Washington State Cable Median Barrier

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ABSTRACT

In the mid 1960's, the New York State Department of Transportation developed a 3-strand cable barrier that has several desirable characteristics as compared to other roadside barriers. This system was crash tested in accordance with the National Cooperative Highway Research Program (NCHRP) Report 350 crash test criteria as a roadside barrier. With the roadside barrier, all 3 cables are placed on the traffic side of the posts.

Since 1988, the American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide* has contained information on a cable median barrier design that has the middle cable mounted on the opposite side of the posts so that it can contain and redirect vehicles that strike the system from either side.

In the early 1990's, the Washington State Department of Transportation (WSDOT) became interested in using this design for medians that are over 10 m in width. As a result of this interest, WSDOT sponsored crash tests to evaluate the performance of this barrier, in accordance with NCHRP Report 350 criteria, with a small car and a pickup truck. In both tests, the vehicle was contained and brought to a stop. The occupant risk values were within the preferred limits set by NCHRP 350 and the damage to both vehicles was relatively minor.

Keywords: cable, guardrail, barrier

Washington State Cable Median Barrier

In the mid 1960's, the New York State Department of Transportation (NYSDOT) developed a 3-strand cable barrier *(1)* that was mounted on "weak" steel posts. In-service evaluations of this system have indicated that it has several desirable characteristics as compared to other roadside barriers. It is less rigid than beam guardrails and concrete barriers, which results in less force being exerted on the occupants of an errant vehicle. Its open design reduces the accumulation of drifting snow along the roadway and minimizes the visual obstruction that other barriers can present. It is also typically cheaper to install than other barriers. This system was crash tested in accordance with the National Cooperative Highway Research Program (NCHRP) Report 350 *(2)* crash test criteria as a roadside barrier *(3)*. With the roadside barrier, all 3 cables are placed on the traffic side of the posts.

Since 1988, the American Association of State Highway and Transportation Officials (AASHTO) *Roadside Design Guide (4)* has contained information on a cable median barrier design that has the middle cable mounted on the opposite side of the posts so that it can contain and redirect vehicles that strike the system from either side. However, there is no evidence that this design was subjected to crash testing.

In the early 1990's, the Washington State Department of Transportation (WSDOT) became interested in using this design for medians that are over 10 m in width as is shown in Figure 1. As a result of this interest, WSDOT sponsored crash tests to evaluate the performance of this barrier in accordance with NCHRP Report 350. Presented in this paper are the results of these crash tests.

FIGURE 1 Typical cable median barrier installation.

CABLE MEDIAN BARRIER DESIGN

The Washington State cable median barrier (see Figure 2) consists of three 19 mm diameter cables supported by S75 x 8.5 x 1.6 m long posts. Installation height from the ground surface to the bottom and top cables is 530 mm and 770 mm respectively with the middle cable evenly spaced between them. The middle cable is mounted on the opposite side of the posts. The posts in this system are spaced 5.0 m on-center.

