DEMONSTRATION OF IN SITU-CONSTRUCTED HORIZONTAL SOIL CONTAINMENT BARRIER AT FERNALD

Paul J. Pettit and David Ridenour
Fernald Environmental Restoration Management Corporation
Fernald, Ohio

Jeffrey Walker
U. S. Department of Energy
Washington, D.C.

Kent Saugier
Halliburton NUS Corporation
Houston, Texas

ABSTRACT

A new design of jet grouting tool that can be guided by horizontal well casings and that operates in the horizontal plane has been used for the in situ placement of grout and construction of a prototype horizontal barrier that is free of "windows". Jet grouting techniques have been advanced to permit construction of horizontal barriers underneath contaminated soil without having to excavate or disturb the waste.

The paper describes progress on the Fernald Environmental Restoration Management Corporation (FERMCO) In Situ Land Containment Project which is sponsored by the U.S. Department of Energy's (DOE) Office of Technology Development (OTD) for DOE's Fernald Environmental Management Project (FEMP). The Fernald project is to demonstrate a novel, enabling technology for the controlled underground placement of horizontal panels of grout, and the joining of adjacent panels to construct practical, extensive barriers. Construction strategy, equipment mechanics and operating details of this new method are described.

INTRODUCTION

"Covering your bottom" is a widespread need in soil contamination containment and site environmental remediation. DOE sites, other government facilities, and industrial installations frequently have need for in-ground barriers to prevent the spread of contamination from soil being contained or treated for restoration. These needs have resulted in the development and application of methods such as slurry walls and various forms of vertically-installed barriers for preventing the horizontal migration of contaminants in soil. Slurry walls can be constructed to halt the spread of contaminants in the horizontal plane, but control of vertical flow in undisturbed soils typically has relied on the existence of naturally-occurring horizontal aquitards such as clay strata. Common practice for "complete" containment is to construct vertical slurry walls that tie in to a competent stratum. In these cases, the performance of the containment system is dependent on the naturally-occurring stratum being free of breaches, natural or otherwise, which is often difficult to assure.

Problems with constructing complete, competent containment systems arise when no natural barrier to vertical migration exists within a practical depth below ground. This situation prevails at several DOE facilities, including Savannah River and Hanford. In similar circumstances at industrial sites where in situ construction of horizontal barriers has been the selected approach, methods of choice have involved pressure and permeation grouting techniques. In all cases, massive applications of grout through closely spaced, overlapping injections have been prescribed to assure formation of a complete horizontal barrier. Nevertheless, complete coverage of leak paths by grout is never assured in the uncertain, non-inspectable conditions that exist deep underground.

This document describes a novel technique for forming horizontal barriers and plans by the DOE Office of Technology Development and FERMCO to demonstrate the method at DOE's Fernald site near Cincinnati, Ohio.

THE NEW TECHNIQUE

The new method is an enabling technology for the predictable, ascertainable, sub-surface placement of panels of grout in extensive, planer structures of horizontal or other orientations. The technique applies jet grouting experience of FERMCO Teaming Partner Halliburton NUS Corporation (HNUS). Jet grouting typically is performed by pumping cement slurry at high pressure through a special drill pipe having orifices (jets) positioned laterally along the sides of the pipe near the extreme end (1). When the drill pipe is thrust into the soil, the slurry exiting the jets with high kinetic energy, shatters the soil and mixes it with grout. Rotating the drill pipe and advancing it slowly through the soil while pumping grout results in the in situ construction of a right cylinder of treated soil. Fig. 1 shows typical cylinders or vertical columns formed by jet grouting and then excavated for illustration purposes. The cylinders are a unit "building block" that can be replicated and joined to form such structures as cut-off walls or slurry barriers (2). Heretofore, jet grouting primary construction has been done only with slurry jets oriented in directions perpendicular to the direction of advancement of the drill pipe or the special tool used to apply the slurry to the soil. Successful construction of cut-off walls of both the vertical and the horizontal type has been completed by conventional jet grouting, but the main disadvantage of using individual columns lies in the inability to verify complete interpenetration, or joining, of adjacent jetted columns along their entire lengths without the existence of "windows" in the barrier wall.

