Progress Report
Fourth Quarter 2008 – October 1st to December 31st
Midwest Roadside Safety Facility
Midwest State's Regional Pooled Fund Program
December 15, 2008

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

Standardizing Posts and Hardware for MGS Transition

At the April 2008 Pooled Fund 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 was successfully performed on July 7, 2008. Later, the 1100C crash test was successfully performed on October 9, 2008. Documentation and evaluation of the test results was performed in this quarter. A draft research report was also begun.

With the completion of these two full-scale crash tests, a simplified, steel post transition option is now available for attaching the MGS to crashworthy approach guardrail transition systems. In the first quarter of 2009, dynamic bogie testing will be performed on wood posts placed in soil in order to determine a simplified wood post transition alternative.

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

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

In 2008, the Pooled Fund Member States voted to use the 10000S funds to re-run the 1100C vehicle test into a modified high-tension, four-cable, barrier system placed in a 4:1 V-ditch using a slightly firmer median soil condition within the impact region. The bottom cable was positioned 13.5 in. above the ground with the remaining cables spaced upward using 10.5 in. between cables. On August 25, 2008, the 1100C re-test (test no. 4CMB-3) was performed in a 46-ft ditch with the cable barrier placed 4 ft up the back slope. Shortly after impact, the vehicle was captured by the lower cable. Following the crash test, it was apparent that the roof and upper A-pillar region had been crushed downward by one of the high-tension cables. The roof crush exceeded the limits provided in MASH-08, thus resulting in a small car test failure. An investigation was performed to determine the cause for the unfavorable outcome. From inspection, the cable brackets detached as designed, thus leaving only the bolts in the post flanges. However, the exposed bolt heads were sufficient to prevent upward cable movement at some post locations, thus not allowing the translation of certain tensioned cables up and over the small car. Refinements to this cable attachment bracket, or the implementation of a new bracket, should prevent this unfavorable outcome. Documentation and reporting of this research and testing program occurred this quarter and will continue into the first quarter of 2009.

Continuation funding for the high-tension, cable barrier system was included in the Year 19 Pooled Fund Program. This research funding was based on an assumption that the small car re-test (test no. 4CMB-3) would result in an acceptable outcome. Following the unsuccessful result, the Pooled Fund member states were surveyed to determine how to proceed with the high-tension, cable barrier R&D program. Two research options were provided – either proceed with the development of simplified cable bracket in barrier system on level terrain or use those funds to develop and implement the simplified bracket in the barrier currently placed in the V ditch. Six responses were received with 100 percent of the responses in support of continuing the R&D effort in the 4:1 V-ditch using a simplified bracket. The design, component testing, and full-scale crash testing of the simplified bracket is anticipated to occur in the first quarter of 2009.

Phase I Development of a TL-3 MGS Bridge Rail

On November 13, 2008, one dynamic bogie test (test no. MGSBRB-6) was performed on a weak-post bridge railing concept attached to a short reinforced concrete deck section. Following the result, design modifications were made, and a new prototype connection was fabricated. The new prototype will be subjected to component testing in the first quarter of 2009. BARRIER VII computer simulation modeling was also continued on the weak-post bridge railing design. Documentation and reporting the test results was conducted in this quarter.

Following the bogie testing program, the preferred post concept and railing design will be submitted to the Pooled Fund members for review and comment, likely in February 2009.

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

Work on this project will commence after crash testing has been 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

Following a survey of the Pooled Fund member states at the 2008 spring Pooled Fund meeting and through emails, a majority of the member states voted for crash testing the MGS with 6-in. curb using the 4 to 8 ft range in lateral offset. Later, MwRSF researchers presented this information, along with a revised research plan, to the states in writing. From this request, the member states decided to crash test the MGS using an 8-ft curb offset. The first 2270P crash test has been delayed and is now planned for the first quarter of 2009. If additional crash testing is required, future funds will be needed to complete this effort.

A Phase I draft research report was prepared and is now undergoing internal editing. It is hopeful that this draft report will be copied this quarter and mailed to the member states in January 2009.

Paper Studies

Cost-Effective Measures for Roadside Design on Low-Volume Roads
An analysis of culvert treatments was completed in the third quarter, indicating a strong need to remove any rigid or semi-rigid railing structures located on bridges which are not properly transitioned to guardrail nor shielded. Safety treatments for roadside trees were also analyzed during the third quarter. Many different hazard arrangements were considered, including small clusters of trees, scattered occurrences, and dense rows of trees located adjacent to the roadway. Results from the tree analysis were completed and indicated a very strong need to remove many trees located up to 10 ft from the side of the roadway for tree diameters greater than 6 in. Documentation of the culvert treatments and tree analyses should be completed by the end of the fourth quarter. A field trip was conducted for two Nebraska counties during the third quarter to evaluate the need for treatment of roadside slopes. Detailed documentation of slope profiles was conducted, analyzed, and treatment possibilities were considered. On many low-volume roadways, slope rates near the roadsides are steeper than 2:1 and more than 10 ft deep, often leveling out near trees or fields. Both cable guardrail and W-beam guardrail systems were selected as treatment options where appropriate. Results from the slope analysis should be completed in the first quarter of 2009. Additionally, a fourth hazard category was initialized, consisting of safety treatments for low-volume bridges, such as bridge rails.

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

To date, 15 components and 21 systems have been submitted to TF-13 for review and approval. Six systems and four components were approved for the Guide at the September 2008 meeting in Savannah, GA. Two systems and six components were reviewed in September 2008 and are planned to be approved in April 2009. Three additional systems are planned for review and discussion at the spring 2009 AASHTO Task Force 13 meeting. However, it should be noted that funding for this effort has been depleted as on November 2008 and additional funding will be needed to complete the currently planned effort.

Development of Warrants for Median Barrier System

The project was completed with the publication of the final report.

