challenge at this site was to work around the significant above and below grade site features that were immovable. These site features and the significant associated challenges were the main reason the gap in the previous cutoff wall was left in the first place. The site features also limited equipment access and available workspace for mixing. The soils at the site consisted of known coarse soils with debris in the upper fill. Groundwater was at about 12-ft. bgs. within the lithology.

Summary of Site Criteria:

- Very limited available workspace – significant above and below grade site features.
- Coarse soils with debris.
- Groundwater – about 12-ft. bgs.
- Key requirement – none.
- Treatability/Mix – self-hardening slag-cement-bentonite used.
- Cutoff Wall Size: 75 lineal feet, 20-ft deep, 2.5-ft wide.
- Cutoff wall type: soil-bentonite (SB)
Due to the site logistics and challenges with working around the site features, the trencher/CMM would seem a logical choice for this site. However, the chemistry of the groundwater at this site was suspected to be a risk to the quality and, in the end, precluded in-situ methods. The Owner selected a self-hardening slurry trench installed with an excavator to remove all the in-place soils from the cutoff wall to mitigate the potential adverse effects of the site constituents present in the soil and groundwater. This method also eliminated backfill mixing in a tight site. Challenging as it was, the excavator was safely positioned along the alignment.

**Lessons Learned:**

- Performance of remedial design - the pros and cons of any of the available options are second to the performance of the design. If the design cannot be achieved, including long term behavior, even the most advantageous method for cost and schedule cannot be considered.
- Documentation of existing site features and further investigation during the design is critical
- Chemistry data of site constituents and knowledge of their effects on the barrier wall backfill are crucial for design and method decisions
- Communication among all parties to share information about the site, approach and construction techniques during procurement and execution are important to ensure safety and quality.

**CONCLUSION**

Trenchers have been in use since the 1950’s and recent innovations have made them popular for demanding sites where conventional slurry methods may be more expensive or time consuming. Trenchers vary in design and practical use and the differences must be considered in regard to the specific site constraints during any review and selection process. As with all tools, the trencher is effective when used correctly offering a unique opportunity to utilize the advantages of a mix-in-place technology with an agile and easy to assemble rig.

Conventional slurry trenching is a proven technology and is the most common method of installing vertical barriers and for well-known reasons. As demonstrated from the case studies herein, slurry trenching with excavators can be a versatile solution. However, slurry filled trenches can be challenging and are not amenable to all sites. Reviewing the advantages and disadvantages of trenchers above shows the advantages of this mix-in-place technology to supplement or replace slurry trench methods where disadvantages are present. Both methods are acceptable and should be considered as appropriate methods for cutoff walls, collection trenches and PRBs.

The case studies also highlight that even when it appears that a site is more conducive to a certain technology all methods must be considered to make the appropriate decision to achieve the intent of the design at the lowest cost. The seemingly logical solution may not be the right solution when the problem is considered in its entirety.

**REFERENCES**

Boersma, B., 2020, Aussie-Drain, personal communication.

