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TECHNICAL MEMORANDUM

Contract No.: **T4541-AO**
Report No.: **405160-19**
Project Name: **F-Shape Concrete Barrier with Slotted Drain Holes**
Sponsor: **Pooled Fund**

DATE: **December 8, 2010**

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SUMMARY REPORT:

INTRODUCTION

The Louisiana Department of Transportation and Development (LaDOTD) currently uses a cast-in-place concrete bridge rail on Louisiana bridges. The F-Shape bridge rail is 32 inches in height and 13.25 inches wide at the base. Presently, for bridges that use this concrete F-Shape bridge rail, drainage is provided only at the ends of the bridge since there is no opening provided through the bridge rail. LaDOTD has proposed the use of 6-inch high by 24-inch long open slots located 10 ft apart at the base of the rail to accommodate drainage through the railing. The purpose of this project was to review the current geometry and placement of the drainage slots to determine if the slots will impact the crash performance of the F-Shape concrete bridge rail. Details of the existing bridge rail are shown in Figure 1.

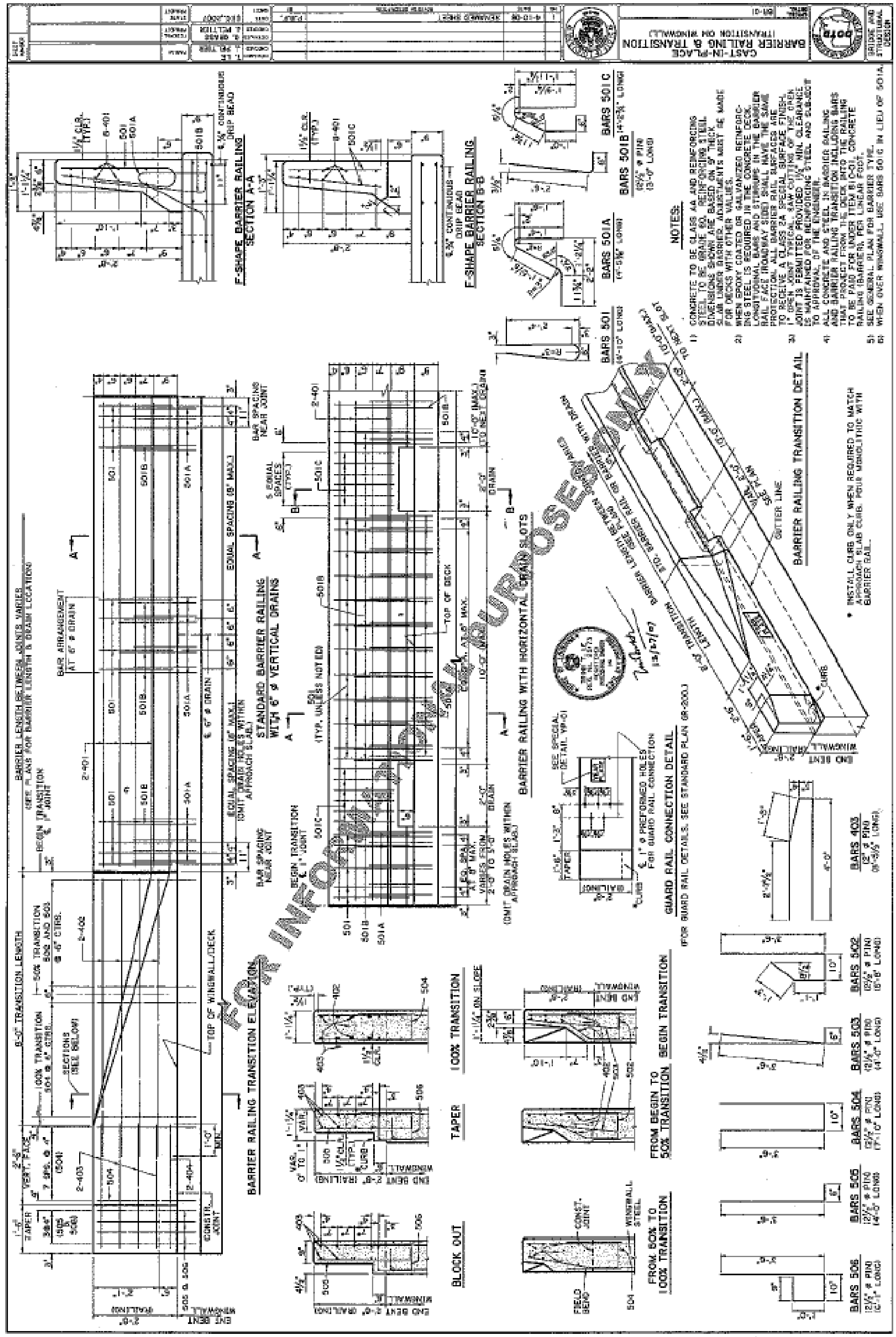

Figure 1 – Details of F-Shape Concrete Barrier with Slotted Drain Holes.

BACKGROUND

Adequate storm water drainage is necessary for safety on vehicular bridges. For bridges utilizing continuous cast-in-place concrete bridge rails with no openings, storm water drainage is typically provided on the ends if drainage scuppers are not provided. During heavy rainfall events, drainage water can accumulate on the bridge structure. Drainage through the bridge railing can provide better drainage of storm water, thus improving vehicular safety. LaDOTD has developed an F-Shape barrier with drainage slots to accommodate drainage through the bridge rail into scuppers or off the sides of the bridge.

OBJECTIVE

The objective of this project was to evaluate the geometry and placement of the drainage slots on the LaDOTD Concrete F-Shape Barrier with respect to vehicle impact performance requirements for National Cooperative Highway Research Program (NCHRP) *Report 350*, Test Level 4 (TL-4) specifications.[1] This project will provide LaDOTD with a viable option to provide drainage through the cast-in-place concrete F-Shape bridge rail.

