PROPERTIES OF A COMPOSITE POLYETHYLENE FIBERGLASS REINFORCED PLASTIC HIGH INTEGRITY CONTAINER FOR THE DISPOSAL OF LOW LEVEL RADIOACTIVE WASTE

Homer Lowenberg
Lowenberg Associates, Inc.
Rockville, Maryland 20852

Mark D. Shaw
Bondico, Inc.
Jacksonville, Florida 32206

ABSTRACT

Bondico, who has been making composite PE/FRP containers for hazardous wastes, has developed a HIC for handling, transportation and disposal of radwastes. To qualify this HIC for NRC acceptance, Bondico has extensively tested the composite material and full size prototype HICs in accordance with the requirements of NRC, DOT and the states containing commercial burial grounds.

The materials testing program, carried out by an independent testing laboratory, determined the baseline physical properties of the composite material and then compared them with similar properties after exposure to NRC's suggested environmental conditions for HICs. The composite was found to be an order of magnitude stronger than normal polyethylene. Properties after environmental exposures are significantly above the baseline lower control limit design values and thus meet NRC criteria for design considerations.

The prototype testing program, carried out by Bondico, convincingly demonstrated that the HICs can maintain their structural integrity under all the proposed conditions of handling, transportation and disposal. Further the HICs showed that they could withstand the maximum burial conditions with a safety factor of 2 or more.

INTRODUCTION

Bondico, Inc. has been making a variety of containers for the handling, transportation and storage of hazardous wastes from a composite material composed of an inner liner of polyethylene (PE) bonded to an outer casing of fiberglass reinforced plastic (FRP). These containers have received DOT certification as overpacks for leaking or damaged containers or as direct packaging for some quantities of toxic materials, e.g. PCBs, doxins, corrosives, etc. In addition they have been qualified under DOT regulations as 7A Type A packaging for radioactive materials. Further, EPA has approved their use for storage or disposal of PCBs, etc.

Bondico has initiated a long range multiphase program to develop a family of high integrity containers (HIC) of a similar design for the handling, transportation, storage and disposal of low level radioactive wastes. The initial phase of the program has been focused on the development of a 7 cubic foot HIC for specialized nuclear wastes as shown in Fig. 1. This will be followed by later phases that will be directed at other HICs including 150-200 cubic foot units which are used for handling bulk nuclear reactor wastes. Only the first phase of the overall program will be discussed in this presentation.

In order to qualify this composite material for use in HIC construction, an extensive materials testing program (covering physical and environmental properties) has been carried out by the Southwest Research Institute (SwRI) on about 700 specimens. This program was modeled to specifically address the HIC concerns of NRC's branch technical position (BTP) of May 1983 (1) that the NRC staff utilizes to implement the requirements of 10 CFR Part 61 (2).

The materials testing program was divided into two overall sections covering: (1) Baseline Physical Properties, and (2) Physical Properties after Environmental Exposures. The section covering Baseline Physical Properties included determination of: tensile, compressive and bond shear strength; creep characteristics; thermal expansion; and hardness. The section covering Physical Properties after Environmental Exposures included tests following: thermal cycling; gamma and ultraviolet radiation; fungi and bacterial degradation; and external and internal chemicals.

In addition to meet the prototype testing requirements of the NRC BTP, production HIC-7s were fabricated, loaded with simulated wastes, sealed and then tested to the NRC, DOT and state criteria. This comprehensive prototype testing program included tests for: compression, external hydrostatic pressure, internal air tightness, penetration, transportation vibration, free drops, passive venting, and lifting deceleration.

