SITE REMEDIATION USING SOIL MIXING TECHNIQUES ON A HAZARDOUS WASTE SITE: A CASE HISTORY

ANDREW D. WALKER
Geo-Con, Inc.
P.O. Box 17380
Pittsburgh, PA 15235

INTRODUCTION

At 2,400 beds, the $112.5 million Allegheny County Jail in Pittsburgh, PA, will be one of the nation's largest county jails.

The disused downtown site chosen by the Urban Redevelopment Authority of Pittsburgh sits alongside the Monongahela River, adjacent to Liberty Bridge, on what was previously the old CSX Railroad facility. The southern edge of the site is bound by the retaining wall of the Parkway East (Interstate I-376); one of the main transport arteries of the Greater Pittsburgh Area.

Previous investigatory activities at the site had indicated the presence of hydrocarbon contamination from a former underground storage tank. Limited soil remediation was therefore necessary in advance of the construction of the 10-story building.

This case history presents the evolution of these remediation measures, with the main emphasis on the insitu treatment of the contaminated soils adjacent to the Parkway structures.

SITE DESCRIPTION

Petroleum hydrocarbons had affected site soils at three separate locations over the estimated area of approximately 32,000 sq. ft. The depth of contamination varied from 3 feet in two areas to over 20 ft. in the area next to the retaining wall. Total Petroleum Hydrocarbon (TPH) concentrations ranged from less than 50 ppm up to 11,000 ppm with levels varying from the surface to the groundwater table which was located at 25 ft. below existing grade.

A typical soil description for the excavation area was sandy silt to silty clay with cinders, rocks, and brick pieces. Standard penetration tests ranged from 2 to 13 blows per foot.

The higher loaded sections of the retaining wall were founded on piles which apparently transferred load to the underlying bedrock. The present condition of these timber piles was unknown. In other sections, loads decreased as the Interstate ramped down, with the wall on spread footings only.

REMEDIATION METHOD CONSIDERATIONS

The remedial approach preferred, from a cost and ease of construction standpoint, involved the decommissioning and disposal of the existing pumping station and product lines and the removal of the affected soils to groundwater for offsite disposal. The excavated areas would then be backfilled with clean fill and soil.

This immediately raised the question of the stability of the retaining wall and hence the Parkway if the proposed excavations were made.

The ultimate adoption of two ground improvement techniques to solve this combined Environmental and Structural problem made this site unique and of specific interest, as to the author's knowledge this was their first application in tandem.

Initial stability assessment focused on two arrangements, namely a cut slope from the footer level of the walls or the construction of a retaining wall along the Parkway. The latter method was discounted after discussions with Penn DOT, the wall owners, since the required bracing or tiebacks may have interfered with the piles holding the structure in place. In addition, the lengthy design review process required by the owner and possibly the U.S. Department of Transportation, since an Interstate highway was involved, could have delayed the project by up to 12 months.

Discussions with the PA Department of Environmental Resources (PADER) indicated a willingness to consider a cut slope arrangement; however, they stipulated that any contaminants left in place must be fixated to reduce their potential mobility.

Accordingly, the Geotechnical Consultant investigated the potential for limited fixation of the hydrocarbon contamination insitu to the extent necessary to support the Parkway East structure.

It was recommended that permeation grouting with a microfine cement grout would adequately fixate the hydrocarbons and that the zone should extend 25 ft. at the base of the retaining wall from the foundation level to the groundwater table. Figure 1 illustrates the area requiring stabilization. This would allow for a near-vertical excavation to be performed against the grout zone to remove the remaining contaminants, with minimum factor of safety against failure of 1.5. It was observed during analysis that the stability of the area was less dependent upon the strength of the grout zone than on the weight that the grouted zone produced upon the underlying ground structure.

Therefore, emphasis was placed on the use of a microfine cement grout for improved permeation, injected using the end of casing method, in order to optimize filling of soil pores to fixate the hydrocarbons and densify the material. Although Ordinary Portland Cement would have been adequate in the coarser general fill and debris, microfine cement was selected for use since portions of the subsurface contained fine granular soils which required fixation to prevent water infiltration. The strength requirement was secondary and was specified as an unconfined compressive strength of 500 psi in order that the zone would be capable of supporting its own structure on near-vertical slopes.

PADER and Penn DOT both concurred with this approach and the project was placed out for bid in the Spring of 1991.

