International Conference on Case Histories in Geotechnical Engineering

(1993) - Third International Conference on Case Histories in Geotechnical Engineering

03 Jun 1993, 2:00 pm - 4:00 pm

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Proceedings: Third International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, June 1-4, 1993, Paper No. 10.01

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SYNOPSIS: Several methodologies are available for the remediation of contaminated soils including bioremediation, vapor extraction, chemical fixation, incineration and direct disposal. A proven innovative and cost effective alternative for the fixation of contaminated soils is via cold-mix Environmentally Processed Asphalt (EPA). EPA methodology utilizes contaminated soil as an ingredient in an industrial process to produce a commercially viable product. Petroleum hydrocarbon and metal affected soil is incorporated with an asphalt emulsion and aggregate to produce a range of cold-mix asphalt product that fulfills the requirements of a variety of end uses. This viable and creative use which is within the intent and spirit of current regulations is producing, in lieu of a landfill waste, an end product for use as a berm, road base, liner, or other site specific application. Consideration of certain factors including durability, chemical resistance and ageing, biological resistance, permeability, and leachability suggests that cold-mix asphalt incorporation of affected soil will perform more than adequately under normal conditions for a long period of time.

INTRODUCTION

A major consideration when formulating remedial action plans is what technology will best serve the specific project needs. No two projects are exactly alike and each has site specific limitations. However, three objectives must always be met in order for the remediation project to be successful. The remedial method must be cost effective, time efficient, and environmentally sound. Recycling petroleum hydrocarbon and metals affected soil (affected soil) via incorporation into cold-mix asphalt is a proven remedial technology (Preston and Testa, 1991; Testa and Patton, 1991; Testa et al, 1992a; Testa et al, 1992b; Testa et al, 1992c). The production of asphalt is conventional in nature and well established (The Asphalt Institute, 1982). In addition, the incorporation of affected soil into asphalt products by the process referenced to as environmentally processed asphalt (EPA) is viewed as environmentally sound, and has proven to be cost-effective while providing the minimal amount of long-term liability in comparison with other soil remediation /options and alternatives. Affected soil, formerly classified as hazardous waste, are incorporate with asphalt emulsion and specified grades of aggregate to produce a range of cold-mix asphalt products that fulfill the requirements of a variety of end uses. Notable among these uses are landfill caps and liners, tank farm dikes and containment structures, parking lot, truck terminal and salvage yard pavements, road construction material and port facility container shipping yard surfacing.

Presented in this paper is the discussion of methodology, regulatory framework, and certain properties of EPA pertaining to durability, chemical resistance, ageing, biological resistance, permeability, leachability, chemical aspects, and product usage.

METHODOLOGY

The incorporation of affected soil to produce a commercially viable product can be accomplished utilizing one of two processes: mixed-in-place for large quantities and windrowing for smaller quantities. For large quantity projects, mixed-in-place is conducted using a portable asphalt batch plant. Providing production averaging 150 tons of cold-mix asphalt per hour, the plant operation consists of a mechanical screening plant, transfer conveyor, electrical generator (all equipment except the rolling stock is electrically powered), the asphalt plant or pug mill, and asphalt emulsion truck (Figure 1). Materials are introduced to the process through the screening unit which serves to separate all deleterious materials (i.e. trash, plastic, large rocks, etc.) from the soil, and to size material in accordance with the design criteria. For example, asphalt sub-base would use 1-1/2" aggregate, whereas pavement may call for 5/8" minus. From the screen, the materials travel on the transfer conveyor to the batch plants 915 soil hopper. There are two hoppers on the plant unit: one for soil and the other for aggregate. These materials are fed at a predetermined rate from each hopper by variable speed conveyors and adjustable feed gates. Mix design such as 50 percent soil and 44 percent aggregate are maintained to within 1 percent of total mix. The feed hoppers discharge onto the plant units transfer conveyor to the mixing chamber. The materials discharge from the conveyor into a fluffer wheel compartment where they are further mixed. Inside this compartment the asphalt spray bar applies the required amount of emulsion. From the asphalt compartment the material discharges into the mixing chamber. Inside this chamber are two counter rotating paddle wheel mixers that

