AESTHETIC BARRIER LITERATURE REVIEW

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16. Abstract (Limit: 200 words) The objective of the literature search described herein was to identify and display aesthetic-type barriers appropriate for use in scenic areas. The barriers identified in this review include parapets, guardrails, and bridge rails and were evaluated according to Test Level 1 (TL-1), Test Level 2 (TL-2), and Test Level 3 (TL-3) safety performance criteria set forth in the NCHRP Report No. 350, Recommended Procedures for the Safety Performance Evaluation of Highway Features.		
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1 INTRODUCTION

The objective of the literature search described herein was to identify and display aesthetic-type barriers appropriate for use in scenic areas. The barriers identified in this review include parapets, guardrails, and bridge rails and were evaluated according to Test Level 1 (TL-1), Test Level 2 (TL-2), and Test Level 3 (TL-3) safety performance criteria set forth in the National Cooperative Highway Research Program (NCHRP) Report No. 350, *Recommended Procedures for the Safety Performance Evaluation of Highway Features* (1).

2 LITERATURE REVIEW

2.1 Parapets

A limited amount of research has been conducted on rock, stone, and concrete parapets. This section is a summary of those studies and results that are relevant to this project.

2.1.1 Deep Cobble-Revealed Textured Barrier with a Type 60 Profile

In 2002, Peter et al. (2) conducted tests (TL-3) on a deep cobble-reveal textured barrier with a Type 60 profile. The Type 60 barrier used as a base profile for all textured barrier testing is show in Figure 1 and the assembled texture barrier used for testing is shown in Figures 2 and 3. The test results are provided in Figure A-1.

Figure 1. Existing Type 60 Profile Used For Testing

Figure 2. Deep Cobble-Revealed Textured Barrier Prior to Testing

Figure 3. Deep Cobble-Revealed Textured Barrier Following Testing

2.1.2 Mission Arch Textured Barrier with a Type 60 Profile

In 2002, Peter et al. (2) conducted tests (TL-3) on a mission arch textured barrier with a Type 60 profile. The assembled barrier used for testing is shown in Figures 4 and 5. The test results are provided in Figure A-2.

Figure 4. Mission Arch Textured Barrier Prior to Testing

Figure 5. Mission Arch Textured Barrier Following Testing

2.1.3 Dry Stack Stone Textured Barrier with a Type 60 Profile

In 2002, Peter et al. (2) conducted tests (TL-3) on a dry stack stone textured barrier with a Type 60 profile. The assembled barrier used for testing is shown in Figures 6 and 7. The test results are provided in Figure A-3.

Figure 6. Dry Stack Stone Textured Barrier Prior to Testing

Figure 7. Dry Stack Stone Textured Barrier Following Testing

2.1.4 Fractured Granite Textured Barrier with a Type 60 Profile

In 2002, Peter et al. (2) conducted tests (TL-3) on a fractured granite textured barrier with a Type 60 profile. The assembled barrier used for testing is shown in Figures 8 and 9. The test results are provided in Figure A-4.

Figure 8. Fractured Granite Textured Barrier Prior to Testing

Figure 9. Fractured Granite Textured Barrier Following Testing

2.1.5 Rough Stone Masonry Guardwall

In 2004, Bullard, Jr. et al. (3) conducted tests (TL-3) on a reinforced precast or cast-in-place concrete stone veneered highway barrier. The assembled barrier used for testing is shown in Figures 10 and 11, the layout is shown in Figure 12, and the test results are provided in Figure A-5.

Figure 10. Top View of Rough Stone Masonry Guardwall

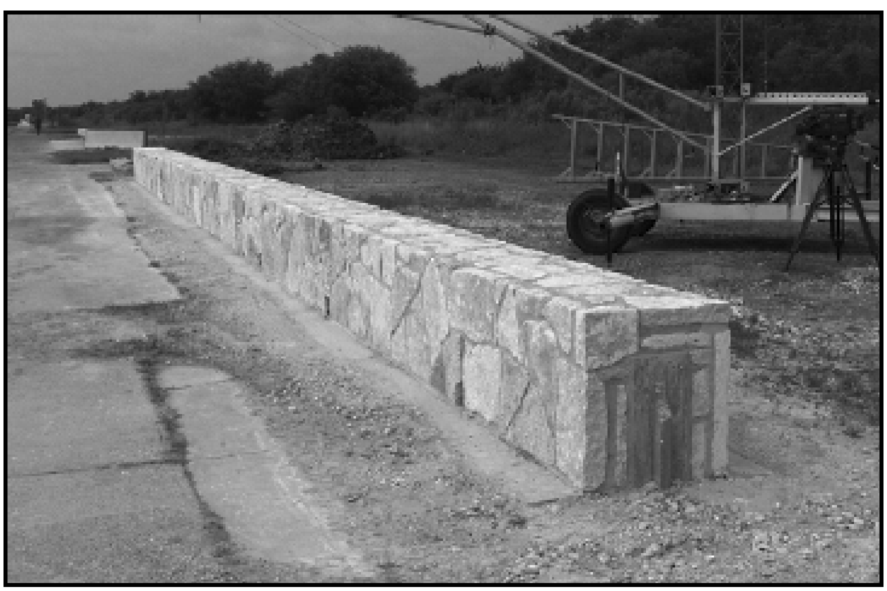

Figure 11. Overall View of Rough Stone Masonry Guardwall

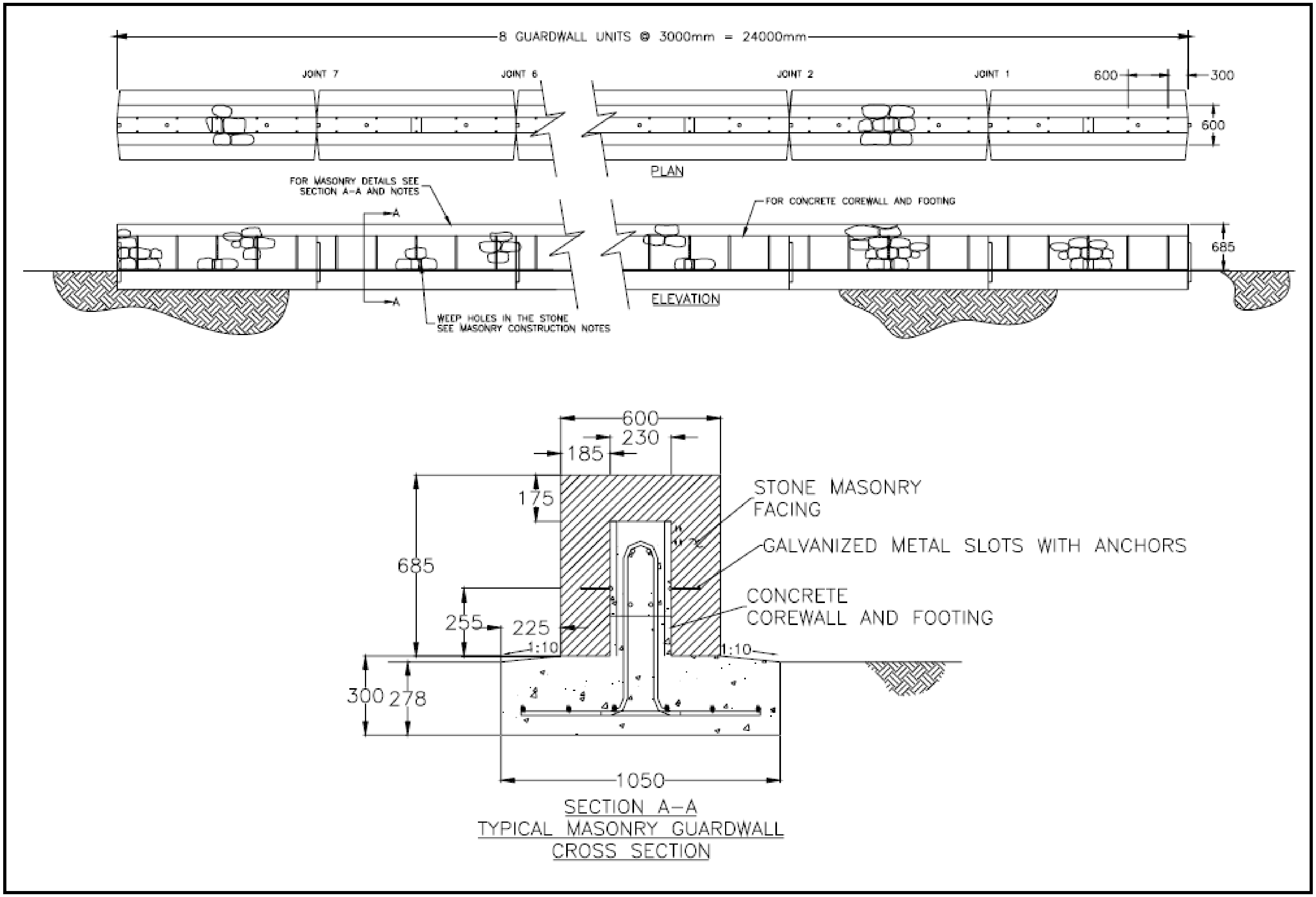

Figure 12. Layout and Cross Section of Rough Stone Masonry Guardwall

2.1.6 Pre-cast Concrete Guardwall

This Pre-cast Concrete Guardwall has been crash tested and meets the requirements of NCHRP Report 230 (4). Though never crash tested to TL-3, the FHWA has accepted this guardwall for use on federal highways (5). The assembled barrier in use on a federal highway is shown in Figures 12 and 13, and the layout is shown in Figure 14.

Figure 13. Top View of Pre-cast Concrete Guardwall

Figure 14. Overall View of Pre-cast Concrete Guardwall

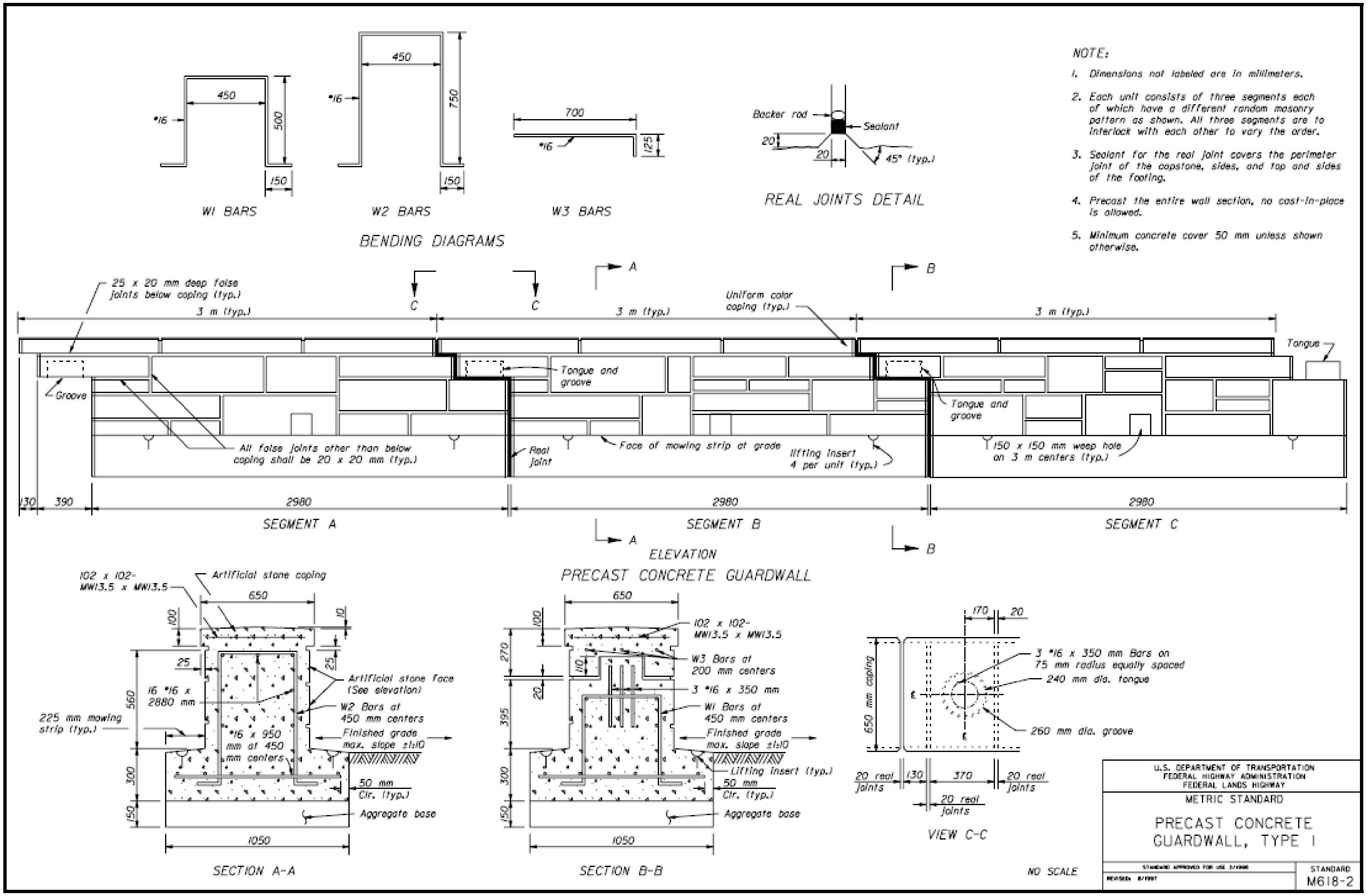

Figure 15. Layout and Cross Section of Pre-cast Concrete Guardwall

2.2 Guardrails

A limited amount of research has been conducted on post and beam guardrails. This section is a summary of those studies and results that are relevant to this project.

2.2.1 Type A Steel-Backed Timber Guardrail

In 2004, Bullard, Jr. et al. (3) conducted tests (TL-3) on a steel-backed wood post and wood rail. The assembled guardrail used for testing is shown in Figures 16 and 17, the layout is shown in Figure 18, and the test results are provided in Figure A-6.

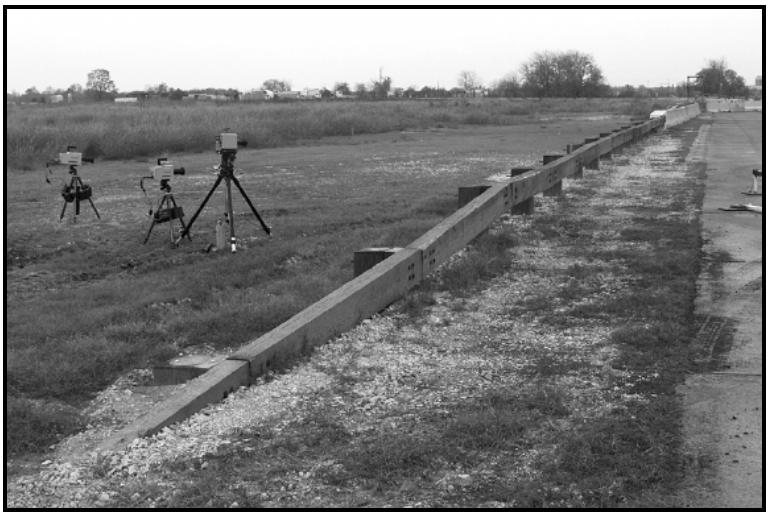

Figure 16. Overall View of Type A Steel-Backed Timber Guardrail

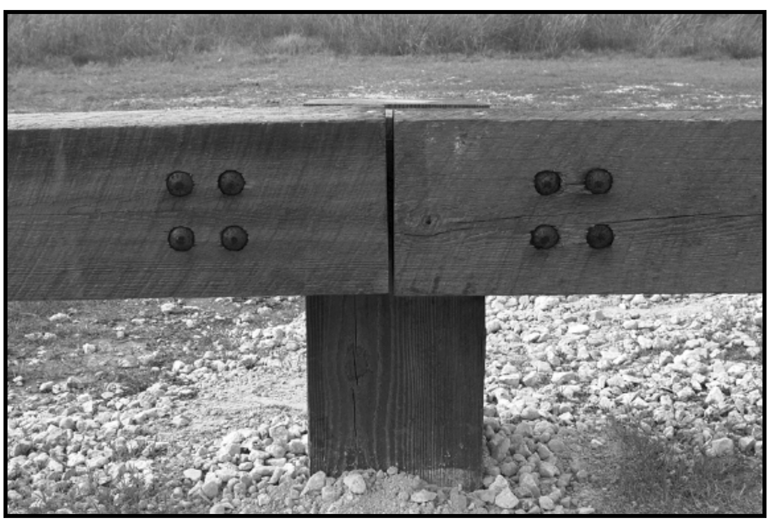

Figure 17. View of Type A Steel-Backed Timber Guardrail Post Splice

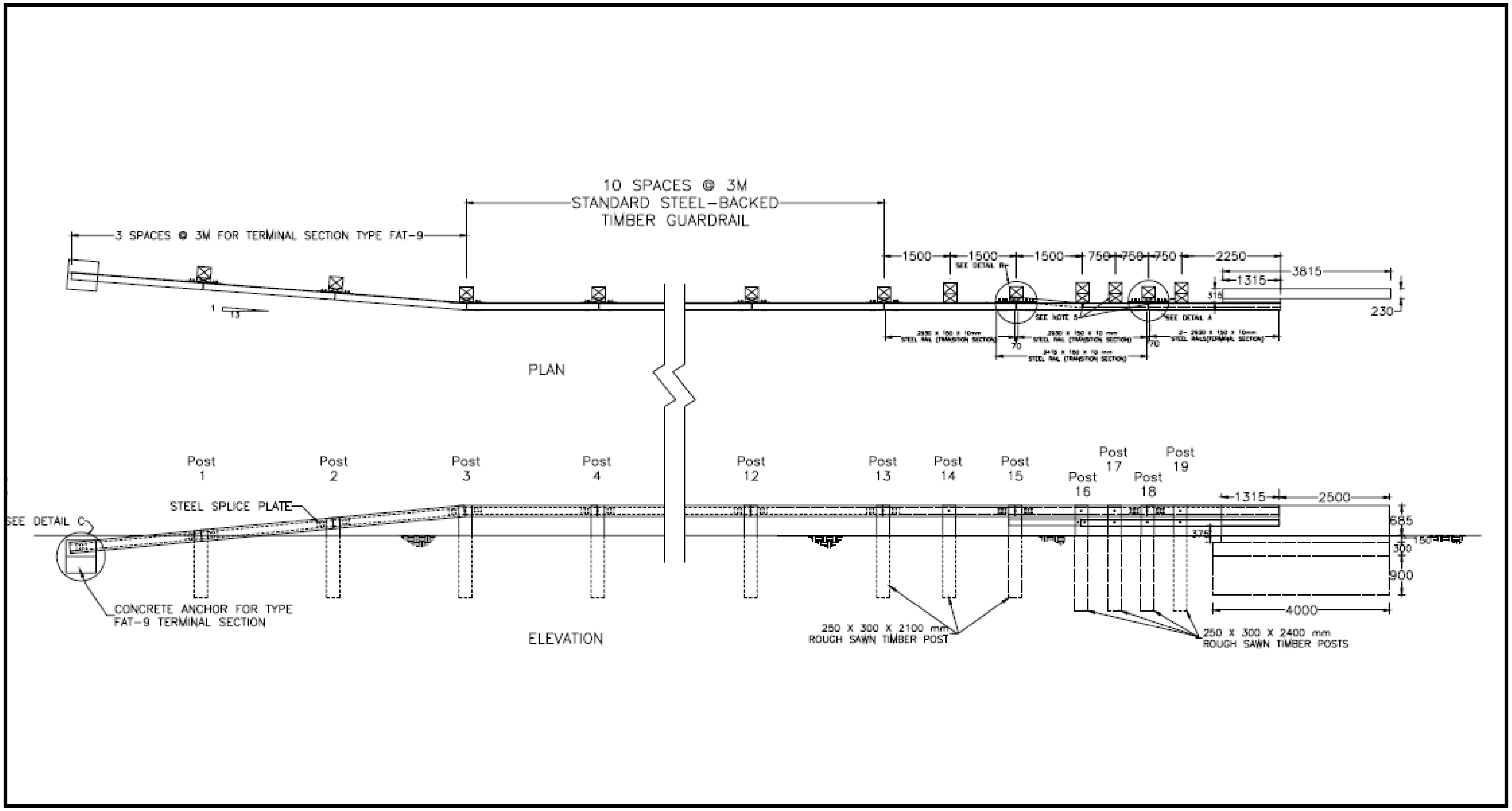

Figure 18. Layout of Type A Steel-Backed Timber Guardrail

2.2.2 Type B Steel-Backed Timber Guardrail

In 2004, Bullard, Jr. et al. (3) conducted tests (TL-2) on a steel-backed wood post and wood rail barrier. The assembled guardrail used for testing is shown in Figures 19 and 20, the layout is shown in Figure 21, and the test results are provided in Figure A-9.

Figure 19. Traffic Side View of Type B Steel-Backed Timber Guardrail

Figure 20. Field Side View of Type B Steel-Backed Timber Guardrail

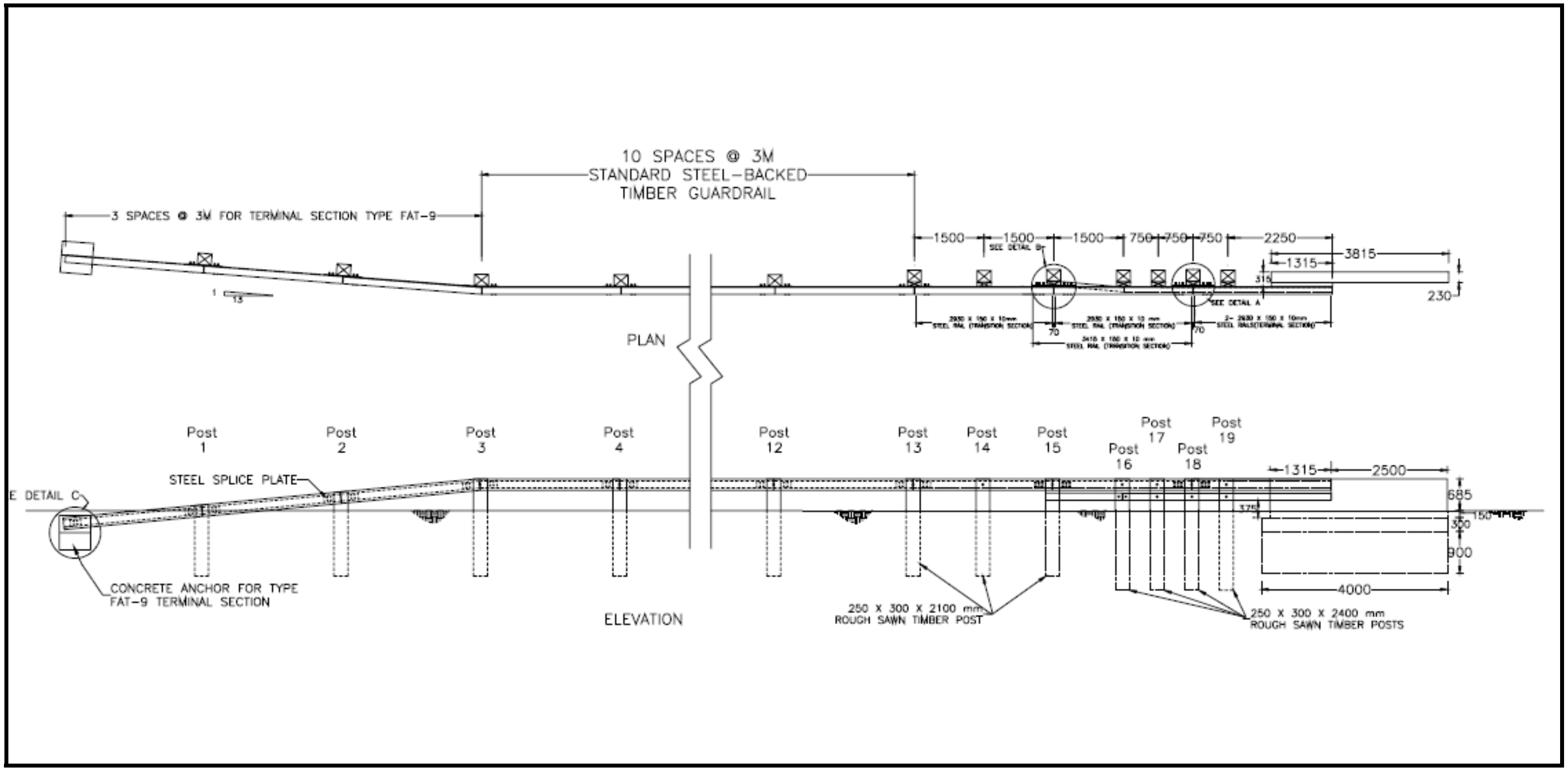

Figure 21. Layout of Type B Steel-Backed Timber Guardrail

2.2.3 Steel-Backed Timber Round Log Rail

In 2004, Bullard, Jr. et al. (3) conducted tests (TL-2) on a steel-backed timber beam-and-post railing system. The assembled guardrail used for testing is shown in Figures 22 and 23, the layout is shown in Figure 24, and the test results are provided in Figures A-7 and A-8.

Figure 22. Traffic Side View of Steel-Backed Timber Round Log Rail

Figure 23. Field Side View of Steel-Backed Timber Round Log Rail

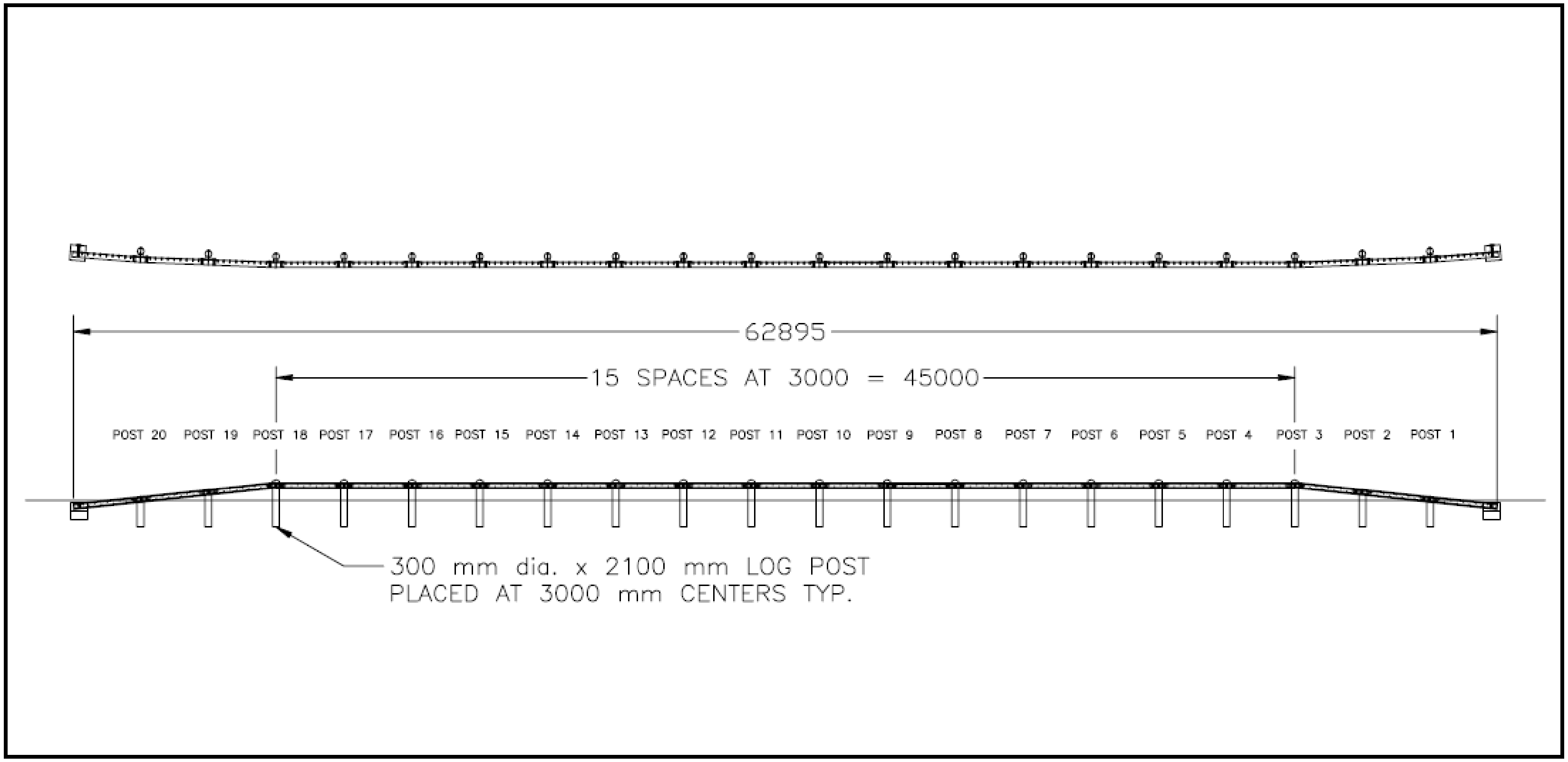

Figure 24. Layout of Steel-Backed Timber Round Log Rail

2.2.4 Glacier Removable Rail

In 2004, Bullard, Jr. et al. (3) conducted tests (TL-2) on a steel-backed timber beam and steel post railing system supported by a cantilevered steel beam embedded in the side of a cast-in-place concrete footing. The assembled guardrail used for testing is shown in Figures 25 and 26, the layout is shown in Figure 27, and the test results are provided in Figures A-10 and A-11.

