

LINDE FUSRAP SITE REMEDIATION, UTILITY TUNNEL REPLACEMENT, AND INDUSTRY OPERATIONS: A CASE STUDY OF CHALLENGES MET IN WESTERN NEW YORK

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ABSTRACT

Building 14 was a radiologically impacted Manhattan Engineer District-era (MED) structure at the Linde Formerly Utilized Site Remedial Action Program (FUSRAP) remediation site in Tonawanda, New York that required dismantlement in 2004. Remedial action at the Linde Site required simultaneous radioactive contamination cleanup, active industrial facility infrastructure relocation and uninterrupted facility operations. The challenge was to design and construct a replacement subsurface utility tunnel, relocate numerous active utilities, and remove all radioactive contamination within the new tunnel's footprint within 16 months to allow Building 14 dismantlement to start on time. The U.S. Army Corps of Engineers – Buffalo District (USACE) and Shaw Environmental, Inc. (Shaw) worked in close cooperation with the facility owner to design and execute the work. Meeting the challenge involved design and construction of a new structure, a large open excavation between closely spaced steel and masonry buildings, and of several utility systems including high-pressure steam, high voltage electric, and fiber optic communications concurrent with removal of several thousand tons of uranium-238 (U-238), radium-226 (Ra-226), and thorium-230 (Th-230) impacted material. Design started in February 2003 and construction was completed in June 2004 to meet the Building 14 dismantlement start date.

INTRODUCTION

Building 14, a radiologically impacted MED-era structure, required dismantlement in 2004 at the Linde FUSRAP remediation site in Tonawanda, New York. Prior to initiating dismantlement activities, it was necessary to design a replacement utility tunnel, including installation of relocated infrastructure, and construct it concurrent with co-located remedial action. Meeting the challenges started by designing the replacement utility tunnel and ended by constructing the tunnel through a harsh western New York winter. The details and methods define the nature of the challenges and magnitude of success for the team as Building 14 dismantlement began on schedule.

Linde Site soils remediation [1] and Building 14 dismantlement [2] are two high profile FUSRAP projects managed by the USACE-Buffalo District and executed by Shaw. The FUSRAP program was established to identify, investigate, and clean up or control sites previously used by the Atomic Energy Commission (AEC) and its predecessor, the MED. The Linde Site projects include remediation of an active industrial facility impacted by uranium ore

refinement waste residues (U-238, Th-230 and Ra-226) generated in the 1940s. The projects are located at Praxair Inc., a research & development (R&D) facility for specialty industrial gases employing 1,400 people and the command / control center for a world-wide network of production plants.

Linde Air Products (LAP), later a division of Union Carbide, built Building 14 and the associated utility tunnel in the 1930's. The northern foundation wall doubled as the exterior wall for the original subsurface utility tunnel. Reinforced concrete foundations built on a stiff dry clay subgrade supported structural steel framing and masonry walls. The MED operated portions of Building 14 as an R&D and proving laboratory. During the early 1940's, the MED and LAP doubled the size of the facility and used the Building 14 utility tunnel to route virtually all water, power, gas, and communication infrastructure. Following cessation of AEC work in the late 1940's, Building 14 remained a vital part of the facility's operations for another 50 plus years.

Between 1976 and 1997 the AEC and U.S. Department of Energy (DOE) undertook multiple efforts to survey and decontaminate Building 14 to certify that residual radioactive material did not exceed applicable exposure standards protecting worker and the public health. In October 1997, the Energy and Water Development Appropriations Act was signed into law and transferred FUSRAP from DOE to the USACE. The most recent decontamination of Building 14 was initiated by DOE in 1996 and was completed by USACE in August 1998. Following the decontamination effort, it was concluded that a number of areas in and around Building 14 retained contamination, including soils beneath the building, inaccessible areas on floors, walls, drain lines, and around various process piping systems [3]. Given that contamination remained present, the USACE considered a series of actions to finish the job including land use controls, further characterization and/or decontamination, and removal. Praxair's future operations and plans for expansion in western New York depended upon the USACE's decision. Therefore, the preferred alternative selected by the USACE in 2002 was dismantlement of Building 14 and removing debris from the Linde site. It was considered to be the most protective of the public and a permanent solution because all potentially contaminated building components and subsurface soils would be removed from the site [2].

