Pierce Chandler

United States
Environmental Protection
Agency

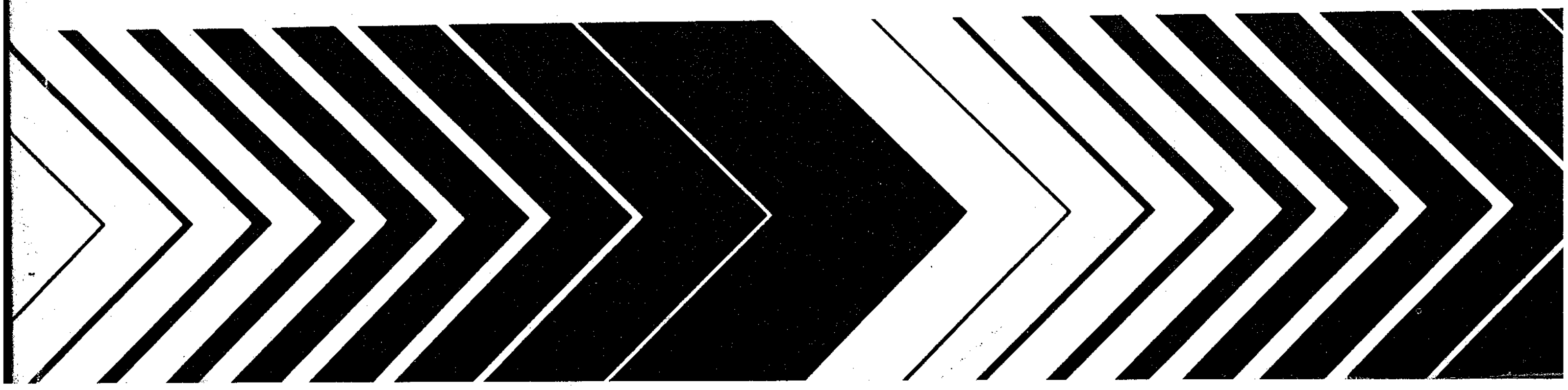
Office of Research and
Development
Washington DC 20460

EPA/600/R-93/182
September 1993

EPA

Technical Guidance Document

Quality Assurance and Quality Control for Waste Containment Facilities



EPA/600/R-93/182
September 1993

Technical Guidance Document:

QUALITY ASSURANCE AND QUALITY CONTROL FOR WASTE CONTAINMENT FACILITIES

by

David E. Daniel
University of Texas at Austin
Department of Civil Engineering
Austin, Texas 78712

and

Robert M. Koerner
Geosynthetic Research Institute
West Wing, Rush Building No. 10
Philadelphia, Pennsylvania 19104

Cooperative Agreement No. CR-815546-01-0

Project Officer

David A. Carson
Risk Reduction Engineering Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

RISK REDUCTION ENGINEERING LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OHIO 45268

♲ *Printed on Recycled Paper*

Table of Contents

Chapter 7

Vertical Cutoff Walls

7.1 Introduction

Situations occasionally arise in which it is necessary or desirable to restrict horizontal movement of liquids with vertical cutoff walls. Examples of the use of vertical cutoff walls include the following:

1. Control of ground water seepage into an excavated disposal cell to maintain stable side slopes or to limit the amount of water that must be pumped from the excavation during construction (Fig. 7.1).
2. Control of horizontal ground water flow into buried wastes at older waste disposal sites that do not contain a liner (Fig. 7.2).
3. Provide a "seal" into an aquitard (low-permeability stratum), thus "encapsulating" the waste to limit inward movement of clean ground water in areas where ground water is being pumped out and treated (Fig. 7.3).
4. Long-term barrier to impede contaminant transport (Fig. 7.4).

Vertical walls are also sometimes used to provide drainage. Drainage applications are discussed in Chapters 5 and 6.

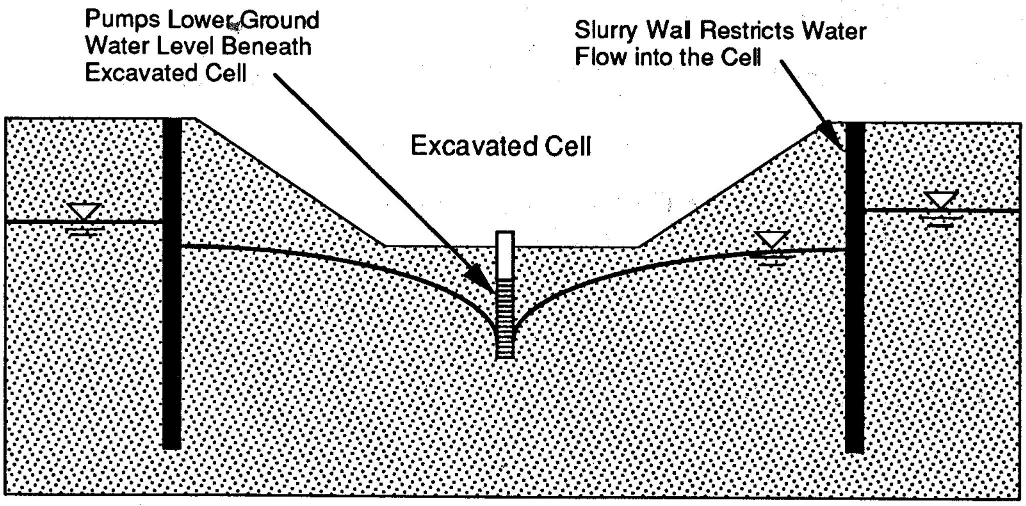


Figure 7.1 - Example of Vertical Cutoff Wall to Limit Flow of Ground Water into Excavation.

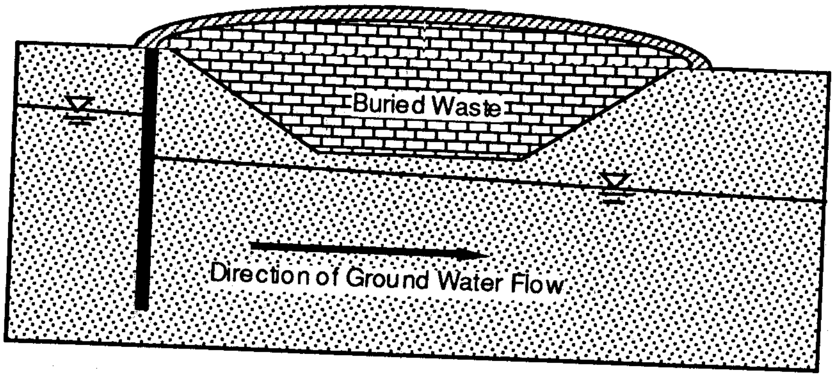


Figure 7.2 - Example of Vertical Cutoff Wall to Limit Flow of Ground Water through Buried Waste.

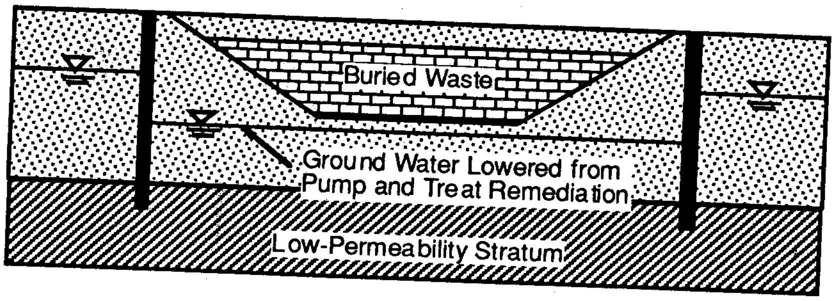


Figure 7.3 - Example of Vertical Cutoff Wall to Restrict Inward Migration of Ground Water.

