Emplacement Techniques: Impervious & Pervious Wall Construction

Fred C. Schmednecht, P.E.[1] and Dana A. Wesolek, P.E.[2]

ABSTRACT

One effective means of constructing an impervious barrier is the vibrated beam method. Over one hundred slurry walls have been installed using this method in the United States and Canada for both the private and public sector, including the Army Corps of Engineers. The need for the vibrated beam continues to escalate due to its reduced health and safety considerations, high level of quality control, lack of excavation, narrow working area, use of "pure" slurry, and ability to achieve depths greater than 100'. One effective construction technique for a pervious wall is the patented mandrel emplacement technique which results in a pervious wall composed of iron sand or any other flowable media with minimal width and depth limitations.

VIBRATED BEAM METHOD

Description. The vibrated beam method was brought to the United States in the early 1970's by Slurry Systems, Inc. The construction process consists of vibrating a steel beam from the surface to the specified depth while a premixed slurry is injected (during beam penetration and extraction) through nozzles affixed to the bottom of the beam. The beam generally penetrates vertically, but may be inserted at a batter to contain small streams and canals. After the beam attains its required depth, it is extracted at a controlled rate to fill the void left by the beam extraction, creating an in-ground panel of slurry with an approximate wall thickness of four inches. This process is repeated along the wall alignment, with each beam insertion overlapping the previously inserted panel (Brunette 1994). Each beam penetration, in plan view, is 47 inches long (33-inch beam plus the 14-inch fin). The continuous barrier is created by advancing the beam 30 inches, thereby overlapping each previous 47-inch beam penetration (panel) approximately 17 inches. The 17-inch overlap is created from the 14-inch fin and 3-inches of beam.

Specific Equipment. The steel beam used is typically a wide flange beam with a 14-inch fin which serves as a guide for the beam to ensure a continuous wall by following the path of least resistance. Attached to the wide flange beam are slurry pipes for the injection of slurry. The same beam is used continuously, is of sufficient length to penetrate the maximum expected depth, and is prepared for wear.

Soil borings along the alignment of the barrier wall are instrumental in determining the size of the vibrator required. An electric vibrator is preferred. The parameters used to determine the type of crane necessary are the anticipated wall depth and the type of vibrator required. An on-site mixing plant is used. The slurry is pumped from the plant, to the slurry pipes on the beam, and out the bottom nozzles.

Material. With the vibrated beam, there is no possibility for contamination of the slurry as it is mixed in a controlled plant and deposited directly into its final in-situ position with stringent control. A "pure" slurry wall results with economical use of material. The type of slurry required is dependent on the purpose of the barrier wall and the hydraulic conductivity desired. Types of slurries available today with the vibrated beam method are: cement bentonite, IMPERMIX® , and ASPEMIX®. Cement-bentonite offers an in-situ hydraulic conductivity of 1×10^{-7} cm/sec or less, IMPERMIX® (a combination of attapulgite clay and slag cement developed by Liquid Earth Support) offers a hydraulic conductivity of 1×10^{-8} cm/sec or less, and ASPEMIX® (a cement asphalt emulsion developed & researched by Slurry Systems, Inc.) offers a hydraulic conductivity of 1×10^{-8} cm/sec or less immediately after mixing. ASPEMIX® that has matured and has been exposed to

---

[1]President, Slurry Systems, Inc., Gary, IN USA; PH 219-938-6667; FX 219-938-3437; e-mail ssi@niia.net; www.slurrysystems.com

[2]Vice President, Slurry Systems, Inc., Gary, IN USA; PH 219-938-6667; FX 219-938-3437; e-mail ssi@niia.net; www.slurrysystems.com

water for prolonged periods or has had reasonable amounts of water penetrated through it seems to undergo internal swelling and seal shut. The permeability thereafter is effectively zero, probably less than 1×10^{-12} cm/sec (Diamond 1978). Both IMPERMIX® and ASPEMIX® are most useful for the containment of chemical and hazardous wastes where bentonite based slurries would fail (concentrated organic liquids, acids, bases, & salts) and have permeabilities that decrease with time of standing. Although the latter two slurries are more expensive than cement-bentonite, they have significant advantages in degree of impermeability, in resistance to attack by industrial chemicals and wastes, in strength, and in degree of flexibility.

In bentonite based slurries, the filter cake is more responsible for the permeability of the wall than the bulk permeability (Diamond 1984). The direct injection method with the vibrated beam using its specially formulated cement-bentonite slurry gives two positively formed filter cakes. Conventional backhoe construction methods create a wider wall, due to the width of bucket used, but poorly formed filter cake due to the back flushing which disrupts the cake formation and to the type of bentonite slurry used. IMPERMIX® and ASPEMIX® are self-hardening pure slurries and rely on their bulk permeabilities which are very, very low.