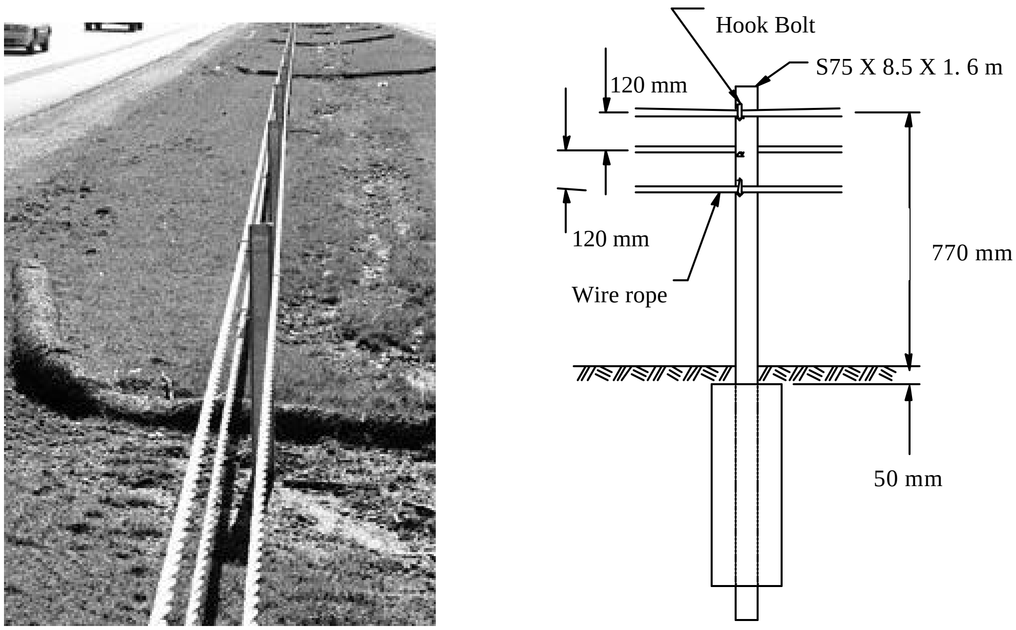

FIGURE 2 Typical cable median barrier installation and details.

The terminal design used by WSDOT for cable barriers are identical, except for a few minor details, to the terminal that was approved by the FHWA *(5)*. The ends of the cables are attached to turnbuckle assemblies that are bolted to a breakaway anchor angle and anchored rigidly to a concrete footing. The last post on each end of the installation is anchored in a concrete footing and made frangible by a slip base connection. The last post is flared back from the tangent a total distance of 1.2 m over a total distance of 7.5 m to the first post in the tangent run of barrier. The WSDOT uses a spring cable end assembly on one end of barrier runs up to 150 m long and on both ends of runs over 150m (up to 600 m). Compressing the springs introduces tension in the cables, which is needed to provide redirection for impacting vehicles. The springs are compressed in increments depending on the ambient temperature and are designed to compensate for temperature variations. The WSDOT uses spring compression values developed by the NYSDOT *(6)*. See Figure 9 for details of the WSDOT cable barrier terminal.

TEST INSTALLATION

The 2 tests discussed in this report were performed several years apart and on different installations. There were several minor differences in these installations that would not affect the results of the test. For the small car test, a 152.4 m long barrier was constructed. The length of the barrier for the pickup truck test was 145 m. In the small car test, the concrete footing for the anchor was integral with the footing for the last post. In the pickup test, the footings were separate but mated together with a tongue and groove joint. In the small car test, a spring cable end assembly was installed on both ends of the test installation. In the pickup test a spring cable end assembly was installed on just one end. For both tests, the springs were compressed 54 mm for a temperature range from 20° C to 25° C at the time of the test.

For both tests, the barrier was constructed so that the vehicle would hit the side with the single cable. Both installations were constructed on level terrain and the posts were installed in *NCHRP Report 350* standard soil.

NCHRP 350 COMPLIANCE TESTING

According to *NCHRP Report 350*, two crash tests are required for evaluation of longitudinal barriers to test level three (TL-3):

***NCHRP Report 350* test designation 3-10**: An 820-kg passenger car impacting the critical impact point (CIP) in the length of need (LON) of the longitudinal barrier at a nominal speed and angle of 100 km/h and 20 degrees. The purpose of this test is to evaluate the overall performance of the LON section in general, and occupant risks in particular.

***NCHRP Report 350* test designation 3-11**: A 2000-kg pickup truck impacting the CIP in the LON of the longitudinal barrier at a nominal speed and angle of 100 km/h and 25 degrees. The test is intended to evaluate the strength of the section for containing and redirecting the pickup truck.

The crash test and data analysis procedures were in accordance with guidelines presented in *NCHRP Report 350*.

Test 3-10: Small Car Test *(7)*

Test Description

A 1991 Ford Festiva, traveling at a speed of 99.7 km/h, impacted the cable median barrier at post 12 at an angle of 20.4 degrees. (See Figure 10 for summary information.) The impact on the post forced the top and bottom cables (installed on the opposite side of the posts) downward. The middle cable engaged the front grill and fender panel of the vehicle and began redirecting the vehicle. As the force caused the middle cable to deflect, the vehicle went over the top and bottom cables. The maximum dynamic deflection of the cable was 2.6 m. As the vehicle continued forward it stayed between the cables, coming to rest with the nose of the vehicle at post 20 (approximately 35 m downstream from the point of impact). The vehicle remained upright and stable during and after the collision (see Figure 3).

