US Department
of Transportation

**Federal Highway
Administration**

400 Seventh St., S.W.
Washington, D.C. 20590

August 19, 1999

Refer to: HMHS-CC60

Mr. King K. Mak
Research Engineer
Safety & Structural Systems Division
Texas Transportation Institute
College Station, TX 77843-3135

Dear Mr. Mak:

In your July 29 letter to me, you requested the Federal Highway Administration's (FHWA) acceptance of Wyoming's box-beam guardrail and median barrier end terminals, called the WYBET-350 and the WYBET-350 (MB), respectively, as National Cooperative Highway Research Program (NCHRP) Report 350 test level 3 (TL-3) designs. The original designs had both been accepted previously under NCHRP Report 230 evaluation criteria. To support your request, you also sent two copies of the Texas Transportation Institute report, entitled "NCHRP REPORT 350 EVALUATION OF THE WYOMING BOX-BEAM END TERMINAL (WYBET-350)", dated June 1999, and videotape copies of the crash tests that were run. Summaries of these tests are shown as Enclosure 1. Test 3-35 was run on both the guardrail and median barrier terminal designs.

The original WYBET designs consisted of an impact head, outer and inner steel tubes containing energy absorbing fiberglass/epoxy composite tubes, and an end anchorage assembly. Both Report 350 designs are similar in design to the Report 230 versions, but have some important differences. Enclosure 2 lists all of the design changes, the most significant one being Item 12, the increased length of the Stage 1 composite tube and the corresponding decrease in the length of the Stage 2 tube. This change was needed to meet the passenger ridedown acceleration in test 3-30. Because the crush force characteristics of the composite tubes are critical to proper impact performance of the WYBET-350 terminal, your test Report recommends that a "rigorous quality control and acceptance/rejection procedure be instituted by (the manufacturer) and the state Departments of Transportation to ensure that the composite tubes used in field installations are within the specifications". I strongly endorse this recommendation. Enclosure 3 shows the general design and layout of the WYBET-350 and the WYBET-350 (MB). Complete drawings are available from Mr. William B. Wilson, Wyoming DOT Standards Engineer, at (307) 777-4216 or via e-mail at bwilson@missc.state.wy.us

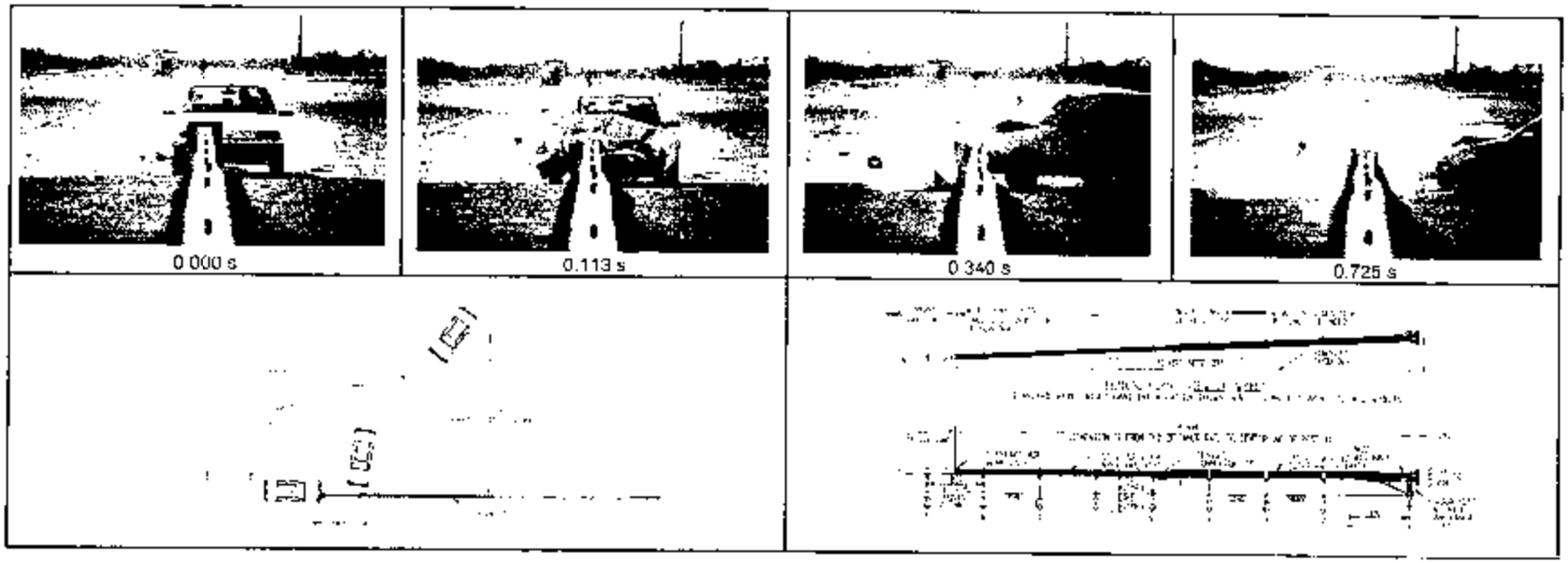
Members of my staff have reviewed the material you have submitted and agree that the WYBET-350 and the WYBET-350 (MB), as tested, satisfy the evaluation criteria recommended in Report 350 for a TL-3 terminal. Either design may be used on the National Highway System when such use is requested by the appropriate transportation agency. I understand that these designs are considered proprietary (except in Wyoming) so their use on Federal-aid projects, except exempt non-NHS projects, is subject to the conditions listed in Title 23, Code of Federal Regulations, Section 635.411. Please call Mr. Richard Powers at (202) 366-1320 should you have any questions.

