National Cooperative Highway Research Program

RESEARCH RESULTS DIGEST

DIGEST 53 - DECEMBER 1973

Development of a Breakaway Cable Terminal for Median Barriers

An NCHRP staff digest of the essential findings from the final report on NCHRP Project 22-2, "Traffic Barrier Performance and Design," by M. E. Bronstad and J. D. Michie, Southwest Research Institute, San Antonio, Texas.

THE PROBLEM AND ITS SOLUTION

Approach ends of guardrails and median barriers have long been recognized as being among the more formidable roadside obstacles with which traffic must contend. The W-beam in upright terminals has penetrated the passenger compartment in numerous end-on impacts, whereas ramped terminals have caused impacting vehicles to be launched, rolled, and tumbled.

Southwest Research Institute has conducted NCHRP Project 22-2 with the objective of developing improved terminals for longitudinal traffic barriers. Findings from research on the breakaway cable terminal (BCT) for guardrails have been reported in *NCHRP Report 129* and *Research Results Digest 43*. Digest 43, published in October 1972, contains the latest information on the BCT as applied to guardrails. The BCT has been the subject of two Federal Highway Administration Notices (HNG-32, December 11, 1972, and HHO-31, May 24, 1973) encouraging its installation as part of National Experimental and Evaluation Program (NEEP) Project 17. Several states have already installed BCTs.

The purpose of this digest is to make available for early implementation the details of a median barrier terminal design that has performed satisfactorily in full-scale crash tests conducted in NCHRP Project 22-2.

The following service requirements for median barrier terminals provided the basis for evaluating the performance of the systems tested. The order of emphasis is first on safety, second on economics, and third on aesthetics.

HIGHWAY RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
NATIONAL ACADEMY OF SCIENCES—NATIONAL ACADEMY OF ENGINEERING

A median barrier terminal should:

1. Develop the tensile and/or flexural strength necessary to ensure desirable redirection performance of the length-of-need section.
2. Either by redirection, containment, or controlled penetration, minimize vehicle/occupant decelerations for terminal-section impacts. This implies that the impacting vehicle is not launched, rolled, or pocketed.
3. Minimize the possibility of penetration of the vehicle passenger compartment by a system component.
4. Be economical in construction, maintenance, and damage repair.
5. Miminize vehicle damage.
6. Have a pleasing and functional appearance.

The guardrail BCT system is flared such that for end-on impacts the vehicle will break away the first two posts and pass safely behind the guardrail system. This flared end treatment is not considered appropriate for median barriers. Because a straight terminal can only provide safety for end-on impacts by absorption of energy, the primary challenge was to develop a terminal capable of both cushioning vehicles for end-on impacts and redirecting vehicles for angular impacts. A median barrier terminal has been developed that satisfies the six service requirements. Further development will take place under a second phase of NCHRP Project 22-2 at Southwest Research Institute. The main need for improvement is considered to be related to service requirements 4 and 6.

FINDINGS

Some 16 full-scale crash tests were used in Project 22-2 to develop and evaluate the median barrier terminal presented herein. The results of these tests are summarized in Tables 1 and 2. The tests in Table 1 were performed on a sequence of modified terminal designs, culminating in the terminal shown in Figure 1. The nine tests in Table 2 were on variations of that terminal. Figure 2 shows the terminal used with various median barrier types. Details of the BCT used with the MB4W and MB3 systems are included in the agency's final report, entitled "Development and Crash Test Evaluation of Traffic Barrier Terminals." Complete documentation of all 26 tests in NCHRP Project 22-2 is given in this report, which is available upon request to the NCHRP Program Director.

A novel feature of this terminal is the use of flat plates as rail elements for about the first 25 ft of the system. The tests showed that this design is effective in reducing the longitudinal resistance for end-on impacts, and that it provides adequate anchorage for redirection of angular impacts within the terminal length. Tests 150, 151, 155, and 158 demonstrated the satisfactory cushioning capability of the terminal for end-on impacts. Tests 150 and 158 used full-sized vehicles at approximately 60 mph, on steel posts and timber posts, respectively. Tests 151 and 155 were on terminals with steel posts using subcompact cars, at approximately 40 and 60 mph, respectively.

