Progress Report
Second Quarter 2008 – April 1 to June 30
Midwest Roadside Safety Facility
Midwest State's Regional Pooled Fund Program
June 20, 2008

Pooled Fund Projects with Bogie Testing or Full-Scale Crash Testing in Past Quarter

Development of a Temporary Concrete Barrier Transition

On April 4, 2008, the first 2270P crash test was performed at the CIP just upstream of the permanent, single-slope barrier and on the last TCB section. For the TL-3 test, the vehicle was contained and redirected, thus resulting in a successful test. On April 23, 2008, the second 2270P crash test was performed at a second CIP found much farther upstream. For this TL-3 test, the vehicle was contained and redirected, thus resulting in another successful test. In the third quarter of 2008, the draft research and test report will be prepared.

Phase I Development of a TL-3 MGS Bridge Rail

Dynamic bogie testing of breakaway post concepts has been performed in order to determine their feasibility for use in an MGS bridge railing system. To date, five post tests have been performed on two general concepts, including refinement of designs and CAD details. A third railing concept has been developed and includes the use of weak S3x5.7 posts spaced on 3 ft - 1.5 in. centers. Preliminary BARRIER VII computer simulation modeling was performed on the weak post variation of the MGS and will continue in the third quarter. An additional literature search was performed on weak-post W-beam guardrail systems in order to evaluate post to rail attachments. Several concepts were also prepared for attaching weak posts to standard reinforced concrete bridge decks. Selection of the preferred concept should be completed in the third quarter following a review and input from the Pooled Fund States.

Pooled Fund Projects with Pending Bogie Testing or Full-Scale Crash Testing

Development of a TL-4, Four-Cable, High-Tension, Barrier System for 4:1 V-Ditch Applications

Two full-scale tests were completed on the high-tension cable barrier system during the 4^{th} Quarter of 2007. Excavation of the V-ditch and construction of the barrier system were completed. Three full-scale crash tests were planned to verify the safety performance of the new system in a V-ditch while utilizing update vehicles (1 @ 1100C, 1 @ 2270P and 1 @ 10000S). The first test of this system was successfully performed on October 30, 2007 using a 2270P vehicle. The cable barrier system was reconstructed and made ready for a subsequent crash test. The second test was performed with an 1100C vehicle on November 15, 2007, where a significant longitudinal occupant impact velocity was encountered along with severe wheel rutting in the soil.

Previously, Pooled Fund members were asked for comment on the 1100C test results. Per those discussions, MwRSF was recommended to seek preliminary FHWA approval of the system based on the current test results. Discussion had occurred with member states on whether to re-run the 1100C test in order to evaluate the propensity for vehicle underride with a more-firm soil condition or move on to other testing. Recently, MwRSF obtained feedback from Nick Artimovich and Mark Bloschock of FHWA with regard to the acceptance of the high-tension, cable barrier system. From the response, it was noted that the 1100C sedan test does not prove MASH 08 compliance at the current cable barrier position in a 4:1 V-ditch. However, FHWA is willing to grant MASH 08 compliance if the barrier is offset 8 ft or more from the ditch. Based on this response, we recommended that the States fund a re-test with the 1100C vehicle at its present position using a 13.5-in. lower cable height, adjusted cable positions, and a slightly firmer median soil condition. With a successful test, the high-tension, cable barrier could be placed at any location within a 4:1 V-ditch.

Subsequently, the Pooled Fund Member States voted to use the 10000S funds to re-test the 1100C vehicle test into a modified high-tension, four-cable, barrier system placed in a 4:1 V-ditch. It is anticipated that the small car re-test will be performed in July 2008 but will be dependent on favorable and dry weather conditions.

Standardizing Posts and Hardware for MGS Transition

Phase I bogie testing was completed in prior quarters and on W6x15 steel posts and 8-in. x 8-in. wood posts. BARRIER VII computer simulation modeling of several prototype system designs was completed. Two designs were submitted to the States for review and comment as well as to obtain input as to which design variation to crash test. Per the States input, a more aggressive design option (Design K) was selected. On January 28, 2008, Test Designation No. 3-21 was conducted under the proposed Update to Report 350 (MASH 08) with a Dodge Quad Cab pickup truck impacting the simplified, steel-post transition design at a speed of 61.7 mph and at an angle of 24.7 degrees. During this test, the upstream anchor released, thus resulting in vehicle pocketing which led to excessive longitudinal occupant ridedown accelerations. As a result, the safety performance of this design was found to be unacceptable.

Following a review of the high-speed videos and damaged barrier hardware, several potential factors affecting the unsatisfactory outcome were observed. First, BCT wood post no. 1 was observed to release due to post fracture. A closer inspection of post no. 1 revealed significant checking through the wide faces of the post along with a critically placed knot on the upstream, back-side corner of the post, just above the steel cable anchor plate. Upon review of the test results, it is believed that the BCT post with checks and a critically-placed knot contributed greatly to the test failure. Second, the steel foundation tube supporting BCT wood post no. 1 was not found to have displaced during the test. This result could have been due to either inadequate load imparted to the foundation tube prior to wood post fracture or a stiffer than normal soil material compacted around the foundation tube. Although an overly stiff foundation tube could increase anchor loading, we believe that this condition would have had only a minor contribution to the failed post and test, since much higher anchor loadings have been observed during prior 2000P tests on the high flare rate MGS designs. Third, Detail K was selected by the States over Detail L due to it being a less costly design (one less steel post) even though it was a more aggressive design. When impacted, Detail K was predicted to result in increased barrier deflection and vehicle pocketing as compared to Detail L. With an increased propensity for vehicle pocketing, combined with greater barrier deflections, it is believed that the selection of the more aggressive design, Detail K, modestly contributed to the failed test. However, it should be noted that FEA modeling of the two modified designs revealed a propensity for both increased vehicle pocketing and barrier deflections as compared to the original acceptable design.

MwRSF discussed these results at the April 2008 Pooled Fund meeting. At that meeting, the States voted to re-test Design K using a 2270P vehicle. Funds for this re-test were added to the Year 19 Pooled Fund program. The 2270P re-test has been planned for May-June 2008 but has been delayed due to wet spring weather conditions. The crash test will be performed as soon as the soil condition is acceptable.

