# W-Beam Approach Treatment at Bridge Rail Ends Near Intersecting Roadways

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**This paper is concerned with guardrail approach treatment at bridge ends near the intersection of two roadways. A state design was evaluated by full-scale crash tests. Based on the findings of this test, design modifications were made and subsequent crash tests were conducted. Success in the later crash tests was realized although the current testing criteria do not give a clear definition of recommended tests for evaluating this unique construction detail.**

A common occurrence in many rural and some urban locations is the presence of a secondary road intersecting near a bridge of a higher-classification roadway. This intersection provides very little distance for an effective guardrail–bridge rail transition to be installed. A design concept by Washington State as shown in Figure 1 was evaluated in one crash test, and based on this and subsequent tests, a modified design was developed for this situation.

### Full-Scale Crash Tests

Crash tests conducted in this investigation included both 1,800-lb (800-kg) and 4,500-lb (2000-kg) vehicles. Test results are briefly described in this paper. Detailed information on the test installation and results may be found elsewhere *(1)*; test results are summarized in Table 1.

### Test Procedures

Due to the uniqueness of this barrier treatment, both end treatment tests and transition tests would be appropriate. The test matrix is summarized in Table 1. A restrained 50th percentile, Part 572 dummy was placed in the driver's seat of the smaller car and a like unrestrained dummy in the full-size car. Impact events were recorded from transducers mounted in the dummies and on the vehicle. Extensive film coverage also documented the barrier, vehicle, and dummy behavior.

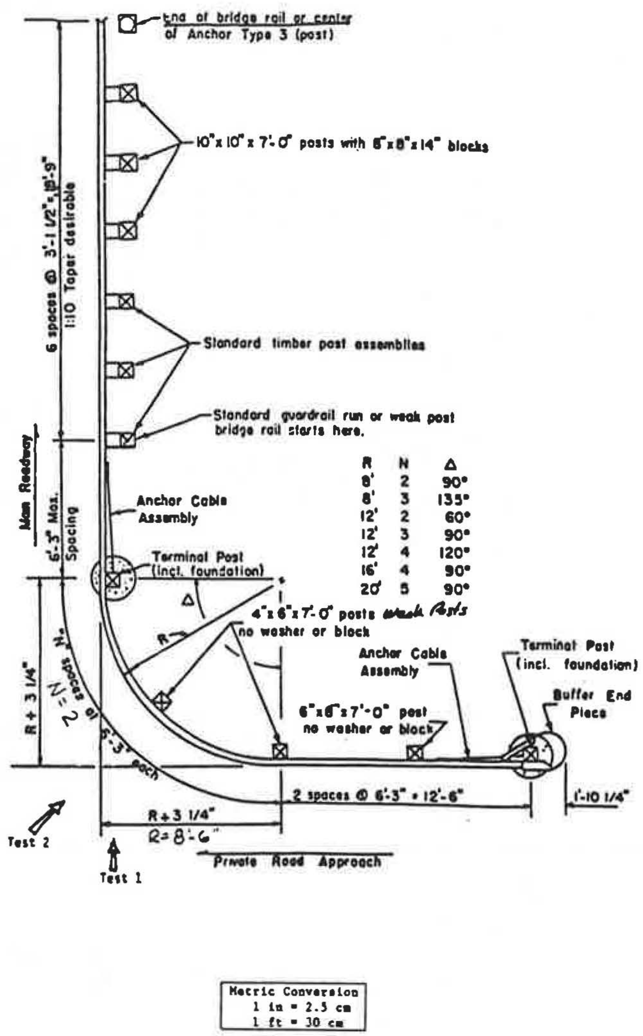


**FIGURE 1 Washington State design drawing.**

### Test WA-1

The test installation (Figure 2) included a 12-ft 6-in. (3.8-cm) tangent section on the intersecting road, an 8.5-ft (2.6-m) radius section, and a 25-ft (7.6-m) tangent transition section leading up the bridge. As shown in Figure 2, a shallow-angle, 60-mph (95-km/hr) impact was selected for the first test of the system. A steep 2:1 embankment was simulated by excavating behind the installation.