Sincerely yours,

Dwight A. Horne

Dwight A. Horne
Director, Office of Highway Safety Infrastructure

3 Enclosures



General Information
- Test Agency . . . . . Texas Transportation Institute
- Test No. 473160-10
- Date 02/15/99

Test Article
- Type . . . . . Terminal
- Name or Manufacturer . . WyBET-350
- Installation Length (m) . 55.1
- Material or Key Elements . . Tubular Steel Rail Elements on Steel posts

Soil Type and Condition . . . Standard soil: dry

Test Vehicle
- Type . . . . . Production
- Designation 820C
- Model . . . . . 1994 Geo Metro
- Mass (kg)
  - Curb 763
  - Test Inertial 820
  - Dummy 76
  - Gross Static 896

Impact Conditions
- Speed (km/h) 98.7
- Angle (deg) 0

Exit Conditions
- Speed (km/h) 14.9
- Angle (deg) . . . 98.7

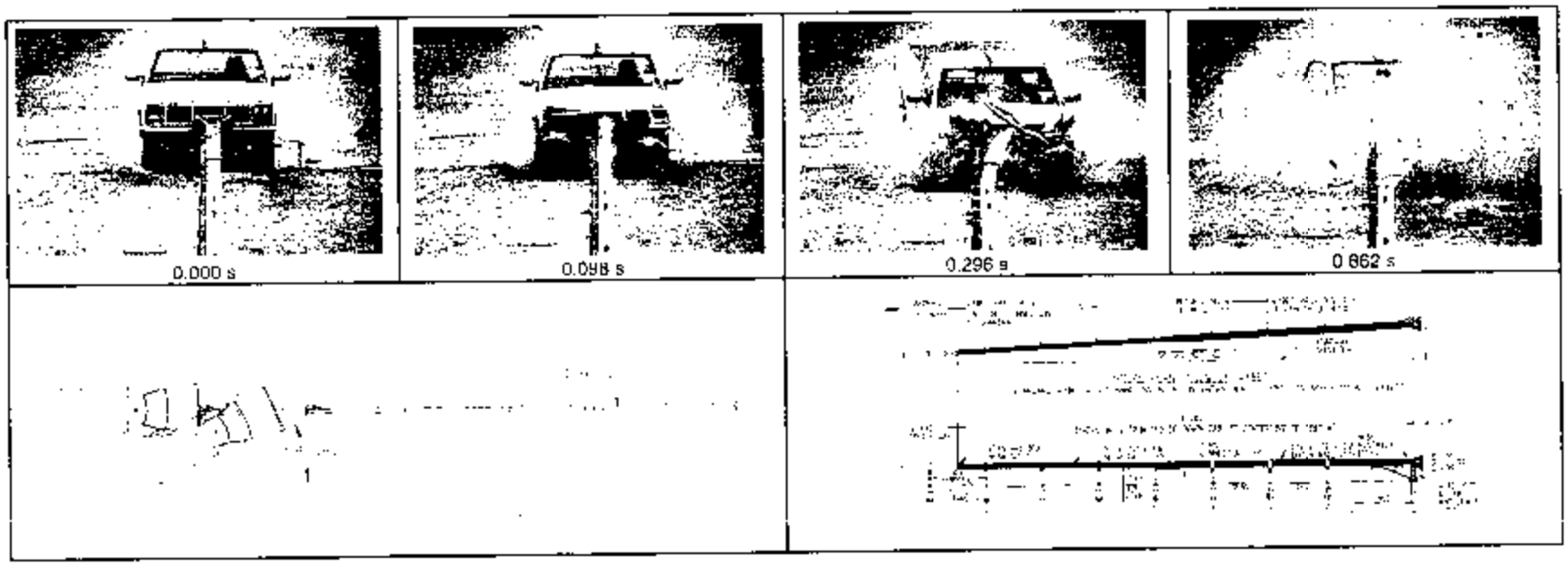
Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 10.9
  - y-direction . . . . . No Contact
- THIV (km/h) 38.9
- Ridedown Accelerations (g's)
  - x-direction . . . . . -12.0
  - y direction . . No Contact
- PHD (g's) . . . 12.1
- ASI 1.17
- Max. 0.050-s Average (g's)
  - x-direction . . . . . -14.0
  - y-direction 3.3
  - z-direction 4.3

Test Article Deflections (m)
- Dynamic 2.88
- Permanent 2.63

Vehicle Damage
- Exterior
  - VDS 12FD4
  - CDC 12FDEW4
- Maximum Exterior Vehicle Crush (mm) . 410
- Interior
  - OCDI FS0020000
- Max. Occ. Compart. Deformation (mm) 107

Post-Impact Behavior (during 1.0 s after impact)
- Max. Yaw Angle (deg) 122
- Max. Pitch Angle (deg) . . . 8
- Max. Roll Angle (deg) . . . -8

Figure 59. Summary of results for test 473160-10, *NCHRP Report 350* test 3-30.



General Information
- Test Agency . . . . . Texas Transportation Institute
- Test No 473160-3
- Date 03/12/98

Test Article
- Type . . . . . End Treatment
- Name WYBET-350
- Installation Length (m) . . 55.1
- Material or Key Elements . . Tubular Steel Rail Elements on Steel posts

Soil Type and Condition . . . Standard Soil, Dry

Test Vehicle
- Type . . . . . Production
- Designation 2000P
- Model . . . . . 1993 GMC 2500 pickup truck
- Mass (kg) Curb 1864
  - Test Inertia . . . 2000
  - Dummy . . . . No dummy
  - Gross Static . . 2000

