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Project Summary

Securing Containerized Hazardous Wastes by Encapsulation with Spray-On/Brush-On Resins

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Methods were investigated for securing containerized hazardous wastes in the field with spray-on or brush-on resins at ambient temperatures. Laboratory-scale, cylindrical specimens of containerized sodium chloride (which simulated soluble salts containing heavy metals) were fabricated 63.5 mm in diameter by 88.9 mm high (2.5 by 3.5 in.). The salt was confined in fiberglass-reinforced, thermosetting resin casings and then sealed with a water-based polyurethane to provide a tough exterior jacket that would protect the contents from leaching and mechanical stress.

The specimens exhibited functional stiffness and kept their contents stable when subject to leaching stresses. The exterior jackets did not fail when specimens were compressed to about 80% of their original heights. Under heavy compression, however, the jackets ruptured where they were thinnest. Several coatings were needed to produce sufficiently thick, tough jackets.

This report is a companion to two other documents on the use of plastics to encapsulate corroding hazardous waste containers: "Securing Containerized Hazardous Wastes with Polyethylene and Fiberglass Encapsulates" (EPA-600/2-81-138) and "Securing Containerized Hazardous Wastes with Welded Polyethylene Encapsulates" (EPA-600/2-81-139).

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Contaminants leaking from corroding 208-L (55-gal) drums of hazardous wastes may harm man and his environment. This laboratory-scale study investigates methods for reinforcing such containers in the field by spraying or brushing onto their surfaces atmospheric-curing, water-based resins. This simple procedure reinforces drums at their disposal site using commercially available, low-cost, commonly used equipment. The use of water-based resins eliminates the hazards and contamination associated with solvents, and processing at atmospheric temperatures has obvious advantages.

Methods and Materials

Cylindrical specimens of containerized sodium chloride (which simulated soluble salts containing heavy metals) were fabricated 63.5 mm in diameter by 88.9 mm high (2.5 by 3.5 in.). The specimens were then encapsulated by spraying first with fiberglass-reinforced thermosetting resins to provide functional stiffness, and then with a water-based polyurethane to provide a tough exterior jacket that would protect the contents from leaching and mechanical stress.

Performance Requirements

Performance requirements for encapsulated specimens were to prevent leaching of their sodium chloride consignments by water and to withstand heavy compression without rupture of their jackets. Retention of the highly soluble sodium chloride was assumed to indicate similar encapsulate performance for soluble heavy-metal-containing salts. We also assumed that specimens compressed heavily without jacket rupture would be able to withstand severe impact. (Although the jacketing resin per se was expected to withstand impact because of its rubber-like qualities, it was subject to additional stresses from distortion of the specimens under compression and fragmentation of the stiff materials.)

The coating materials were required to spread and cure on the container surfaces and, with further processing (e.g., post heating), to give rise to monolithic, tough, chemically stable encapsulates. The encapsulates were expected to hold the hazardous consignments securely when subjected to mechanical and chemical stresses associated with sequestering them in disposal sites. Such stresses could include (1) impact and compression during transit, (2) tear and overburden resulting from depositing and processing at the ultimate disposal sites, (3) disposal site leachates, and (4) corrosive action of hazardous consignments.

Structuring encapsulates to withstand impact and compression stresses was particularly difficult. According to DOT guidelines, containers geared for transporting hazardous wastes must withstand the test of dropping on edge without rupture. Since a 208-L (55-gal) drum and its contents weigh about 226.8 kg (500 lb), such a test would inflict severe tensile and flexural stresses on the encapsulates, thus requiring the use of tough, flexible materials for container fabrication. Furthermore, encapsulates must be composed of stiff materials to withstand compression stresses resulting from the stacking of heavy objects. Other stresses were less difficult to deal with. Pressures exerted by landfill overburdens were not particularly severe when encapsulates were deposited deeply enough for the soil to act as a fluid. Encapsulate resistance to chemical degradation did not need to be characterized in detail because it could be estimated by data from resin vendors and performance data provided in the chemical literature. Permeability resistance data were not readily available for resins that were not mass produced, and thus some determinations were required.

Materials

No material was currently available for encapsulate fabrication that could provide impact and compression resistance as well as chemical stability with spray-on and brush-on techniques. Metals and ceramics were obviously ruled out. Resins, on the other hand, gave rise to difficult problems: impact resistance was usually gained at the expense of stiffness, and toughness was related to processing parameters. Unfortunately, state-of-the-art resins used in spray-on and brush-on applications were, as a class, weak materials. Production of stronger materials required the use of newly developed resins.