As shown in Figure 3, the vehicle struck the transition, fractured several wood posts, and was then launched into a

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TABLE 1 SUMMARY OF W-BEAM APPROACH AT INTERSECTING ROADWAYS

| Test No. | WA-1 | WA-1M | WA-2M | WA-3M | WA-4M | WA-5M |
|---|---|---|---|---|---|---|
| Barrier | State Design | ---------- Modified Design | ---------- | ---------- | ---------- See Figure 1 | ---------- |
| Test Vehicle | 1978 Plymouth | 1978 Honda | 1977 Dodge | 1978 Dodge | 1978 Plymouth | 1978 Plymouth |
| Gross Vehicle Weight, lb | 4520 | 1903 | 4789 | 4640 | 4650 | 4640 |
| Impact Speed (film), mph | 60.0 | 60.8 | 60.6 | 58.9 | 58.8 | 59.0 |
| Impact Angle, deg | 0 | 23.7 | 13.4 | 16.6 | 14.6 | -1.1 |
| Impact Duration, sec | .47 | Not Avail. | Not Avail. | Not Avail. | Not Avail. | .57 |
| Maximum Deflection, in | | | | | | |
| Dynamic | Not Avail. | Not Avail. | Not Avail. | Rail fractured | Barrier on ground | 3.5 |
| Permanent | Barrier on ground | 153 | Barrier on ground | Rail fractured | Barrier on ground | 3.0 |
| Exit Angle, deg | | | | | | |
| Film | Did not exit | Did not exit | Did not exit | Did not exit | Did not exit | -19.6 |
| Yaw Rate Transducer | Did not exit | Did not exit | Did not exit | Did not exit | Did not exit | -9.6 |
| Exit Speed, mph | | | | | | |
| Film | Did not exit | Did not exit | Did not exit | Did not exit | Did not exit | 41.6 |
| Accelerometer | Did not exit | Did not exit | Did not exit | Did not exit | Did not exit | 40.0 |
| Maximum 50 ms Avg Accel (film/accelerometer) | | | | | | |
| Longitudinal | Not Avail. | -11.0/-12.2 | -4.3/-6.7 | -4.3/Not Avail. | -5.3/-8.3 | -2.3/-5.5 |
| Lateral | Not Avail. | 5.4/7.4 | -1.7/-1.7 | -1.7/Not Avail. | -1.3/-5.4 | 2.7/4.1 |
| Occupant Risk, NCHRP Report 230 (film/accelerometer) | | | | | | |
| Δv long., fps (30) | Not Avail. | 37.9/Not Avail. | 19.9/18.9 | 13.9/Not Avail. | 16.7/18.1 | 16.2/18.0 |
| Δv lat, fps (20) | Not Avail. | -16.6/Not Avail. | 7.5/5.6 | 7.9/Not Avail. | 6.3/6.5 | -7.7/-10.5 |
| Ridedown Acceleration, g's (accelerometer) | | | | | | |
| Longitudinal (15) | Not Avail. | Not Avail. | -8.8 | Not Avail. | -10.5 | -7.6 |
| Lateral (15) | Not Avail. | Not Avail. | -4.6 | Not Avail. | -7.1 | 8.0 |
| NCHRP Report 230 Evaluation | | | | | | |
| Structural Adequacy (A,D) | Failed | Passed | Failed | Failed | Passed | Passed |
| Occupant Risk (E,F,G) | Failed (E) | 40 < Δv > 30 | Passed | Passed | Passed | Passed |
| Vehicle Trajectory (H,I) | Failed | Passed | Failed | Failed | Passed | Passed |

