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Bench-Scale Evaluation of Asphalt Emulsion Stabilization of Contaminated Soils

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ABSTRACT: The application of ambient temperature asphalt emulsion stabilization technology to the environmental fixation of soils contaminated by organic contaminants, primarily hydrocarbons, was pioneered in 1987. Since that time, the process has seen many applications in recycling contaminated soils into an environmentally stable, structurally enhanced, paving base material. A bench-scale demonstration was undertaken to evaluate and demonstrate the effectiveness of the process in immobilizing environmental contaminants, at various concentrations, from four common petroleum products. Results of the tests presented demonstrate the degree of effectiveness of the stabilization process for soils contaminated by No. 2 Fuel Oil, No. 6 Fuel Oil, Gasoline, and Jet Fuel (JP4). The analytical parameters for which the fixation effectiveness is demonstrated include volatile organic compounds (VOCs), total petroleum hydrocarbons (TPH), and polynuclear aromatic hydrocarbons (PAHs). Descriptions of the process and details regarding the environmental and structural characteristics of the final product are presented.

KEY WORDS: asphalt emulsion, contaminated soils, leachability, petroleum-contaminated soils, recycling, stabilization.

I. INTRODUCTION

Mobile, ambient temperature asphalt emulsion stabilization of hydrocarbon-contaminated soils was pioneered by United Retek Corporation in 1987. Since that time, Retek Recycling, a low-tech yet elegant solution to the liability and the economic, regulatory, and environmental problems posed by the presence of contaminated soils, has seen hundreds of applications.

The Retek process is mobile and is conducted on-site, where the contaminated soils originate. The process is conducted at ambient temperature; no heat is added. This tends to minimize contaminant volatilization and associated air quality issues. The stabilizing medium used in the process is a proprietary asphalt emulsion formulation containing water, surfactant, and asphalt that, in the curing process, binds the hydrocarbon contaminants rendering them environmentally unavailable.

The manufacture and use of asphalt emulsions is not new. Emulsions were used as early as the 1920s for road construction and maintenance, primarily in spray applications and as a dust palliative (USDOT, 1979). Asphalt emulsions are used in road construction and maintenance in the United States today for surface treatments, patching and thin overlays, structural stabilization, and slurry sealing. Asphalt emulsions are also used in base and surface course mixes and in pavement recycling. The objective in asphalt emulsion manufacture is to provide a dispersion of asphalt cement in water that will maintain stability for pumping, storage, and mixing, but will quickly break down on application and, on curing, will provide the adhesion, durability, and water resistance of the asphalt cement from which it was manufactured (USDOT, 1979). Asphalt emulsions are categorized as anionic, cationic, or nonionic, depending on the presence and type of electrical charges surrounding the asphalt particle. Emulsions are further classified on the basis of setting rates, emulsion viscosities, and hardness of the base asphalt cements.

Variables in the manufacture of asphalt emulsions that effect application and performance include the chemistry, hardness, and quality of base asphalt cement; size and ionic charge of asphalt particles; chemistry and concentration of emulsifying agent; and temperatures, pressures, shear, and equipment used in the manufacturing process.

Retek fixatives, manufactured under private label, fall within the range of normal asphalt emulsion manufacture and are not patented. The emulsions used in Retek Recycling are formulated according to proprietary combinations of manufacturing variables, identified through research, to provide the desired contaminant stabilization properties. In proprietary evaluations conducted by Retek, alternative formulations, which vary with regard to electrical charge, surfactant, setting rate, and other manufacturing variables, have been shown to be ineffective or less effective in coating the contaminated aggregate and eliminating contaminant leachability. The Retek process constitutes recycling and beneficial reuse. The contaminated soils are used as feedstock in the manufacture of asphalt emulsion stabilized material (AESM), which is then utilized as a paving base.