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 be surveyed as part of a filed investigation in January 2009 in order to document selected guardrail installations.

Evaluation of Safety Performance of Vertical and Safety Shaped Concrete Barriers

For this research project, preliminary data analysis was completed. This analysis consisted of two modeling efforts. Initially, only roadway data was used in the analysis due to data limitations. Using only roadway information, the analysis did not reveal any statistical evidence demonstrating that that the rollover propensity and impact severity differed for vertical and safety shape bridge railings. However, this analysis was naive because other data, such as vehicle and occupant data, was not considered. Later, vehicle and occupant data were incorporated as a result of greater access to different data fields. As such, the accident analysis was repeated using a greater amount of information. Using more data types, the results from the analysis showed that the New Jersey shape bridge rail tends to increase rollover propensity as compared to a vertical shape bridge rail. It was also found that impact injury severity levels did not significantly differ between New Jersey and vertical rails. On the other hand, it has been found that rollover has a significant impact on injury severity according to the analysis using the same data.

In the future, the research team will include an additional 5 years of accident data, totaling 10 years of data in the final database. The main reason for this decision has been the fact that the number of accidents analyzed was small after controlling for several factors. Also, it has been found that many accidents included in the Iowa DOT database did not involve bridge railing impacts, which further decreased the available number of accidents.

The collection of the additional 5 years of accident data is planned for the spring/summer of 2009, pending MwRSF and the IA DOT working out any scheduling conflicts.

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. Review of the draft final report was completed by the Iowa DOT. MwRSF is currently making report revisions in order to publish a final report.

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

The original project objective was to develop a TL-4, aesthetic, open concrete bridge railing for use on cast-in-place decks as well as precast deck panels. At a July 2008 meeting with the sponsor, the grouted joint detail was selected for implementation into the CAD details so that the single rail section could be fabricated. Dynamic impact testing of a single rail section attached to a short section of cast-in-place deck was planned to occur in the third quarter of 2008. Construction of the bridge support beam had been constructed previously. The casting of a short deck section was planned for August 2008. Fabrication of the 16-ft long, single rail section was also planned for August 2008. However, planning for this single bogie test was delayed while other funding opportunities were explored. Originally, once the single rail test was completed, MwRSF planned to conduct two full-scale crash tests on the new bridge railing and deck system.

In the fourth quarter, members of the research team continued to seek in-kind contributions for the construction, repair, and removal of the deck and railing components. It is anticipated that team members will be meeting in January 2009 to discuss these options. Additionally, MwRSF plans to submit a proposal to the NCHRP IDEA program in March 2009 in order to obtain additional project funding to complete the research project. Construction of the bridge deck and rail sections as well as the completion of the crash testing program will commence after new project funding and/or in-kind contributions are obtained.

In the fourth quarter, documentation and reporting of the Phase I R&D program was continued.

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. 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. Additional test results are planned for this report. In 2008, a continuation project was approved to provide new funding for an additional crash testing program. Two 2270P crash tests were performed in the third quarter – one on July 11th and another on July 31st. Two crash tests were performed in the fourth quarter – an 1100C test on October 3rd and a 2270P test on November 3rd. A draft report is currently being prepared for the four crash tests performed in the third and fourth quarters.

Universal Breakaway Steel Post for Guardrail (Minnesota DOT)

Data analysis, documentation, and reporting of the breakaway post testing were continued in the fourth quarter. CAD details for bullnose median barrier system were revised. Two full-scale vehicle crash tests were planned for the fourth quarter of 2008. Test no. USPBN-1 was performed on November 26, 2008 using a 2000P pickup truck according to test designation 3-38 of NCHRP Report No. 350. During the test, the vehicle was being slowed and redirected. However, the vehicle later overrode the rail and rolled over within the bullnose system. As a result of the failed test, MwRSF researchers are currently studying this failed test in order to make comparisons to the successful test using wood posts and two unsuccessful tests using steel breakaway posts.

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

The project consisted 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. Documentation and reporting of the research project is in progress. Completion of the draft report is expected in the first quarter of 2009.

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 consisted 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. Draft CAD details for the bridge railing and transition systems were completed in the fourth quarter and are under internal review by MwRSF researchers. Documentation and reporting of the research project is in progress. Completion of the draft report is expected in the first quarter of 2009.

Awaiting Reporting

Development of a Temporary Concrete Barrier Transition

Two pickup truck crash tests were successfully performed on a transition between temporary concrete barrier and permanent concrete median barrier. The evaluation was performed using the MASH-08 guidelines. In the third quarter of 2008, significant progress was made toward the completion of the draft research and test report. A draft report should be submitted to the Pooled Fund members for review and comment in the first quarter of 2009.

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 remains 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 remains under internal review.

Draft Pooled Fund Reports Completed

Polivka, K.A., Sicking, D.L., Reid, J.D., Bielenberg, R.W., Faller, R.K., and Rohde, J.R., *Performance Evaluation of Safety Grates for Cross-Drainage Culverts*, Draft Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-196-08, Project No.: SPR-3(017), Project Code: RPFP-04-02 and RPFP-05-07 – Years 14 and 15, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, September 3, 2008.

Final Pooled Fund Reports Completed

Polivka, K.A., Sicking, D.L., Reid, J.D., Bielenberg, R.W., Faller, R.K., and Rohde, J.R., *Performance Evaluation of Safety Grates for Cross-Drainage Culverts*, Final Report to the Midwest States' Regional Pooled Fund Program, Transportation Research Report No. TRP-03-196-08, Project No.: SPR-3(017)-Years 14 and 15, Project Codes: RPFP-04-02, RPFP-05-07, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, October 23, 2008.

