Recycling of Hydrocarbon-Contaminated Soil into Asphalt Emulsified Treated Base

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Abstract

Harding Lawson Associates (HLA) conducted a pilot treatability study at Fort Hunter Liggett (FHL), an Army base in Monterey County, California, to demonstrate the effectiveness of using asphalt stabilization technology to combine the remediation of petroleum-contaminated soil with conventional road construction. The work was performed for the U.S. Army Corps of Engineers, Sacramento District, in September 1994.

The purpose of the pilot study was to demonstrate the effectiveness of encapsulating contaminated soil with an asphalt emulsion and using the material as a road base. An asphalt emulsion was mixed with hydrocarbon-contaminated soil to form an emulsified treated base (ETB), a cold mix type of asphalt. The ETB was designed to meet industry construction specifications and engineering materials standards and to be suitable for use onsite as a pavement base or for landfill caps, berms, dikes, or similar applications. In addition to the cost savings of substituting contaminated soil for imported aggregate base rock, recycling the contaminated soil onsite eliminated the high cost and generator liability associated with landfill disposal of contaminated materials. The ETB end-product is considered a nonhazardous, nonregulated material by California environmental regulatory agencies.

Recycling petroleum-contaminated soil into an ETB is a viable remediation option primarily for sandy soil contaminated with heavy hydrocarbons or heavy metals. If the soil contains more than 50 percent clay or its moisture content is greater than 20 percent, the soil particles may not be effectively encapsulated by the emulsion. An asphalt materials laboratory analyzed soil samples of the material proposed to be treated to evaluate its suitability for encapsulation and to design a site-specific asphalt emulsion mix.

Approximately 780 tons of sandy soil containing primarily heavy hydrocarbons at concentrations in excess of 10,000 milligrams per kilogram (mg/kg) was excavated and screened to remove oversized aggregates. The screened soil was processed with the selected asphalt emulsion mix and placed on a FHL Primitive Campground road and parking area as substitute for Class 2 aggregate base rock. A double chip-seal was applied over the ETB in accordance with California road standards. Core samples of the final road section analyzed to assess the leaching potential of the hydrocarbons in the ETB were nondetect (clean).

The FHL pilot project successfully demonstrated the technical feasibility of using asphalt emulsion encapsulation as a soil stabilization technology and the potential cost-savings of combining site remediation with standard construction projects.

Background

Four pilot treatability studies were performed as part of a feasibility study to evaluate the effectiveness of using remedial cleanup technologies at FHL. The tested technologies included: asphalt stabilization, low temperature thermal desorption (LTTD), bioremediation, and soil vapor extraction (SVE). Although several of these technologies have proven effective at other sites, these studies were performed to evaluate their effectiveness at FHL, given its unique geologic and climatic conditions. The following describes the results of asphalt stabilization of contaminated soil, an innovative technology that was successfully implemented at FHL to demonstrate the recycling potential of ETB.

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STUDY OBJECTIVES

For large volumes of contaminated soil, asphalt stabilization may be a cost-effective environmental cleanup alternative as well as a method for recycling. The study was designed to address the following objectives:

- Transform petroleum-contaminated soil into a nonhazardous roadway construction material that meets industry design specifications and engineering materials standards and is suitable for use as a pavement base, for landfill caps, berms, or dikes, or in similar applications.
- Satisfactorily address regulatory agency compliance requirements, including soil cleanup and air pollution control criteria.
- Demonstrate the feasibility of recycling petroleum-contaminated soil into ETB as a cost-effective environmental cleanup method either for contaminated soil that is nonhazardous or for hazardous contaminated soil that meets certain regulatory requirements.