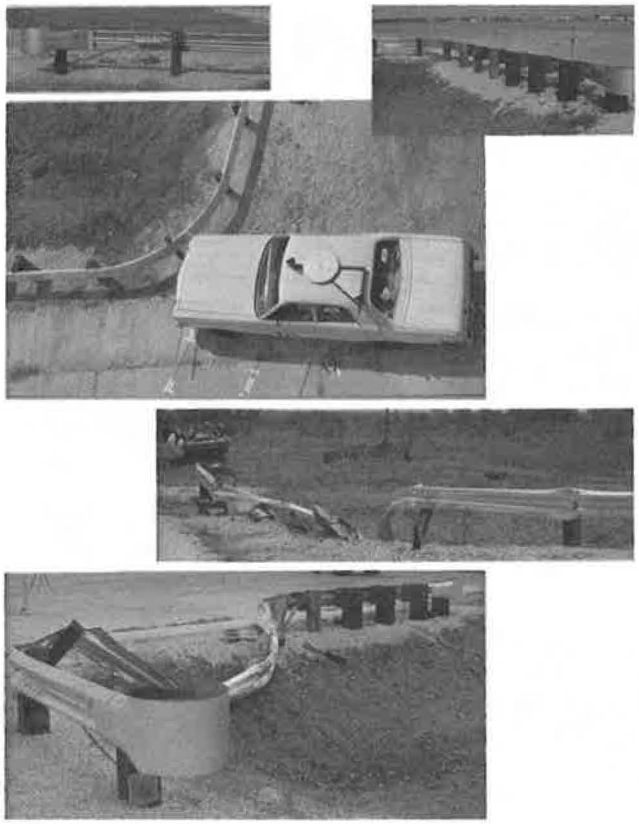

**FIGURE 2 Test WA-1.**

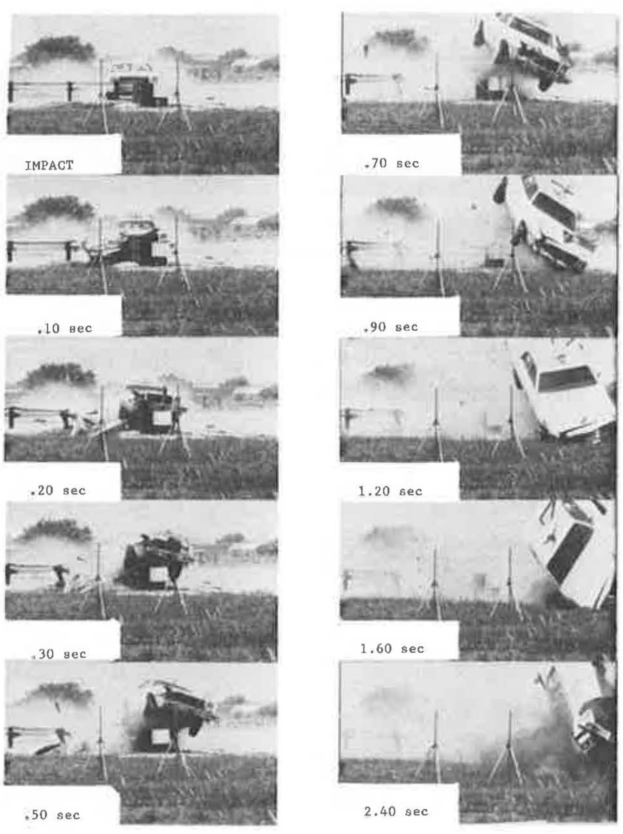


**FIGURE 3 Sequential photographs, Test WA-1.**

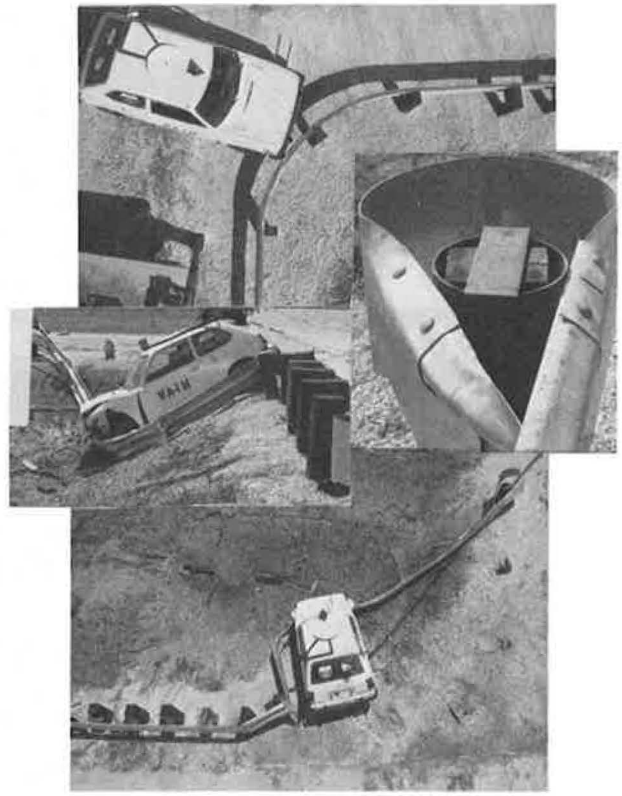

**FIGURE 4 Test WA-1M.**

rollover-tumbling mode by the system. Pocketing in the system and the leaning of posts in the soil contributed to the launching of the vehicle over and behind the system.

### Test WA-1M

Some of the posts and beam-anchorage details from the previous test installation were changed as shown in Figure 4. A pipe section used at the end anchorage post permits the beam to rotate about the end post without torsion being applied to the post. In addition, breakaway posts were substituted in the curved-beam area.

Impact conditions selected for this test were 60 mph and a 25-degree angle with an 1,800-lb car. The purpose of this test was to examine the containment capacity of the modified design and determine the occupant risk values. As shown in Figure 5, the vehicle was contained by the system, although the 37-ft/sec (11.3 m/sec) longitudinal $\Delta$V-value exceeded the 30 ft/sec (9 m/sec) recommended in NCHRP Report 230 *(2)*.