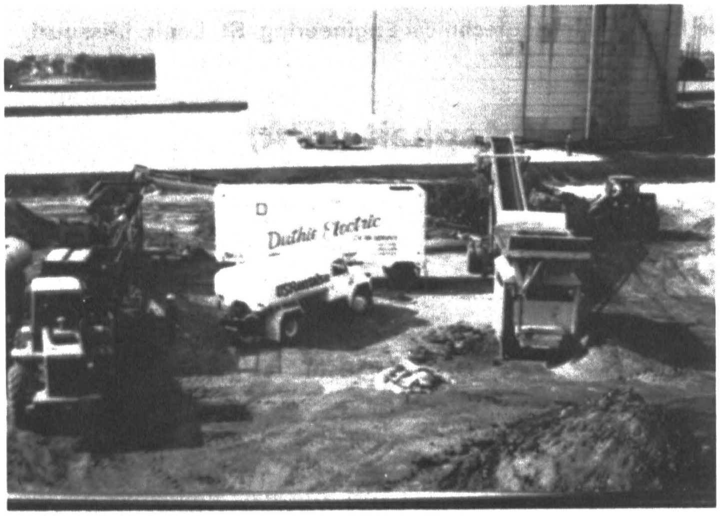

Figure 1: Portable asphalt batch plant processing cold-mix EPA via mixed-in-place process.

have adjustable rotating speeds. This provides the proper retention time to ensure a complete blending of all materials. The product is then transferred into trucks or to a stockpile ready for application. The product can be stockpiled for months until need is acquired. For smaller quantities, windrowing involves coating the soil with a proprietary emulsion and mixing the materials in place (Figure 2). Trans Section 38 specifications as commonly used by County and State Road Departments to produce road mixed asphalt.

Figure 2: Grader producing cold-mix EPA via the windrowing process.

REGULATORY FRAMEWORK

The regulatory framework of the Federal environmental laws (and such states as California) do not deem everything as "hazardous" and mandate its disposal in a Class I landfill or by incineration. A review of current regulations proves quite the contrary. The letter, spirit and intent of current Hazardous Materials legislation is to promote and develop alternate technology that encourages the use, reuse and recycling of materials rather than the archaic load, haul and dump remediation techniques that have produced more environmental problems than they ever solved. Specifically, the recycling of affected soil into EPA is for example carried out in California under the following enabling legislation:

- o California Code of Regulations (CCR) Title 22, Section 66262.11 "Hazardous Waste Determination";
- o CCR Title 22, Section 66261.2 "Definition of Waste";
- o CCR Title 22, Section 66261.3 "Definition of Hazardous Waste";
- o CCR Title 22, Section 66261.4 "Exclusions";
- o California Health and Safety Code (CHSC) Chapter 6.5 Article 4 Section 25143.2(b) "Recyclable Material";
- o Code of Federal Regulations (CFR) Title 40, Part 261 Section 2 (40 CFR 261.2) "Definition of Solid Waste"; and
- o 40 CFR 261.2(e) "Materials that are not solid waste when recycled".

The above are the main sections which deal with the use, reuse and recycling of materials. There are a myriad of subsections and cross references to other sections that the reader will note upon review of these main listed regulations. Briefly stated, to paraphrase CHSC 25143.2(b), recyclable material which is or will be recycled by any of the following methods is excluded from classification as a waste:

1) Used or reused as an ingredient in an industrial process to make a product; or

2) Used or reused as a safe and effective substitute for commercial products.

Hence, if the regulations do not classify recyclable materials as "waste" and are not regulated as "hazardous waste", the use, reuse and recycling of these materials are therefore within the letter, spirit and intent of environmental legislation.

Thus, the objectives of EPA methodology as a soil remediation option are:

- o To effectively reuse affected soil as an ingredient in a stable, non-hazardous cold-mix asphalt which would be utilized on the property of origin as paving material;
- o To reduce generator liability to a minimum by complying with pertinent Federal and State regulations;

- To reduce the cost of remediation by reusing affected soil as an ingredient in cold-mix asphalt thereby eliminating many of the Hazardous Waste taxes, pretreatment and landfill disposal costs;
- To demonstrate that the EPA method effectively stabilizes the hazardous constituents comprising affected soil; and
- To demonstrate that EPA is a cost effective, time efficient and environmentally sound remediation alternative to landfill disposal of Hazardous Wastes.