RESEARCH METHODOLOGY

Openings and penetrations in roadside barriers can adversely affect the crash performance of the barrier system. These openings and/or penetrations can cause vehicular snagging, instability or other undesirable performance when impacted by an errant vehicle. Often, full-scale crash testing is warranted to evaluate the performance of a specific barrier system that utilizes openings and penetrations. A drainage opening, like the one proposed for the LaDOTD F-Shape Bridge Rail, is one such opening in a barrier system that is commonly used. The purpose of this project was to evaluate the performance of the proposed LaDOTD F-Shape Barrier with drainage opening and see if a comparison(s) can be made to other acceptable barriers that have a similar drainage opening.

Texas Transportation Institute (TTI) researchers received a drawing entitled “Cast-in-Place Barrier Railing & Transition (Transition on Wingwall)” prepared by LaDOTD, and dated April 10, 2008. These drawings show the proposed details for the LaDOTD Concrete F-Shape Barrier with 6-inch high by 24-inch long drainage slot openings. The current drainage slot details have been compared with other barriers systems utilizing similar type slots. This review consisted of comparisons with the Texas Department of Transportation (TXDOT) Single Slope Concrete Barrier (Wildlife Crossing) Precast SSCB (TXDOT Wildlife Crossing Barrier) and the Washington Pin & Loop Barrier System designed and crash tested by TTI for the Washington State DOT.

TTI researchers performed a similar review of the TXDOT Wildlife Crossing Barrier for TXDOT with respect to the size and potential interaction of these openings with respect to the small car and pickup truck for *NCHRP Report 350* crashworthiness criteria. The details of the TXDOT Wildlife Crossing Barrier are provided in Figure 2.

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[1] H. E. Ross, D. L. Sicking, R. A. Zimmer, and J. D. Michie, "Recommended Procedures for the Safety Performance Evaluation," in *NCHRP Report 350*, ed. National Academy Press, Washington, D.C.: National Cooperative Highway Research Program, 1993.