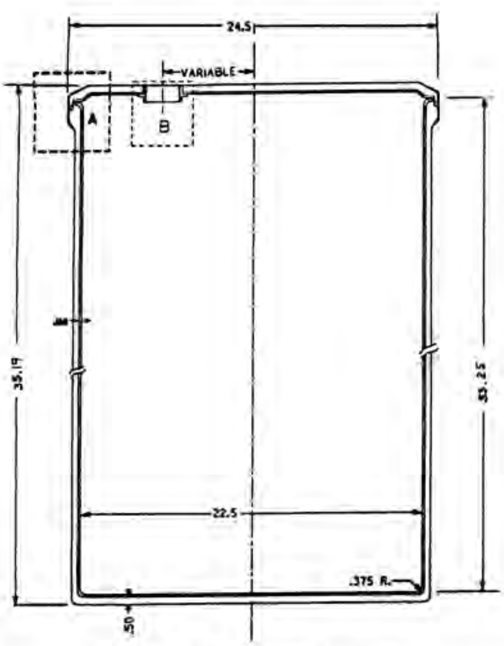

Fig. 1. Elevation of HIC-7.

TABLE I

Baseline Mechanical Strength of Bondico PE/FRP Composite Material

	Tensile Properties, psi.	Compressive Properties, psi.	PE/FRP Bond Shear, psi.
Average Strength	38,200	39,200	331
Upper Control Limit	48,600	51,500	523
Lower Control Limit	27,800	26,900	139
Average Modulus	2,330,000	2,360,000	---

Poisson's Ratio - 0.128

BASELINE PHYSICAL PROPERTIES

Mechanical Strengths

One hundred specimens were used for each strength determination in accordance with ASTM procedures (3,4,5). The database from these tests was analyzed to obtain the following information: average strength; standard deviation; upper and lower control limits; histogram of strengths; control chart of individuals; and empirical distribution function. A summary of the key baseline mechanical strength data is presented in Table I.

Thus this composite material is about an order of magnitude stronger in tension than normal polyethylene.

Creep Characteristics

Since no creep of the composite material in tension is expected due to the glass fibers, a very demanding flexural test of this material similar to ASTM procedures (6) was carried out. The tests were run for 3000 hrs. without encountering either failure or tertiary creep. Thus it is clear that this material will not encounter creep under burial conditions.

Thermal Expansion

Thermal expansion properties of FRP material were determined and were found to lie between the coefficients of thermal expansion of glass fibers (3 X 10-6/oF) and of polyester resin (30 X 10-6/oF). The average coefficient of thermal expansion of FRP was determined to be 10.7 X 10-6/^{o}F.

Hardness

The hardness of PE material was judged by the testing laboratory to be the most appropriate measure of its resistance to chemical attack. Accordingly the hardness of unexposed PE specimens was measured for baseline purposes in accordance with ASTM procedures (7) using the Shore Durometer on scale D-2. The hardness values for the 162 tests performed ranged from 58 to 64.

PHYSICAL PROPERTIES AFTER ENVIRONMENTAL EXPOSURE

A summary of the average strength properties of the Bondico composite PE/FRP material after exposure to the environments suggested by the NRC BTP is presented in Table II. For ease of comparison, the comparable baseline values are included at the bottom of the table. The table is followed by a brief explanation of each of the exposure tests and the related results.

Thermal Cycling

Specimens of composite material were exposed to thermal cycling by ASTM procedures (8) as suggested by NRC. The average mechanical and bond strengths after 10, 20 and 30 thermal cycles are within 10% of the average baseline values and significantly exceed the lower control limit values. Thus these temperature variations had essentially no deleterious effect on the FRP strength or the bond between the PE and FRP.

TABLE II

Bondico Composite PE/FRP Material Properties After Environmental Exposure

Exposure	Tensile Str., psi.	Comp. Str., psi.	Bond Shear, psi.	Hardness Range, Shore, D-2
Thermal Cycling	38,400	35,200	313	---
Gamma Radiation	38,500	38,400	275	---
Ultraviolet Light	39,000	40,000	364	---
Biodegradation,				
Fungi & Bacteria	37,700	37,400	359	---
Chemical Resistance				
Exterior	36,900	31,200	285	---
Interior	---	---	---	59-65
Baseline, Average	38,200	39,200	331	58-64
Baseline, LCL	27,800	26,900	139	---

Gamma Radiation

Composite material specimens were exposed to 100 Mrad of gamma radiation. The average strengths of the FRP material after exposure to this environment were essentially the same as the comparable baseline values but greatly exceeded the lower control limits. The bond strength was reduced by about 17%, but significantly exceeded the lower control limit. Thus this maximum radiation exposure had little significant effect on HIC structural integrity.

