Slurry walls for the rehabilitation of land disposal sites

J. C. Evans
Department of Civil and Environmental Engineering, Bucknell University, USA

Abstract

Slurry trench cutoff walls have been used as vertical barriers in the rehabilitation of land disposal sites to mitigate subsurface contaminant transport and permit safe reuse of the site. This paper presents two detailed case studies where soil bentonite slurry trench cutoff walls have been used for the rehabilitation of existing land disposal sites. The first case study, a hazardous waste land disposal site, was successfully closed and subsurface migration of contaminants to offsite receptors was controlled by a subsurface vertical barrier installed using the slurry trench method of construction. Portions of the site have been converted to a golf course. This second case study, a municipal and industrial waste landfill, was originally the site of a sand and gravel quarry. Using a soil-bentonite slurry trench cutoff wall, the existing landfill was contained to prevent the spread of ground water contamination and converted into an industrial use. Specifically, the site cap cover was designed as a “wear surface” cap designed to accommodate regular use for the storage of heavy equipment. The paper describes the site and subsurface conditions, the design, laboratory and analytical studies supporting the design, the construction, construction quality control measures and results and the performance of the completed systems. Based on the results of this study, it is concluded that the installation of vertical barriers using the soil-bentonite slurry trench method of construction can provide an economical and environmentally sound means to control subsurface contaminant migration from land disposal sites and, when combined with a properly designed and constructed cover, allows for site reuse.

1 Introduction

This paper describes the use of soil-bentonite slurry trench cut off walls as vertical barriers for the rehabilitation of two land disposal sites: one a solid and
industrial waste landfill and the other a hazardous waste land disposal site. For the solid and industrial waste landfill, the purpose of the slurry trench cutoff wall was to form a containment transport barrier to minimize the risk of aquifer contamination. This cutoff wall in conjunction with a cover system allows for site redevelopment for industrial use as a heavy equipment storage area. For the hazardous waste land disposal facility, the slurry trench cutoff wall was also a contaminant transport barrier to permit closure of the landfill and subsequent redevelopment of the site as a golf course. For each of these projects, site and subsurface characteristics are described along with design considerations. Finally, construction aspects of each project are presented. It is believed that these two case histories provide insight into the use of soil-bentonite slurry trench cutoff wall technology and, in particular, its use for the rehabilitation of land disposal sites.

2 Slurry wall technology

Soil-bentonite (SB) slurry trench cut off walls are constructed using a two-phase method of construction. In the first phase, a trench is excavated along the cutoff wall alignment and to the desired depth. Trench stability is maintained by using slurry comprised of 5% bentonite and 95% water (by weight). During the second phase, the slurry in the trench is displaced by a soil-bentonite backfill. This backfill is composed of a mixture of soil, bentonite and water. This technique has been found to be rapid and inexpensive and forms a continuous subsurface barrier having a permeability of less than $1 \times 10^{-9}$ m/s. The excavation, backfill mixing, and backfill placement are shown schematically on Figure 1.

![Schematic of soil-bentonite slurry trench cutoff wall construction](image)

Figure 1: Schematic of soil-bentonite slurry trench cutoff wall construction [1]

Notice that this technique differs substantially from the single-phase technique of cement-bentonite widely employed in the United Kingdom and
throughout Europe. In the UK a mixture of water, granulated ground blast furnace slag, and cement (slag-CB) is used for trenching and then left to harden (cure) in the trench to form the permanent cutoff wall. A comparison of these two techniques is shown on Table 1.

Table 1. Comparison of US and UK practices and outcomes [2]

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>US PRACTICE</th>
<th>UK PRACTICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barrier composition</td>
<td>Soil-bentonite (SB)</td>
<td>Slag-cement-bentonite (CB)</td>
</tr>
<tr>
<td>Hydraulic conductivity</td>
<td>&lt; 1x10^-9 m/s</td>
<td>&lt; 1x10^-9 m/s after 90 days</td>
</tr>
<tr>
<td>Solids content (M/M_r)</td>
<td>~ 70%</td>
<td>~20%</td>
</tr>
<tr>
<td>Unconfined compressive strength</td>
<td>~0</td>
<td>&gt; 100 kPa @ 28 days</td>
</tr>
<tr>
<td>Strain to failure</td>
<td>plastic</td>
<td>brittle</td>
</tr>
<tr>
<td>Time dependency</td>
<td>Consolidation: rapidly (within a few days)</td>
<td>Initial set: within one day Complete hydration reactions: 90 days or more</td>
</tr>
<tr>
<td>Construction Stages</td>
<td>Two phase</td>
<td>One phase</td>
</tr>
<tr>
<td>Excavation Equipment</td>
<td>Backhoe, clamshell</td>
<td>Backhoe, clamshell</td>
</tr>
<tr>
<td>Depth (typical)</td>
<td>20 m</td>
<td>15 m</td>
</tr>
<tr>
<td>Width (typical)</td>
<td>0.75m</td>
<td>0.6m</td>
</tr>
<tr>
<td>Length (typical)</td>
<td>&gt; 1 km</td>
<td>&lt; 1 km</td>
</tr>
<tr>
<td>Working space needed</td>
<td>Large for slurry plant &amp; backfill mixing</td>
<td>Small for slurry plant &amp; excavation spoil disposal</td>
</tr>
<tr>
<td>Material assessment</td>
<td>Hydraulic conductivity, compatibility during design</td>
<td>Hydraulic conductivity, strength, strain at failure</td>
</tr>
</tbody>
</table>