Johnson, E.M., Lechtenberg, K.A., Reid, J.D., Sicking, D.L., Faller, R.K., Bielenberg, R.W., and Rohde, J.R., *Approach Slope for Midwest Guardrail System*, Final Report to the Midwest States' Regional Pooled Fund Program, Transportation Research Report No. TRP-03-188-08, Project No.: SPR-3(017)-Years 14 and 15, Project Codes: RPFP-04-05 and 05-06, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, December 4, 2008.

Sicking, D.L., Albuquerque, F.D., and Lechtenberg, K.A., *Cable Median Barrier Guidelines*, Final Report to the Midwest States' Regional Pooled Fund Program, Transportation Research Report No. TRP-03-206-08, Project No.: SPR-3(017)-Year 17, Project Codes: RPFP-07-02, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, December 8, 2008.

Molacek, K.J., Polivka, K.A., Faller, R.K., Rohde, J.R., Sicking, D.L., Bielenberg, R.W., Reid, J.D., Stolle, C.J., Johnson, E.M., and Stolle, C.S., *Design and Evaluation of a Low-Tension Cable Median Barrier System*, Final Report to the Midwest States' Regional Pooled Fund Program, Transportation Research Report No. TRP-03-195-08, Project No.: SPR-3(017)-Year 12, Project Codes: RPFP-01-05, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, December 8, 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

Not applicable in this quarter.

Pooled Fund Consulting Summary

Midwest Roadside Safety Facility
October 2008– December 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 –Bridge Pier Protection

State Question:

This email is to follow up with our conversation about bridge pier protection. We have a project in the KC area that involves reconstruction of two high-speed (65 mph) major highways; however, the existing bridge columns are to remain in place. These columns will not accommodate the AASHTO LRFD requirement for impact load (1800 kN or about 400 kips). We plan to protect these median columns with a 51" or 54" barrier. The attached detail provides details for an application that was previously done for a TL-3 design; we used 32" barrier for that application.

On this project we plan utilize a barrier that will meet TL-5 criteria. We propose to use a tall wall and construction diaphragms between the barrier to isolate the columns if a TL-5 level impact is experienced. The thought is that if the columns are not isolated then the impact load will be transmitted through the barrier and aggregate backfill to the column. Is the last statement true, if not is there an approximation on the amount of load that gets transmitted to the column.

Can we meet TL-5 by tying the barrier into the concrete shoulder and having a granular backfill with diaphragms near the column area?

Can we go vertical for the entire height? If not any recommendations on the shape to address head slap?

Thanks!

Rod Lacy

MwRSF Response:

Rod:

You note below that you desire to use either 51" or 54" tall barriers to shield the bridge piers. Currently, there are several 42" tall, reinforced concrete barriers that meet the TL-5 impact conditions of NCHRP Report No. 350. Years ago, MwRSF also developed details for tall, TL-5 single-face, safety shape barriers for the WsDOT. The use of 42" high, concrete barriers placed in front the bridge piers would prevent a head-on collision into the piers when a truck leaves the roadway at 15 degrees or less. Using an adequate length of need upstream of the piers would reduce the tendency for the truck to get behind the barrier. A gradual flaring of the barrier toward the median (i.e., away from the roadway) would reduce the required barrier length. The available, 42" reinforced concrete median barriers can be placed on a aggregate base with asphalt placed on both sides or doweled into a RC slab or footing. For the 50+" single-face, TL-5 barriers, anchorage options have consisted of RC slabs or footings.

For these barrier and anchorage options, the RC barriers resist the heavy truck lateral impact loads. With 42" tall barriers, a portion of the tractor-trailer vehicle extends over the top of the barriers. For this truck and trailer-box lean over the barrier top, this vehicle portion could potentially impact the exposed portion of the pier above the top of the parapet. However, the truck and trailer box would not be expected to provide a significant impact event against the stout bridge pier columns. To further protect against this truck-pier impact event, RC diaphragms could be installed between the piers (i.e., parallel to the roadway) in order to stiffen and strengthen the piers to resist truck, trailer lean and subsequent pier impact.

Do you plan to use TL-5 barriers placed forward from the piers? If yes, can you use any of the existing double-face or single-face designs? Do you also want to mitigate pier impact with those vehicle components that lean over 42" tall parapets? Or, do you want to use 50+" parapets to reduce the lean over lower height parapets.

If you want to use a vertical shape parapet, you certainly could do so. If you want to mitigate any tendencies for head ejection and head slap against taller parapets for passenger vehicle impacts, modifications to the new TL-5 barrier could be made. However, the basic top geometry (setback) should be followed and as published in the research report.

With regard to placing traverse diaphragms or compacted fill between the parapets, I do not think either is necessary as long as the appropriate barrier is selected for use.

Please provide any clarifications, comments, and/or questions regarding the information provided above. Once we receive that information, we will continue brainstorming solutions for your situation. Thanks!