### Test WA-2M

On the basis of the results of the previous test, it was obvious that the containment capacity of the system would not be sufficient to restrain a 4,500-lb car striking at 60 mph. Accordingly, an additional 12.5 ft of beam was added to the secondary roadside to give the system more "stroke" as shown in Figure 6. Conditions for this test included a 4,500-lb car striking the nose of the system at 60 mph and a 15-degree angle. As shown in Figure 7, all the posts, including the end anchor, on the secondary roadside were fractured during the impact, thus allowing penetration of the system by the vehicle. Because of

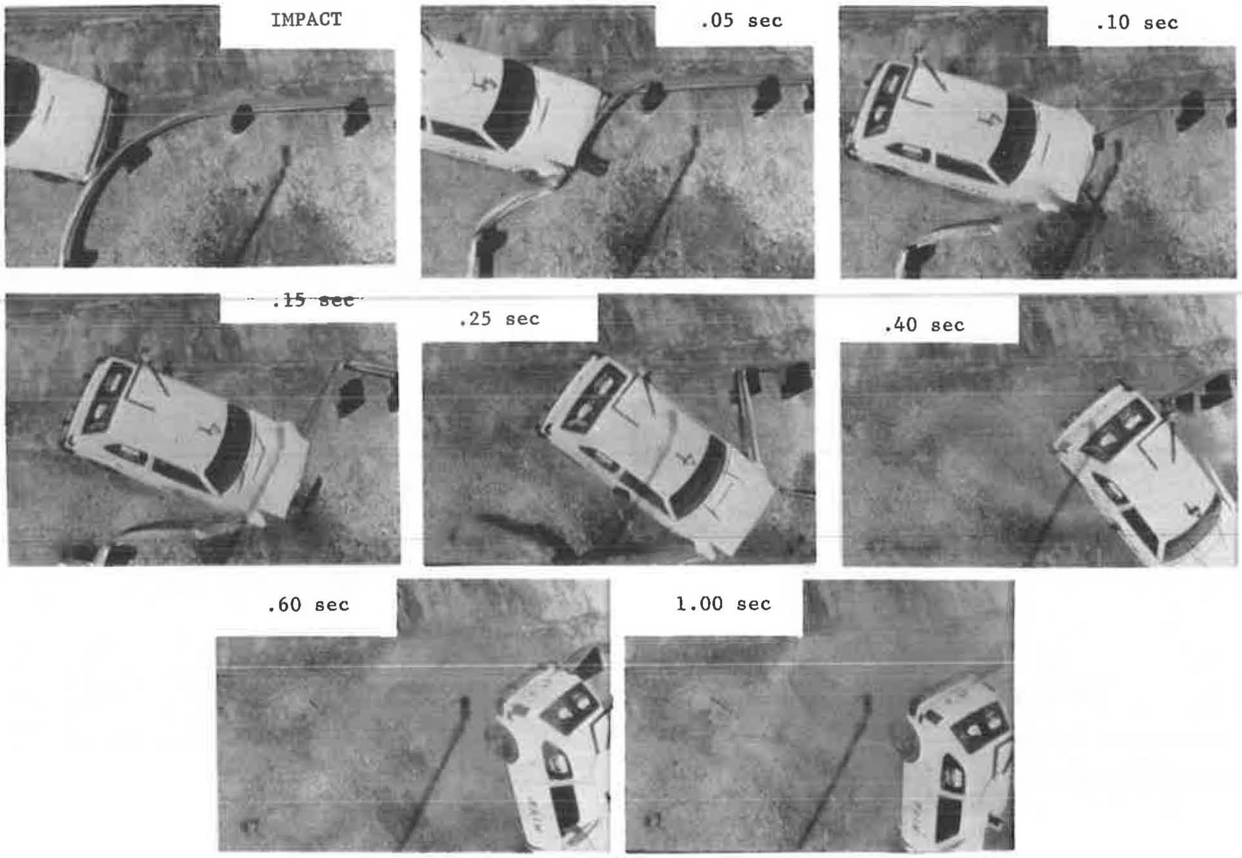


**FIGURE 5** **Sequential photographs, Test WA-1M.**

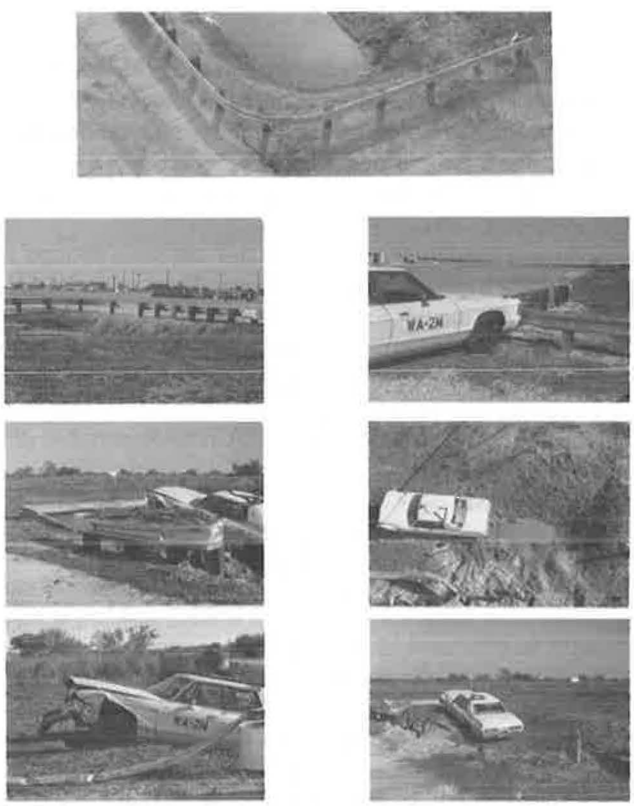


**FIGURE 6** **Test WA-2M.**

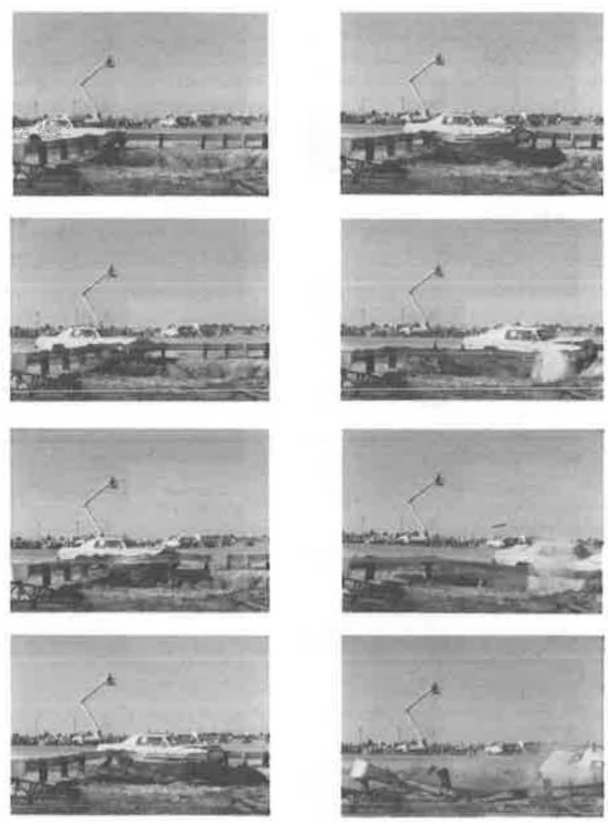

**FIGURE 7** **Sequential photographs, Test WA-2M.**

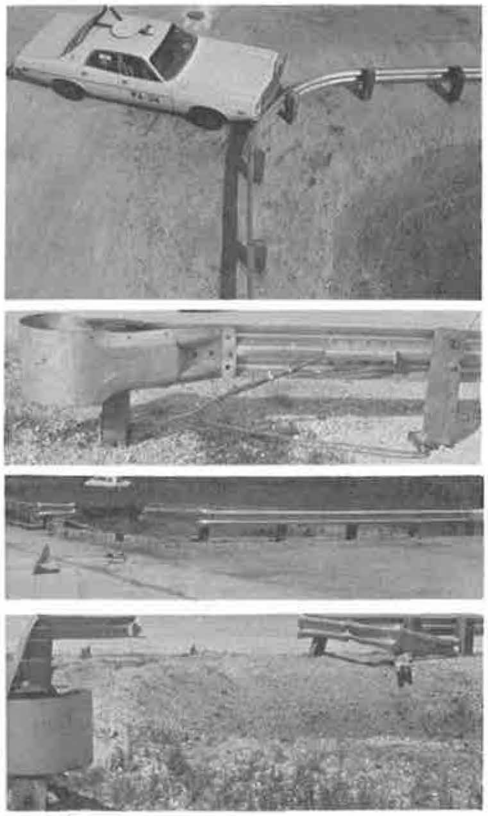

FIGURE 8 Test WA-3M.