A further disadvantage in constructing horizontal barriers by conventional jet grouting often arises from the need to work from a pit or excavation in order to "drill" horizontally and install the columns at the required depth.

The novel method to be demonstrated at Fernald uses a newly developed, special type of (horizontal) jetting tool and an entirely new system for applying the tool to soil for the in situ construction of horizontal barriers. Figure 2 shows an

Fig. 1. Example of soil-cement columns formed by jet grouting.

example of a new tool in the form of a bar (as distinct from the drill-form of tool generally used for jet grouting). The bar has several jet orifices along its length, and is designed to be advanced through the soil in a direction perpendicular to the long axis of the bar. The unique system of application involves attaching cables or other linkage to each end of the bar and advancing it by dragging it through the soil while fluid (grout) at high pressure is pumped through the jet orifices. As the bar is pulled, the jets of fluid impinge on soil in front of the bar and fluidize it, allowing the bar to advance easily through the disrupted zone. When the jets fluidize the soil, they also mix the fluid grout material with it to form an amended soil with barrier properties. Advancing the bar by dragging, leaves in its pathway a panel-shaped, treated zone the width of the bar and of a thickness equal to the effective cutting distance of the fluid jets, which can be as much as 18" in soft soil. Selection of a jetting fluid or grout with waterproofing properties enables the construction of a groundwater barrier. Figure 3 illustrates the use of the new method to construct a barrier under a contaminated area. The section of barrier constructed by a single pass of the jetting bar, the panel, is the unit "building block" for larger barriers.

Control over the location and orientation of the constructed barrier is achieved by installing pathway guide tubes prior to construction. The guide tubes are placed by directional drilling, and roughly parallel the intended pathway to be traced by the right and left ends of the jetting bar as it advances through the soil. With the pathway guide tubes in place, cables are installed through both and then attached to the jetting bar to drag it along the pathway. The configuration resembles a capital "H", with the jetting bar serving as the cross member. A winch or pulling vehicle is used to drag the slurry-pressurized jetting bar along the pathway and form a panel of barrier. For the multiple passes or panels needed to form an extensive barrier, the pattern of the guide tubes resembles ribs. Guide tubes of jet-friable PVC may be used, or steel drill pipe from the directional drilling operation can serve as guides, as well as linkage, and be withdrawn at the time of jetting. Precise parallel placement of the guide tubes is not essential, because the advancement method and design of the jetting bar allow relatively wide tolerances (of the order of 24").

A demonstration has been completed using the new method for the in situ construction of a unit "building block" of barrier. Figures 4a and 4b show an excavated portion of the 10-feet wide, by 12-inches thick, by 100-ft long panel constructed 10-feet deep in clay soil by jetting with cement slurry. The proof of concept for this novel method has been completed; nevertheless, several additional developments must be

Fig. 2. Jet grouting tool (bar) for horizontal use.