Ron

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

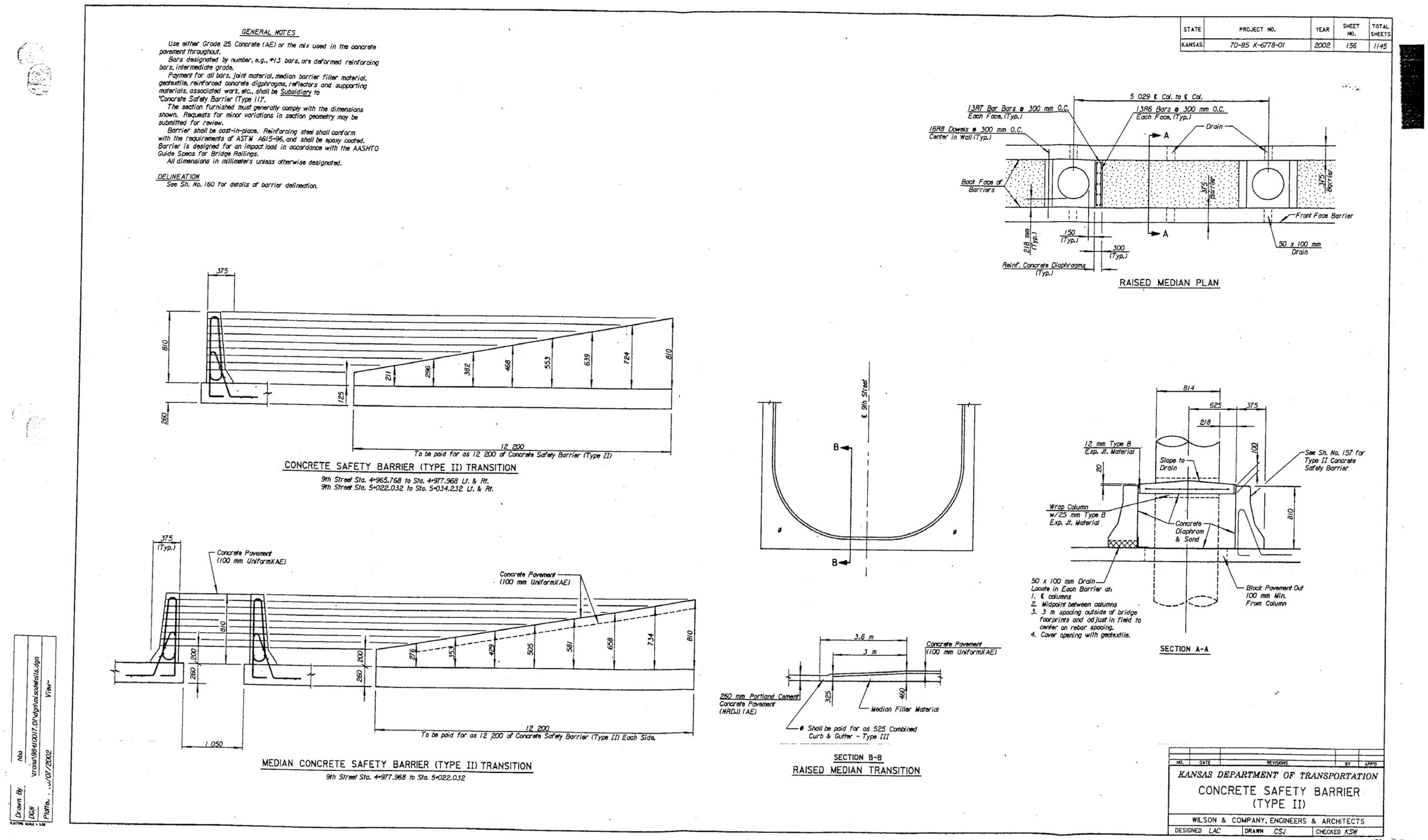


Figure 1. Proposed BridgePier Protection

Problem # 2 – KsDOT Guardrail Question

State Question:

I wanted to pass a guardrail-slope question past you. KDOT uses 6”x8”x6’6” wood posts or W6x9x6’6” steel post for guardrail. Typically, we would use a 10:1 platform that is a minimum of 4’ from the face of the rail to the slope break line. Below are details of our wood and steel post with the 4’ minimum platform. Would it be acceptable on a guardrail site to allow a 3:1 slope graded from the back of post (no platform behind post) with our 6’6” posts at normal 6’3” post spacing or would it be preferable to use half post spacing (any nesting?) ? I recall your study grading a 2:1 slope with 7’ posts on half post spacing. I believe you did not nest the rail either. Anyway, please give me your thoughts. I appreciate it!

Thanks,
Scott King
KDOT- Road Design

MwRSF Response:

Scott:

As you noted, MwRSF has conducted two studies on the placement of strong-post, W-beam guardrail systems near fill slopes.

The first study involved the development and testing of metric height, W-beam rail (706 mm = 27-3/4”) supported by W6x9 by 7’ long steel posts spaced 37.5” on center. The center of each post was placed at the slope breakpoint for a 2:1 fill slope.

The second study involved the development and testing of the MGS, W-beam rail (787 mm = 31”) supported by W6x9 by 9’ long steel posts spaced 75” on center. The center of each post was placed at the slope breakpoint for a 2:1 fill slope.

Following this research and upon receiving requests for guidance on the placement of guardrail near slopes, Dean and Bob developed additional guidance for the two designs and for varying fill slopes and fill distances behind posts. This guidance was noted in MwRSF’s prior Pooled Fund consulting summaries as well as in the 2007 discussions on MGS implementation. It is as follows:

MwRSF (10-29-2007 Email to MGS Implementation Routing List): Recently, the Mn DOT requested guidance for placement of standard and MGS guardrail adjacent to slopes of various configurations. In response to this request and using available crash test data as well as engineering judgment, Dr. Dean Sicking and Mr. Bob Bielenberg prepared the preliminary guidance, subject to refinement in the future. It is as follows:

For standard W-beam guardrail:

1. Standard W-beam guardrail placed adjacent to any slope with 2' of level soil behind the posts is acceptable.
2. For w-beam guardrail placed 1'-2' adjacent to a 6:1 or flatter slope, standard 6' W6x9 posts at standard spacing are recommended.
3. For w-beam guardrail placed 1'-2' adjacent to a 3:1 to 6:1 slope, 7' W6x9 posts at standard spacing are recommended.
4. For w-beam guardrail placed less than 1' adjacent to a 3:1 or steeper slope, 7' W6x9 posts at half spacing are recommended.

For MGS guardrail:

1. Standard MGS guardrail placed adjacent to any slope with 2' of level soil behind the posts is acceptable.
2. For MGS guardrail placed 1'-2' adjacent to a 6:1 or flatter slope, standard 6' W6x9 posts at standard spacing are recommended.
3. For MGS guardrail placed 1'-2' adjacent to a 3:1 to 6:1 slope, 7' W6x9 posts at standard spacing are recommended.
4. For MGS guardrail placed less than 1' adjacent to a 3:1 or steeper slope, 9' W6x9 posts at standard spacing are recommended.

