TECHNICAL MEMORANDUM 505-19

Texas Transportation Institute
Texas A&M Research Foundation

FEASIBILITY STUDY OF VEHICLE CRASH CUSHIONS CONSTRUCTED OF READILY AVAILABLE MATERIALS

A Test And Evaluation Report On Contract No. CPR-11-5851

U.S. Department of Transportation
Federal Highway Administration

by

M. A. Pittman
Research Associate

and

T. J. Hirsch
Research Engineer

These crash tests and evaluations were conducted under the Office of Research and Development, Structural and Applied Mechanics Division's Research Program on Structural Systems in Support of Highway Safety (4S Program).

The opinions, findings and conclusions expressed in this report are those of the authors and not necessarily those of the Federal Highway Administration.

July 1971

INTRODUCTION

During the latter part of 1967, four crash tests were conducted on impact attenuators which were predecessors to the present Modular Crash Cushion[1,2,5*]. Barrier configurations tested ranged from burlap bags filled with empty beverage cans to an arrangement of 55-gallon steel drums filled with empty beverage cans. One of the purposes of this study was to design crash cushions of readily available materials. These barriers were conceived by researchers at the Texas Transportation Institute (TTI) and were tested at the Texas A&M Research Annex in cooperation with the Federal Highway Administration. This report discussed the results of the four tests.

TEST DESCRIPTIONS

In the first test, 505-1A, the barrier consisted of 21 burlap bags filled with empty beverage cans and held together with poultry wire. The bags were arranged as shown in Figure 1. A 3500 lb Ford impacted the barrier head-on at a speed of 22 mph. The vehicle's front end rose off the ground during impact, but the vehicle remained stable. Average longitudinal deceleration was 3.9 g's, with a stopping distance of 6.3 ft. Vehicle damage was very minor, as shown in Figure 2. This test was conducted to investigate the feasibility of using waste metal beverage containers as an energy absorbing material for highway crash cushions. Since some of the burlap bags ruptured and allowed the cans to scatter, it was concluded that the beverage containers should be packaged in a stronger

---

*Superscript numbers refer to corresponding references at the end of this report.

FIGURE 1. BURLAP BAGS FILLED WITH EMPTY BEVERAGE CANS BEFORE TEST 505-1A.

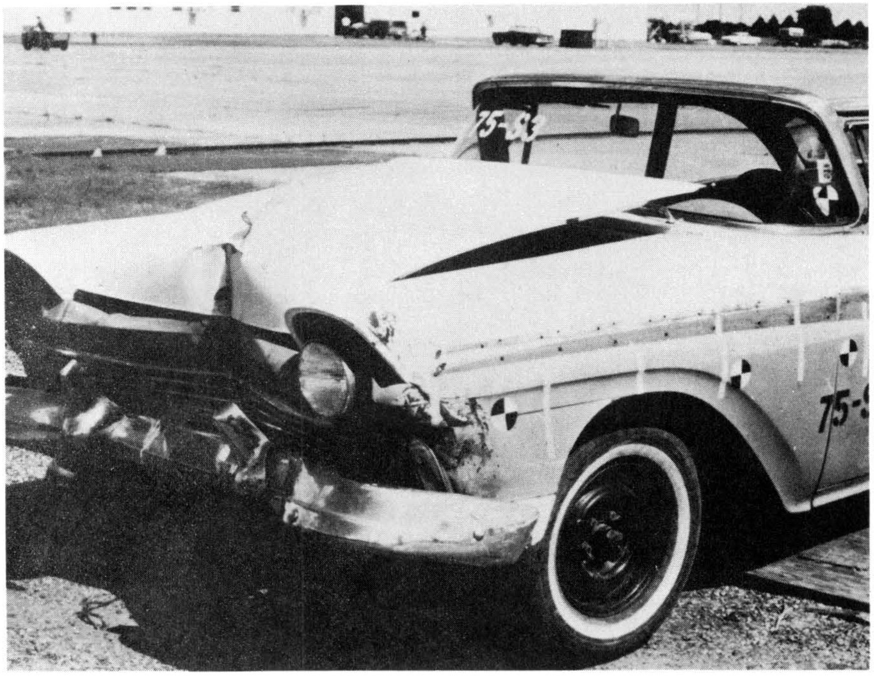

FIGURE 2. VEHICLE AFTER TEST 505-1A.