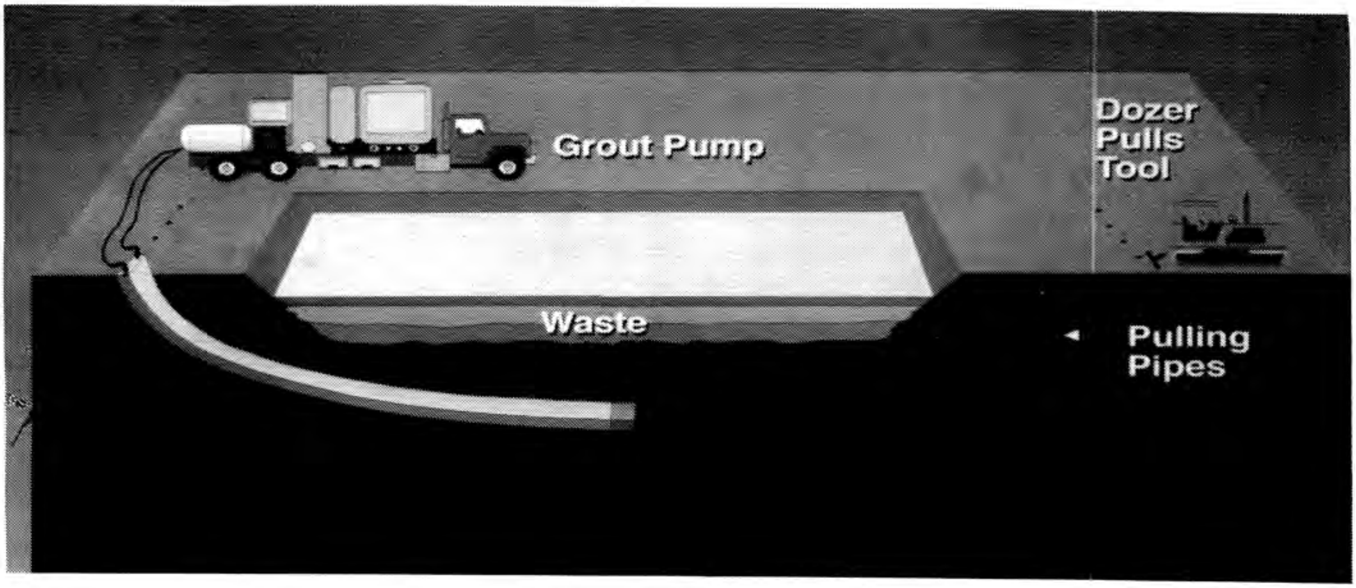

Fig. 3. Horizontal panels joined to form barrier.

Fig. 4a. Proto type in situ-constructed barrier strip.

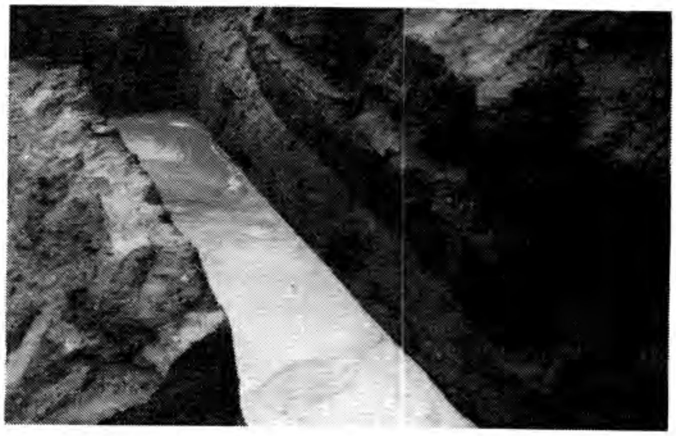

Fig. 4b. Cross-section of proto type barrier.

achieved and demonstrated before the jet grouted horizontal barrier can be put to widespread use as a reliable method for site remediation. The DOE-sponsored work in progress at FEMP addresses the needed developments.

THE FEMP PROGRAM

Although proof of concept is demonstrated for the basic technology for placing grout, the ability to construct a competent barrier of useful dimensions and properties remains to be demonstrated. It remains to be shown that neighboring units of horizontal panels, formed on individual passes of the jetting bar, can be joined in a reliable and reproducible method. The technical challenge is to make the joints (seams) competent.