A literature review subsequently disclosed a promising and novel generation of atmospheric-temperature-curing polyurethanes free of the deficiencies of those considered earlier. Four coating formulations were subsequently selected as potential candidates for jacket studies. The coating finally chosen for detailed studies was Neorez R-960* cross-linked with CX-100. This coating had strong mechanical and chemical properties, was workable, and was generally easy to process.

Although the water-based polyurethanes exhibited appropriate toughness and flexibility to withstand impact stresses, they did not possess the stiffness required for container encapsulates. Toughness and stiffness were realized by fabrication of composite structures that provided properties not found in a single material. In this work, fiberglass-reinforced epoxides were used to provide encapsulates with required functional stiffness. Furthermore, they could be sprayed onto substrates using commercial techniques.

Procedures

During the encapsulation of containers, the stiff materials were first sprayed onto the container walls. Because stiffness only was required, there was no need to realize the watertight structures that are sought in plastics fabricating. Sealing of the fiberglass-treated containers would be effected by spraying water-based polyurethane resin onto the stiff materials. The essential features of the spray-up procedure and the encapsulate are illustrated in Figure 1.

In addition to sealing the encapsulates, the polyurethane resin was expected to provide them with impact resistance. (Structuring stiff materials per se to withstand severe impact stresses without fracture would be prohibitive in terms of material and processing costs. Consequently, the stiff materials would provide functional stiffness and impact resistance only under normal handling conditions; but under severe stresses, they were expected to fracture.) The hazardous contents were expected to remain secure as a result of the presence of the tough sealing resin. Even with fracture, the encapsulates were expected to exhibit sufficient residual stiffness to allow manipulation to and deposition within a direct disposal site.

Results and Discussion

The criteria for estimating suitable performance of encapsulates under field conditions was the satisfactory performance of the test specimens under heavy compression. The sealing resin had to exhibit the property of withstanding the stresses without rupture stemming from the fracture of the stiff materials. Such performance would indicate that the sealing resin would secure the hazardous consignments in the event that the encapsulates were subjected to severe impact stresses.

The specimens exhibited functional stiffness and kept their contents stable when subjected to leaching stresses. The exterior jackets did not fail when specimens were compressed to about 80% of their original heights. Under heavy compression, however, the outer polyurethane jackets ruptured where they were thinnest.

The results of this work led to the realization of several attractive features and disadvantages of the process.

The principal advantages of the process are:

- No need exists for applied thermal energy, as with thermoplastics and thermosets.

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Environmental Protection Agency.

- State-of-the-art spray-on equipment may be used for resin application.
- The process offers a method for managing distorted 208-L (55-gal) drums. This advantage may adversely affect subsequent handling techniques, however.
- No need exists for heavy-duty or high-tolerance equipment.
- The technique is generally applicable without tailoring the process to waste type (wet or dry).

The main disadvantages of the process are:

- Use of a special, higher-priced, marginally characterized resin is required.
- Special safety equipment must be used by personnel during formulation/fabrication because of the toxicity of the cross-linker.
- Formation of thick coatings requires multiple applications.
- Coatings require longer curing times at lower atmospheric temperatures.

Of the disadvantages listed, the overriding limitation affecting feasibility is the inability to achieve sufficiently thick, tough coatings with one or a few applications. A minimal number of applications is desirable to reduce manhour requirements.

Mitigation of this deficiency would require modification of the advanced resin formulation, which would inherently define several new areas of concern:

- Identification of one or more additives (possibly thixotropic) that would enhance thicker coatings and not hinder curing.
- Identification of a compatible pigmentation system (thixotropic agent and pigment might be a single component).
- Demonstration that the altered formulation is manageable with state-of-the-art spray-on equipment.
- Demonstration that the altered formulation does not degrade coating properties or encapsulate performance.