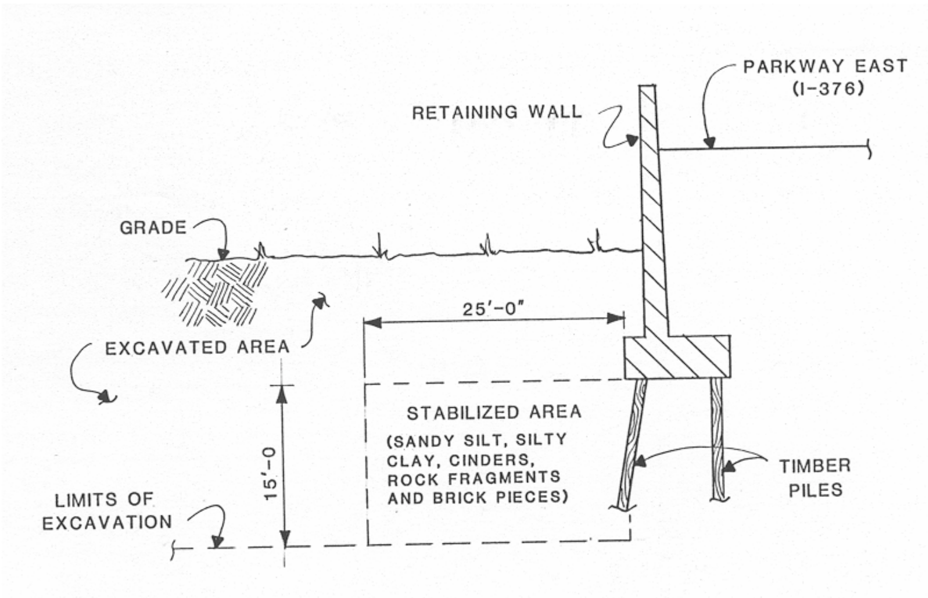

Figure 1. Cross Section of Stabilized Area

REMEDIATION METHOD SELECTION

The Specialist Geotechnical Contractor who was low bid on the Remediation Contract offered a Value Engineering alternate to the microfine cement grouting specified, namely the use of Shallow Soil Mixing (SSM) in conjunction with single-phase Jet Grouting. This alternate was attractive both technically and commercially and was reviewed, accepted and the contract awarded. The remainder of the cleanup work was implemented as planned.

SHALLOW SOIL MIXING

Although the process of soil mixing originated in the United /states in the 1950's, its major development has occurred over the last twenty years in Japan. To date, there have been thousands of projects performed in Japan using some form of soil mixing, however, the first use for Environmental cleanups was in the United States. In North America, it has been used for foundation elements, block stabilization, gravity walls, and fixation/solidification of contaminated soils. the first geotechnical construction application was completed in 1990 in Canada [1].

The process uses a crane-mounted drill attachment which turns a single-shaft, large diameter auger head which consists of two or more cutting edges and mixing blades. As the auger head is advanced into the soil, grout is pumped through the hollow kelly bar and injected into the soil at the pilot bit. the cutting edges and mixing blades blend the soil and grout with a shearing action. When the design depth is reached, the auger head is normally raised to expose the mixing blades at the surface and then allowed to readvance to the bottom.

The mixing head can also be enclosed in a bottom-open cylinder to allow for closed system mixing of waste and powdered reagents. The dry treatment chemicals are then transferred pneumatically.

A total of 110,000 CY of hydrocarbon contaminated sludge ahs recently been stabilized in this manner at the Amoco Refinery in Whiting, Indiana, using dry cement as the reagent.

The advantages of the system on the Pittsburgh site were numerous and were key in the client’s decision to sanction its use.

- The technique is totally independent of soil type. This is a very significant advantage over permeation grouting which, as previously mentioned, will prove ineffective in silts and clays. With soil mixing everything in the area is mixed and treated.
- The system has a vertical blending action which will tend to “average out” the soil stratigraphy and produce a well-mixed, homogeneous soilcrete block.
- Treatment is carried out in one pass with no additional work in problem areas as required by the split-space grouting approach.
- Cement grout is metered at a fixed rate into the ground, and the precise volume of ground treated in an identical manner is precisely known. The fixed mixing vanes assure the full column diameter and column contact. This is very important technically. With permeation grouting, the quantity of grout accepted per unit volume of ground is totally dependent on soil type, is therefore variable and is difficult to quantify due to the random nature of grout travel and actual injection elevation.
- Contaminants within the ground are locked in place within the soilcrete after thorough dispersal. Permeation grouting does not provide this dispersal

effect with contaminant concentrations remaining at their original levels within a cement impregnated soil matrix.