3 Case Study 1: Hazardous waste land disposal facility

After many years of study considering a number of alternatives for the closure of a hazardous waste landfill, a containment remedy was selected. As it relates to this paper, the selected remedy had two features of note. First, the containment system employed a vertical barrier constructed using the soil-bentonite slurry trench method of construction. Second, the rehabilitation of the landfill site was based on the reuse of the site for golfing and as a wildlife sanctuary. In a press release [3], the U.S. Environmental Protection Agency (EPA) announced a press event at the McColl Superfund Site “to commemorate completion of a waste containment system on over 100,000 cubic yards of hazardous waste and to showcase a section of golf course that has been expanded onto the site.” They go
on to note “the golf course will be managed as a wildlife sanctuary, including enhanced habitats for native and migratory birds.”

3.1 Site history

The site was used for land disposal of oil and refinery sludge beginning in the 1940’s. Subsequently, oil-based drilling mud was also disposed on the site. The wastes were disposed of in pits known as sumps. By 1982, the site was placed on the National Priorities List (Superfund). The sludge readily emitted Volatile Organic Compounds and sulfur dioxide when disturbed. A temporary oil cap to minimize odors was installed in 1982. The 1989 remediation plan called for thermal destruction that necessitated excavation of the waste. A trial excavation was conducted in 1990 to evaluate how readily the materials could be excavated with conventional equipment, if additives might alter the excavation material properties and the magnitude of the air emissions resulting from excavation. In 1993, in situ stabilization/solidification was selected as a remedial alternative and treatability studies subsequently followed. By 1995, noting concerns of the community, the US EPA decided to cap the site. The final closure implemented included a cap and soil bentonite slurry trench cutoff wall. The slurry was to prevent inward migration of ground water and outward migration of contaminants.

3.2 Design studies

The site varied significantly in elevation and was mostly undeveloped open space. Soil cover over the pits varied from 0.8 m to 2.7 m. Material within the pits included soft flowable tar, drilling mud, and semi-solid asphaltic waste. In situ soils (often reworked) consisted of interbedded sands, silts and clays. Regional ground water is found at depths of 50 to 80 m.

As expected, a major design consideration was the compatibility of SB backfill with the contaminants in the subsurface. To investigate this, a chemical compatibility laboratory testing program was conducted using a waste-derived liquid thought to be representative of a worst case scenario. The long-term triaxial permeability tests conducted to evaluate compatibility of the backfill with the waste-derived liquid revealed that the permeability could be expected to increase slightly. Typical results (in cm/s) showing a slight increase in hydraulic conductivity are presented on Figure 2. Also notice the very low pH of the effluent. Based upon application of concepts from colloidal surface chemistry and bentonite clay mineralogy, low pH would be expected to cause a permeability increase in SB backfill [4]. From these compatibility studies, the construction specifications required a maximum permeability of $6 \times 10^{-10} \text{ m/s}$ to provide a barrier permeability that would remain below for the $1 \times 10^{-9} \text{ m/s}$ design life [5].
Figure 2: Compatibility test results for the McColl site

3.3 Construction of slurry wall containment

Construction proceeded in a manner similar to that shown on the schematic presented as Figure 1. Excavation was performed with a backhoe and using bentonite-water slurry to maintain trench stability. While Figure 1 shows backfill being mixed along the trench, for better control over backfill quality, remote mixing is preferred. Thus, for this project, to improve the quality control of the SB backfill, excavated soils were transported to a remote mixing area where batches of backfill were all prepared (see Figure 3).
Figure 3: Backfilling mixing pit for the McColl site slurry trench

Figure 4: Backfilling the McColl site slurry trench
Once a batch of backfill was determined to have met the project requirements, it was transported by truck for placement in the trench as shown on Figure 4. Notice the existing golf course adjoining the site in this picture.

3.4 Field quality control

An extensive program of quality control was implemented during the construction phase of this project. Laboratory testing on the bentonite included a total of 38 measurements of filtrate loss (< 25 ml in 30 min. at 100 psi) and a free swell test (> 25 ml for 2 g.). Field testing conducted on field-mixed on fresh slurry included Marsh viscosity and density (2 per day) and filtrate loss and pH (3 per day). Samples of slurry were also obtained from the trench and tested for Marsh Viscosity and density. Field tests on the backfill were conducted to measure slump and density. Soundings were obtained every 20 feet along the trench alignment for control of cutoff wall depth. Typical results are plotted on Figure 3 showing ground surface, excavation depth and soundings showing the backfill surface. Laboratory tests on field mixed samples included moisture content, Atterberg Limits, fines content (% passing the No. 200 sieve), grain size distribution by sieve and hydrometer, grain size distribution by wash sieve analysis, and hydraulic conductivity using the flexible wall permeability test. Over 30 triaxial permeability tests were conducted on field mixed samples with an average permeability of less than 1x10^-9 m/s.