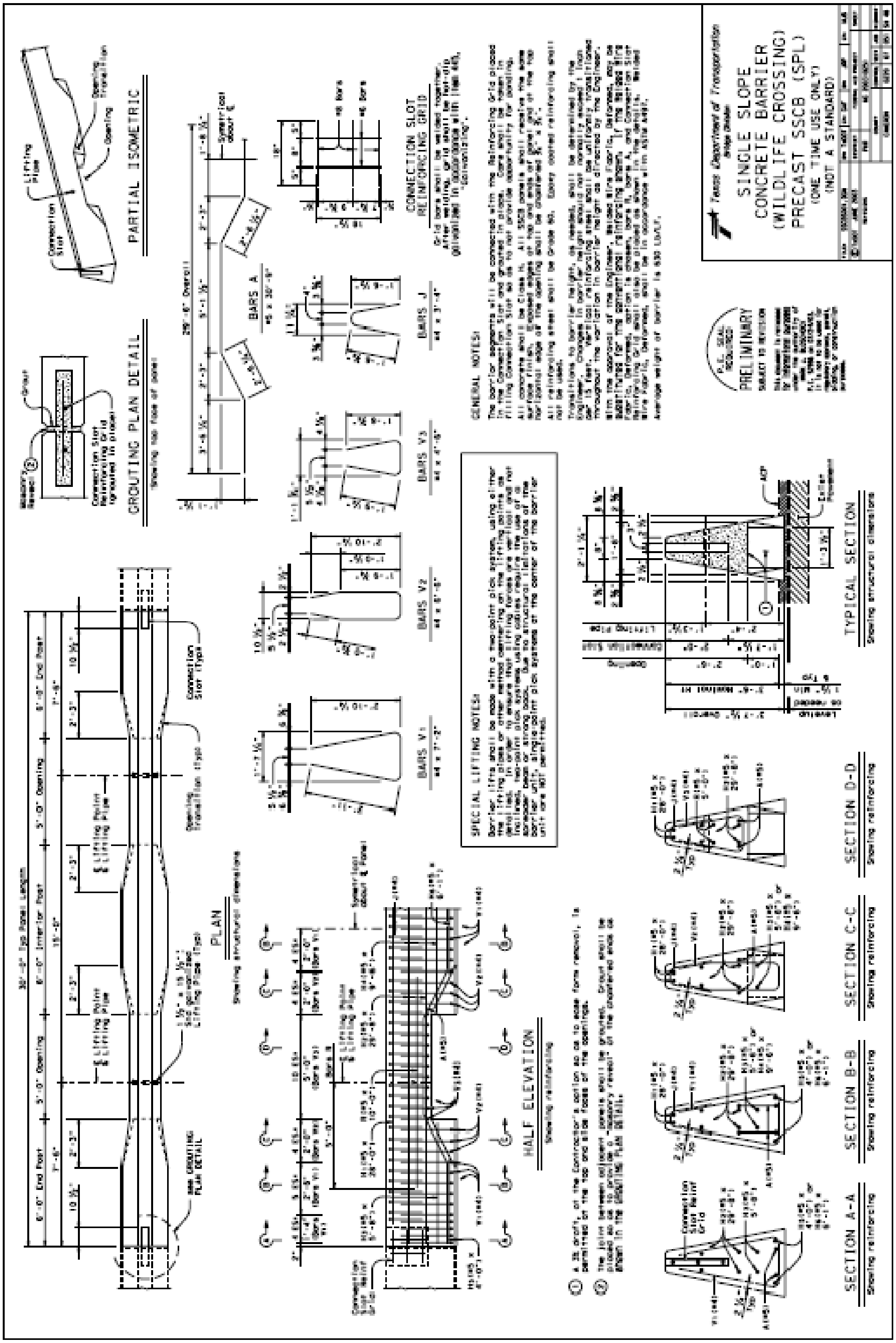

Figure 2 – TXDOT Single Slope Concrete Barrier (Wildlife Crossing) SSCB.

The TXDOT Wildlife Crossing Barrier is 42 inches in height above the pavement surface and has openings for wildlife access through the barrier. Each unit is 30 ft in length and contains two openings that are 12 inches high and 5 ft in length. Based on the review of the geometric features of this barrier, it was determined that the TXDOT Wildlife Crossing Barrier was crashworthy with respect to *NCHRP Report 350* TL-3 performance criteria. TXDOT is currently using this barrier on approximately 10 miles of high speed roadway in South Texas near Padre Island where wildlife crossing access is needed. At the time of this writing, several vehicular impacts have occurred on the 10-mile stretch of barrier. No fatalities or serious injuries have been reported from these vehicle impacts. Photos of the TXDOT Wildlife Crossing Barrier are shown as Figures 3 and 4.

Figure 3 – TXDOT Single Slope Concrete Barrier (Wildlife Crossing) SSCB.

Figure 4 – Vehicle Impact at 12-inch High Opening in TXDOT Wildlife Crossing Barrier.