Construction Aspects. Minimal excavation is required, as only a 2' x 2' reservoir trench needs to be dug along the wall's alignment. The reservoir trench is filled with slurry and maintained to ensure the availability of a sufficient volume of slurry to fill the void left by the beam, plus voids in the surrounding soil during extraction (Brunette 1994). The vibrated beam method can be installed successfully with as little as a 16' (prefer 25') wide flat area that is a minimum of 3' above the groundwater table.

The width of a vibrated beam slurry wall is self-regulating. It becomes wider in granular (pervious) soils and narrower in cohesive (impervious) soils. With the vibration of each beam, the nearby soils are compacted so as to reduce their permeability forming a consolidation zone. The depth of the barrier wall is site specific. The depth may be specified to refusal, to a specified depth, and/or to the confining layer with a predetermined key measured in feet, e.g. 2' into the clay layer.

The confining layer is located with each beam penetration due to the change in slurry pressure at the nozzles of the beam, as the permeable soil layers take less pressure during beam penetration than impermeable soil layers. At a project performed in Baltimore, Maryland, the key depth was verified to be in agreement with the depth of the low permeable confining layer as determined by the soil drilling activities performed during the design phase. It was determined that the magnitude of the pressure increase is a function of the blow count and the natural moisture content of the soil material (Ahtchi-Ali 1998).

Walls with the vibrated beam method may be built at depths exceeding 100', through hard dense soils with a slight modification - a high pressure/low volume jetting system, and on slopes of 3% using a fish ladder technique.

Effective Life. The effective life of a vibrated beam slurry wall is indefinite provided it is not disturbed mechanically or by unforeseen chemical attack.

Highlights. Some highlights of the vibrated beam method for impervious barrier construction are as follows: (1) "pure" slurry wall with economical use of low permeability material, (2) positive filter cake formation with bentonite based slurry, (3) minimal spoils - only for a 2' x 2' reservoir trench, (4) narrow working platform, (5) every 30" along alignment - impervious layer is verified, (6) reduced health & safety requirements, (7) angular installations up to 45 degrees, (8) non-seasonal - can be installed in freezing weather conditions, (9) excellent utility crossing options, (10) minimal site and community disturbance, (11) depths exceeding 100', (12) construct in both soft and hard soils, and (13) average square footage per day is 3,000.

Case History - Marinette, Wisconsin. The ANSUL site was the site of herbicide manufacturing in the 1970's. A byproduct of the herbicide production was waste salts that contained approximately 2% arsenic, with the remainder of the wastes containing sodium chloride and sodium sulfates. The wall was specified to have a maximum hydraulic conductivity of 1×10^{-7} cm/sec. Slurry Systems, Inc. constructed an IMPERMIX® vibrated beam slurry wall at the ANSUL site. The wall totaled approximately 28,000 square feet, 700 linear wall feet at an average depth of 40'. The wall was constructed to contain the former salt vault area and protect the Menominee River. The duration of the project was approximately three weeks.

The soils at this site were a dense till composed of sand, silt, gravel, and few cobbles. The blow counts of the subsurface material varied between 80 and 100 blows/foot. The equipment used was a WF33x152 specially fabricated high pressure beam, a 4-75 vibrator, and a 150 T crawler crane.

MANDREL EMPLACEMENT TECHNIQUE

Description. The mandrel emplacement technique is a patented method of constructing continuous pervious walls, approximately 6 inches wide. This width may be varied and/or double walls may be constructed. A hollow steel mandrel is vibrated into the ground until at its desired depth. The penetrating mandrel has a shoe at the bottom to prevent the mandrel from filling with earthen material. The shoe remains in the ground. The granular material may be delivered at the top of the mandrel while the mandrel sits at its desired depth. The mandrel serves as a guide for the granular material to follow and structural support of the adjacent ground walls until the granular material is added for that section. The granular material is added systematically until the entire panel is composed of granular material. After one panel is complete, a shoe is added to the mandrel and it begins its second penetration extending 2" into the previously filled iron sand panel.

Specific Equipment. The hollow steel mandrel outside footprint is approximately 33 inches long by 6 inches wide. The mandrel is fabricated from three sections of square steel tubing. An eight inch double fin is welded to the mandrel to avoid the mixing of soils with previously placed iron. A shoe is required for each mandrel penetration. As the beam is continuously re-used in the vibrated beam method, the mandrel is continuously re-used with this emplacement technique. Rotating claws may be placed at the bottom of the mandrel. The claws extend approximately 1 inch from the mandrel upon penetration and, upon removal of the mandrel, the claws extend approximately 2 inches from the mandrel. The claws aid in rendering the surrounding earthen material “loose”. Due to the vibrating of the mandrel, the earthen material may compact and become less pervious and/or, if there is a lens of clay that the beam must penetrate prior to reaching its final depth, the clay may reduce the permeability of the surrounding earthen material. The claws help to compensate for these possibilities.