Figure 25. Traffic Side View of Glacier Removable Rail

Figure 26. Field Side View of Glacier Removable Rail

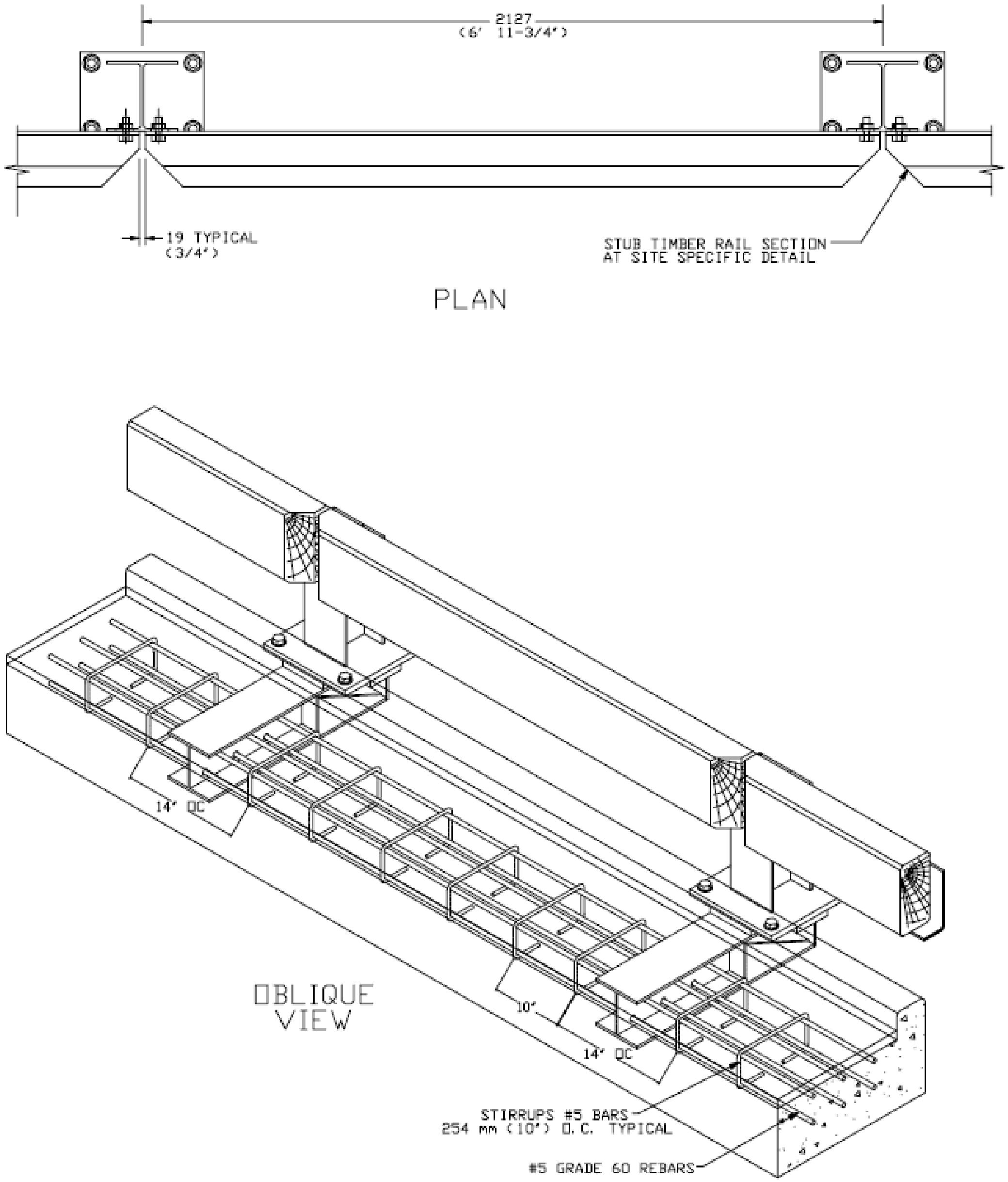

Figure 27. Plan and Oblique Views of Glacier Removable Rail

2.2.5 Glacier Round Log Removable Rail

In 2004, Bullard, Jr. et al. (3) conducted tests (TL-1) on a steel-backed timber beam and steel post railing system supported by a cast-in-place concrete footing. The assembled guardrail used for testing is shown in Figures 28 and 29, the layout is shown in Figure 30, and the test results are provided in Figures A-12 and A-13.

Figure 28. Traffic Side View of Glacier Round Log Removable Rail

Figure 29. Field Side View of Glacier Round Log Removable Rail

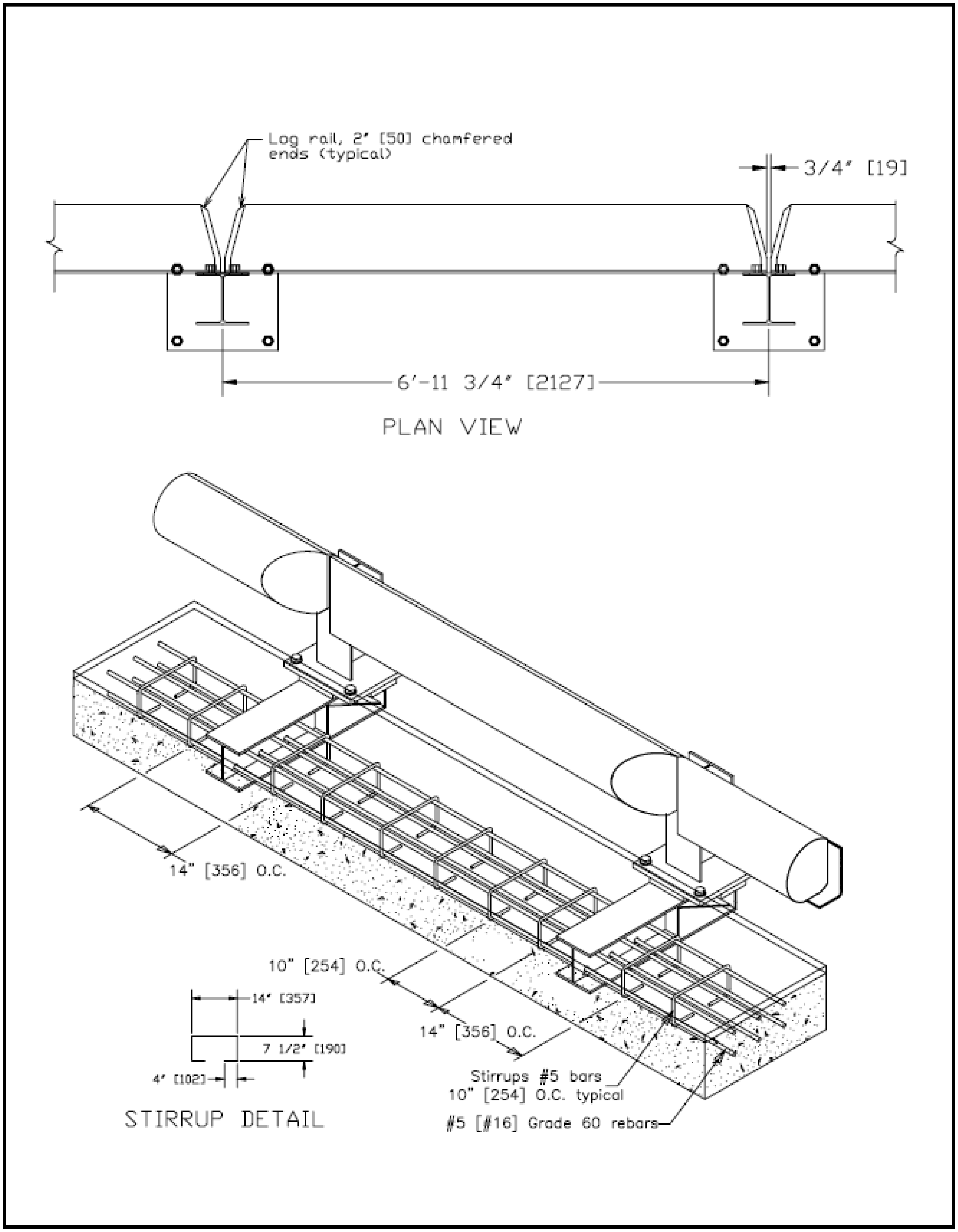

Figure 30. Plan and Oblique Views of Glacier Removable Rail

2.2.6 Deception Pass State Park Log Rail

In 2004, Jepperson et al. (6) conducted tests (TL-2) on a stone masonry bollard and steel-backed log rail system. The assembled guardrail used for testing is shown in Figures 31 and 32, the layout is shown in Figure 33, and the test results are provided in Figures A-14 and A-15.

Figure 31. Deception Pass State Park Log Rail Prior to Testing

Figure 32. Deception Pass State Park Log Rail Following Testing

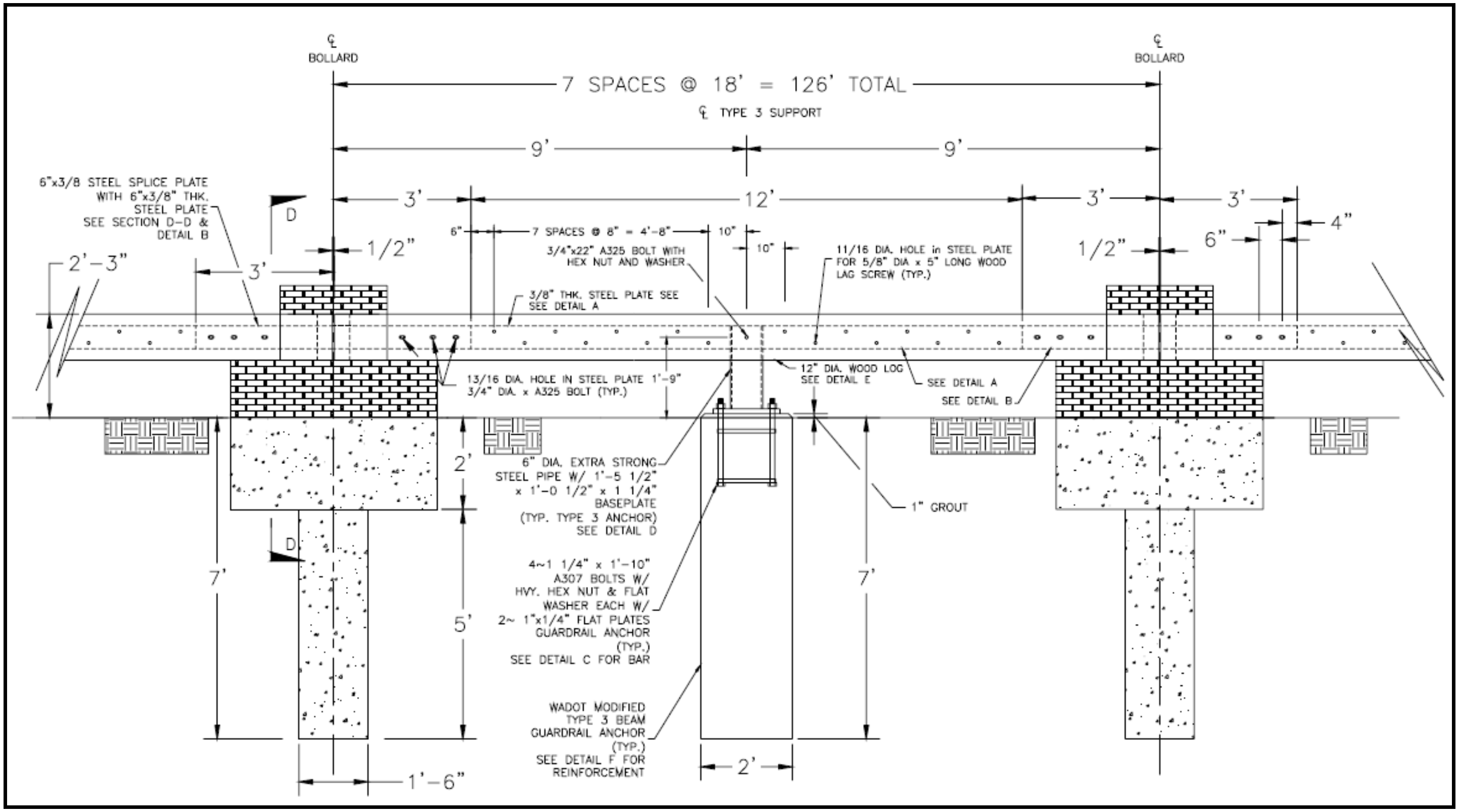

Figure 33. Layout of Deception Pass State Park Log Rail

2.2.7 Ironwood Guardrail

In 1999, Hubbell (7) conducted tests (TL-3) on a composite wood and steel rail system. The assembled guardrail in use on a federal highway is shown in Figures 34, the layout is shown in Figure 35, and the test results are provided in Figures A-16 and A-17.

Figure 34. Ironwood Guardrail in Use on a Federal Highway

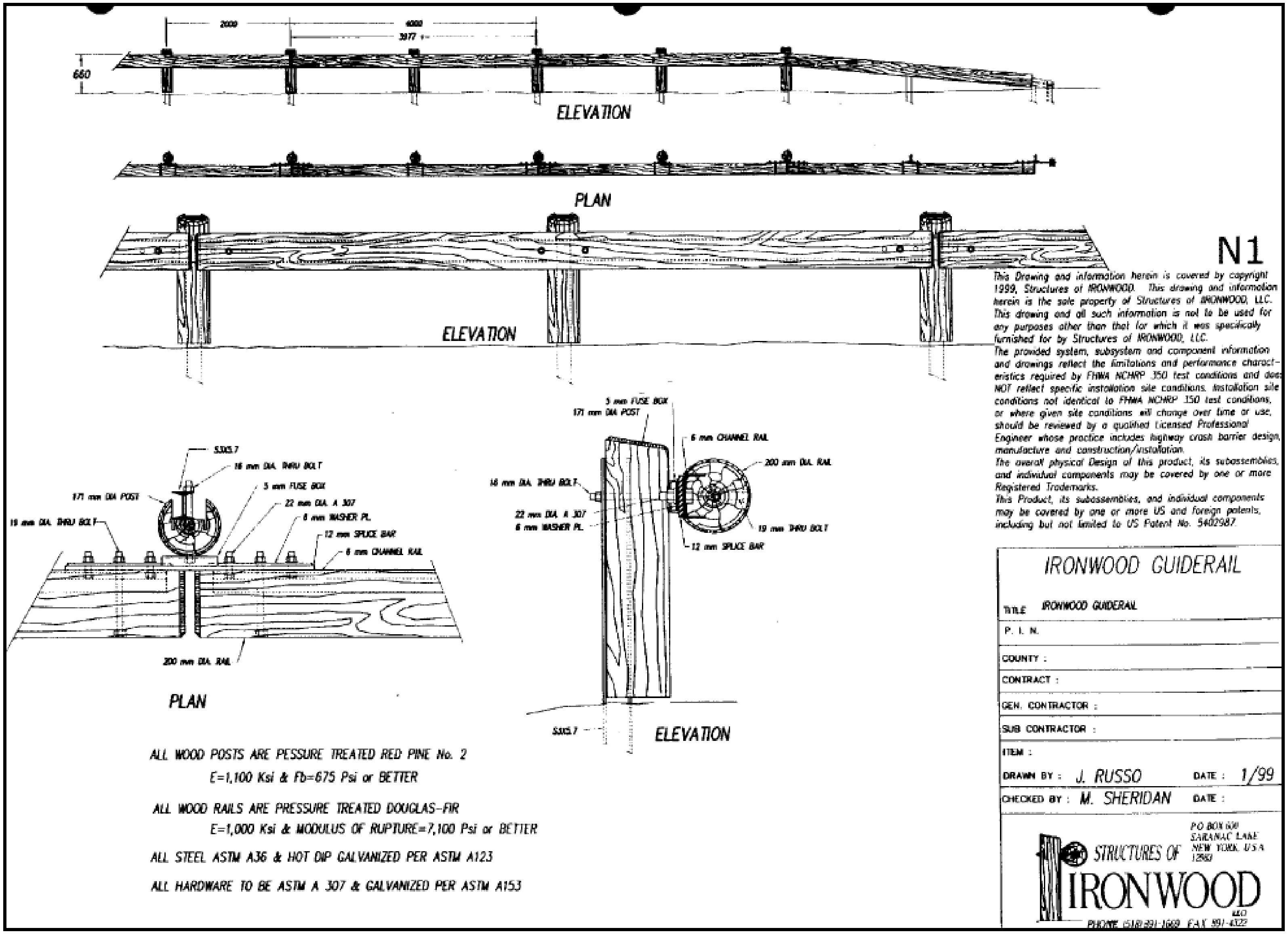

Figure 35. Layout and Cross Section of Ironwood Guardrail

2.3 Bridge Rails

A large amount of research has been conducted on bridge rails, such as open concrete and tubular steel bridge rails. Due to extensive amount of existing research, only some examples of these types of rails have been presented in this literature search. Additional information can be provided concerning such rails if needed.

2.3.1 George Washington Memorial Parkway (GWMP) Bridge Rail

In 2004, Bullard, Jr. et al. (3) conducted tests (TL-3) on a steel tri-rail mounted on curb bridge rail, which is a bam-and-post system consisting of three steel pipe rail elements welded to flat steel plate posts. The assembled bridge rail used for testing is shown in Figure 36, the layout is shown in Figure 37, and the test results are provided in Figure A-18.

Figure 36. Traffic Side View of GWMP Bridge Rail

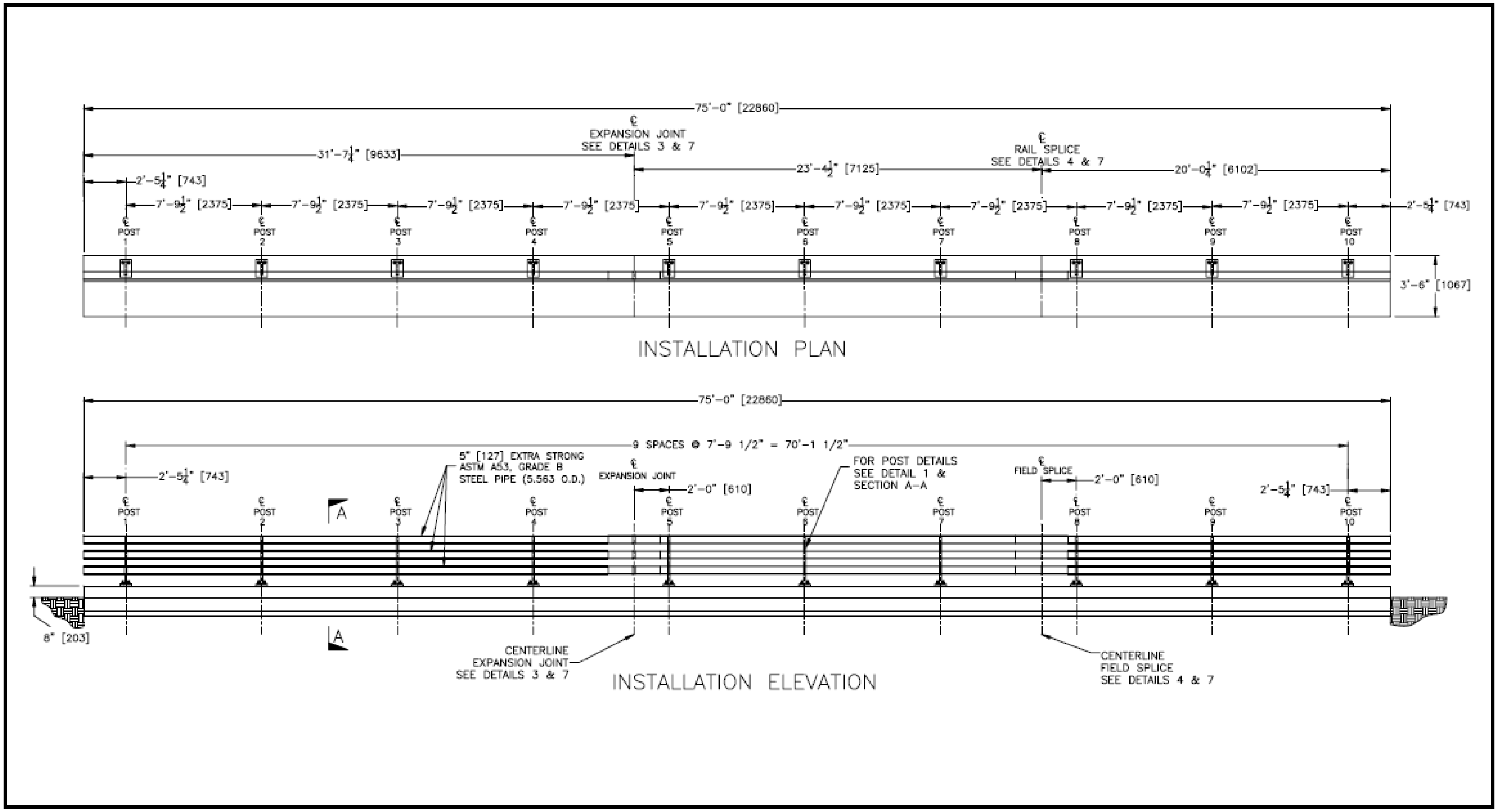

Figure 37. Layout of George Washington Memorial Parkway Bridge Rail

2.3.2 Open Concrete Rail - Natchez Trace Bridge Rail

In 2004, Bullard, Jr. et al. (3) conducted tests (TL-3) on a concrete beam-and-post bridge rail mounted on top of a concrete curb. The assembled bridge rail used for testing is shown in Figures 38 and 39, the layout is shown in Figure 40, and the test results are provided in Figures A-19 and A-20.

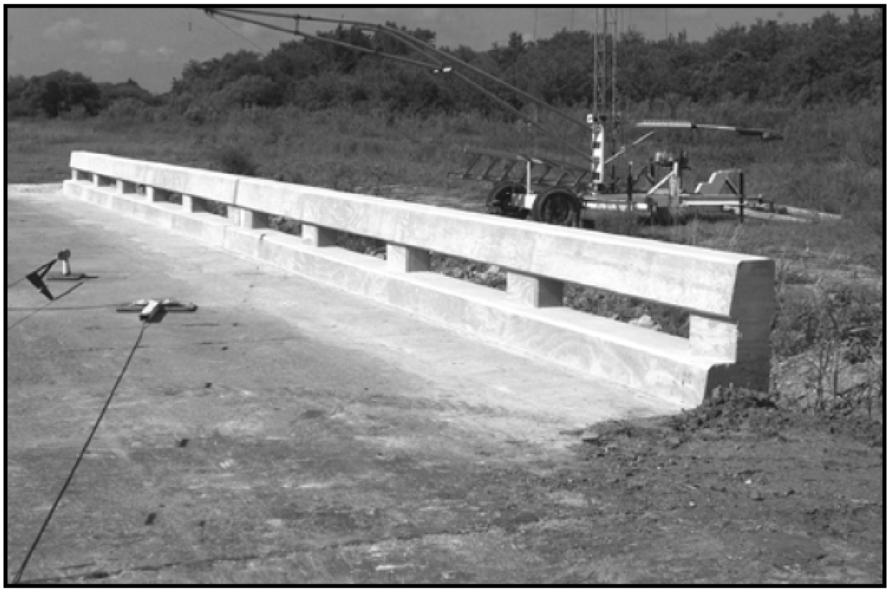

Figure 38. Traffic Side View of Natchez Trace Bridge Rail

Figure 39. Field Side View of Natchez Trace Bridge Rail

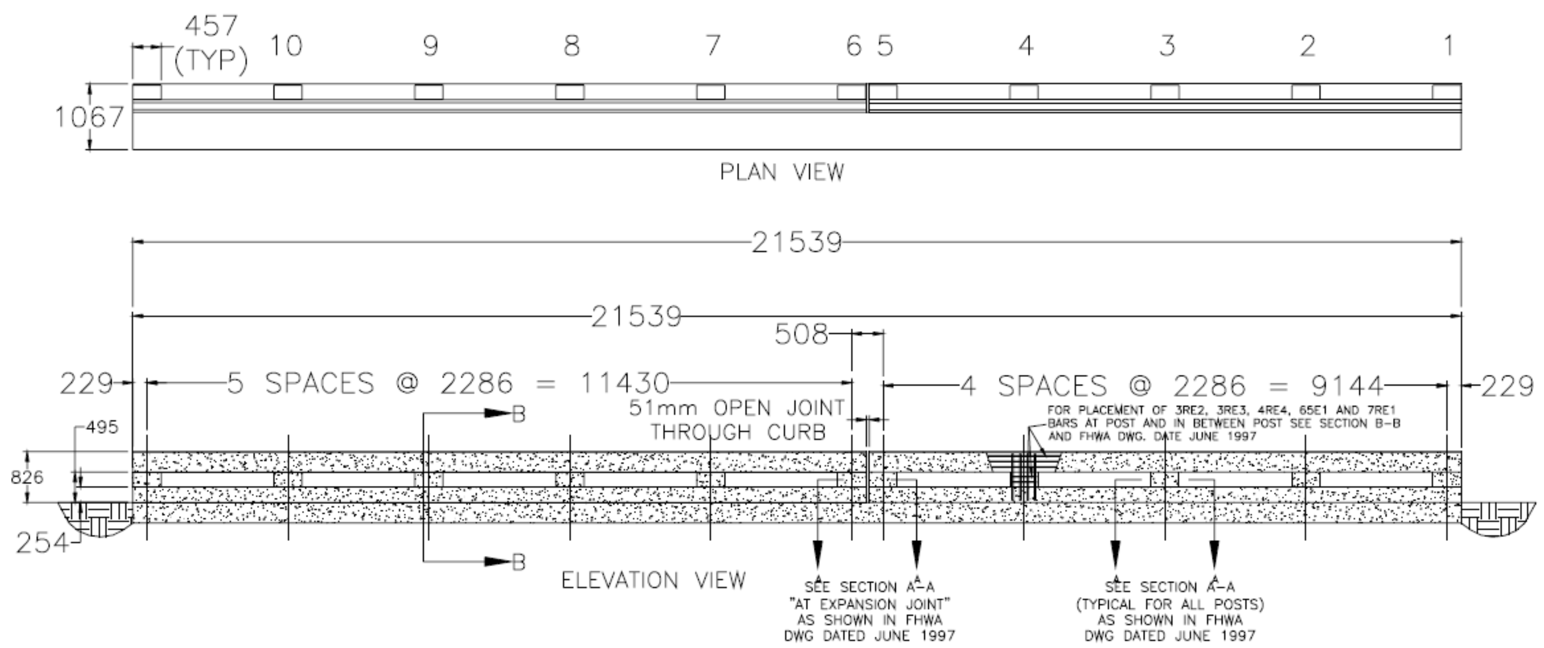

Figure 40. Layout of Natchez Trace Bridge Rail

2.3.3 Tubular Steel-Backed Timber Bridge Rail

In 2004, Bullard, Jr. et al. (3) conducted tests (TL-3) on a tubular steel-backed timber beam-and-post railing system. The assembled bridge rail used for testing is shown in Figures 41 and 42, the layout is shown in Figure 43, and the test results are provided in Figure A-21.