Ultraviolet Light

After 3000 hrs. of exposure to this environment, the mechanical strengths exceeded the baseline average values and were significantly greater than the lower control limits. This environment had no effect on the composite material.

Biodegradation

Composite material specimens were exposed to the effects of fungi and bacteria in accordance with NRC recommended ASTM procedures (9, 10). There were no visible signs of attack from either media. The average mechanical strengths were slightly decreased (1-5%) from the baseline averages, but they were much higher than the baseline lower control limits. The average bond strength was increased over the baseline average by 8% and thus was considerably greater than the baseline lower control limit. The small effects of this environment should have no observable effect on the design properties of the composite material.

Chemical Resistance

After exposure by ASTM procedures (11) to eight classes of chemicals at concentrations greater than would be encountered in burial trenches, FRP material average mechanical strengths were decreased by 3-20%, but ranged from 16-32% greater than the baseline lower control limits. The average bond strength was 14% less than the baseline average, but exceeded the lower control limit by over 100%

PE specimens were exposed by ASTM procedures to eight classes of chemicals that might be in low level radioactive wastes. The hardness of the exposed specimens was essentially the same as the baseline values.

While there was some effect on FRP mechanical properties from exterior chemicals, the average strength exceeded the design values, the lower control limit, by a minimum of 16%. The PE material was essentially unaffected by the chemicals expected in low level radioactive wastes.

Summary

Thus the Bondico HIC composite PE/FRP material has been extensively tested to determine its baseline physical properties and its comparable properties after all the environmental exposures suggested by NRC's BTP for implementation of 10 CFR Part 61. The composite material has outstanding physical properties more than one order of magnitude greater than plain polyethylene. Further these properties have been shown to be maintained to levels well above the lower control limits, which are used as the design values of the material, even after exposure of the composite material to all the environments considered of importance to HIC performance.

PROTOTYPE TESTING

An extensive series of prototype HIC-7 tests has been performed by Bondico. In each test, multiple production fabricated HICs were used. The HICs were filled with appropriate simulated loose wastes, sealed in accordance with Bondico's standard sealing procedure and checked for HIC integrity prior to test performance using a solid bung plug and an air tightness test. The series of tests included the following conditions:

- DOT and NRC Type A Package Tests (12)

Free Drop on Unyielding Surface

Reduced External Pressure

Increased External Pressure

Transportation Vibration

Compression

Penetration

- State Free Drop Tests on Compacted Soil
- NRC Lift Test
- Burial Pressure Simulation, External Hydrostatic Pressure

In addition to those full prototype HIC tests, full size prototype passive vents were tested for air and water flow under simulated burial conditions.

Free Drop on Unyielding Surface

Sealed HIC-7s with full loads of simulated loose wastes were dropped on a concrete surface from a 4 ft. height in three orientations. The tested drop positions included impacts on the top and bottom corners and the full side. All prototypes dropped on the side showed no effect from the drop. In some cases, the prototypes dropped on the corners showed slight air leakage. However these units showed no water or simulated waste leakage after 24 hr. storage in a position most likely to indicate any loss of contents. Thus the HICs showed no loss of integrity following this drop test.

Reduced External Pressure

The reduced external pressure requirement of 3.5 psia is equivalent to an increased internal pressure of 11.2 psig. Accordingly sealed and loaded HIC-7's were pressurized internally by air to this internal pressure and maintained this pressure differential for 5 min. with no signs of leakage or other effects.