REGULATORY CONSIDERATIONS

If a waste is determined to be a Resource Conservation and Recovery Act (RCRA) listed or characteristic waste, it will not qualify for the recycling exemption under the California Health and Safety Code (HSC). Under the recycling exemption, certain products derived from non-RCRA hazardous waste are not classified or managed as a waste if they meet several requirements. HSC recycling exemption requirements are open to interpretation, however, and the Department of Toxic Substances Control, the agency responsible for enforcing RCRA and the HSC in California, is currently writing regulations to be added to Title 22, California Code of Regulations (CCR), to clarify HSC recycling sections. When considering a site, it is important to discuss site-specific conditions with regulators, and obtain regulatory approval prior to the start of a recycling project.

ASPHALT STABILIZATION PROCESS

Asphalt stabilization is a viable remediation option primarily for large volumes of sandy soil contaminated with heavy petroleum hydrocarbons (diesel, crude oil or motor oil) or heavy metals (e.g., copper, lead, zinc). If the soil has more than 50 percent clay or its moisture content is greater than 20 percent, the soil particles may not be effectively encapsulated by the emulsion intended primarily for relatively large volumes of soil (more than 3,000 cubic yards) contaminated with heavy petroleum hydrocarbons such as diesel, crude oil or motor oil or with metals such as copper, lead, and zinc. The method is less effective with soil contaminated with gasoline because gasoline is a lighter hydrocarbon that is likely to volatilize, causing air emissions problems. Contaminated soil is mechanically crushed and screened to create suitable aggregate, which is mixed with asphalt emulsion to create an asphalt paving mix. The contaminants become stabilized, that is, chemically bonded with the asphalt. The mixture can be used in place of a treated or non-treated roadway base or subbase.

"Hot mix" and "cold mix" asphalt paving mixtures, can be used to stabilize petroleum hydrocarbons (see Figure 1). In the hot mix...
process, hot liquid asphalt (300°F to 500°F) is mixed with aggregate in a heated pugmill; however, setup costs for this process were considered too high to justify its use for the small volume of soil to be treated in the pilot study. Air emissions concerns are also a problem with hot mix remediation. In the cold mix process (less than 200°F), either cut back asphalt, which is asphalt cement that has been liquified by blending it with petroleum solvents, or asphalt emulsion is mixed with aggregate. The cutback asphalt cold mix process was not selected for the pilot study because of air emissions concerns related to the use of the solvents.

The asphalt emulsion cold mix process was evaluated in the FHL asphalt stabilization pilot study.

An asphalt emulsion consists of asphalt cement, water, and an emulsifying agent. Asphalt cement is a semisolid asphalctic material refined from petroleum via steam distillation. The emulsifying agent is composed of aliphatic mononuclear aromatic hydrocarbons and polynuclear aromatic hydrocarbons. The water governs the curing process; as the water evaporates, the emulsion develops its curing and adhesion characteristics.

During mixing, the emulsion coalesces and coats (encapsulates) the aggregate. The hydrocarbons in the soil preferentially adsorb onto the asphalt surface, and over time, diffuse into the asphalt, becoming an integral, stable part of the mixture, and achieving full chemical binding. Upon curing, the emplaced ETB retains the adhesive, durability, and water resistant properties of the asphalt cement from which it was produced, provided the emulsion mix was properly designed. Even if the pavement subsequently cracks or is structurally damaged, the contaminants remain stabilized.

The ETB meets California Department of Transportation (Caltrans) design specifications for aggregate road base or subbase for normal construction projects, and in some cases, may be stronger than a typical aggregate base course. It reaches full hardness within 30 days and is an excellent road base substitute for standard Caltrans Class 2 aggregate base rock.

FHL PILOT STUDY

Laboratory testing for the FHL pilot study was started in August 1994 and field placement of ETB was completed on September 22, 1994.

Approximately 780 tons of contaminated soil was available for the FHL pilot study. Although asphalt stabilization is more economical for larger quantities of soil (more than 3,000 cubic yards), the available quantity of soil was considered adequate for the pilot study.

The pilot study comprised three phases: site specific emulsion mix design, onsite mixing (microencapsulation), and placement (macroencapsulation).

