[Form 2 (to be reported to Committee on Countermeasures for Contaminated Water Treatment and to be disclosed to public)

Technology Information	
Area	5: Management measures to block groundwater from flowing into the site
Title	Cast In-Situ Cutoff Wall Technologies and Alternate Measures
Submitted by	Westinghouse Electric Company, LLC/GZA GeoEnvironmental, Inc./Paul C. Rizzo Associates, Inc.

1. Overview of Technologies (features, specification, functions, owners, etc.)

Cast in-situ cutoff walls, including slurry walls, vibrated-beam walls, structural concrete diaphragm walls, auger cast walls and impregnation and jet grouted walls, etc., have been proven effective through a very long history of use. These technologies have been the mainstay of the geotechnical engineering ground-modification field for control of groundwater migration into excavations, foundations and tunnels, as well as for temporary and permanent earth support.

Westinghouse has been partnering with several firms with specific expertise in this field. Both Paul C. Rizzo Associates, Inc. (PCR) and GZA GeoEnvironmental, Inc. (GZA) are two such firms. PCR background in this area is included as an attachment. GZA background is enclosed. Westinghouse is eager to lead for either or both partners.

In the late 1970s and early 1980s, GZA was at the forefront of the effort to significantly upgrade the implementation of a number of these technologies to meet the increasingly stringent demands of more critical geotechnical and environmental applications.

For example, the concrete diaphragm slurry walls for the MBTA Redline subway tunnels in Boston, Massachusetts had to not only function as the temporary and permanent groundwater control measure and earth support during construction, but also constituted the permanent walls of the final structure. This was the first time that “slurry walls” were used for a permanent structure in this country, and this was also the first time such walls were installed in sensitive, “quick clays.” GZA was awarded a sole-source contract from the Federal Highway

Administration to research and pilot test these walls[1], and then designed and implemented them on the Redline project. GZA staff were also involved in research for Oak Ridge National Laboratory focused on consideration of various grouting technologies in support of nuclear waste isolation facility design/construction[2].

In addition to advancing the implementation of cast in-situ cutoff walls for these more traditional civil engineering uses, GZA led the development of these technologies for the more critical environmental engineering application of hazardous chemical waste containment under the USEPA NPL Superfund program (a.k.a. CERCLA) beginning in the 1970s. For example, soil-bentonite and cement-bentonite backfilled slurry walls (SB and CB walls) had been used for groundwater control for a number of years, where some degree of leakage was typically expected and not at all problematic given that the water was not-contaminated and could be discharged directly to adjacent surface water bodies. However, at contaminated sites, this level of leakage was not acceptable for walls intended to support the more critical environmental remediation projects requiring containment of hazardous chemical wastes. For these applications, where more stringent performance is required, GZA researched the underlying causes of the sometimes poor performance of these walls as part of the design of the first cooperatively funded slurry wall under CERCLA (the USEPA Superfund program). A similarly stringent requirement applies to the design of groundwater barriers for the Fukushima Daiichi site because, while the walls will likely be used as “clean water exclusion barriers” (a term coined by GZA to differentiate the incorporation of active hydrodynamic control within the wall from purely passive physical containment – see below), any leakage through the wall will result in an increase in volume of radioactively contaminated water requiring treatment. This work was funded in part through an in-house research program, as well as by the State of New Hampshire and through a sole-source USEPA research grant[3]. This work demonstrated that the

---

1 Barvenik, M.J. and D.T. Goldberg, "Performance of Two Instrumented 60' Deep Slurry Wall Test Panels in Quick Clay," Proceedings of ASCE National Convention, Session 52, New York, New York, May 1981.

2 Einstein, H.H. and M.J. Barvenik, "Grouting Applications in Civil Engineering," Geotechnical Research on Seal Boreholes for Nuclear Waste Isolation, Oak Ridge National Laboratory Publication No. 3960-1, 1975.

3 Barvenik, M.J. and J.E. Ayres, "Construction Quality Control and Post-Construction Performance Verification for the Gilson Road Hazardous Waste Site Cutoff Wall." U.S. EPA Report No. EPA/600/2-87/065, Hazardous Waste Engineering Research Laboratory, Cincinnati, OH. August, 1987.

technology was capable of high performance, including SB backfill resistance to chemical degradation, but often the actual as-constructed wall performance suffered from lack of adequate design and/or poor workmanship during construction. In response, GZA developed an in-depth backfill design approach based on a “first principle” understanding of the mechanisms governing the attainment of a stable very low hydraulic conductivity backfill, and also formulated a rigorous QA/QC protocol including real time field testing to be sure the design was appropriately implemented during the actual construction[4].

Given that all passive physical containment barriers, including cutoff walls, surface caps and bottom aquicludes, exhibit a finite value of hydraulic conductivity, even if perfectly implemented in the field, these barriers will allow for some small amount of groundwater flux through the containment. Estimating the amount of this flux, and that associated with parameter studies simulating less-than-perfect conditions (particularly with respect to imperfect bottom aquicludes), is often required for both feasibility study risk assessments as well as post-construction monitoring/verification. These site-specific quantitative estimates require numerical modeling (see 6: Understanding the groundwater flow). This is a direct consequence of the dependence of flux through the containment on mounding along the upgradient wall, which is in turn dependent, in part, on the initial site gradient and the geometry and orientation of the containment in the hydrologic flow regime. The effect of containment geometry and orientation in three dimensions can only be accurately predicted utilizing three-dimensional numerical analyses.