Figure 41. Traffic Side View of Tubular Steel-Backed Timber Bridge Rail

Figure 42. Field Side View of Tubular Steel-Backed Timber Bridge Rail

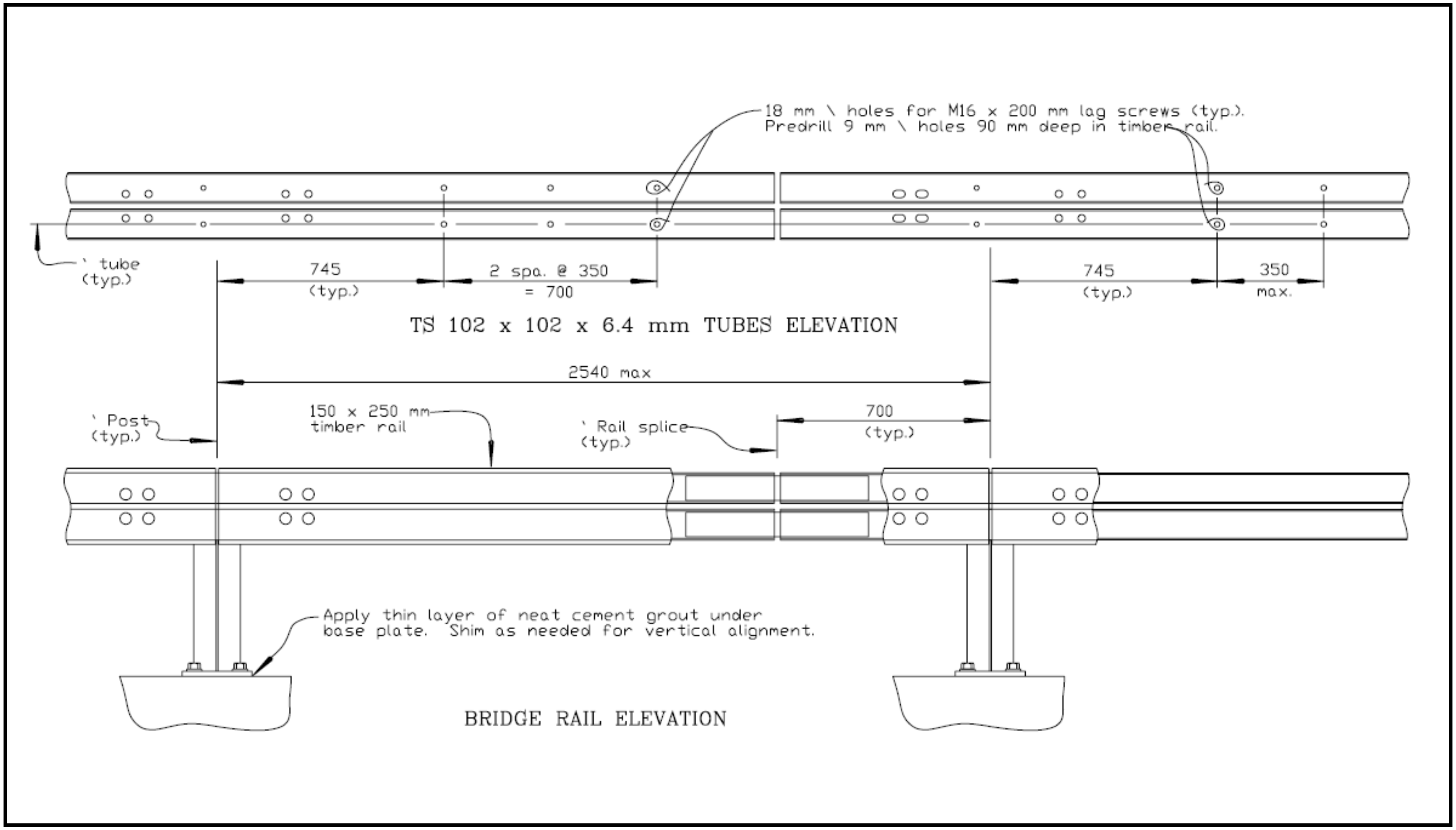

Figure 43. Layout of Tubular Steel-Backed Timber Bridge Rail

2.3.4 NDOR Low-Profile Bridge Rail

In 2002, Polivka et al. (15) conducted tests (TL-2) on a reinforced concrete bridge railing system. The assembled bridge rail used for testing is shown in Figures 44 and 45, the layout is shown in Figure 46, and the test results are provided in Figures A-22.

Figure 44. NDOR Low-Profile Bridge Rail

Figure 45. NDOR Low-Profile Bridge Rail

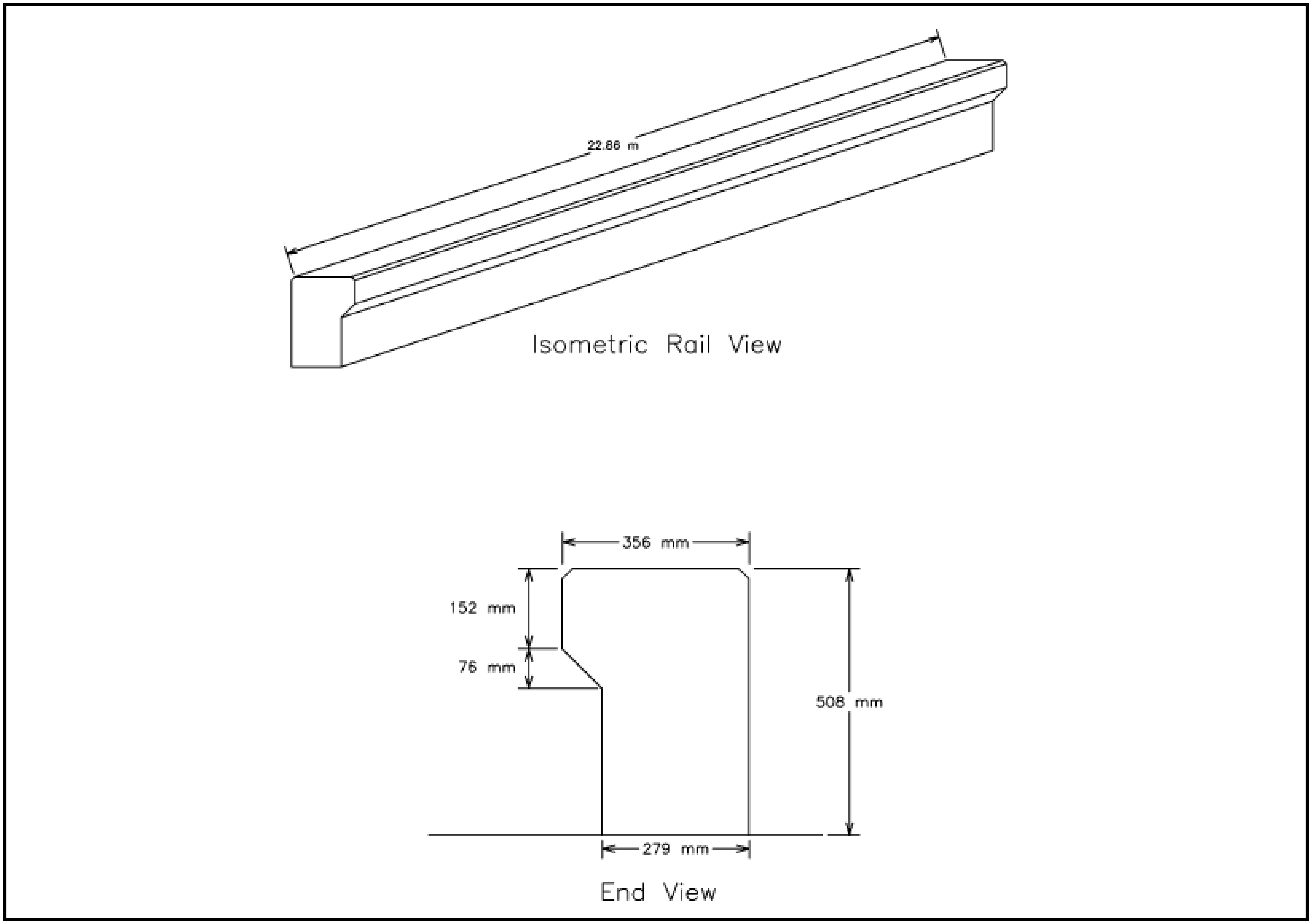

Figure 46. Layout of NDOR Low-Profile Bridge Rail

2.3.5 NDOR Aesthetic Open Concrete Bridge Rail

In 2005, Polivka et al. (8) conducted tests (TL-5) on an aesthetic open concrete bridge railing system. The assembled bridge rail used for testing is shown in Figures 47 and 48, the layout is shown in Figure 49, and the test results are provided in Figure A-23.

Figure 47. NDOR Aesthetic Open Concrete Bridge Rail

Figure 48. NDOR Aesthetic Open Concrete Bridge Rail

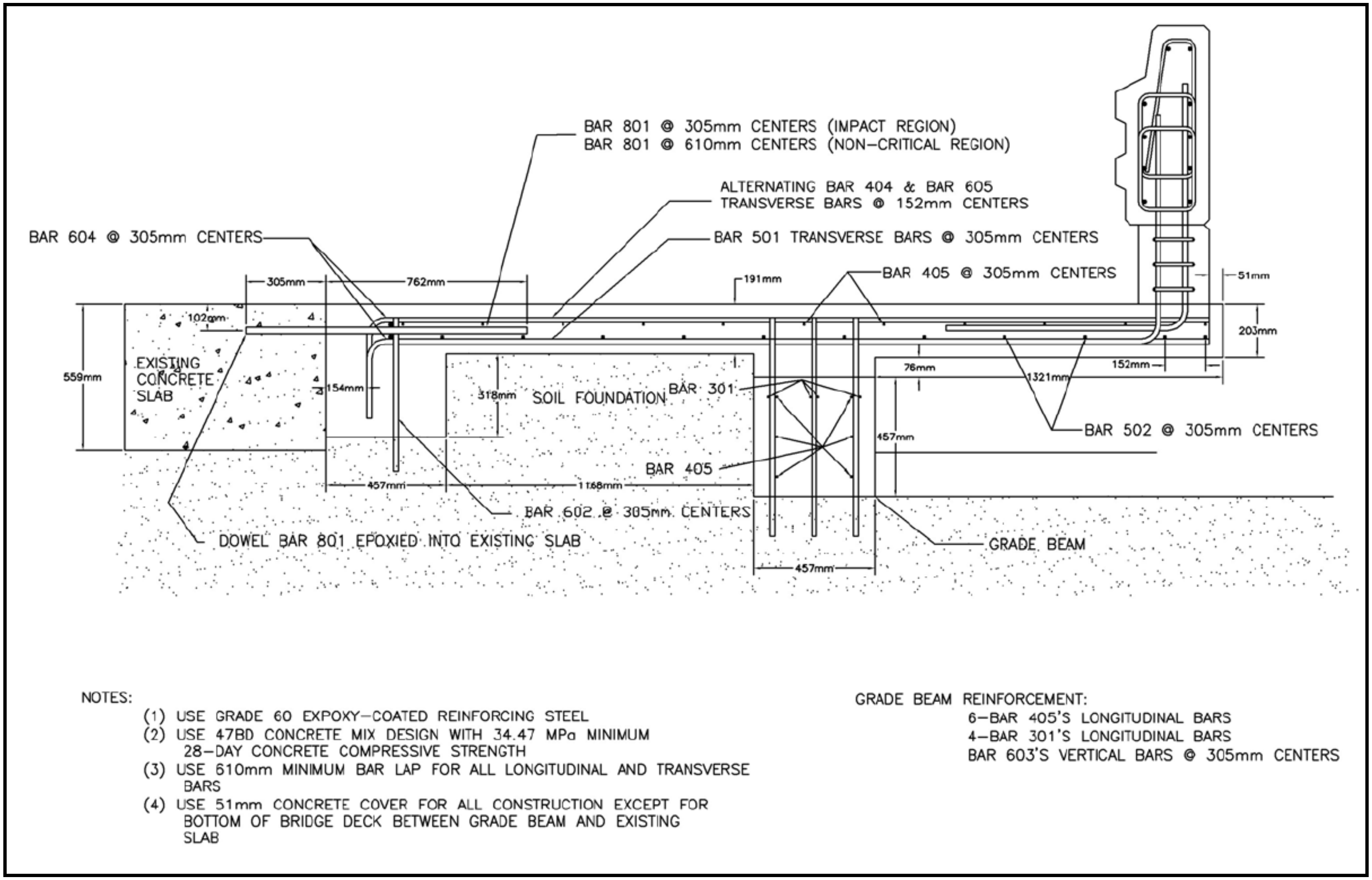

Figure 49. Layout of NDOR Aesthetic Open Concrete Bridge Rail

2.3.6 TxDOT F411 Bridge Rail

In 2002, Bullard, Jr. et al. (9) conducted tests (TL-3) on an aesthetic concrete bridge railing system. The assembled bridge rail used for testing is shown in Figures 50 and 51, the layout is shown in Figure 52, and the test results are provided in Figures A-24 and A-25.

Figure 50. TxDOT F411 Bridge Rail

Figure 51. TxDOT F411 Bridge Rail

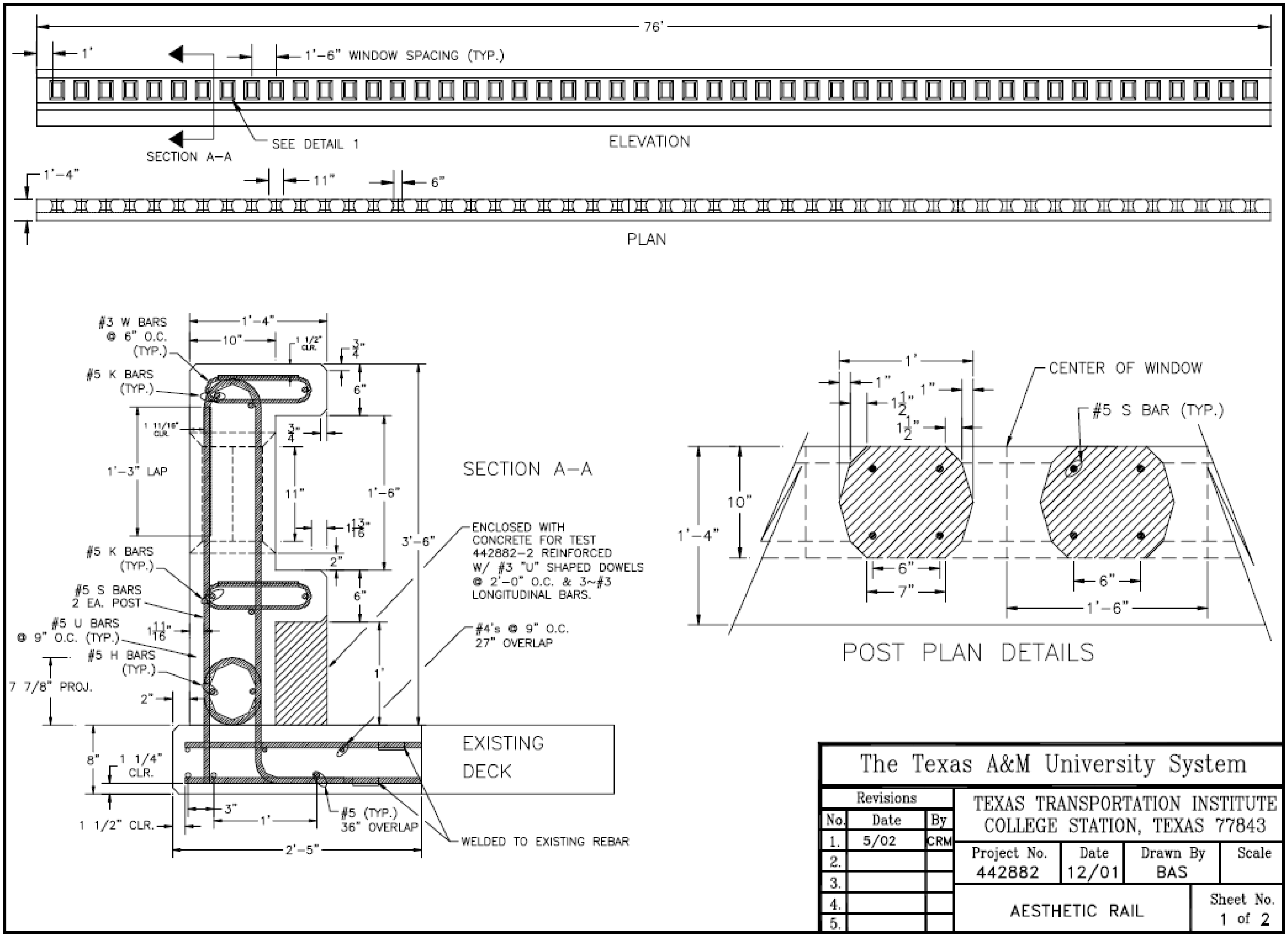

Figure 52. Layout of TxDOT F411 Bridge Rail

2.3.7 Tubular Steel Bridge Rail - TxDOT T77 Bridge Rail

In 2002, Bullard, Jr. et al. (9) conducted tests (TL-3) on an aesthetic tubular steel bridge railing system. The assembled bridge rail used for testing is shown in Figures 53 and 54, the layout is shown in Figure 55, and the test results are provided in Figures A-26 and A-27.

Figure 53. TxDOT T77 Bridge Rail

Figure 54. TxDOT T77 Bridge Rail

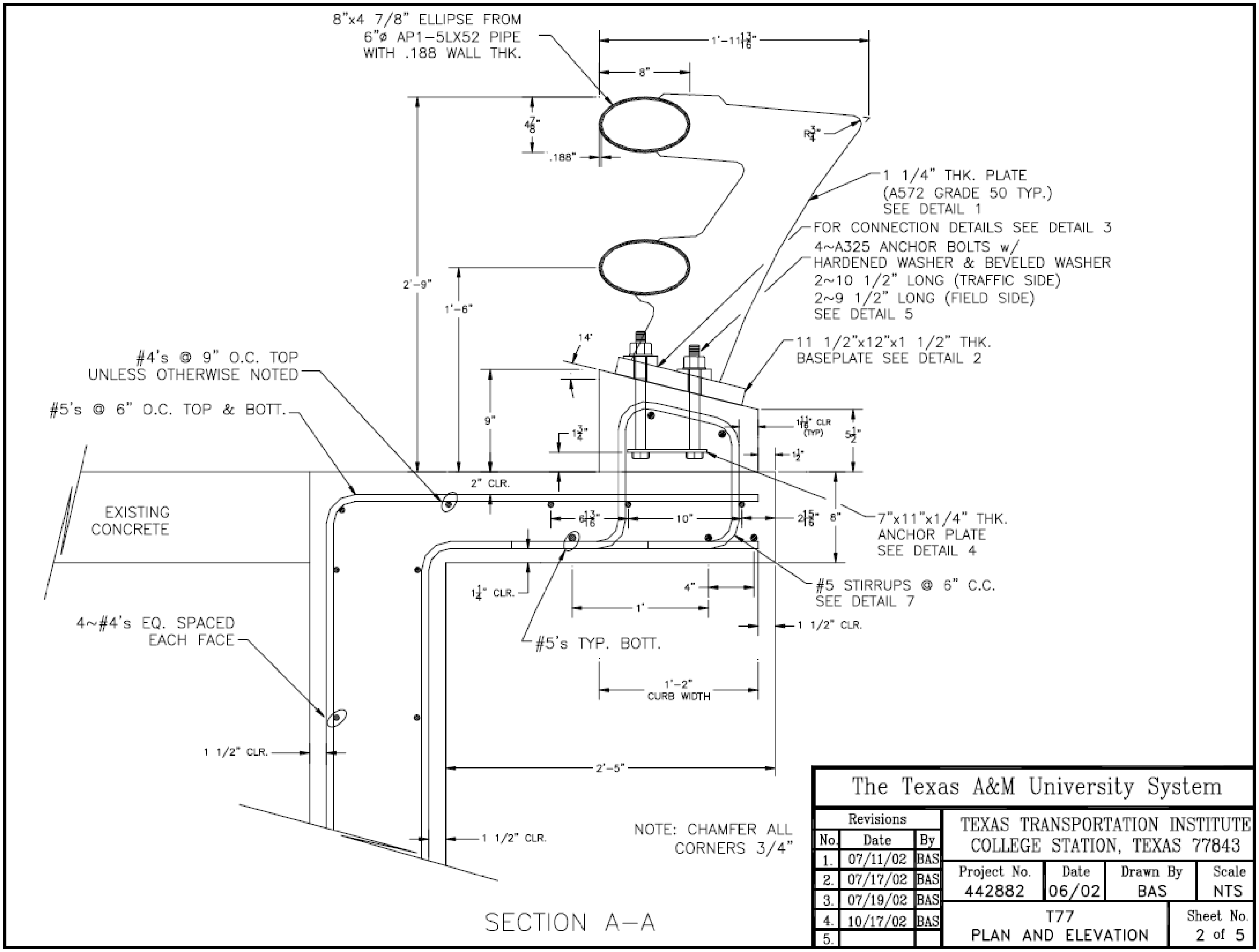

Figure 55. Layout of TxDOT T77 Bridge Rail

2.3.8 TxDOT T411 Bridge Rail

In 1998, Buth et al. (10) conducted tests (TL-3) on an aesthetic concrete bridge railing system. The assembled bridge rail used for testing is shown in Figures 56 and 57, the layout is shown in Figure 58, and the test results are provided in Figures A-28.

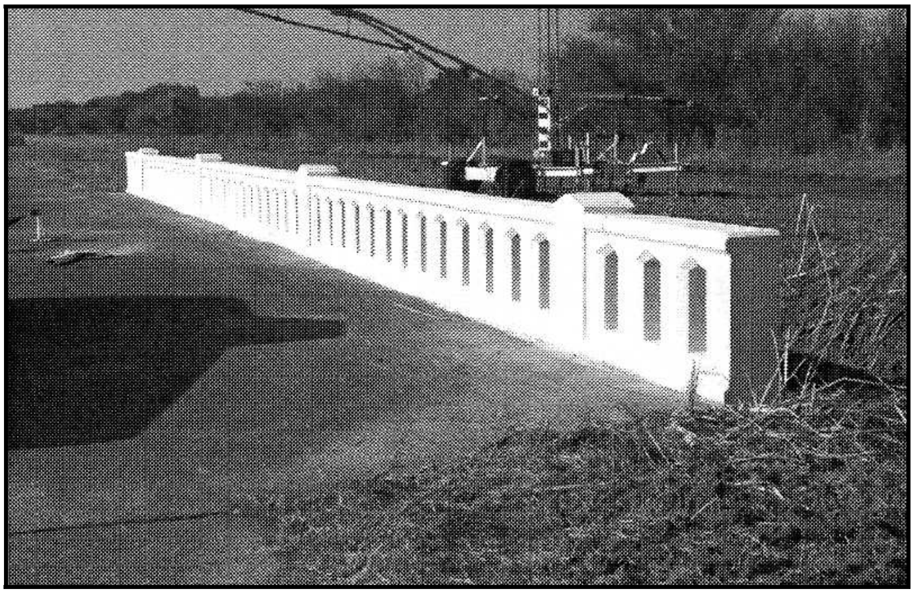

Figure 56. TxDOT T411 Bridge Rail

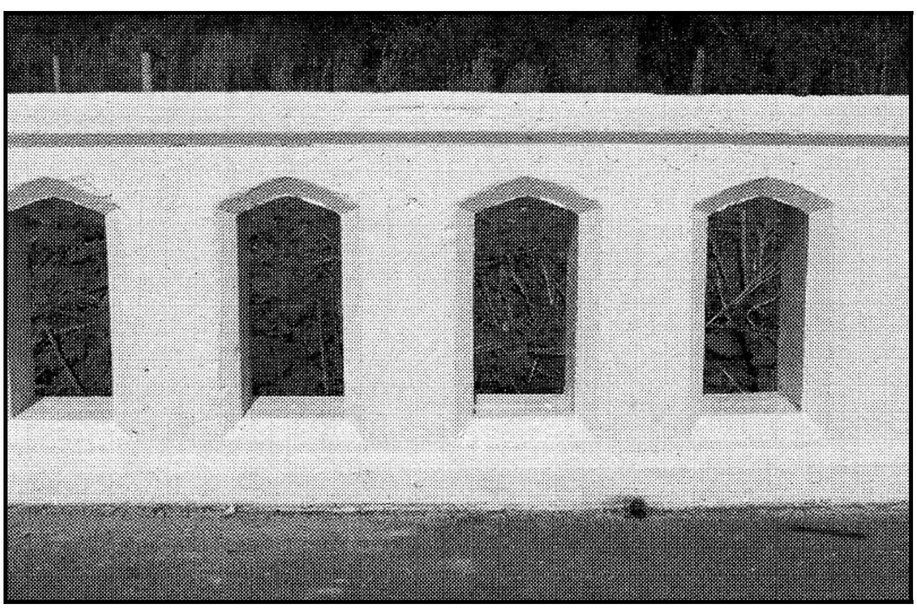

Figure 57. TxDOT T411 Bridge Rail

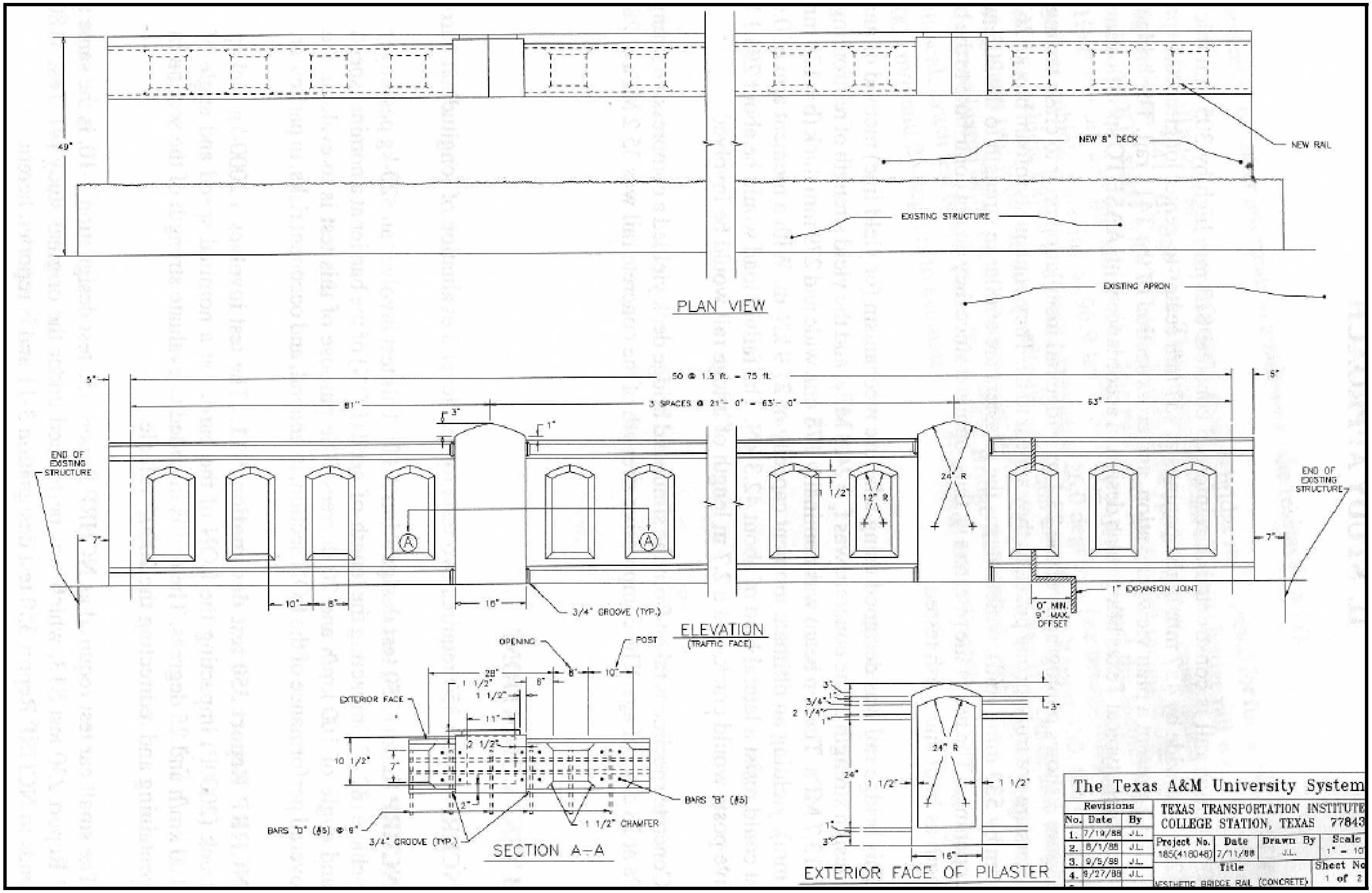

Figure 58. Layout and Cross Section of TxDOT T411 Bridge Rail

2.3.9 Forest Service Glulam Bridge Rail

In 1990, Hancock et al. (11) conducted tests (TL-2) on a glulam timber bridge railing system. The assembled bridge rail used for testing is shown in Figures 59 and 60, the layout is shown in Figure 61, and the test results are provided in Figures A-29 and A-30.