Once a successful crash test has been performed, preparations will be made to conduct the 1100C crash test on the same design. Please note that the wood post alternative cannot be developed until the simplified, steel-post alternative has been successfully verified through 1100C and 2270P crash testing.

Testing of Cable Terminal for High Tension Cable (1100C & 2270P)

Work on this project will commence after crash testing is completed on the high-tension, four cable barrier system. It is planned to adapt the breakaway cable lever arm technology, developed during the low tension testing, into the high-tension barrier system. Partial project funding is available in this program.

Performance Limits for a 6-in. High, AASHTO Type B Curb Placed in Advance of the MGS

Four high-speed vehicle tests into curbs were performed in October 2007 in order to evaluate vehicle trajectory. This test data was utilized as input to the modeling effort for the project as well as to determine the critical lateral offset for placement of the MGS behind the curb for both 1100C and 2270P vehicles.

An analysis of the test results revealed critical placement of the MGS to be 4 ft and 8 ft for the standard 31-in. and modified 37-in. designs, respectively. For the standard MGS, testing would likely be needed using a 2270P vehicle at the 4-ft offset. For the 37-in. tall, MGS, testing would likely be needed using a 2270P vehicle at the 8-ft offset. In addition, the 37-in. tall MGS may also require 1100C vehicle testing at the 4-ft offset location. Originally, the 31-in. tall MGS was constructed 4-ft behind a 6-in. tall, AASHTO Type B curb. Testing with a 2270P vehicle was delayed due to rain and wet soil conditions. The project was then discussed at the April 2008 Pooled Fund meeting. Later, the curb system was removed.

Following a survey of the Pooled Fund member states at the meeting and through emails, the majority voted for the 4 to 8 ft range of use for the MGS. More recently, MwRSF researchers planned to present this information, along with a revised research plan, to the states in writing in the near future and further discuss this proposed plan with FHWA. Once a consensus is reached as to the plan details, MwRSF will re-construct the MGS and curb system with an 8-ft offset for use in the crash testing program.

The first 2270P crash test is anticipated in August to September 2008. If additional crash testing is required, additional funds will be needed to complete this effort.

Paper Studies

Cost-Effective Measures for Roadside Design on Low-Volume Roads

A field trip to document roadside hazards found along low-volume roads was previously completed in Kansas. More recently, additional field trips have been made to two Nebraska counties to find typical hazards on similar roads. Detailed documentation of the Kansas hazards has been performed. Additional documentation of Nebraska hazards is planned for the third quarter of 2008. It is anticipated that RSAP analyses of 4 or 5 of the most common hazards can be completed under the current study. The first hazard to be evaluated was the safety treatment of large cross-drainage culverts. Many of these culverts are currently treated with ineffective concrete post and beam bridge railings without any approach guardrails. Treatments considered for these hazards included removing any existing railing, erecting a long span guardrail system, and constructing culvert safety grates. An RSAP benefit-to-cost analysis was undertaken on this feature. Results on culverts treatments should be completed in the third quarter. Other feature categories are to be analyzed in the 3rd through 4th Quarters of 2008.

Submission of Pooled Fund Guardrail Developments to AASHTO TF-13 Hardware Guide

To date, 19 systems have been submitted to TF-13 for review and approval. Ten systems were approved for the Guide at the September 2007 meeting. Nine systems more were reviewed in May. MwRSF is waiting to receive comments from TF-13 on the CAD details recently submitted.

Development of Warrants for Median Barrier System

This project has encountered a number of setbacks. The primary problems have been related to quality control during construction of the original database and difficulties associated with determining the numbers of unreported median crashes. Thorough cross checking and rechecking of the database has been undertaken and will be completed shortly. It is believed that all quality control problems will then be resolved. The number of unreported median crashes is needed in order to estimate the number of barrier crashes that can be expected whenever a median barrier is installed. Unfortunately, it appears that the only way to produce this estimate is from an encroachment probability model such as RSAP. It is therefore proposed to utilize RSAP to estimate barrier impact frequencies. Barrier crash severities will be obtained from the Missouri DOT study of median barrier crashes. Note that the MoDOT data also provides a ratio of reported barrier crashes to numbers of barrier repairs. This information will be used to adjust average barrier crash severity to account for unreported accidents. Historical cross-median crash data from Kansas, RSAP barrier impact frequencies, and average barrier crash severities will then be combined to estimate the accident costs associated with unprotected and protected medians. It is estimated that this study will produce preliminary findings by the end of this quarter or early next quarter.

Cost-Effective Upgrading of Existing Guardrail System

The literature review of historical W-beam accident studies has been completed. A listing of W-beam guardrail installations has been obtained from Kansas for use in the RSAP study. These sites will soon be surveyed to document selected guardrail installations. The field investigation process is now planned for the fall of 2008.

Projects Funded by Individual State DOTs and Routed Through NDOR and/or Pooled Fund Program

Iowa RSAP Analysis of Culvert Treatments (Iowa Department of Transportation)

The RSAP analysis of safety treatments for cross drainage culverts has been completed. The analysis examined the safety performance of untreated culverts, extending the culvert out of the clear zone, installing safety grates, and shielding the hazard with W-beam guardrail. The variability in construction costs for extending culvert grates forced this study to focus on identifying accident costs associated with each treatment alternative. Accident costs for each alternative were tabulated for a wide variety of roadway and roadside characteristics. Highway designers can use these tabulated accident costs to calculate benefit-to-cost ratios for each of the safety treatments studied. The analysis appeared to indicate that the use of culvert safety grates was most appropriate for low and medium volume roadways, while culvert extension appeared to provide the most cost beneficial alternative for some high volume facilities. The draft final report remains under review by the Iowa DOT.

Development of a New, TL-4 Precast Concrete Bridge Railing System (Nebraska Department of Roads)

The project objective is to develop a TL-4, aesthetic, open concrete bridge railing for use on cast-in-place decks as well as precast deck panels. Thus far, researchers have iterated through the design of several concepts based on input from sponsors, industrial partners, and design team members. This effort has taken much greater time and resources than envisioned to work toward the final open concrete rail detail. Subsequently, consideration was given to the connection detail between precast rail sections. Once again, much effort was expended in this design phase. Dynamic testing of two joint details was performed in September 2007. Following an analysis of the test results, it was determined that modifications were necessary to the initial joint concepts.