Impact Conditions
- Speed (km/h) . . . 102.5
- Angle (deg) 0

Exit Conditions
- Speed (km/h) 6.9
- Angle (deg) 24.0

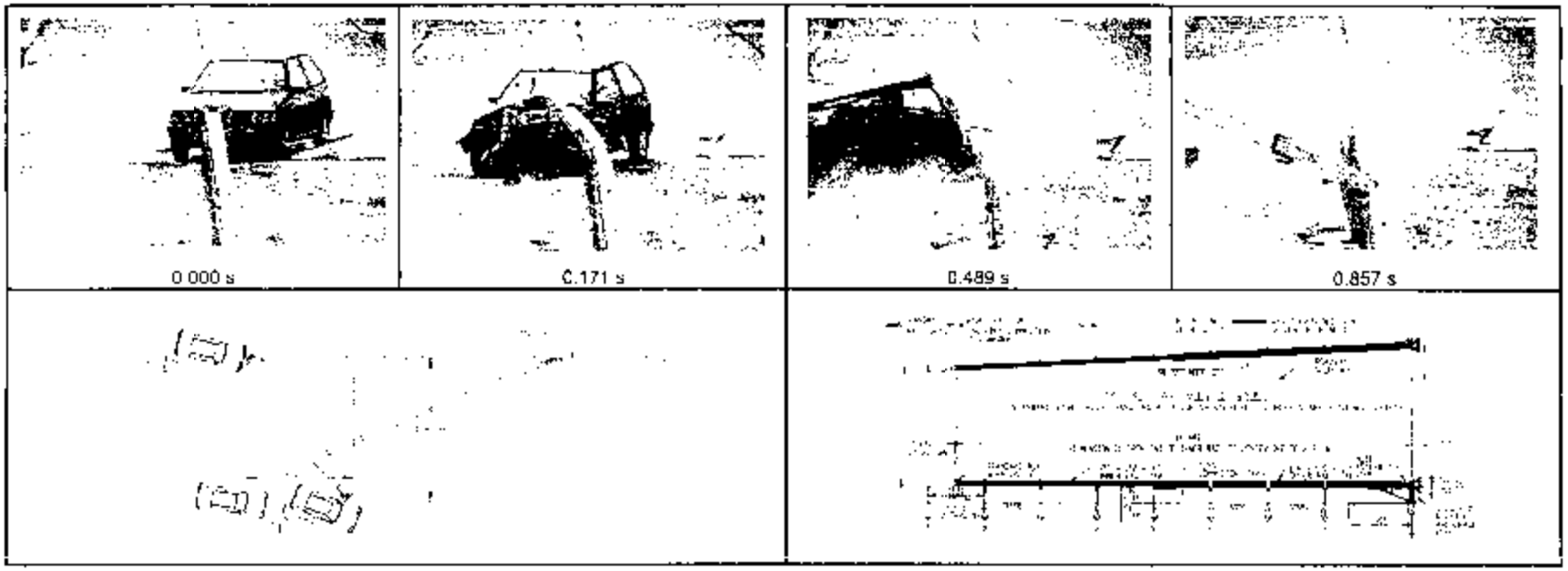
Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 9.5
  - y-direction 2.3
- THIV (km/h) 39.6
- Ridedown Accelerations (g's)
  - x-direction . . . . . -15.9
  - y-direction . . . . . -2.9
- PHD (g's) 15.9
- ASI 1.20
- Max. 0.050 s Average (g's)
  - x-direction . . . . -14.7
  - y-direction . . . . -1.9
  - z-direction 4.4

Test Article Deflections (m)
- Dynamic 4.11
- Permanent 4.11

Vehicle Damage
- Exterior
  - VDS 12FC3
  - CDC 12FCEN3
- Maximum Exterior Vehicle Crush (mm) . 530
- Interior
  - OCDI FS1000000
- Max. Occ. Compart. Deformation (mm) 35

Post-Impact Behavior (during 1.0 s after impact)
- Max. Yaw Angle (deg) . . . -23
- Max. Pitch Angle (deg) . . -14
- Max. Roll Angle (deg) 13

Figure 34. Summary of results for test 473160-3, *NCHRP Report 350* test 3-31.



General Information

Test Agency	Texas Transportation Institute
Test No.	473160-1
Date	03/04/98

Test Article

Type	End Treatment
Name or Manufacturer	WYBET-350
Installation Length (m)	55.1
Material or Key Elements	Tubular Steel Rail Elements on Steel Posts
Soil Type and Condition	Standard soil, Dry

Test Vehicle

Type	Production
Designation	820C
Model	1993 Ford Festiva
Mass (kg)	
Curb	846
Test Inertial	820
Dummy	75
Gross Static	895

Impact Conditions

Speed (km/h)	99.5
Angle (deg)	14.7

Exit Conditions

Speed (km/h)	8.7
Angle (deg)	22.3

Occupant Risk Values

Impact Velocity (m/s)	
x-direction	10.3
THIV (km/h)	37.0
Ridedown Accelerations (g's)	
x-direction	-9.7
y-direction	4.5
PHD (g's)	9.9
ASI	1.3
Max. 0.050-s Average (g's)	
x-direction	-15.2
y-direction	2.5
z-direction	2.4

Test Article Deflections (m)

Dynamic	9.16
Permanent	7.46

Vehicle Damage

Exterior	
VDS	12FD5
CDC	12FDEK3
Maximum Exterior Vehicle Crush (mm)	300
Interior	
OCDI	FS0010000
Max. Occ. Compart Deformation (mm)	45