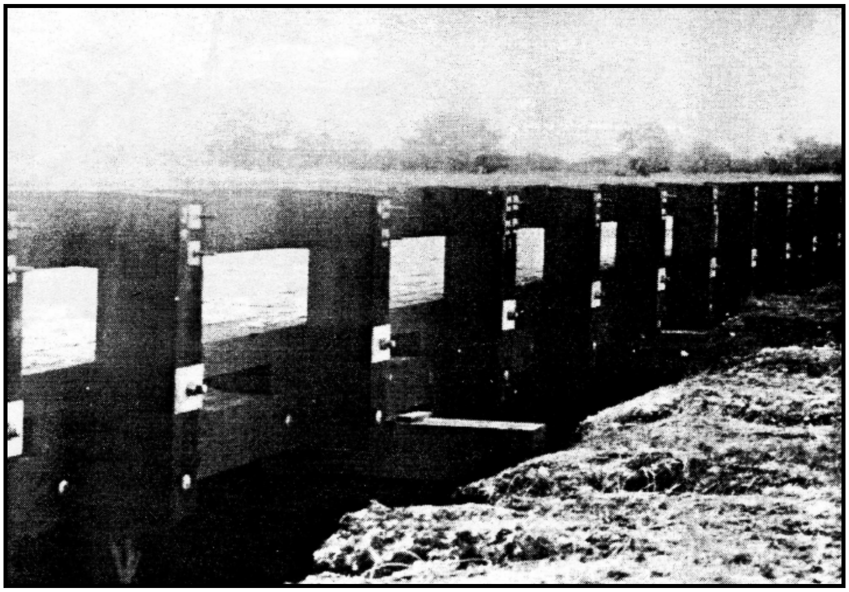

Figure 59. Forest Service Glulam Bridge Rail

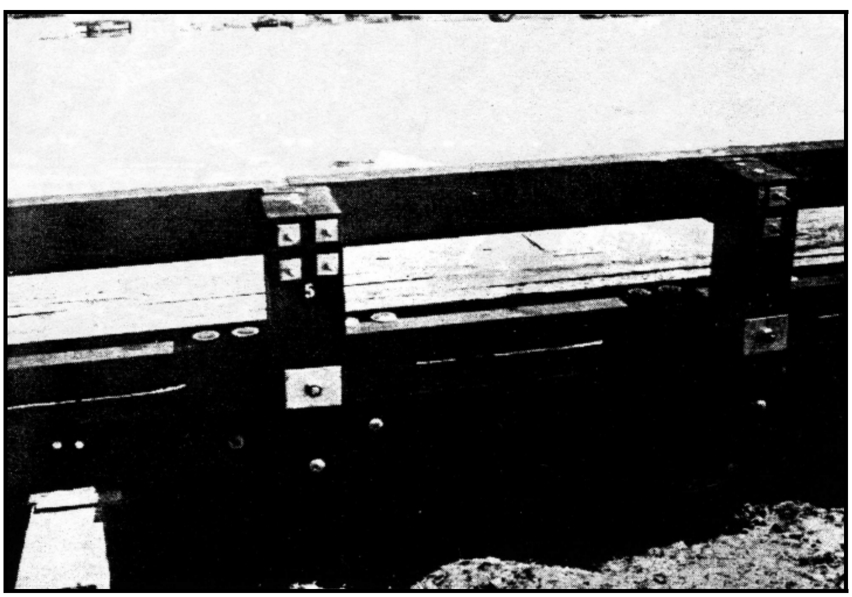

Figure 60. Forest Service Glulam Bridge Rail

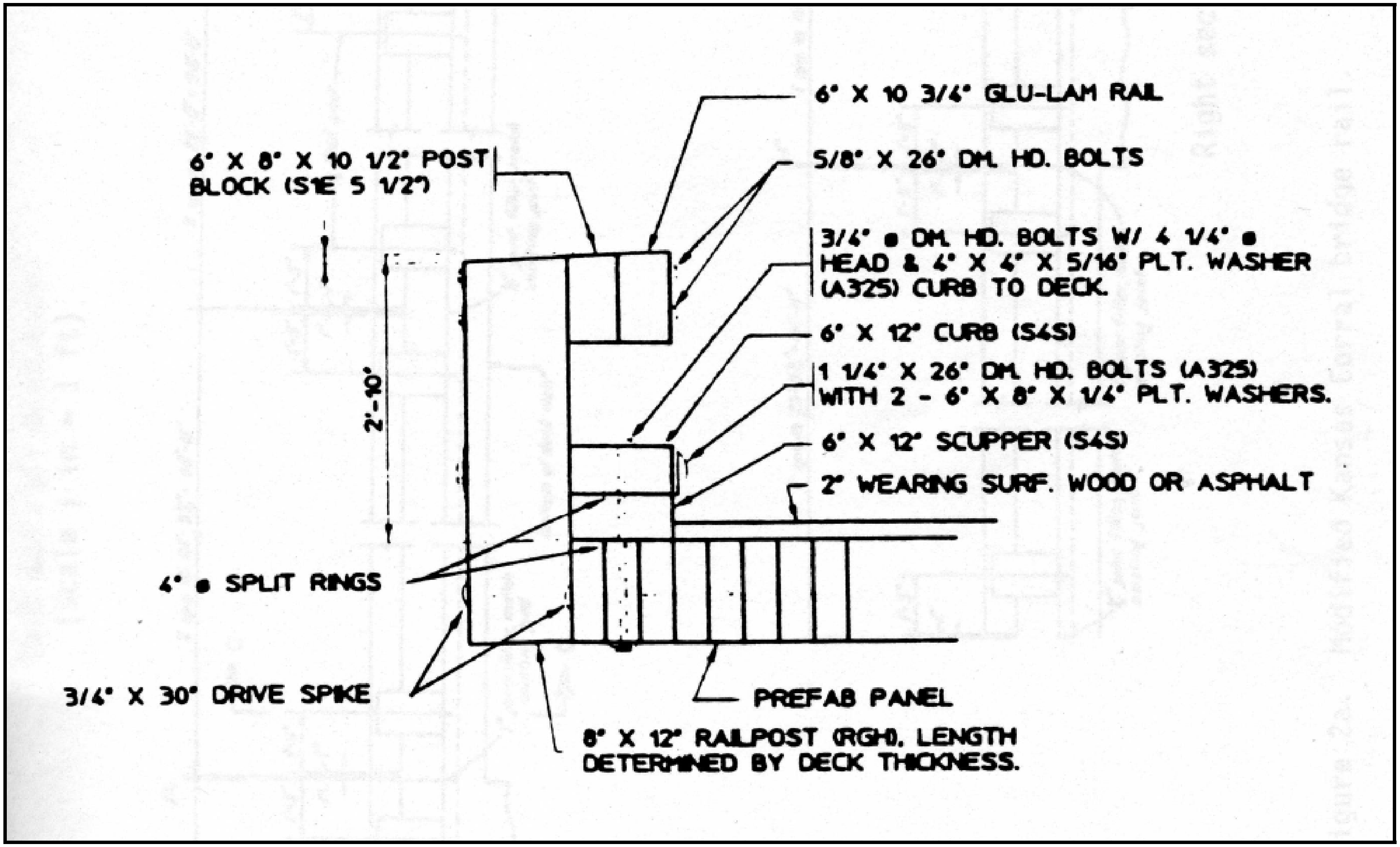

Figure 61. Cross Section of Forest Service Glulam Bridge Rail

2.3.10 Curb-Type Glulam Bridge Rail

In 1996, Faller et al. (12) conducted tests (TL-1) on a timber curb-type bridge railing system. The assembled bridge rail used for testing is shown in Figures 62 and 63, the layout is shown in Figure 64, and the test results are provided in Figures A-31.

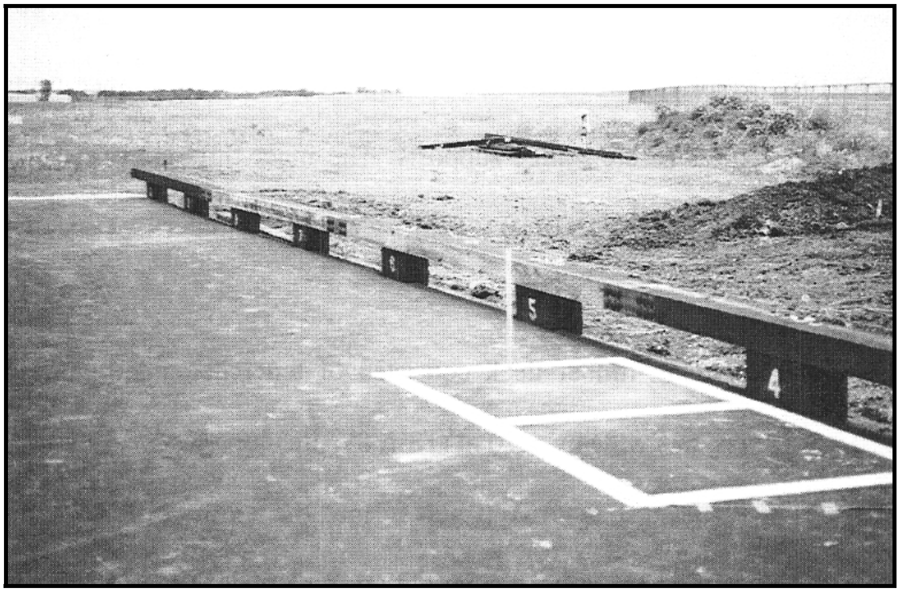

Figure 62. Curb-Type Glulam Bridge Rail

Figure 63. Curb-Type Glulam Bridge Rail

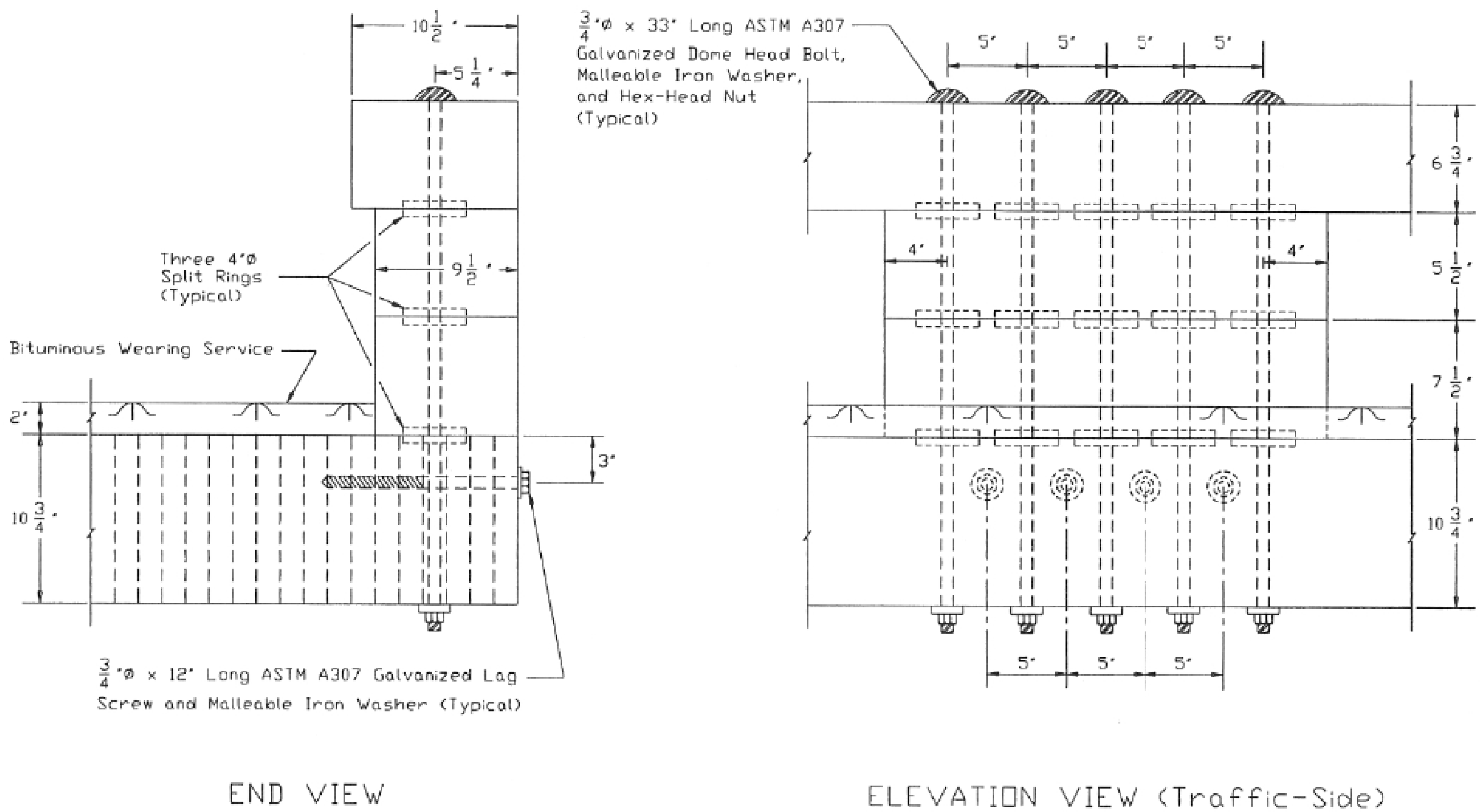

Figure 64. Cross Section of Curb-Type Glulam Bridge Rail

2.3.11 FPL Glulam Bridge Rail

In 2002 and 2003, Polivka et al. (13,14) conducted tests (TL-2 and TL-4) on a deck mounted glue-laminated timber bridge railing system. The assembled bridge rail used for testing is shown in Figures 65 and 66, the layout is shown in Figure 67, and the test results are provided in Figures A-32 through A-35.

Figure 65. FPL Glulam Bridge Rail

Figure 66. FPL Glulam Bridge Rail

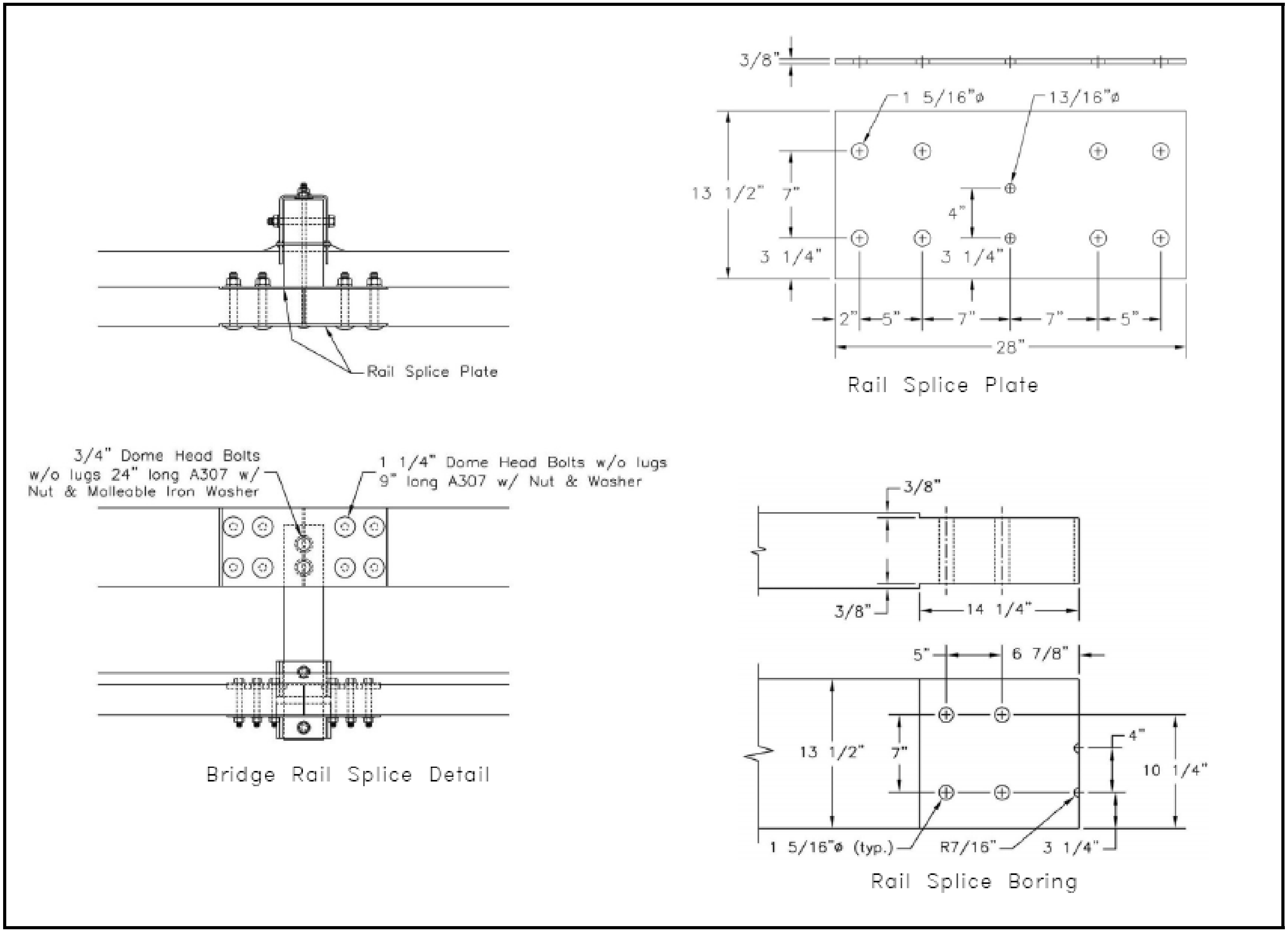

Figure 67. Splice Details of FPL Glulam Bridge Rail

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4 APPENDICES

APPENDIX A Test Summary Sheets

A summary sheet for each test is provided in this section. Summary sheets include acceleration, velocity, and displacement of all barriers tested.

Data Summary Sheet

t= 0.000 sec | t= 0.250 sec | t= 0.500 sec | t= 0.750 sec

t= 1.000 sec | t= 1.250 sec | t= 1.500 sec | t= 1.750 sec

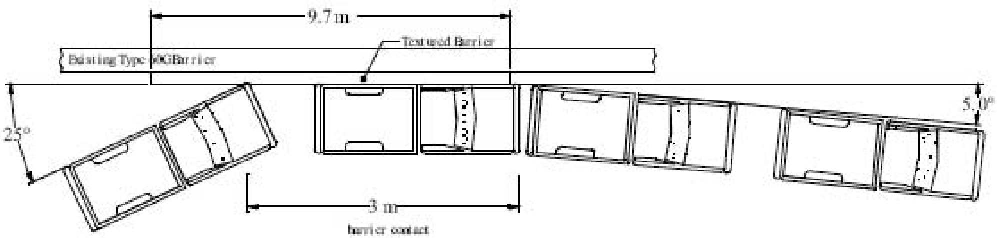
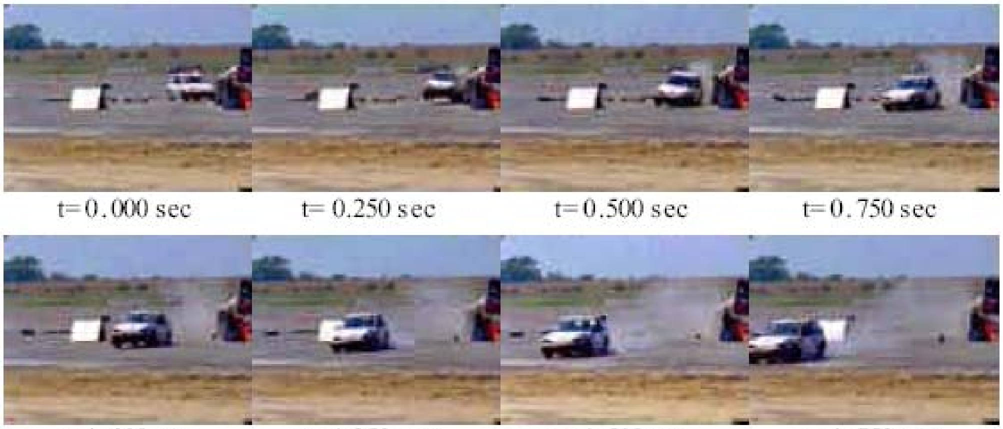


Figure 2-37 Impact sequence and diagram for Test 585

Test Barrier: Type: 1422-mm high, deep cobble-reveal textured barrier with a Type 60 profile
Length: 9.75-m total length.
Test Date: June 27, 2001
Test Vehicle: Model: 1990 Chevrolet 2500
Inertial Mass: 1958 kg
Impact / Exit Velocity: 99.2 km/h / 71.7 km/h
Impact / Exit Angle: 24.3° / < 3°
Test Dummy: None used
Test Data: Occ. Impact Velocity (Long / Lat): 6.83 m/s / -7.57 m/s
Ridedown Acceleration (Long / Lat): -12.26 g / 12.35 g
ASI: 1.97
Exterior: VDS(3)/CDC(4) LFQ-4, LD-2 / 11LDAS3
Interior: OCDI(1) 2011101
Barrier Damage: Very minor scraping of the sandblast and cobblestone surfaces. No chipping or gouging was observed. The barrier would not require immediate repair.

Figure A-1. Deep Cobble-Reveal Textured Barrier with a Type 60 Profile

Data Summary Sheet



t= 0.000 sec | t= 0.250 sec | t= 0.500 sec | t= 0.750 sec

t= 1.000 sec | t= 1.250 sec | t= 1.500 sec | t= 1.750 sec

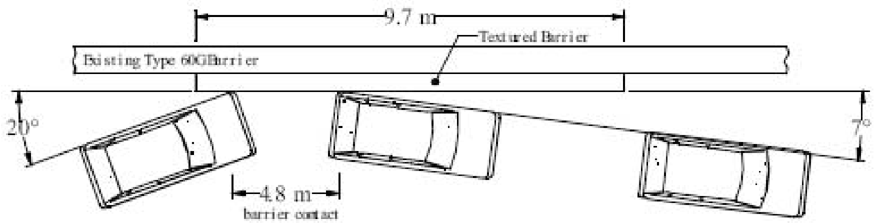


Figure 2-31 Impact sequence and diagram for Test 584

Test Barrier: Type: 1220-mm high, Mission Arch textured barrier with a Type 60 profile
Length: 9.75-m total length
Test Date: May 8, 2001

Test Vehicle: Model: 1992 Geo Metro
Inertial Mass: 842 kg
Impact / Exit Velocity: 95.8 km/h / 74.4 km/h
Impact / Exit Angle: 19.3° / <7°

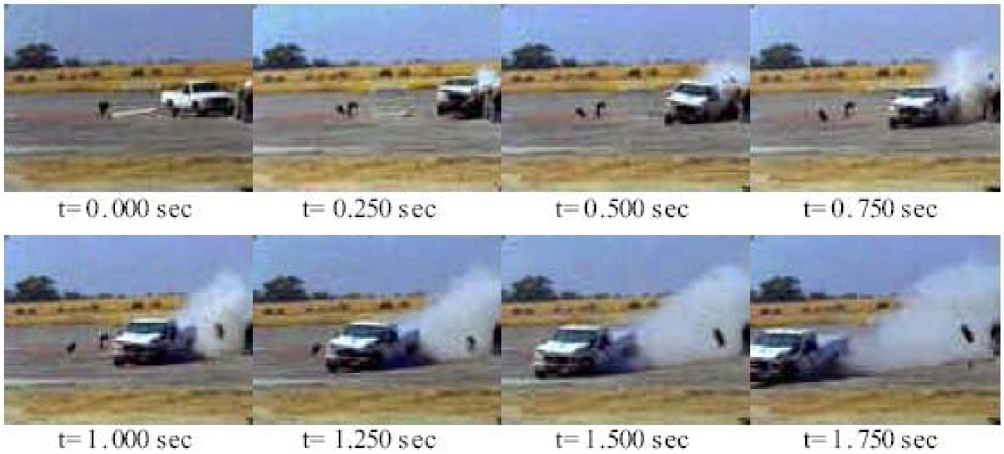
Test Dummy: Type: Hybrid III
Weight / Restraint: 74.8 kg / lap and shoulder belt
Position: Front Left

Test Data: Occ. Impact Velocity (Long / Lat): 5.36 m/s / -6.70 m/s
Ridedown Acceleration (Long / Lat): -4.07 g / 9.81 g
ASI: 1.62
Exterior: VDS(3)/CDC(4) LFQ-3, LP-1 / 11LDES2
Interior: OCDI(1) 0101000

Barrier Damage: Very minor scraping of the sandblast surfaces. No chipping or gouging was observed. The barrier would not require immediate repair.

Figure A-2. Mission Arch Textured Barrier with a Type 60 Profile

Data Summary Sheet



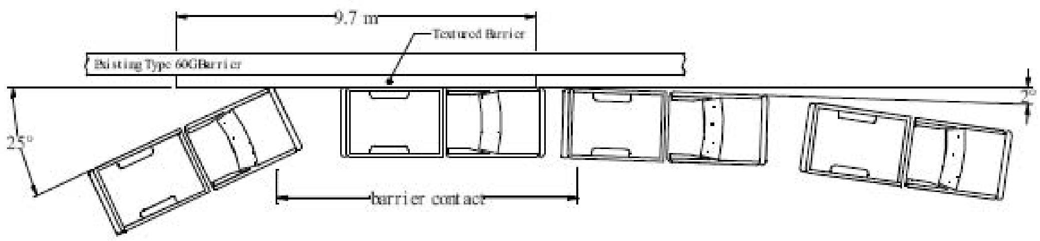


Figure 2-45 Impact sequence and diagram for Test 587

Test Barrier: Type: 1422-mm high, dry stack stone textured barrier with a Type 60 profile
Length: 9.75-m total length.

Test Date: July 25, 2001

Test Vehicle: Model: 1998 GMC 2500
Inertial Mass: 2027 kg
Impact / Exit Velocity: 101.1 km/h / 75.8 km/h
Impact / Exit Angle: 23.6° / < 2°

Test Dummy: None used

Test Data: Occ. Impact Velocity (Long / Lat): 7.02 m/s / -8.21 m/s
Ridedown Acceleration (Long / Lat): -13.60 g / 11.55 g
ASI: 1.68
Exterior: VDS[3]/CDC[4] LFQ-5, LD-1 / 11LDAS3
Interior: OCDI[1] 0010010

Barrier Damage: Very minor scraping of the "stone" surface. No chipping or gouging was observed. The barrier would not require immediate repair. The barrier would not require immediate repair.

Figure A-3. Dry Stack Stone Textured Barrier with a Type 60 Profile

Data Summary Sheet

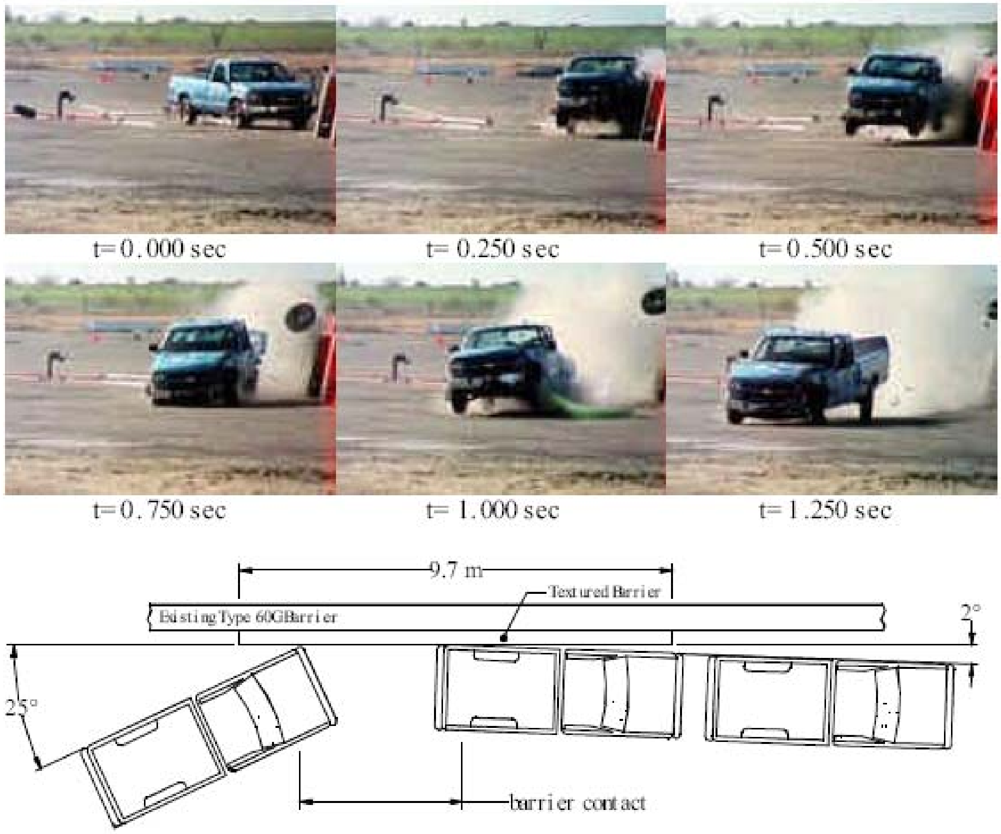


Figure 2-53 Impact sequence and diagram for Test 588

Test Barrier: Type: 1422-mm high, fractured granite textured barrier with a Type 60 profile
Length: 9.75-m total length.

Test Date: November 27, 2001

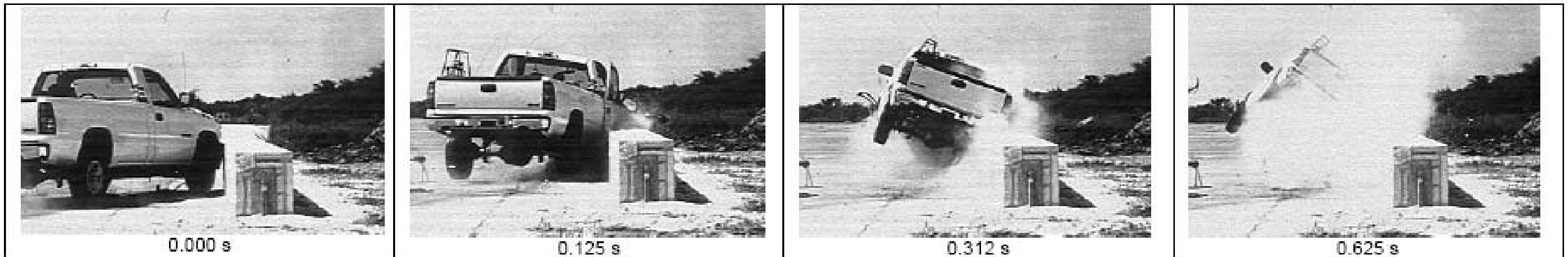
Test Vehicle: Model: 1994 Chevrolet 2500
Inertial Mass: 1965 kg
Impact / Exit Velocity: 100.3 km/h / 79.0 km/h
Impact / Exit Angle: 25.0° / < 2°

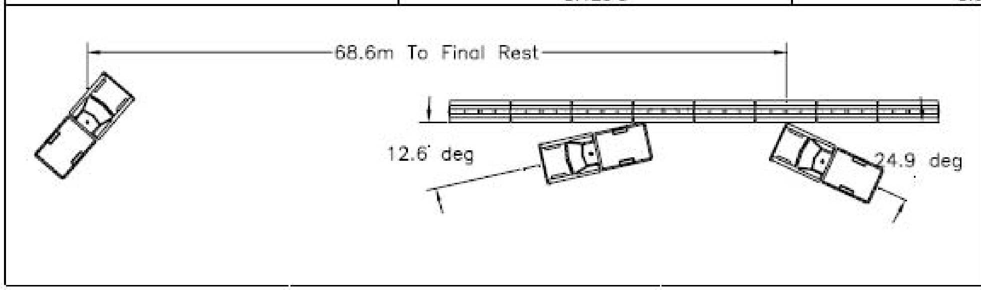
Test Dummy: None used

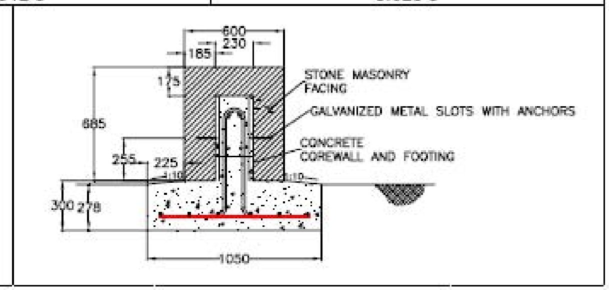
Test Data: Occ. Impact Velocity (Long / Lat): 6.28 m/s / -9.03 m/s
Ridedown Acceleration (Long / Lat): -14.56 g / 9.39 g
ASI: 2.15
Exterior: VDS[3]/CDC[4] LFQ-5, LD-3 / 11LDAS3
Interior: OCDI[1] 0113000

Barrier Damage: Very minor scraping of the "stone" surface. Minor chipping and gouging. The barrier would not require immediate repair.