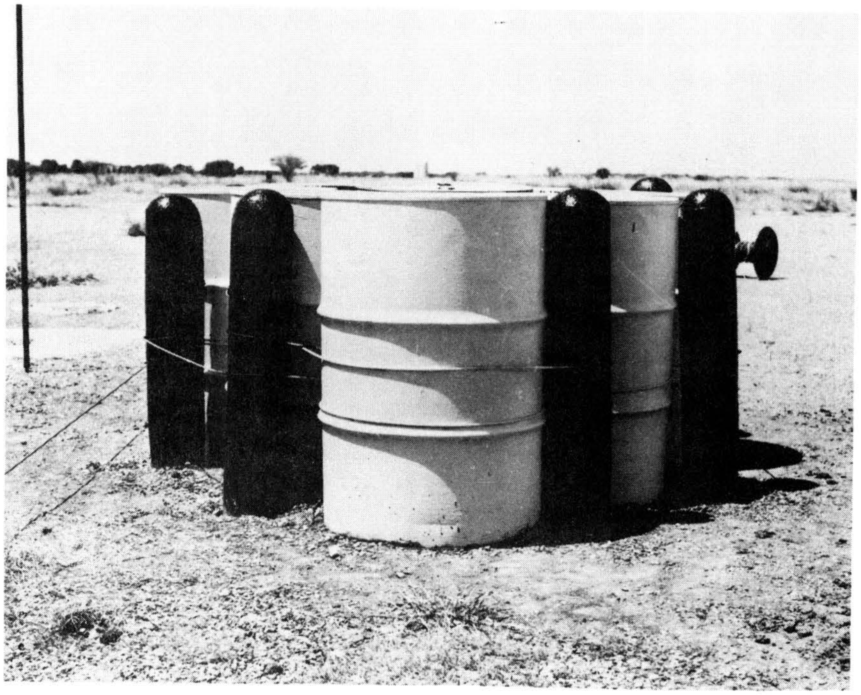

FIGURE 3. EIGHT 55-GALLON STEEL DRUMS FILLED WITH EMPTY BEVERAGE CANS AND ARRANGED BETWEEN TIMBER POSTS BEFORE TEST 505-1B.

FIGURE 4. BARRIER AND VEHICLE AFTER TEST 505-1B.

container so their behavior would be more predictable.

The next configuration tested (505-1B) is shown in Figure 3. Eight 55-gallon steel drums (16 gage steel) filled with empty beverage cans were arranged between seven 7-in. diameter timber posts. These posts were 5.5 ft in length and were embedded in 2.5 ft of soil. A 1/2-in. diameter steel cable was looped around the barrel system in an attempt to hold it together. The initial speed of the 3380 lb vehicle as it impacted the barrier was 63 mph. Shortly after the head-on impact, the vehicle was launched into the air by the timber posts. The vehicle was still moving at a speed of 8 mph after being launched. Thus its change in speed during impact was only 55 mph. The barrels and posts scattered, and the vehicle came to a stop on top of the barrier as shown in Figure 4. The vehicle was damaged considerably. Average longitudinal deceleration was 14.2 g's, with a peak of 40.0 g's. Since the barrels and post were scattered by the vehicle impact and this caused the vehicle to launch and become airborne, it was concluded that such a system should have a rigid backup support. It was felt that the rigid backup support would assure more predictable crushing of the energy absorbing material and provide more stability to the system.

In test 505-1C, fifteen 55-gallon, 16-gage steel drums filled with empty beverage cans were arranged 3 drums wide and 5 drums deep. The barrels were held together by a 1/2-in. diameter cable which was looped around and between them (see Figure 5). The steel drum system was placed against a rigid backup support wall. A 3520 lb Plymouth impacted the barrier head-on at a speed of 59 mph. During contact, the vehicle's front end became slightly airborne, and the barrel system was slightly lifted off the ground. The vehicle received severe damage. Both vehicle