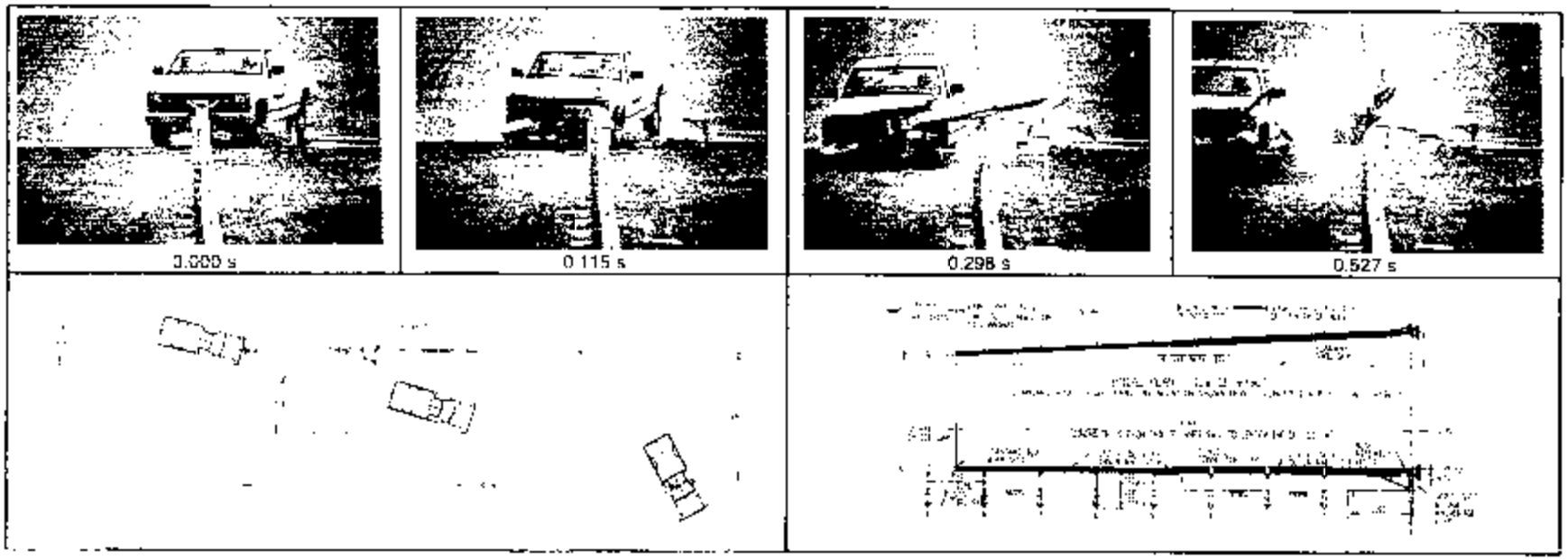
Post-Impact Behavior

(dummy 1.0 s after impact)

Max. Yaw Angle (deg)	31
Max. Pitch Angle (deg)	3
Max. Roll Angle (deg)	7

Figure 16. Summary of results for test 473160-1, *NCHRP Report 350* test 3-32.

ENCLOSURE 1 (3 of 6)



General Information
- Test Agency ..... Texas Transportation Institute
- Test No. 473160-11
- Date 03/05/99

Test Article
- Type ..... End Treatment
- Name or Manufacturer WyBET-350
- Installation Length (m) 55.1
- Material or Key Elements ..... Tubular Steel Rail Elements on Steel posts

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

Test Vehicle
- Type ..... Production
- Designation 2000P
- Model ..... 1994 Chevrolet 2500 pickup truck
- Mass (kg)
  - Curb 1845
  - Test Inertial 2000
  - Dummy ..... No Dummy
  - Gross Static 2000

Impact Conditions
- Speed (km/h) 99.8
- Angle (deg) 14.4

Exit Conditions
- Speed (km/h) 62.2
- Angle (deg) 17.4

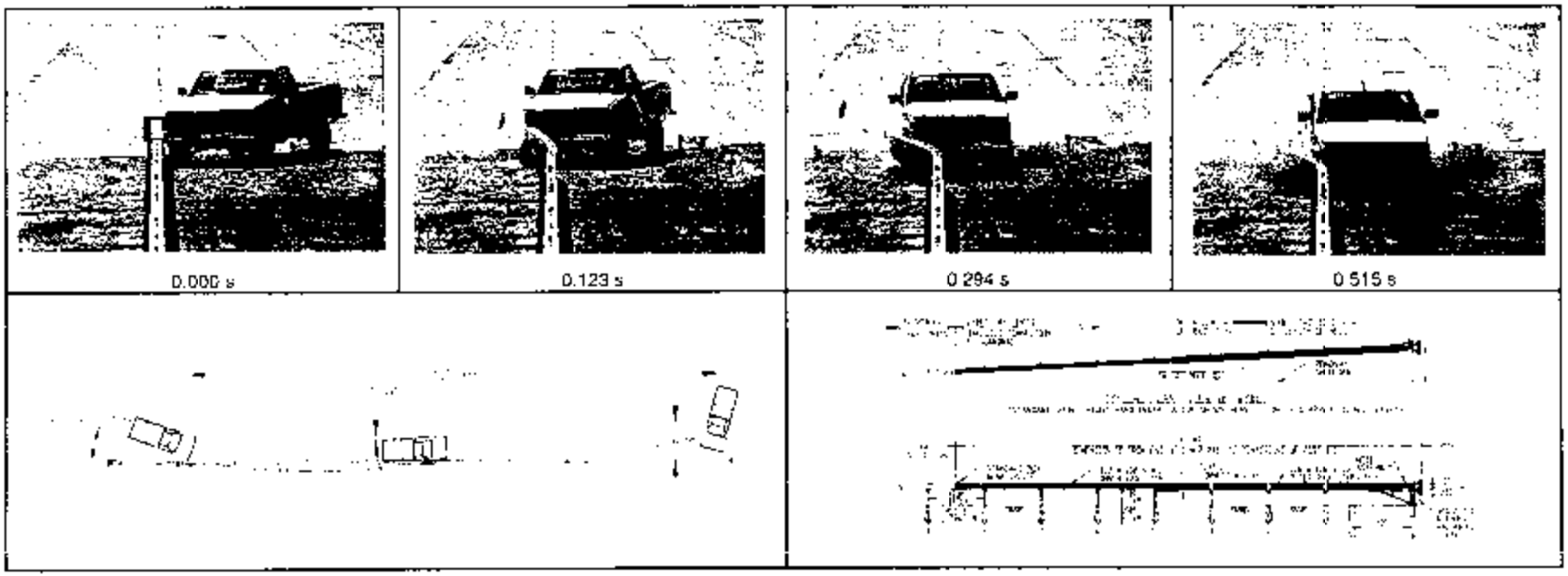
Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction 7.0
  - y-direction ..... No contact
- THIV (km/h) 25.1
- Ridedown Accelerations (g's)
  - x-direction ..... -5.8
  - y-direction ..... No contact
- PHD (g's) 6.5
- ASI 0.57
- Max. 0.050-s Average (g's)
  - x-direction ..... -6.8
  - y-direction 2.2
  - z-direction ..... -1.6