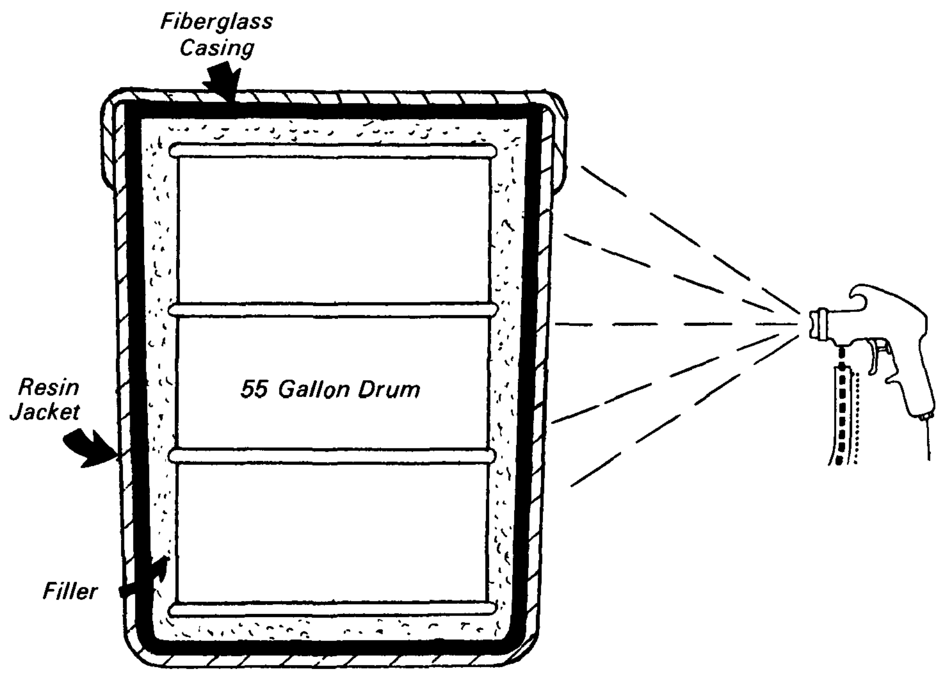

Figure 1. *Management of containerized wastes by spray-up with organic resins. (Note: Fiberglass and resin thicknesses not to scale.)*

Conclusions

Encapsulates of containers holding hazardous wastes can be fabricated under atmospheric conditions using the resins tested here and of brushing or spraying materials onto the surfaces of containers. The watertight encapsulate materials studied here are considered to be unique because they are stiff but retain their watertight properties when distorted by compression. Generally, only metals and thermoplastics yield such properties. But metals are prone to corrosion, and thermoplastics lack comparable stiffness unless thickly applied.

The use of fiberglass-reinforced resins (epoxides) and water-based polyurethane resins gives rise to room-temperature-cured encapsulates that keep their water-soluble salt consignments stable under aqueous leaching conditions. The application of the polyurethanes to the surfaces of fiberglass/epoxide substrates effectively seals porosity existing in the substrates. Consequently, watertight, double-walled composites are obtained, with the outer wall acting as a jacket for the encapsulates.

The polyurethane resins that exhibit best performance are those containing chemical cross-linking agents. The curing of the polyurethane resins on surfaces of preformed glass/epoxides yield double-wall composites showing excellent resistance to hydrolysis. Thereby the sealing effect of the polyurethane jackets is assured. Since the polyurethane resin per se was not expected to transpire salt, this work showed that the high retention performance of encapsulates with double-walled composites is because of wetting and sealing by water-based polyurethane resin in fiberglass/epoxide substrates and the forming of hydrolytically stable bonds between the applied resins and the substrates.

The fiberglass/epoxide substrates give expected stiffness to encapsulates. With compression of the encapsulates, the substrates yield, as expected, by fracture. The encapsulate load-bearing properties under heavy compression were because of residual strengths of the fractured substrates and the existence of the polyurethane jackets.

The jackets do not show satisfactory performance under heavy encapsulate compression (i.e., greater than 20%). Rupture of the jackets was the observed mode of jacket failure. To be sure that full-scale encapsulates would satisfy DOT guidelines concerning transportation of containerized hazardous wastes, it was assumed that the jackets should remain functional under very heavy (at least 80%) encapsulate compression. Thus the present development of this work does not assure realization of full-

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scale encapsulates that would comply with DOT regulations.

This study does, however, provide means for securing the contents of hazardous-waste-containing, corroding containers at the site of their disposition. Containers threatening to lose their contents can be reinforced on the spot by simple means. The entire container or the greatly corroded areas can be effectively treated by applying fiberglass/epoxide to the surface (glass mat applied to container, then wetted by epoxide spray would be desirable) followed by application of water-based polyurethane resin.

The conclusions reached by this study are as follows:

- Encapsulate fabrication is readily realized under atmospheric conditions using simple means (e.g., spraying and/or brushing on resins and using fiberglass, possibly either as mat or as sprayable, chopped fibers).
- High performance retention of heavy metal salts can be expected based on results of water leaching of encapsulates holding sodium chloride as a waste simulant.
- Thicker jackets must be realized for assuring compliance with DOT guidelines.

Recommendations

Advancement of this work requires bench-scale development to achieve thick coatings with one or two applications at most. This additional work would be necessary to fabricate encapsulates of 208-L (55-gal) drums of hazardous wastes that can meet DOT guidelines for containers used to transport hazardous materials.

The present status of the work permits ready refinement for application to the sealing of 208-L (55-gal) drums of hazardous materials that have undergone appreciable corrosion. This operation would secure the contaminants until provision is made for their final disposition.

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The complete report, entitled "Securing Containerized Hazardous Wastes by Encapsulation with Spray-On/Brush-On Resins," (Order No. PB 81-231 284; Cost: $8.00, subject to change) will be available only from:
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