Two modified joint details, along with a new concept, were configured for another round of bogie impact testing. Fabrication of the three joint details was completed by the PCAN partners and delivered to MwRSF. Dynamic testing of these three joints was completed in May 2008. Two out of the three joints showed potential for use in the new bridge railing system. Results from the dynamic testing program were submitted to PCAN and NDOR for review and comment. It should be noted that it may be possible to test the weaker of the two acceptable joint details in the full-scale crash testing program and obtain approval for both joint concepts.

At this time, a joint detail must be selected for implementation into the CAD details so that the single rail section can be fabricated. Dynamic impact testing of a single rail section attached to a short section of cast-in-place deck should occur in the third quarter of 2008. Construction of the bridge support beam has been completed. The deck section should be cast in August 2008. Fabrication of the 16-ft long, single rail section is to occur in July 2008.

Once the single rail test is completed, MwRSF will make plans for the construction and full-scale testing of the new bridge railing and deck system.

Qualification of Type II and Type I End Terminals for Box Beam (New York DOT)

In 2007, three 1100C full-scale vehicle crash tests were performed on two NYSDOT box beam terminal systems. For the first design, vehicle rollover resulted in an unsuccessful test. On the second design, two successful tests have been obtained thus far, with additional testing required in order to complete the certification process. Project funding has been nearly expended. A draft report documenting the test results has been prepared and submitted to NYSDOT for review and comment. Preliminary comment has been obtained and report edits are completed.

In 2008, a continuation project was approved to provide new funding for an additional crash testing program. For this project, construction materials for the box beam guardrail and terminal systems have been ordered. These materials will be used in the first three crash tests. Testing is planned to begin in July 2008.

Universal Breakaway Steel Post for Guardrail (Minnesota DOT)

A new, breakaway steel post option is under development and designed for use in thrie beam bullnose barrier systems as well as other longitudinal barrier applications, such as guardrail end terminals and long-span guardrail systems. The new post would be considered an alternative to existing wood CRT posts. In order to better develop a steel post alternative, six dynamic bogie tests have been performed on CRT wood posts placed in a rigid sleeve and under varying impact orientations. Two bogie tests have been performed at each angle orientation – 0, 45, and 90 degrees. A report documenting these findings has been completed.

In addition, several breakaway concepts have been brainstormed and designed, with CAD details prepared. Thirteen dynamic bogie tests have been performed on the initial and modified concepts, along with data analysis. Concept refinement and new CAD details were also completed. In June 2008, six additional bogie tests were performed on MGS CRT posts placed in soil and impacted at varying impact orientations – 0, 45, and 90 degrees. Data analysis is underway and will be used to compare test results from the steel-post breakaway concepts. Two full-scale vehicle crash tests are planned for the 3rd to 4th Quarters of 2008. Acquisition of curved and slotted thrie beam bullnose sections is underway.

Development of a Test Level 1 Timber Curb-Type Railing for Use on Transverse, Timber, Nail-Laminated Deck Bridges (West Virginia DOT)

The project consists of adapting and modifying a crashworthy TL-1 timber bridge railing system for use on nail-laminated, transverse timber deck bridges, while using the proposed MASH 08 guidelines. A sloped end section is also to be developed for rural, low-speed, low-volume applications. Five static tests and one 2270P crash test are planned. Design details have been prepared and reviewed by WVDOT officials. Selected construction materials have been ordered, including glulam rails, dimensional deck boards, and selected structural steel hardware. Construction of the timber bridge deck has begun in June 2008 and should be completed this month as well. Deck surfacing will be applied this month. Static testing is also planned for June to July 2008, while the 2270P full-scale crash test is planned for early 3rd Quarter of 2008.

Development of a Test Level 2 Steel Bridge Railing and Transition for Use on Transverse, Timber, Nail-Laminated Deck Bridges (West Virginia DOT)

The project consists of adapting and modifying a crashworthy TL-2 steel bridge railing system for use on nail-laminated, transverse timber deck bridges, while using the proposed MASH 08 guidelines. An approved TL-2 approach guardrail transition is to be implemented into the design. Four dynamic bogie tests on posts attached to nail-laminated timber deck bridges will be performed. Testing should demonstrate whether the alternative deck system can withstand the post loading without damaging the deck. Draft design details have been prepared in the 2nd Quarter of 2008. Internal review of these details is planned for the 3rd Quarter of 2008. The bridge deck system used in the TL-1 project will also be used for this study. As previously noted, construction of the timber bridge deck was planned for the 2nd Quarter of 2008.

Awaiting Reporting

Evaluation of Transverse Culvert Safety Grates

The culvert grate on a 3:1 slope performed well with both the 2000P and 820C vehicles. A draft report has been prepared and is under internal review. A TRB paper was presented at the 2008 Annual Meeting of the Transportation Research Board and accepted for publication.

Approach Slopes for W-Beam Guardrail Systems

At the conclusion of this testing program, the MGS guardrail system can now safely be located at a 5-ft offset distance from the edge of the traveled way on slopes of 8:1 or flatter. A draft report documenting this research is currently under internal review.

Retest of the Cable End Terminal

Based on successful testing of this low-tension, cable terminal system, a draft report of the project has been prepared and is currently under review by the Pooled Fund members.

Flare Rates for MGS W-Beam Guardrail

This crash testing program has shown that the MGS can be installed with flares as steep as 5:1, as measured to the traveled way. A draft report on this project has been prepared and is currently under review by the Pooled Fund members. We also prepared a paper for the 2007 TRB meeting based on this project.

Midwest Guardrail System Placed at the Breakpoint of a 2:1 Slope

An MGS system utilizing 9-ft long, W6X9 steel posts spaced at 6-ft 3-in. centers was successfully crash tested utilizing a 2270P Dodge Quad Cab vehicle. The vehicle was safely redirected. A draft report has been prepared and is under internal review. A TRB paper was presented at the 2008 Annual Meeting of the Transportation Research Board and accepted for publication.

Termination of Temporary Concrete Barrier

An anchor system utilizing two driven steel posts and soil plates from the existing cable anchorage system was tested with a 2270P impacting 4 ft - 3.6 in. upstream of the joint between barriers 1 and 2. The crash test met all salient test criteria. A test report documenting the results has been prepared and is under internal review.