Figure A-4. Fractured Granite Textured Barrier with a Type 60 Profile





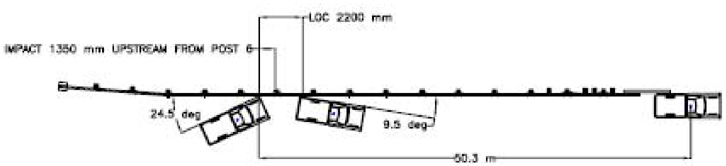


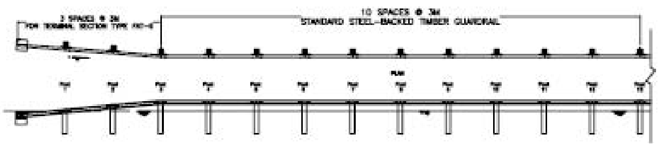
General Information	
Test Agency	Texas Transportation Institute
Test No.	405181-1
Date	6/29/00
Test Article	
Type	Guardwall
Name	Rough Stone Masonry Guardwall
Installation Length (m)	24.0
Material or Key Elements	3.0 m long Precast Concrete Cores with Stone Masonry Veneer
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1999 Chevrolet 2500 Pickup Truck
Mass (kg)	
Curb	2135
Test Inertial	2000
Dummy	76
Gross Static	2076

Impact Conditions	
Speed (km/h)	99.1
Angle (deg)	24.9
Exit Conditions	
Speed (km/h)	65.8
Angle (deg)	12.6
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	6.8
y-direction	7.7
THIV (km/h)	36.1
Ridedown Accelerations (g's)	
x-direction	-8.5
y-direction	-7.7
PHD (g's)	8.8
ASI	1.61
Max. 0.050-s Average (g's)	
x-direction	-9.6
y-direction	-12.6
z-direction	-2.6

Test Article Deflections (m)	
Dynamic	N/A
Permanent	0.015
Vehicle Damage	
Exterior	
VDS	01RFQ4
CDC	01FREK3 & 01RYEW3
Maximum Exterior Vehicle Crush (mm)	550
Interior	
OCDI	FS1014000
Max. Occupant Compartment Deformation (mm)	125
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	-43
Max. Pitch Angle (deg)	-8
Max. Roll Angle (deg)	34

Figure A-5. Rough Stone Masonry Guardwall



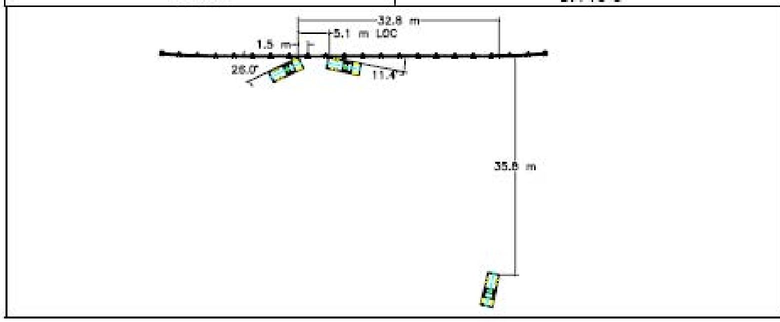


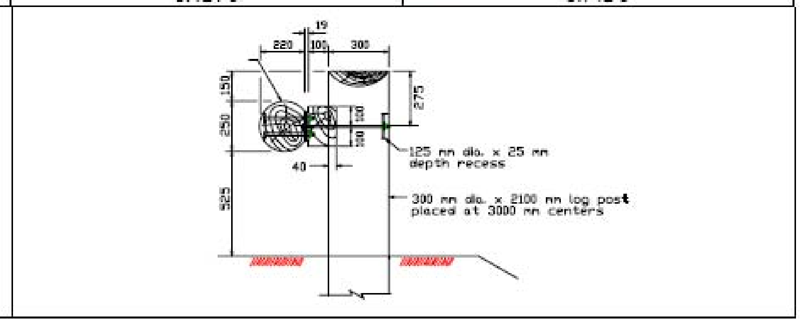
General Information	
Test Agency	Texas Transportation Institute
Test No.	405181-2
Date	12/11/00
Test Article	
Type	Guardrail
Name	Type A Steel-Backed Timber Guardrail
Installation Length (m)	49.2
Material or Key Elements	Steel-Backed Timber Guardrail with Blockouts
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1996 Chevrolet 2500 Pickup Truck
Mass (kg)	
Curb	1899
Test Inertial	2000
Dummy	75
Gross Static	2075

Impact Conditions	
Speed (km/h)	98.7
Angle (deg)	24.5
Exit Conditions	
Speed (km/h)	58.2
Angle (deg)	9.5
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	5.1
y-direction	5.4
THIV (km/h)	25.4
Ridedown Accelerations (g's)	
x-direction	-12.1
y-direction	16.4
PHD (g's)	18.0
ASI	0.97
Max. 0.050-s Average (g's)	
x-direction	-6.5
y-direction	8.0
z-direction	-5.8

Test Article Deflections (m)	
Dynamic	0.580
Permanent	0.315
Working Width	0.760
Vehicle Damage	
Exterior	
VDS	11LFQ2
CDC	11FLEK2 &11LYEW2
Maximum Exterior Vehicle Crush (mm)	380
Interior	
OCDI	LF0100000
Max. Occupant Compartment Deformation (mm)	88
Post-Impact Behavior	
(during 1.0 s after impact)	
Max. Yaw Angle (deg)	33
Max. Pitch Angle (deg)	-5
Max. Roll Angle (deg)	8

Figure A-6. Type A Steel-Backed Timber Guardrail



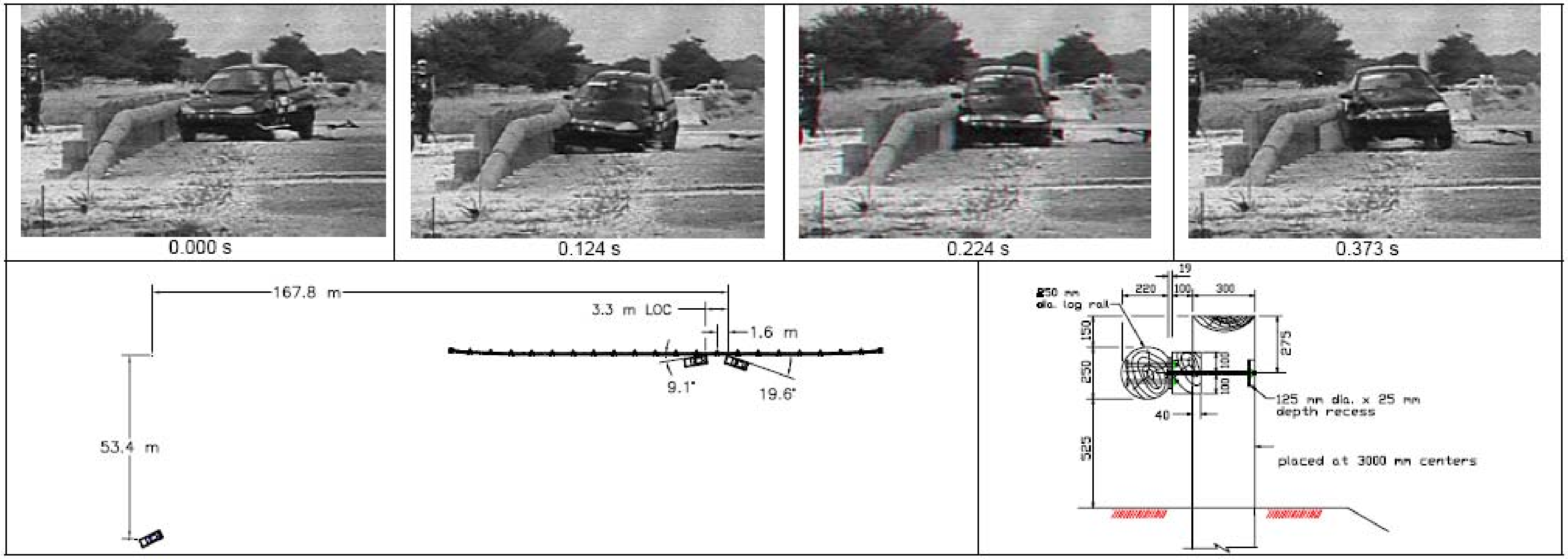


General Information	
Test Agency	Texas Transportation Institute
Test No.	405181-3
Date	05/06/03
Test Article	
Type	Guardrail
Name	Steel-Backed Timber Round Log Rail
Installation Length (m)	63.0
Material or Key Elements	Steel-Backed Douglas Fir Round Rail Elements And Douglas Fir Round Posts
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1998 Chevrolet 2500 Pickup
Mass (kg)	
Curb	2088
Test Inertial	2000
Dummy	77
Gross Static	2077

Impact Conditions	
Speed (km/h)	70.5
Angle (deg)	26.0
Exit Conditions	
Speed (km/h)	45.2
Angle (deg)	11.4
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	4.3
y-direction	4.9
THIV (km/h)	22.4
Ridedown Accelerations (g's)	
x-direction	-5.4
y-direction	6.0
PHD (g's)	7.3
ASI	0.72
Max. 0.050-s Average (g's)	
x-direction	-4.3
y-direction	5.6
z-direction	-2.2

Test Article Deflections (m)	
Dynamic	0.34
Permanent	0.11
Working Width	0.97
Vehicle Damage	
Exterior	
VDS	11FL3
CDC	11FLEW3
Maximum Exterior Vehicle Crush (mm)	460
Interior	
OCDI	LF0101000
Max. Occupant Compartment Deformation (mm)	67
Post-Impact Behavior	
(during 1.0 s after impact)	
Max. Yaw Angle (deg)	55.2
Max. Pitch Angle (deg)	-1.6
Max. Roll Angle (deg)	5.5

Figure A-7. Steel-Backed Timber Round Log Rail Test 1

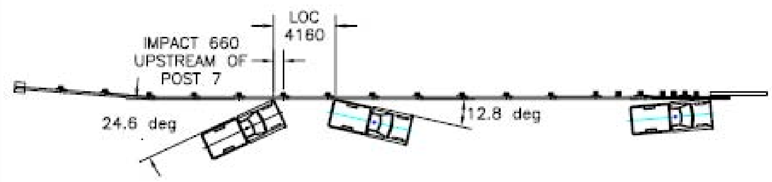


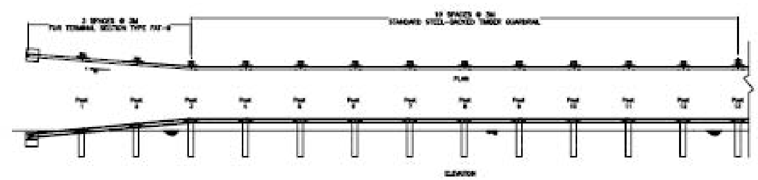
General Information	
Test Agency	Texas Transportation Institute
Test No.	405181-4
Date	04/28/03
Test Article	
Type	Guardrail
Name	Steel-Backed Timber Round Log Rail
Installation Length (m)	63.0
Material or Key Elements	Steel-Backed Douglas Fir Round Rail Elements And Douglas Fir Round Posts
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	820C
Model	1997 Geo Metro
Mass (kg)	
Curb	855
Test Inertial	874
Dummy	77
Gross Static	951

Impact Conditions	
Speed (km/h)	69.5
Angle (deg)	19.6
Exit Conditions	
Speed (km/h)	57.4
Angle (deg)	9.1
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	2.8
y-direction	5.5
THIV (km/h)	21.4
Ridedown Accelerations (g's)	
x-direction	-1.9
y-direction	-2.7
PHD (g's)	3.1
ASI	0.83
Max. 0.050-s Average (g's)	
x-direction	-3.9
y-direction	-7.0
z-direction	-1.7

Test Article Deflections (m)	
Dynamic	0.09
Permanent	0.02
Working Width	0.75
Vehicle Damage	
Exterior	
VDS	01RF1
CDC	01RFEW1
Maximum Exterior Vehicle Crush (mm)	220
Interior	
OCDI	RS0000000
Max. Occupant Compartment Deformation (mm)	None
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	-41.9
Max. Pitch Angle (deg)	3.3
Max. Roll Angle (deg)	-6.9

Figure A-8. Steel-Backed Timber Round Log Rail Test 2



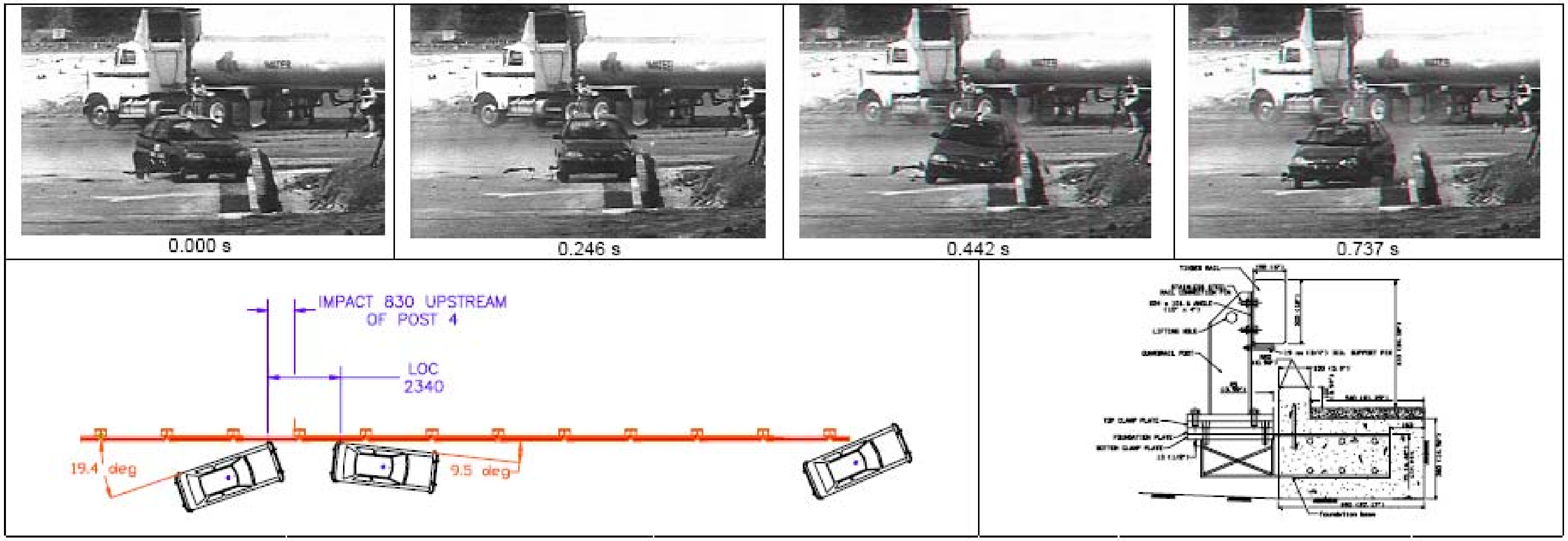


General Information	
Test Agency	Texas Transportation Institute
Test No.	405181-13
Date	09/19/01
Test Article	
Type	Guardrail
Name	Type B Steel-Backed Timber Guardrail
Installation Length (m)	50.5
Material or Key Elements	Wooden Post, Metal Backed Wooden Rail Elements, No Blockouts
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1997 Chevrolet 2500 Pickup Truck
Mass (kg)	
Curb	2139
Test Inertial	2043
Dummy	76
Gross Static	2119

Impact Conditions	
Speed (km/h)	70.2
Angle (deg)	24.6
Exit Conditions	
Speed (km/h)	45.1
Angle (deg)	12.8
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	4.5
y-direction	4.3
THIV (km/h)	21.3
Ridedown Accelerations (g's)	
x-direction	-4.4
y-direction	5.6
PHD (g's)	6.9
ASI	0.60
Max. 0.050-s Average (g's)	
x-direction	-4.3
y-direction	4.4
z-direction	2.1

Test Article Deflections (m)	
Dynamic	0.215
Permanent	0.249
Working Width	0.525
Vehicle Damage	
Exterior	
VDS	11FL2
CDC	11FLEN2
Maximum Exterior Vehicle Crush (mm)	400
Interior	
OCDI	LF0000000
Max. Occupant Compartment Deformation (mm)	N/A
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	36.3
Max. Pitch Angle (deg)	-8.8
Max. Roll Angle (deg)	-11.1

Figure A-9. Type B Steel-Backed Timber Guardrail



General Information

Test Agency	Texas Transportation Institute
Test No.	405181-14
Date	08/02/01

Test Article

Type	Bridge Rail
Name	Glacier Removable Rail
Installation Length (m)	24.6
Material or Key Elements	Steel-Backed Timber Beam & Steel Post Railing System Supported by Cast-In-Place Concrete Footing
Soil Type and Condition	Concrete Footing, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1997 Geo Metro
Mass (kg)	
Curb	849
Test Inertial	820
Dummy	76
Gross Static	896

Impact Conditions

Speed (km/h)	50.3
Angle (deg)	19.4

Exit Conditions

Speed (km/h)	37.9
Angle (deg)	9.5

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	3.6
y-direction	3.4
THIV (km/h)	17.1
Ridedown Accelerations (g's)	
x-direction	-0.9
y-direction	2.5
PHD (g's)	2.6
ASI	0.57
Max. 0.050-s Average (g's)	
x-direction	-4.0
y-direction	4.1
z-direction	-1.3

Test Article Deflections (m)

Dynamic	0.063
Permanent	N/A
Working Width	0.204

Vehicle Damage

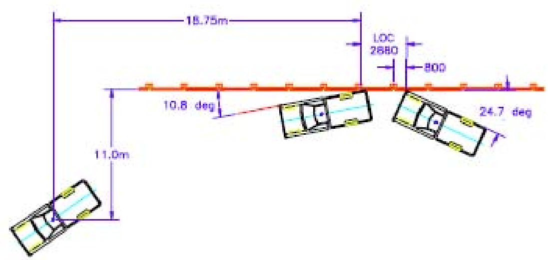
Exterior	
VDS	11LFQ2
CDC	11FLEK2 &11LYEW2
Maximum Exterior Vehicle Crush (mm)	160
Interior	
OCDI	LF0000000
Max. Occupant Compartment Deformation (mm)	7

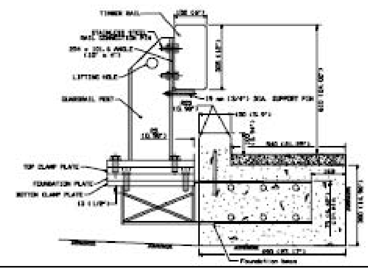
Post-Impact Behavior

(during 1.0 s after impact)	
Max. Yaw Angle (deg)	31
Max. Pitch Angle (deg)	-3
Max. Roll Angle (deg)	-11

Figure A-10. Glacier Removable Rail Test 1

0.000 s | 0.197 s | 0.345 s | 0.739 s





General Information

Test Agency	Texas Transportation Institute
Test No.	405181-15
Date	08/08/01

Test Article

Type	Bridge Rail
Name	Glacier Removable Rail
Installation Length (m)	24.6
Material or Key Elements	Steel-Backed Timber Beam & Steel Post Railing System Supported by Cast-In-Place Concrete Footing

Soil Type and Condition .... Concrete Footing, Dry

Test Vehicle

Type	Production
Designation	2000P
Model	1996 Chevrolet 2500 Pickup Truck
Mass (kg)	
Curb	1905
Test Inertial	2000
Dummy	76
Gross Static	2076

Impact Conditions

Speed (km/h)	51.6
Angle (deg)	24.7

Exit Conditions

Speed (km/h)	33.6
Angle (deg)	10.8

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	4.3
y-direction	4.5
THIV (km/h)	21.9
Ridedown Accelerations (g's)	
x-direction	-3.7
y-direction	-3.1
PHD (g's)	3.9
ASI	0.66
Max. 0.050-s Average (g's)	
x-direction	-4.3
y-direction	-5.3
z-direction	-1.8

Test Article Deflections (m)

Dynamic	0.620
Permanent	nil
Working Width	0.197

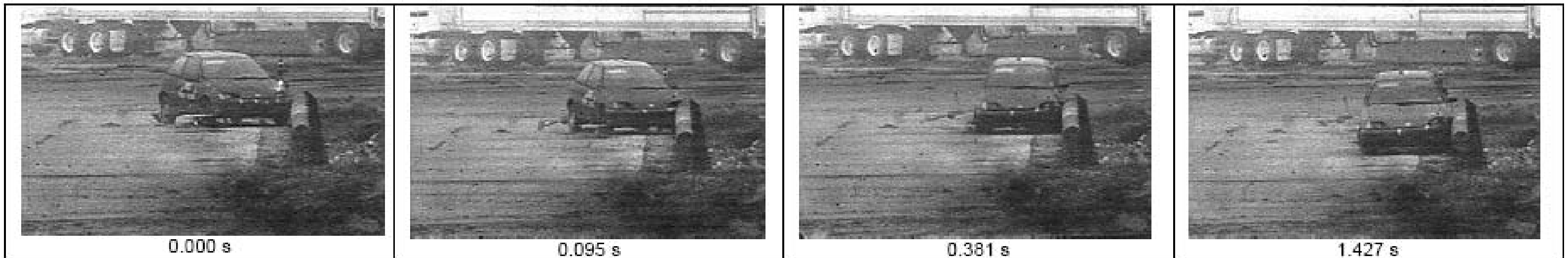
Vehicle Damage

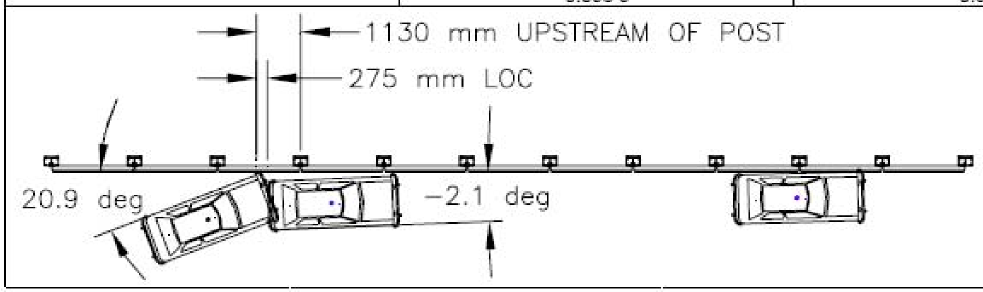
Exterior	
VDS	01FR2
CDC	01FREW1
Maximum Exterior Vehicle Crush (mm)	350
Interior	
OCDI	FS0000000
Max. Occupant Compartment Deformation (mm)	9

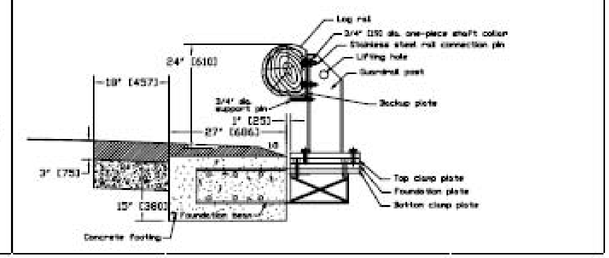
Post-Impact Behavior
(during 1.0 s after impact)

Max. Yaw Angle (deg)	-49
Max. Pitch Angle (deg)	2
Max. Roll Angle (deg)	9

Figure A-11. Glacier Removable Rail Test 2





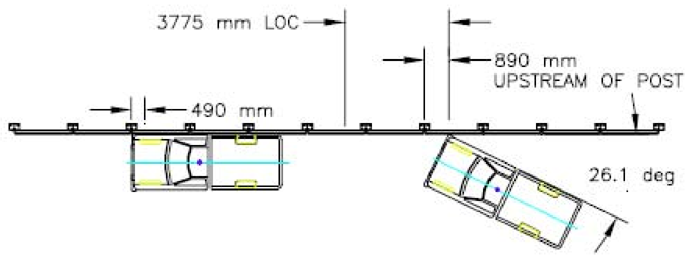


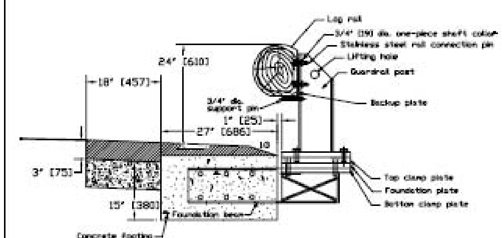
General Information	
Test Agency	Texas Transportation Institute
Test No.	405181-19
Date	03/05/03
Test Article	
Type	Bridge Rail
Name	Glacier Round Log Removable Rail
Installation Length (m)	24.6
Material or Key Elements	Steel-Backed Round Timber Beam & Steel Post Railing System
Soil Type and Condition	Concrete Footing, Dry
Test Vehicle	
Type	Production
Designation	820C
Model	1997 Geo Metro
Mass (kg)	
Curb	797
Test Inertial	820
Dummy	77
Gross Static	897

Impact Conditions	
Speed (km/h)	50.9
Angle (deg)	20.9
Exit Conditions	
Speed (km/h)	20.0
Angle (deg)	-2.1
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	4.6
y-direction	3.1
THIV (km/h)	18.2
Ridedown Accelerations (g's)	
x-direction	-1.2
y-direction	1.2
PHD (g's)	3.0
ASI	0.65
Max. 0.050-s Average (g's)	
x-direction	-4.9
y-direction	4.8
z-direction	0.7

Test Article Deflections (m)	
Dynamic	None
Permanent	0.01
Working Width	None
Vehicle Damage	
Exterior	
VDS	11FL1
CDC	11FLEW1
Maximum Exterior Vehicle Crush (mm)	260
Interior	
OCDI	LF0000000
Max. Occupant Compartment Deformation (mm)	None
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	19.9
Max. Pitch Angle (deg)	-2.3
Max. Roll Angle (deg)	-2.5

Figure A-12. Glacier Round Log Removable Rail Test 1



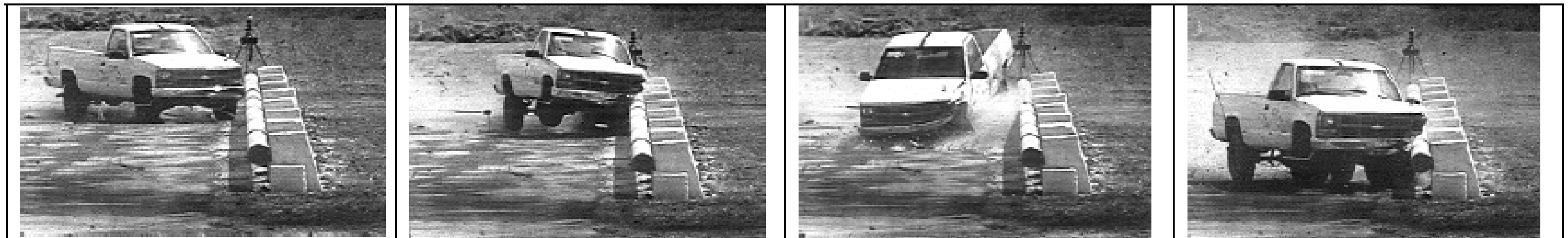


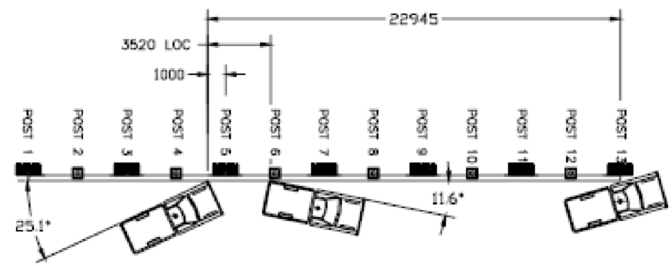
General Information	
Test Agency	Texas Transportation Institute
Test No.	405181-20
Date	03/07/03
Test Article	
Type	Bridge Rail
Name	Glacier Round Log Removable Rail
Installation Length (m)	24.6
Material or Key Elements	Steel-Backed Round Timber Beam & Steel Post Railing System
Soil Type and Condition	Concrete Footing, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1998 Chevrolet 2500 Pickup
Mass (kg)	
Curb	2156
Test Inertial	2050
Dummy	77
Gross Static	2127