FIGURE 3 Small car at rest.

Damage to Test Installation

Most of the damage to the cable median barrier was to the posts and anchor system. Five posts were bent laterally and another five were disturbed (see Figure 4). The concrete foundations on the anchors were pulled up 25mm to 38 mm. The downstream anchor post was bent and twisted (see Figure 4). The springs on the downstream anchor were pulled out 41 mm to 108 mm.

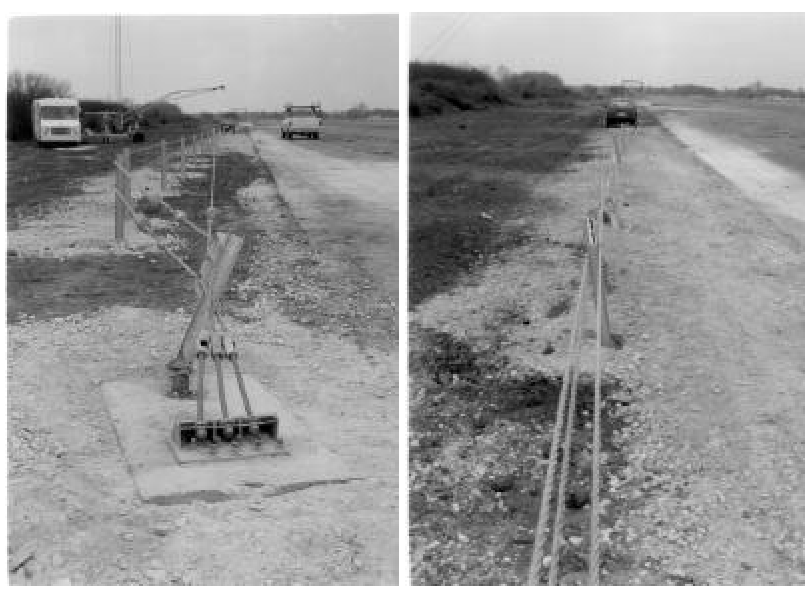

FIGURE 4 Barrier damage from small car test.

Vehicle Damage

The vehicle received minimal damage. The front bumper, grill, headlights, and both front fender panels were damaged (see Figure 5). Both doors were jammed and the undercarriage was scraped by contact with the cables. Maximum crush to the exterior of the vehicle was 280 mm deep above the bumper on the left side. The maximum deformation of the occupant compartment was 10 mm at the center front floorpan area.

FIGURE 5 Small car damage.

Occupant Risk Values

The occupant risk values for this test were within the preferred limits. The occupant impact velocity was 4.1 m/s in the longitudinal direction and 2.9 m/s in the lateral direction. The NCHRP Report 350 limits the occupant impact velocity to 12 m/s with 9 m/s being the preferred limit. The maximum ridedown acceleration was -3.6 g's in the longitudinal direction and 3.9 g's in the lateral direction. The NCHRP Report 350 limits the ridedown accelerations to 20 g's with 15 g's being the preferred limit.

Test 3-11: Pickup Truck Test *(8)*

Test Description

A 1995 Chevrolet 2500 pickup truck, traveling at a speed of 101.4 km/h, impacted the cable median barrier at post 11 at an angle of 24.8 degrees. (See Figure 11 for summary information.) As the vehicle contacted the barrier, the top and middle cable engaged the front grill and fender panel of the vehicle. The bottom cable was forced down to the ground and as the vehicle deflected the other 2 cables it went partially over the bottom cable. The

FIGURE 6 Pickup truck at rest.

maximum dynamic deflection during the test was 3.4 m. The vehicle began to be redirected parallel with the test installation and then was pulled back sideways toward the posts. The vehicle came to rest on top of post 22, approximately 50 m downstream from the point of impact (see Figure 6).

Damage to Test Installation

Other than damage to the posts, damage to the cable median barrier was minimal. Seven posts were bent and another nine were disturbed (see Figure 7). The upstream anchor had minor stress cracks radiating from the anchor bolts in the concrete footing. The downstream foundation moved 5 mm upstream. The downstream anchor post was bent and twisted similar to the damage shown in Figure 4. The cables were slack throughout the length of the installation.

FIGURE 7 Barrier damage from pickup truck test.