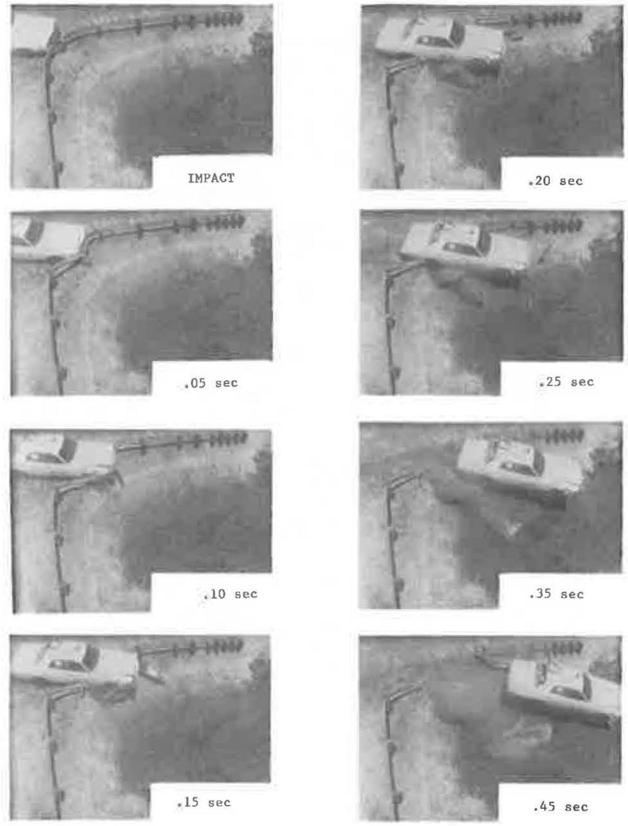


FIGURE 9 Sequential photographs, Test WA-3M.

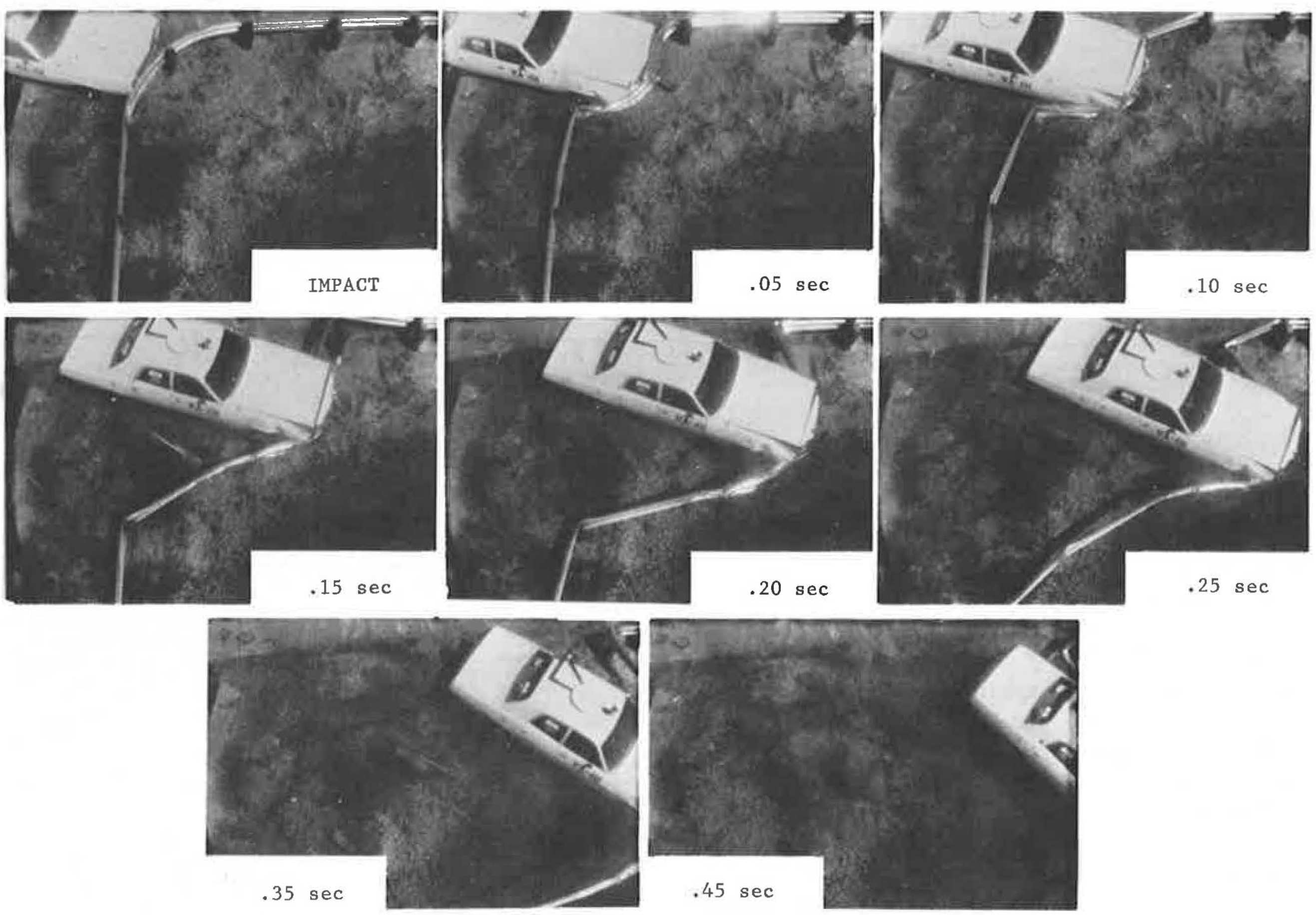


FIGURE 10 Sequential photographs, Test WA-4M.