Draft Pooled Fund Reports Completed

Stolle, C.S., Polivka, K.A., Reid, J.D., Faller, R.K., and Sicking, D.L., *Evaluation of Critical Flare Rates for the Midwest Guardrail System (MGS)*, Draft Report to the Midwest States' Regional Pooled Fund Program, Transportation Research Report No. TRP-03-191-08, Project No. SPR-3(017)-Years 14 and 15, Project Codes: RPFP-04-03, RPFP-05-05, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 17, 2008.

Hitz, R.A., Molacek, K.J., Stolle, C.S., Polivka, K.A., Faller, R.K., Rohde, J.R., Sicking, D.L., and Reid, J.D., *Design and Evaluation of a Low-Tension Cable Guardrail End Terminal System*, Draft Report to the Midwest States' Regional Pooled Fund Program, Transportation Research Report No. TRP-03-131-08, Project No. SPR-3(017)-Years 11, 14, 15, Project Codes: RPFP-01-03, RPFP-04-07, RPFP-05-03, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, February 28, 2008.

Final Pooled Fund Reports Completed

Rosenbaugh, S.K., Faller, R.K., Hascall, J.A., Allison, E.M., Bielenberg, R.W., Rohde, J.R., Polivka, K.A., Sicking, D.L., and Reid, J.D., *Development of a Stand-Alone Concrete Bridge Pier Protection System*, Final Report to the Midwest States' Regional Pooled Fund Program, Transportation Research Report No. TRP-03-190-08, Project No. SPR-3(017)-Year 14, Project Code: RPFP-04-05, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, April 18, 2008.

Draft Reports – Projects Funded by Individual State DOT and Routed Through NDOR and/or Pooled Fund Program

Albuquerque, F.D., Sicking, D.L., and Polivka, K.A., *Evaluation of Safety Treatments for Roadside Culverts*, Draft Report to the Iowa Department of Transportation, Transportation Research Report No. TRP-03-201-08, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, February 25, 2008.

Final Reports – Projects Funded by Individual State DOT and Routed Through NDOR and/or Pooled Fund Program

Arens, S.W., Faller, R.K., Rohde, J.R., and Polivka, K.A., *Dynamic Impact Testing of CRT Wood Posts in a Rigid Sleeve*, Final Report to the Minnesota Department of Transportation, Transportation Research Report No. TRP-03-198-08, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, April 11, 2008.

Pooled Fund Consulting Summary

Midwest Roadside Safety Facility
April 2008– June 2008

This is a brief summary of the consulting problems presented to the Midwest Roadside Safety Facility over the past quarter and the solutions we have proposed.

Problem # 1 –Guardrail blocks on US 52

State Question:

These are photos of our recently installed MGS system over curb (Figure 1). The plans detailed a 16-d nail into each blockout that apparently wasn't installed.

Had heavy snowfalls all season in this area (and all of Iowa for that matter). Trying to figure out why these blockouts are tipped in this direction, but we're thinking it may be related to snow-removal operations.

My question of the day boils down to repairing this installation. You can see on some of these blockouts, the flange of the post has fractured off portions of the routed channel in the back side of the blockout. Any opinion as to how much of this channel would need to be intact to reuse the blockouts (basically straightening the blockout and placing the nail)?

David L. Little, P.E.
Assistant District Engineer
Iowa DOT, District 2
641-422-9464 (direct phone)

MwRSF Response:

Dave:

We agree that this blockout rotation would appear to be caused by snow removal operations. To resolve your blockout issue and eliminate the requirement to field drill holes in the steel flanges, we recommend that you place four (4) nails in the top and bottom corners on both sides and bend the nails over the flanges. The four nails should provide adequate resistance to block rotation, even under snow removal operations. For this solution, you could use 16-d nails, but it may be preferred to use 20-d nails with this alternative. Please note that it would not be necessary to have the post webs on the back of the blockout using this option.

Ron

Ronald K. Faller, Ph.D., P.E.
Research Assistant Professor

Figure 1. Guardrail blocks on US 52

Problem # 2 – Regarding Ballot AASHTO Manual for Assessing Safety Hardware 2008

State Question:

Dear Dr. Sicking and Faller,

WisDot's Structures Bureau has some concerns over the implementation of the update to NCHRP 350 otherwise known as MASH (see below). My understanding of the implementation is the following (please correct me if I am wrong):

All existing NCHRP 350 compliant hardware will be accepted to install (this would include existing parapet/barrier designs that WisDot's currently uses), until an AASHTO technical committee decides that there is a performance problem with a specific device or they believe that there are sufficient number of MASH compliant devices available. A specific time frame after the AASHTO approves the implementation of MASH all new products (eats, crash cushions, parapet designs...) would have to be crash tested using the MASH criteria (e.g. if 5 years from now WisDOT want to develop a new parapet design they would have to use MASH criteria to crash test the parapet).

There are changes to the test vehicles that will increase the amount of force that the barriers will have to withstand; but this change is being driven by changes in the vehicle fleet. Most experts believe that the majority of TL3 devices will be sufficiently strong enough to withstand the new loads. It should be noted that in a resent crash testing at MwRSF, TRP-03-190-08, indicated that vertical steel reinforcement had stresses greater that 60Ksi with the existing NCHRP 350 TL3 crash test vehicle. If the weight limits for semi trucks increased, wouldn't we strengthen our standard bridge designs to accommodate the increase in load? The same logic would apply to changes in the vehicle fleet for roadside barrier.

If MwRSF could provide our structure department additional information about the implementation of the MASH update and the effects on current designs it would be greatly appreciated.

Sincerely,

Erik Emerson

MwRSF Response:

I will do my best to answer your questions and/or provide additional comment below. My comments will be shown in RED. I will also ask that Dean provide additional comment if deemed necessary, or if he disagrees with my assessment.

Ron

Dear Dr. Sicking and Faller,

WisDot's Structures Bureau has some concerns over the implementation of the update to NCHRP 350 otherwise known as MASH (see below). My understanding of the implementation is the following (please correct me if I am wrong):

All existing NCHRP 350 compliant hardware will be accepted to install (this would include existing parapet/barrier designs that WisDot's currently uses), until an AASHTO technical committee decides that there is a performance problem with a specific device or they believe that there are sufficient number of MASH compliant devices available. A specific time frame after the AASHTO approves the implementation of MASH all new products (eats, crash cushions, parapet designs...) would have to be crash tested using the MASH criteria (e.g. if 5 years from now WisDOT want to develop a new parapet design they would have to use MASH criteria to crash test the parapet).