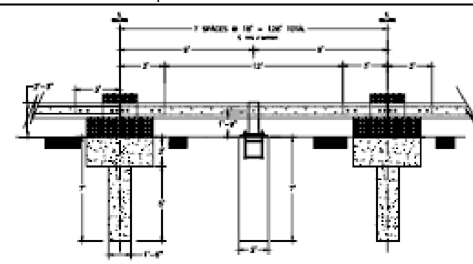
Impact Conditions	
Speed (km/h)	51.0
Angle (deg)	26.1
Exit Conditions	
Speed (km/h)	13.5
Angle (deg)	0.1
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	5.2
y-direction	3.5
THIV (km/h)	21.4
Ridedown Accelerations (g's)	
x-direction	-5.3
y-direction	-4.1
PHD (g's)	5.4
ASI	0.61
Max. 0.050-s Average (g's)	
x-direction	-4.3
y-direction	-3.8
z-direction	-3.0

Test Article Deflections (m)	
Dynamic	0.08
Permanent	0.04
Working Width	0.45
Vehicle Damage	
Exterior	
VDS	01FR1
CDC	01FREW1
Maximum Exterior Vehicle Crush (mm)	120
Interior	
OCDI	RF0000000
Max. Occupant Compartment Deformation (mm)	None
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	-30.0
Max. Pitch Angle (deg)	4.4
Max. Roll Angle (deg)	14.2

Figure A-13. Glacier Round Log Removable Rail Test 2





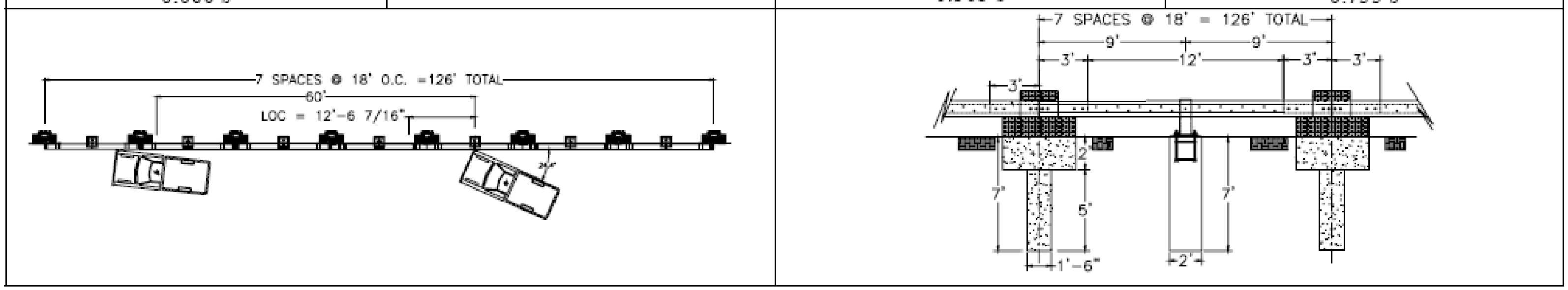


General Information	
Test Agency	Texas Transportation Institute
Test No.	400561-1
Date	07/01/03
Test Article	
Type	Guardrail
Name	Deception Pass State Park Log Rail
Installation Length (ft)	126.0 (38.4 m)
Material or Key Elements	Steel-Backed Log Rail Supported By Stone Bollards And Steel Pipe Posts
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1999 Chevrolet Cheyenne 2500 P/U
Mass (lb)	
Curb	4686 (2128 kg)
Test Inertial	4514 (2050 kg)
Dummy	N/A
Gross Static	4514 (2050 kg)

Impact Conditions	
Speed (mi/h)	44.5 (71.6 km/h)
Angle (deg)	25.1
Exit Conditions	
Speed (km/h)	26.9 (43.2 km/h)
Angle (deg)	11.6
Occupant Risk Values	
Impact Velocity (ft/s)	
x-direction	21.0 (6.4 m/s)
y-direction	17.1 (5.2 m/s)
THIV (mi/h)	18.1 (29.1 km/h)
Ridedown Accelerations (g's)	
x-direction	-4.0
y-direction	4.0
PHD (g=s)	5.2
ASI	1.29
Max. 0.050-s Average (g's)	
x-direction	-8.7
y-direction	7.8
z-direction	-7.5

Test Article Deflections (in)	
Dynamic	Not measurable
Permanent	0.4 (10 mm)
Working Width	Not measurable
Vehicle Damage	
Exterior	
VDS	11FL2
CDC	11FLEW2
Maximum Exterior Vehicle Crush (in)	25.0 (640 mm)
Interior	
OCDI	LF0102000
Max. Occ. Compart. Deformation (in)	2.3 (58 mm)
Post-Impact Behavior	
(during 1.0 s after impact)	
Max. Yaw Angle (deg)	36.4
Max. Pitch Angle (deg)	-9.9
Max. Roll Angle (deg)	-17.1

Figure A-14. Deception Pass State Park Log Rail Test 1

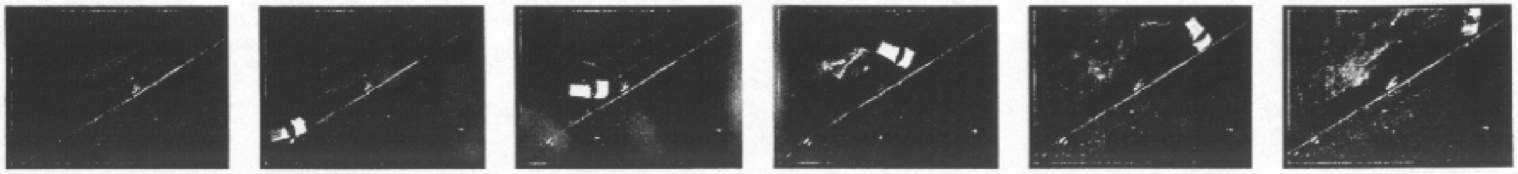


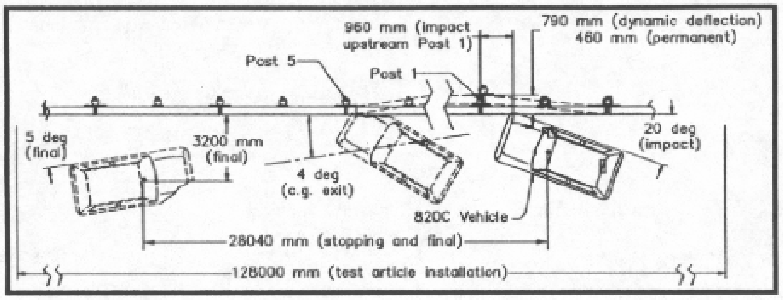
General Information	
Test Agency	Texas Transportation Institute
Test No.	400561-2
Date	06/14/2004
Test Article	
Type	Guardrail
Name	Deception Pass State Park Log Rail
Installation Length (ft)	126.0 (38.4 m)
Material or Key Elements	Steel-Backed Log Rail Supported by Stone Bollards and Steel Pipe Posts
Soil Type and Condition	Standard Soil, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1989 Chevrolet 2500 Pickup Truck
Mass (lb)	
Curb	4758 (2160 kg)
Test Inertial	4529 (2056 kg)
Dummy	N/A
Gross Static	4529 (2056 kg)

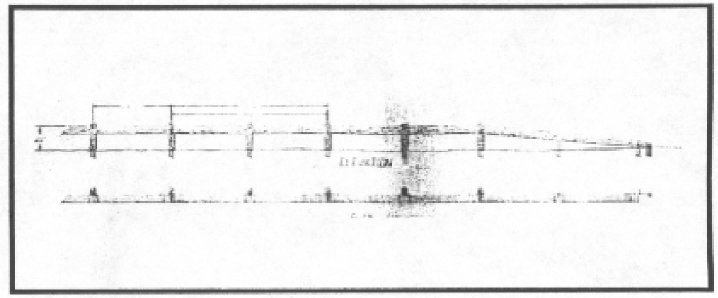
Impact Conditions	
Speed (mph)	44.7 (71.9 km/h)
Angle (deg)	25.0
Exit Conditions	
Speed (mph)	22.0 (35.4 km/h)
Angle (deg)	6.5
Occupant Risk Values	
Impact Velocity (ft/s)	
Longitudinal	23.0 (7.0 m/s)
Lateral	16.7 (5.1 m/s)
THIV (km/h)	29.7
Ridedown Accelerations (g's)	
Longitudinal	-4.2
Lateral	-3.9
PHD (g's)	7.1
ASI	1.09
Max. 0.050-s Average (g's)	
Longitudinal	-8.9
Lateral	-6.8
Vertical	-4.3

Test Article Deflections (ft)	
Dynamic	N/A
Permanent	Disturbed
Working Width	1.6 (0.5 m)
Vehicle Damage	
Exterior	
VDS	01RF2
CDC	01RFEW2
Maximum Exterior Vehicle Crush (inches)	23.6 (600 mm)
Interior	
OCDI	RF0104000
Maximum Occupant Compartment Deformation (inches)	2.5 (63 mm)
Post-Impact Behavior (during 1.0 sec after impact)	
Max. Yaw Angel (deg)	-33
Max. Pitch Angle (deg)	-4
Max. Roll Angle (deg)	-7

Figure A-15. Deception Pass State Park Log Rail Test 2





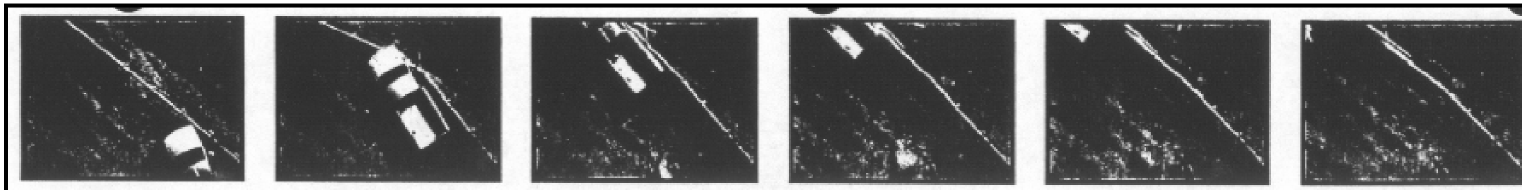


E-TECH Testing Services, Inc.

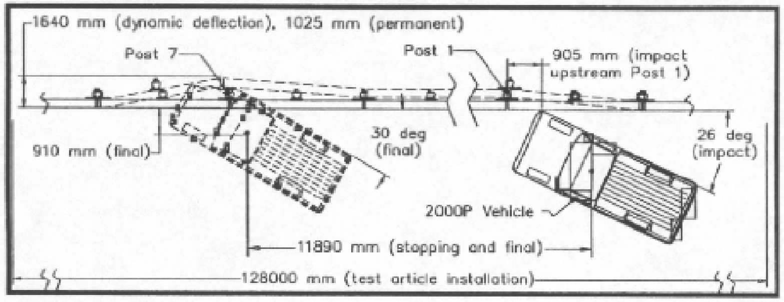
General Information	
Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCHRP 350 Test 3-10
Test No.	12-0102-002
Date	2/4/99
Test Article	
Type	Structures of Ironwood, LLC
	IRONWOOD Guiderail
Installation Length, (m)	128 (length of need)
Size and/or dimension and material of key elements	660 mm Rail height,
	2000 mm Post spacing
Foundation Type and Condition	NCHRP 350 Weak soil,
	well drained and compacted
Test Vehicle	
Type	Production Model
Designation	820C
Model	1988 Ford Festiva
	Hatchback
Mass (kg)	
Curb	838.6
Test inertial	825.0
Dummy	75.0
Gross Static	900.0
Impact Conditions	
Speed (km/h)	102.5
Angle (deg)	20
Impact Severity (kJ)	39.1

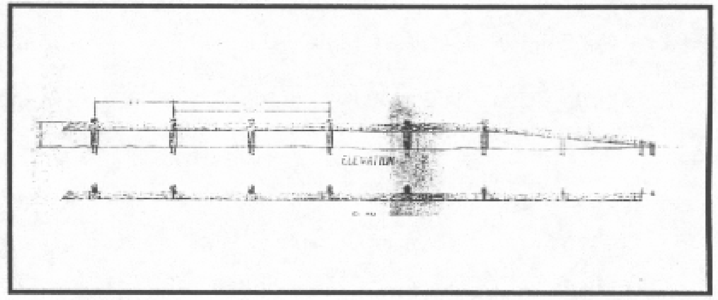
Exit conditions	
Speed (km/h)	41.8
Angle (deg)	4
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	5.0
y-direction	-4.9
Ridedown Acceleration (g's)	
x-direction	-14.2
y-direction	10.0
THIV (m/s)	10.0
PHD (g's)	5.9
ASI	0.8
Test Article Deflections (mm)	
Dynamic	790
Permanent	460
Vehicle Damage	
Exterior	
VDS	RFQ-5
CDC	01RYEW2
Interior	
OCDI	AS0010000
Post-Impact Vehicular Behavior (deg - rate gyro)	
Maximum Roll Angle	10.9
Maximum Pitch Angle	7.9
Maximum Yaw Angle	155.9

Figure A-16. Ironwood Guardrail Test 1



t = 0.000 sec | t = 0.240 sec | t = 0.480 sec | t = 0.720 sec | t = 0.960 sec | t = final



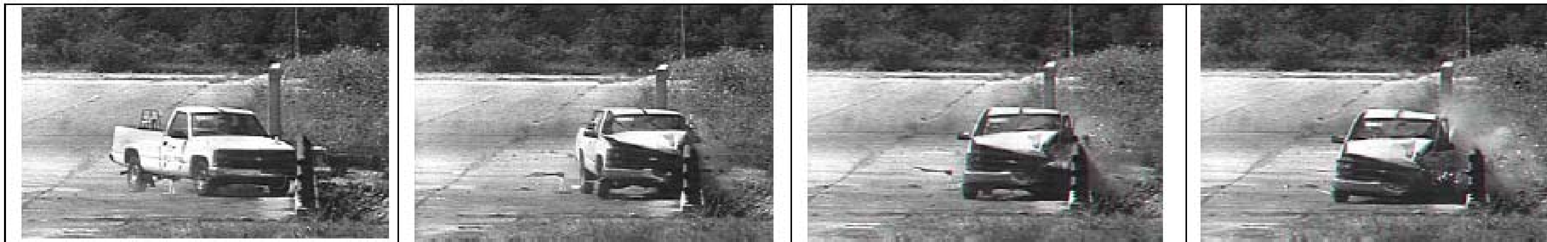


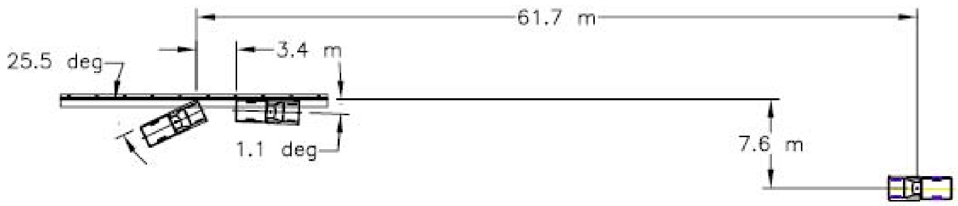
E-TECH Testing Services, Inc.

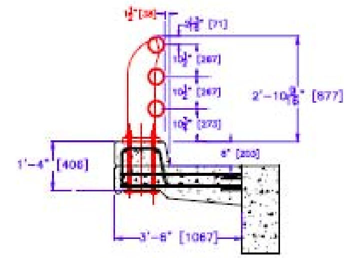
General Information	
Test Agency	E-TECH Testing Services, Inc.
Test Designation	NCHRP 350 Test 3-11
Test No.	12-0102-001
Date	2/3/99
Test Article	
Type	Structures of IronWood, LLC IRONWOOD Guiderail
Installation Length, (m)	128 (length of need)
Size and/or dimension and material of key elements	660 mm Rail height, 2000 mm Post spacing
Foundation Type and Condition	NCHRP 350 Weak soil, well drained and compacted
Test Vehicle	
Type	Production Model
Designation	2000P
Model	1988 Chevrolet C2500 3/4 Ton Pickup
Mass (kg)	
Curb	1937.2
Test inertial	2009.8
Dummy	N/A
Gross Static	2009.8
Impact Conditions	
Speed (km/h)	98.3
Angle (deg)	26
Impact Severity (kJ)	144.0

Exit conditions	
Speed (km/h)	N/A
Angle (deg)	N/A
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	5.7
y-direction	-4.0
Ridedown Acceleration (g's)	
x-direction	-13.0
y-direction	-11.9
THIV (m/s)	8.6
PHD (g's)	6.4
ASI	0.8
Test Article Deflections (mm)	
Dynamic	1640
Permanent	1025
Vehicle Damage	
Exterior	
VDS	RFQ-5
CDC	01RYEW2
Interior	
OCDI	AS1010000
Post-Impact Vehicular Behavior (deg - rate gyro)	
Maximum Roll Angle	-8.5
Maximum Pitch Angle	-1.9
Maximum Yaw Angle	-24.2

Figure A-17. Ironwood Guardrail Test 2





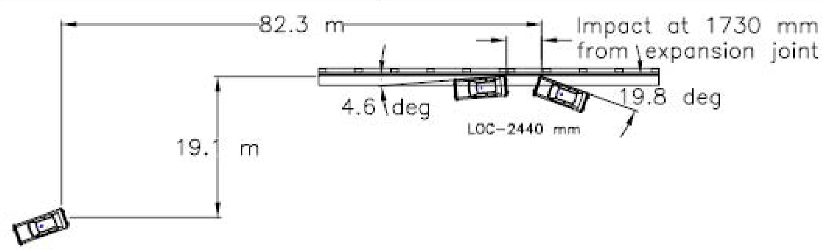


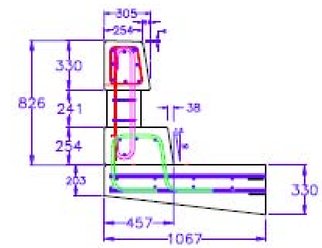
General Information	
Test Agency	Texas Transportation Institute
Test No.	405181-9
Date	07/25/01
Test Article	
Type	Bridge Rail
Name	George Washington Memorial Parkway Bridge Rail
Installation Length (m)	22.86
Material or Key Elements	Three Steel Pipe Rail Elements Welded to Flat Steel Plate Posts
Soil Type and Condition	Concrete, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1996 Chevrolet 2500 Pickup Truck
Mass (kg)	
Curb	1917
Test Inertial	2000
Dummy	76
Gross Static	2076

Impact Conditions	
Speed (km/h)	98.7
Angle (deg)	25.5
Exit Conditions	
Speed (km/h)	78.6
Angle (deg)	1.1
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	4.9
y-direction	7.3
THIV (km/h)	31.8
Ridedown Accelerations (g's)	
x-direction	-7.7
y-direction	11.5
PHD (g's)	13.1
ASI	1.94
Max. 0.050-s Average (g's)	
x-direction	-8.3
y-direction	16.3
z-direction	-5.2

Test Article Deflections (m)	
Dynamic	0.060
Permanent	N/A
Working Width	0.183
Vehicle Damage	
Exterior	
VDS	11LFQ2
CDC	11FLEK2 &11LYEW2
Maximum Exterior Vehicle Crush (mm)	550
Interior	
OCDI	LF1102010
Max. Occupant Compartment Deformation (mm)	100
Post-Impact Behavior	
(during 1.0 s after impact)	
Max. Yaw Angle (deg)	36
Max. Pitch Angle (deg)	-4
Max. Roll Angle (deg)	-5

Figure A-18. George Washington Memorial Parkway Bridge Rail





General Information
- Test Agency .... Texas Transportation Institute
- Test No. 405181-11
- Date 06/20/01

Test Article
- Type .... Bridge Rail
- Name .... Natchez Trace Bridge Rail
- Installation Length (m) 21.5
- Material or Key Elements .... Concrete Beam and Post on Curb

Soil Type and Condition .... Concrete Pavement, Dry

Test Vehicle
- Type .... Production
- Designation 820C
- Model .... 1997 Geo Metro
- Mass (kg)
  - Curb 845
  - Test Inertial 820
  - Dummy 76
  - Gross Static 896

Impact Conditions
- Speed (km/h) 99.9
- Angle (deg) 19.8

Exit Conditions
- Speed (km/h) 77.6
- Angle (deg) 4.6

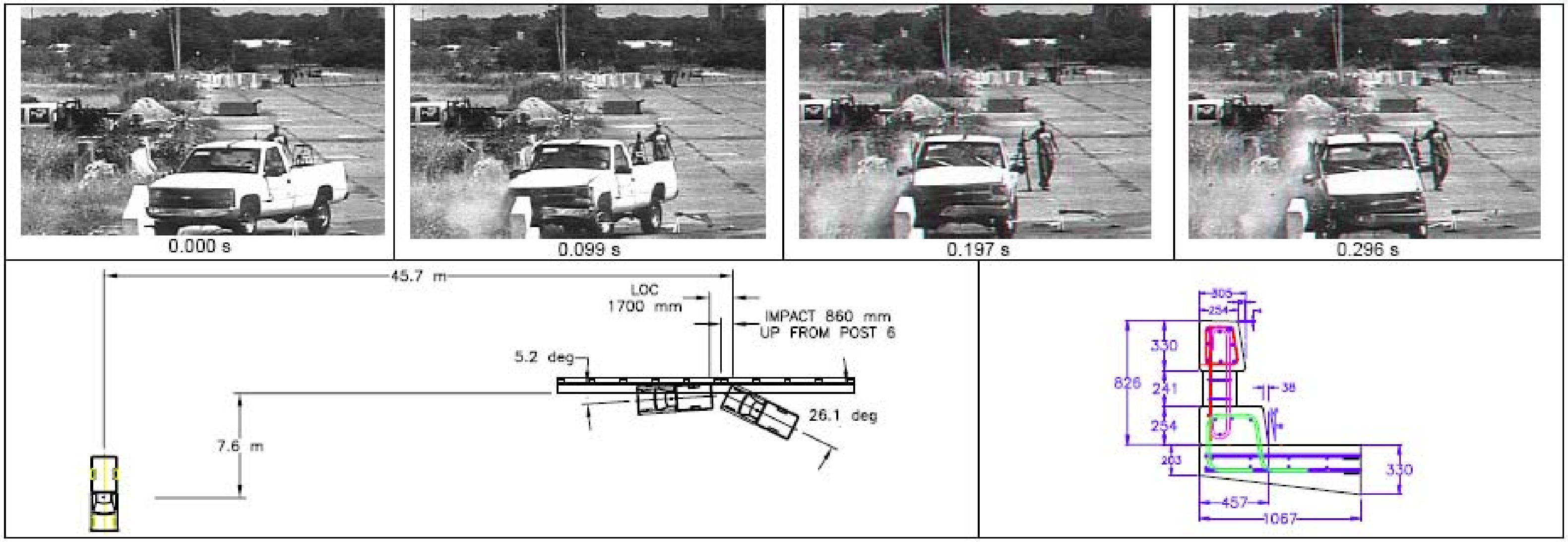
Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 6.0
  - y-direction 7.3
- THIV (km/h) 32.9
- Ridedown Accelerations (g's)
  - x-direction .... -4.0
  - y-direction .... -5.3
- PHD (g's) 5.5
- ASI 1.81
- Max. 0.050-s Average (g's)
  - x-direction .... -10.7
  - y-direction .... -13.8
  - z-direction .... -3.7

Test Article Deflections (m)
- Dynamic 0
- Permanent 0
- Working Width .... N/A

Vehicle Damage
- Exterior
  - VDS 01RFQ2
  - CDC .... 01REK2 &01RYEW2
- Maximum Exterior
  - Vehicle Crush (mm) 230
- Interior
  - OCDI FS0002000
- Max. Occupant Compartment
  - Deformation (mm) 40

Post-Impact Behavior
- (during 1.0 s after impact)
- Max. Yaw Angle (deg) .... -47
- Max. Pitch Angle (deg) .... -5
- Max. Roll Angle (deg) 21

Figure A-19. Natchez Trace Bridge Rail Test 1



General Information
- Test Agency .... Texas Transportation Institute
- Test No. 405181-12
- Date 07/23/01

Test Article
- Type .... Bridge Rail
- Name .... Natchez Trace Bridge Rail
- Installation Length (m) 21.5
- Material or Key Elements .... Concrete Beam and Post on Curb

Soil Type and Condition .... Concrete Pavement, Dry

Test Vehicle
- Type .... Production
- Designation 2000P
- Model .... 1997 Chevrolet 2500 pickup truck
- Mass (kg)
  - Curb 2131
  - Test Inertial 2000
  - Dummy 116
  - Gross Static 2116

Impact Conditions
- Speed (km/h) 98.3
- Angle (deg) 26.1

Exit Conditions
- Speed (km/h) 73.7
- Angle (deg) 5.2

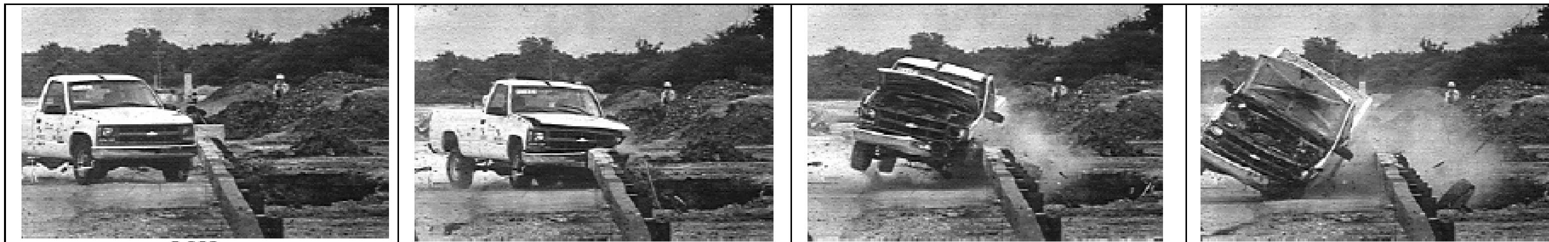
Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 5.4
  - y-direction 7.4
- THIV (km/h) 32.1
- Ridedown Accelerations (g's)
  - x-direction .... -11.8
  - y-direction .... -8.7
- PHD (g's) 13.8
- ASI 1.50
- Max. 0.050-s Average (g's)
  - x-direction .... -9.6
  - y-direction .... -11.9
  - z-direction .... -4.3

Test Article Deflections (m)
- Dynamic .... N/A
- Permanent .... N/A
- Working Width 0.587

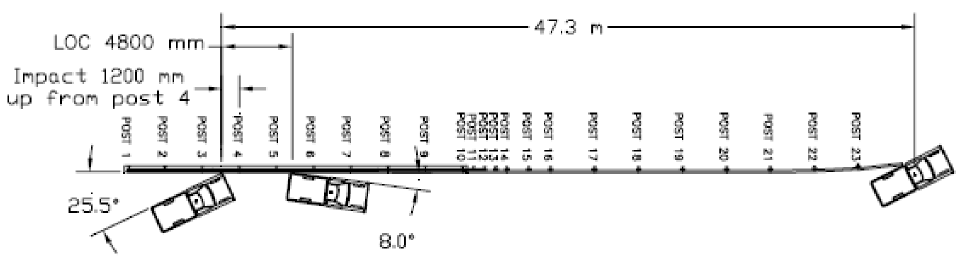
Vehicle Damage
- Exterior
  - VDS 01RFQ2
  - CDC .... 01REK2 &01RYEW2
- Maximum Exterior
  - Vehicle Crush (mm) 680
- Interior
  - OCDI FS1112000
- Max. Occupant Compartment
  - Deformation (mm) 130

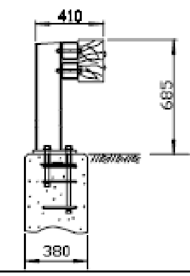
Post-Impact Behavior
- (during 1.0 s after impact)
- Max. Yaw Angle (deg) .... -33
- Max. Pitch Angle (deg) .... -12
- Max. Roll Angle (deg) 15

Figure A-20. Natchez Trace Bridge Rail Test 2



0.000 s | 0.099 s | 0.297 s | 0.496 s





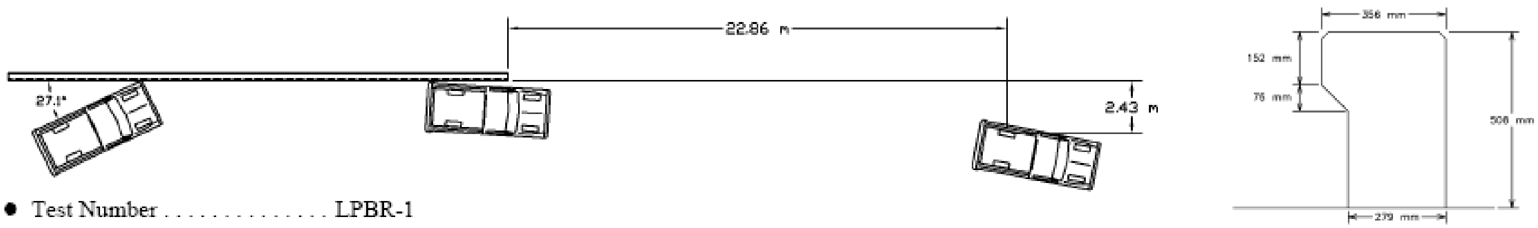
General Information	
Test Agency	Texas Transportation Institute
Test No.	405181-21
Date	06/04/03
Test Article	
Type	Bridge Rail
Name	Tubular Steel-Backed Timber Bridge Rail
Installation Length (m)	22.8 (bridge rail only; 53.1 m total)
Material or Key Elements	Steel Tube Backed Timber Rail Elements With Steel Posts
Soil Type and Condition	Concrete Footing, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1998 Chevrolet 2500 Pickup Truck
Mass (kg)	
Curb	2145
Test Inertial	2085
Dummy	77
Gross Static	2162