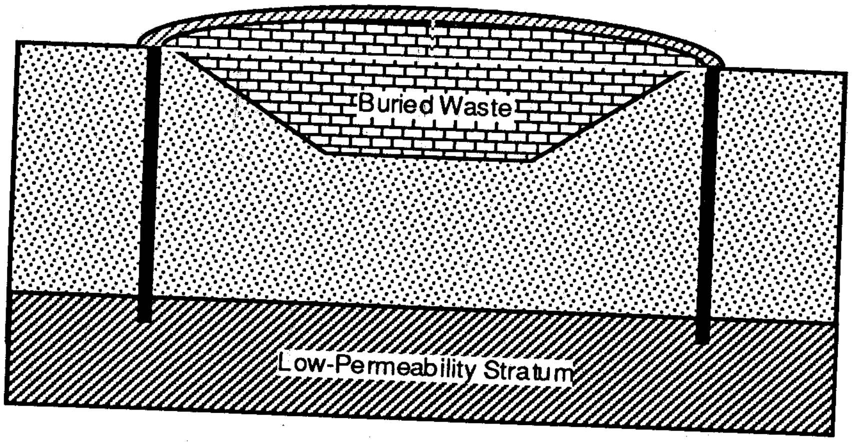


Figure 7.4 - Example of Vertical Cutoff Wall to Limit Long-Term Contaminant Transport.

7.2 Types of Vertical Cutoff Walls

The principal types of vertical cutoff walls are sheet pile walls, geomembrane walls, and slurry trench cutoff walls. Other techniques, such as grouting and deep soil mixing, are also possible, but have rarely been used for waste containment applications.

7.2.1 Sheet Pile Walls

Sheet pile walls are interlocking sections of steel or plastic materials (Fig. 7.5). Steel sheet piles are used for a variety of excavation shoring applications; the same type of steel sheet piles are used for vertical cutoff walls. Plastic sheet piles are a relatively recent development and are used on a limited basis for vertical cutoff walls. Sheet piles measure approximately 0.5 m (18 in.) in width, and interlocks join individual sheets together (Fig. 7.5). Lengths are essentially unlimited, but sheet piles are rarely longer than about 10 to 15 m (30 to 45 ft).

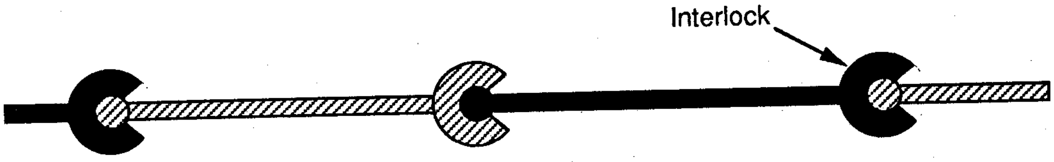


Figure 7.5 - Interlocking Steel Sheet Piles.

Plastic sheet piles are different from geomembrane panels, which are discussed later. Plastic sheet piles tend to be relatively thick-walled (wall thickness > 3 mm or 1/8 in.) and rigid; geomembrane panels tend to have a smaller thickness (< 2.5 mm or 0.1 in.), greater width, and lower rigidity.

Sheet pile walls are installed by driving or vibrating interlocking steel sheet piles into the ground. Alternatively, plastic sheet piles can be used, but special installation devices may be needed, e.g., a steel driving plate to which the plastic sheet piles are attached. To promote a seal, a cord of material that expands when hydrated and attains a very low permeability may be inserted in the interlock. Other schemes have been devised and will continue to be developed for attaining a water-tight seal in the interlock.

Sheet pile walls have a long history of use for dewatering applications, particularly where the sheet pile wall is also used as a structural wall. Sheet pile walls also have been used on several occasions to cutoff horizontal seepage through permeable strata that underlie dams (Sherard et al., 1963).

Sheet pile walls have historically suffered from problems with leakage through interlocks, although much of the older experience may not be applicable to modern sheet piles with expanding material located in the interlock (the expandable material is a relatively recent development).

Leakage through sheet pile interlocks depends primarily on the average width of openings in the interlocking connections, the percentage of the interlocks that leak, and the quality and integrity of any sealant placed in the interlock. The sheet piles may be damaged during installation, which can create ruptures in the sheet pile material or separation of sheet piles at interlocks. Because of these problems, sheet pile cutoffs have not been used for waste containment facilities as extensively as some other types of vertical cutoff walls. Sheet pile walls are not discussed further in this report.

7.2.2 Geomembrane Walls

Geomembrane walls represent a relatively new type of vertical barrier that is rapidly gaining in popularity. The geomembrane wall consists of a series of geomembrane panels joined with special interlocks (examples of interlocks are sketched in Fig. 7.6) or installed as a single unit. If the geomembrane panels contain interlocks, a water-expanding cord is used to seal the interlock.

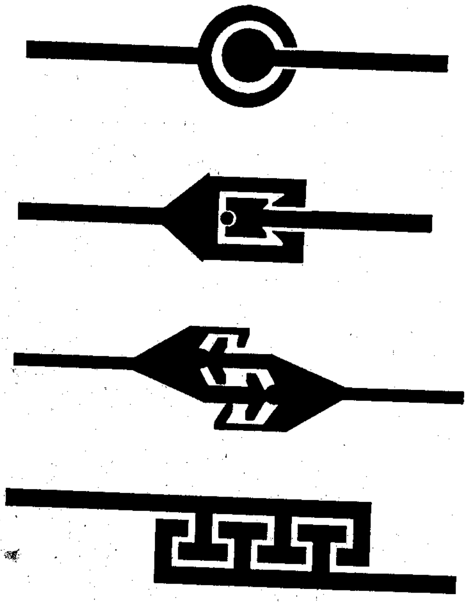


Figure 7.6 - Examples of Interlocks for Geomembrane Walls (Modified from Manassero and Pasqualini, 1992)

The technology has its roots in Europe, where slurry trench cutoff walls that are backfilled with cement-bentonite have been commonly used for several decades. One of the problems with cement-bentonite backfill, as discussed later, is that it is difficult to make the hydraulic conductivity of the cement-bentonite backfill less than or equal to 1×10^{-7} cm/s, which is often required of regulatory agencies in the U.S. To overcome this limitation in hydraulic conductivity and to improve the overall containment provided by the vertical cutoff wall, a geomembrane may be inserted into the cement-bentonite backfill. The geomembrane may actually be installed either in a slurry-filled trench or it may be installed directly into the ground using a special insertion plate.