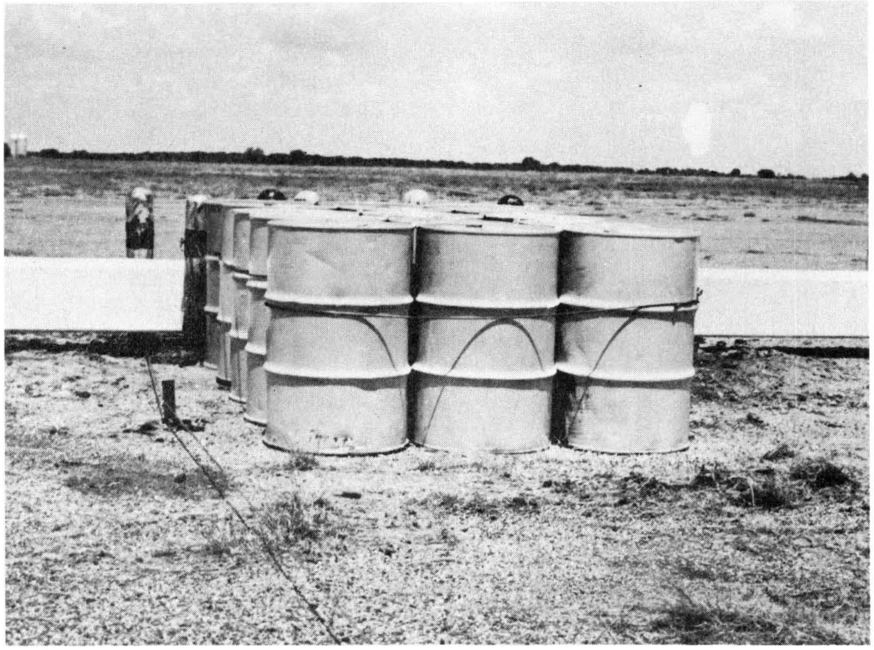

FIGURE 5. FIFTEEN 55-GALLON STEEL DRUMS FILLED WITH EMPTY BEVERAGE CANS BEFORE TEST 505-1C.

FIGURE 6. BARRIER AND VEHICLE AFTER TEST 505-1C.

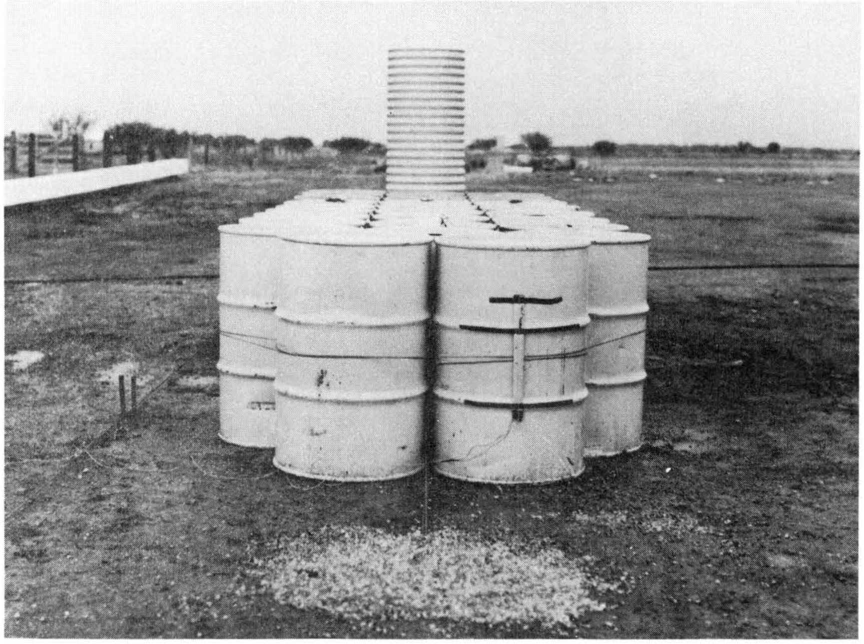

FIGURE 7. TWENTY-NINE 55-GALLON STEEL DRUMS FILLED WITH EMPTY BEVERAGE CANS BEFORE TEST 505-1D.

FIGURE 8. BARRIER AND VEHICLE AFTER TEST 505-1D.

and barrier are shown after the test in Figure 6. The average longitudinal deceleration was 14.2 g's over a distance of 7.1 ft. It was concluded that the 10 ft long barrier did not provide sufficient stopping distance. The length of the next barrier tested was increased to 20 ft.

The barrier for the next test (505-1D) consisted of twenty-nine 55-gallon, 16-gage steel drums filled with empty beverage cans placed in front of a simulated bridge pier as shown in Figure 7. There were nine rows, 3 drums wide, and the first row was 2 drums wide. The tops and bottoms of the barrels were welded together and a cable was looped around and threaded through the system. This cushion was hit head-on by a 4480 lb vehicle traveling 67 mph. The front end of the vehicle was lifted slightly off the ground, as were several rows of barrels. The vehicle was stopped after 10.4 ft of travel, with an average longitudinal deceleration of 16.7 g's. The vehicle sustained considerable damage, as shown in Figure 8.

SUMMARY

Table 1 contains a summary of the pertinent data obtained from these early tests. Tables 2 through 5 give the high-speed film data for tests 505-1A through 505-1D.