The flat plate system displayed the same accordion-like collapse mechanism, shown in Figures 3 and 4, in all end-on impact tests conducted in the program, including those on the earlier versions of the terminal (i.e., Tests 143, 144, 145, 146, 147, and 149).

The redirectional capability of the terminal with the MB4S and MB3 systems was demonstrated in Tests 154 and 157, respectively, using full-sized cars at 60 mph impacting at 25° near the third post.

Several essential elements of the median barrier BCT are worthy of review:

Nose. - A 55-gal steel barrel is used as the terminal nose. Upon impact the crushed barrel grips the front of the vehicle, helping to prevent the vaulting encountered in earlier tests.

Rail Elements. - The four 3/16-in. plates carry out their primary function of cushioning the vehicle during end-on impacts. The two exterior plates are 30 in. and the two interior plates are 12 in. deep. The depth of the exterior plates and the 42-in. mounting height were effective in preventing launching for end-on impacts and underide for angular impacts.

Posts. - The five posts in the terminal are intended to break away easily when impacted parallel to the traveled way. Three types of breakaway posts were tested successfully in this program: W6X8.5 and TS6X6X0.1875 steel posts, and a 6X8 timber post with a 2-3/8-in. hole drilled through the centroidal axis parallel to the traveled way.

BCT Hardware. - For each type of post, hardware similar to that shown in Figure 1 is required to anchor the cable during side impacts and to release it upon an end-on impact. An effective anchorage assembly was developed for each of the three post types. Details are included in the agency's final report.

Table 3 contains a summary of median barrier terminal cost estimates based on values obtained from traffic barrier manufacturers. It can be seen that the estimated cost of a breakaway cable terminal exceeds that for the more conventional terminal used with the MB4W system by about $900. However it is expected that future research will make possible some cost reduction in the BCT.

Additional development and full-scale crash test evaluation of the breakaway cable terminals for both guardrails and median barriers will be carried out during the second phase of Project 22-2, now under way at Southwest Research Institute. Emphasis will be placed on improving the safety of the guardrail BCT for end-on impacts by small cars. The researchers will also investigate ways of making the terminals more economical in terms of first cost, maintenance, and repair. Results of this research are expected to be available in late 1974.

APPLICATION

Although research on the BCT continues, the findings presented herein stand alone. Evaluation of test results has shown the median barrier BCT to perform acceptably for the following traffic barrier systems shown in *NCHRP Report 118:* MB3 - Steel box beam median barrier; MB4S - blocked-out W-beam median barrier, steel post; and MB4W - blocked-out W-beam median barrier, timber post. Although not confirmed by crash tests, it is expected that the BCT could also be applied to these other systems in *Report 118:* MB2 - W-beam on weak steel post median barrier; MB5 and MB6 concrete median barriers. The BCT is detailed explicitly enough in Figure 1 and in the agency's final report to permit immediate trial implementation.