Test Article Deflections (m)
- Dynamic 2.85
- Permanent 1.65

Vehicle Damage
- Exterior
  - VDS 12FC2
  - CDC 12FDEW2
- Maximum Exterior
  - Vehicle Crush (mm) 480
- Interior
  - OCDI FS0000000
- Max. Occ. Compart. Deformation (mm) ..... nil

Post-Impact Behavior (during 1.0 s after impact)
- Max. Yaw Angle (deg) ..... -8
- Max. Pitch Angle (deg) ..... -4
- Max. Roll Angle (deg) 10

Figure 67. Summary of results for test 473160-11, *NCHRP Report 350* test 3-33.



General Information
- Test Agency . . . Texas Transportation Institute
- Test No . . . 473160-2
- Date . . . 03/10/98

Test Article
- Type . . . End Treatment
- Name or Manufacturer . . . WYBET-350
- Installation Length (m) . . . 55 '
- Material or Key Elements . Tubular Steel Rail Elements on Steel posts

Soil Type and Condition . . Standard soil Dry

Test Vehicle
- Type . . . Production
- Designation . . . 2000P
- Model . . . 1992 Chevrolet 2500 pickup
- Mass (kg)
  - Curb . . . 2078
  - Test Inertia . . . 2000
  - Dummy . . . No dummy
  - Gross Static . . . 2000

Impact Conditions
- Speed (km/h) . . . 99.5
- Angle (deg) . . . 20 2

Exit Conditions
- Speed (km/h) . . . 69 4
- Angle (deg) . . . 1 9

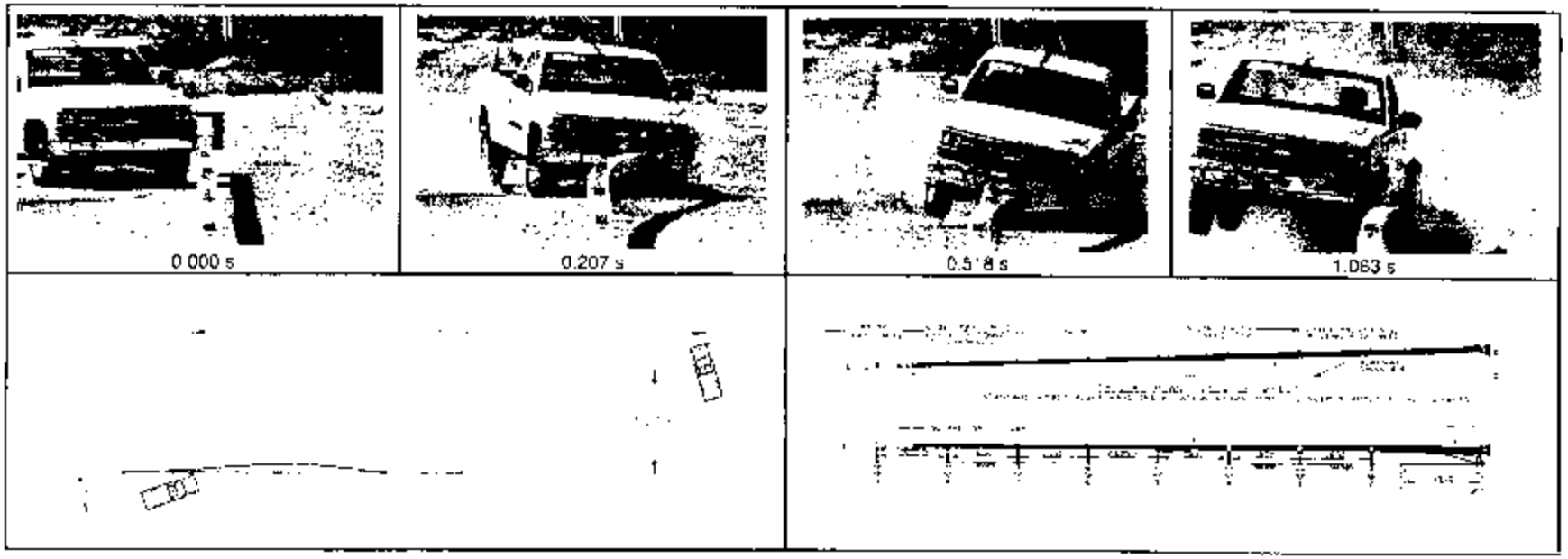
Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction . . . 4 1
  - y-direction . . . 4 1
- THIV (km/h) . . . 16 7
- Ridedown Accelerations (g's)
  - x-direction . . . -12.7
  - y-direction . . . -7.0
- PHD (g's) . . . 21.4
- ASI . . . 0 5
- Max 0 050-s Average (g's)
  - x-direction . . . -3.3
  - y-direction . . . -4.4
  - z-direction . . . 2 2

Test Article Deflections (m)
- Dynamic . . . 0.96
- Permanent . . . 0.75

Vehicle Damage
- Exterior
  - VDS . . . 01RFQ3
  - CDC . . . 01RFEW2
- Maximum Exterior Vehicle Crush (mm) . . . 475
- Interior
  - OCDI . . . FS0000000
- Max. Occ. Compart Deformation (mm) . . . 0

Post-Impact Behavior (during 1.0 s after impact)
- Max. Yaw Angle (deg) . . . 27
- Max. Pitch Angle (deg) . . . -3
- Max. Roll Angle (deg) . . . -6

Figure 24. Summary of results for test 473160-2, *NCHRP Report 350* test 3-35.