**You are correct in stating that existing crashworthy hardware (e.g., 350 approved hardware) will still be allowed to be installed in the future. In addition, I am currently unaware of any date being designated as to when hardware meeting MASH 08 must replace 350 hardware. I personally do not see that happening for a very long time. At the present time, we have been working under the guidance that all new hardware developments occurring after January 2008, or even early 2008, are to utilize the proposed MASH 08 guidelines. However, if the first test in the program occurred prior to this period, the research and development program is allowed to continue by using the NCHRP 350 requirements.

There are changes to the test vehicles that will increase the amount of force that the barriers will have to withstand; but this change is being driven by changes in the vehicle fleet. Most experts believe that the majority of TL3 devices will be sufficiently strong enough to withstand the new loads. It should be noted that in a resent crash testing at MwRSF, TRP-03-190-08, indicated that vertical steel reinforcement had stresses greater that 60Ksi with the existing NCHRP 350 TL3 crash test vehicle. If the weight limits for semi trucks increased, wouldn't we strengthen our standard bridge designs to accommodate the increase in load? The same logic would apply to changes in the vehicle fleet for roadside barrier.

**Changes to the mass of the pickup truck used for TL-3 testing will likely increase the impact loads imparted to longitudinal barrier systems. However, this mass change is not deemed significant in terms of impact load nor should it result in any concern for the majority of the existing crashworthy barrier systems. The recently developed vertical parapet was designed to meet TL-3 found in the NCHRP 350 guidelines. In this test, some of the barrier reinforcement yielded and diagonal cracking was observed in the parapet, as was expected from using the yield-line analysis procedures. Although some formwork shifting caused the barrier width to be greater than planned, it would seem reasonable that this barrier system could contain and redirect the 2270P vehicle under TL-3 conditions according to MASH 08. However, increased damage to the barrier would occur. One additional thing to note is that the pickup truck extent over the barrier top would be unknown as well as the resulting vehicle snag on the pier. Barrier translation and rotation occurring due to the additional barrier damage and foundation rotation in the soil would also be unknown for the 2270P test.

**The TL-4 single-unit truck test is expected to result in a much greater increase in the impact loads imparted to barriers. This opinion is based on an increase in vehicle mass from 8,000 to 10,000 kg and a speed increase from 80 to 90 km/h. With these changes, along with a slightly taller vehicle c.g. heights, new stronger barriers will be designed to meet TL-4 of MASH 08 as new R&D barrier projects are funded. However, it should be noted that existing 350-approved bridge railings and barrier systems will continue to be installed into the future and will be allowed to remain in place.

**I do not anticipate any changes occurring for TL-5 barriers.

Problem # 3 – Beam Guard Question

State Question:

Dear MwRSF,

I have to beam guard questions.

1. What is the deflection distance for a standard beam guard system using 7'
long steel post spaced at 3' 1.5" on a 2:1 slope that starts at the middle of the steel post?

2. I've been trying to find the crash test report from TTI that used an asphalt curb near beam guard. Unfortunately, I and our library staff are having a hard time finding a copy of this report.
Does MwRSF have a copy?
Could MwRSF provide me with a PDF detail of the curb and gutter and its'
installation near the beam guard?

I believe the report was titled: "NCHRP 350 Test 3-11 on the G4 (2W) Strong Post Beam Guard with 100mm High Asphalt Curb" done by Bullard and Menges.

Thanks,

Erik Emerson P.E.
Wisconsin Department of Transportation
Standards Development Engineer

MwRSF Response:

Erik:

Within the report/paper, I have found that the dynamic deflection of the barrier system on a 2:1 slope was found to be 821 mm (32.3). I do not have a working width value at this time.

I do not have a pdf copy of the TTI report. I know we have a copy of the report in our library somewhere. I will look for it and find the number you are seeking.

Ron

Ronald K. Faller, Ph.D., P.E.
Research Assistant Professor

Problem # 4 – Cable Guardrail Next to Slopes

State Question:

I know the pooled fund did a crash test and report with low tension cable guardrail placed in four feet in front of a 1V:1 1/2H slope using a four foot post spacing. Is it possible to correlate your results to a high tension cable guardrail system. For example, we are using Trinity's TL-3 system with the C-Channel post. Deflection is reported to be 9 ft. at a standard post spacing of 16'-6". I was wondering what post spacing would be necessary for it to work similar to MwRSF's test.
I know the reported deflection in the crash test was around 9 feet, but I also remember Dean Sicking saying deflection is greater on a slope than flat ground, therefor presumably the low tension system would have been a bit stiffer than the 9 foot deflection as seen in the slope test.

Our field guys are wanting to use some high tension cable barrier for shoulder applications so we need to develop some criteria.

-Bill

William B. Wilson, P.E.
Standards Engineer
Wyoming Dept. of Transportation

MwRSF Response:

Hello Bill,

I have reviewed your request for guidance on placement of the CASS system adjacent to steep slopes. You stated that you are using the CASS with 16'-6" (5-m) post spacing. Review of the FHWA approval letter for the CASS with that configuration showed that the CASS system had a dynamic deflection of 2.8 m. The CASS uses a top cable height of 750 mm and a C-section post embedded 813-mm into the soil. The system is a high tension system.

The cable adjacent to steep slope research at MwRSF was conducted on a low-tension cable system with a top cable height of 813 mm. The system used S3x5.7 posts with 813-mm embedment and a 203-mm wide soil plate. Post spacing for the system was 1.22-m (4'), and the system was offset 1.22-m from the slope breakpoint. Dynamic deflection for this system was approximately 3.16 m.

Comparison of the two systems shows that the MwRSF system had a top cable height approximately 63-mm (2.5") higher than that of the CASS and had 1/4 post spacing. While the two systems displayed similar dynamic deflections, the CASS system was tested on a relatively short installation on flat ground, while the MwRSF low-tension system was tested with a 494-ft installation adjacent to a steep slope. Thus, we expect that the deflection for the CASS system would increase if installed under similar conditions.