Emulsion Mix Design

Soil analysis and site investigations were completed by HLA prior to the start of the pilot study. The maximum concentration of total petroleum hydrocarbons (TPH) as motor oil in the soil samples was 8,000 milligrams per kilogram (mg/kg). The soil samples were "spiked," however, to achieve a maximum concentration of 15,000 mg/kg. Two months prior to field production of ETB, ENCAPCO, the asphalt emulsion laboratory and supplier for this study, performed laboratory testing on samples of contaminated soil from the site and formulated an asphalt emulsion mix design that met construction and regulatory requirements. ENCAPCO then formulated the asphalt emulsion used in the field.

Onsite Mixing

The mix design was based on a maximum aggregate size of 1 inch because the pugmill could not process oversize material without damaging its augers. Some of the soil to be treated contained aggregate up to 6 inches in diameter. Consequently, Granite Construction Company (Granite), HLA's subcontractor, set up a portable screening unit on September 9, 1994, to screen out materials greater than 1 inch. The entire stockpile was screened in 2 days and the rocks were stockpiled separately within the exclusion zone. Approximately 50 tons of rock were segregated.

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On September 19, 1994, the portable pugmill mixing unit was set up onsite. The unit had been modified to meet project requirements. Modifications included installing a digital belt scale, five dust suppression spray bars on the conveyor to comply with air quality constraints, emulsion spray bars inside the pugmill, and additional motor controls for accurate feed and mixing adjustments. The hopper and conveyor were located in an exclusion zone to comply with OSHA requirements. Because the soil is not considered hazardous after it has been mixed with the asphalt emulsion, the pugmill feed was outside the exclusion zone. Figure 2 is a schematic of the field mixing process.

Calibration of the belt scale and a system check was an important initial step. Granite conducted a dry run where 10 cubic yards (cy) of soil were processed through the pugmill without adding emulsion. The soil was loaded into a truck and returned directly to the stockpile for reprocessing.

ETB production began September 20, 1994, and continued through September 22. Prior to the start of processing, the plant was inspected by a Monterey Bay Unified Air Pollution Control District (MBUAPCD) representative and an operating permit was issued. The MBUAPCD air quality engineer monitored the operations on the first day to ensure compliance with the operating permit.

Based on the specified mix design, it was determined that the asphalt emulsion was to be metered at a rate between 17 percent and 22 percent by dry weight of aggregate. A digital metering device accurately maintained emulsion flow rates based on the soil being fed into the pugmill. On a larger volume project, the emulsion and soil metering operations could be combined automatically using a computerized metering system that would maintain the proper flow of emulsion without having to make manual adjustments.

The pugmill produced an average of 75 tons of soil per hour. Throughout this procedure, Granite's plant manager oversaw the operation to provide quality control and to document areas for potential improvements. A number of improvements to the pugmill were identified that could effectively raise hourly productions to at least 350 tons/hr while maintaining the same daily quality control.

Placement

The ETB was loaded directly into dump trucks parked under the pugmill and transported to the placement area, a dirt roadway and parking area at the FHL Primitive Campground. No special health and safety requirements were necessary after the ETB was loaded into the trucks because the material was not hazardous. Because the asphalt emulsion "breaks" within a couple of hours, as do other emulsions such as slurry seal, it was critical to transport and place the ETB as quickly as possible, preferably no more than 1 hour after mixing. A schematic of the placement process is shown on Figure 3.
The dirt roadway had previously been graded and "chokers" constructed on either side to contain the ETB, in much the same way as is done with Class 2 base rock. An asphalt prime coat had been applied to the roadway soil to prevent it from absorbing emulsion from the treated soil. Application of this prime coat was optional because laboratory test results indicated that the emulsion would not leach into the clean 'subgrade. Trucks dropped the ETB onto the roadway, and a motor grader spread it in a 4- to 6-inch lift.

