Self-Healing Soft Grouts Form *In Situ* Bottom Barrier In EarthSaw Field Demo

Ernie E. Carter, P.E.
President, Carter Technologies Co., Sugar Land, Texas 77478, USA
Phone: 281-495-2603; www.cartertechnologiesco.com; e-mail: cartertech@prodigy.net

Abstract
Radioactive mixed waste buried in multi-acre size un-lined pits and trenches is a huge problem. A field test of a new type of barrier material along with a unique *in situ* construction method is described. The new barrier material is installed as a viscous liquid but does not harden like a conventional grout but instead cures to a plastic state similar to modeling clay. Even in its liquid state it provides physical and hydraulic bias which acts to isolate contaminants inside the barrier as well as preventing contamination of the grout itself. The soft grout is able to tolerate earth movements and can self-heal drilling penetrations.

The EarthSaw field test formed a 24-inch thick bottom and perimeter wall barrier around a simulated waste site using the soft grout. Plans for a larger 200-foot square basin are described. Even larger barrier construction under large multi-acre sites is also discussed. This method divides the bottom barrier into sections using directionally drilled holes and operating the abrasive cutting cable through these holes. An HDPE and clay cap structure completes a vault around the waste and allows enhanced closed system techniques for monitoring of vault integrity.

Introduction

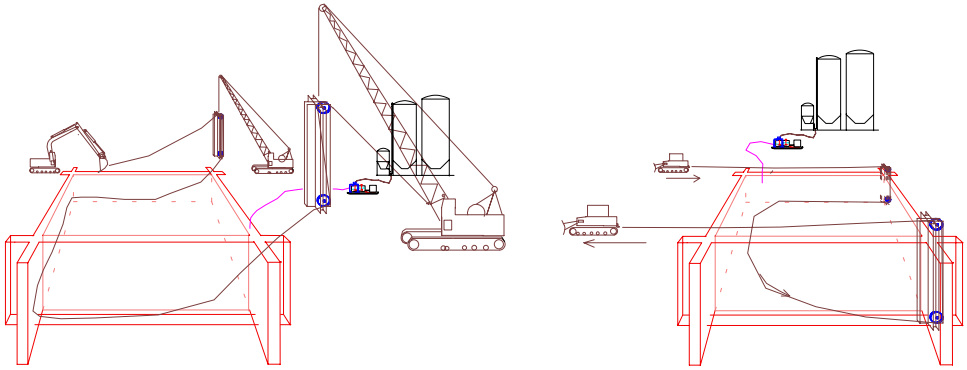
Many government disposal sites which received low level and mixed radioactive waste during the period from the mid 1940s to the early 1980s received this waste in unlined pits and trenches. Over 3 million cubic yards of these wastes were buried. Some of this waste now presents an unacceptable environmental risk but for various technical reasons it is exceedingly difficult and costly to safely remove and re-dispose.

In the early nineties, engineers at the Idaho National Engineering Laboratory viewing a presentation on grouting methods expressed a wish list for containment technology for creating a bottom barrier under a closed disposal pit. Objectives for the technology were for a method which could work in almost any soil type, including cobbles and even fractured rock, and which could safely isolate a waste site holding undocumented waste. Since the waste could be almost any type of material with any characteristics we concluded that we would be unable to drill through the waste or invade it by any chemical or physical means. It was also determined that for the technology to be acceptable it must initially provide an absolute proof of the continuity of the barrier as well as a means of verifying the continuity of the barrier year by year.

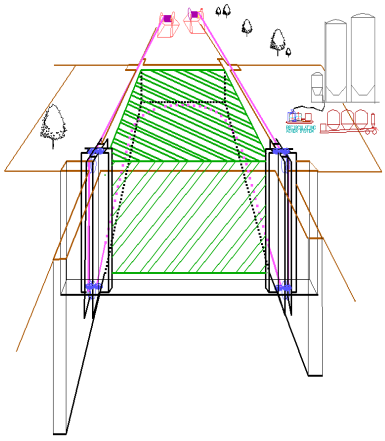
The EarthSaw technique was developed to address these issues. The EarthSaw technology is a method of constructing a high integrity barrier under and around an existing landfill, waste burial site, or underground tank without contacting or exposing