As part of the Washington State Pooled Fund project, TTI performed a full scale crash test on a pin and loop concrete barrier system. The Washington Pin & Loop Barrier system consisted of precast concrete barrier segments that were 12 ft-6 inches in length and 34 inches in height. The barrier segment was 8 inches wide at the top and 21 inches wide at the base with a uniform single slope surface on each side face of the barrier. A 4-inch high by 15-inch wide "V" shaped drainage slot was constructed in the base of the barrier. This drainage slot was centered in the base of the barrier and continuous along the entire length of the barrier segment. In addition to this longitudinal drainage slot, a transverse drainage scupper opening was constructed at the mid-length of the barrier segment. The drainage scupper opening was 9 inches high by 28 inches in length. This drainage scupper opening permits drainage from the roadway through the barrier segment or along the barrier through the "V" shape drainage slot located in the base of the barrier. Three ¾-inch diameter steel loops were constructed at the ends of the barrier segments. These loops served to connect the barrier segments together. Mating loops on each end of the segment permitted the segments to be connected together using a 1-inch diameter rod at each barrier joint connection. At each barrier connection the rod was placed through the mating loops to connect the barrier segments together. The ¾-inch steel loops were fabricated using A36 material. The 1-inch diameter steel rods were fabricated from AISI 4142 material and were 31 inches in length.

Vertical reinforcement (stirrups) in each barrier segment consisted of #4 rebar stirrups spaced as close as 4 inches on the ends to 11½ inches toward the center of the barrier segment. The stirrups were spaced on 7-inch centers (3 spaces) immediately above the drainage scupper located in the center of the segment. Longitudinal reinforcement in the barrier segment consisted of 12 #5 bars. The bars located in the bottom of the barrier segment were bent to accommodate the drainage scupper opening located in the center of the barrier segment.

Finite element analyses using LS-DYNA were performed on the Washington Pin & Loop Barrier System. Analyses were performed using the 1100C small car and 2270P pickup truck as specified in the American Association of State Highway and Transportation Officials (AASHTO) *Manual for Assessing Safety Hardware* (*MASH)* specifications.[2] Results from these analyses indicated that the size of the drainage opening used for the Washington Pin & Loop Barrier System did not cause undesirable vehicle performance characteristics with respect to *MASH* specifications.

A full-scale test installation was constructed for the Washington Pin & Loop Barrier System. The test installation consisted of 16 barrier segments connected together using the 1-inch diameter AISI 4142 heat-treated rods. The total length of the test installation was approximately 200 ft. A full-scale crash test was performed in accordance with *MASH* specifications for TL-3. Based on the results from the crash test, the barrier did not perform acceptably in accordance with the *MASH* Specifications. The Washington Pin & Loop Barrier system did contain and redirect the pickup truck. However, as the truck was exiting the system, the truck rolled over. As a result, the barrier system did not meet the *MASH* specifications. Upon review of the test installation, crash data, and video, it was concluded that the 9-inch high

[2] American Association of State Highway and Transportation Official (AASHTO). *Manual for Assessing Safety Hardware*. Washington D.C., 2009

by 28-inch wide drainage slots did not contribute to the vehicle instability .The rollover of the vehicle was attributed to the barrier joint connection and not by the drainage slots in the barrier.

Evaluation of LaDOTD F-Shape Concrete Barrier with Slotted Drain Holes with Current AASHTO Bridge Design Specifications

The potential for vehicular interaction with the LaDOT F-Shape Barrier was evaluated with respect to the criteria in the AASHTO *LRFD Bridge Design Specificatio*ns. Two figures are presented in the AASHTO *LRFD Bridge Design Specifications* that provide general guidelines for the crash performance of barrier that contain openings or penetrations. These figures provide guidelines for the preferred post set-back from the face of the railing elements and the preferred ratio of the rail contact widths to the overall height of the bridge rail system (see Figure A13.1.1-2-Potential for Wheel, Bumper, or Hood Impact with a Post and Figure A13.1.1-3-Post Setback Criteria, AASHTO *LRFD Bridge Design Specifications*). The potential for wheel interaction with the opening in the barrier was investigated for the LaDOTD F-Shape Barrier design. For the proposed design, the post setback from the face of the rail elements was considered to be zero inches. The maximum vertical clear opening distance between the bridge top of the bridge deck and the top of the opening is 7-5/8 inches. Based on this information and the information provided in Figure A13.1.1-2, the clear opening height of 7-5/8 inches presents a low potential for vehicular interaction with the opening in the barrier during a vehicular crash. Please refer to Figure 5 which shows a plot of the geometric features for the LaDOTD F-Shape Barrier with respect to Figure A13.1.1-2 in the AASHTO *LRFD Bridge Design Specifications*.