At the time of the USACE decision, most of the infrastructure and resources required to complete the Building 14 work were in already place, such as rail spurs, a crane and rail car movement equipment, and trained personnel. Since 2000, the USACE and Shaw had been executing a separate remedial action at the facility, known as the Linde Soils project, to remove, transport and dispose of similar radiologically impacted materials (150,000 metric tons had been removed at the time of the decision). The USACE selected Shaw to complete the Building 14 dismantlement design and general contracting work to assure efficient project execution by sharing the Linde Soils project resources and experience.

CHALLENGES AND DESIGN

The utility tunnel replacement task required simultaneous MED radioactive material remedial action, specialty gas R&D infrastructure replacement and industrial facility operation. Additionally, the schedules for two FUSRAP projects, Building 14 Demolition and Linde Site Remediation, challenged the project and facility team by requiring replacement of the utility

tunnel, including relocated infrastructure installation, in less than 16 months. On-schedule completion would allow Building 14 dismantlement to start on time without causing adverse impact to Praxair's operations. The USACE and Shaw undertook a design/build process to meet the challenges.

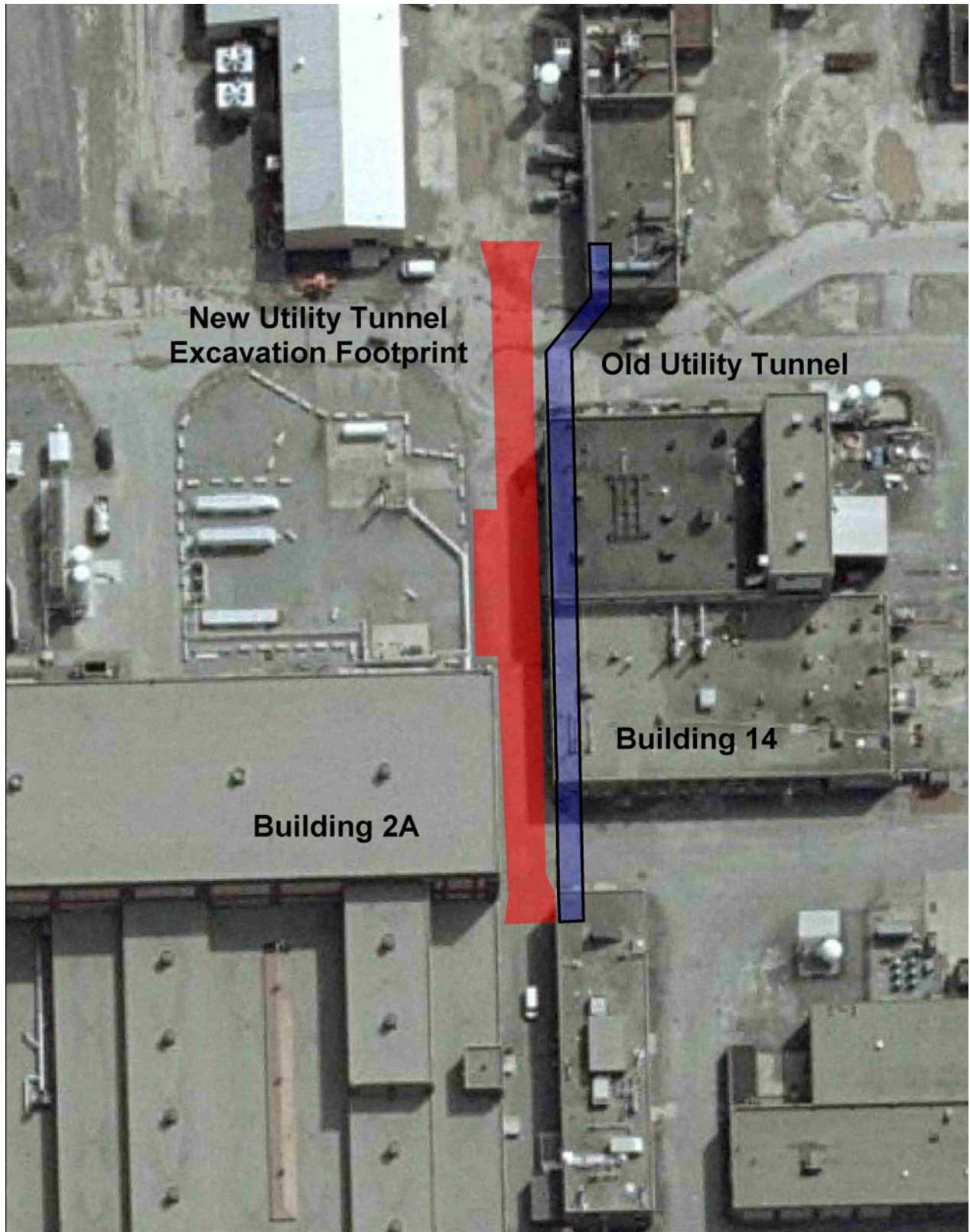
Engineered Design

Figure 1 shows the layout of Praxair's Building 14, the existing utility tunnel and the new utility tunnel in the subject area. An existing 9.1 m wide corridor between two 60-year old, multi-story steel and masonry buildings was the only siting option available for the new tunnel. A substantial portion of the new tunnel's footprint was in areas contaminated with low-level radiological material produced by MED activities. Approximately 4,500 metric tons (5,000 tons) of impacted material required removal prior to the new tunnel installation.

The new 106 m long tunnel (2.4 m square interior) was to be constructed below surrounding grade in a shored open excavation located in a vehicular corridor between the two buildings containing active R&D operations. The typical excavation depth was 3.7 m below grade and the typical width was 5.6 m. Geotechnical borings and analyses completed during the design phase showed the native clay subgrade to have excellent bearing capacity, greater than 380 kPa.

Structure designers selected reinforced concrete box culverts and junction boxes as the best structure to contain the rerouted utilities. American Concrete Institute (ACI) code and guidance [4] were used to design the cast-in-place junction boxes joining the new tunnel with Praxair's existing infrastructure. The New York State Department of Transportation (NYSDOT) and the American Society for Testing and Materials (ASTM) each have standard specifications [5, 6] for pre-cast reinforced