Vehicle Damage

The vehicle sustained minor damage. There were scuff marks on the left front and rear quarter panels and left door (see Figure 8). In addition, the left front and rear tires were cosmetically damaged. Maximum exterior crush to the vehicle was 320 mm above the front bumper at the left front corner. No deformation or intrusion into the occupant compartment occurred from the impact with the cable barrier.

FIGURE 8 Pickup truck damage.

Occupant Risk Values

The occupant risk values for this test were within the preferred limits. The occupant impact velocity was 2.2 m/s in the longitudinal direction and 2.9 m/s in the lateral direction. The NCHRP Report 350 limits the occupant impact velocity to 12 m/s with 9 m/s being the preferred limit. The maximum ridedown acceleration was -2.7 g's in the longitudinal direction and 4.9 g's in the lateral direction. The NCHRP Report 350 limits the ridedown accelerations to 20 g's with 15 g's being the preferred limit.

CONCLUSIONS

The Washington State cable median barrier was successfully crash tested in accordance with the NCHRP Report 350 criteria with a small car and a pickup truck. In both tests, the vehicle was contained and brought to a stop. The occupant risk values were within the preferred limits set by NCHRP 350 and the damage to both vehicles was relatively minor.

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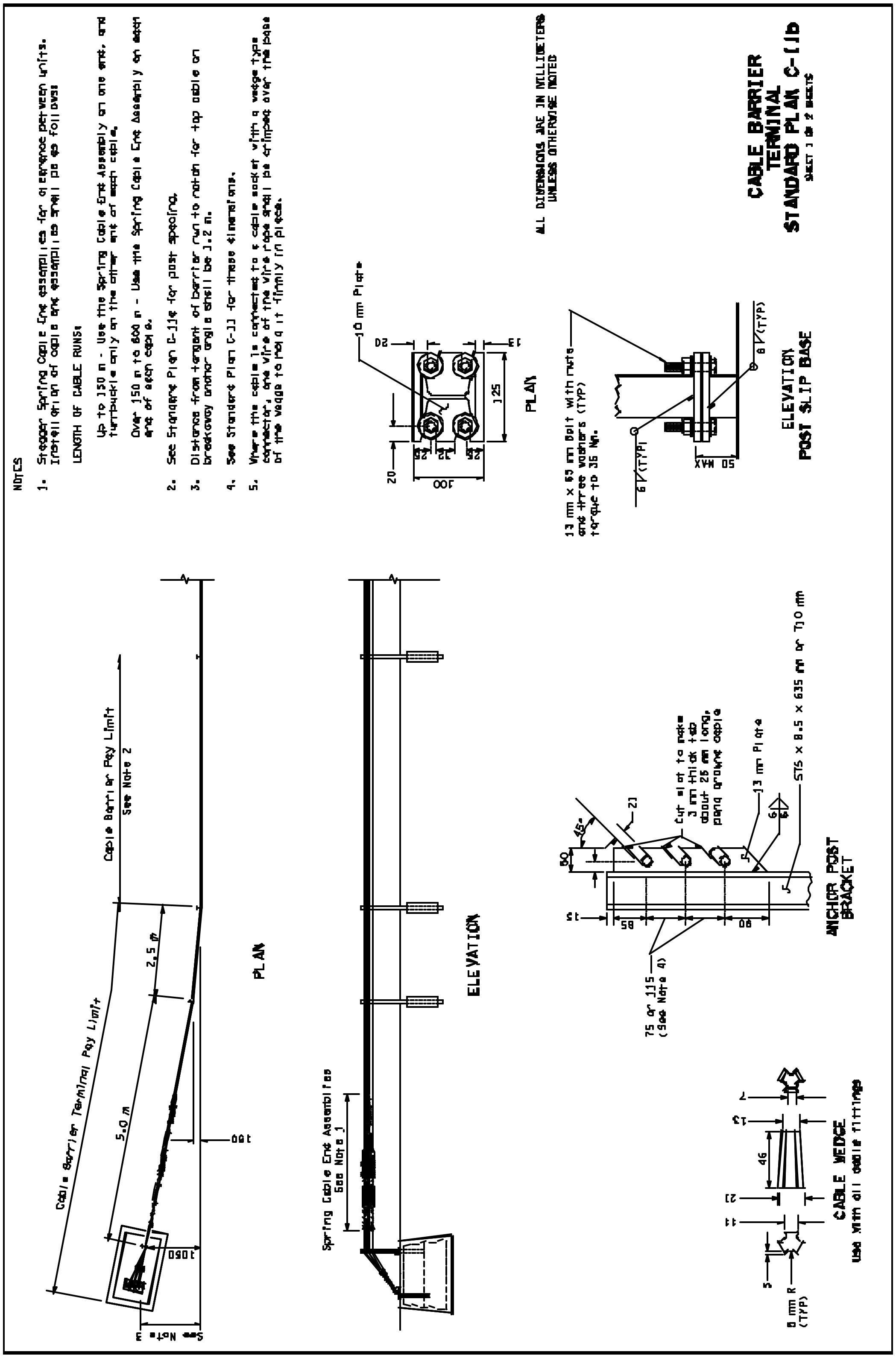