TABLE 1

SUMMARY OF PRELIMINARY MEDIAN BARRIER BCT TESTS

Test	Barrier System	Terminal Length (ft-in.)	Terminal* Post	Terminal Beam Elements	Terminal Rail Height (in.)	Vehicle Weight (lbs)	Vehicle Speed (mph)	Impact Angle (deg)	Max Average Deceleration + Long. (g)	Max Average Deceleration + Lat (g)	Remarks
143	A, B	12-6	8x8 timber (two)	10 ga x 12 in. (two)	30	3900	63.1	1.6	20.7	2.1	Vehicle stability and acceleration forces were favorable until vehicle reached more rigid W-beam and third post. Vehicle was launched by third post and W-beam ends and rolled on right side.
144	A, B	18-9	8x8 timber (three)	3/16 x 12 in. (two)	30	3800	59.7	1.3	12.6	3.1	Vehicle stability and acceleration forces were favorable until vehicle contacted W-beam ends at fourth post; vehicle was launched but did not roll over.
145	A, B	25-0	8x8 timber (five)	3/16 x 12 in. (four)	30	3900	55.2	4.0	6.4	4.9	Vehicle stability was good until launching was initiated due to contact of rub-rail with front cross member.
146	A, C	25-0	8x8 timber (five)	3/16 x 12 in. (four)	30	4000	66.0	1.1	10.0	2.0	Vehicle stability was good until vehicle contacted W-beam and fifth post; launching occurred at this point. Vehicle impact speed produced initial energy of 20 percent above planned test conditions.
147	A, C	25-0	8x8 timber (five)	3/16 x 12 in. (four)	30	2200	43.5	1.3	14.0	5.0	Vehicle broke first post, but launching occurred in second span; vehicle was launched over second post and rolled on right side before coming to rest upright with left rear wheel on rail.
148	A, C	25-0	8x8 timber (five)	3/16 x 18 in. (four)	33	3900	63.0	27	5.9	5.7	The vehicle impacted the rail at the second post and was redirected.
149	D, E	25-0	W6x8.5 steel (five)	3/16 x 18 in. (four)	30	3900	62.0	1.2	6.1	1.8	Vehicle stability and decelerations favorable until the vehicle was near end of terminal where launching occurred; vehicle rolled on right side.

*All terminal posts set in 24" dia reinforced concrete footing x 41" deep.

Barrier System Code:

A - Timber post "W" beam median barrier MB4W
B - Rub rail terminated at second post
C - Rub rail terminated at sixth post
D - Steel post "W" beam median barrier MB4S, no rub rail
E - W6x8.5 terminal posts welded to base plate at grade

+Maximum deceleration averaged over 50 millisecond duration obtained from high-speed cine.

TABLE 2

SUMMARY OF FINALIZED MEDIAN BARRIER BCT TESTS

Test	Barrier System	Terminal Length (ft-in.)	Terminal* Post	Terminal Beam Elements	Terminal Rail Height (in.)	Vehicle Weight (lbs)	Vehicle Speed (mph)	Impact Angle (deg)	Max Average Deceleration + Long. (g)	Max Average Deceleration + Lat (g)	Remarks
150	D, E, F	25-0	W6x8.5 steel	3/16 x 30 in. (two)	42	3800	63.0	.5	7.2 (4.4)	1.2	Vehicle smoothly decelerated in contact with barrier (30 ft stopping distance).
151	D, E, F	25-0	W6x8.5 steel	3/16 x 30 in. (two)	42	2200	41.5	.4	5.7 (4.4)	2.4	Vehicle smoothly decelerated in contact with barrier (13 ft stopping distance).
152	D, E, F	25-0	W6x8.5 steel	3/16 x 30 in. (two)	42	3900	57.0	27	6.2	2.5	Vehicle impacted rail just upstream of second post; no redirection was evident as vehicle penetrated the system. Local anchorage failure occurred.
153	D, F, G	25-0	TS6x6x0.1875	3/16 x 30 in. (two)	42	4000	54.5	26.7	7.0	3.3	Vehicle impacted rail 2 ft upstream of second post; little redirection occurred at vehicle penetrated system. Local anchorage failure occurred.
154	D, F, G	25-0	TS6x6x0.1875	3/16 x 30 in. (two)	42	4000	61.1	26	7.1	7.6	Vehicle impacted at third post and was smoothly redirected.
155	D, F, G	25-0	TS6x6x0.1875	3/16 x 30 in. (two)	42	2400	62.4	1.5	13.3 (8.1)	2.7	Vehicle came to rest in contact with barrier with little change in direction (16 ft stopping distance).
156	F, G, H	25-0	TS6x6x0.1875	3/16 x 30 in. (two)	42	3800	60	25	-	-	Vehicle was redirected although unanchored box beam spans disengaged from posts.
157	F, G, H	25-0	TS6x6x0.1875	3/16 x 30 in. (two)	42	3900	58	25	8.5	6.4	Vehicle was redirected, noticeable roll away from barrier was evident in redirection. Vehicle impacted rail upstream of third post.
158	A, C, F	25-0	6x8 timber posts with hole through neutral axis	3/16 x 30 in. (two)	42	3900	64.8	1.2	11.6 (6.4)	5.0	Vehicle decelerated in contact with barrier; stopping distance 22 ft.