Impact Conditions	
Speed (km/h)	99.6
Angle (deg)	25.5
Exit Conditions	
Speed (km/h)	65.5
Angle (deg)	8.0
Occupant Risk Values	
Impact Velocity (m/s)	
x-direction	5.6
y-direction	6.6
THIV (km/h)	29.9
Ridedown Accelerations (g's)	
x-direction	-8.5
y-direction	9.0
PHD (g's)	9.5
ASI	1.34
Max. 0.050-s Average (g's)	
x-direction	-8.2
y-direction	9.2
z-direction	-6.3

Test Article Deflections (m)	
Dynamic	0.28
Permanent	0.05
Working Width	0.73
Vehicle Damage	
Exterior	
VDS	11FL3
CDC	11FLEW3
Maximum Exterior Vehicle Crush (mm)	530
Interior	
OCDI	LF0102000
Max. Occupant Compartment Deformation (mm)	66
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	34.1
Max. Pitch Angle (deg)	-12.2
Max. Roll Angle (deg)	-37.3

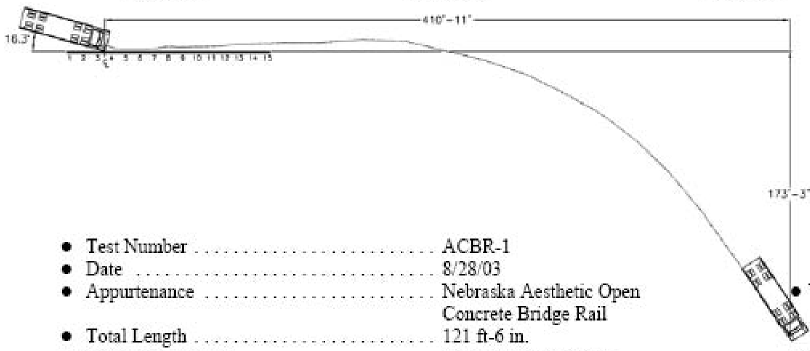
Figure A-21. Tubular Steel-Backed Timber Bridge Rail

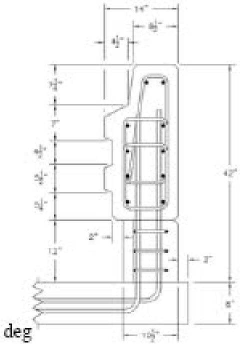
0.000 sec 0.070 sec 0.114 sec 0.246 sec 0.378 sec



- Test Number LPBR-1
- Date 4/9/01
- Appurtenance .... Low-Profile Concrete Bridge Rail
- Total Length .... 22.86 m
- Concrete Material .... Nebraska Mix
- Reinforcing Steel Material ... Grade 60 Rebar - Epoxy Coated
- Bridge Rail Profile
  - Height .... 508 mm
  - Bottom Width .... 279 mm
  - Top Width .... 356 mm
  - Front Vertical Length ... 152 mm
  - Front Angled Length .... 76 mm
- Vehicle Model .... 1995 GMC 2500 SL ¾-ton pickup
  - Curb .... 2,023 kg
  - Test Inertial .... 2,018 kg
  - Gross Static .... 2,018 kg
- Vehicle Speed
  - Impact .... 70.0 km/hr
  - Exit (resultant) .... 46.1 km/hr
- Vehicle Angle
  - Impact .... 27.1 deg
  - Exit .... est. 5-7 deg
- Vehicle Snagging .... None
- Vehicle Pocketing .... None
- Vehicle Stability .... Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal .... 7.87 < 20 G's
  - Lateral (not required) 8.10
- Occupant Impact Velocity
  - Longitudinal .... 6.61 < 12 m/s
  - Lateral (not required) 4.78
- Vehicle Damage .... Minimal
  - TAD[14] 11-FL-2
  - SAE[15] 11-LFEE3
- Vehicle Stopping Distance .... 39.62 m downstream
  2.43 m traffic-side face
- Barrier Damage .... Minimal
- Maximum Deflections
  - Permanent Set .... NA
  - Dynamic .... NA
- Working Width .... 457 mm

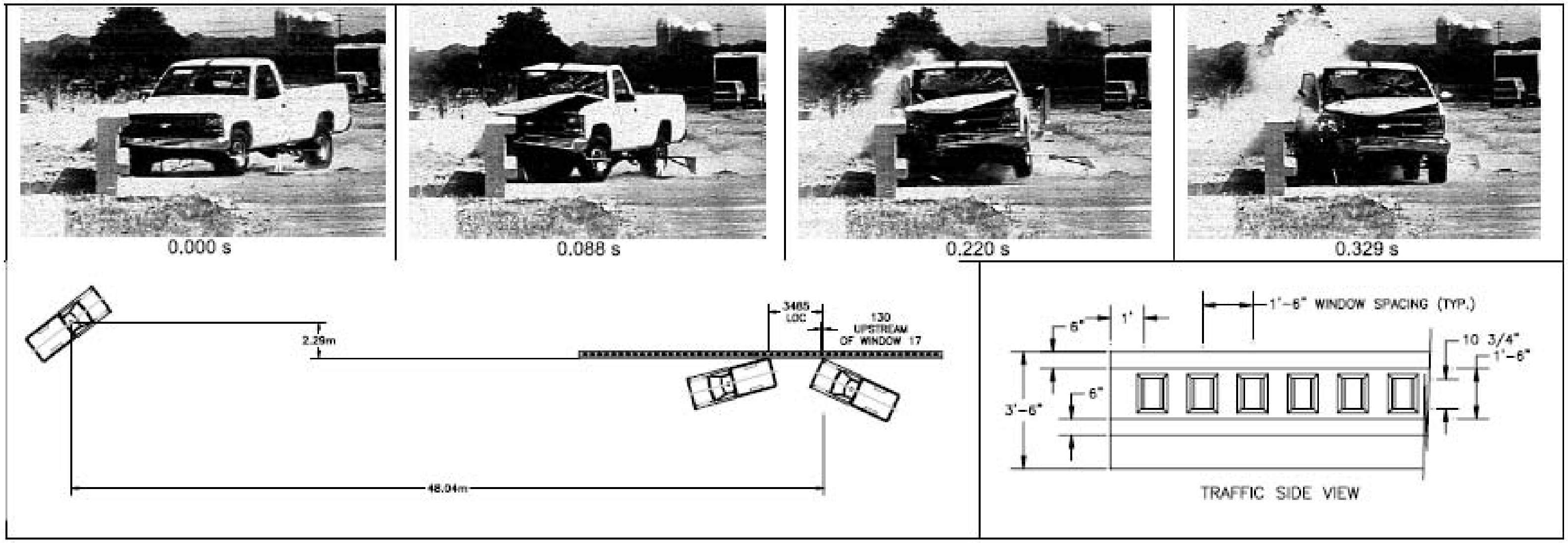
Figure A-22. NDOR Low-Profile Bridge Rail Test





- Test Number ACBR-1
- Date 8/28/03
- Appurtenance .... Nebraska Aesthetic Open Concrete Bridge Rail
- Total Length .... 121 ft-6 in.
- Concrete Material .... Nebraska 47-BD Mix
- Reinforcing Steel Material .... Grade 60 Rebar - Epoxy Coated
- Concrete Bridge Rail
  - Length .... 121 ft-6 in.
  - Width .... 14 in.
  - Depth .... 30 in.
  - Top Mounting Height .... 42 in.
- Concrete Bridge Posts
  - Length .... 30 in.
  - Width .... 10.5 in.
  - Height .... 12 in.
  - Spacing .... 8 ft-6 in.
  - Offset from Back Edge of Deck ...... 2 in.
- Concrete Bridge Deck
  - Length .... 121 ft-6 in.
  - Width .... 134 in.
  - Thickness .... 8 in.
- Vehicle Model .... 1989 General Motors Brigadier Tractor 1989 Great Dane Brigadier Trailer
  - Curb .... 30,525 lbs
  - Test Inertial .... 78,975 lbs
  - Gross Static .... 78,975 lbs
- Vehicle Speed
  - Impact .... 49.4 mph
  - Exit .... NA
- Vehicle Angle
  - Impact .... 16.3 deg
  - Exit .... approximately 5 deg
- Vehicle Snagging .... None
- Vehicle Pocketing .... None
- Vehicle Stability .... Satisfactory
- Occupant Ridedown Deceleration (10 msec avg.) – Tractor
  - Longitudinal (not required) ..... 8.05/-6.98 g's < 20 g's
  - Lateral (not required) .... 6.06/-7.91 g's
- Occupant Impact Velocity – Tractor
  - Longitudinal (not required) ..... 2.99 ft/s < 39.37 ft/s
  - Lateral (not required) .... 18.05 ft/s
- Occupant Ridedown Deceleration (10 msec avg.) – Trailer
  - Longitudinal (not required) ..... 3.52/-2.17 g's < 20 g's
  - Lateral (not required) .... 11.74/-7.88 g's
- Occupant Impact Velocity – Trailer
  - Longitudinal (not required) ..... 3.55 ft/s < 39.37 ft/s
  - Lateral (not required) .... 7.60 ft/s
- Vehicle Damage .... Moderate
  - TAD[25] .... 1-RFQ-3 and 1-RD-3
  - SAE[26] .... 1-FREN3 and 1-RDES2
- Vehicle Stopping Distance .... 410 ft-11 in. downstream 173 ft-3 in. laterally behind
- Barrier Damage .... Moderate
- Maximum Rail Deflections
  - Permanent Set .... NA
  - Dynamic .... 11.2 in
- Working Width .... 75.4 in.

Figure A-23. NDOR Aesthetic Open Concrete Bridge Rail

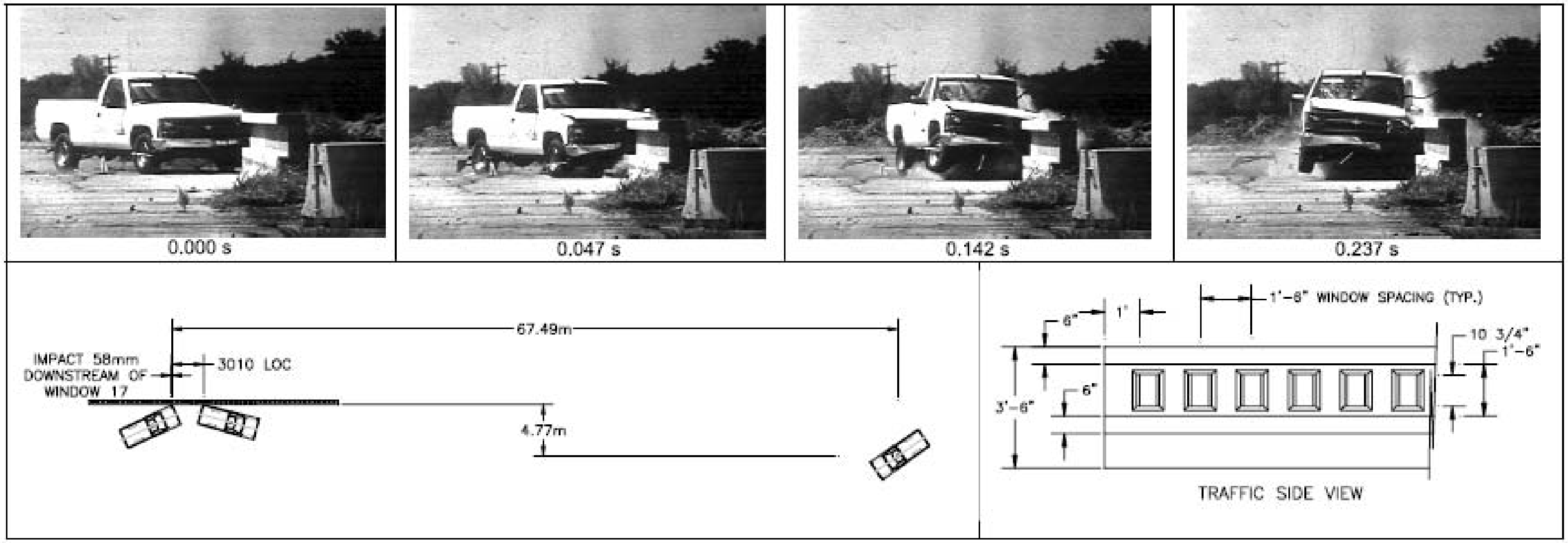


General Information	
Test Agency	Texas Transportation Institute
Test No.	442882-1
Date	05/06/02
Test Article	
Type	Bridge Rail
Name	F411 Aesthetic Bridge Rail
Installation Length (ft)	76 (23.2 m)
Material or Key Elements	Concrete Bridge Rail With Two Concrete Rails And Aesthetic Openings
Soil Type and Condition	Concrete Footing, Dry
Test Vehicle	
Type	Production
Designation	2000P
Model	1997 Chevrolet 2500 Pickup
Mass (lbs)	
Curb	4778 (2170 kg)
Test Inertial	4502 (2044 kg)
Dummy	N/A
Gross Static	4502 (2044 kg)

Impact Conditions	
Speed (mi/h)	61.4 (98.8 km/h)
Angle (deg)	24.8
Exit Conditions	
Speed (mi/h)	36.0 (57.9 km/h)
Angle (deg)	7.3
Occupant Risk Values	
Impact Velocity (ft/s)	
x-direction	26.2 (8.0 m/s)
y-direction	23.0 (7.0 m/s)
THIV (mph)	23.5 (37.8 km/h)
Ridedown Accelerations (g's)	
x-direction	-6.0
y-direction	-5.4
PHD (g's)	6.8
ASI	1.50
Max. 0.050-s Average (g's)	
x-direction	-12.3
y-direction	-10.5
z-direction	5.2

Test Article Deflections (ft)	
Dynamic	None
Permanent	None
Working Width	1.41 (0.43 m)
Vehicle Damage	
Exterior	
VDS	01FR2
CDC	01RFAW3
Maximum Exterior Vehicle Crush (in)	25.6 (650 mm)
Interior	
OCDI	RF2222010
Max. Occ. Compart. Deformation (in)	8.3 (210 mm)
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	-30.5
Max. Pitch Angle (deg)	-2.2
Max. Roll Angle (deg)	4.1

Figure A-24. TxDOT F411 Bridge Rail Test 1



General Information
- Test Agency .... Texas Transportation Institute
- Test No. 442882-2
- Date 07/18/02

Test Article
- Type .... Bridge Rail
- Name .... F411 Aesthetic Bridge Rail
- Installation Length (ft) .... 76 (23.2 m)
- Material or Key Elements .... Concrete Bridge Rail With Two Concrete Rails And Aesthetic Openings

Soil Type and Condition .... Concrete Footing

Test Vehicle
- Type .... Production
- Designation 2000P
- Model .... 1998 Chevrolet 2500 Pickup
- Mass (lbs)
  - Curb .... 4569 (2075 kg)
  - Test Inertial .... 4518 (2052 kg)
  - Dummy .... N/A
  - Gross Static .... 4518 (2052 kg)

Impact Conditions
- Speed (mi/h) .... 62.8 (101.1 km/h)
- Angle (deg) 26.1

Exit Conditions
- Speed (mi/h) .... 49.6 (79.9 km/h)
- Angle (deg) 4.5

Occupant Risk Values
- Impact Velocity (ft/s)
  - x-direction .... 24.6 (7.5 m/s)
  - y-direction .... 28.5 (8.7 m/s)
- THIV (mph) .... 25.5 (41.0 km/h)
- Ridedown Accelerations (g's)
  - x-direction .... -6.7
  - y-direction 8.0
- PHD (g's) 8.6
- ASI 1.76
- Max. 0.050-s Average (g's)
  - x-direction .... -10.7
  - y-direction 13.8
  - z-direction 4.3

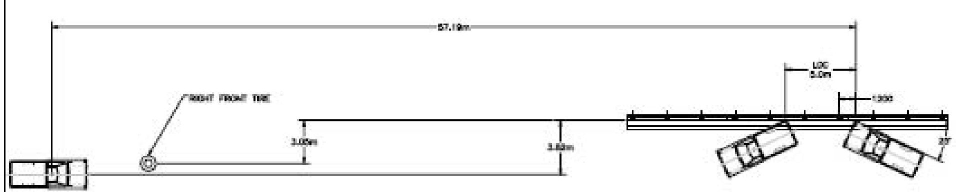
Test Article Deflections (ft)
- Dynamic .... None
- Permanent .... None
- Working Width .... 1.71 (0.52 m)

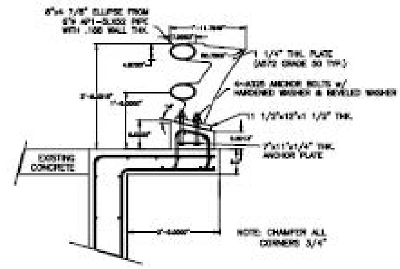
Vehicle Damage
- Exterior
  - VDS 11FL3
  - CDC 11LFAW3
- Maximum Exterior
  - Vehicle Crush (in) .... 26.4 (670 mm)
- Interior
  - OCDI LF2010000
- Max. Occ. Compart.
  - Deformation (in) .... 4.6 (118 mm)

Post-Impact Behavior
- (during 1.0 s after impact)
- Max. Yaw Angle (deg) 33.5
- Max. Pitch Angle (deg) .... -2.9
- Max. Roll Angle (deg) .... -7.6

Figure A-25. TxDOT F411 Bridge Rail Test 2

0.000 s — 0.077 s — 0.180 s — 0.386 s





General Information

Test Agency	Texas Transportation Institute
Test No.	442882-3
Date	08/23/02
Test Article	
Type	Bridge Rail
Name	T77 Aesthetic Bridge Rail
Installation Length (ft)	75 (22.7 m)
Material or Key Elements	Tubular Steel Rail Elements Mounted On Steel "7" Shaped Posts
Soil Type and Condition	Concrete Footing
Test Vehicle	
Type	Production
Designation	2000P
Model	1997 Chevrolet 2500 Pickup
Mass (lbs)	
Curb	4723 (2145 kg)
Test Inertial	4500 (2043 kg)
Dummy	N/A
Gross Static	4500 (2043 kg)

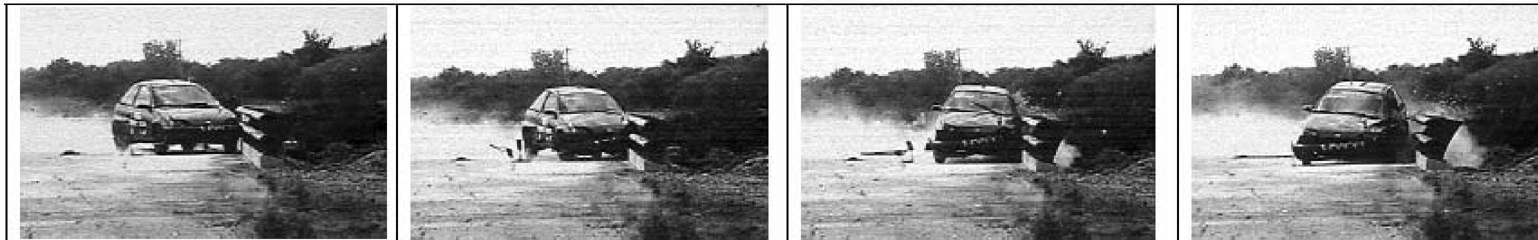
Impact Conditions

Speed (mi/h)	60.8 (97.8 km/h)
Angle (deg)	24.2
Exit Conditions	
Speed (mi/h)	44.7 (71.9 km/h)
Angle (deg)	10.8
Occupant Risk Values	
Impact Velocity (ft/s)	
x-direction	21.6 (6.6 m/s)
y-direction	21.0 (6.4 m/s)
THIV (mph)	19.9 (32.1 km/h)
Ridedown Accelerations (g's)	
x-direction	-5.6
y-direction	-13.5
PHD (g's)	14.2
ASI	1.23
Max. 0.050-s Average (g's)	
x-direction	-9.8
y-direction	-9.4
z-direction	-4.7

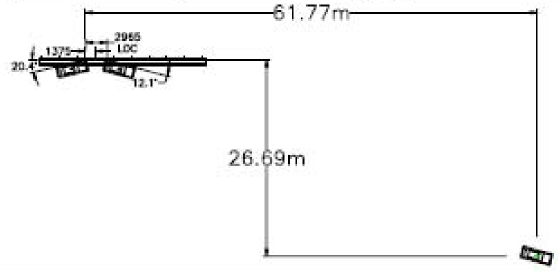
Test Article Deflections (ft)

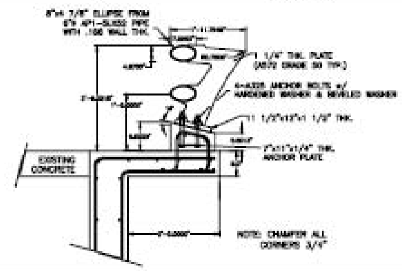
Dynamic	0.18 (0.05 m)
Permanent	0.04 (0.01 m)
Working Width	2.10 (0.64 m)
Vehicle Damage	
Exterior	
VDS	01FR3
CDC	01FRAW3
Maximum Exterior Vehicle Crush (in)	30.7 (780 mm)
Interior	
OCDI	RF0020000
Max. Occ. Compart. Deformation (in)	8.7 (222 mm)
Post-Impact Behavior (during 1.0 s after impact)	
Max. Yaw Angle (deg)	-37.8
Max. Pitch Angle (deg)	4.1
Max. Roll Angle (deg)	18.2

Figure A-26. TxDOT T77 Bridge Rail Test 1



0.000 s | 0.049 s | 0.147 s | 0.294 s





General Information
- Test Agency .... Texas Transportation Institute
- Test No. 442882-4
- Date 08/27/02

Test Article
- Type .... Bridge Rail
- Name .... T77 Aesthetic Bridge Rail
- Installation Length (ft) .... 75 (22.7 m)
- Material or Key Elements .... Tubular Steel Rail Elements Mounted On Steel "7" Shaped Posts

Soil Type and Condition .... Concrete Footing

Test Vehicle
- Type .... Production
- Designation 820C
- Model .... 1997 Geo Metro
- Mass (lbs)
  - Curb .... 1792 (814 kg)
  - Test Inertial .... 1806 (820 kg)
  - Dummy .... 169 (77 kg)
  - Gross Static .... 1976 (897 kg)

Impact Conditions
- Speed (mi/h) .... 61.6 (99.1 km/h)
- Angle (deg) 20.4

Exit Conditions
- Speed (mi/h) .... 51.0 (82.0 km/h)
- Angle (deg) 12.1

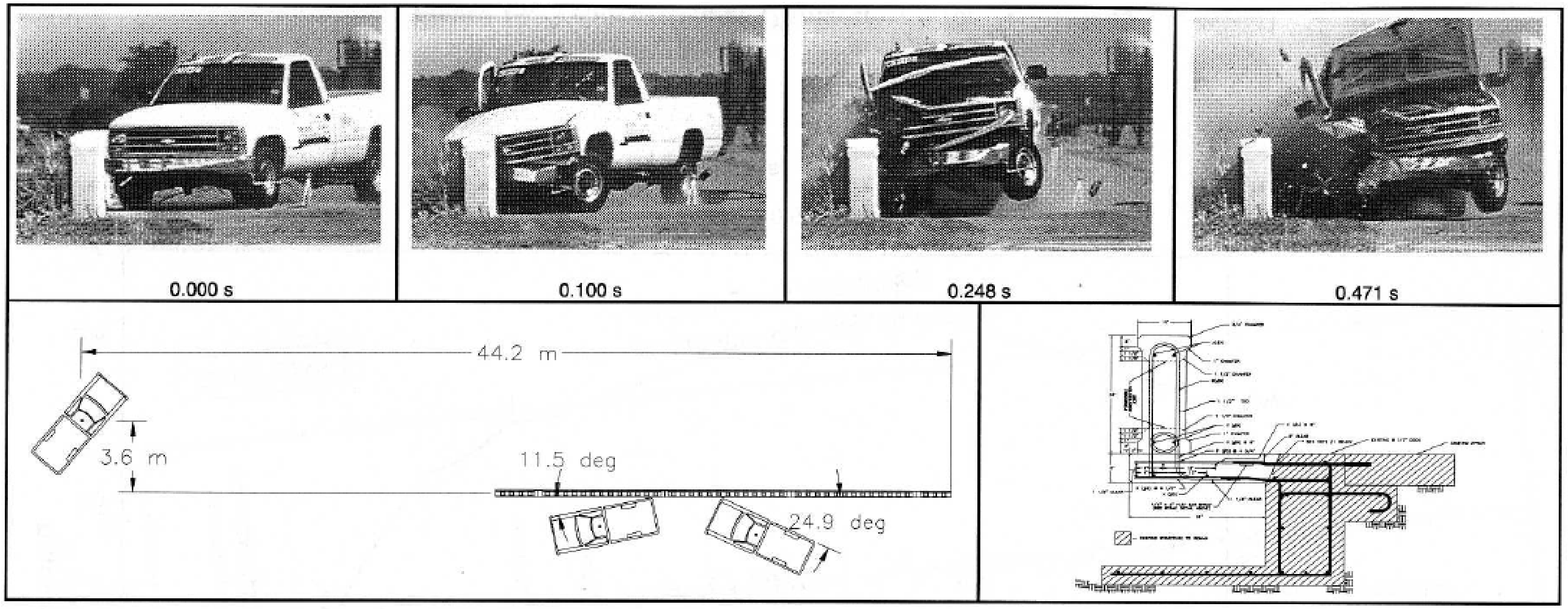
Occupant Risk Values
- Impact Velocity (ft/s)
  - x-direction .... 16.7 (5.1 m/s)
  - y-direction .... 25.6 (7.8 m/s)
- THIV (mph) .... 19.8 (31.9 km/h)
- Ridedown Accelerations (g's)
  - x-direction .... -2.3
  - y-direction 10.0
- PHD (g's) 10.0
- ASI 1.79
- Max. 0.050-s Average (g's)
  - x-direction .... -9.8
  - y-direction 14.3
  - z-direction .... -3.2

Test Article Deflections (ft)
- Dynamic .... None
- Permanent .... 0.04 (0.01 m)
- Working Width .... 1.90 (0.58 m)

Vehicle Damage
- Exterior
  - VDS 11FL2
  - CDC 11LFEW2
- Maximum Exterior
  - Vehicle Crush (in) .... 8.9 (230 mm)
- Interior
  - OCDI LF0010000
- Max. Occ. Compart.
  - Deformation (in) .... 1.0 (25 mm)

Post-Impact Behavior
- (during 1.0 s after impact)
- Max. Yaw Angle (deg) 38.2
- Max. Pitch Angle (deg) .... -3.2
- Max. Roll Angle (deg) .... -14.2

Figure A-27. TxDOT T77 Bridge Rail Test 2



General Information
- Test Agency .... Texas Transportation Institute
- Test No. 418048-1
- Date 04/20/98

Test Article
- Type .... Bridge Rail
- Name or Manufacturer ...... Texas Type T411
- Installation Length (m) 23.1
- Material or Key Elements .... Concrete Beam and Posts

Soil Type and Condition .... Concrete deck, dry

Test Vehicle
- Type .... Production
- Designation 2000P
- Model .... 1993 Chevrolet pickup truck
- Mass (kg) Curb 2142
  - Test Inertial 2000
  - Dummy .... No dummy
  - Gross Static 2000

Impact Conditions
- Speed (km/h) 101.3
- Angle (deg) 24.9

Exit Conditions
- Speed (km/h) 69.5
- Angle (deg) 11.5

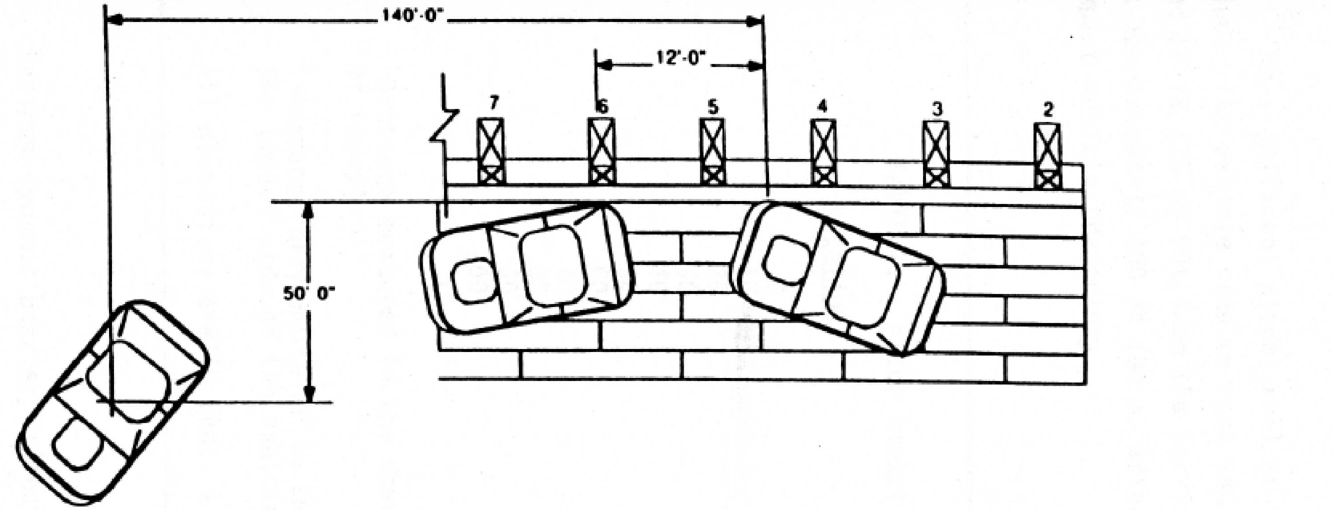
Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 9.5
- THIV (km/h) 37.4
- Ridedown Accelerations (g's)
  - x-direction .... -11.7
  - y-direction .... -9.2
- PHD (g's) 15.4
- ASI 1.4
- Max. 0.050-s Average (g's)
  - x-direction .... -11.5
  - y-direction .... -10.9
  - z-direction 5.0

Test Article Deflections (m)
- Dynamic .... nil
- Permanent .... nil

Vehicle Damage
- Exterior
  - VDS 01FR6
  - CDC 01FREW6
- Maximum Exterior
  - Vehicle Crush (mm) 1040
- Interior
  - OCDI FS1012000
- Max. Occ. Compart.
  - Deformation (mm) 117

Post-Impact Behavior
- (during 1.0 s after impact)
- Max. Yaw Angle (deg) ...... -32
- Max. Pitch Angle (deg) 3
- Max. Roll Angle (deg) 7

Figure A-28. TxDOT T411 Bridge Rail Test



Test No. WB-1
Test Date . . . . Sept. 21, 1988
Installation Length - ft [m] . . . . 72 [22]
Beam
Member . . . . . 6-in (15.2 cm) x10-3/4-in (27.3) laminated wood
Length - ft [m] . . . . 18.0 [5.5]

Maximum Deflections - in. [cm]
Permanent . . . . 1.5 [3.8]
Dynamic . . . . 6.3 [16.0]
Post
Details of the posts, blockouts, curb, and deck are included in figure 8.