In order for the CASS system to function safely adjacent to a steep slope, the deflection of the system may need to be reduced in order to assume that the the cables effectively interlock with the front and rear corners of the vehicle. Because the CASS has a lower top cable height and we expect the it to have higher deflections in this type of installation, as mentioned above, we would recommend a reduced post spacing for the CASS with a 1.22-m offset from the slope similar to the MwRSF testing. The CASS has been successfully tested with reduced post spacing's of 2-m and 3-m with dynamic deflections of 2.06-m and 2.4-m, respectively. We could recommend that CASS systems adjacent to steep slopes use the 3-m post spacing with a 1.22-m offset from the slope breakpoint. While this recommendation is believed to be conservative, it should account for the effect of the lower cable height on capture and the higher deflections expected for the CASS when installed adjacent to a slope.

If you have any further questions or concerns feel free to contact me.

Thanks

Bob Bielenberg, MSME, EIT
Research Associate Engineer
Midwest Roadside Safety Facility

Problem # 5 – Cable Guardrail Next to Slopes – Part II

State Question:

Great analysis! That was the recommendation I was looking for. I would rather be a little on the conservative side without actually crash testing.

One additional question I have. Has there been any evaluation as to what a minimum post spacing would be for the S3x5.7 post (both for cable and other applications)? We use that post for box beam guardrail as well. We have usually regarded 4 ft. as the minimum spacing. Does that sound appropriate? I realize it may depend on the post release mechanism. It appears it worked well on the low tension cable system, but that was the pickup test. I thought I saw one state specify up to a 3 ft. spacing to limit deflections, that seems a little much.

-Bill

William B. Wilson, P.E.
Standards Engineer
Wyoming Dept. of Transportation

MwRSF Response:

Bill,

To my knowledge, there has been no cable testing with post spacing less than 4 ft. I have always recommended this as a minimum spacing to limit the possibility of post interaction. When we tested closely spaced flanged channel u-posts for mail box supports, we saw interaction that produced rollover in a small car. If I recall correctly, this behavior disappeared at a spacing of about 4 ft.

Hence we would recommend a 4 ft minimum spacing.

Any other input is welcome.

Dean

Problem # 6 – FHWA Short Radius Beam Guard Technical Memo

State Question:

Dear MwRSF,

I have some questions about the FHWA short radius beam guard technical memo (see attached). From the FHWA technical memo the top of rail is 27 1/8" from the ground. The Roadside Design Guide indicates that the top of a beam guard rail should be 27" or 28" (page 5-13 Roadside Design Guide and Figure B4.b in Appendix B) from the ground. WisDOT standard detail drawing uses a top rail height of 27 3/4".

Would it be acceptable to adjust the rail height of the FHWA short radius system to match WisDOT's use of the 27 3/4" rail height?

If WisDOT would switch to the MGS system, would it be acceptable to adjust the top of rail height for the FHWA technical memo to match the 31" of the MGS system? Because the MGS system places the lap of the rail in the middle of the span between posts, would the FHWA short radius system need to be lapped similarly?

Are the specifications for the Wood Break Away Post on page 10 of the FHWA technical memo standard for all Wood Break Away Post (e.g. stress grade...)?
Are there standards for the CRT and regular beam guard post similar to the Wood Break Away Post (e.g. stress grade...)?

The FHWA details are using "A Guide to Standardized Highway Barrier Rail Hardware from 1979. I assume that this book was the previous guide for "A Guide to Standardized Highway Barrier Hardware". The problem I'm having is that the old nomenclature used in 1979 is not synchronized with the Online barrier hardware guide at:
http://aashtotf13.tamu.edu/Guide/nameindex2.html

For an example F-3 from the FHWA technical memo does not match any of the fastener hardware designations in the online manual. Is there a translation key from the 1979 manual to the online version (i.e F-3 in the tech memo = FBB04)?

I was reviewing the Yuma County detail, I assume that the two CRT post that are 2-3 feet behind the railing are there to slow impact vehicle. Would a similar set up of CRT posts help prevent the pick-up truck from sliding over the thrie beam rail in the MwRSF thrie beam system?

I'm guessing that MwRSF has looked into adding multiple CRT post behind the rail like Yuma County and decided that it would not work. I would appreciate it if MwRSF could explain to me why the addition of CRT post behind the rail would not work with the MwRSF thrie beam system, or how the Yuma system uses the CRT post behind the rail during an impact. I'm just trying to get a better handle on how these systems work.

Thanks
<<FHWA Tech advisory short Rad.pdf>>

Erik Emerson P.E.
Wisconsin Department of Transportation
Standards Development Engineer

MwRSF Response:

Hi Erik,

I have some replies to your short-radius questions.

First, we cannot recommend changing the height of the Yuma County short radius guardrail. We do not have any basis for evaluating the effects of the change in rail height, and our estimation of the effects of any change in rail height would be extremely limited. We know that changing the height will affect the capture of sedans that the system was designed for as well as the capture of small car and pickup truck size vehicles. Thus, without further analysis, we would recommend leaving the rail height as stated in the memo.

Similarly we could not recommend a change to the 31" rail height of the MGS system. One of the critical issues in the design of a short radius system is capture of the vehicles. This is why our current design uses a slotted thrie beam section as the rail element. We want to maximize the ability of the system to capture both small cars and larger cg vehicles. We have seen in our current design that we are near the limit for effectively capturing the small car even with thrie beam. Thus, we would not recommend raising he w-beam height on the FHWA recommended system.

The posts shown on page 10 are standard BCT end terminal posts, so you can feel free to use whatever post spec you usually use when calling out BCT posts.

We did look at placing a series of posts behind the system in order to further slow down the vehicle, but we did not pursue it for two main reasons.

1. Testing with the small car vehicle showed that we are currently at or near the occupant risk limit for the small car. AS such, putting more posts behind the system will increase the deceleration of the small car and be detrimental.
2. We have shown in our pickup truck testing that we have issues with debris build up causing vehicle instability. As such, we were leery of placing more posts in the system and creating more debris.

The Yuma county system is old and did not have to meet our more stringent test demands with two vehicles. They used the extra posts to increase vehicle deceleration, but that is not a good option for our system.

Thanks

Bob Bielenberg, MSME, EIT
Research Associate Engineer
Midwest Roadside Safety Facility

Problem # 7 – High-Tension Cable Barrier

State Question:

Dear MwRSF,

We have been contacted by Gibraltar about requiring the maximum post spacing of cable barriers being 15'. We based our 15-foot maximum post spacing (as many other states have) on an FHWA memo. Gibraltar has provided me with an email from Nick Artimovich indicating that 20 foot spacing is O.K. based on crash testing.