DURABILITY

The best indication that asphalt liners and structures have long-term durability and performance is the existence of surviving asphaltic structures from antiquity (MRM Partnership, 1988). Asphalt was in general use in western civilizations from about 2,000 BC to the 1st century AD, where its use was superseded by more economic methods of working wood, tar and pitch, and the exhaustion of deposits available to existing mining technologies. Surprisingly, the ancient mixes are not that dissimilar to modern ones. Besides the obvious uses as mortars, pavements, revetments and foundations, many Mesopotamian sites asphalt liners were commonly used in drainage, water tanks, and plumbing fixtures, having thicknesses from 0.1 mm to several centimeters. In many of these cases, the asphaltic structures that have escaped intentional or accidental destruction are still adequately performing their primary function. Samples taken from these structures often show favorable properties, including low permeabilities, but it is unsure how long exposure to UV-light and surface conditions have affected the asphalt relative to the general ageing processes expected in the subsurface environment.

CHEMICAL RESISTANCE

The testing and performance assessment of asphalt has traditionally focused on structural performance as pavement and building materials. However, when evaluating the long-term performance of asphalt liners produced with affected soil as part of the aggregate, the focus is on the chemical performance. Because of the great immiscibility of petroleum products with respect to the aqueous phases expected under impoundment conditions, large favorable free energy change exists for preventing the release of contaminants from the asphalt. Therefore, the chemical behavior and performance of the petroleum contaminant should parallel the behavior and performance of the asphalt itself. Detailed chemical tests have been performed on asphalt liners for disposal sites of uranium mill tailings (Buelt, 1983) and for land disposal of radioactive waste (Eschrich, 1980). These studies can be used to make a preliminary evaluation of the use of affected soil for cold-mix EPA incorporation.

The resistance of asphalt to many reagents at atmospheric temperatures is well documented (MRM Partnership, 1988; Buelt, 1982; Benedetto et al, 1970). Prolonged contact with dilute acidic solutions can result in hardening of the asphalt by formation of asphaltenes. Nitric acid is very reactive with asphalt even in dilute solutions, while hydrochloric acid does not affect asphalt. Asphalt reaction with sulfuric acid is intermediate. Asphalt are generally more resistant to alkaline solutions than to acidic solutions, a favorable effect for asphalt liner. However, alkaline solutions can react to form salts such as sodium napthenates which form excellent emulsifying agents. Theoretically, this could be a problem for affected soil if contaminants are mobilized in the emulsified solution. However, the emulsification depends on the degree of alkalinity and the diffusion and hydraulic resistances of the asphalt which is generally extremely low; less than 10^{-12} cm^2/s and 10^{-9} cm/s, respectively (Hickle, 1976). Without further experimental verification, emulsification of an asphalt liner is not expected to be important nor leachable to the extent of releasing hydrocarbon constituents in excess of regulatory limits. The resistance of asphalt to selected chemicals under a variety of conditions are presented by MRM Partnership (1988).

AGEING

Of most importance to an asphalt liner for example is the effects of ageing. Although not documented, hardening and other ageing effects might increase mobilization of the petroleum contaminants from the EPA by supplying pathways out of the asphalt and by causing separation of petroleum constituents from the asphalt phases during ageing. However, these effects would have to be excessive and affect a large proportion of the asphalt to mobilize the small amount of contaminants in the 10 percent fines of the aggregate.

Physical hardening due to peptisation, paraffin crystallization and volatilization occurs to different degrees in all types of asphalt and are unaffected by the presence of petroleum-contaminated soil as a small part of the aggregate. Chemical hardening, however, may be important. The rate of reaction of asphalt with oxygen is very temperature dependent and varies with asphalt type at high temperatures, but below 50°C, the reactions are independent of temperature and asphalt type, are restricted to the asphalt surface, and should not be affected by affected soil. The hardening rate is higher in the presence of light, but because of the dark conditions of the subsurface environment, only the ageing reactions that occur in the dark are of importance to an asphalt liner. In the dark, oxygen is bound after short ageing times as SO-groups, and after long ageing times as CO-groups. Petroleum contaminants are not present in great enough quantities to effect the rate or degree of these reactions. Experiments show that the maximum depth of oxygen penetration is in the range of 2.5 mm to 5 mm (MRM Partnership, 1988) but the rate of hardening reduces considerably with time.