Vehicle . . . . 1982 V.W. Rabbit
Mass - lb [kg]
Test Inertia . . . . 1818 [825]
Dummy . . . . 165 [75]
Gross Test Weight . . . . 1983 [900]
Speed - mi/h [km/h] . . . . 59.2 [95.3]

Angle - degrees
Impact 20
Exit . . . . -12.0

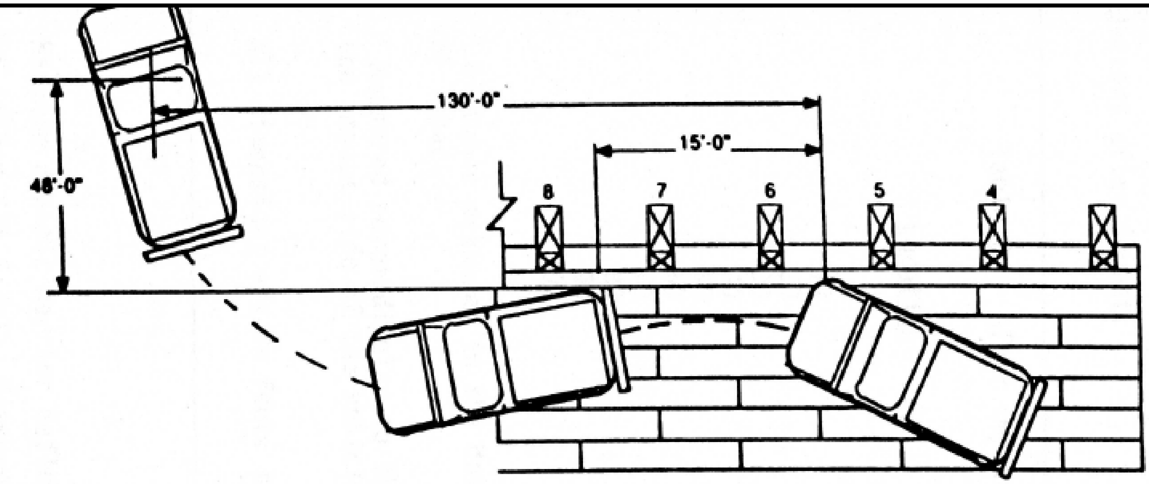
Occupant Impact Velocity - ft/s [m/s]
Forward (accel) . . . . -10.6 [-3.2]
Lateral (accel) . . . . -18.6 [-5.7]

Occupant Ridedown Accelerations - g's
Forward (accel) . . . . -0.7
Lateral (accel) 7.6

Maximum 50 m/s Avg Accelerations - g's
Longitudinal (accel) . . . . -5.0
Lateral (accel) 8.5

Vehicle Damage
TAD 01-FR-4
VDI 01FREE6

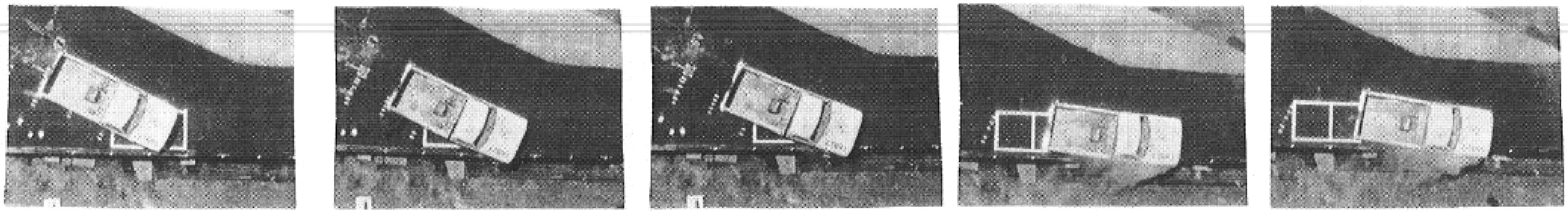
Figure A-29. Forrest Service Glulam Bridge Rail Test 1



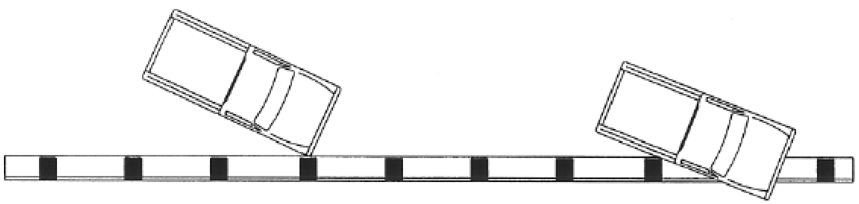
Test No.	WB-2
Test Date	Sept. 27, 1988
Installation Length - ft [m]	72 [22]
Beam	
Member	6-in (15.2 cm) x 10-3/4 -in (27.3 cm) laminated wood
Length - ft [m]	18.0 [5.5]
Maximum Deflections - in. [cm]	
Permanent	2.3 [5.8]
Dynamic	8.5 [21.6]
Post	
Details of the posts, blockouts, curb, and deck are included in figure 11.	
Vehicle	1984 Ford F150 Pickup
Mass - lb [kg]	
Test Inertia	5254 [2383]
Dummy	165 [75]
Gross Test Weight	5419 [2458]
Speed - mi/h [km/h]	47.5 [76.4]

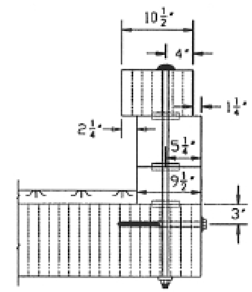
Angle - degrees	
Impact	20
Exit	-4.9
Occupant Impact Velocity - ft/s [m/s]	
Forward (accel)	8.1 [2.5]
Lateral (accel)	-17.2 [-5.2]
Occupant Ridedown Accelerations - g's	
Forward (accel)	-1.7
Lateral (accel)	6.9
Maximum 50 m/s Avg Accelerations - g's	
Longitudinal (accel)	-3.2
Lateral (accel)	5.2
Vehicle Damage	
TAD	01-FR-4
VDI	01FREE6

Figure A-30. Forrest Service Glulam Bridge Rail Test 2



0.000 sec | 0.124 sec | 0.144 sec | 0.433 sec | 0.483 sec



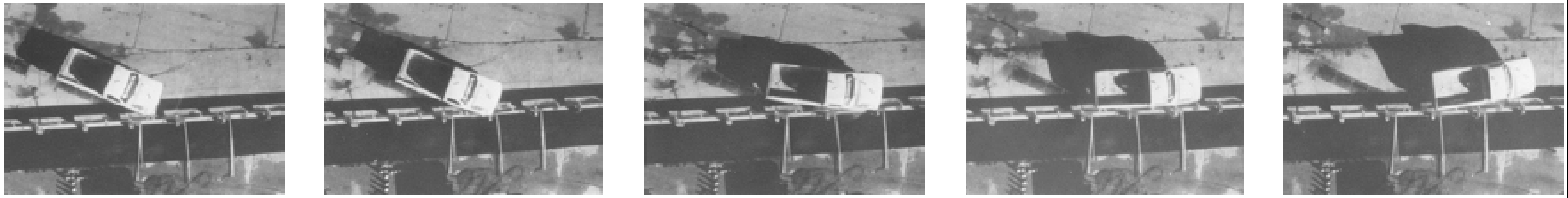


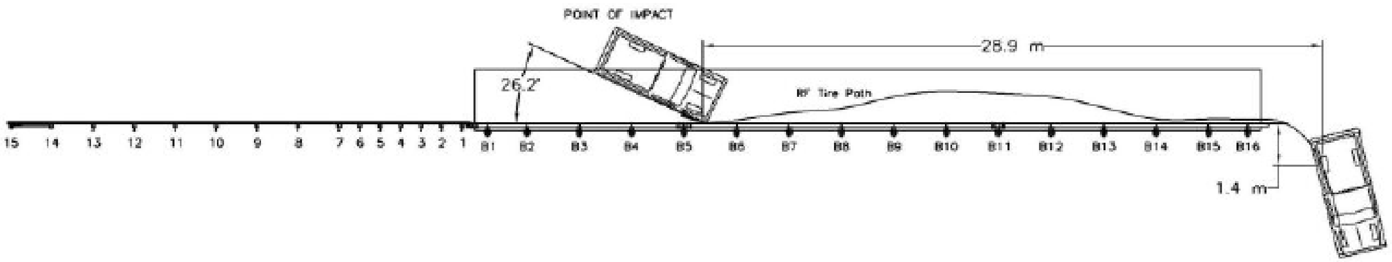
- Test Number CTBR-1
- Date 6/23/95
- Bridge Rail Installation . . . . TL-1 Curb-Type Railing System
- Total Length . . . . 100 ft
- Glulam Curb Rail
  - Size . . . . 6¾ in. x 10½ in.
  - Top Mounting Height . . . . 17¾ in.
  - Material . . . . West Coast Douglas Fir
  - Grade . . . . Combination No. 2
- Scupper Blocks
  - Size . . . . 7½ in. x 9½ in. 23 in. & 5½ in. x 9½ in. 23 in.
  - Material . . . . Douglas Fir
  - Grade . . . . No. 1
  - Spacing . . . . 10 ft
- Anchorage Bolts
  - Type . . . . ASTM A307, Galvanized
  - Size . . . . Four ¾-in. ϕ Bolts Per Location
  - Length . . . . 33 in.
- Bridge Deck Installation . . . . Longitudinal Glulam Timber Bridge Deck Panels
  - Panel Size . . . . 10¾ in. x 4 ft x 18 ft - 9 in.
  - Material . . . . West Coast Douglas Fir
  - Grade . . . . Combination No. 2
- Vehicle Model . . . . 1985 Ford F-250
  - Curb Weight . . . . 4,110 lbs
  - Test Inertial Weight . . . . 4,435 lbs
  - Gross Static Weight . . . . 4,435 lbs

- Vehicle Speed
  - Impact . . . . 31.6 mph
  - Exit . . . . NA
- Vehicle Angle
  - Impact . . . . 24.3 degrees
  - Exit . . . . NA
- Vehicle Snagging . . . . Minor steel rim and undercarriage gouging on the rail
- Vehicle Stability . . . . Satisfactory but with moderate vaulting on traffic-side face of bridge railing
- Occupant Ridedown Deceleration (0.010-sec average)
  - Longitudinal . . . . 7.1 G's ≤ 20 G's
  - Lateral . . . . 4.1 G's ≤ 20 G's
- Occupant Impact Velocity (normalized)
  - Longitudinal . . . . 3.9 m/s ≤ 12 m/s
  - Lateral . . . . 3.2 m/s ≤ 12 m/s
- Vehicle Damage . . . . Minor
  - TAD[22] 1-RFQ-1
  - SAE[23] 01RDWN2
- Vehicle Stopping Distance . . . . 50 ft
- Barrier Damage . . . . Minor scrapes and gouges on the rail as well as deformed steel splice plates
- Maximum Rail Deflections
  - Permanent Set . . . . 0.1 in.
  - Dynamic . . . . 2.7 in.

(1 in. = 25.4 mm, 1 lb = 0.454 kg, 1 mph = 1.609 kph)

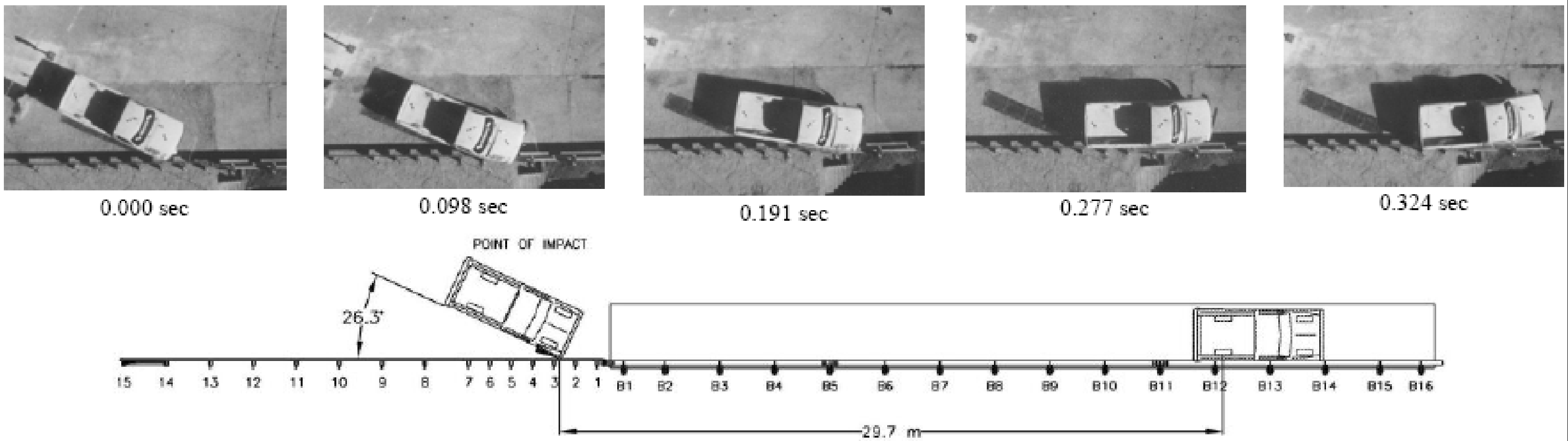
Figure A-31. Curb-Type Glulam Bridge Rail Test





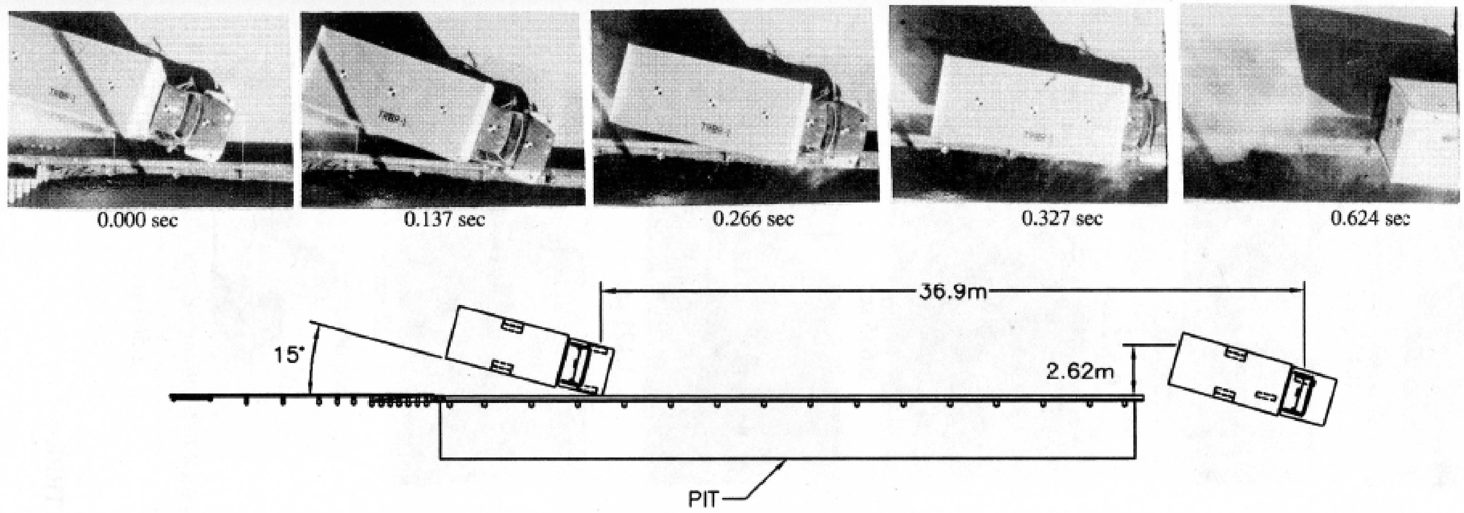
- Test Number WRBP-1
- Date 12/15/99
- Appurtenance .... Wood Bridge Rail System for Transverse Decks
- Total Length .... 37.24 m
- Wood Rail
  - Material .... Southern Yellow Pine, Combination No. 48
  - Dimensions .... 171 mm x 343 mm x 37.24 m
  - Top Mounting Height .... 721 mm
- Rail Wood Post Nos. 1-16
  - Material .... Southern Yellow Pine, Combination No. 48
  - Dimensions .... 171 mm x 191 mm x 935 mm
- Rail Wood Spacer Blocks Nos. 1-16
  - Material .... Southern Yellow Pine, Combination No. 47
  - Dimensions .... 171 mm x 191 mm x 267 mm
- Vehicle Model .... 1994 Ford F-250 3/4 Ton Pickup Truck
  - Curb .... 2,045 kg
  - Test Inertial .... 2,031 kg
  - Gross Static .... 2,031 kg
- Vehicle Speed
  - Impact .... 69.0 km/hr
  - Exit .... 47.1 km/hr
- Vehicle Angle
  - Impact 26.2deg
  - Exit .... 5.9 deg
- Vehicle Snagging .... None
- Vehicle Stability .... Satisfactory
- Effective Coefficient of Friction (μ) 0.48
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal .... 3.86 < 20 G's
  - Lateral (not required) 6.28
- Occupant Impact Velocity
  - Longitudinal .... 5.47 < 12 m/s
  - Lateral (not required) 5.45
- Vehicle Damage .... Moderate
  - TAD[32] 1-RFQ-3/1-RD-4
  - SAE[33] 01-RDES3
- Vehicle Stopping Distance .... 28.9 m downstream
1.4 m laterally behind
- Bridge Rail Damage .... Moderate
- Maximum Deflections
  - Permanent Set .... est. 63 mm
  - Dynamic .... 189 mm

Figure A-32. FPL Glulam Bridge Rail TL-2 Test 1



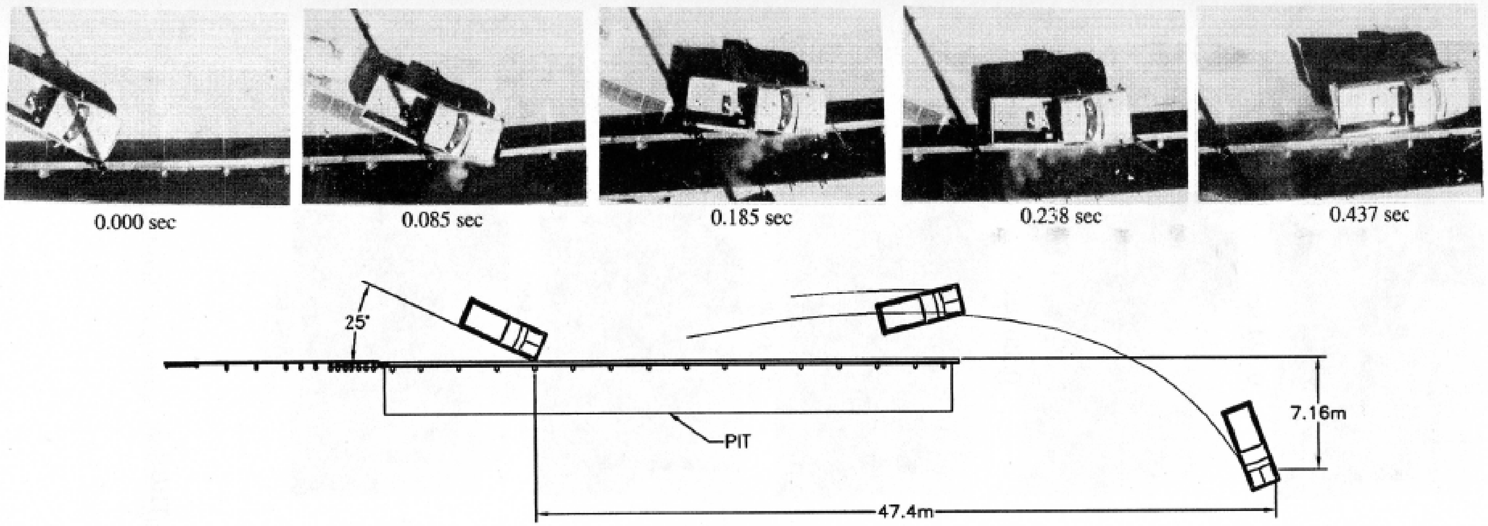
- Test Number WRBP-2
- Date 2/03/00
- Appurtenance .... Approach Guardrail Transition attached to a Wood Bridge Rail System for Transverse Decks
- Total Length .... 24.77 m
- Steel W-Beam Rail (Nested)
  - Thickness .... 2.66 mm
  - Top Mounting Height .... 706 mm
- Steel W-Beam Rail
  - Thickness .... 2.66 mm
  - Top Mounting Height .... 706 mm
- Steel Posts
  - Post Nos. 1 -5 .... W152x13.4 by 2,134-mm long
  - Post Nos. 6 - 7 .... W152x13.4 by 1,981-mm long
  - Post Nos. 8 - 13 .... W152x13.4 by 1,829-mm long
- Wood Posts
  - Post Nos. 14 - 15 (BCT) ...... 140 mm x 190 mm by 1,080 mm long
- Wood Spacer Blocks
  - Post Nos. 1 - 13 .... 152 mm x 203 mm by 368-mm long
- Vehicle Model .... 1993 Ford F-250 ¾-Ton Pickup Truck
  - Curb .... 2,092 kg
  - Test Inertial .... 2,011 kg
  - Gross Static .... 2,011 kg
- Vehicle Speed
  - Impact .... 71.6 km/hr
  - Exit .... 54.6 km/hr
- Vehicle Angle
  - Impact .... 26.3 deg
  - Exit .... 3.5 deg
- Vehicle Snagging .... None
- Vehicle Stability .... Satisfactory
- Effective Coefficient of Friction (μ) 0.26
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal .... 5.51 < 20 G's
  - Lateral (not required) 9.74
- Occupant Impact Velocity
  - Longitudinal .... 4.43 < 12 m/s
  - Lateral (not required) 6.42
- Vehicle Damage .... Moderate
  - TAD[82] 1-RFQ-3/1-RD-2
  - SAE[83] 01-RDES3
- Vehicle Stopping Distance .... 29.7 m downstream
  0.0 m lateral
- Barrier Damage .... Minor
- Maximum Deflections
  - Permanent Set .... 29 mm
  - Dynamic .... 125 mm

Figure A-33. FPL Glulam Bridge Rail TL-2 Test 2



- Test Number TRBR-1
- Date 3/11/97
- Appurtenance .... Wood Bridge Rail with Curb Rail System for Transverse Decks
- Total Length .... 37.19 m
- Wood Upper Rail
  - Material .... Southern Yellow Pine, Combination No. 48
  - Dimensions .... 222 mm x 343 mm x 36.58 m
  - Top Mounting Height .... 838 mm
- Upper Rail Wood Post Nos. 1-16
  - Material .... Southern Yellow Pine, Combination No. 48
  - Dimensions .... 222 mm x 267 mm x 943 mm
- Upper Rail Wood Spacer Blocks Nos. 1-16
  - Material .... Southern Yellow Pine, Combination No. 47
  - Dimensions .... 79 mm x 222 mm x 267 mm
- Wood Lower Curb Rail
  - Material .... Southern Yellow Pine, Combination No. 47
  - Dimensions .... 171 mm x 305 mm x 36.58 mm
  - Top Mounting Height .... 292 mm
- Lower Curb Rail Wood Scupper Blocks Nos. 3-14
  - Material .... Southern Yellow Pine, Combination No. 47
  - Dimensions .... 171 mm x 305 mm x 1,372 mm
- Vehicle Model .... 1986 Ford F-800 Series Single-Unit Truck
  - Curb .... 5,284 kg
  - Test Inertial .... 8,000 kg
  - Gross Static .... 8,000 kg
- Vehicle Speed
  - Impact .... 74.8 km/hr
  - Exit .... 47.3 km/hr
- Vehicle Angle
  - Impact .... 16.0 deg
  - Exit .... 0 deg
- Vehicle Snagging .... None
- Vehicle Stability .... Satisfactory
- Effective Coefficient of Friction (μ) 0.65
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal (not required) .... 3.27 < 20 G's
  - Lateral (not required) 5.00
- Occupant Impact Velocity
  - Longitudinal (not required) .... 2.15 < 12 m/s
  - Lateral (not required) 2.78
- Vehicle Damage .... Moderate
  - TAD[28] 1-RFQ-4
  - SAE[29] 01-RFEW3
- Vehicle Stopping Distance .... 36.9 m downstream, 2.6 m lateral
- Bridge Rail Damage .... Moderate
- Maximum Deflections
  - Permanent Set .... 10 mm
  - Dynamic .... 84 mm

Figure A-34. FPL Glulam Bridge Rail TL-4 Test 1



- Test Number TRBR-2
- Date 3/19/97
- Appurtenance .... Wood Bridge Rail with Curb Rail System for Transverse Decks
- Total Length .... 37.19 m
- Wood Upper Rail
  - Material .... Southern Yellow Pine, Combination No. 48
  - Dimensions .... 222 mm x 343 mm x 36.58 m
  - Top Mounting Height .... 838 mm
- Upper Rail Wood Post Nos. 1 - 16
  - Material .... Southern Yellow Pine, Combination No. 48
  - Dimensions .... 222 mm x 267 mm x 943 mm
- Upper Rail Wood Spacer Block Nos. 1 - 16
  - Material .... Southern Yellow Pine, Combination No. 47
  - Dimensions .... 79 mm x 222 mm x 267 mm
- Wood Lower Curb Rail
  - Material .... Southern Yellow Pine, Combination No. 47
  - Dimensions .... 171 mm x 305 mm x 36.58 m
  - Top Mounting Height .... 292 mm
- Lower Curb Rail Wood Scupper Block Nos. 3 - 14
  - Material .... Southern Yellow Pine, Combination No. 47
  - Dimensions .... 171 mm x 305 mm x 1,372 mm
- Vehicle Model .... 1988 Ford F-250 ¾-Ton Pickup Truck
  - Curb .... 1,822 kg
  - Test Inertial .... 1,993 kg
  - Gross Static .... 1,993 kg
- Vehicle Speed
  - Impact .... 99.2 km/hr
  - Exit .... 62.3 km/hr
- Vehicle Angle
  - Impact .... 27.4 deg
  - Exit .... 2.1 deg
- Vehicle Snagging .... None
- Vehicle Stability .... Satisfactory
- Effective Coefficient of Friction (μ) 0.48
- Occupant Ridedown Deceleration (10 msec avg.)
  - Longitudinal .... 7.09 < 20 G's
  - Lateral (not required) 8.95
- Occupant Impact Velocity
  - Longitudinal .... 7.39 < 12 m/s
  - Lateral (not required) 7.50
- Vehicle Damage .... Moderate
  - TAD[28] 1-RFQ-6
  - SAE[29] 01-RYAW5
- Vehicle Stopping Distance .... 47.4 m downstream, 7.2 m lateral behind
- Bridge Rail Damage .... Moderate
- Maximum Deflections
  - Permanent Set .... 29 mm
  - Dynamic .... 203 mm

Figure A-35. FPL Glulam Bridge Rail TL-4 Test 2