These four tests clearly indicated that the crushing strength of the barrels had to be decreased and the empty beverage cans removed in order to reduce the impact force levels encountered and to minimize vehicle damage. Static crush tests[1,3,4] were conducted on uncut, 18 and 20-gage, tighthead, 55-gallon steel drums with 4 elliptical holes cut in the top and bottom of the barrel. Results of these static tests indicated the importance of removing some of the metal from the top and bottom of each drum in order to reduce the crushing strength of the barrel. The uncut barrels generated approximately 3 times as much stopping force as the barrels with the elliptical holes.

Results of full-scale crash tests conducted on modified barrel systems have been very favorable. These tests have been reported previously.[1,2,4,5]

TABLE 1

SUMMARY OF DATA

Factor	Test No.			
	1A	1B	1C	1D
Vehicle Weight, lb	3500	3380	3520	4480
Initial Speed, mph	22	63	59	67
fps	33	92	86	98
Change in Speed, mph	22	55*	59	67
fps	33	80	86	98
Average Long. Decel., g's ($\Delta V/\Delta Tg$)	3.9	14.2	14.2	16.7
Stopping Distance, ft	6.3	8.5+	7.1	10.4
Time in Contact, sec	0.265	0.177	0.188	0.182

*Vehicle was launched and became airborne while still moving at a speed of 8 mph.

TABLE 2

TEST 505-1A

HIGH-SPEED FILM DATA

Time (msec)		Displacement (ft)
-47		-1.53
-31		-1.02
-16		-0.51
0	Impact	0
16		0.51
31		1.02
47		1.53
78		2.48
109		3.40
140		4.27
172		5.04
203		5.71
234		6.16
265		6.34
296		6.34
328		6.20
484		5.64
640		5.16

TABLE 3

TEST 505-1B

HIGH-SPEED FILM DATA

Time (msec)		Displacement (ft)
-16		-1.50
-14		-1.25
-11		-1.00
- 8		-0.75
- 5		-0.50
- 3		-0.25
0	Impact	0
21		1.75
40		3.25
65		5.00
73		5.50
82		6.00
88		6.25
100		6.75
107		7.00
123		7.50
143		8.00
156		8.25
177		8.50

TABLE 4

TEST 505-1C

HIGH-SPEED FILM DATA

Time (msec)		Displacement (ft)
-44		-3.80
-33		-2.85
-22		-1.90
-11		-0.95
0	Impact	0
11		0.90
22		1.52
33		2.29
44		3.05
55		3.78
66		4.41
78		4.98
89		5.50
100		5.96
111		6.26
122		6.56
133		6.79
144		6.96
155		6.98
166		7.04
177		7.08
188		7.08

TABLE 5

TEST 505-1D

HIGH-SPEED FILM DATA

Time (msec)		Displacement (ft)	Time (msec)	Displacement (ft)
-36		-3.55	(Continued)	
-29		-2.84	87	7.10
-22		-2.13	95	7.53
-15		-1.42	102	7.90
- 7		-0.71	109	8.24
0	Impact	0	116	8.56
7		0.69	124	8.87
15		1.38	131	9.11
22		2.03	138	9.34
29		2.68	146	9.56
36		3.31	153	9.77
44		3.92	160	9.98
51		4.53	167	10.17
58		5.09	175	10.33
66		5.62	182	10.43
73		6.14	189	10.43
80		6.65		

REFERENCES

1. Hirsch, T. J., "Barrel Protective Barrier," Technical Memorandum 505-1, FHWA Contract No. CPR-11-5851, Texas Transportation Institute, Texas A&M Research Foundation, July 1968.
2. Hirsch, T. J., Hayes, Gordon G., and Ivey, Don L., "The Modular Crash Cushion," Technical Memorandum 505-1S, FHWA Contract No. CPR-11-5851, Texas Transportation Institute, Texas A&M Research Foundation, August 1970.
3. White, Monroe C., "The Modular Crash Cushion: Design Data From Static Crush Tests of Steel Drums and of Corrugated Steel Pipes," Technical Memorandum 505-17, FHWA Contract No. CPR-11-5851, Texas Transportation Institute, Texas A&M Research Foundation, April 1971.
4. Hirsch, T. J., and Ivey, Don L., "Vehicle Impact Attenuation by Modular Crash Cushion," Research Report No. 146-1, Texas Highway Dept. HPR Study 2-8-68-146, Texas Transportation Institute, June 1969.
5. Hayes, G. G., Ivey, D. L., Hirsch, T. J., and Viner, J. G., "A Hybrid Barrier for Use at Bridge Piers and Medians," Technical Memorandum 505-15, FHWA Contract No. CPR-11-5851, Texas Transportation Institute, Texas A&M Research Foundation, May 1971.