FIGURE 9 Washington State Cable Barrier Terminal Details.

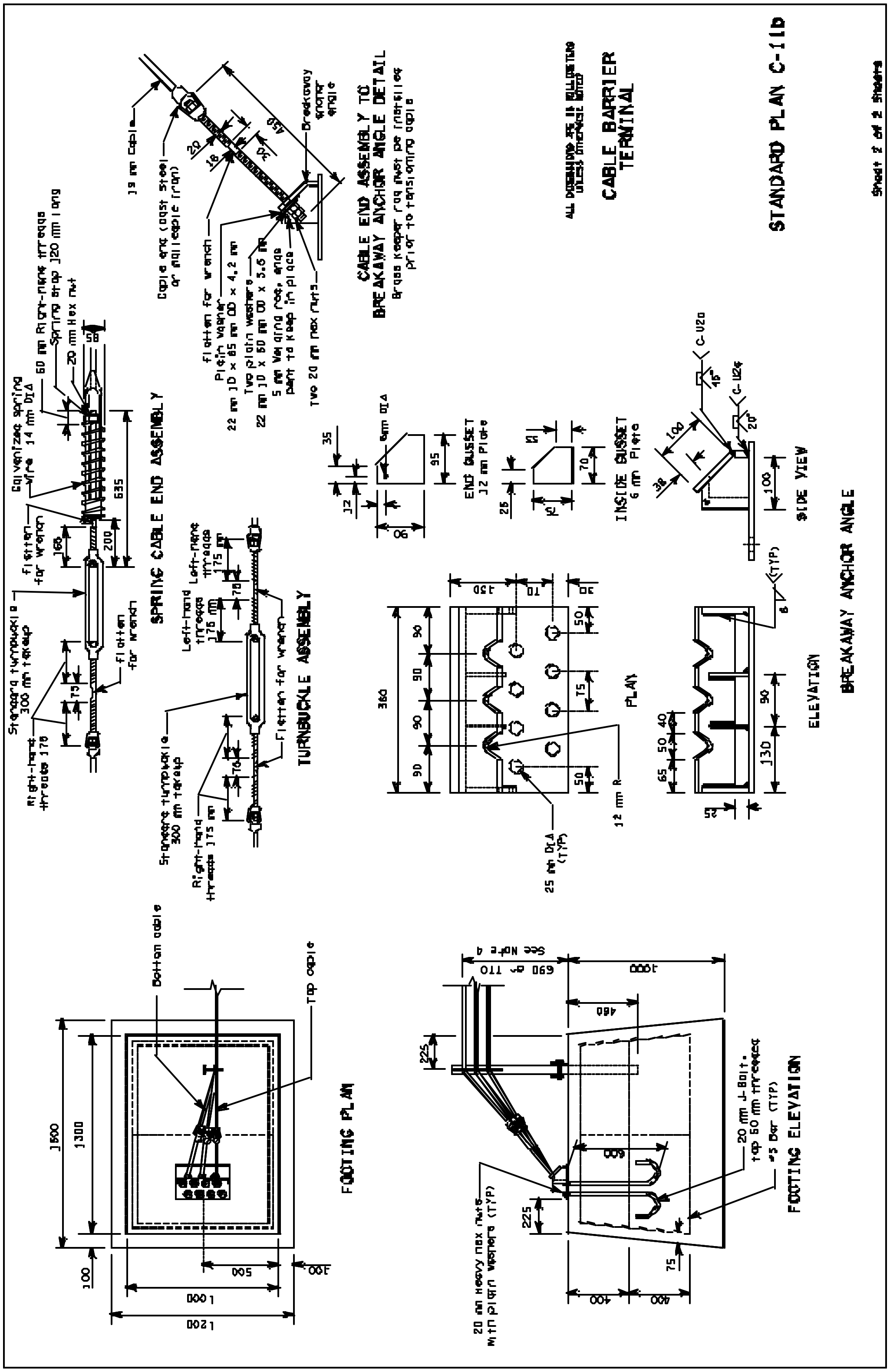
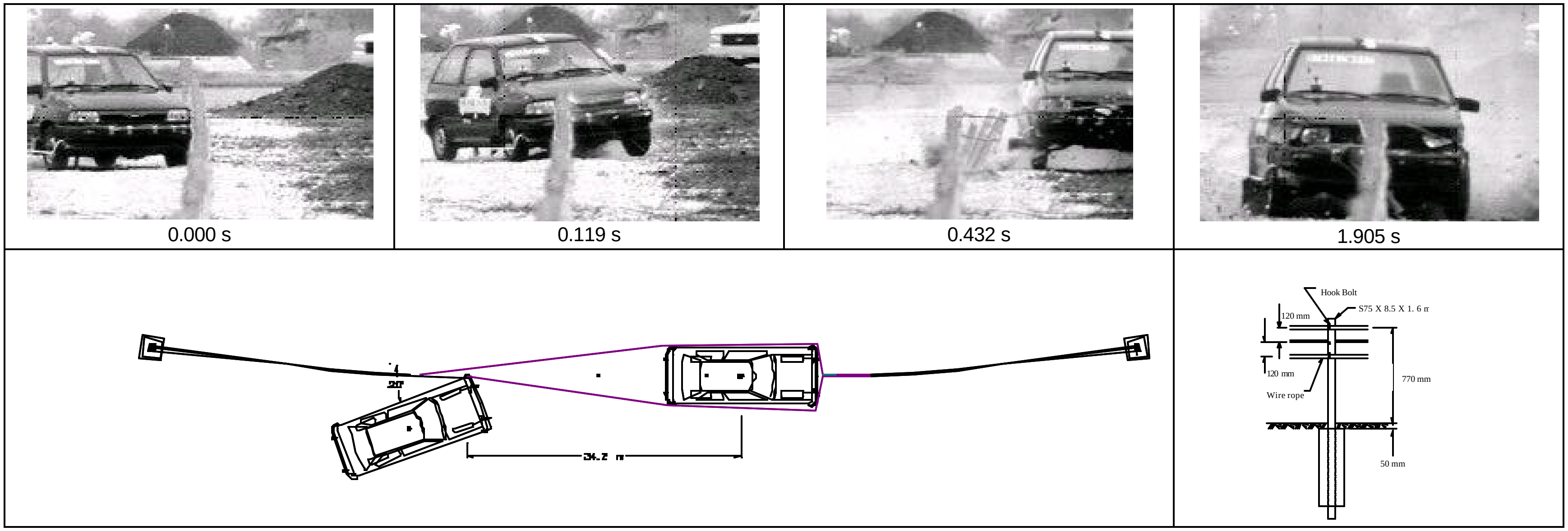


FIGURE 9 (continued) Washington State Cable Barrier Terminal Details.



General Information

- Test Agency........................... Texas Transportation Institute
- Test No.................................. 270687-WDT2
- Date.. 03/06/96

Test Article

- Type .... Cable Rail
- Name .... WSDOT Three Strand Cable Rail
- Installation Length (m) 152.4
- Size and/or dimension and material of key elements .... 3 each 19 mm diameter wire cables on Type 3 S76x8.5x1.6 posts

Soil Type and Condition........... Standard soil, dry

Test Vehicle

- Type .... Production
- Designation............................. 820C
- Model...................................... 1991 Ford Festiva
- Mass (kg) Curb....................... 851
  - Test Inertial 820
  - Dummy 76
  - Gross Static........... 896