Gibraltar is also indicating that it and other manufactures of HTCG believe that close post spacing leads to underrides. I was wondering what is MwRSF's opinion on post spacing and if narrower post spacing is leading to under rides?

Also we have required that the fittings for our cable barrier project have a minimum breaking strength of 39,000 lbs. Gibraltar is indicating that there are no fittings that meet the 39,000 lbs breaking strength. They do indicate that the 1-inch fittings have a 36,000 lbs breaking strength. They are also indicating that they have miles of cable barrier with 3/4-inch fittings (breaking strength of 26,000 lbs) that are working fine.

Personally, "a chain is only as strong as its' weakest link" is my theory (i.e. use 1-inch fittings) and I believe Dr. Faller and I have exchanged some emails on this topic. However, with information about cable barrier changing so fast, I wanted to make sure that I had the most current research on this topic.

As always, MwRSF's help is always appreciated.

Sincerely,

Erik

MwRSF Response:

Erik,

1. I strongly disagree with Gibraltar's opinion about close post spacing leading to under ride. In fact, I believe just the opposite, long post spacing is likely more to lead to under ride. I would like to hear any support they have for such a claim. ALthough we recommend a 16' maximum rather than 15', I think that in this range, shorter is generally better.

2. Couplers (splice components) rated at 26,000 lbs are too weak. We have tested these and they are much weaker than the cable. We tested Bennet Bolt's non-proprietary, reinforced couplers and found them to be as strong as the cable system (about 40kip dynamic).

3. The 3/4" end fittings are also too weak.

4. Make sure you specify that all connections should have strengths comparable to the cable, about 38-39Kips. These could be dynamic strengths, if necessary.

Dean

Problem # 8 – Temporary Barrier Anchorage in Medians

State Question:

Dear MwRSF,

On a project on the interstate, a designer has indicated that the barriers need to be pinned to the concrete when traffic is on both sides of the barrier. Given that this is on the interstate (high speeds and ADT) the designer does not want the barrier to be deflected near the already narrow roadway lanes. I happen to think that the designer is making the right call in this situation.

The contractor has asked if they need to pin the barrier and install the connection pin. I don't there is much of an option about installing the connecting pin between barriers. I also, given the importance of the facility (main highway between Milwaukee and Madision and in the Milwaukee Metro area), I don't want to see the facility completely shut down because a barrier deflected too close to a lane.

Currently, WisDOT has only directions to pin the barrier when traffic is on one side of the barrier (see attached SDD sheets). Would the pinning requirements be the same for traffic on both sides of the barrier? If MwRSF could provide guidance on pinning the barrier in both directions it would be appreciated.

Sincerely

Erik

MwRSF Response:

Hi Erik,

I have some recommendations/guidance with respect to your TCB installation issues.

1. Currently, we do not recommend pinning or anchoring both side of the TCB in a tie-down application. Anchoring the barrier on the both sides creates a pivot point on the non-impacted side of the barrier that promotes barrier rotation and tipping and thus promotes vehicle instability. We cannot eliminate this concern without further analysis and/or testing, so we would strongly recommend against it.
2. We do not believe that you need to tie-down the barriers in the installation shown. The installation in the detail has three 11’ wide lanes separated by a 6’ space between the opposing traffic lanes for the separating TCB. In MwRSF Research Report No. TRP-03-113-03 (attached), we recommend that the pooled fund states TCB can be installed with the assumption of a 2’ deflection based on the 85th percentile impact expected. The 2’ deflection is based on modeling with the impact conditions for the 85th percentile impact severity based on accident data. The basic argument behind the recommendation is that most impact in the work zone do not generate barrier deflections as large as those observed in full-scale crash tests. You have room for the 2’ of deflection recommended in your 6’ separation area.
3. In addition, potential higher deflections are not believed to be as critical for several reason in the type of installation you have. First, you have 11’ wide lanes and vehicles tend to drive near the middle of those lanes not near the edge. This is much more prevalent in work zones were drivers tend to be more cautious and shy away from the barriers when placed close to the travel lane. This has been proven in an accident study in Iowa where they looked at accident rates in work zones when the barriers were placed very close to traffic. The accident frequency was very low. Then they moved the barriers farther away from the traffic and the accident rate increased. The outcome of the study found that placing barriers within 6’ of traffic reduced the impact frequency and severity. Because of this factor, you effectively have more than the required two feet need for deflection.
4. Although larger deflections could begin to intrude into the normal paths of oncoming traffic, the risk of an accident involving opposing traffic is still relatively low. Even when a vehicle in the opposing lane strikes a deflected barrier, the impact angle associated with any resulting crash would be expected to be extremely low. For this situation, the consequences of exceeding the deflection limit are not catastrophic.

Based on my comments above, we would recommend that you use free-standing PCB's in the installation you have shown. We believe that free-standing barriers will provide adequate protection without intruding into adjacent lanes in an unsafe manner.

Thanks

Bob Bielenberg, MSME, EIT
Research Associate Engineer
Midwest Roadside Safety Facility

Problem # 9 – TL-5 Barrier Height

State Question:

Dear MwRSF,

Our structures department is in the process of developing guidance for their bridge designers. To comply with LRFD, the are asking me for a 54" tall TL5 barrier. Does MwRSF know of any TL5 crash tested barriers that are 54" tall?

Is it possible to modify the MwRSF TL5 barrier to be 54" tall? Does it make much sense to construct a 54" tall barrier verses a 42" barrier to protect a pier from a semi truck leaning over and striking the pier of a bridge? How far has TTI gotten with their research on the LRFD 400 KIP load requirement?

Sincerely,

Erik Emerson P.E.
Wisconsin Department of Transportation
Standards Development Engineer

MwRSF Response:

Erik:

To date, I am aware of one TL-5 barrier that was 54 in. tall and one TL-6 barrier that was 90 in. tall. These barriers are described and referenced in MwRSF Research Report No. TRP-03-149-04. A copy of this report is included in this email. Other TL-5 barriers are noted in this report as well. MwRSF developed two TL-5 bridge railings and median barriers that are not included in this report. Those barrier systems and associated reports have been sent to you previously. If you need additional copies, I can send them to you in pdf format.