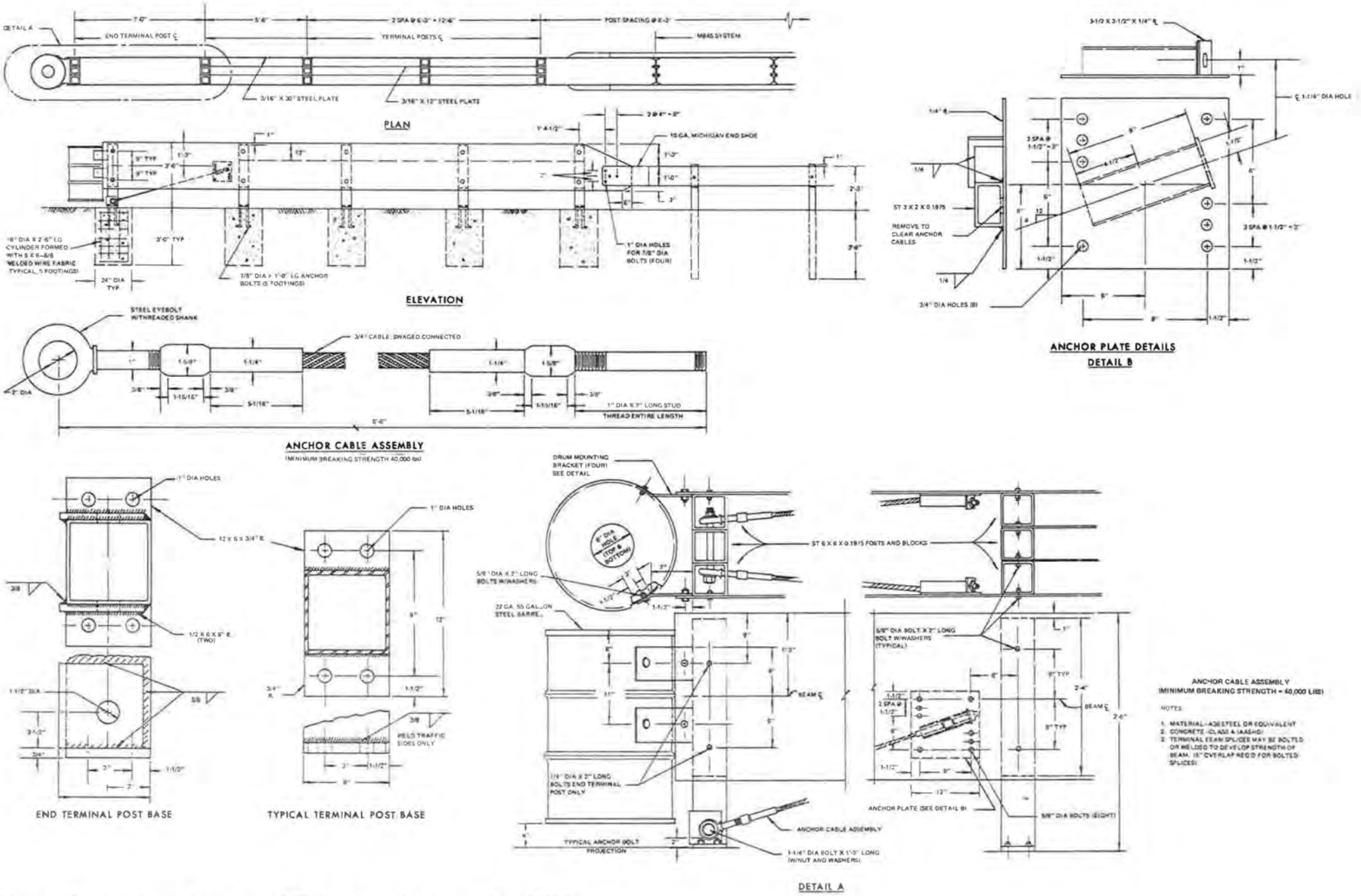


Figure 1. Median barrier BCT design drawing for MB4S.