7.2.3 Walls Constructed with Slurry Techniques

Walls constructed by slurry techniques (sometimes called "slurry trench cutoff walls") are described by Xanthakos (1979), D'Appolonia (1980), EPA (1984), Ryan (1987), and Evans (1993). With this technique, an excavation is made to the desired depth using a backhoe or clamshell. The trench is filled with a clay-water suspension ("mud" or "slurry"), which maintains stability of sidewalls via hydrostatic pressure. As the trench is advanced, the slurry tends to flow into the surrounding soil. Clay particles are filtered out, forming a thin skin of relatively impermeable material along the wall of the trench called a "filter cake." The filter cake has a very low hydraulic conductivity and allows the pressure from the slurry to maintain stable walls on the trench (Fig. 7.7). However, the level of slurry must generally be higher than the surrounding ground water table in order to maintain stability. If the water table is at or above the surface, a dike may be constructed to raise the surface elevation along the alignment of the slurry trench cutoff wall.

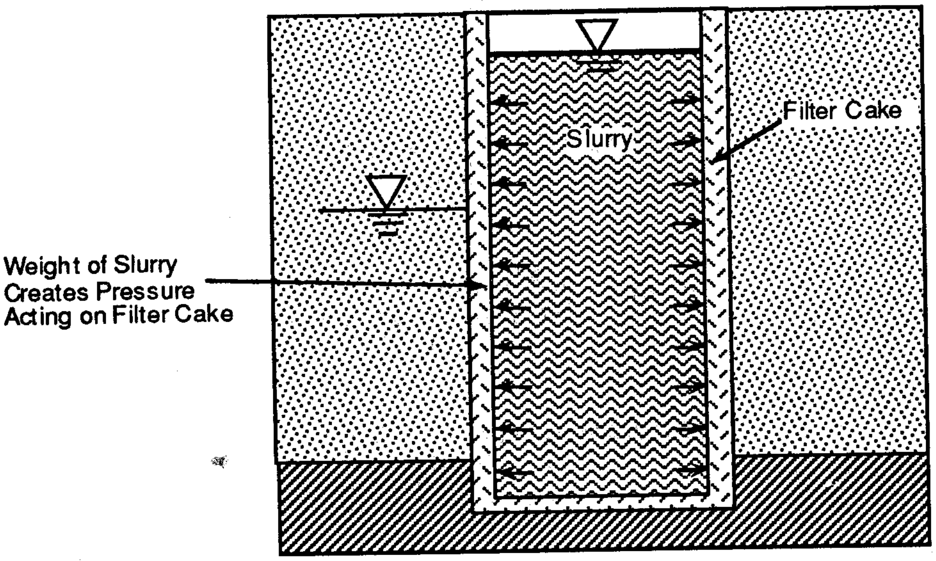


Figure 7.7 - Hydrostatic Pressure from Slurry Maintains Stable Walls of Trench.

In most cases, sodium bentonite is the clay used in the slurry. A problem with bentonite is that it does not gel properly in highly saline water or in some heavily contaminated ground waters. In such cases, an alternative clay mineral such as attapulgite may be used, or other special materials may be used to maintain a viscous slurry.

The slurry trench must either be backfilled or the slurry itself must harden into a stable material -- otherwise clay will settle out of suspension, the slurry will cease to support the walls of the trench, and the walls may eventually collapse. If the slurry is allowed to harden in place, the slurry is usually a cement-bentonite (CB) mixture. If the slurry trench is backfilled, the backfill is usually a soil-bentonite (SB) mixture, although plastic concrete may also be used (Evans, 1993).

In the U.S., slurry trenches backfilled with SB have been the most commonly used vertical cutoff trenches for waste containment applications. In Europe, the CB method of construction has been used more commonly. The reason for the different practices in the U.S. and Europe stems at least in part upon the fact that abundant supplies of high-quality sodium bentonite are readily available in the U.S. but not in Europe. Also, in most situations, SB backfill will have a somewhat lower hydraulic conductivity than cured CB slurry, and in the U.S. regulations have tended to drive the requirements for hydraulic conductivity to lower values than in Europe.

The construction sequence for a soil-bentonite backfilled trench is shown schematically in Fig. 7.8.

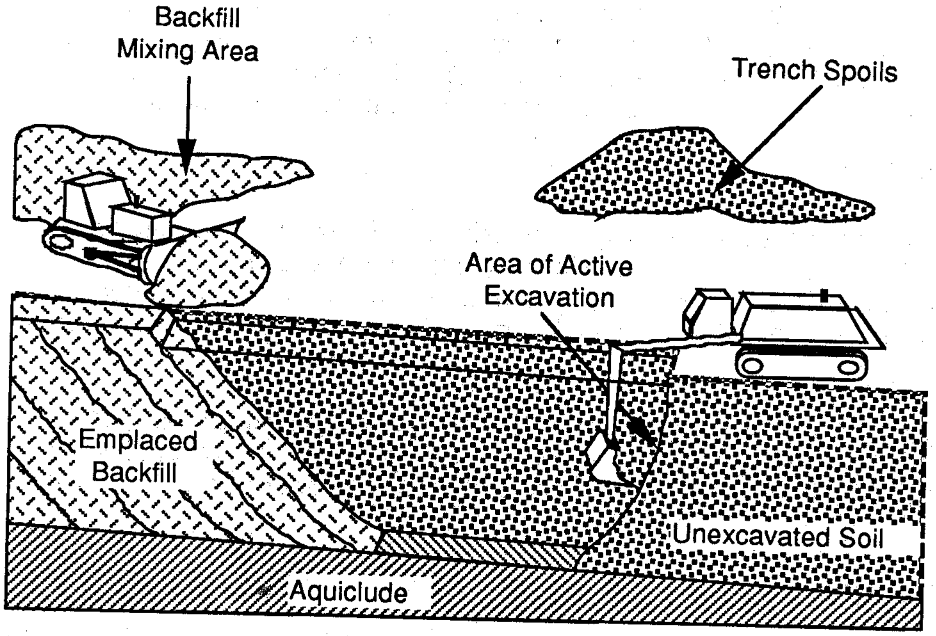


Figure 7.8 - Diagram of Construction Process for Soil-Bentonite-Backfilled Slurry Trench Cutoff Wall.

The main reasons why slurry trench cutoff walls are so commonly used for vertical cutoff walls are:

1. The depth of the trench may be checked to confirm penetration to the desired depth, and excavated materials may be examined to confirm penetration into a particular stratum;

2. The backfill can be checked prior to placement to make sure that its properties are as desired and specified;

3. The wall is relatively thick (compared to a sheet pile wall or a geomembrane wall);

4. There are no joints between panels or construction segments with the most common type of slurry trench cutoff wall construction.

In general, in comparison to sheet-pile walls, deep-soil-mixed walls, and grouted walls, there is more opportunity with a slurry trench cutoff wall to check the condition of the wall and confirm that the wall has been constructed as designed. In contrast, it is much more difficult to confirm that a sheet pile wall has been installed without damage, that grout has fully penetrated all of the desired pore spaces in the soil, or that deep mixing as taken place as desired.

7.3 Construction of Slurry Trench Cutoff Walls

The major construction activities involved in building a slurry cutoff wall are preconstruction planning and mobilization, preparation of the site, slurry mixing and hydration, excavation of soil, backfill preparation, placement of backfill, clean-up of the site, and demobilization. These activities are described briefly in the paragraphs that follow.

7.3.1 Mobilization

The first major construction activity is to make an assessment of the site and to mobilize for construction. The contractor locates the slurry trench cutoff wall in the field with appropriate surveys. The contractor determines the equipment that will be needed, amounts of materials, and facilities that may be required. Plans are made for mobilizing personnel and moving equipment to the site.