General Information
- Test Agency ... Texas Transportation Institute
- Test No. ... 473160-5
- Date ... 04/30/98

Test Article
- Type ... End Treatment
- Name ... WYBEST-350-Median Barrier
- Installation Length (m) ... 55.1
- Material or Key Elements ... Tubular Steel Rail Elements on Steel posts

Soil Type and Condition ... Standard Soil Dry

Test Vehicle
- Type ... Production
- Designation ... 2000P
- Model ... 1992 Chevrolet 2500 pickup truck
- Mass (kg) Curb ... 2060
  - Test Inertial ... 2000
  - Dummy ... No dummy
  - Gross Static ... 2000

Impact Conditions
- Speed (km/h) ... 100.1
- Angle (deg) ... 20.5

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

Occupant Risk Values
- Impact Velocity (m/s)
  - x-direction ... 3.8
  - y-direction ... 3.1
- THIV (km/h) ... 13.5
- Ridedown Accelerations (g's)
  - x-direction ... -4.4
  - y-direction ... 6.7
- PHD (g's) ... 8.2
- ASI ... 0.46
- Max. 0.050-s Average (g's)
  - x-direction ... -2.3
  - y-direction ... 4.0
  - z-direction ... 2.0

Test Article Deflections (m)
- Dynamic ... 1.61
- Permanent ... 1.60

Vehicle Damage
- Exterior
  - VDS ... 01LFQ3
  - CDC ... 01LFEW2
- Maximum Exterior
  - Vehicle Crush (mm) ... 220
- Interior
  - OCDI ... FS0000000
- Max. Occ. Compart. Deformation (mm) ... 0

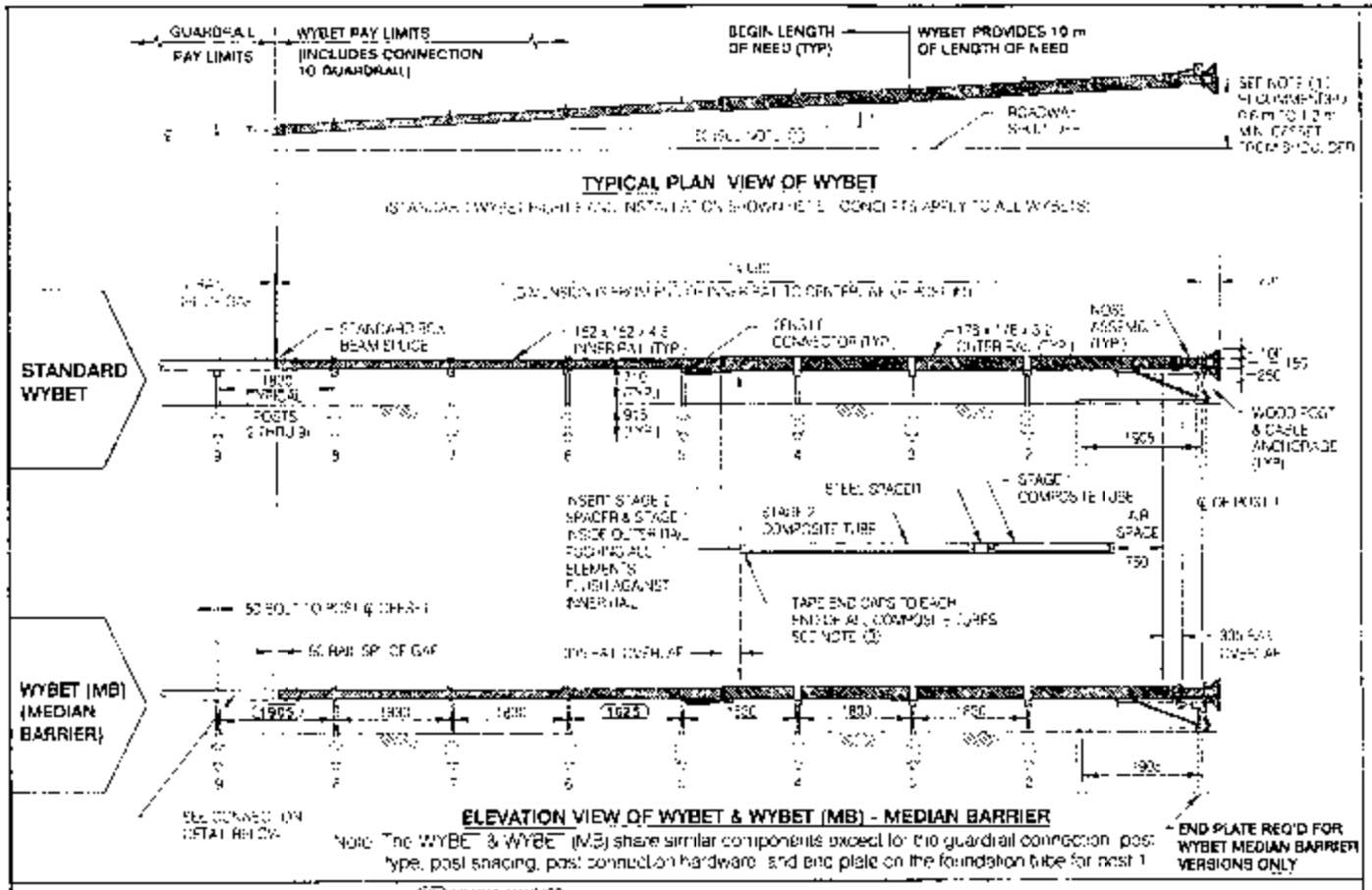
Post-Impact Behavior (during 1.0 s after impact)
- Max. Yaw Angle (deg) ... 26
- Max. Pitch Angle (deg) ... -3
- Max. Roll Angle (deg) ... -24

Figure 75. Summary of results for test 473160-5, *NCHRP Report 350* test 3-35.