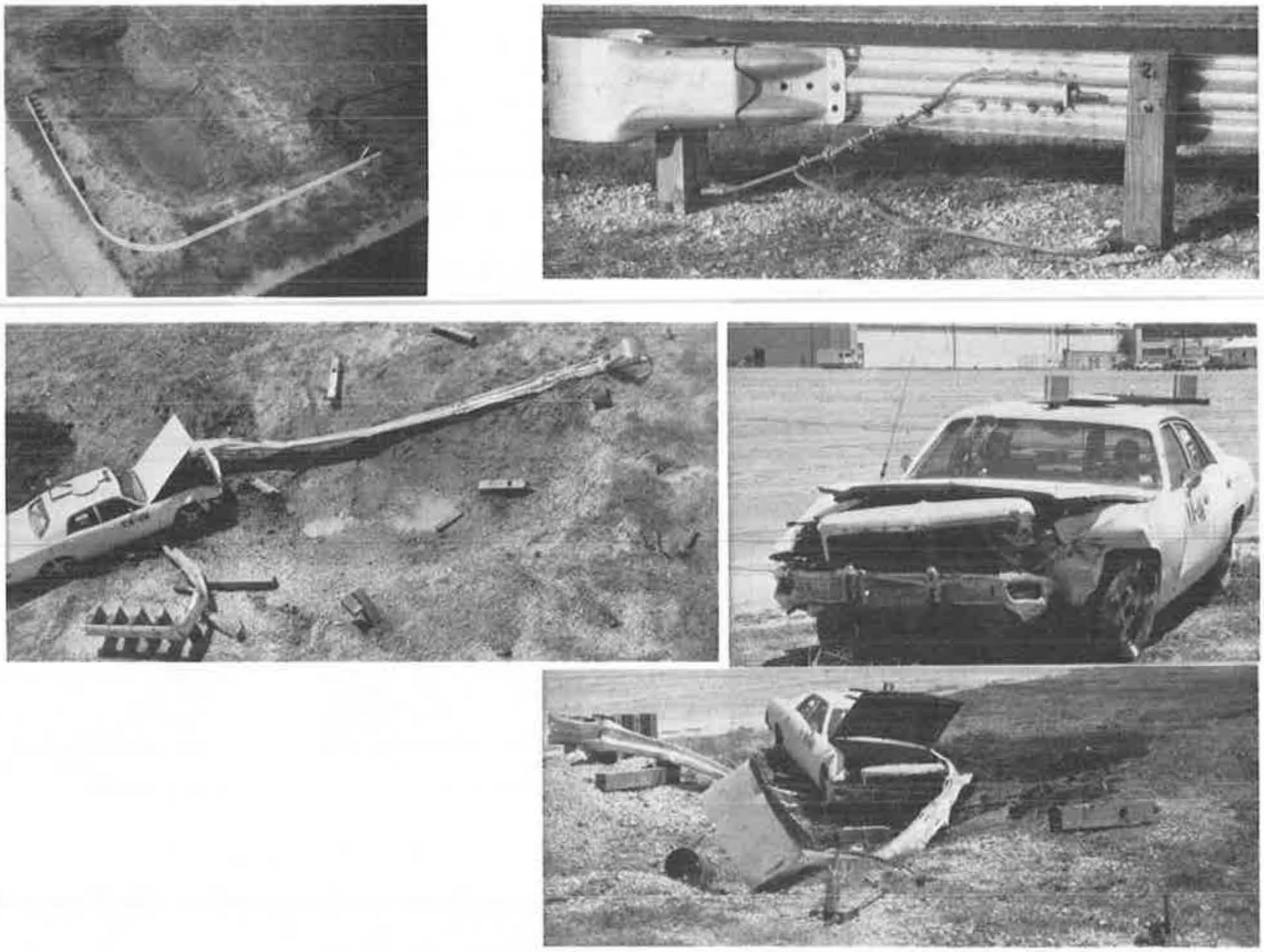

**FIGURE 11 Test WA-4M.**

the length of the simulated embankment, the vehicle was partially stopped by the slope of the downstream end of the excavation as shown in Figure 6.

### Test WA-3M

On the basis of the results of the previous test, it was concluded that additional anchorage was needed to contain the 4,500-lb vehicle. In addition, the length of the excavation behind the installation was increased to allow the vehicle to continue down the ditch.

An anchorage system was installed that used a second cable attached to the end anchor cable and a second post foundation as shown in Figure 8. The attachment to the second post foundation is not the breakaway type and thus provides a positive anchor after all the secondary road posts have failed. Failure of the end post releases the first cable, as designed for end-on impacts from the secondary roadside.