The overall objective of the Fernald project is to implement needed technical advancements and demonstrate a practical, reliable method for jet grouting in situ construction of horizontal barrier waste containment structures. Related objectives involve:

- Producing and testing jetting bars for efficient construction of barriers and seams.
- Installation, in situ, of four adjacent (unit) barrier panels with competent joints or seams in both the transverse and longitudinal directions.
- Gaining acceptance of the technology by regulators through their early involvement in the detail planning and demonstration.
- Developing construction cost information of the type needed by site remediators for decision making on alternative approaches and technologies.
- Developing "enabling technology" for the expanded use or enhanced application of previous technical developments by DOE, namely directional drilling and advanced grout materials.
- Transferring successfully this new technology to other DOE sites and to industry.

The FEMP plan demonstrates the in situ construction of four joined test panels of barrier structure. Each panel is to be approximately 200-feet long, 10-feet wide and 1-foot thick. The demonstration site is outside the main plant area and has clay-loam soil, typical of the plant and general area. Guide tubes will be installed in a concave upward pattern resembling the layout required to construct an actual barrier. Installation of the guide tubes will be made by excavating the pathway with a backhoe, placing the tubes in the trenches, and then covering them with compacted soil to simulate their placement by directional drilling. The maximum depth of the guide tube trajectory is intended to be 10-feet (the depth of the test panels), with the ends of each guide tube emanating from the surface at a low angle, in the manner resembling installation by slant or directional drilling.

The work at the FEMP calls for the production and testing of enhanced jetting bars. The purpose is to demonstrate new bars that operate with high efficiency and address the main technical challenge: construction of barriers of practical width. One design concept involves bars with special slurry orifices at the ends. The intent of the new end design is to have, as a new panel is being constructed, the jetting bar apply lateral jet streams that direct slurry to overlap and join with (penetrate) the edge of a previously placed neighboring panel. Two jetting bar designs, "A" and "B" are scheduled.

Integrity of joints is the focus of the scheduled demonstrations. Two test panels are intended with jetting bar "A", and two with bar "B". All test panels are to be joined in a manner to provide for comparison of three types of longitudinal joint: A-A, A-B, and B-B. In addition, demonstration is planned of the transverse "recovery joint" formed upon resumption of *slurry* jetting after inadvertent or other cessation of operations with the jetting bar only partially along the intended pathway.

The slurry to be used in the FEMP tests planned to date will consist of Portland cement containing approximately 2 weight percent bentonite mixed in water to a consistency of 12 pounds composite weight per gallon of mixture. The design of the jetting bars and support systems are intended to facilitate the use of the new method for the in situ placement of other materials with special or enhanced barrier-forming properties. Advanced grouts developed by DOE at Brookhaven and other locations have been shown to have superior qualities, but await methods for applying them at the locations where they need to be used. An objective of the FEMP program is to demonstrate an effective placement method for grout. The new method holds promise for use in applying the advanced grouts and other materials developed with DOE funding. Brookhaven National Laboratory grout experts are involved in the FEMP program to facilitate the use of advanced grouts in future applications of the novel barrier method for remediation purposes.

Halliburton NUS is the subcontractor to FERMCO and DOE for design and supply of the advanced jetting bars, as well as for field operations for demonstration of the novel method for in situ construction of barriers. HNUS has a patent pending on the method.

Independent testing and verification of results is planned for the FEMP barrier demonstration project. The Alliance of Ohio Universities has been engaged separately from the construction contractor to devise and conduct the independent review through the University of Cincinnati. Plans are to excavate large portions of the demonstration barrier for detail inspection, sampling and in-place testing of barrier materials and native soil. Physical integrity of the main barrier portions, as well as the joints between individually-constructed panels, will be examined in detail. Ring permeometers will be installed on excavated and exposed, undisturbed joints and other in situ-constructed barrier material to evaluate its effectiveness as a barrier. Samples of native soil from the vicinity of the test barrier will be used for comparison. Samples of the test barrier will be removed for laboratory analyses including permeability and compressive strength.

The project is scheduled to begin in February 1994 with installation of the demonstration barrier planned for Summer 1994. The project duration is estimated to be ten months.

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