ENCLOSURE 1 (6 of 6)

Table 1. Summary of design modifications to WYBET.

Item	Description	Design Modification
1	Slotted bearing plate	Eliminate the 25 mm × 6 mm (1 in. × ¼ in.) spacer strap on top of the plate.
2	Pipe sleeve	Change the length from 150 mm to 140 mm (6 in. to 5-1/2 in.).
3	Ground line strut bolt	Change the length from 250 mm (10 in.) to 240 mm (9-1/2 in.).
4	Bearing plate attachment hardware	Change from 5 mm × 50 mm (3/16 in. × 2 in.) lag bolts to 16d nails
5	Washers @ soil plate	Eliminate 2 washers at each bolt on the soil plate.
6	Head to post lag screw	Change the length from 130 mm (5 in.) to 100 mm (4 in.).
7	16-mm (5/8-in.) nut	Replace the small finished nuts with large guardrail nuts.
8	End post (post 1)	Place the impact head on top of the end post for the shoulder barrier, similar in design to that of the median barrier.
9	Wood strut	Add the wood strut to the end post of the shoulder barrier version, similar in design to that of the median barrier version.
10	Tensile connector bracket	Add a bracket at the upstream end of the tensile connector to keep it from dropping out of the slots.
11	Width of composite tube cap	Increase the width of the composite tube caps from 75 mm (3 in.) to 100 mm (4 in.) to minimize the potential for splintering of the composite tubes.
12	Lengths of composite tubes	Increase the length of the stage 1 composite tube from 1830 mm (6 ft) to 2290 mm (7-1/2 ft) and reduce the length of the stage 2 composite tube from 3860 mm (12 ft 8 in) to 3400 mm (11 ft-2 in) to provide more energy absorbing capability for the small car impacts.



WYBET & WYBET (MB) GENERAL NOTES

WYBET Terminals Shown Herein have been successfully tested to NCHRP 350, Test Level 3 with no field testing required for performance.

(1) **GUARDRAIL & WYBET ALIGNMENT:** Where no flare is indicated on the plans (i.e. tangent layout) and the guardrail is located at the roadway shoulder, it is strongly encouraged to place the last 200 ft of guardrail including the WYBET on a 1:50 flare to offset the head of the terminal roughly 4 feet from the shoulder to prevent nuisance impacts with snowplows etc. Where grading won't permit a 4 foot offset, a 2 foot offset is acceptable. It is recommended that WYBET terminals not be placed greater than a 1:25 with respect to the roadway (1:15 desirable maximum flare). The entire length of the WYBET shall be straight without kinks and should match the alignment of the adjacent guardrail to the greatest extent possible.

(2) **PRE-INSTALLATION PROCEDURE:** The contractor shall slide the 6" x 6" inner rail inside the 7" x 7" outer rail using only manual labor to insure there is no binding or residual warpage caused by welding or other defects.

(3) **COMPOSITE TUBES:** Stage 1 & 2 composite tubes provide the energy absorption mechanism for the WYBET and shall be manufactured in strict conformance to the specifications including proper cutting of tubes and testing of end caps at each end of each tube. End caps shall be taped by double wrapping with 4" wide duct tape or a 4X wrap of 2" wide duct tape. Tape shall cover a minimum of 2 1/2" on the end cap and 2 1/2" on the composite tube.

(4) **TENSIONING THE WYBET:** The contractor shall tighten the cable anchor and retighten the tensile connector. Once the system is tight, the tensile connector retaining bracket shall be installed in the location shown at the leading edge of the tensile connector.

(5) **WYBET MEDIAN BARRIER INSTALLATIONS:** Connection of WYBET's to older cable mounted median barrier shall require that a minimum of the next 10 posts beyond the WYBET be modified to a positive connection as a part of the WYBET installation.

NOTE:
ALL DIMENSIONS GIVEN ARE IN MILLIMETERS (mm) UNLESS NOTED OTHERWISE.

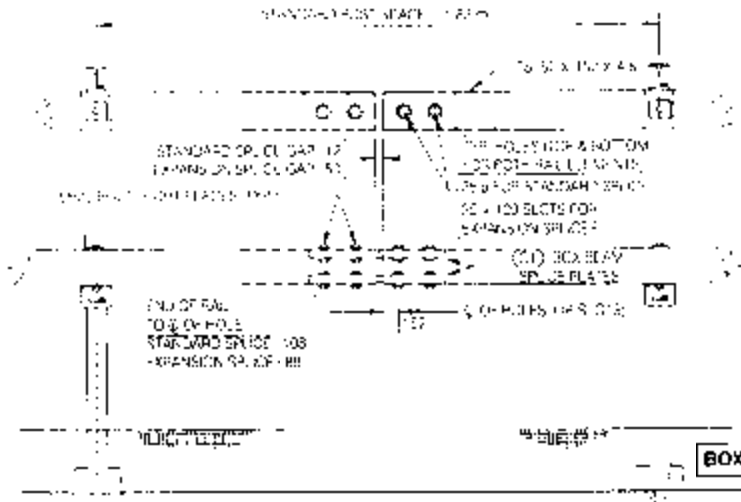
WYOMING DEPARTMENT OF TRANSPORTATION
STANDARD PLAN