Based on your inquiry, the KsDOT provides approximately 29” of fill behind the wood posts and 31” of fill behind the steel posts. For both KsDOT configurations, more than 2’ of fill is provided behind the steel and wood posts, thus resulting in guidance that any slope could be used beyond the 24” of generally level terrain. This recommendation is based on the use of 6’ long posts in standard W-beam and MGS systems. The use of 6’-6” posts would provide increased post-soil forces over those provided with the 6’ long posts. In addition, the safety performance of the KsDOT W-beam guardrail systems using 6’-6” post lengths would be nearly identical for systems installed in level terrain as well as the terrain described in your email. Finally, the two guardrail systems shown below could utilize 6’ post lengths instead of the current length of 6’-6” in standard installations with sufficient compacted soil fill is placed behind the posts.

Respectively,

Ron

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

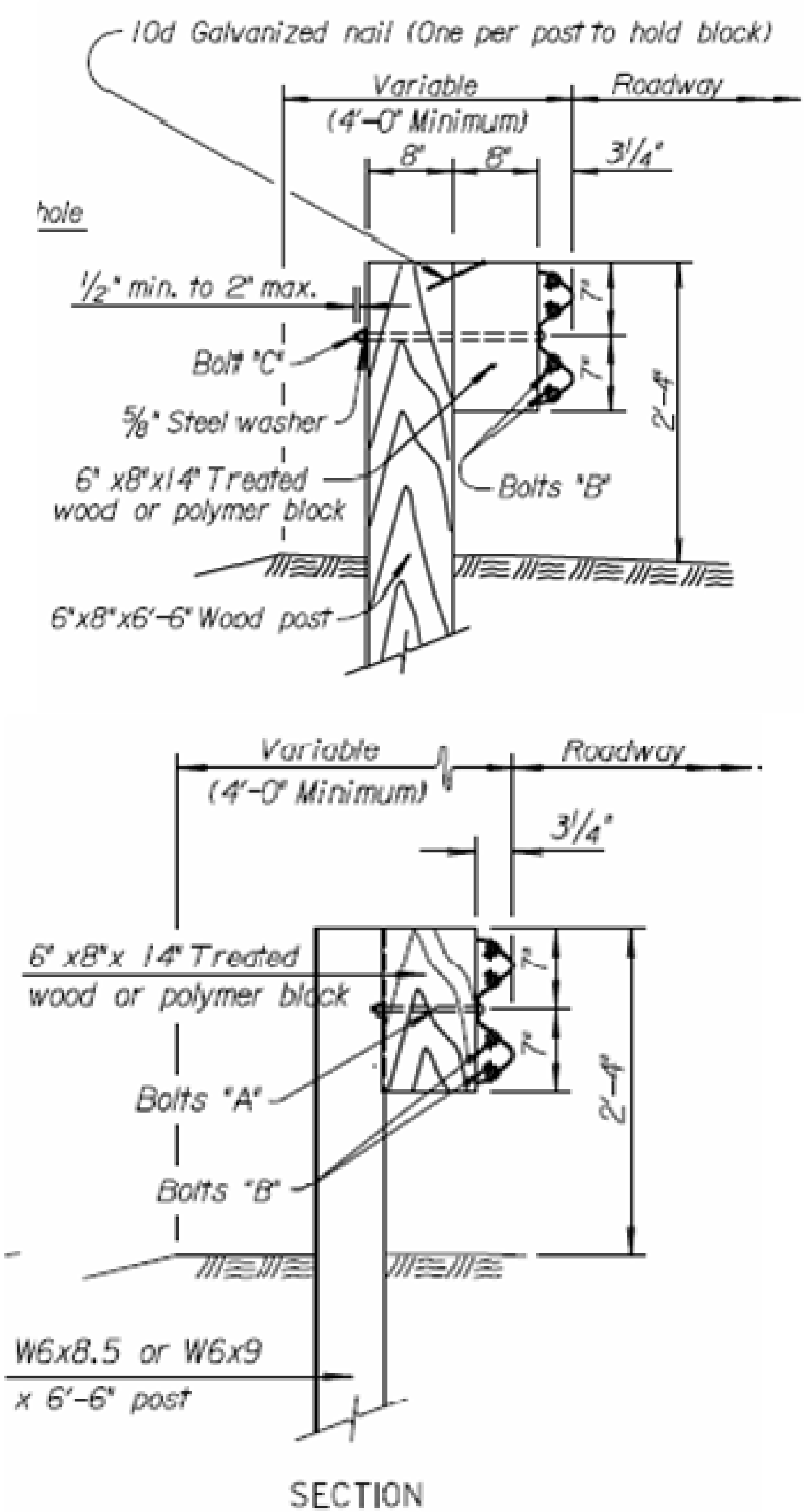


Figure 2. KsDOT Guardrail Posts Adjacent to Slope

Problem # 3 – IaDOT Questions

State Question:

Ron,

1. Do you have a recommendation regarding the partial use of an existing w-beam bullnose installation? Specifically, we have a situation where an existing bullnose is protecting the open area in the median between two bridges. One of the bridges is being replaced and traffic will be head-to-head on the remaining bridge. So some of the bullnose will need to be removed in order for the contractor to replace the bridge. Question: how much, if any, of the remaining bullnose installation can we use as a standalone guardrail installation for the head-to-head traffic during the construction period? This would not be used long-term following construction.
2. I have attached a drawing of a bracket used to connect high tension cable to a concrete barrier or bridge end. Our intent is to use these brackets on the trailing end of bridges, instead of a ground anchor, to provide continuous protection for errant vehicles. For continuous median installations, this bracket would be located beyond the clear zone for opposing traffic. The manufacturer has informed me that the bracket is the same one that is used on a ground anchor, and it is almost identical to a low-tension bracket used by South Dakota (detail attached), but with larger bolt holes. This cable attachment portion of the bracket would be located behind the bridge rail where it cannot be hit. However, part of the bracket is exposed on the front side of the bridge rail and could possibly be a snag point. I was hoping you could give me your opinion on this design in general. Also, I would like to know whether you feel this setup would require additional crash testing. The manufacturer has told me that since this is an anchor, and not a terminal, that crash testing is not required.
3. I have also attached a drawing of what we call our "Permanent Road Closure Barricade." The design is based on that of a Type III Barricade. However, this design has more than two posts and the rails extend entirely across the width of the road. We are in the process of updating the drawing, and I am questioning the crashworthiness of this design. Specifically, I was unable to find any crashworthy Type III Barricades that were wider than 8 feet. Or is this barrier not subject to that restriction since it is not used in a work zone? Additionally, the change we are making to the drawing is a result of the reflective sheeting peeling off some of the installations. To combat this, we are proposing to have the sheeting applied to thin aluminum sign stock and that, in turn, would be bolted to the rails of the barricade. Would this change the structural integrity of the barricade and if so, the requirement that it be crash tested?

Thanks so much for your help. Please let me know if you have questions concerning any of my requests.

Chris Poole, P.E.
Litigation/Roadside Safety Engineer

Office of Design
Iowa Department of Transportation

MwRSF Response:

1. Please send us details of the W-beam bullnose system along with a description of how much of the system is desired to be removed and/or detached from the bridge. Once we have this information, we will review the design and test reports to determine if your proposed changes would affect the results of those observed in testing.
2. The cable bracket is depicted on the front face of the parapet near the downstream end. This type of bracket would appear to provide concerns for vehicle snag on the bracket and anchored cables. You noted that it would be on the back-side face even though it is shown on the front face. It would be cleaner to attach the bracket on the back side. You note that the manufacturer stated the bracket is nearly identical to the SD DOT bracket used on low-tension designs and identical to their own ground anchor for HT or LT designs? The manufacturer plans to use this on high-tension designs as part of a system. If it already has been evaluated in HT cable barrier testing, then I do not see an issue with structural capacity. If it has not, then the manufacturer would need to provide some assurance that it would also work with HT systems through calculations, components tests, full-scale test, etc. The downstream cable anchorage scenario would not likely need to be re-tested as it is a rigid barrier transitioning into a flexible barrier.
3. I am not aware of any crash testing on such a design but will have a staff member review the designs and then get back to you.

