PRELIMINARY INVESTIGATION ON THE SUITABILITY OF USING
FIBER REINFORCED CONCRETE IN THE CONSTRUCTION OF
A HAZARDOUS WASTE DISPOSAL VESSEL

by

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INTRODUCTION

There are certain hazardous wastes that must be contained in an extremely secure vessel for transportation and disposal. The vessel, among other things, must be able to withstand relatively large impacts without rupturing. Such containment vessels therefore must be able to absorb substantial amounts of energy during an impact and still perform their function. One of the impacts that the vessel must withstand is a 30-foot fall onto an unyielding surface. For some disposal scenarios it is proposed to encase the waste in a steel enclosure which is to be surrounded by a thick layer of concrete which, in turn, is encased by a relatively thin steel shell.

Tests on concrete in compression and flexure, including static, dynamic and impact tests, have shown that low modulus concretes tend to behave in a less brittle manner than higher modulus concretes. Tests also show that fiber reinforced concretes have significantly greater ductility, crack propagation resistance and toughness than conventional concretes. Since it is known that concrete is a reasonably brittle material, it is necessary to do impact tests on sample containment structures consisting of a thin-walled metal containers having closed ends which are filled with concrete, grout, or fiber reinforced concrete. This report presents the results of simple tests aimed at observing the behavior of sample containment structures subjected to impacts due to a fall from 30 feet.

IMPACT TEST PROCEDURE

In actual usage the containment vessels can be as large as 43 ft long by 18 ft in diameter. Much smaller and simpler vessels were used in this project so that many variables could be tried and the impact tests could be conducted in an easy manner. Both

12-oz aluminum beverage cans and one-gallon paint cans were filled with the various concretes and dropped 30 feet onto two one-inch thick steel plates.

The cans were dropped from a wooden frame constructed on top of the roof of the laboratory. The frame had a small shelf attached so that cans could be rolled off to produce side drop impacts. This worked most of the time. End drop impacts were to be achieved by merely holding the can by its top and releasing it. With practice one was able to achieve end drops but the cans tended to tumble and provide us with quite a few corner drops. Figure 1 shows a drop test in progress.

A video camera was used to record the falling cans and, with the aid of a measuring pole placed in the background of the landing area, an attempt was made to measure the height of rebound. It was found that most cans did not rebound sufficiently to permit meaningful measurements to be taken so further attempts at measuring rebound were eliminated.

PRELIMINARY SPECIMENS AND TESTS

To simply look at the problems of constructing, dropping, and evaluating the behavior of the small concrete filled specimens, preliminary tests were done using 30 12-oz aluminum beverage cans filled with five variations of concrete. Table 1 presents a summary of these specimens. Generally, there were six specimens in each of the five groups. A local sand was used for the mortar and the fiber reinforced specimens. The same sand was used for the grout specimens in addition to fly ash. All specimens were made with Type III cement (high early strength) to allow testing two weeks later. All curing was done in a curing room having a temperature of about 72° F and 90% humidity.

It was anticipated that fiber reinforced concrete would be a likely filler material, therefore specimens were made using 1-in long by 0.01-in diameter steel fibers (volume fraction = 2%) and 3/4-in long polypropylene fibers (volume fraction = 1/2%).

FIGURE 1.
Drop test in progress

TABLE 1. Specimens used for preliminary tests. Containers were 12-oz aluminum beverage cans.

	Number of specimens	Mix Design†	Compressive strength (psi)
mortar I	6	Mix 1	3200
mortar II	6	Mix 2	2500
steel fiber reinf. mort	6	Mix 1*	5200
polypropylene fiber reinf. mort.	6	Mix 1**	3500
grout	6	Mix 3	1900

Notes:

* Includes 2% by volume of 1" x 0.01" steel fibers.

** Includes 1/2% by volume of polypropylene fibers.

† See Table 1a

TABLE 1a. Mix proportions for preliminary specimens made with aluminum beverage cans.

	Cement (parts)	Sand (parts)	Fly Ash (parts)	Water/cement ratio
Mix 1	1.0	2.45	0.0	0.55
Mix 2	1.0	4.90	0.0	0.55
Mix 3	1.0	1.92	0.0	0.85

All mixes contained 1 fl. oz/ 15 lb cement of pozzolith 322N admixture.

The aluminum beverage can was slightly modified by enlarging the opening to 1-in diameter to allow for the placement of the concrete.

Twenty of the specimens were dropped and we obtained end, side and corner impacts. Damage to the aluminum can was most severe in the case of the corner impacts. Several dropped specimens were sawn longitudinally and inspected for internal damage. In general we found the cracking to be rather localized in the region of impact and that vast internal cracking was not generally observed particularly in the grout specimens. For this reason it was determined that future tests would emphasize the behavior of grout or mortar specimens with lesser attention given to fiber concrete samples. Although it is known that fiber reinforced concretes have excellent impact resistance, it appeared that such impact resistance was not necessary in this instance.