The treatment process in the field typically requires preprocessing, which consists of crushing and/or screening to produce a physically uniform (3-in. minus) material. In this step, the material is sized and blended and miscellaneous debris, unsuitable for use in the final paving product, is separated from the recyclable soil. The actual recycling process involves blending the preprocessed, contaminated soils with the asphalt emulsions. The soil is fed by front-end loader into a hopper, from which it is conveyed by belt to the mixing chamber. As the soil passes through a series of counterrotating blades in the pugmill, the emulsion is applied at a predetermined rate. The asphalt emulsion-coated material exits the pugmill mixing chamber and is stockpiled for curing (typically, 72 h). Asphalt emulsions depend on the evaporation of water for development of curing characteristics. During curing, the stockpile is covered, if required, for precipitation protection. If such covering is required, the curing duration can be extended accordingly. After curing, the AESM may be used immediately or maintained in a stockpile for later use.

II. BENCH-SCALE TEST DESIGN

Although significant amounts of field data had been generated over years of Retek process application, the natural heterogeneities of soil and contaminant distribution in the field imposed limitations on understanding the true effectiveness of the process in eliminating environmental mobility and potential exposure pathways. In an attempt to address these limitations, in November 1991, a laboratory bench-scale demonstration was conducted to comprehensively evaluate and demonstrate the effectiveness of the process in immobilizing the environmental contaminants resulting from four common petroleum products: No. 2 Fuel Oil (2-oil), No. 6 Fuel Oil (6-oil), Gasoline, and Jet Fuel (JP4).

A. Sample Preparation

In the field, Retek Recycling is necessarily applied to whatever type of soil has been contaminated. From the standpoint of environmental stabilization, any soil matrix into which the fixative emulsions can be adequately dispersed and blended is a candidate for recycling. Well-graded, coarse aggregates not only provide the most workable soils from a blending and coating standpoint but also result in the best paving base material from a structural standpoint. To approximate less than ideal conditions, a representative base soil of fine to medium sand with 18.9%, passing the #200 sieve was used. Results of gradation (sieve) analysis are presented in Table 1. Qualitative evaluations indicate that the material passing the

TABLE 1
Gradation Analysis
Bench-Scale Test Base Soils
Washed Sieve Results (% passing by weight)

Sieve size	Result
0.75	100
0.50	99
4	97
10	86
20	73
40	55
50	42
80	30
200	18.9

#200 sieve were primarily nonplastic silts. Bench-Scale Test samples were made up by the addition of the indicated volumes of virgin petroleum product to the base soil.

The No. 2 Fuel Oil sample was made up by weighing out 5367 g of soil and adding and thoroughly mixing in 55 g of 2-oil, equivalent to approximately 1% by weight. The No. 6 Fuel Oil sample was made up by weighing out 3633 g of soil and adding and mixing in 182 g of 6-oil, equivalent to approximately 5%. The Gasoline sample was made up by weighing out 2072 g of soil and adding and mixing in 6 g of unleaded gasoline, equivalent to approximately 0.29%. The Jet Fuel sample was made up by weighing out 5109 g of soil and adding and mixing in 27 g of JP4, equivalent to approximately 0.53%.

Although the results of the preprocess soils analyses discussed in the following section were not available until after the bench scale tests were complete, the amounts of petroleum product added were selected in an attempt to approximate the upper ranges of contaminant concentrations typically encountered in the field.

B. Contaminated Soil Sample Analyses

Multiple subsamples of each soil/contaminant matrix were collected and composited to yield one sample representative of each prepared contaminated soil. These samples were then submitted for laboratory analyses. The 2-oil sample was analyzed for both total and toxicity characteristic leaching potential (TCLP) extractable concentrations of total petroleum hydrocarbons (TPH) and volatile organic compounds (VOC). The 6-oil sample was analyzed for both total and TCLP extractable TPH and polyaromatic hydrocarbons (PAH). The gasoline sample was analyzed for both total and TCLP extractable VOC, and the JP4 sample was analyzed for both total and extractable VOC, TPH, and PAH. The analytical results are presented in Table 2. The remainder of each soil volume was immediately placed in tightly filled sample jars and maintained under refrigeration until the bench-scale batching was conducted.