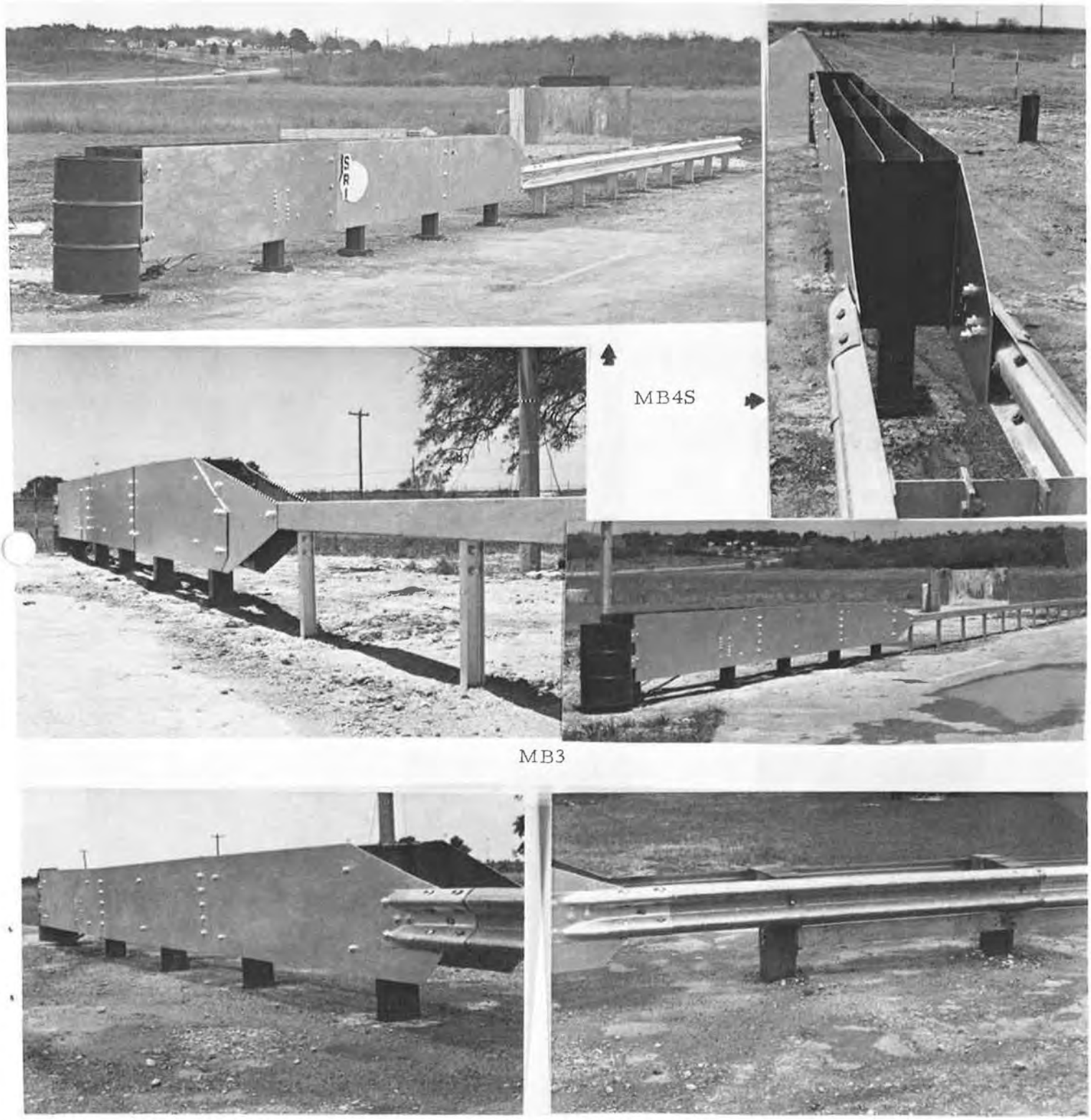


Figure 2. Median barrier BCT test installations.