BIOLOGICAL RESISTANCE

Micro-organisms can degrade certain asphaltic components under ideal conditions (Atlas, 1981). Research into microbial degradation of asphalt can be summarized as follows (Eschrich, 1980; Jones, 1965; Harris, 1958):

- There is no single micro-organism that will oxidize all asphaltic components;

- o Microbial degradation occurs only at the outermost surfaces;
- o The higher the molecular weight of the asphalt component, the more resistant to microbial degradation;
- o Most soil asphalt-oxidizing microbes grow best at pH 6-8;
- o Even under ideal conditions, microbial degradation rates do not exceed 10^{-6} cm/day (0.7 mm penetration per hundred years) and are usually an order of magnitudes less;
- o The rate of anaerobic degradation is much slower than aerobic degradation;
- o Microbial attack is fastest for stream refined bitumens, followed by air-blown and, finally, coal-tar pitches;
- o Microbial inhibitors are ineffective over long time periods; and
- o Environmental factors, e.g., temperature, pH, state of hydrocarbons, nutrient and oxygen concentrations have to be perfect for a very long time to result in any noticeable asphalt degradation.

Overall, microbial degradation will be unimportant for all practical purposes.

PERMEABILITY

Permeability tests were performed on a variety of liners after being subjected to ageing tests (Buelt, 1983). The permeabilities obtained for each liner is presented in Table 1. Permeability results generated as part of this study on five samples of cold-mix EPA incorporating affected soil are presented in Table 2. Accelerated ageing tests of an asphalt liner at 20°C under oxygen partial pressures of 0.21, 1 and 1.7 atm, with continuous exposure as a liner at 20° C under varying oxygen partial pressures to an acidic leachate have been performed (Buelt, 1983). A solution pH of 2.5, 2.0 and 1.5 was designated as normal, intermediate and highly accelerated conditions. Acidity levels were shown to have an unmeasurable effect on asphalt ageing. Permeability was used as a means to measure the immediate effectiveness of the asphalt liner. The permeability appears relatively unaffected under these exposure conditions as shown in Figure 3.

LEACHABILITY

A normal asphaltic concrete or cold-mix EPA paving material is somewhat acceptable as an environmentally safe product even though there may be VOC emissions during manufacture and placement, notably in regards to the hot-mix process. The question of contamination is not frequently associated with asphaltic concrete even though

TABLE 1

Anticipated Field Liner Permeabilities

Liner	Average Final Permeabilities (K, cm/s)	Assumed Field Thickness (L, cm)	Effectiveness Factor (K/L, S^{-1})
Asphalt Concrete	7×10^{-8}	10	7×10^{-9}
Hypalon	2×10^{-10}	0.12	2×10^{-9}
Asphalt Rubber Membrane	4×10^{-6}	0.8	5×10^{-6}
Catalytic Air-blown Membrane	7×10^{-9}	0.9	8×10^{-9}
Sodium Bentonite	1×10^{-7}	10	8×10^{-8}
Saline Seal 100	8×10^{-6}	10	8×10^{-7}
GSR-60	$6x10^{-6}$	10	6×10^{-7}
Soil (as a liner)	1×10^{-5}	10	1×10^{-6}

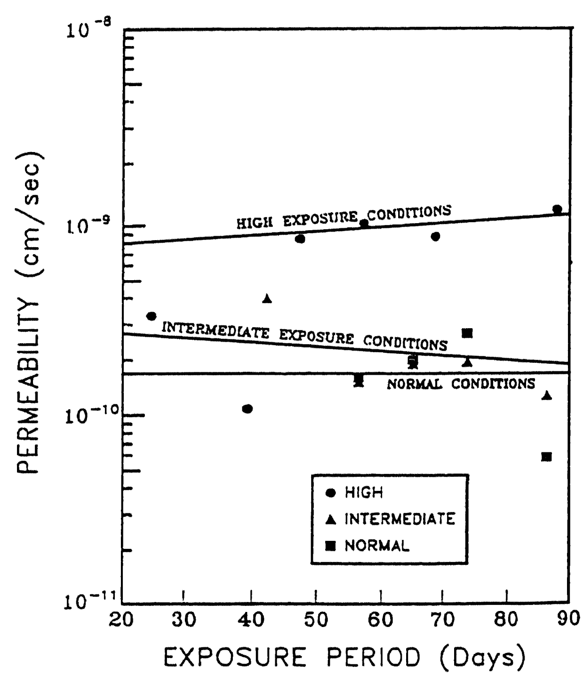

Figure 3: Permeability of an asphalt liner at normal, intermediate, and highly accelerated conditions (after Buelt, 1993)