Beginning in 1981, GZA has been involved in a number of projects requiring numerical analysis of

---

[4] Ayres, J.E., M.J. Barvenik, and D.C. Lager, "The First EPA Superfund Cutoff Wall; Design and Specifications," Proceedings of the 3rd National Symposium and Exposition on Aquifer Restoration and Groundwater Monitoring, sponsored by NWWA, Columbus, Ohio, May 1983.

Schulze, D., M.J. Barvenik, and J.E. Ayres, "Design of the Soil/Bentonite Backfill Mix for the First EPA Superfund Cutoff Wall," Proceedings of the 4th National Symposium and Exposition on Aquifer Restoration and Groundwater Monitoring, sponsored by NWWA, Columbus, Ohio, May 1984.

Barvenik, M.J., W.E. Hadge, D.T. Goldberg, "Quality Control Procedures for Determination of Hydraulic Conductivity and Bentonite Content During Construction of Soil/Bentonite Cutoff Walls," Eleventh Annual EPA Research Symposium, Cincinnati, Ohio, April 1985.

predicted, as well as post-construction, cutoff wall performance. In a number of cases, GZA has also employed these numerical models in the design and monitoring of hydrodynamic isolation/ recirculation systems used to upgrade purely passive physical containment (wall alone) into active "clean water exclusion barriers". These combination active/passive systems are commonly implemented to clean up the groundwater within the passive containment vessel and establish hydrodynamic gradients which preclude off-site migration of contaminants. As such, GZA was instrumental in the initial development of specific expertise in the numerical techniques required to allow modeling of the severe and abrupt changes in hydraulic conductivity associated with high permeability aquifers truncated by low permeability cutoff wall barriers. This approach and expertise was used in the design of the first cutoff wall at a Superfund Site given the environmental consequences of leakage.

This, the first CERCLA slurry cutoff wall was then constructed under GZA's specifications, as well as GZA field QA/QC inspection. After construction, the in-place wall was subject to field testing to demonstrate performance[5]. In recognition of the innovative engineering on this USEPA Superfund project, GZA was awarded the 1982 New Hampshire American Society of Civil Engineers (ASCE) Outstanding Engineering Achievement Award, the ACEC New England Grand Conceptor Award and the National ACEC Grand Award for Engineering Excellence.

GZA has also designed and implemented many other cast in-situ cutoff wall technologies. Based on this body of work, GZA was an invited lecturer to present Design Options Using Vertical Barriers at the 1992 ASCE International Convention & Exposition[6].

2. Notes (Please provide following information if possible.)

- <u>Technology readiness level (including cases of application, not limited to nuclear industry, time line for application):</u> Cast in-situ cutoff wall technologies are readily accessible and have been applied by GZA at numerous industrial sites where a high standard of wall

[5] Barvenik, M.J., D. Brown, and T. Kern, "Evaluation of Cutoff Wall Containment Efficiency Using Aquifer Stress Tests: Gilson Road Hazardous Waste Site, Nashua, New Hampshire," 12th Annual EPA Research Symposium, Cincinnati, Ohio, April, 1986.

[6] Barvenik, M.J., "Design Options Using Vertical Barriers," American Society of Civil Engineers (ASCE) International Convention & Exposition, New York, New York, September 17, 1992.

performance was required to contain hazardous chemical wastes. As exemplified above, GZA has been instrumental in the improvement of these technologies to achieve the more stringent requirements associated with environmental protection, and thus can bring this experience and expertise to bear on design and implementation of these technologies for the Fukushima Daiichi project.

Challenges: The most significant challenge would be the selection of the appropriate site-specific approach(s) from the overall suite of cast in-situ cutoff wall technologies, particularly relative to the stability of overall wall hydraulic conductivity under seismic loading. The selection needs to be based on a sound understanding of subsurface conditions at the site, as well as a substantial level of prior experience and expertise with these technologies. A thorough review of the existing data set (including site geology (soil and bedrock), major faults, groundwater elevations with depth, hydraulic conductivities of major strata, plant construction information, groundwater chemistry, local precipitation records, tidal records, etc.) would be needed as part of this process.

Overall, some of these technologies, such as Auger-Cast Walls are limited relative to maximum depth and ability to penetrate soils with high bolder content (not expected to be an issue at the Fukushima Daiichi site). Other technologies, such as slurry trench installed SB walls can be implemented at depths of hundreds of feet and can penetrate even very coarse-grained soils. Once selected, all of these technologies can be implemented relatively readily once the design and specification phases are completed and appropriate health and safety measures are integrated.

- Others (referential information on patent if any): References and additional supporting documentation can be provided upon request.

【Areas of Technologies Requested】

(1) Accumulation of contaminated water (Storage Tanks, etc.)
(2) Treatment of contaminated water (Tritium, etc.)
(3) Removal of radioactive materials from the seawater in the harbor
(4) Management of contaminated water inside the buildings
(5) Management measures to block groundwater from flowing into the site
(6) Understanding the groundwater flow