- The result is a stabilized mass free of any significant pockets of untreated materials. This greater quantity of stabilized material generated by these processes effectively create a more stable end product with typically higher and more consistent unconfined compressive strengths and lower TCLP constituent leaching.
- The SSM technique can produce a greater volume of treated ground per day than traditional grouting, thus easing pressure on the schedule and relieving the risk of time overruns.
- The soil mixing system does not involve the pressurizing of the ground that is required during grouting, with no possibility of uplift.

While microfine cement grouting was feasible to treat the areas of low-level contamination, it had some limitations, in contrast to the advantages of SSM, namely:

- The soil profile was extremely heterogenous with material varying from rock and brick fragments to cinder, sandy silts, and silty clays. While the former may be injected by a cementitious grout, the latter will not be permeated by a particulate grout [2]. Hydrofracture may well occur if not closely monitored which, rather than strengthening the soil mass, may create weak sliding planes with the body. Uniformly consistent treatment throughout the zone is impossible to achieve since the microfine cement will extend into only "groutable" soils and voids.
- The use of the end-of-casing method, in which grout is pumped from the bottom of an open pipe, is often employed with success in loose formations but has numerous disadvantages. With the method, it is impossible to know positively at which elevations the grout ahs been accepted into the ground. It is quite possible for grout to pass up the side of the injection pipe and enter the soil at a higher elevation than that of the pipe tip. In extreme cases, the grout may daylight at the surface. Therefore, monitoring of grout takes by elevation, an important QA/QC control on grouting work, may be difficult and in some cases, misleading.
- With specified method, it was not possible to inject different grout or grout mixes successively in the same hole. For instance, highly permeable rubble which may be present on site would probably accept a more economical ordinary Portland grout rather than the high-cost microfine cement.
- The extent of ground treatment required cannot be ascertained in advance of commencing grout injection on site. Work would proceed in a Primary, Secondary, Tertiary split-spacing manner with grout acceptance monitored until acceptable reductions in take had been achieved, at which time work would cease. This increases the risk of schedule overrun on a method which, in addition, is intrinsically slower than the alternate proposed. This was significant on a contract let on a very tight schedule, where all risks of time extensions must be mitigated.

JET GROUTING

Jet grouting is a soil improvement technique which is now beginning to gain wide acceptance in the United States as the recent conference in New Orleans clearly demonstrated [3].

There are at present three general forms of jet grouting involving the injection of a single fluid (grout), two fluids (grout/air), or three fluids (air/water/grout). The single-phase system (CCP) was used on the Pittsburgh site in which the grout both excavates and cements the soil. This is in contrast to the two-phase system in which an air shroud is used to improve cutting efficiency and the three-phase in which the excavation and cementing operations are separated. In this respect, the single-phase system can be regarded as more of a jet mixing method rather than pure replacement.

Whatever, the form, the method relies on the use of ultra-high pressures (typically 4,000 psi to 6,999 psi) to impart energy to a fluid which is injected at about 800-1000 ft.sec. the high speed fluid cuts and mixes the native soil usually, as in the case here, with a neat cement grout. The high velocity is developed by using 350 HP triplex piston pumps which inject the grout through small nozzles set in a monitor mounted on the tip of a drill string. Figure 2 shows the monitor above ground. By varying the rotation speed and the rate that the drill string is lifted from the bottom of the treatment zone, soilcrete columns of different sizes may be formed. the type of soil being mixed has a significant effect on the final properties of the column.

Figure 2. Jet Grout Monitor

SOILCRETE BLOCK DESIGN

In order to create the block of stabilized soil, a total of 2,200 CY of contaminated soil required treatment, extending 175 ft. along the Parkway and under Liberty Bridge.

As shown in Figure 3, three rows of 8 ft. diameter columns on a 6 ft. x 6, 7 ft. grid were installed. They were formed on a primary and secondary sequence within each row, with the installation of the secondary columns timed to occur before the adjacent primary columns reached full strength. In this manner, block of ground over the full width were completed as the soil mixing progressed along the wall. In order to stabilize/fixate areas that could not be accessed safety with the 150-ton crane jet grouting was necessary. These zones were limited to adjacent to the timber piles and under Liberty Bridge. In these areas 3 ft. diameter jet grout columns were formed, either contiguous or on a 2.5 ft. triangular grid.