As a result of these preliminary tests it was decided that future tests would be done using a larger can that was made of steel. Additionally, it was necessary to prepare a grout filled insert to represent the mass of the hazardous waste of the actual containment vessel.

FILLED PAINT CAN SPECIMENS AND TESTS

A second group of specimens were tested using one-gallon paint cans as the containment vessel. These were used to work out the details of fabricating specimens containing an insert and to develop a proper dropping technique. Paint cans were chosen because they were easily obtainable from a can manufacturer and could easily be filled simply with the concrete and the insert. A total of 40 specimens were prepared; 20 filled with a grout mixture and 20 filled with a sand based mortar. The ingredients used for the mixes is shown in Table 2. The grout was based on a mix contained in UNC Industries Report to C. K. Chou of Lawrence Livermore National Laboratory, May, 1987, Procedure No. 99Z, Attachment "A", pg. 8 with the exception of the water/cement ratio.

TABLE 2. Mix design and compressive strength for the first group of one-gallon paint can specimens

	Grout (parts)	Mortar (parts)
cement	1.0	1.0
sand	1.82	2.45
fly ash	1.0	0.0
water/cement ratio	0.60	0.55
compressive strength (psi)	3700	6900

Notes:

- 1) All sand air dried and sifted to use all that passed a #40 sieve
- 2) All mixes contained 1 fl. oz/15 lb cement of pozzolith 322N admixture.

The sand used in the grout mix was sifted and only that which passed the #40 sieve was used.

All specimens had a steel insert filled with mortar placed in the center of the paint can to simulate the payload. Figure 2 shows a sketch of the specimen containing the insert. The insert was made from 3-in inside diameter steel pipe which was cut to 4.38-in lengths. Circular top and bottom pieces, 0.25 in thick, were cut to fit the inside diameter of the pipe. The bottom piece was welded to the pipe and three 8 penny nails were welded perpendicular to the bottom of the plate. The nails were needed to support the insert 1.56" from the bottom of the paint can. In this stage, the insert looked like a cup supported by three legs. The insert was then filled with the mortar, fitted with the top plate flush to the top of the pipe, and welded in place.

After the inserts were prepared, the mortar or grout to be used to fill the paint can was mixed. The can was filled about half full and then the insert was firmly pressed into place making sure the small legs, welded to the bottom of the insert, touched the bottom of the can. The remainder of the mortar/grout was placed in the can and lightly consolidated by placing an immersion type vibrator on the outside of the can. The cans were fitted with lids, which had a 1-inch diameter hole drilled at the center to allow the excess mortar/grout to exit. The hole was subsequently covered with tape to prevent moisture from escaping during the curing period. The specimens were stored in the main part of the laboratory until tested. Prior to testing, the lid was welded to the body of the can so it would not pop off during the drop tests.

The drop technique was the same used on the aluminum beverage cans. It was found that if one used proper care either end drops, side drops, or corner drops could be obtained as required.

A third set of specimens was made with one-gallon paint cans exclusively using a grout mixture. Three groups of ten specimens were prepared where half of each group was

FIGURE 2.
Sketch of one-gallon paint can specimens

made with medium strength mortar while the other half was made with low strength mortar. The grout in one group was reinforced with a one percent volume fraction of the 3/4-in long polypropylene fibers used in the aluminum beverage can tests. Additionally, one group did not contain the insert while the other two groups did. Table 3 shows the mix design used for these specimens. The lower strength grout mix without the fibers was similar to a mix that was to be used in an actual hazardous waste disposal project.

The specimens were subjected to end, side and corner drops as before. In addition, however, selected ones were dropped so they would land on their side on the edge of a steel angle section. The drop onto the edge of the steel angle was done to observe what would happen when the containment vessel landed on some sort of sharp edge. Several untested paint can specimens from the second set were also side dropped onto the angle section.

RESULTS

With the exception of drops onto the edge of the steel angle, the corner drops produced the most damage to the outer containment vessel (paint can). In some instances the can was ruptured as shown in Fig. 3. The damage to the containment vessel was more severe for the specimens made with higher strength grout/mortar than for the specimens made with the lower strength grout/mortar. Some specimens were sawn longitudinally to inspect for damage to the filler material. It was found that the cracks were generally of a local nature (see Fig. 4). This was true for both the high and the low strength mortar/grout.