Impact Conditions

- Speed (km/h)............................. 99.7
- Angle (deg) 20.4

Exit Conditions

- Speed (km/h)............................. N/A
- Angle (deg) .... N/A

Occupant Risk Values

- Impact Velocity (m/s)
  - x-direction 4.1
  - y-direction 2.9
- THIV (optional)............................
- Ridedown Accelerations (g's)
  - x-direction .... -3.6
  - y-direction 3.9
- PHD (optional).............................
- ASI (optional)..............................
- Max. 0.050-s Average (g's)
  - x-direction .... -2.5
  - y-direction 2.8
  - z-direction .... -2.2

Test Article Deflections (m)

- Dynamic.................................. 2.58
- Permanent 1.10

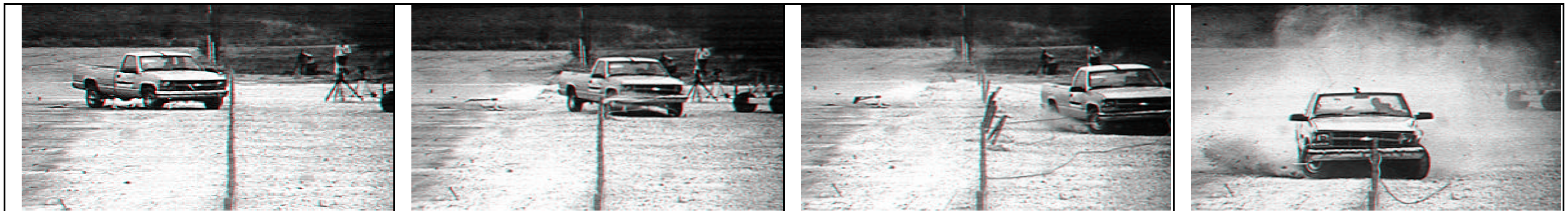
Vehicle Damage

- Exterior
  - VDS .... N/A
  - CDC .... N/A
- Interior
  - OCDI FS0000000
- Maximum Exterior Vehicle Crush (mm)............ 280
- Max. Occ. Compart. Deformation (mm) 10

Post-Impact Behavior

- Max. Roll Angle (deg)............. -5.2
- Max. Pitch Angle (deg)........... 2.4
- Max. Yaw Angle (deg)........... 27.3

FIGURE 10 Small car test results.



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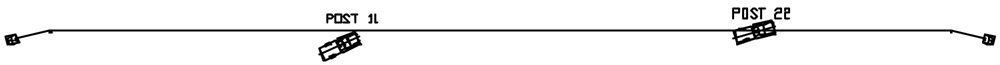

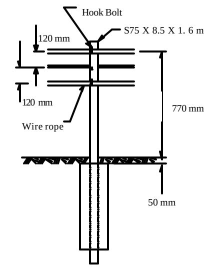

General Information	
Test Agency	Texas Transportation Institute
Test No.	404211-8
Date	02/16/00
Test Article	
Type	Cable Barrier
Name	WSDOT Cable Rail with NY terminal
Installation Length (m)	145.0
Material or Key Elements	3 Strand Wire Cable, Top at 770 mm, with New York Cable Terminal
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1995 Chevrolet 2500 Pickup Truck
Mass (kg)	
Curb	1932
Test Inertial	2000
Dummy	No dummy
Gross Static	2000

Impact Conditions	
Speed (km/h)	101.4
Angle (deg)	24.8
Exit Conditions	
Speed (km/h)	Stopped
Angle (deg)	N/A
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	2.2
y-direction	2.9
THIV (km/h)	12.0
Ridedown Accelerations (g's)	
x-direction	-2.7
y-direction	4.9
PHD (g=s)	5.2
ASI	0.26
Max. 0.050-s Average (g's)	
x-direction	-1.6
y-direction	2.1
z-direction	-1.2

Test Article Deflections (m)	
Dynamic	3.4
Permanent	0.7
Vehicle Damage	
Exterior	
VDS	11LFQ2
CDC	11FLEK2 & 11LDEW2
Maximum Exterior Vehicle Crush (mm)	320
Interior	
OCDI	FS0000000
Max. Occ. Compart. Deformation (mm)	0
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	18
Max. Pitch Angle (deg)	3
Max. Roll Angle (deg)	-3

FIGURE 11 Pickup truck test results.