Test conditions were the same as in the previous test. As shown in Figure 9, the vehicle broke through the railing early in the event because of beam failure at the first post struck. The failure of this beam was attributed to snagging of the bolt head in the slot of the beam, which initiated tearing.

**FIGURE 12 Test WA-5M.**

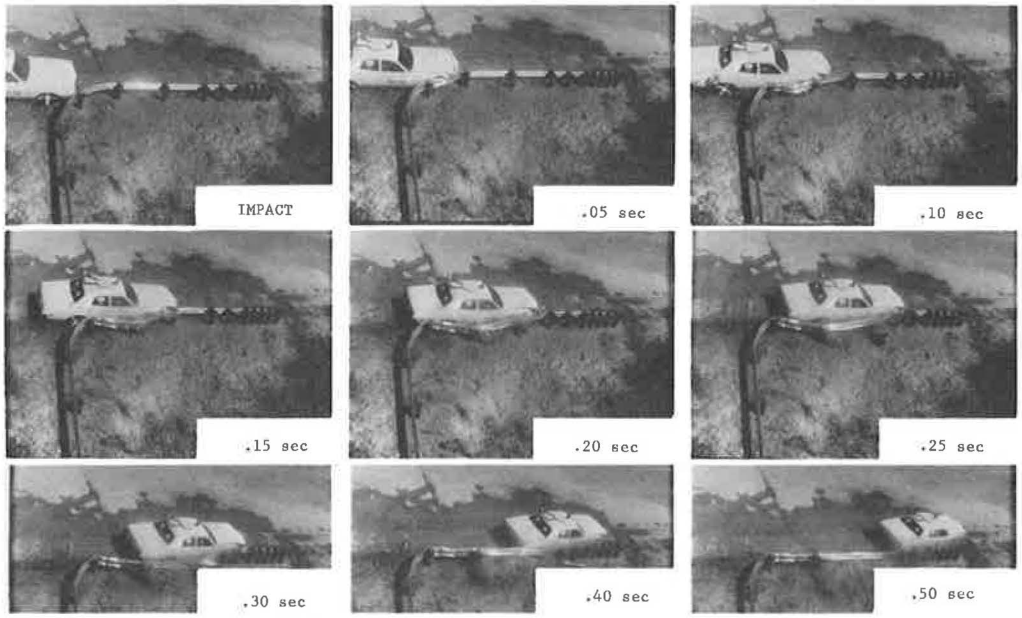


**FIGURE 13 Sequential photographs, Test WA-5M.**

### Test WA-4M

Because of the beam tearing that occurred in Test WA-3M, the bolt was omitted at Post 6, where the beam tearing had occurred. This bolt is not required for support of the beam and on the basis of Tests WA-1M and WA-2M, the beam tearing was considered to be a freak occurrence that could only be attributed to the bolt. All other details were identical to those in the previous test.

The vehicle struck the barrier with the same conditions as in the two previous tests and was contained by the system. The vehicle began a clockwise (looking down) yaw during the event, as shown in Figure 10, and the rear end eventually yawed over the barrier before coming to rest as shown in Figure 11, with approximately one-third of the vehicle protruding beyond the end of the bridge. The beam and anchorage system remained intact and successful containment of the vehicle was achieved.

### Test WA-5M

This test repeated the conditions of the first test on the Washington design (WA-1). The installation was identical to that of the previous test, as shown in Figure 12.

The vehicle struck the barrier as shown in Figure 13 and was smoothly redirected. All elements of the barrier performed as designed.

## CONCLUSIONS AND RECOMMENDATIONS

The guardrail approach treatment at a bridge when an intersecting roadway occurs near the bridge is a common problem in many states. A series of crash tests is described that investigated the problem. Some success in the crash tests is reported, although a test matrix that is applicable to this treatment is not currently in NCHRP Report 230 because of the unique geometry of the treatment investigated.

The straight breakaway cable terminal (BCT) on the intersecting roadway is justified based on the assumption that vehicles approaching this end are in a slowing/stopping mode for yielding to the main roadway traffic. This factor together with the low traffic volume on such an intersecting roadway lowers the probability of an end-on impact. For situations not covered by this assumption, the full BCT flare should be installed.

Until further research is accomplished, the treatment described in this paper and the report on which it is based *(1)* could provide interim solutions. FHWA and the Washington State Department of Transportation have plans for conducting research into this problem.

## ACKNOWLEDGMENT

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## REFERENCES

1. *Guardrail-Bridge Rail Transition Designs.* SwRI Project 06-7642. Southwest Research Institute, San Antonio, Tex., in preparation.
2. J. D. Michie. *NCHRP Report 230: Recommended Procedures for the Safety Performance Evaluation of Highway Appurtenances.* TRB, National Research Council, Washington, D.C., 1981.

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