Increased External Pressure

The increased external pressure requirement of 20 psia is equivalent to a reduced internal pressure of minus 5.3 psig. Accordingly sealed HIC-7s loaded with loose simulated wastes were subjected to a vacuum that reduced the internal pressure to about minus 6 psig. This vacuum was maintained for 5 min. with no signs of leakage or other effects.

Transportation Vibration

Sealed HIC-7s, loaded with a minimum amount of loose simulated waste were placed in a closed trailer truck. The HICs were not fastened to the truck bed in any manner and they were transported over normal road conditions for 66 hrs. After this transportation they were all unaffected and showed no signs of leakage to internal air pressure.

Compression

The same HICs exposed to the transportation vibration test were then subjected to a 5000 lb. compression test on a special compression test machine. In all cases the HICs showed no measurable deflection or damage during the test and after test completion they continued to maintain their leak tightness to an internal pressure check.

Penetration

Sealed HIC-7s were subjected to the drop of a 13 lb. round steel bar from a 40 in. height in the following locations: center of body bottom, center of body sidewall, center of lid, location of electrical wire penetrations in lid, passive vent in bung plug. In all cases when a solid bung plug was used the leak tightness of the HICs was unaffected by the penetration test. In the cases using a vented bung plug, the bung plug and passive vent were unaffected by the blow of the penetrator rod. Thus the penetration test had no effects on the HICs in any position.

State Free Drop Tests on Compacted Soil

The states of South Carolina and Washington require free drop tests of HICs from a 25 ft. height on compacted soil in numerous orientations. To meet these requirements, sealed and loaded HICs were tested in the following orientations: full top, top corner, full bottom, bottom corner, and full side. After each test, the HICs were checked for air tightness without any signs of leakage evident. Thus the HIC-7 has been shown to meet the state free drop tests in all orientations.

NRC Lift Test

NRC requires that HICs be subjected to a 3g. lift test. To simulate this requirement, loaded and sealed HICs were lifted while supporting a weight of twice their own loaded weight. In all cases, this test had no effect on the HIC or its leak tightness.

Burial Pressure Simulation External Hydrostatic Pressure Test

NRC requires that HICs be tested to demonstrate their ability to withstand proposed disposal conditions. Bondico proposes to use its HICs under the maximum burial conditions for commercial waste disposal in the U.S. at a depth of 55 ft. The pressure equivalent to burial at that depth is about 46 psig. To demonstrate the outstanding structural stability of its HICs, Bondico exposed them to an external hydrostatic pressure of about 100 psig using solid bung plugs. Under these most demanding conditions, the HICs easily withstood the 46 psig pressure level and the pressure was increased. The HICs finally failed structurally at 92-106 psig by vertical cracking of the FRP side walls. This shows that the HIC-7 can meet design burial conditions with a safety factor of 2 or greater which is consistent with NRC staff objectives as stated in recent criteria (13). In addition to meeting this structural integrity objective, the HICs after failure to external pressure, were retested to internal pressure and the inner PE liner was shown to be airtight to as much as 11 psig (the Type A package internal pressure requirement).

Passive Vent Testing

Full size passive vents, of porous polymeric material, mounted in bung plugs were tested in a special test fixture for the flow of air and water under simulated burial conditions. The passive vent permitted the flow of gases at a sufficient rate to prevent the internal pressurization of the HIC. Further the passive vent minimized the flow of water into the HIC and also limited any movement of contained radwaste out of the HIC.

SUMMARY

Multiple prototype HICs have been tested to demonstrate their performance under conditions of handling, transportation (Type A packages) and disposal. In all cases the HIC-7s have clearly demonstrated their ability to maintain waste containment integrity under all the proposed conditions. In addition, for the demanding maximum burial conditions they have shown the capability to handle that condition with a safety factor of two or more and even after outer layer structural failure have demonstrated inner layer waste containment integrity.

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