4 Case Study 2: Municipal and industrial waste landfill

A soil bentonite slurry trench cutoff wall was used to enable the Delaware Sand and Gravel site to be converted from a landfill to industrial use as a parking area for heavy equipment. Originally a sand and gravel quarry, the site then was used for the disposal of approximately 500,000 cubic meters of municipal and industrial wastes between 1968 and 1976. The site is now covered and the drum disposal area is surrounded by a soil-bentonite slurry trench cutoff wall. On the site, specially designed “wear surface” cover allows for the storage of heavy equipment. The ground water is protected from further contamination by the slurry wall barrier. Projects such as this one are part of a Superfund Redevelopment Initiative. Under this initiative, categories of site reuse include recreational, residential, commercial, ecological and public. Sites such as this case study can be remediated using “presumptive remedies” focused on source control. Typical components in source control remedies include a cover system and a vertical barrier.

4.1 Site history

The Delaware Sand and Gravel Company site is 27 acres and borders on another waste site, commercial facilities, and residential areas. The nearest resident is within 20m and a residential development is within 0.5 miles. Underlying the site is an aquifer that is used as a public water source. In addition to household
and construction wastes, approximately 7000 drums of industrial wastes were landfilled in the drum disposal area (DDA). By 1971 there was evidence of ground water contamination and by 1976 the landfill stopped receiving wastes. Contaminants included volatile organic compounds such as benzene, toluene and xylene, other organic compounds such as PCB and PAH and metals such as chromium and lead.

Remedial actions included excavation and on-site mobile incineration of selected wastes and contaminated soils, excavation and off-site disposal of selected surface debris, a cap system, some ground water pumping with treatment and a vertical barrier. The purpose of the vertical barrier, a slurry wall, was described as follows [6]: "...a slurry wall around the DDA to isolate the soil containing the majority of hazardous constituents in the unsaturated and saturated portion of the aquifer from the surrounding subsurface environment..."

4.2 Design studies

A total of 17 test borings were drilled along the proposed alignment of the slurry wall surrounding the drum disposal area. These borings, at approximately 30m on center, were drilled to delineate the subsurface conditions along the proposed alignment (see Figure 5). Specifically, soil samples were collected and field screened for volatile organic contaminants as well as for geotechnical laboratory testing. This testing included moisture content, grain size distribution and Atterberg limits. The slurry wall mix design was developed to account for variations in material along the cutoff wall alignment. This illustrates one of the disadvantages of the SB cutoff wall commonly used in the US as compared to the slag-CB wall used in the UK. Since slag-CB is formulated entirely of off-site ingredients, the variation along the trench is minimized as compared to SB which reuses excavated soils.

As with the McColl project described above, compatibility between the SB backfill and the contaminants was a concern during the design phase. In order to assess the impact of the site contaminants on the bentonite-water slurry two indicator test types were conducted using three difference bentonite products. The Free Swell test consist of measuring the swelling volume of bentonite in water and in contaminated water from a monitoring well thought to represent worst-case conditions. All bentonite slurries tested exhibited a substantially lower free swell when tested with contaminated water compared to potable water. The Relative Filtration Loss Test was also conducted for slurry mixtures made from each of the three bentonite products. Using the filtrate loss device, the hydraulic conductivity of the filter cake was determined using both potable water and water from the contaminated monitoring well. The ratios of hydraulic conductivity values were 2.62, 3.25 and 3.48 for the three bentonite slurries. Based upon the free swell and relative filtrate loss testing, the best performing bentonite was selected. In order to evaluate the compatibility of the SB backfill, two long-term triaxial permeability (compatibility) tests were conducted supporting the compatibility of the cutoff wall with the contaminated ground water from the site.
5 Summary and conclusions

Two case studies have been presented supporting the use of SB slurry trench cutoff walls in the rehabilitation of land disposal sites. Both cases illustrate examples of site reuse after implementation of the containment remediation strategy. In both of these case studies, a SB subsurface vertical cutoff wall was constructed using the slurry trench method of construction. For both cutoff walls, the critical design and performance issue was the compatibility of the SB backfill with the site contaminants. Data are presented from design studies and construction that illustrate the studies conducted to evaluate this critical question of compatibility. The paper also presents a comparison of the US style SB cutoff walls with the UK style slag CB walls. It is concluded that vertical barriers, when used in conjunction with cover systems, can provide effective containment for contaminant migration allowing for the rehabilitation and reuse of land disposal sites.

References