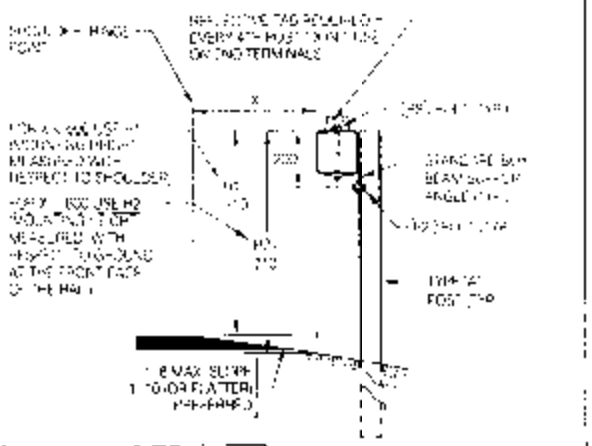
BOX BEAM GUARDRAIL

WYBET INSTALLATION DETAILS

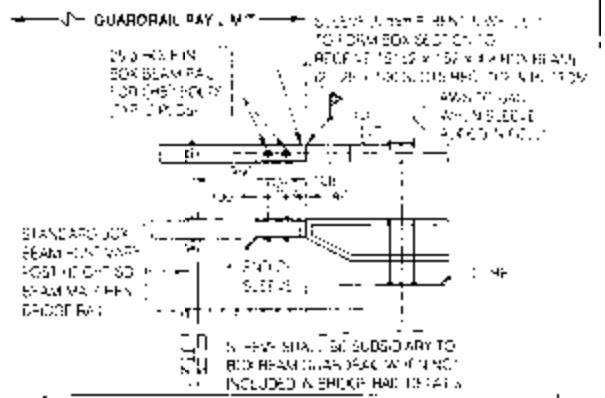
M606-02C
SHEET 05 OF XX

ENCLOSURE 3 (1 of 2)





BOX BEAM GUARDRAIL DETAILS



EXIT END CONNECTION TO STEEL BRIDGE RAILING

(Only for exit ends of one-way traffic bridges or divided roadways)

MODIFYING EXISTING PADDLE MOUNTED MEDIAN BARRIER TO STANDARD MEDIAN BARRIER CONNECTION.

BOTTOM VIEW

GENERAL NOTES FOR BOX BEAM AND BOX BEAM MEDIAN BARRIER

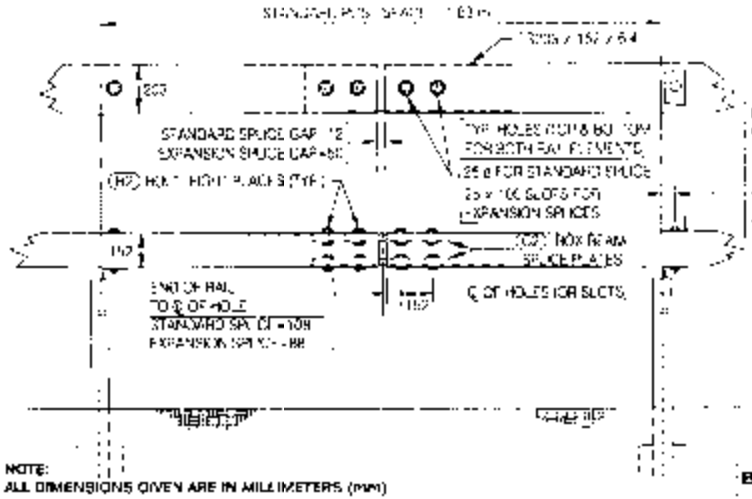
The standard post spacing shall be 1.85 m. The minimum post spacing shall be 1.2 m.

Rail elements shall be furnished in nominal lengths to provide either 3, 4, 5 or 6 post spaces unless physical constraints require odd lengths of rail elements. The nominal rail length shall not be less than 5.49 m.

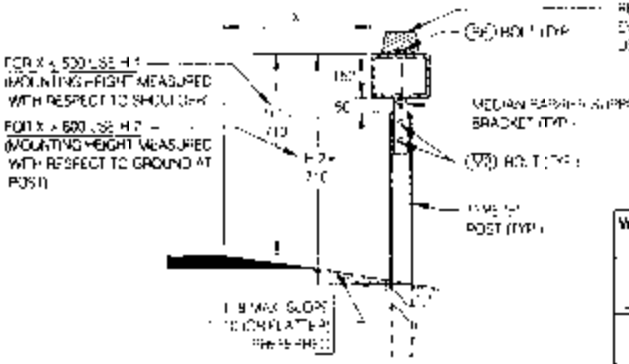
Expansion splices shall be placed in the box beam installations over 90 m long and at intervals not to exceed 150 m. Expansion splices shall be roughly equally spaced in the guardrail run.

BOLT REQUIREMENTS

	HIGH STRENGTH HEAVY HEX RAIL SPLICE BOLTS
(M2)	16 X 55 (A325) - 1 HARDENED WASHER (F436)
(M3)	19 X 130 (A325) - 2 HARDENED WASHERS (F436) - 1 NUT (A194 2H)
(M16)	19 X 230 (A325) - 2 HARDENED WASHERS (F436) - 1 NUT (A194 2H)
	POSTS BOLTS - HEX HEAD (MILD STEEL)
(M7)	19 X 40 (A307) - 2 WASHERS (F844) - 1 NUT (A563)
(M8)	19 X 40 (A307) - 2 WASHERS (F844) - 1 NUT (A563)
	RAIL BOLTS - HEX HEAD (MILD STEEL)
(M4)	16 X 90 (A307) - 2 WASHERS (F844) - 1 NUT (A563)
(M5)	16 X 190 (A307) - 2 WASHERS (F844) - 1 NUT (A563)



BOX BEAM MEDIAN BARRIER DETAILS



STANDARD MEDIAN BARRIER POST (TYPICAL)

(POSITIVE CONNECTION)

NOTE:
ALL DIMENSIONS GIVEN ARE IN MILLIMETERS (mm) UNLESS NOTED OTHERWISE.

WYOMING DEPARTMENT OF TRANSPORTATION
STANDARD PLAN

BOX BEAM GUARDRAIL

QUARDRAIL INSTALLATION DETAILS

Designed	W.K.	Standard Plan Number
Drawn	T.S.	M606-02C
Checked	J.P.A.	SHEET 06 OF XX
Approved	J.P.A.	

ENCLOSURE 3 (2 of 2)