A preconstruction meeting between the designer, contractor, and CQA engineer is recommended. In this meeting, materials, construction procedures, procedures for MQA of the bentonite and CQA of all aspects of the project, and corrective actions are discussed (see Chapter 1).

7.3.2 Site Preparation

Construction begins with preparation of the site. Obstacles are removed, necessary relocations of utilities are made, and the surface is prepared. One of the requirements of slurry trench construction is that the level of slurry in the trench be greater than the level of ground water. If the ground water table is high, it may be necessary to construct a dike to ensure that the level of slurry in the trench is above the ground water level (Fig. 7.9). There may be grade restrictions in the construction specifications which will require some regrading of the surface or construction of dikes in low-lying areas. The site preparation work will typically also include preparation of working surfaces for mixing materials. Special techniques may be required for exacavation around utility lines.

7.3.3 Slurry Preparation and Properties

Before excavation begins, as well as during excavation, the slurry must be prepared. The slurry usually consists of a mixture of bentonitic clay with water, but sometimes other clays such as attapulgite are used. If the clay is bentonite, the specifications should stipulate the criteria to be met, e.g., filtrate loss, and the testing technique by which the parameter is to be determined. The criteria can vary considerably from project to project.

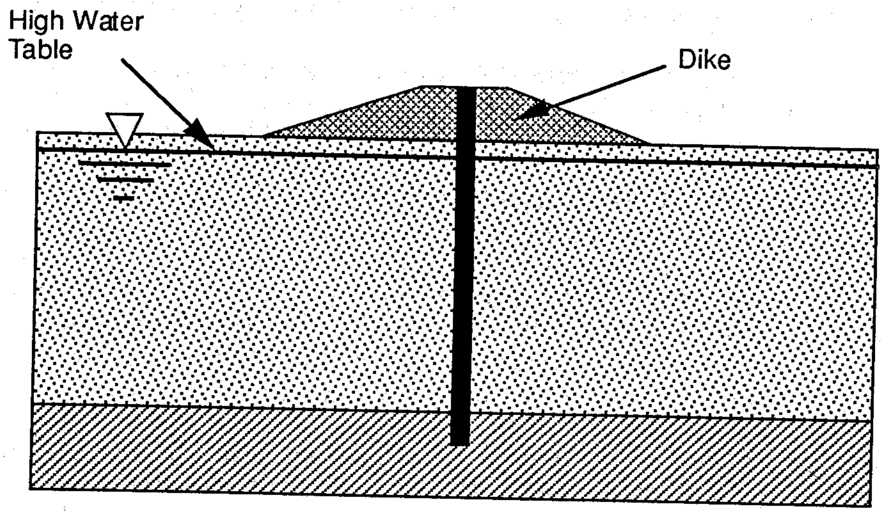


Figure 7.9 - Construction of Dike to Raise Ground Surface for Construction of Slurry Trench.

The clay may be mixed with water in either a batch or flash mixing operation. In the batch system specified quantities of water and bentonite are added in a tank and mixed at high speeds with a pump, paddle mixer, or other device that provides adequate high-speed colloidal shear mixing. Water and clay are mixed until hydration is complete and the desired properties of the slurry have been achieved. Complete mixing is usually achieved in a few minutes. The size of batch mixers varies, but typically a batch mixer will produce several cubic meters of mixed slurry at a time.

Flash mixing is achieved with a venturi mixer. With this system, bentonite is fed at a predetermined rate into a metered water stream that is forced through a nozzle at a constant rate. The slurry is subjected to high shear mixing for only a fraction of a second. The problem with this technique is that complete hydration does not take place in the short period of mixing. After the clay is mixed with water, the resulting slurry is tested to make sure the density and viscosity are within the requirements set forth in the CQA plan.

The mixed slurry may be pumped directly to the trench or to a holding pond or tank. If the slurry is stored in a tank or pond, CQA personnel should check the properties of the slurry periodically to make sure that the properties have not changed due to thixotropic processes or sedimentation of material from the slurry. The specifications for the project should stipulate mixing or circulation requirements for slurry that is stored after mixing.

The properties of the slurry used to maintain the stability of the trench are important. The following pertains to a bentonite slurry that will ultimately be displaced by soil-bentonite or other backfill; requirements for cement-bentonite slurry are discussed later in section 7.3.6. The slurry must be sufficiently dense and viscous to maintain stability of the trench. However, the slurry must not be too dense or viscous: otherwise, it will be difficult to displace the slurry when backfill is placed. Construction specifications normally set limits on the properties of the slurry. Typically about 4-8% bentonite by weight is added to fresh water to form a slurry that has a specific gravity of about 1.05 to 1.15. During excavation of the trench additional fines may become suspended in the slurry, and the specific gravity is likely to be greater than the value of the freshly mixed slurry. The specific gravity of the slurry during excavation is typically on the order of 1.10 - 1.25.

The density of the slurry is measured with the procedures outlined in ASTM D-4380. A known volume of slurry is poured into a special "mud balance," which contains a cup on one end of a balance. The weight is determined and density calculated from the known volume of the cup.

The viscosity of the slurry is usually measured with a Marsh funnel. To determine the Marsh viscosity, fluid is poured into the funnel to a prescribed level. The number of seconds required to discharge 946 mL (1 quart) of slurry into a cup is measured. Water has a Marsh viscosity of about 26 seconds at 23°C. Freshly hydrated bentonite slurry should have a Marsh viscosity in the range of about 40 - 50 seconds. During excavation, the viscosity typically increases to as high as about 65 Marsh seconds. If the viscosity becomes too large the thick slurry must be replaced, treated (e.g., to remove sand), or diluted with additional fresh slurry.

The sand content of a slurry may also be specified. Although sand is not added to fresh slurry, the slurry may pick up sand in the trench during the construction process. The sand content by volume is measured with ASTM D-4381. A special glass measuring tube is used for the test. The slurry is poured onto a No. 200 sieve (0.075 mm openings), which is repeatedly washed until the water running through the sieve is clear. The sand is washed into the special glass measuring tube, and the sand content (volumetric) is read directly from graduation marks.

Other criteria may be established for the slurry. However, filtrate loss and density, coupled with viscosity, are the primary control variables. The specifications should set limits on these parameters as well as specify the test method. Standards of the American Petroleum Institute (1990) are often cited for slurry test methods. Limits may also be set on pH, gel strength, and other parameters, depending on the specific application.

The primarily responsibility for monitoring the properties of the slurry rests with the construction quality control (CQC) team. The properties of the slurry directly affect construction operations but may also impact the final quality of the slurry trench cutoff wall . For example, if the slurry is too dense or viscous, the slurry may not be properly displaced by backfill. On the other hand, if the slurry is too thin and lacks adequate bentonite, the soil-bentonite backfill (formed by mixing soil with the bentonite slurry) may also lack adequate bentonite. The CQA inspectors may periodically perform tests on the slurry, but these tests are usually conducted primarily to verify test results from the CQC team. CQA personnel should be especially watchful to make sure that: (1) the slurry has a sufficiently high viscosity and density (if not, the trench walls may collapse); (2) the level of the slurry is maintained near the top of the trench and above the water table (usually the level must be at least 1 m above the ground water table to maintain a stable trench); and (3) the slurry does not become too viscous or dense (otherwise backfill will not properly displace the slurry).