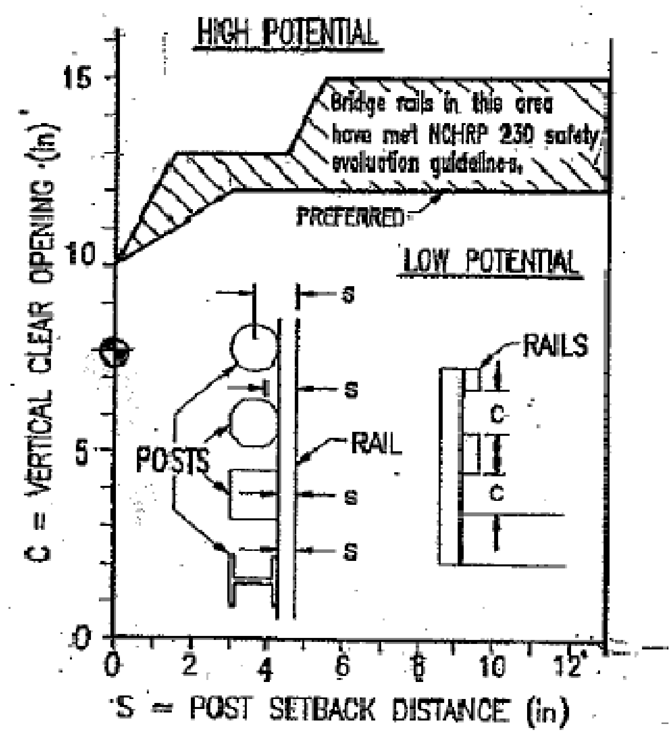

Figure A13.1.1-2 Potential for Wheel, Bumper, or Hood Impact with Post.

Figure 5 – Potential for Wheel Interaction with Barrier Opening in the LaDOTD F-Shape Barrier

The ratio of rail contact width to height is 0.762 (ratio of the height of the contact length of the F-Shape Barrier to the total height of rail 32 inches). Based on the proposed railing geometry and the information provided in Figure A13.1.1-3, the LaDOTD F-Shape Barrier with slotted drain hole is considered marginal. For the proposed design, the post setback from the face of the rail was considered to be zero inches. Please refer to Figure 6 which shows a plot of the geometric features for the LaDOT F-Shape Barrier with Slotted Drain Holes with respect to Figure A13.1.1-3 in the AASHTO *LRFD Bridge Design Specifications*.

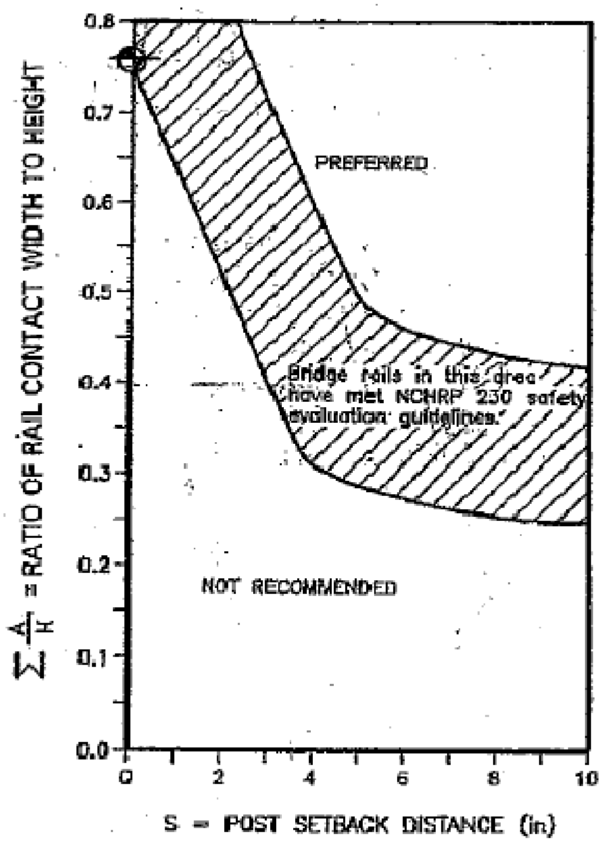

Figure A13.1.1-3 Post Setback Criteria.