concrete box culverts that matched structural requirements. Both incorporated design parameters to meet American Association for State Highway and Transportation Officials (AASHTO) HS-20 [7] or better load bearing requirements. Also western New York has excellent pre-cast concrete vendors possessing expertise and experience providing products to meet the design specifications and challenging schedule. Ultimately the ASTM C 1433-03 standard specification [6] provided the best design guidance for the task. The standard offered a detailed information for recommended steel areas that varied based on dead load (design earth cover) and live load (vehicular traffic) parameters. Designers and fabricators took note that the ASTM standard specified use of welded wire fabric (WWF) for steel reinforcement and it required steel areas to be increased if Grade 60 bar were substituted for WWF to account for reduced yield strength. The roof design was enhanced further to account for punch shear stresses to be encountered when rigging and hoisting 43 pre-cast box culvert sections weighing 14,100 kg each.

Siting constraints dictated that the centerline of the new tunnel be located 3.8 m from Building 14's north wall. Design of the open excavation set bracing for a 4.0 m vertical wall to be located within 1.5 m of Building 14. Shoring options considered were sheet pile, soldier piles with lagging, and a slide rail system. Sheet pile was selected as the most effective method when considering the tight tunnel construction schedule and difficult logistics of winter season construction of a wide and deep excavation in a relatively narrow corridor between buildings. A cantilevered sheet pile system was designed for both sides of the entire excavation.



Base Photo Source: New York State GIS Clearinghouse, 2002

Fig. 1. Building 14 Utility Tunnel Replacement Layout.

Lateral earth pressures and soil stress envelopes posed by the nearby buildings caused selection of a PZ27 sheet, 7.3 m in length with a 2.7 m toe, to shore the excavation.

Engineers designed more than 20 systems to relocate Praxair's existing utilities into the new tunnel. The systems included 103 kPa and 1034 kPa steam, condensate, compressed air, fire water, natural gas, nitrogen, oxygen, five proprietary lab gases, fiber optic and wire communications cable, and seven separate electrical systems ranging from 120 V to 4160 V. Additionally, storm sewer and water supply lines located inside of the new tunnel footprint required designed relocation.

It is worth noting that little design consideration was provided for constructing the new utility tunnel in winter conditions. Management and craft personnel exercised experience and ingenuity while overcoming daily adverse conditions caused by freezing and frozen water, soil, materials and equipment. Shaw initiated the design effort in February 2003 and the USACE approved the design in July 2003.