TABLE 2

Results of Permeability Testing on Cold-Mix EPA

Asphalt Sample No.	Sample Length (cm)	Sample Diameter (cm)	Bulk Volume (cc)	Effective Permeability (millidarcy)	Hydraulic Conductivity (cm/s)
A-B-1	6.02	5.05	120.58	0.135	1.42×10^{-7}
A-B-2	6.81	5.06	136.94	0.013	1.37×10^{-8}
A-B-5	4.87	4.98	94.86	0.034	3.58×10^{-8}
A-B-7	6.42	5.06	129.10	0.096	1.01×10^{-7}
A-B-10	7.52	5.05	150.62	0.142	1.50×10^{-7}

certain halogenated volatile organics may be present in association with hot-mix bituminous products, notably, those containing cut back asphalt utilizing kerosene, diesel or other solvents in their dilution process (Testa et al, 1992c).

Asphalt concrete or cold-mix EPA may be accepted by Class III landfills and is commonly crushed and used as a component for road base material. The fact that there are few questions about the safety of asphaltic concrete is justified by the existence of thousands of miles of paved roadways constructed every year. As well, the performance of leachate tests on asphalt show a definite lack of contaminants that might leach out under extreme conditions. Leachate analytical results for certain petroleum constituents in both hot-and cold-mix asphalt incorporating affected soil is presented in Table 3.

GEOCHEMICAL ASPECTS

The chemical aspects associated with the incorporation of metals-affected soil (and other contaminates) has been extensively studied in regards to pavement properties, leaching behavior, sensitivities to moisture-damage and function group analysis (Conca and Testa, 1992). These studies provide information that can be used to evaluate the stability of metals and other contaminants in soils that have been asphalted. These studies indicate that asphalted contaminated soil will be highly stable and will perform adequately as an end product. For the best chemical performance, the asphalt should have high contents of pyridinic, phenolic and ketone groups, which can be achieved by carefully choosing the source material. If the situation requires special stability or redundancy, small amounts of shale oil and lime can be used as additives. Situations and conditions which favor the presence of inorganic sulfur, monovalent salts and high ionic strength solutions in the asphalt should be avoided because these conditions decrease the chemical stability of the asphalt cement by disruption of the functional group-aggregate bonds and by increasing the overall permeability. However, these conditions are not expected in the anticipated uses of

TABLE 3

Leachate Analysis of Typical Asphaltic Concrete Samples

Parameter	Analytical Method	Concentration	Unit	Detection Limit
<u>Cold-Mix Asphalt (EPA)</u>				
Cyanide, Total	SM412 E/D	ND[(a)]	mg/kg(b)	1
Flash Point	EPA 1010	>220	°F	5
pH	EPA 9045	7.62	±1	.01
Sulfide	EPA 376.1	ND	mg/kg	1
Gasoline	EPA 8015	ND	mg/l(c)	.5
Diesel	EPA 418.1	ND	mg/l	.5
<u>Hot-Mix Asphalt</u>				
Cyanide, Total	SM412 E/D	ND	mg/kg	1
Flash Point	EPA 1020	>220	°F	5
pH	EPA 9085	8.43	±1	.01
Sulfide	EPA 376.1	ND	mg/kg	1
Gasoline	EPA 8015	ND	mg/l	.5
Diesel	EPA 418.1	ND	mg/l	.5

(a) ND = Not detected above the respective detection limit.
(b) mg/kg = Mllligrams per kilogram.
(c) mg/l = Milligrams per liter.

asphalt cement to stabilize contaminants in metals-affected soil using environmentally processed remedial technology.

DISCUSSION OF USE

EPA can at best be describes as user friendly. There currently exists a multitude of uses for cold-mix EPA incorporating affected soil. One of the more viable and creative is keeping contaminated soils out of land fills as a "waste" and placing it in landfills as an "end product" (MRM Partnership, 1988). The imminent closure of many of the nations Class III and municipal landfills creates the potential use of hundreds of thousands of tons of contaminated soils incorporated into asphalt for use as a landfill liner or cap. The cost effectiveness of this method of capping landfills proves very attractive to financially strained municipalities. Prior to the advent of EPA for use as a liner or a cap, clay was the specified material. In addition to environmental concerns associated with mining vast quantities of clay for these uses, the cost of landfill closure had no cost recovery options. By the use of EPA, the municipalities and landfill owners have the capability to charge attractive fees for the acceptance of affected soil. In most cases, this acceptance fee pays for the cost of on-site processing of the affected soil into the asphalt end product. The effectiveness of the cost recovery is obvious as the capping materials production process becomes a profit center. By the use of on-site material not only is the cost of obtaining the clay negated, but transportation costs are eliminated. In essence, the capping process of landfill closure is more affordable, utilizes a product far superior to the traditional clay method and reduces a broad spectrum of environmental concerns by keeping affected soil out of landfills as a waste. Instead it places affected soil as environmentally sound end products such as caps or liners.