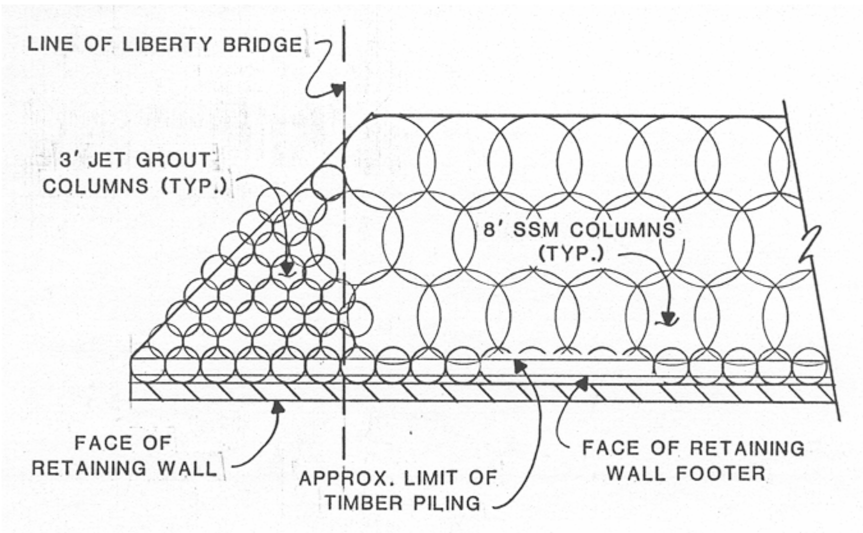

Figure 3. Layout of Soilcrete Columns

For both techniques, the stabilizing reagent was a Portland Cement slurry.

In the case of SSM, based on previous experience, a cement replacement by dry weight of soil of between 15% and 20% was adopted sufficient water added to the grout mix to provide enough lubrication for a satisfactory auger penetration rate.

For the jet grouting, the parameters were set at:

Grout Pressure	5,000 psi
Lift Rate	1 ft./min.
Grout Flow	40 to 45 gals/minute
Rotation	1 rpm (per step)

A neat cement grout of water/cement ratio by weight of one was felt adequate to produce in excess of the specified 500 psi compressive strength at 28 days.

It was the intention to produce similar strengths for the SSM columns at an earlier date in order for excavation to proceed quickly after column construction, thus ensuring compliance with the very tight overall project schedule of 60 days. Grout control was performed by frequent checks on the grout mix unit weight by use of a mud balance. The test location was at the batching plant prior to pumping grout to the SSM and jet grout rigs.

CONSTRUCTION

The SSM rig consisted of a high torque turntable mounted on a 150-ton crane which powered the 8 ft. diameter auger. Figure 4 illustrates the rig in operation. Grout was supplied by a high-speed, continuous-mix, colloidal grout plant. This consisted of a storage silo, 1,000-gallon colloidal mixer and a progressive cavity pump. this same setup was used for the jet grouting with the exception of the use of a 350 HP pressure, triplex piton jet pump. This pump was rated at pressures up to 20,000 psi and flow rates up to 170 gpm. While plant was being assembled, initial shallow excavation of contaminated material away from the retaining wall took place, along with concrete removal operations and waste characterization profile soil sampling. Test pits were also dug along the line of the wall to confirm the location of the piles.

Figure 4. SSM Rig in Operation

The jet grout drill stem was mounted on a diesel hydraulic DK 70 drill rig fitted with a Wirth Rotary Head on shown in Figure 5. the 2-1/2 in. grout pipe was advanced to the groundwater table and a check ball seated at the end of the grout pipe to initialize lateral flow through jet nozzles located on the sides of the grout pipe. As the grout was pumped, the pipe was rotated and extracted at the set levels thus creating the jet grout columns. Exhaust material in small quantities, of very similar properties to the insitu soilcrete, was channeled into the open excavation to be incorporated as suitably fixated backfill material.

Figure 5. Jet Grouting in Progress

All grouting work was completed within twenty days with initial excavation of a vertical face against the stabilized block taking place only four days after column construction, thanks to the excellent early soilcrete strengths obtained. Figure 6 gives a good indication of the columns produced.

Excavation and backfilling operations involving 10,000 CY of soil went smoothly with no unforeseen difficulties.

Throughout all operations the requirements of 29 CFR 1910.120, the Occupational Safety and Health Administration's (OSHA) Hazardous Waste Operations and Emergency Response Standard were strictly complied with.