The maximum clear vertical opening between succeeding rails or posts shall be as specified in Sections 13.8, 13.9, and 13.10.

Figure 6 – Post Setback Criteria for Modified TxDOT Wyoming Rail

SUMMARY AND CONCLUSIONS

The TXDOT Wildlife Crossing Barrier has a taller opening in the base compared to the Washington Pin & Loop Barrier design. The drainage slot used in the Washington Pin & Loop Barrier appeared to perform well in LS-DYNA impact simulations with both the small car and pickup truck. Although the WSDOT barrier did not meet the *MASH* test specifications, the

9-inch high drainage slot used in the WSDOT Pin & Loop Barrier system did not adversely affect the performance of the crash vehicle. In addition, the potential for vehicle interaction with the drainage slot opening was considered low to marginal with respect to the criteria as provided in AASHTO Section 13 specifications. Figure 7 shows the side-by-side comparisons between the size of the openings between the TXDOT Wildlife Crossing Barrier, Washington Pin & Loop Barrier, and the LaDOTD F-Shape Barrier with drainage slots.

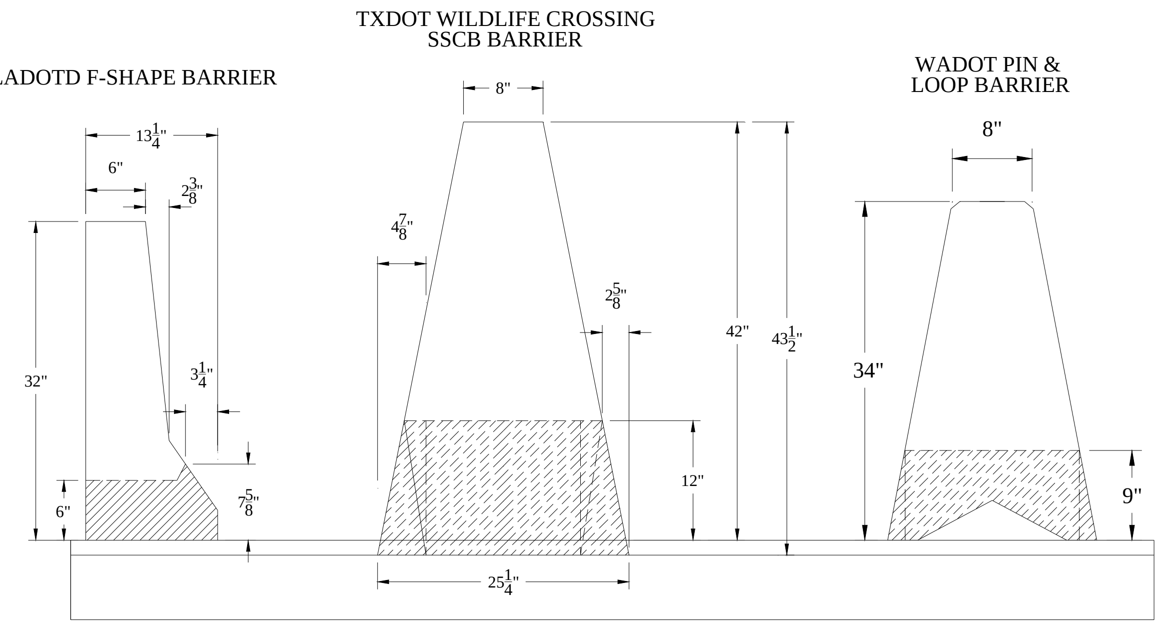

Figure 76 – LaDOTD F-Shape Barrier, TXDOT Wildlife Crossing Barrier WSDOT Pin & Loop Barrier Cross-Sections

TTI researchers have reviewed the current details of the LaDOTD Cast-in-Place Barrier Railing (F-Shape Barrier with Drainage Slots) details as shown in Figure 1. Based on TTI researchers' review, the F-Shape barrier with drainage slots as shown on Figure 1 (LaDOTD Drawing Cast-in-Place Barrier & Transition (Transition on Wingwall)) is considered acceptable with respect to *NCHRP Report 350* TL-4 performance criteria.