The vibrator and crane selections are the same as for the vibrated beam method. A steel hopper with chute may be used to guide the granular material into the hollow mandrel sections to avoid overspill. As the mandrel sits at its required depth, a lift is required for personnel to aid in the hopper placement and granular material delivery at the top of the mandrel.

Material. Currently, Slurry Systems, Inc. has only used the mandrel emplacement technique with iron sand. A reactive, zero-valent, granular iron medium oxidizes and thereby induces dechlorination of chlorinated VOCs, yielding simple hydrocarbons and inorganic chlorides as by-products. This iron sand technology may be applicable to a wide range of chlorinated methanes, ethanes, and ethenes in water (U.S. EPA 1998).

Construction Aspects. The mandrel emplacement technique may be used for any granular flowable media and/or slurry. If a slurry is used, a mixing plant would be required. Typically, the mandrel emplacement technique is cost effective for sites where there is a need for a deep continuous pervious wall with no spoils generated. Gates & funnels may be created with the funnels created by the vibrated beam method and gates by the mandrel emplacement technique.

Effective Life. Depending on the longevity of the reactive medium, the pervious wall may have to be rejuvenated or replaced periodically. Initial evidence of iron sand indicates that the reactive medium is used up very slowly and, therefore, permeable reactive barriers have the potential to passively treat the plume over several years or decades (Gavaskar 1997).

Highlights. Some highlights of the mandrel emplacement technique for pervious wall installations are as follows: (1) granular material (pure or mixed) or slurry may be emplaced, (2) reactive material may be of larger diameter, e.g. 1 inch, (3) no spoils, (4) minimal depth or width limitations, (5) clean work site, and (6) reduced health and safety requirements.

Case History - Cape Canaveral. Slurry Systems, Inc. used its now patented mandrel technique for the permeable reactive treatment (PeRT) wall installation at the Cape Canaveral Air Station in Florida. The contaminants of concern at this site were trichloroethene (TCE), cis- and trans-1,2-dichloroethene (c/t-DCE), 1,1- dichloroethene (DCE), and vinyl chloride. The PeRT wall was a new in-situ remediation strategy which lacked a proven construction method. The need for a thin wall filled with pure iron sand at a depth of approximately 60' seemed to point directly to Slurry Systems, Inc. expertise. The PeRT Wall was installed in October 1997 as a pervious iron sand reactive wall. The technique allowed for the placing of iron in its pure form. Water to facilitate iron delivery was not required for this project. Slurry Systems, Inc. installed three separate walls approximately 4" wide and 45' deep. This depth was different from the intended 60' due to the location of the semi-confining layer. It was decided by others that the maximum depth of each wall should not penetrate this layer. The 7 T mandrel was vibrated into the ground with a 4-75 PTC vibro-hammer weighing 22 tons until at its desired depth. A 150 T crane was used for the installation.

CONCLUSIONS

- The patented vibrated beam method is an effective means of constructing an impermeable barrier to depths exceeding 100' using pure, low permeability material with little spoils generated.

- The patented mandrel emplacement technique is an effective means of constructing a continuous pervious wall with either a pure granular material or slurry, especially where great depths are desired.

ACKNOWLEDGMENTS

Slurry Systems, Inc. wishes to express a warm thank-you to its customers for their support and to its employees for their commitment and hard work. IMPERMIX® is a registered trademark of Liquid Earth Support. Envirometal Technologies is the patent holder of the use of zero valent iron.

REFERENCES

AHTCHI-ALI, F. and SCHMEDNECHT, FRED C., 1998. Construction quality control of a cutoff wall installed with the vibrated beam. Draft report.

BRUNETTE, PATRICK T. and SCHMEDNECHT, ERIC J., 1994. Vibrating beam, curtainwall™, and jet grouting used to form a vertical barrier wall. Ground Engineering. June/July 1994.

DIAMOND, S., 1978. Cement-asphalt emulsion fly ash mixes as slurry wall components.

DIAMOND, S., 1984. Report on lab tests of current cement bentonite slurry formulations.

GAVASKAR, A., GUPTA, N., SASS, B., FOX, T., JANOSY, R., CANTRELL, K., and OLFENBUTTEL, R., 1997. Design guidance for application of permeable barriers to remediate dissolved chlorinated solvents.

U.S. EPA/ 540/R-98/501, 1998. EnviroMetal Technologies, Inc., Metal-enhanced dechlorination of volatile organic compounds using an in-situ reactive iron wall. Innovative technology report.