Studies of asphalt, clay and other membrane liners subjected to a variety of aging tests in exposure columns under various temperatures, pH conditions, oxygen concentrations and hydrostatic pressures have been discussed (Buelt, 1988). The conclusions were that the asphalt liners and membranes were extremely stable chemically and physically. An ageing period equivalent to 7 years produced penetration of reaction products to only 0.5mm (0.5 percent of the 10 -cm liner thickness). The results showed that if the asphalt content of the liner exceeded about 6 percent, theses liners would perform adequately under impoundment conditions for over 1000 years, conditions which are similar to those expected for cold-mix EPA (Haxo, 1976). Catalytically-blown asphalt was considered the best liner material and was selected for long-term field testing. Field tests of the catalytically-blown asphalt over a 2-year period showed superior performance of the asphalt liners over that of the clay liners. This will be especially true for the petroleum constituents in cold-mix EPA's liner overall, asphalt is a much better liner material for this application than clay.

It's use as a cap or liner is only one example of this methods cost effectiveness and versatility, but what of its more traditional use as a pavement. To best describe "user friendly", one should visualize a typical multi-lane high traffic volume freeway and the load bearing and durability that must be designed into the asphalt product utilized in its construction. Now visualize the typical bicycle path winding it's way through our urban areas. The point being, both the freeway and the bicycle path are asphalt pavements, but the end use of each is drastically different. Cold-mix EPA pavement is certainly nothing new. There are very few, if any, state and county road departments that do not use variations of cold-mix EPA. The end use of asphalt dictates its specifications, or better said, if the asphalt mix will perform it's required function, from freeway to bicycle paths, it is within specifications. In fact, the ASTM procedure for cold-mix asphalt design includes a section which states that the mix must fulfill the requirements of intended application. Recalling the term "user friendly" it becomes apparent that the function of the end product will determine the asphalt mix design.

Pavement for a heavy equipment yard has been constructed from affected soil recovered from leaking underground tanks and utilized in EPA. By producing parking lot pavement for on-site use the generator eliminated the inherent liability of disposing of their contaminated soil in a dump site. Approximately $80.00 per ton is disposal taxes were not required to be paid as the materials was recycled and not disposed of. The pavement produced not only kept the projects pricing below any other option but created a paved parking lot of extremely low permeability to prevent further contamination. The mix design was not the same as that required to construct a freeway, but then a freeway was not the intended use. The intended use was for low traffic volume but extremely high load bearing strength. Another project utilized affected soil from an oil tank spill to pave the loading and unloading facilities at an oil refinery. Again, the affected soil were not disposed of as hazardous waste but were recovered and utilized in a cold mix asphalt pavement to remediate the contaminated soil and prevent further contamination. Again the mix design was consistent with the end use.

Stability (as measured by the Marshall Test) achieved by various mix designs of cold-mix EPA is presented in Table 4. Mix designs utilized for actual applications range from a 95 percent contaminated soil (native silt, sand and gravel contaminated with diesel fuel to 32,000 parts per million total petroleum hydrocarbons) with a 5 percent emulsion to a 5 percent contaminated soil (heavy black clay contaminated with machine cutting oils to 55,000 parts per million total petroleum hydrocarbons) plus 90 percent Class II 3/4-inch minus base rock and 5 percent emulsion. To date EPA has been successfully utilized on projects ranging from road base and road pavement to containment dikes and drain channels. The procedure was to determine the requirements then design the EPA mix to fit the use. As the equipment utilized to produce EPA is portable and certainly not complex, field test batches of 20 tons or more are utilized rather than bench scale tests. In this manner the actual field mix is tested rather than a small hand mixed batch. Bearing ratio for processed EPA for Class II base is presented in Figure 4.