For the MwRSF barrier, a 54 in. median version could be developed as long as the additional height did not penetrate the head ejection envelope. This change would cause the barrier width to

increase significantly and without knowledge as to how much trailer lean would still occur over the barrier.
The upper barrier section would also get more complex and costly. What distance is available from the front face of a barrier to the front face of a pier? Are you more concerned with vehicles hitting the piers head on or from allowing the box to lean over and snag on the pier? Remember that the box lean will not impart as high as a load as would a head-on impact. Head on impacts could be prevent using long TL-5 barriers that provide adequate length of need protection. I recall that we had 1 or 2 Pooled Fund problem statements that addressed this issue but were held back to wait for the TTI/TxDOT study to be completed.

I received a note from Gene Buth with regard to the site where updates can be found pertaining to the TTI/TxDOT pier protection project. See link below:

It is TPF-5(106) and it is at:
http://www.pooledfund.org/projectdetails.asp?id=338&status=6

Ron

Ronald K. Faller, Ph.D., P.E.
Research Assistant Professor

Problem # 10 – Strong Post W Beam Guardrail Placed Adjacent to Steep Slope

State Question:

Gentlemen,

We have a situation as shown below. Please provide guidance or a recommendation regarding the W Beam Guardrail Wood post spacing and length of posts. This situation did not fall into the categories as stated on pages 28 and 29 of the recent Pooled Fund Quarterly Report.

Thank You,
Bernie Clocksin
Standards Engineer

MwRSF Response:

Hi Bernie,

I looked at your schematic of the w-beam guardrail installation on what appears to be a 3:1 slope with a 1:1 or a 2:1 slope behind it. Missouri had a similar issue in the past. We recommended to them that they use 9’ posts at ½ post spacing (3’-1 ½”). I have attached the detail they made based on this recommendation.

We would recommend a similar post length and spacing for your installation.

Thanks

Bob Bielenberg, MSME, EIT
Research Associate Engineer
Midwest Roadside Safety Facility

Hi Bernie

You had asked me at the pooled find meeting about the recommendation below. I believe that you said the installation below was TL-2 rather than TL-3 and you wanted to know if you could shorten the posts.

I looked at the energy of the TL-2 impact, and I believe that you can use 7' long post at ½ post spacing in this installation for TL-2. That should help you out quite a bit.

Let me know if you need anything else.

Thanks

Bob Bielenberg, MSME, EIT
Research Associate Engineer
Midwest Roadside Safety Facility

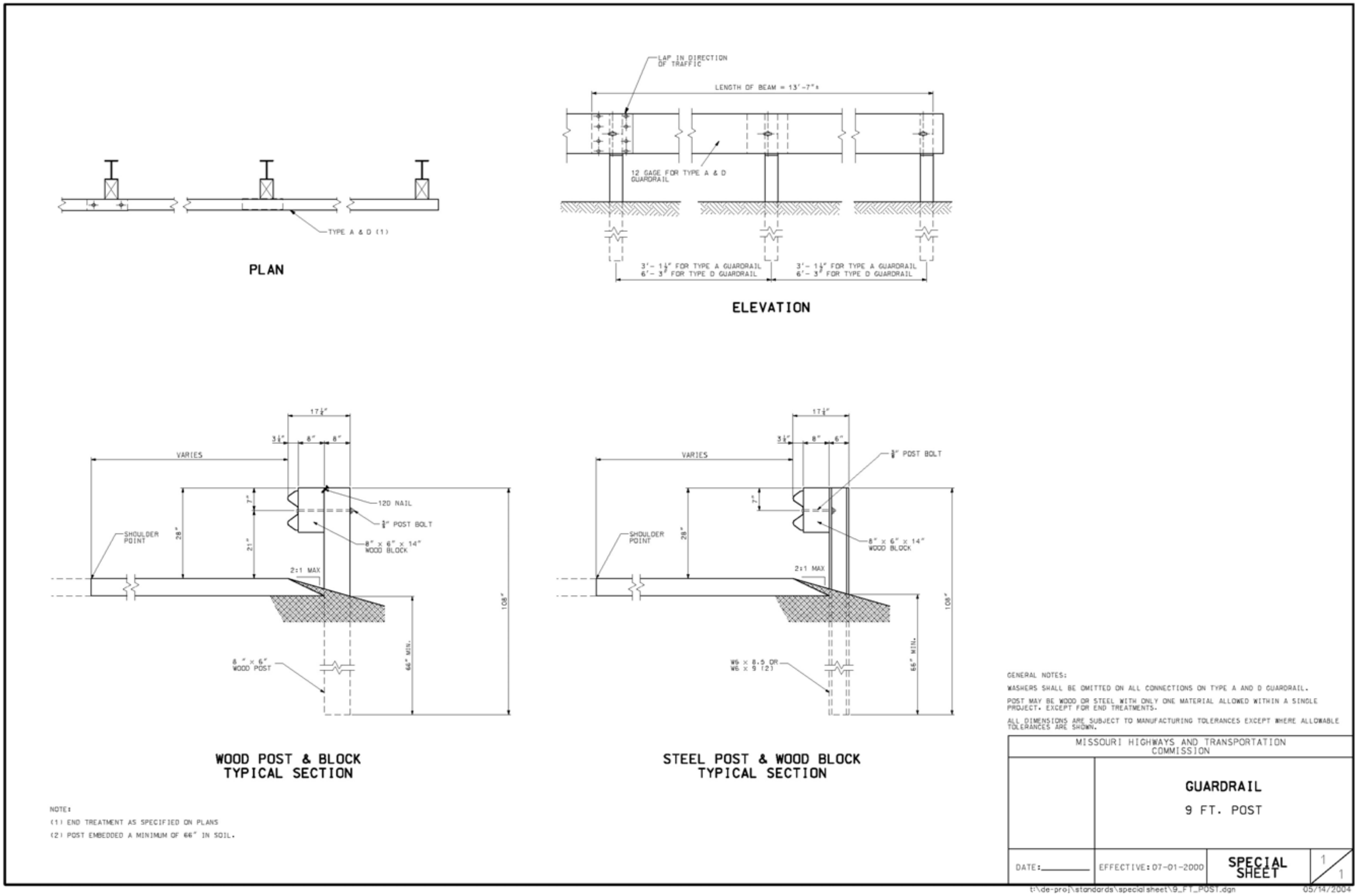

Figure 2. Nine Foot Post Detail