III. BENCH SCALE RETEK RECYCLING

Bench-scale Retek Recycling was conducted on each of the four contaminated soil samples. The batching was conducted using a precleaned bowl and mixing paddle for each batch. Emulsion and water, when required to facilitate mixing, were added to the contaminated soils from preweighed containers and amounts used were determined by subtraction. The degree of environmental stabilization achieved is related to the effectiveness of mixing and coating of the contaminated soils with the asphalt emulsion, and the performance of the process can be anticipated by an

TABLE 2
Bench-Scale Test Data Summary: Results of Environmental Analyses on Hydrocarbon-Contaminated Soils before and after Retek Recycling

Contaminant	Analytical parameter (units)	Before Retek	After Retek
#6 Fuel oil	Total TPH (mg/kg)	39,218	
	TCLP TPH (mg/l)	826	ND (3)
	Total PAH (μg/kg)	139,129	
	TCLP PAH (μg/l)	52.8	ND (5)
#2 Fuel oil	Total TPH (mg/kg)	8,067	
	TCLP TPH (mg/l)	117	ND (3)
	Total VOC (μg/kg)	3,657	
	TCLP VOC (μg/l)	221	ND (25)
JP4	Total TPH (mg/kg)	1,006	
	TCLP TPH (mg/l)	62	ND (3)
	Total PAH (μg/kg)	2,050	
	TCLP PAH (μg/l)	11.2	ND (5)
	Total VOC (μg/kg)	3,590	
	TCLP VOC (μg/l)	151	ND (25)
Gasoline	Total VOC (μg/kg)	508,550	
	TCLP VOC (μg/l)	8,727	ND (25)

Abbreviations: ND, Indicates contaminants not detected at detection limit indicated in parenthesis; TPH, Total petroleum hydrocarbons by standards methods 503B and 503E; PAH, Polynuclear aromatic hydrocarbons by EPA method 8250; VOC, Volatile organic compounds by EPA method 8240; TCLP, Toxicity characteristic leaching potential (extraction procedure) EPA method 1311.

experienced observer from the appearance of the emulsion-coated soils. The amount of emulsion added to the soils is determined based on trained observation and varies as a function of soil type, antecedent moisture content, and type and degree of contaminant present. For example, the presence of 6-oil in a soil may produce a wetting effect and facilitate emulsion blending and coating to result in a reduced emulsion requirement compared with the amount of emulsion required to treat the same soils contaminated with gasoline.

The tare weight of the mixing bowl was determined, and 1123 g of the previously prepared 2-oil soil sample was measured out. Retek Emulsion was added in increments and blended into the soil and 50 ml of tapwater was added to facilitate even mixing. The entire mixing duration continued for approximately 90 s. The amount of emulsion used was recorded as 118 g, which is approximately equivalent to a 25 gallons-per-ton mixture. The blended material was folded out of the bowl onto an aluminum tray (cookie sheet) in a simulated stockpile configuration for curing.

The process for the other three samples followed the same general protocol. The soil and emulsion weights for each sample are as follows:

- The 6-oil batch used 964 g of soil and 74 g of emulsion approximating an 18 gallons-per-ton mixture.
- The gasoline batch test used 1001 g of contaminated soil and 98 g of emulsion. This is approximately equivalent to a 23 gallons-per-ton mixture.
- The JP4 batch test used 1047 g of soil and 111 g of emulsion for a 25 gallons-per-ton mix equivalent.

All of the samples were placed on aluminum trays and allowed to cure at room temperature (55°F) for approximately 48 h. On completion of the curing period, the processed material samples were separated into appropriate size sample jars for postfixation analyses.

IV. POSTPROCESSING ANALYSES

All postprocess analyses included TCLP extraction followed by analyses for the appropriate analytical parameters. The 2-oil posttreatment sample was analyzed for extractable concentrations of TPH and VOC. The 6-oil posttreatment sample was analyzed for extractable concentrations of TPH and PAH. The gasoline posttreatment sample was analyzed for extractable concentrations of VOC, and the posttreatment JP4 sample was analyzed for extractable concentrations of VOC, TPH, and PAH. The posttreatment sample analytical results are presented in Table 2. The analytical results are discussed in the following section.