7.3.4 Excavation of Slurry Trench

The slurry trench is excavated with a backhoe (Fig. 7.10) or a clam shell (Fig. 7.11). Long-stick backhoes can dig to depths of approximately 20 to 25 m (60 to 80 ft). For slurry trenches that can be excavated with a backhoe, the backhoe is almost always the most economical means of excavation. For trenches that are too deep to be excavated with a backhoe, a clam shell is normally used. The trench may be excavated first with a backhoe to the maximum depth of excavation that is achievable with the backhoe and to further depths with a clam shell. Special chopping, chiseling, or other equipment may be used as necessary. The width of the excavation tool is usually equal to the width of the trench and is typically 0.6 to 1.2 m (2 to 4 ft).

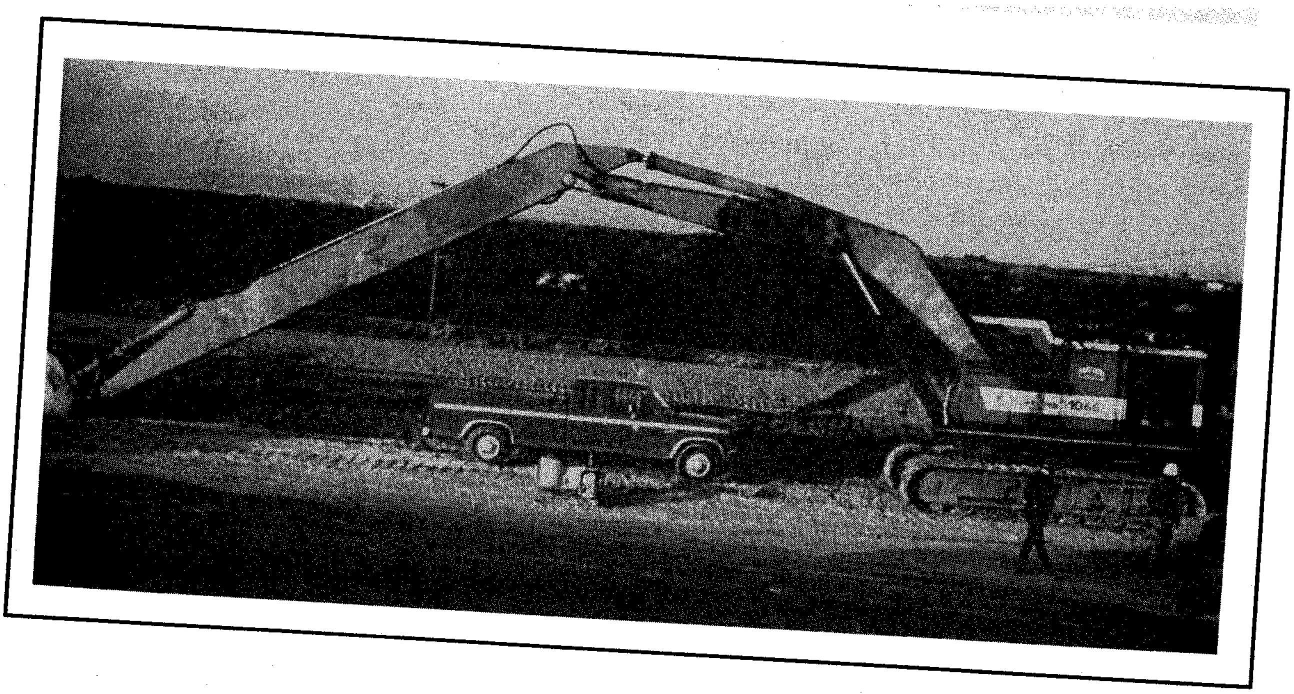


Figure 7.10 - Backhoe for Excavating Slurry Trench.

In most instances, the slurry trench cutoff wall is keyed into a stratum of relatively low hydraulic conductivity. In some instances, the vertical cutoff wall may be relatively shallow. For example, if a floating non-aqueous phase liquid such as gasoline is to be contained, the slurry trench cutoff wall may need to extend only a short distance below the water table surface, depending upon the site-specific circumstances. CQC/CQA personnel monitor the depth of excavation of the slurry trench and should log excavated materials to verify the types of materials present and to ensure specified penetration into a low-permeability layer. Monitoring normally involves examining soils that are excavated and direct measurement of the depth of trench by lowering a weight on a measuring tape down through the slurry. Additional equipment such as air lifts may be needed to remove sandy materials from the bottom of the trench prior to backfill.

7.3.5 Soil-Bentonite (SB) Backfill

Soil is mixed with the bentonite-water slurry to form soil-bentonite (SB) backfill. If the soil is too coarse, additional fines can be added. Dry, powdered bentonite may also be added, although it is difficult to ensure that the dry bentonite is uniformly distributed. In special applications in which the properties of the bentonite are degraded by the ground water, other types of clay may be used, e.g., attapulgite, to form a mineral-soil backfill. If possible, soil excavated from the trench is used for the soil component of SB backfill. However, if excavated soil is excessively contaminated or does not have the proper gradation, excavated soil may be hauled off for treatment and disposal.

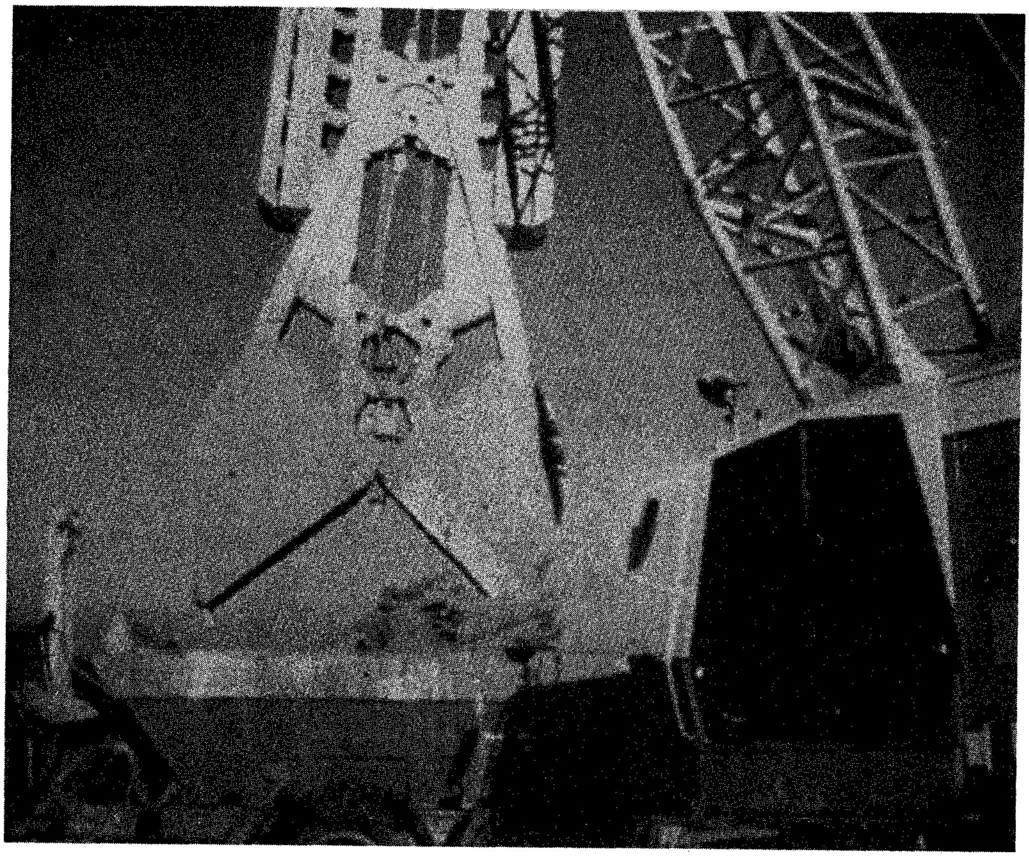


Figure 7.11. Clamshell for Excavating Slurry Trench.