REPLACEMENT UTILITY TUNNEL CONSTRUCTION

Execution of the design required construction management, engineers and a skilled craft labor force to work seamlessly with radiation safety personnel and facility managers. Virtually all task elements overlapped performance durations so that separate crews executed the tasks. The construction sequence is listed below and detail for selected elements follows:

1. Relocate multiple active utilities from the new utility tunnel footprint.
2. Remove at grade and below grade interferences to sheet pile installation.
3. Install sheet pile shoring.
4. Excavate radiologically impacted material within the shoring limits.
5. Conduct gamma radiation walkover surveys and associated sampling to verify remedial action complete and obtain USACE approval for construction and backfilling in the cleared area.
6. Construct the replacement utility tunnel structure.
7. Install mechanical and electrical components of the new utility systems.
8. Complete transition of existing utility routing to the new infrastructure installed in the replacement tunnel.

Sheet Pile Installation

Sheet pile was selected over slide rail systems to shore the excavation based on task execution schedule and cost considerations. An optimization of the shoring approach involved a change of

sheet section and material. The selected sheet pile installation subcontractor proposed substitution of a CZ114RD sheet for the designed PZ27 section. Selecting the CZ114RD sheet provided a cold-formed steel versus hot rolled, a 343 MPa yield strength steel versus 264 MPa, and a 15.24 cm wider section per sheet to produce a calculated \$50,000 cost reduction.

Over 214 linear meters and 1,580 m² of sheet pile were installed in 14 days through dense clay using a vibratory, variable static moment hammer sheet-piling rig (Figure 2). The ABI Delmag TM-16 rig proved to be an excellent piece of equipment to complete the installation given the site conditions. Impact vibration from traditional hammer stroke pile drivers would have caused excessive low frequency vibration and potential damage in buildings less than 3 m away. The TM-16 handled the 7.3 m long sheets easily with a 16 m stroke. The TM-16 applied up to 90 kN of crowd (down-force) and 2,400 rpm frequency at 10% increments to drive sheets with a minimum of adverse vibration.



Fig. 2. Sheet Pile Installation Using the ABI Delmag TM-16 in Close Confines.

Vibration from pile installation can cause damage to nearby structures and sensitive equipment, and the facility owners requested assurances. Measurement of pile driving vibration is obtained easily using a portable seismograph and collecting data at sensitive locations prior to pile driving and during pile driving operations. Data produced by portable seismographs generally are predominant vibration frequency in Hz and peak particle velocity (PPV) in mm/s in 3 vector directions: vertical, longitudinal, and transverse. The chief difficulty is knowing the vibration values that may cause damage to structures and equipment. In this case, engineers compared vibration data to guidance for blasting vibration safe levels produced by the U.S. Bureau of Mines, Office of Surface Mining (OSM) [8]. In summary, similar PPVs at higher frequencies generally have less potential for causing damage than at lower frequencies. Operation of the

TM-16 produced frequencies greater than 30 Hz on each vector direction. The OSM guidance indicates that PPVs less than 1.5 in/s (38 mm/s) are safe vibration levels at 30 Hz or greater for structures at measurement locations. Safe vibration levels for equipment were uncertain; therefore, engineers used comparisons to background. The maximum PPV vector sums 13 mm/s were measured in the existing utility tunnel approximately 1.5 m from sheet driving locations – a factor of 3 less than OSM defined safe vibration levels. Measurements conducted at sensitive equipment locations showed pile-driving vibrations less than 2x background levels 1.8 mm/s. No damage to facility assets occurred during pile driving.

All radioactive contamination in the area was subsurface. Radiation safety personnel supported the sheet pile installation activity by monitoring all work and scanning any area where subsurface material was brought to ground surface. Worker protection was the main focus of this support.

Remedial Action and Radioactive Materials

Remedial action at the Linde FUSRAP Remediation project is performed in accordance with a MARSSIM-based final status survey plan [9, 10]. Schedule and logistical constraints required development of a unique procedure to sequence concurrent trench excavation, radiological survey, and tunnel construction activities within feet of one another. Radiologically impacted soil was excavated and packaged into 15 m³ inter-modal containers for shipment and the area cleared prior to tunnel installation. Site-specific radiological survey and sampling procedures were developed to clear soil, steel, and concrete surfaces in as little as four hours.