Ron

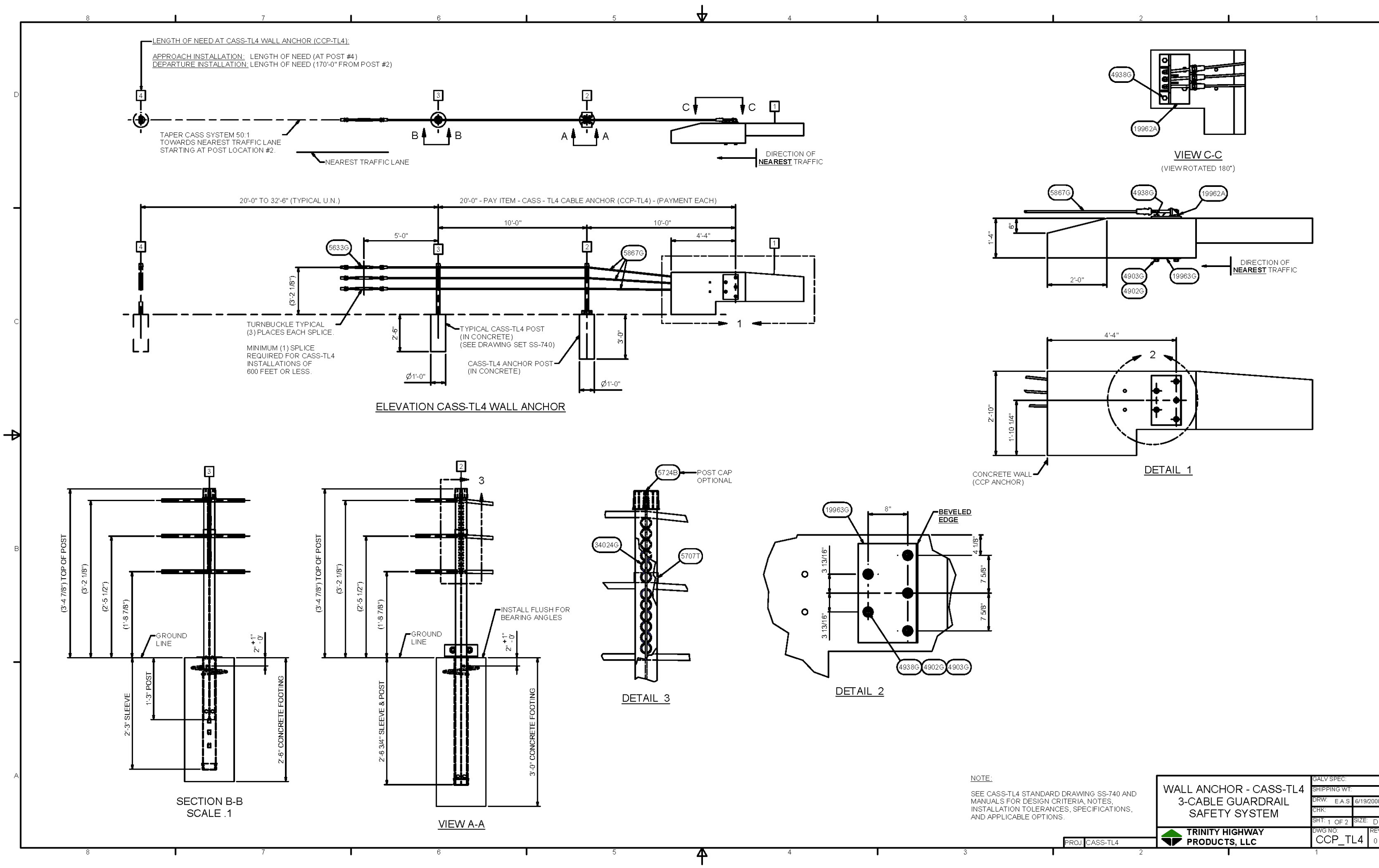
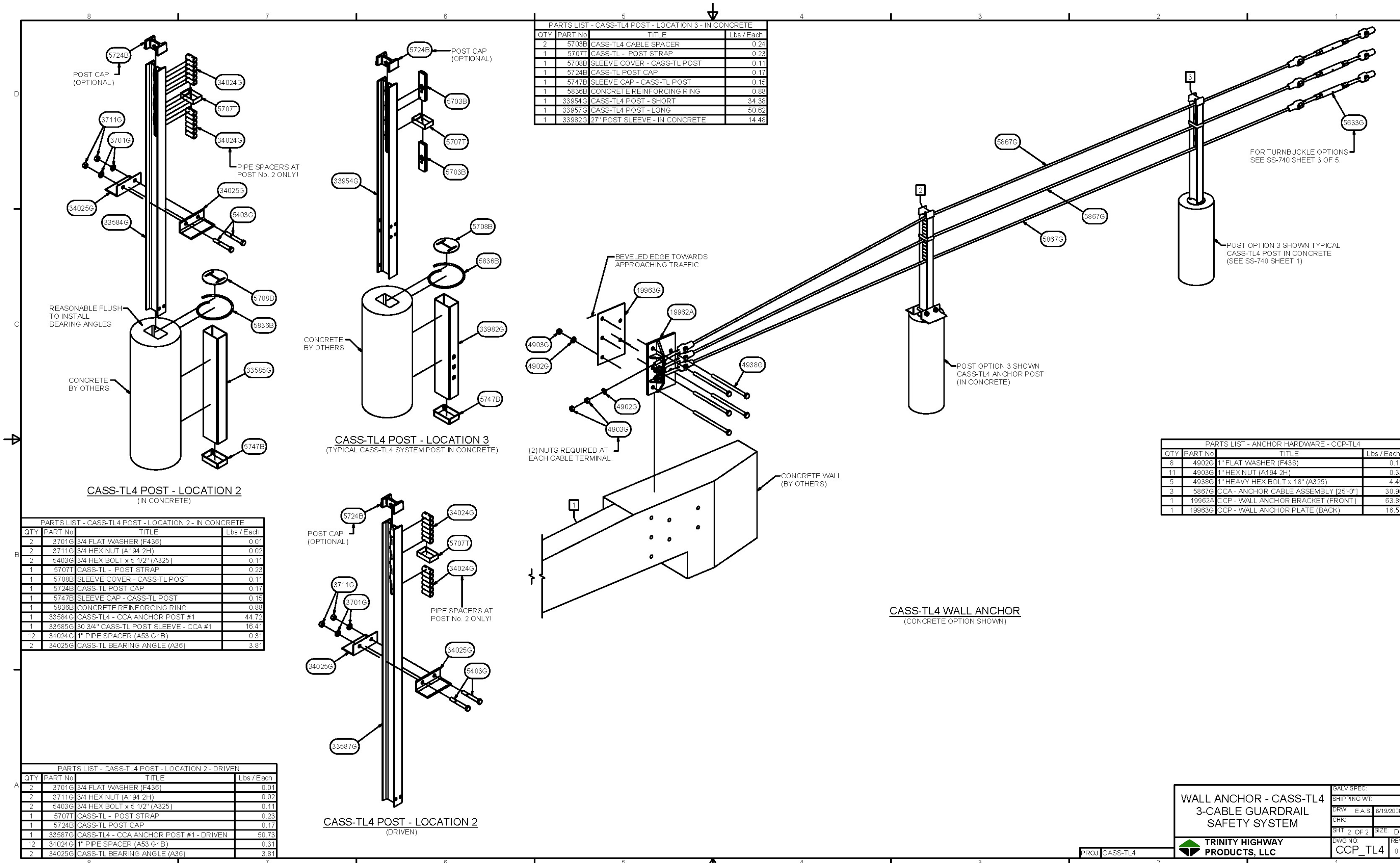


Figure 3. High-Tension Cable Connection



PARTS LIST - CASS-TL4 POST - LOCATION 3 - IN CONCRETE			
QTY	PART No	TITLE	Lbs / Each
2	5703B	CASS-TL4 CABLE SPACER	0.24
1	5707T	CASS-TL - POST STRAP	0.23
1	5708B	SLEEVE COVER - CASS-TL POST	0.11
1	5724B	CASS-TL POST CAP	0.17
1	5747B	SLEEVE CAP - CASS-TL POST	0.15
1	5836B	CONCRETE REINFORCING RING	0.88
1	33954G	CASS-TL4 POST - SHORT	34.38
1	33957G	CASS-TL4 POST - LONG	50.62
1	33982G	27" POST SLEEVE - IN CONCRETE	14.48

PARTS LIST - CASS-TL4 POST - LOCATION 2 - IN CONCRETE			
QTY	PART No	TITLE	Lbs / Each
2	3701G	3/4 FLAT WASHER (F436)	0.01
2	3711G	3/4 HEX NUT (A194 2H)	0.02
2	5403G	3/4 HEX BOLT x 5 1/2" (A325)	0.11
1	5707T	CASS-TL - POST STRAP	0.23
1	5708B	SLEEVE COVER - CASS-TL POST	0.11
1	5724B	CASS-TL POST CAP	0.17
1	5747B	SLEEVE CAP - CASS-TL POST	0.15
1	5836B	CONCRETE REINFORCING RING	0.88
1	33584G	CASS-TL4 - CCA ANCHOR POST #1	44.72
1	33585G	30 3/4" CASS-TL POST SLEEVE - CCA #1	16.41
12	34024G	1" PIPE SPACER (A53 Gr.B)	0.31
2	34025G	CASS-TL BEARING ANGLE (A36)	3.81