Two parameters concerning the backfill are very important: (1) the presence of extremely coarse material (i.e., coarse gravel and cobbles), and (2) the presence of fine material. Coarse gravel is defined as material with particle sizes between 19 and 75 mm (ASTM D-2487). Cobbles are materials with particle sizes greater than 75 mm. Fine material is material passing the No. 200 sieve, which has openings of 0.075 mm. Cobbles will tend to settle and segregate in the backfill; coarse gravel may also segregate, but the degree of segregation depends on site-specific conditions. In some cases, the backfill may have to be screened to remove pieces that exceed the maximum size allowed in the specifications. The hydraulic conductivity of the backfill is affected by the percentage of fines present (D'Appolonia, 1980; Ryan, 1987; and Evans, 1993). Often, a minimum percentage of fines is specified. Ideally, the backfill material should contain at least 10 to 30% fines to achieve low hydraulic conductivity (< 10^{-7} cm/s).

The bentonite may be added in two ways: (1) soil is mixed with the bentonite slurry (usually with a dozer, as shown in Fig. 7.12) to form a viscous SB material; and (2) additional dry powdered bentonite may be added to the soil-bentonite slurry mixture. Dry, powdered bentonite may or may not be needed. D'Appolonia (1980) and Ryan (1987) discuss many of the details of SB backfill design.

Figure 7.12 - Mixing Backfill with Bentonite Slurry.

When SB backfill is used, a more-or-less continuous process of excavation, preparation of backfill, and backfilling is used. To initiate the process, backfill is placed by lowering it to the bottom of the trench, e.g., with a clamshell bucket, or placing it below the slurry surface with a tremie pipe (similar to a very long funnel) until the backfill rises above the surface of the slurry trench at the starting point of the trench. Additional SB backfill is then typically pushed into the trench with a dozer (Fig. 7.13). The viscous backfill sloughs downward and displaces the slurry in the trench. As an alternative method to initiate backfilling, a separate trench that is not part of the final slurry trench cutoff wall, called a lead-in trench, may be excavated outside at a point outside of the limits of the final slurry trench and backfilled with the process just described, to achieve full backfill at the point of initiation of the desired slurry trench.

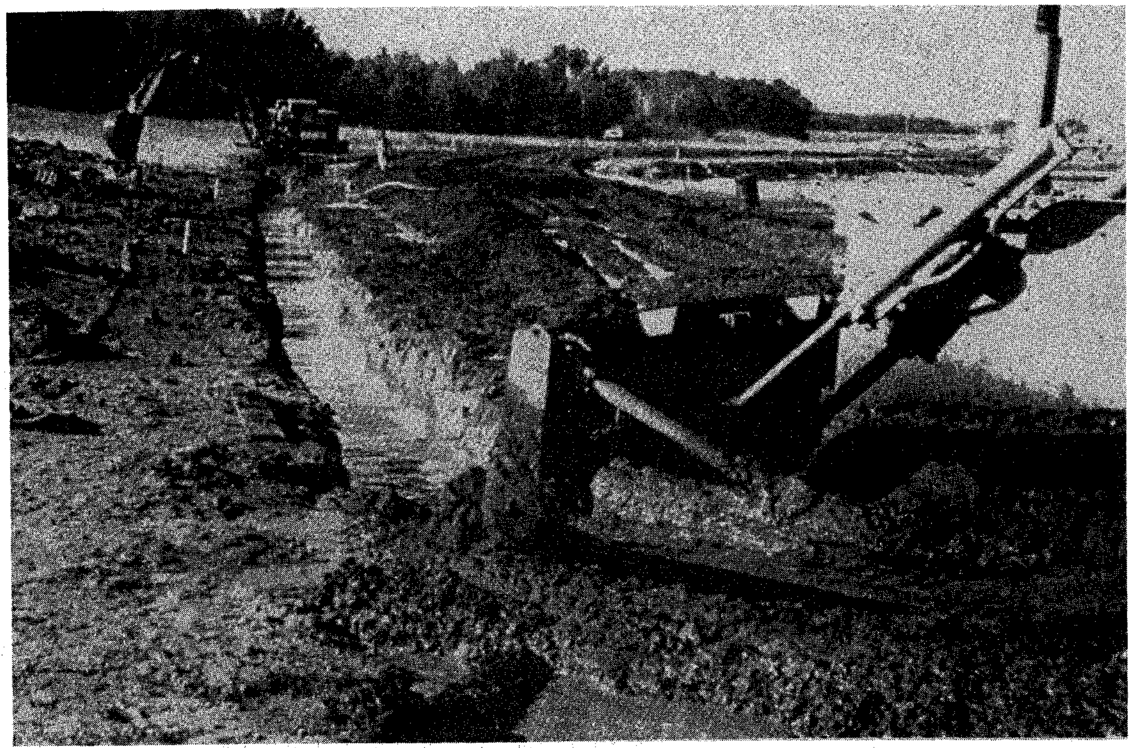


Figure 7.13 - Pushing Soil-Bentonite Backfill Into Slurry Trench with Dozer.

After the trench has been backfilled, low hydraulic conductivity is achieved via two mechanisms: (1) the SB backfill itself has low hydraulic conductivity (typical design value is $\leq 10^{-7}$ cm/s), and (2) the filter cake enhances the overall function of the wall as a barrier. Designers do not normally count on the filter cake as a component of the barrier; it is viewed as a possible source of added impermeability that enhances the reliability of the wall.

The compatibility of the backfill material with the ground water at a site should be assessed prior to construction. However, CQA personnel should be watchful for ground water conditions that may differ from those assumed in the compatibility testing program. CQA personnel should familiarize themselves with the compatibility testing program. Substances that are particularly aggressive to clay backfills include non-water-soluble organic chemicals, high and low pH liquids, and highly saline water. If there is any question about ground water conditions in relationship to the conditions covered in the compatibility testing program, the CQA engineer and/or design engineer should be consulted.

Improper backfilling of slurry trench cutoff walls can produce defects (Fig. 7.14). More details are given by Evans (1993). CQA personnel should watch out for accumulation of sandy materials during pauses in construction, e.g., during shutdowns or overnight; an airlift can be used to remove or resuspend the sand, if necessary.