Derived concentration guideline levels (DCGLs) for uranium, Th-230, and Ra-230 in soils have been developed for the Linde FUSRAP remediation project [10]. Two general approaches were used for the development of DCGLs using the RESRAD software model [11]. Approach 1 determined the average radionuclide concentrations that could be distributed uniformly on-site and meet the risk-based criteria for an industrial use scenario. This method is a back-calculation method similar to that used in the development of preliminary remediation goals typically used by the U. S. Environmental Protection Agency. The second approach evaluated the expected residual concentrations after remediation. This approach takes into account the fact that over-excavation occurs on most remedial actions and presents a more realistic model for the site. The subsurface soil DCGLs for the Linde FUSRAP remediation project are 3,021 pCi/g for total uranium, 44 pCi/g for Th-230, and 15 pCi/g for Ra-226. In addition to the soil DCGLs, concrete surface DCGLs were developed for the contaminated tunnel section to which the new installation connected. These DCGLs used a facility-specific demolition/renovation scenario and applied the same type of back-calculation method as approach 1 using RESRAD-Build [12]. The tunnel surface DCGL is 2,200 dpm/100 cm². Based upon historical data for steel surface contamination, the sheet piles were considered non-impacted and released based upon Army Regulation 11-9 criteria [13].

The typical final status survey process sequence at Linde is as follows.

1. After completion of excavation Shaw performs the final status survey and sampling (Figure 3) in accordance with the FSSP and declares the unit as having met the DCGLs.



Fig. 3. Gamma Walkover Surveys Using Global Positioning Systems.

2. The USACE performs a quality assurance survey and reviews the sample analytical results.
3. Shaw develops a formal technical data package for review and approval by the USACE.
4. The New York State Department of Environmental Conservation (NYSDEC) performs an independent survey and sampling of the unit and provides concurrence of completion of the remedial action for the unit.

The duration for this process generally is several weeks. This was not consistent with the task schedule or construction method. In order to expedite the final status survey process, Shaw performed several steps in parallel with the USACE and NYSDEC review actions. Because the entire excavation area was pre-defined to allow for tunnel installation, the random systematic sample locations were identified prior to initiation of excavation. This allowed for excavation, final status surveying and sampling, and tunnel construction to occur at the same time.

Excavation preceded final status activities to allow for a buffer between the work crews. Strict radiological controls and construction safety boundaries were maintained between the excavation cut face, the area of the unit undergoing final status surveying and sampling, and the new tunnel installation. Upon concurrence of remediation by the USACE and NYSDEC following the final status surveying and sampling, USACE provided direction to install each tunnel section in the unit. In most cases, this direction was received prior to receipt of the off-site laboratory analytical results. Thus, the team proceeded at risk. The end result was that all analytical results confirmed a successful remediation and the task schedule was met.

Tunnel Installation and Utility Replacement

Following radioactive material removal and receipt of the USACE direction to proceed, Shaw relocated all obstructing active utilities and installed the pre-cast reinforced concrete box culverts. A 61 cm reinforced concrete storm water collector line under 2.1 m of hydraulic head required by-pass and replacement due to unexpected leakage from degraded 60-year old joint seals. Overburden pressure contained leakage from the time of installation in the 1930's until excavation approached within 0.61 m of the joints. Storm sewage under pressure broke through the remaining overburden and filled the excavation from each pipe segment joint, 0.91 m apart, until excavated material was replaced and compacted to re-establish confinement pressure. A 50.5 l/s temporary lift station was used to bypass the leaking storm sewer to allow replacement with a 6.1 m non-flexible 61 cm ductile iron segment.

A 270 metric ton crane (Delmag 615S) hoisted sections over a 2-story portion of Building 14 for non-line of sight placement at a radius of up to 37.2 m (Figure 4).



Fig. 4. Pre-Cast Box Culvert Placement.

Tunnel section placement was accomplished to within a 0.003 m/m grade tolerance. A critical lift plan was prepared for each lift in accordance with the USACE health and safety requirements [14].

Construction personnel handled the typically harsh western New York winter conditions as a matter of fact and with efficiency when building the new tunnel structure. Snow and water removal from the excavation was the top priority to prevent saturation, freezing, or heaving of subgrade clay or the new tunnel underdrain. Snowfalls measuring over 10 cm occurred on more

than five occasions and an accumulated winter snow total of approximately 230 cm were endured without loss of a single day of excavation or tunnel construction. Temperatures averaged less than -11 C during a 26-day period in January and early February 2004. Crews covered and heated the active tunnel construction work location to assure minimal weather delays. Shaw encountered two unexpected adverse effects caused by winter conditions: frozen hydraulic lines on the crane and deflected sheet pile. The frozen hydraulics caused hydraulic fluid pressure loss and leakage resulting in less than two days delay in placing pre-cast sections. Sheet pile deflection was caused by frozen subgrade clay expansion behind the sheets. The minor deflections were monitored to assure no excavation safety loss or added risk to personnel, equipment or the new structure within the dig.

