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SLURRY CUT-OFF WALL APPLICATIONS
IN THE CONTROL OF HAZARDOUS WASTE LEACHATES

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ABSTRACT

Slurry cut-off walls are non-structural barriers constructed to intercept and impede the flow of fluids underground. There are two basic types of slurry cut-off walls, soil-bentonite (SB) and cement-bentonite (CB). Depending on the nature of the project, either method may have some technical or economic advantage over the other. In both cases, a narrow trench is excavated into the ground using a backhoe or other more specialized equipment. The trench is prevented from collapsing by keeping it full at all times with bentonite slurry similar to drilling mud. In the case of SB walls, the trench is subsequently backfilled with a mixture of soil and bentonite slurry that forms the permanent impervious cut-off wall. With the CB method, cement is added to the slurry which later sets up, forming the permanent seepage barrier.

Slurry cut-off walls are being used in an increasing variety of applications to provide a barrier to the lateral underground flow of various fluids. Principal applications are site dewatering, underground pollution control and seepage barriers under dams. In this paper, case studies are used to provide examples of recent applications in the control of leaching hazardous wastes.

Projects cited include:

- containment of potential leachates from a new paper sludge holding lagoon.
- containment of oil seeping through a reservoir abutment.
- cleanup of a PCB contaminated site.

All of the examples are selected because of the unusual conditions under which they were constructed or dramatic evidence of results.

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INTRODUCTION

Public awareness of the dangers of the effects of leachates from buried hazardous wastes is mounting. The Federal EPA has been charged with containing the damage on hundreds of unclaimed sites under the Super Fund act. Meanwhile, thousands of businesses, local governments, and other owners are seeking remedies for underground pollution problems on their property. The slurry cut-off wall has already been applied to several hundred such sites and is contemplated on many more.

Recent advances in the capacity of excavating equipment and refinements in technique have brought the cost of slurry walls down and they now compete economically on projects where leachate collectors or clay barriers or sheeting would have previously been used. The types of walls discussed herein are non-structural; they are relatively impervious but are not capable of supporting bending moments or significant shear stress. Normally, their strength is of the same order as the surrounding ground.

The techniques discussed herein involve excavating a trench which is kept filled with slurry, whose primary ingredients are bentonite clay and water, and whose function is to maintain the trench open with vertical sides, even below the water table. The excavation is carried out through the slurry from the ground surface using any equipment capable of excavating the trench widths and depths required. Once the trench is excavated to its final depth, a mixture of soil and bentonite is placed in the trench, displacing the bentonite slurry. This type of construction is called a Soil-Bentonite (SB) slurry cut-off wall.

With a variation on the above technique called a Cement-Bentonite (CB) slurry trench, cement is added to the bentonite slurry just before it is introduced into the trench. The resultant slurry has properties substantially similar to normal bentonite slurry with respect to maintaining the sides of the trench. However, once excavation is complete, the CB slurry remains in the trench, sets up and forms the permanent watertight wall.

CONSTRUCTION METHODS

Trench Backfill

The Soil-Bentonite slurry trench technique has been in use in the United States for about thirty years. Figure 1 shows the excavation for a SB cut-off. On projects where the material excavated from the trench is suitable for use as backfill, the SB system can be economical because of the minimum amount of materials required. After the trench has been excavated under a bentonite slurry, more slurry is mixed with the soil adjacent to the trench. A bulldozer is used to work the material to a smooth consistency and it is then pushed into
the trench so that the backfill slope displaces the bentonite slurry forward (Fig. 2). Excavation and backfilling are phased to make the operation continuous with relatively small quantities of new slurry required to keep the trench full and to mix backfill.

Cement-Bentonite slurry trenches have been in use in Europe for at least ten years and in the United States for about six years. Figure 3 shows a CB batch plant. Since the entire trench must be filled with slurry materials and a significant amount of slurry is wasted due to the excavation process and seepage losses through the sides of the trench, the backfill is considerably more expensive than under the SB method. This increased cost is partially off-set by the elimination of the backfill mixing operation. However, the CB method can provide the following technical and construction advantages over the SB method:

- The technique is not dependent on the availability or the quality of soil for backfill.

- The CB system is more suitable for trenching through areas with difficult access or not enough room for backfill mixing.