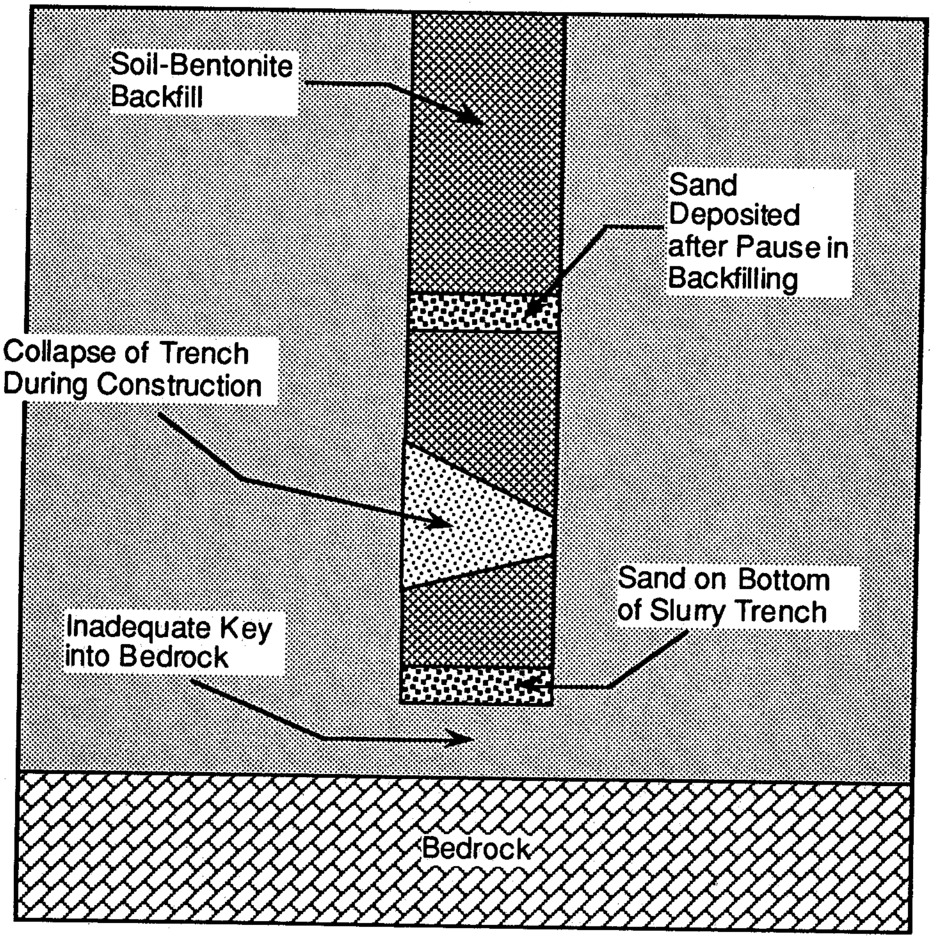


Figure 7.14 - Examples of Problems Produced by Improper Backfilling of Slurry Trench.

Some slurry trench cutoff walls fully encircle an area. As the slurry trench reaches the point of initiation of the slurry trench cutoff wall, closure is accomplished by excavating into the previously-backfilled wall.

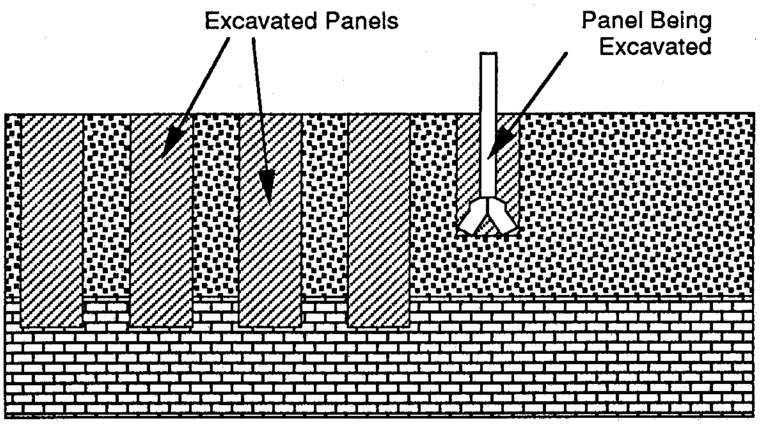
Hydraulic conductivity of SB backfill is normally measured by testing of small cylinders of material formed from field samples. Ideally, a sample of backfill material is scooped up from the backfill, placed in a cylinder of a specified type, consolidated to a prescribed effective stress, and permeated. It is rare for borings to be drilled into the backfill to obtain samples for testing.

7.3.6 Cement-Bentonite (CB) Cutoff Walls

A cement-bentonite (CB) cutoff wall is constructed with a cement-bentonite-water mixture that hardens and attains low hydraulic conductivity. The slurry trench is excavated, and excavated soils are hauled away. Then the trench is backfilled in one of two ways. In the usual method, the slurry used to maintain a stable trench during construction is CB rather than just bentonite-water, and the slurry is left in place to harden. A much-less-common technique is to construct the slurry trench with a bentonite-water slurry in discrete diaphragm cells (Fig. 7.15), and to displace the bentonite-water slurry with CB in each cell.

The CB mixture cures with time and hardens to the consistency of a medium to stiff clay (CB backfill is not nearly as strong as structural concrete). A typical CB slurry consists on a weight basis of 75 to 80% water, 15 to 20% cement, 5% bentonite, and a small amount of viscosity reducing material. Unfortunately, CB backfill is usually more permeable than SB backfill. Hydraulic conductivity of CB backfill is often in the range of 10^{-6} to 10^{-5} cm/s, which is about an order of magnitude or more greater than typical SB cutoff walls.

(A) Excavate Panels



(B) Excavate Between Panels

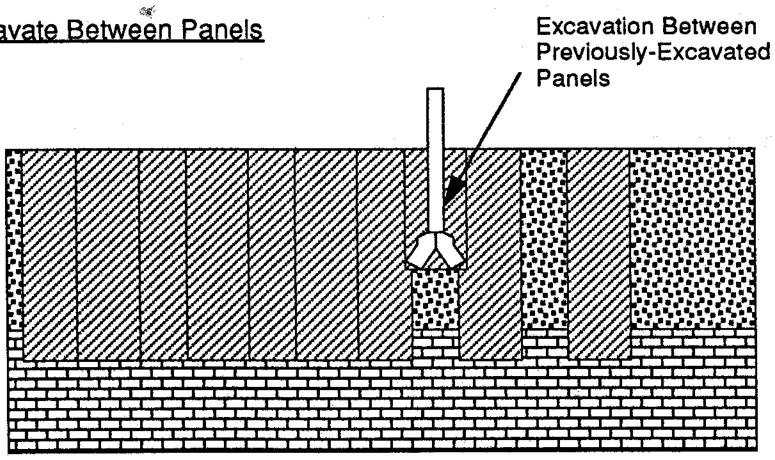


Figure 7.15 - Diaphragm-Wall Construction.

The CB cutoff wall is constructed using procedures almost identical to those employed in building structural diaphragm walls . In Europe, CB backfilled slurry trench cutoff walls are much more common than in the U.S., at least partly because the diaphragm-wall construction capability is more broadly available in Europe and because high-grade sodium bentonite (which is critical for soil-bentonite backfilled walls) is not readily available in Europe. In Europe, the CB often contains other ingredients besides cement, bentonite, and water, e.g., slag and fly ash.