Due to the high emulsion content of the ETB, it was necessary to wait until the emulsion started setting up before the material was compacted; if it is compacted too soon, it can lose its strength and excessive "pumping" will occur. After the ETB started setting, it was compacted with a vibratory sheepsfoot roller until it was uniformly compacted. The motor grader created a surface and a smooth drum roller was used to finish the base course. A double chip-seal was applied over the ETB in accordance with Caltrans standards.

Health and Safety, Permitting, and Quality Control

Health and safety and construction quality control are a very important part of the remediation work process. To meet schedule requirements, it was imperative that project planning and permitting was completed prior to start of production. A number of governmental agencies were involved, each with specific permitting and compliance requirements. At FHL, all personnel working within the exclusion zone were required to have received 40-hour hazardous materials training in conformance with OSHA 29 CFR 1910.120, as well as pre- and post-job medical examinations. An air pollution use permit from MBUAPCD was required.

After production began, several of the following items required close monitoring. A full time onsite inspector was present to monitor:

- Air pollution emissions (if any)
- Emulsion mixing proportions
- Pugmill production rates
- Placement timing and methods
- Soil moisture sampling and conditioning
- Compaction testing
- Post placement coring.

After production was underway and the plant production rates stabilized, the operation ran smoothly without fluctuations in the mixing process. Because of the contaminants and dust in the soil, Granite incorporated strict air quality measures in its screening and asphalt mixing operations.

A critical balance had to be reached between the mix design's maximum allowable moisture content and air quality constraints. Continuous onsite quality control monitoring was performed by HLA to confirm that the project was executed as designed. Core samples were taken of the final road section, and analyzed for leaching potential of contaminants bound into the ETB. All samples were nondetect (clean).

CONSTRUCTION FEASIBILITY AND COMPARATIVE COSTS

Cost savings can be realized on an ETB project based on the following factors:

- Cost of imported aggregate base rock and its distance from the site
- Cost of asphalt concrete
- Structural section reductions due to ETB's higher gravel equivalent over conventional base rock
- Proximity of ETB plant to its end use
- Quantity of contaminated material to be remediated.

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Project feasibility depends upon combining remediation with ongoing capital improvements. For this reason, ETB is best suited to facilities with large quantities of contaminated soil and ongoing pavement maintenance, such as military installations, refineries, and airports. A key factor in evaluating whether ETB is an effective remediation method is site-specific soil conditions.

For cost evaluation purposes, estimated costs, duration, and production rates for a project incorporating 20,000 tons of soil into ETB were compared with remediating the soil using other methods. Figure 4 shows the relative costs for each remediation method, and Figure 5 shows relative daily production rates. ETB is more cost effective and takes less time to implement than other methods.

One reason that ETB is more cost effective is that it can be substituted for commercial baserock on a standard construction project. For example, assuming a traffic index of 12 and R values of 78 for Class 2 aggregate base, 50 for aggregate subbase, and 10 for subgrade, the structural section thickness for ETB will be 10 percent thinner than the equivalent Class 2 base rock section using the design formula and the gravel equivalent table from the Caltrans highway design manual: This is an important factor in determining the relative costs of remediation on any site restoration or installation closure. Not only can the ETB be a cost-effective substitute for base rock but it allows less earthwork to be performed on the construction project. The result is a potential savings on aggregate base rock, particularly after taking into account the net deduction in the amount of total base course material required on the project.

CONCLUSIONS

With the current emphasis on waste reduction by recycling, asphalt stabilization technology provides a very attractive alternative to other soil remediation technologies. ETB is a 100 percent recyclable product, emitting no detectable air pollution during production or placement. The pilot study at FHL successfully demonstrated that petroleum contaminated soil can be transformed from an environmental liability to a useable resource. This technology offers owners of a wide variety of facilities with petroleum contaminated soils to achieve a cost-effective solution to their waste management concerns.

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