V. DISCUSSION OF BENCH SCALE TEST RESULTS

The results of all analyses conducted are summarized in Table 2.

The 2-oil TPH results indicate that the untreated sample exhibited a total TPH concentration of 8067 ppm and TCLP-extractable TPH concentration of 117 ppm. The post-Retek treatment sample of the material did not exhibit any TCLP-extractable TPH above the 3.0 ppm detection limit. Likewise, the untreated sample exhibited 3657 ppb total VOCs and 220.5 ppb TCLP-extractable VOCs, and the posttreatment 2-oil sample exhibited no VOCs above the 25 ppb detection limit.

The 6-oil data set indicates a similar trend. The before-fixation sample exhibited total TPH at 39,218 ppm and extractable TPH at 826 ppm. The post-Retek treatment sample did not exhibit any TPH in the TCLP extract above the

3.0 ppm detection limit. For the same sample, the untreated PAH data indicate a total concentration of 139,159 ppb and TCLP-extractable concentration of 52.8 ppb. The posttreatment analysis did not detect any PAH above the 5.0 detection limit.

The before-fixation JP4 sample exhibited 3590 ppb total VOCs and 151 ppb TCLP-extractable VOCs. The post-Retek sample analysis did not detect any extractable VOCs above the 25 ppb detection limit. The untreated JP4 sample exhibited 1006 ppm total and 62 ppm TCLP-extractable TPH, and the post-Retek sample analysis did not detect any TCLP-extractable TPH above the 3.0 ppm detection limit. The before-fixation JP4 sample exhibited 2050 ppb total and 11.2 ppb TCLP-extractable PAH. The post-Retek treatment analysis did not detect any TCLP-extractable PAH, at a 5.0 ppb detection limit.

The gasoline sample exhibited 508,550 ppb total VOCs and 8727 ppb TCLP-extractable VOCs before Retek fixation. Following Retek fixation, no VOCs were detected in the sample above the 25 ppb detection limit.

VI. STABILIZED MATERIAL UTILIZATION

As discussed previously, AESM manufactured in field applications of the Retek process is typically utilized as base or subbase in normal paving applications such as parking lots or roadways. For some such applications, the structural bearing capacity of the AESM has been tested to verify the suitability of the material for the proposed application.

Table 3 presents results of testing performed on Retek-processed materials in accordance with Federal Highway Administration (FHWA) prescribed Modified HVEEM Method as specified by ASTM procedure D-1560–81 (ASTM, 1989) to determine resilience and cohesivity. The data indicate that a relatively poor soil, with 24% by weight passing a #200 sieve, readily exceeds the FHWA specifications for the road base performance when stabilized by the Retek process. In addition, Swell tests were conducted on the same Retek-processed material. After 7 d of being submerged in water, the recorded expansion was only 0.11%, well below the criteria of 1.1%, indicating a stable, well-bonded material.

VII. SUMMARY AND CONCLUSIONS

The analytical results from the bench-scale tests reported here indicate the effectiveness of the Retek asphalt emulsion stabilization process in immobilizing the environmental contaminant constituents of petroleum products. Fixation effectiveness is demonstrated for soils exhibiting TPH concentrations approaching 40,000 ppm, PAH concentrations in excess of 139,000 ppb, and total VOC concentrations greater than 500 ppm.

TABLE 3

Results of Structural Testing on Hydrocarbon-Contaminated Soils after Retek Recycling

Before Retek							
Material sieve analysis[a]		**After Retek Recycling**					
Size	% Passing						
1.5"	100						
1.0"	90						FHWA
0.75"	84	Binder-Retek fixative	A	B	C	D	specifications
0.5"	76						
0.375"	67	Initial cure conditions[b]					
4	59	R-value	79	85	90	89	
8	54	C-value	502	726	726	665	≥50
16	48	R_t-value(R+0.05C)	104	121	126	122	≥70
30	42						
50	36	Sample density (PCF)	138.5	138.5			
100	29						
200	24						

[a] Evenly graded material with high fines content.

[b] Air cured in mold 24 h; tested at ambient temperature.

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