- Because of the cement content, the backfill sets up quickly to a stiff consistency. Trenches may be cut through the wall without sloughing of the backfill. Construction traffic can cross the trench after a few days. There is no significant consolidation with time.

- Since the trench can be constructed in sections with later sections keyed-in by reexcavating a short section, the construction sequence is more flexible to meet site constraints. The long slope of the backfill under the SB system normally requires trenching continuously in one direction.

The SB technique has other advantages over CB, besides lower cost:

- The resultant wall is of lower permeability than CB walls.

- The backfill can have various materials blended in to suit design conditions.

- SB backfill is generally more resistant to degradation by most pollutants.

- Where spoil can be placed back into the trench, no spoil disposal problem is created.
Given the relative advantages between the two systems, the project requirements should be evaluated to determine the best method to be selected. Where possible, it may be most economical to specify both methods and allow the contractor to bid with the least expensive system.

Excavating Equipment

The primary requirement for the excavating equipment is the capability to excavate a trench of the design width to the required depths within permissible verticality tolerances. A variety of equipment has, in fact, been used. In the following paragraphs, the principal types are discussed, along with their relative advantages.

The hydraulic excavator, or backhoe, has been used on many slurry cut-off wall projects in the United States (Figure 4). The depth limitation of the largest hoes is presently about 65 ft, but new advances in equipment technology will undoubtedly extend this range. The backhoe, because of its fast cycle time, is the most economical means of excavation. Minimum trench widths are controlled by the thickness of the boom. For large hoes, this can mean 2½ ft. or more. The thickness of the wall is an important cost factor for CB slurry cut-offs.

The clamshell bucket rigs which were originally developed for cast-in-place concrete slurry walls have been applied to slurry cut-off trenching. These buckets may be cable-mounted or attached to a rigid sliding kelly bar (Figure 5). They may be powered by mechanical means (cables) or by hydraulic cylinders operated by a remote power supply. These rigs have a maximum range up to 250 ft. and can be used with hoes as thin as 2 ft. Their production is much lower than other methods, so unit costs for excavation are higher.

Another technique more recently introduced into the United States from Europe involves driving a beam into the ground with a vibrating pile-hammer while simultaneously jetting with CB slurry to form a "thin-wall cut-off". The beam is withdrawn while more slurry is injected under pressure. The beam is driven in overlapping imprints to form a continuous wall. The result is a curtain about 2 inches thick with the additional protection of grouting coarse-grained strata with CB slurry. Given the right soil conditions, production is rapid and the thin wall cut-off uses far less CB slurry than conventional slurry trenching. However, the same narrow width mandates more careful quality control since each square foot of the wall is subjected to one pass of the beam which does not mix the slurry as in the case of slurry trenching. The principal problem of the vibrated beam has been assuring continuity between adjacent passes at depth. Its range is approximately 30-50 ft., but even within these depths slight deviations may leave "windows" in the wall. Soil profiles with cobbles or boulders are a particular
problem and keying into underlying weathered rock or hardpan may not be possible to the extent feasible with excavated slurry trenches. The narrow width of wall makes this type of cut-off less suitable for applications in soil where movements due to settlement, subsidence, etc. can be expected later. Design parameters and quality control for thin-wall cut-offs are specialized topics, not treated in this paper.

APPLICATIONS

Because of the range of slurry cut-off wall applications to the control of hazardous waste leachates, it is difficult to pick a few projects to demonstrate the possibilities. Projects completed include containments for:

- Sanitary landfill leachates
- Oil and gas spills
- Low-level radioactive waste
- Acid mine drainage
- Phenols
- PCB's
- Trichlorethyelene, Benzene and many other organic chemicals
- Phosphate Mine Tailings
- Flyash impoundments
- and many others.

The three projects selected for a more detailed look are:

Paper mill sludge containment. This project shows how a typical soil bentonite wall, excavated with a backhoe, was used as a redundant containment in the construction of a new lagoon.

Repair of leaky storage lagoon. This project illustrates the construction advantages of a cement-bentonite wall, used to repair an abutment of a dam used to contain oily refinery storm run-off.