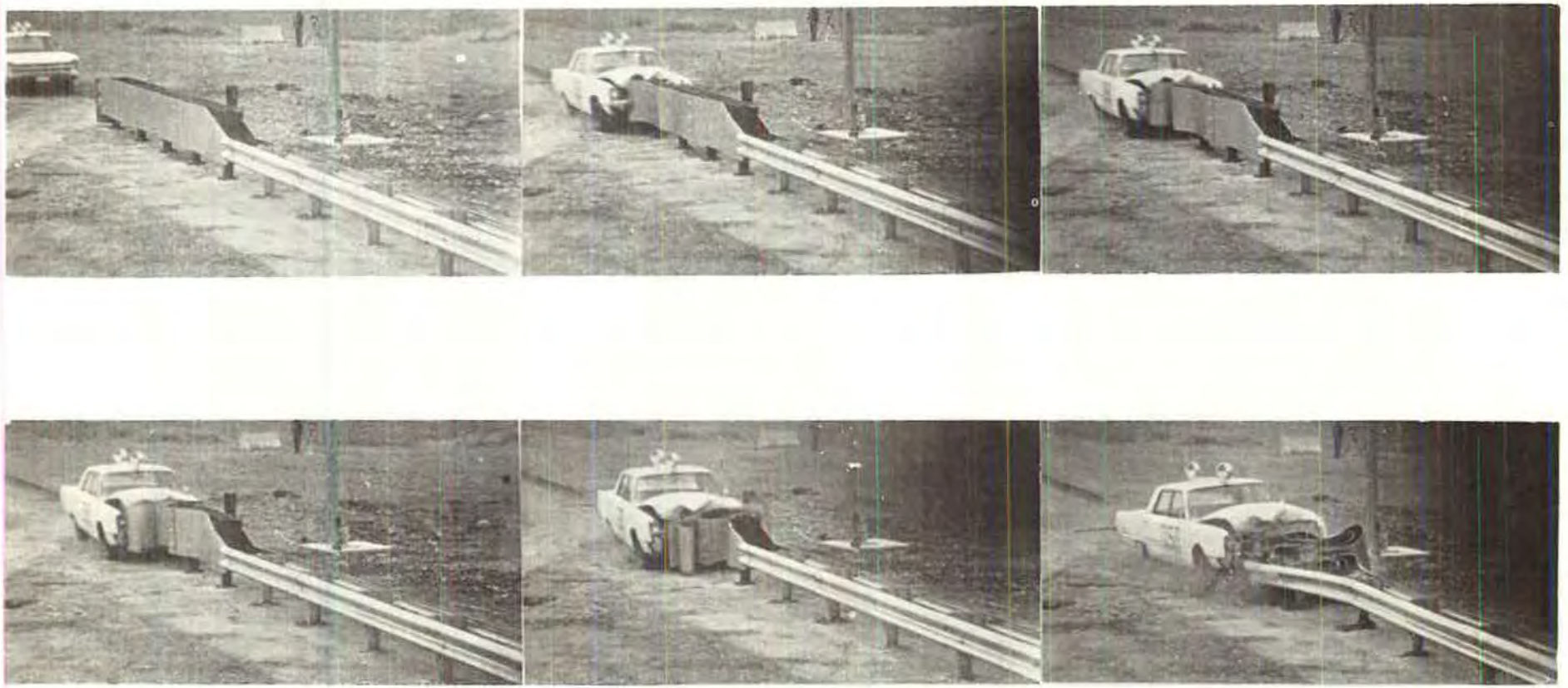
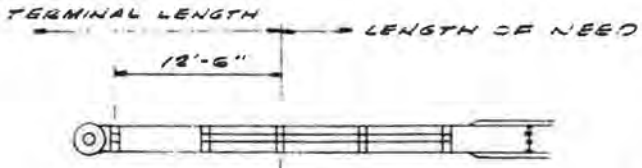


Figure 3. Sequential photographs, Test 150.