7.3.7 Geomembrane in Slurry Trench Cutoff Walls

Geomembranes may be used to form a vertical cutoff wall. The geomembrane may be installed in one of at least two ways:

1. The geomembrane may be inserted in a trench filled with CB slurry to provide a composite CB-geomembrane barrier (Manassero and Pasqualini, 1992). The geomembrane is typically mounted to a frame, and the frame is lowered into the slurry. The base of the geomembrane contains a weight such that when the geomembrane is released from the frame, the frame can be removed without the geomembrane floating to the top. CQA personnel should be particularly watchful to ensure that the geomembrane is properly weighted and does not float out of position. Interlocks between geomembrane panels (Fig. 7.6) provide a seal between panels. The panels are typically relatively wide (of the order of 3 to 7 m) to minimize the number of interlocks and to speed installation. The width of a panel may be controlled by the width of excavated sections of CB-filled panels (Fig. 7.15).

2. The geomembrane may be driven directly into the CB backfill or into the native ground. Panels of geomembrane with widths of the order of 0.5 to 1 m (18 to 36 in.) are attached to a guide or insertion plate, which is driven or vibrated into the subsurface. If the panels are driven into a CB backfill material, the panels should be driven before the backfill sets up. Interlocks between geomembrane panels (Fig. 7.6) provide a seal between panels. This methodology is essentially the same as that of a sheet pile wall.

Although use of geomembranes in slurry trench cutoff walls is relatively new, the technology is gaining popularity. The promise of a practically impermeable vertical barrier, plus excellent chemical resistance of HDPE geomembranes, are compelling advantages. Development of more efficient construction procedures will make this type of cutoff wall increasingly attractive.

7.3.8 Other Backfills

Structural concrete could be used as a backfill, but if concrete is used, the material normally contains bentonite and is termed *plastic concrete* (Evans, 1993). Plastic concrete is a mixture of cement, bentonite, water, and aggregate. Plastic concrete is different from structural concrete because it contains bentonite and is different from SB backfill because plastic concrete contains aggregate. Other ingredients, e.g., fly ash, may be incorporated into the plastic concrete. Construction is typically with the panel method (Fig. 7.15). Hydraulic conductivity of the backfill can be $< 10^{-8}$ cm/s. High cost of plastic concrete limits its use.

A relatively new type of backfill is termed soil-cement-bentonite (SCB). The SCB wall uses native soils (not aggregates, as with plastic concrete). Placement is in a continuous trench rather than panel method.

7.3.9 Caps

A cutoff wall cap represents the final surface cap on top of the slurry trench cutoff wall. The cap may be designed to minimize infiltration, withstand traffic loadings, or serve other purposes. CQA personnel should also inspect the cap as well as the wall itself to ensure that the cap conforms with specification.

7.4 Other Types of Cutoff Walls

Evans (1993) discusses other types of cutoff walls. These include vibrating beam cutoff walls, deep soil mixed walls, and other types of cutoff walls. These are not discussed in detail here because these types of walls have been used much less frequently than the other types.

7.5 Specific CQA Requirements

No standard types of tests or frequencies of testing have evolved in the industry for construction of vertical cutoff walls. Among the reasons for this is the fact that construction materials and technology are continually improving. Recommendations from this section were taken largely from recommendations provided by Evans (personal communication).

For slurry trench cutoff walls, the following comments are applicable. The raw bentonite (or other clay) that is used to make the slurry may have specific requirements that must be met. If so, tests should be performed to verify those properties. There are no standard tests or frequency of tests for the bentonite. The reader may wish to consult Section 2.6.5 for a general discussion of tests and testing frequencies for bentonite-soil liners. For the slurry itself, common tests include viscosity, unit weight, and filtrate loss, and other tests often include pH and sand content. The properties of the slurry are normally measured on a regular basis by the contractor's CQC personnel; CQA personnel may perform occasional independent checks.

The soil that is excavated from the trench should be continuously logged by CQA personnel to verify that subsurface conditions are similar to those that were anticipated. The CQA personnel should look for evidence of instability in the walls of the trench (e.g., sloughing at the surface next to the trench or development of tension cracks). If the trench is to extend into a particular stratum (e.g., an aquitard), CQA personnel should verify that adequate penetration has occurred. The recommended procedure is to measure the depth of the trench once the excavator has encountered the aquitard and to measure the depth again, after adequate penetration is thought to have been made into the aquitard.

After the slurry has been prepared, and CQC tests indicate that the properties are adequate, additional samples are often taken of the slurry from the trench. The samples are often taken from near the base of the trench using a special sampler that is capable of trapping slurry from the bottom of the trench. The unit weight is particularly important because sediment may collect near the bottom of the trench. For SB backfill, the slurry must not be heavier than the backfill. The depth of the trench should also be confirmed by CQA personnel just prior to backfilling. Often, sediments can accumulate near the base of the trench -- the best time to check for accumulation is just prior to backfilling. CQA personnel should be particularly careful to check for sedimentation after periods when the slurry has not been agitated, e.g., after an overnight work stoppage.

Testing of SB backfill usually includes unit weight, slump, gradation, and hydraulic conductivity. Bentonite content may also be measured, e.g., using the methylene blue test (Alther, 1983). Slump testing is the same as for concrete (ASTM C-143). Hydraulic conductivity testing is often performed using the API (1990) fixed-ring device for the filter press test. Occasional comparative tests with ASTM D-5084 should be conducted. There is no widely-applied frequency of testing backfill materials.

7.6 Post Construction Tests for Continuity

At the present time, no testing procedures are available to determine the continuity of a completed vertical cutoff wall.

7.7 References

Alther, G. R. (1983), "The Methylene Blue Test for Bentonite Liner Quality Control," *Geotechnical Testing Journal*, Vol. 6, No. 3, pp. 133-143.

American Petroleum Institute (1990), *Recommended Practice for Standard Procedure for Field Testing Drilling Fluids,* API Recommended Practice 13-B-1, Dallas, Texas.

ASTM C-143, "Slump of Hydraulic Cement Concrete."

ASTM D-2487, "Classification of Soils for Engineering Purposes (Unified Soil Classification System)."

ASTM D-4380, "Density of Bentonitic Slurries."

ASTM D-4381, "Sand Content by Volume of Bentonite Slurries."

ASTM D-5084, "Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter."

D'Appolonia, D. J. (1980), "Soil-Bentonite Slurry Trench Cutoffs," *Journal of Geotechnical Engineering*, Vol. 106, No. 4, pp. 399-417.

Evans, J. C. (1993), "Vertical Cutoff Walls," in *Geotechnical Practice for Waste Disposal*, D. E. Daniel (Ed.), Chapman and Hall, London, pp. 430-454.

Manassero, M., and E. Pasqualini (1992), "Ground Pollutant Containment Barriers," in *Environmental Geotechnology*, M.A. Usmen and Y.B. Acar (Eds.), A.A. Balkema, Rotterdam, pp. 195-204.

Ryan, C. R. (1987), "Soil-Bentonite Cutoff Walls," in *Geotechnical Practice for Waste Disposal '87*, R. D. Woods (Ed.), American Society of Civil Engineers, New York, pp. 182-204.

Sherard, J. L., Woodward, R. J., Gizienski, S. F., and W. A. Clevenger (1963), *Earth and Earth-Rock Dams*, John Wiley and Sons, Inc., New York, 725 p.

U.S. Environmental Protection Agency (1984), "Slurry Trench Construction for Pollution Migration Control," Office of Emergency and Remedial Response, Washington, DC, EPA-540/2-84-001.

Xanthakos, P. P. (1979), *Slurry Walls*, McGraw-Hill Book Company, New York, 822 p.