Air monitoring started as soon as work commenced using the HNU, LEL, and PDM3. At no time did ratings exceed background levels. On this basis, Level D personal protective equipment (PPE) was stipulated for the SSM work. This was modified to include a two-piece chemical-resistant splash suit (PE or PVC Tyvek) and outer inner gloves for the jet grouting work where there was a possibility of splashing.

Figure 6. Trial SSM Column with Completed Wall to Left

Thereafter, monitoring was done on an occasional basis by the Health and Safety Officer (HSO) as site conditions altered, but no change in the level of protection was found necessary.

STRENGTH RESULTS

Wet samples were retrieved from columns for testing from each day's work. these samples were taken by a special sampling tool below the surface of the column immediately following installation. The tool, mounted on a beam and deployed by the crane, consisted of a cylinder with a bottom flap that could be activated from the surface.

Compressive strength tests were performed in accordance with ASTM C39, the results of which are shown in Figures 7 and 8.

These results indicate some interesting general trends:

1. Higher soilcrete strengths are produced by SSM than by jet grouting for both short and longer term curing periods.
2. A much quicker early strength gain for the SSM compared with jet grouting and better strength gain with age.

Even though more cement is used per unit volume of treated soil in jetting, these results demonstrate that SSM is a more effective tool, producing a technically superior final material at a lower cost. This is partly the result of the cement wastage inherent in jet grouting.

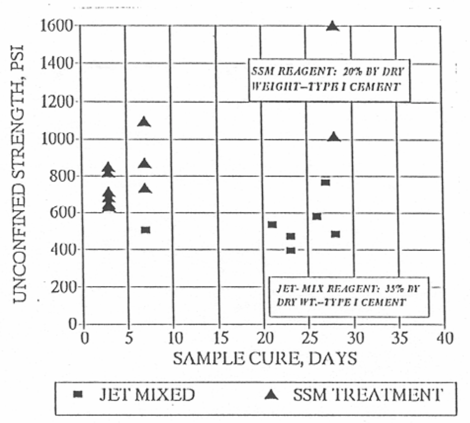

Figure 7. Soilcrete Strengths, Short Term

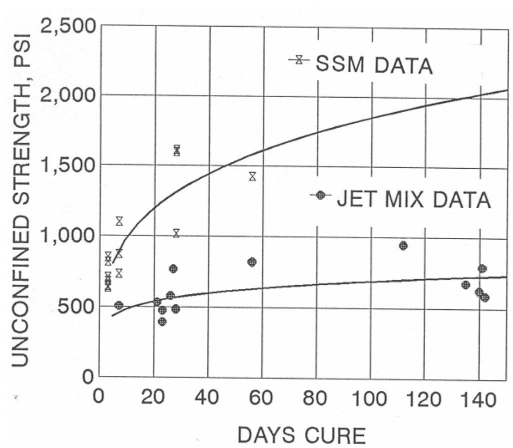

Figure 8. Soilcrete Strengths, Long Term

These comments only apply to the particular soil conditions on this site, and results may be radically different for other soils.

CONCLUSIONS

This case history clearly demonstrates the role that the soil mixing technologies, initially developed for General Civil Engineering work, can and are now playing in the Environmental market, to provide cost-effective proven solutions in hazardous site remediation.

As a concluding additional example, the work carried out in Hialeah, Florida, under the auspices of EPA's SITE Program is noteworthy [4]. The test program and follow-on production work involved the use of the Deep Soil Mixing (DSM) system with a proprietary reagent to create a hardened leachate-resistant mass from PCB-contaminated soil.

The DSM rig is similar to the SSM rig except that four hydraulically driven 36-in. diameter augers are used instead of one large mixing unit.

With this method, much greater depths up to 100 ft. may be reached.

REFERENCES

1. Broomhead D. and Jasperse B. H., 1992. “Shallow Soil Mixing—A Case History,” Grouting, Soil Improvements and Geosynthetics. ASCE Geotechnical Publication No. 30.

2. Caron, C., 1982. “The State of Grouting in the 1980’s.” Grouting in Geotechnical Engineering , ASCE Conference, New Orleans.

3. Grouting, Soil Improvement and Geosynthetics, 1992. ASCE Geotechnical Publication No. 30, pp. 144-206.

4. Environmental Protection Agency, 1990. “International Waste Technologies/Geo-Con Insitu Stabilization/Solidification.” Applications Analysis Report EPA/540/A5-89/004.