any contaminated material. The method works by mechanical cutting of a thin subterranean pathway and then expanding that pathway into a thick impermeable barrier. The cutting work is done by an abrasive steel cable which is circulated or reciprocated through the cut like a band saw. The technology is similar to the diamond wire quarry saw method used to cut large blocks of stone. Cutting of horizontal barriers is made possible by the use of high specific gravity fluids which hydraulically support the overburden material above the horizontal cut. These fluids have special properties which allow them to provide lubricity and cuttings transport while maintaining hydrostatic pressure against a permeable formation. Several types of grout fluids are available. Some harden into a rock-like solid while others remain soft and pliable.

The patented technique can take several different forms. The most basic is the **vertical block method**. This method is preferred for smaller sites of less than 2 acres in size. Consider a hypothetical 200-foot by-600 foot site located in a sand and cobble alluvial soil adjacent to an inland river contaminated with uranium, arsenic, and mercury. Contamination extends 50 feet deep and the water table is 10 feet below grade.



In this method we begin by constructing a conventional 3-foot wide slurry trench around the perimeter of the site using extended backhoe or clamshell excavation to a depth of 60 feet. However we do not backfill the trench with soil bentonite. Instead, we install a special cable saw device into the perimeter trench. This cable saw uses a load frame device at one or more corners of the perimeter trench to transition the horizontal pull on the cable at the bottom of the trench to a horizontal pull at the surface. The load frame is a heavy steel beam with a top and bottom cable pulley, which fits vertically into the intersection corner of the slurry trench. After the cable saw device is installed, the slurry in the trench is replaced with a special high specific gravity TECT B grout. The grout has a higher specific gravity (21.379 pounds per gallon) than the block of earth (18 pounds per gallon) to be isolated. The trench is filled to within 10 feet of the surface with the heavy grout leaving approximately 8 feet of light weight bentonite slurry



on top of the grout to keep the top of the trench from collapsing. (If the entire trench were filled with heavy grout the buoyant force would be too strong and the block could break free before the cable saw finishes the cut.)

The cable saw is then activated and the earth block is undercut. Gravity causes the grout to flow into the horizontal cut and to support the block as it is severed from the earth. After the cut proceeds about 100 foot downrange the free end of the block will begin to rise a few inches. During the cut additional light weight slurry is replaced with grout using the actual rise of the block to gauge how much additional grout is needed. After the block is floating free, The rest of the light slurry is removed as additional grout is added to the perimeter trench filling it to within 5-1/2 feet of the surface. This causes the block to rise to the desired elevation of 4 feet. The thickness of the layer of grout below the block is equal to the rise of the block above the surface. Approximately 27,500 cubic yards of grout will make up the final barrier in this example.

After the barrier is installed an engineered synthetic cap may be installed and keyed into the side walls of the barrier. This cap will cover the perimeter trench and prevent drying of the grout near the surface. Extraction wells within the isolated block may be used to remove some or all of the free water within the containment system. Monitoring of residual interior moisture levels against outside levels may be used as a passive monitoring means.

The first EarthSaw field demonstration of the vertical block method was carried out in September of 1999 in an industrial park near Houston, Texas. The soil at this site was an unconsolidated river sand which was quite damp below the surface. We performed the method on two adjacent areas. Each test area involved a bedroom-sized block of clean earth. The grout slurry is prepared and placed as a viscous liquid with a specific gravity between 2.5 and 3.0 relative to water. Most soil has a bulk specific gravity of 2.0 or less while rocks typically range from 2.5 to the 3.0 value.