Another design optimization included replacement of a portion of specified aggregate backfill with a controlled low strength material (CLSM) known as flowable fill. The specified structural backfill was a well-graded granular aggregate – 50 mm limestone crusher run that required compaction to 95% maximum density and +/- 2% of optimal moisture. Engineers designed and specified the CLSM as a structural backfill with a compressive strength range of 275 – 1,034 kPa in accordance with ASTM standard specifications [15-19] using cement and Class F fly ash. The greatest benefit of using flowable fill is the ease of placement – the material is poured as a viscous fluid by a ready-mix concrete vendor. It flows into place and achieves designed density within hours and strength generally within days (temperature dependent).

Potentially negative factors associated with were frost susceptibility, floating of placed box culverts, and potential characteristic hazardous constituents in fly ash as described below:

- Flowable fill is frost susceptible and subject to expansion causing heave when frozen due to water content. Flowable fill use was limited to depths below typical frost penetration, 1.1 m below finished grade, to limit potential for heaving. Non-frost susceptible granular material, NYSDOT Type 1 or 1A material (pea gravel) was used as structural fill in the active layer above the flowable fill and below pavement grade.
- Flowable fill is, initially, a dense, viscous fluid with a specific gravity approximately 60% greater than water. The placed box culvert sections may have floated if the flowable fill was installed too deeply relative to the structure height and weight. Flowable fill was placed in 0.91 m (3 ft) maximum lifts to assure box culvert buoyancy would not occur.
- Fly ash, the major component of flowable fill, contains many of the constituents of the source coal, such as heavy metals and Ra-226. Fly ash is a by-product of coal combustion and some regulated hazardous chemicals are accumulated in high concentrations. Although the NYSDEC has labeled Class F fly ash as a “beneficial use” recyclable material and exempted it from hazardous waste regulation, toxic characteristic leachate procedure (TCLP) and radiological testing were completed on samples provided by flowable fill suppliers to assure USACE acceptance criteria were met.

Flowable fill served as an effective replacement for the excavated native clay by density and structural characteristics.

The shift of “old” utility systems to the “new” systems required detailed engineering and creative execution methods developed by the project and facility team. To ensure minimal impacts to facility operations, a series of regularly scheduled workweek and weekend shut downs were used to relocate utilities into the new tunnel.

Construction Management

Construction started in September 2003 and proceeded through the winter to a successful completion in June 2004. To complete the utility tunnel replacement construction on schedule, more than 25 laborers and operators were employed and 10 specialty service vendors utilized. More than 20% of subcontracted specialty work was issued to native-owned, minority-owned, women-owned, or Hub-Zone businesses. The cost at completion was \$2,300,000 excluding waste transportation and disposal. More than 20,000 man-hours were applied to the work without a lost time accident or Occupational Safety and Health Administration (OSHA) recordable incident.

CONCLUSIONS

Dismantlement of Building 14 in 2004 at the Linde FUSRAP Site, a MED-era structure in Tonawanda, New York, required prior execution of design and remedial action in a 17-month period. The challenges included design and construction of a replacement subsurface utility tunnel, relocation of numerous active utilities, and removal of all radioactive contamination within the new tunnel’s footprint. The USACE Buffalo District and Shaw Environmental, Inc. worked in close cooperation with the facility owner to design and execute the work.

Meeting the challenges involved the combined efforts of a multi-disciplinary team of professional and craft personnel not typically associated with a radioactive materials remedial action project. Following preparation of an engineered design to build a new utility tunnel structure and relocate 20 utility systems, more than 214 linear meters and 1,580 m² of sheet pile were installed to shore the open excavation between 60 year old structures located within 2 m on each side. More than 4,500 metric tons of U-238, Ra-226 and Th-230 impacted material was removed and packaging/transporting for offsite disposal. Remedial action verification involved surveying and sampling over 650 m² of subgrade clay, sheet pile steel, and existing concrete structure surfaces per MARSSIM Final Status Survey procedure to complete remedial action. Concurrent with remedial action operations, a new 106 m reinforced concrete tunnel was constructed over a harsh western New York winter. Installing and commissioning the relocated vital utility systems necessary to operate the host industrial facility was the final task toward successful completion to enable Building 14 dismantlement to start on time. A successful performance by the Linde Site project team and a challenge met in western New York.

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