When the cans landed on the side the damage to the containment vessel was about the same for both the higher and low strengths mortar/grout. Figure 5 shows typical damage to the containment vessel for both strengths of mortar/grout. The internal damage to the filler material was more severe for the side drops than for either the end or corner

TABLE 3. Mix design and compressive strength for the second group of one-gallon paint can specimens

	Grout				Fiber reinforced grout with insert	
	with insert		without insert			
cement†	1.0		1.0		1.0	
fly ash	1.0		1.0		1.0	
sand	1.66		1.82		1.66	
water-cement ratio	0.77	1.0	0.77	1.0	0.77	1.0
14-day compr. strength (psi)	4600	2000	4200	1800	3500	2000

Note:

- 1) Sand was air-dried and sifted to use all that passed a #40 sieve.
- 2) † -- Mix design proportions are specified in relative parts.

FIGURE 3.
Damage from a corner drop

FIGURE 4.

Longitudinal section showing the local
damage sustained from a corner drop

a) Medium strength grout

b) Low strength grout

FIGURE 5.

Results of side drops for different
strength filler materials

drops. This was seen when some of the grout specimens that did not contain an insert were sawn longitudinally.

The longitudinal section showed that there was considerable shrinkage of the filler material so that it was not in contact with the top surface of the can. This no doubt had a significant effect on the behavior of the specimen at impact because the filler material was essentially unconfined. It is well known that the toughness of confined concrete is substantially better than the toughness of unconfined concrete.

The fiber concrete specimens behaved very much like the mortar/grout specimens for the end, corner and side drops.

When the specimens were dropped onto the edge of the steel angle the can was ruptured and there was a large wedge shaped depression deep into the concrete. The mortar/grout specimens that did not contain an insert showed a single large crack which extended nearly through the entire width of the can (Fig. 6). The specimens containing an insert showed that the crack extended only as deep as the insert (Fig. 7). The fiber reinforced concrete specimens fared much better as indicated by a considerably smaller crack (Fig. 8).

CONCLUDING REMARKS

The tests described were all of a preliminary nature and designed to take a simple look at the behavior of various concrete-like filler materials confined in a metal containment vessel and subjected to the impacts of a fall. It was found that there was considerable damage to both the containment vessel and the adjacent filler material at the point of impact but that the anticipated severe cracking throughout the filler material was not observed. It was initially thought that the impacts might cause the interior filler material to become completely rubblized. It was also found that upon impact the lower modulus filler materials

FIGURE 6.

Damage to a grout filled post can not
containing an insert after a fall
onto the edge of a steel angle

FIGURE 7.

Damage to grout filled joint containing an insert after a fall onto the edge of a steel angle

FIGURE 8.

Damage to a paint can filled with fiber
reinforced grout and an insert after a fall onto
the edge of a steel angle

tended to flow more than the higher modulus filler materials which in turn tended to diminish the likelihood of rupture of the present containers.

The drop test used here was only an expedient way to consider the effects of the impact. It was difficult to obtain identical impacts for the various specimens of a set because of the dropping motion employed. In the future it will be better to develop an impact device to deliver the blow to the specimen. The specimen could be placed at a particular orientation relative to the impact hammer to achieve the effect of side, end or corner drops. The head of the impact hammer could be shaped to produce flat or raised surfaces. Finally, the device could be designed to produce a variety of energy inputs that would represent falls from various heights.

The containment vessels used in this project (aluminum beverage cans and one-gallon paint cans) were chosen merely for convenience. Future tests should be done using containment vessels made in configurations and with materials that more nearly approximate the vessel likely to house the actual hazardous waste.

The shrinkage of the mortar/grout materials produced an unconfined state in these materials. As a result the toughness and ductility of the mortar/grout was no doubt less than it would be if the materials were in a confined state as desired. In order to minimize damage to the outer steel shell of the container vessel during falls and to provide as tough and ductile a poured material inside as possible, it is suggested that non-shrink grouts or concretes be used in future applications.

The preliminary tests associated with the project used aluminum beverage cans as the containment vessel. They were chosen simply because of their ready availability and ease of fabrication. Simple tensile stress-strain curves were obtained for the materials of the beverage cans by testing "dog-bone" shaped specimens in an Instron universal testing machine. Figure 1 shows a typical specimen.

The aluminum beverage cans were those used to hold fruit juice, beer and carbonated soda. (For future reference these were designated as 'Grape Juice Can', 'Soda Can' and 'Coors Can', respectively.) Figure 2 shows typical stress-strain curves for each of these materials. It is seen that the tensile strengths were between 30,000 and 40,000 psi.

Since these specimens were merely used to develop the basic fabrication and testing process for subsequent tests, no specific use of this tensile stress-strain data was made.

FIGURE 1

Aluminum Beverage Can Tensile Tests

FIGURE 2