PCB containment. This project illustrates the use of a CB wall for rapid containment of a very small spill. This case shows that the technique can be an economic solution to small problems.
Paper Mill Sludge

A Wisconsin paper mill was running out of room in its existing sludge lagoons and wanted to build a large new lagoon for future needs. Timing requirements dictated that a conservative solution be presented to the environmental agency so that there would be no approval delays. In addition, the project was located in an environmentally sensitive area, and the paper company wanted to assure itself that there would be no future problems. The solution was to use several layers of protective liner with intervening leachate collectors (Figure 6). The whole system was automated with visual alarm signals that would alert plant personnel if any part ceased to function. This system provides for a negative head differential into the site, so it may be called a zero outflow solution.

The wall was excavated under a bentonite slurry (Figure 7). In this case, the consultant had engineered a backfill of select silty sand with additional dry bentonite blended in to further reduce permeability. This was accomplished in the borrow area (Figure 8 & 9). Afterwards the soil was taken to the trench area where it was blended with bentonite slurry and placed into the trench (Figure 10). The result was a very impervious cut-off wall.

Repair of Leaky Storage Lagoon

In this case, there was a concrete dam at a refinery in Texas that was designed to contain all of the storm-water runoff (Figure 11). There was a significant amount of oil mixed with the runoff water. The oily water was seeping through one abutment and accumulating on the downstream side of the dam (Figure 12). The client wanted the positive protection that a slurry cut-off wall would provide, yet there was a serious access problem, since the abutment was very narrow and steep.

The only solution was to use a cement-bentonite wall. It was excavated from the top with a heavy slurry clamshell (Figure 13). Very short primary panels were dug about 8 feet long (Figure 14). These were allowed to set before being connected by secondary panels. In this manner, the wall was stair-stepped up the steep slope until completion. The cement-bentonite forms the permanent backfill with the excavated spoil (Figure 15) being reshaped on the abutment.

PCB Containment

The two previous projects illustrate medium-sized projects that require a significant scale of operations. In this example, we look at a site where the job was mobilized in one day and completed in three, despite a record snowstorm. During a strike against a Western Pennsylvania utility, a transformer was vandalized resulting
in several hundred gallons of PCB - contaminated liquid being spilled on the ground. The power company hired a spill cleanup service, but was making little headway and the PCB's were starting to show up in an adjacent creek. The quick installation of a slurry cut-off wall contained the size of the spill, and allowed the clean-up firm the time it needed to complete its work. The power company gained an additional significant savings in that off-site water could not get into the affected area, thereby decreasing the amount of fluid that needed to be collected and disposed of.

SUMMARY

Slurry cut-off walls have achieved wide recognition in a variety of applications as seepage barriers for pollution control. The two principal techniques, soil-bentonite and cement-bentonite, have different relative advantages, but under some conditions are technically interchangeable.

A design for a slurry cut-off wall should take into consideration whether the wall is for permanent or temporary use, the loadings anticipated, and other construction constraints in selecting the technique to be used and the extent to which the work should be controlled by the engineer. Specifications should take account of the built-in safety factors in slurry cut-offs (e.g. more thickness than required in most cases), allow the variability in slurry properties normally experienced during this type of work and give maximum flexibility to the contractor in selecting materials, equipment and technique. The economy, convenience and positive control of seepage afforded by slurry cut-off walls will bring them acceptance and application on an increasing number of construction projects in the United States.
FIG. 1 EXCAVATION FOR SOIL-BENTONITE SLURRY CUT-OFF WALL

FIG 2. SCHEMATIC SECTION THROUGH SB SLURRY CUT-OFF
FIG. 3 CEMENT-BENTONITE BATCH PLANT

FIG. 4 EXTENDED-STICK BACKHOE
FIG. 5 SLURRY CLAMSHELL BUCKET
A THREE-LAYER SOLUTION

FIG. 6
FIG. 7 EXCAVATING UNDER A BENTONITE SLURRY

FIG. 8 ADDITION OF DRY BENTONITE
FIG. 9 BLENDING IN DRY BENTONITE

FIG. 10 PLACING BACKFILL
FIG. 11 OVERVIEW OF DAM ABUTMENT PROJECT

FIG. 12 SEEPAGE AT TOE OF DAM
FIG. 13 REACHING OUT WITH THE CLAMSHELL

FIG. 14 EXCAVATING THE CB PRIMARY PANELS
FIG. 15  EXCAVATED SPOIL WITH POLLUTED POND IN BACKGROUND