CONCLUSIONS

In consideration of certain factors including durability, chemical resistance and ageing, biological resistance, permeability and leachability, cold-mix EPA is anticipated to perform more than adequately under normal conditions for a long period of time, probably over 1,000 years. The use of EPA as a liner, cap or any number of other site specific applications has vast potential.

TABLE 4
SUMMARY OF MARSHALL TEST RESULTS FOR EPA STABILITY

SAMPLE NUMBER	1	2	3	4	5	6
75/25 BLEND; 3/4" CLASS II BASE, AND CONTAMINATED SOIL						
Asphalt in Emulsion (a)	62-64	62-64	62-64	62-64	62-64	62-64
Residual Asphalt in Mixture(a,b)	5	5	5	6	6	6
Total Mix Water (a)	5.2	5.2	5.2	5.2	5.2	5.2
COMPACTED SPECIMEN DATA (Emulsion in prcent)						
Bulk Density	2.08	2.07	2.11	2.05	2.07	2.05
Weight in Air	1116.1	1125.1	1130.0	1120.1	1122.6	1120.7
Weight in Water	584.4	586.5	599.0	577.2	584.4	577.5
Weight SSD	1120.1	1129.0	1134.1	1124.0	1126.5	1124.9
Thickness	2 5/8"	2 11/16"	2 5/8"	2 11/16"	2 11/16"	2 11/16"
Stability	3100	2350	2800	2450	2250	2200
Adjusted Stability	2880	2090	2600	2180	2000	1960
Flow	30	27.5	31	31	30	24
Average Stability	NT(c)	2520	NT	NT	2050	NT
SAMPLE NUMBER	7	8	9	10		
85/15 BLEND; 3/4" CLASS II BASE,AND CONTAMINATED SOIL						
Residual Asphalt in Mixture(a,b)	6.5	6.5	6.5	6.5		
Bulk Density	2.02	2.02	2.00	2.00		
Stability	3548	NT	3260	NT		
24-Hour Soak	NT	1410	NT	1056		
SAMPLE NUMBER	11	12	13	14		
85/15 BLEND; 3/4" CLASS II BASE, AND CONTAMINATED SOIL						
Residual Asphalt in Mixture (a,b)	6	6	6	6		
Bulk Density	2.01	2.03	2.01	2.03		
Stability	3158	NT	2640	NT		
24-Hour Soak	NT	1577	NT	1201		
Moisture Absorbed	X	X	X			
Maximum Total Voids (a)				X	X	X

(a) In percent
(b) Emulsion
(c) Not tested

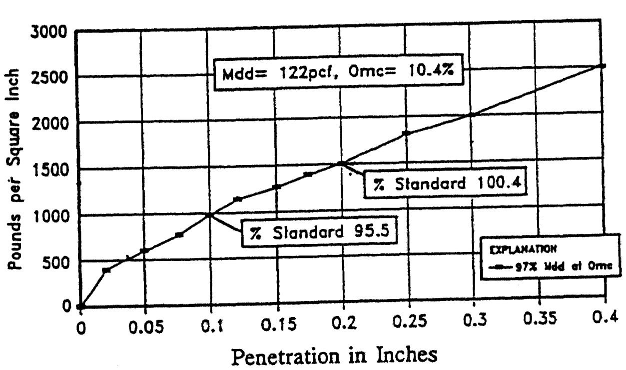

Figure 4: California bearing ratio for Class II base using cold-mix EPA

Hazardous waste clean-up projects become cold-mix asphalt production projects. Contaminated soil becomes a recoverable resource and is within the letter, spirit and intent of current regulations.

Under California regulations for example, Non-RCRA regulated recyclable materials used in a manner such that they are not considered to be "used in a manner constituting disposal" are not subject to the provisions of Health and Safety Codes of the State of California, subsection 25143.2(b). Thus, if the recyclable materials satisfy the conditions of subsection 25143.2, then they are 1) not considered hazardous waste, and 2) are conditionally exempt from the California Department of Health Services hazardous waste regulations. Providing the conditions summarized above are met, permanent fixation of petroleum-contaminated soils via asphalt incorporation is viable, cost-effective soil remediation option which can be accomplished within a relatively short period of time with minimal long-term liability. Furthermore, although highway-type paving materials as a resultant product is limited, multiple secondary markets exist including liners and landfill caps, road base, dust abatement, bank stabilization and paved storage areas, among other uses.

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