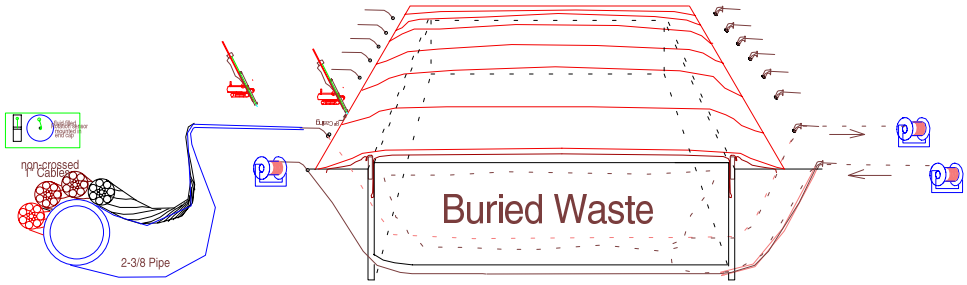
In this demonstration we used a novel type of grout, which we call "TECT B". This grout is made from a highly dispersed clay augmented with non-toxic heavy weight additives. After placement in the ground for many months, TECT B grout undergoes a type of curing process in which it reaches equilibrium with the vapor pressure of water vapor in the ground. The end result of this process is that the TECT B grout develops a plastic consistency similar to stiff peanut butter. Under typical subterranean conditions the grout will never harden and therefore will never have the potential to crack. Since this stiff material remains under hydrostatic pressure on the bottom of the barrier it will flow as a liquid and self-heal any displacement caused by earth movement, drilling, or other factors.

When first introduced into the trench, the liquid TECT B grout creates a hydraulic barrier. Even though the grout is in a liquid state it produces an impermeable filter cake on the exposed surfaces of the trench and the horizontal cut as billions of microscopic sheet-like structures stack up on those surfaces. The hydrostatic force of the dense fluid also produces a hydraulic gradient which prevent contaminated water in the soil from passing into the fluid grout. In its liquid form the permeability of the grout starts out in the range of 10^{-6} cm/sec but as curing proceeds it reaches a final permeability of less than 10^{-8} cm/sec. As with conventional vertical slurry walls, Bottom barriers made with TECT B type grout are limited to applications which are not subject to severe subterranean drying conditions. The TECT B soft grout is made from natural materials which are thermodynamically stable in the environment. In a properly designed application where the grout is not exposed to drying conditions, we do not anticipate degradation over time. TECT B grouts can be formulated to adsorb organic liquids as well as aqueous liquids.

In addition to its properties of crack resistance and low permeability TECT B grout can be formulated to capture or reactively treat certain contaminants. We call this technology "Semi-Permeable Reactive Barriers". Unlike conventional reactive barriers which lose effectiveness within a few years due to permeability reduction and loss of reactive potential, these semi-permeable barriers can last indefinitely. Since the barrier surrounds the source of the contamination no funnel and gate are required and the contaminated groundwater cannot go around or under the barrier. This eliminates the need for making the reactive wall (barrier) more permeable than the soil. The barrier may begin as a low permeability material and therefore it may retain its reactive potential for hundreds of years. Reaction products that further reduce permeability only enhance the performance of the barrier.

EarthSaw barriers using the Vertical Block Method described here can be constructed to the same depths as slurry trench technology. Slurry trenching with extended reach backhoes is routinely done to depths of 90 feet or more. Clamshell techniques allow significantly greater depths. It has not been determined what the maximum width and length of single bottom barrier cuts may be. We believe that widths of 200 feet and lengths of 800 feet are feasible in common soil types. We expect that working in rock will reduce this significantly.

A larger scale form of the technology is also available. This method uses a similar cable saw to cut between adjacent directionally drilled holes instead of between open trenches. The directionally drilled holes may be up to 1000 feet long and 100 feet apart and need not be parallel to one another or precisely spaced. This allows us to form a bottom barrier under very large landfills without drilling through the waste or exposing personnel to its hazards. The directional drilling units are used to pull a patented pipe and cable bundle into each hole. One cable from each of two adjacent holes is joined by a long splice and used to pull a specialized cutting cable into position to begin cutting the section of the barrier between those two holes. Cables which break in service can be replaced as many times as needed and the cutting process resumed. Fresh grout is introduced by the pipe in the zone of the cut to help flush cuttings away.



This method is intended for larger sites on the order of 25 acres in size. Due to the cost of working such large sites, this method has not yet been field demonstrated but may be the subject of future papers.

The EarthSaw method using soft self-healing grouts is an exciting new technology which promises to be a major advance in technology to address legacy buried radioactive waste in pits and trenches.

Floating block of Soil