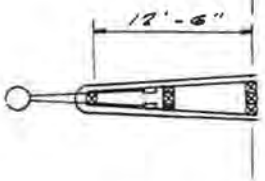
TABLE 3

SUMMARY OF MEDIAN TERMINAL COST ESTIMATES



MEDIAN BARRIER BCT

Material			Labor		
1.	Outer Beams	$280	1.	5.00/ft x 25 ft =	$125
2.	Inner Beams	90	2.	Concrete (5 at 50)	250
3.	End Post	47			$375
4.	Terminal Posts (4 at 27)	108			
5.	10 Blocks at $9.00	90			
6.	2 Anchor Plates	31			
7.	4 Barrel Straps at 1.75	7			
8.	Barrel	23			
9.	2 Michigan End Shoes	17			
10.	Anchor Cables	56	Average MB4S System cost $7.00/ft - 7 x 12.5 = $84		
11.	Tie Bolt	23			
12.	Concrete Footings (5 at 40)	200			
		$972	Total = 1,347 - 84 = $1,263		



MB4W

Material			Labor		
1.	W-Beam (12'-6" w/8 extra holes)	$42	1.	2.50/ft x 12.5 ft	31
2.	Posts 8x8x6'-0" Timber (two)	20	2.	Concrete (1 at 75)	75
3.	Anchor Plates (two)	60			$106
4.	Anchor Cables (two)	32			
5.	Eye Bolt	50			
6.	Terminal Section	15			
7.	Concrete Footing	30			
		$249	Total = $355		

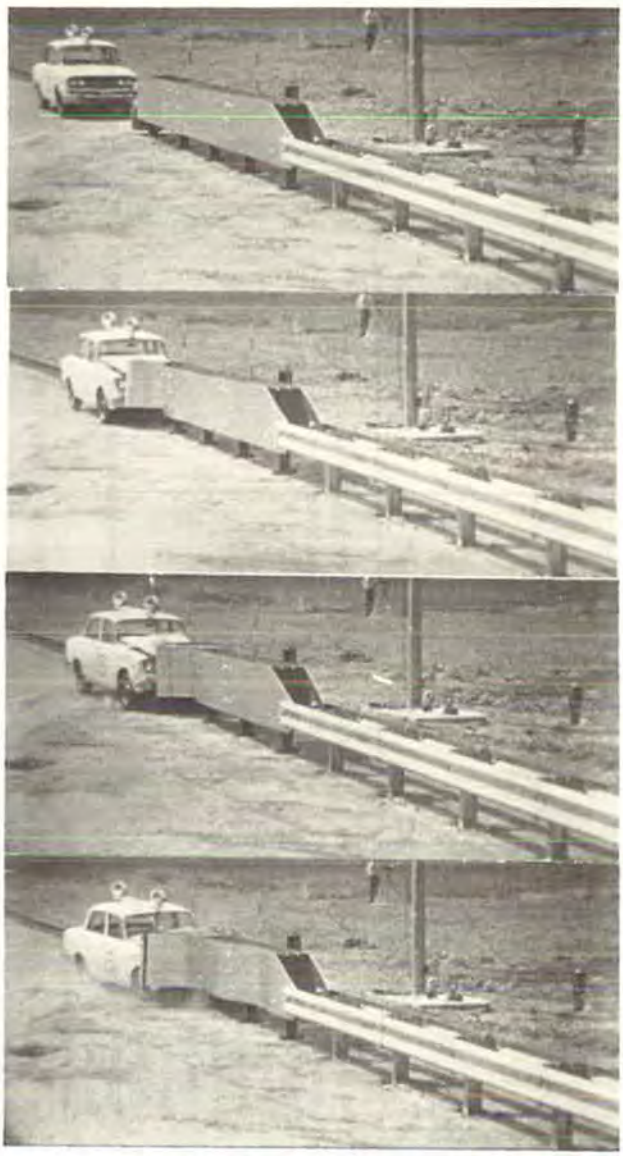


Figure 4. Sequential photographs, Test 151.