PARTS LIST - CASS-TL4 POST - LOCATION 2 - DRIVEN			
QTY	PART No	TITLE	Lbs / Each
2	3701G	3/4 FLAT WASHER (F436)	0.01
2	3711G	3/4 HEX NUT (A194 2H)	0.02
2	5403G	3/4 HEX BOLT x 5 1/2" (A325)	0.11
1	5707T	CASS-TL - POST STRAP	0.23
1	5724B	CASS-TL POST CAP	0.17
1	33587G	CASS-TL4 - CCA ANCHOR POST #1 - DRIVEN	50.73
12	34024G	1" PIPE SPACER (A53 Gr.B)	0.31
2	34025G	CASS-TL BEARING ANGLE (A36)	3.81

PARTS LIST - ANCHOR HARDWARE - CCP-TL4			
QTY	PART No	TITLE	Lbs / Each
8	4902G	1" FLAT WASHER (F436)	0.11
11	4903G	1" HEX NUT (A194 2H)	0.33
5	4938G	1" HEAVY HEX BOLT x 18" (A325)	4.45
3	5867G	CCA - ANCHOR CABLE ASSEMBLY [25'-0"]	30.90
1	19962A	CCP - WALL ANCHOR BRACKET (FRONT)	63.89
1	19963G	CCP - WALL ANCHOR PLATE (BACK)	16.51

Figure 4. High-Tension Cable Connection

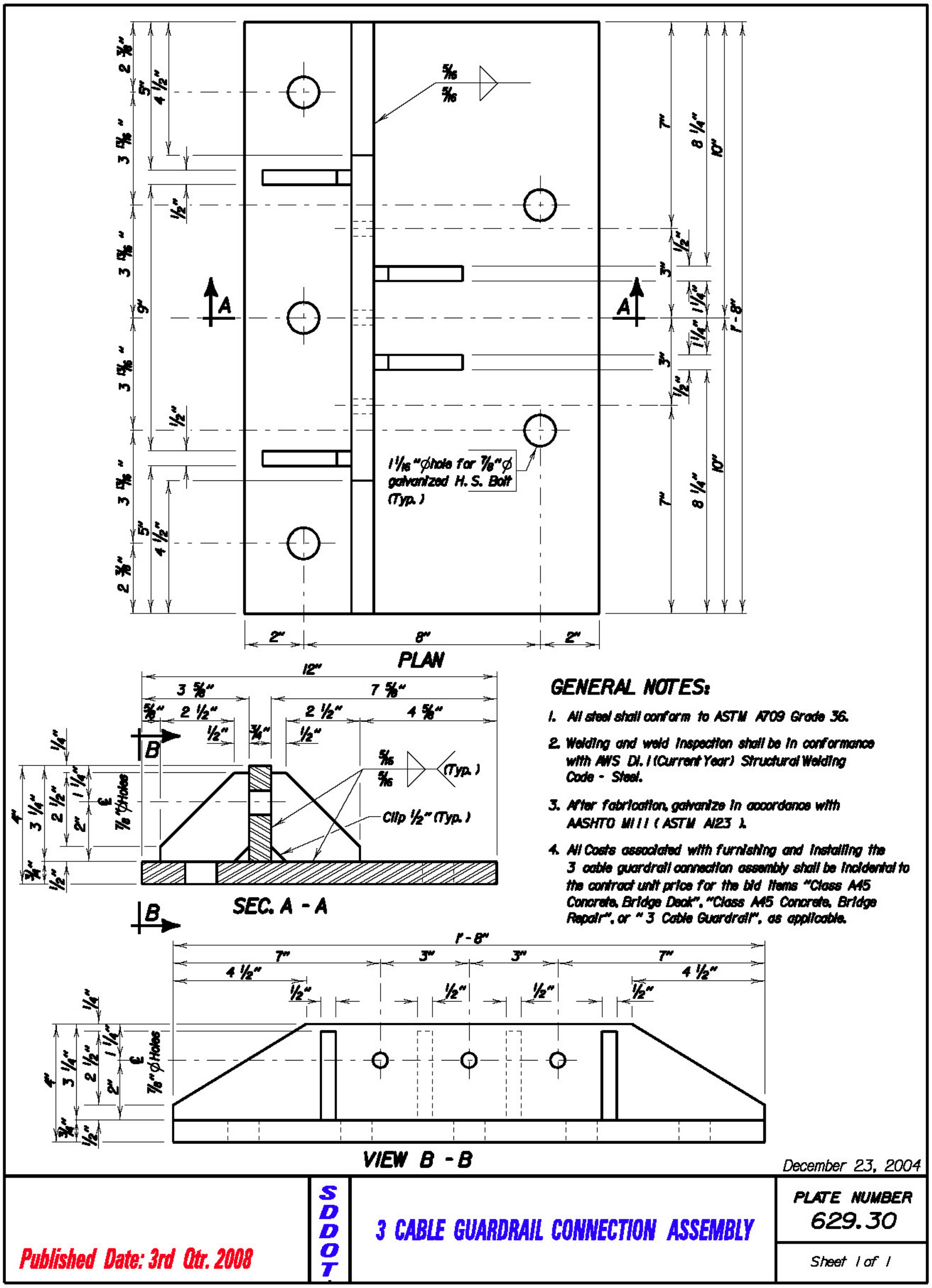


Figure 5. High-Tension Cable Connection

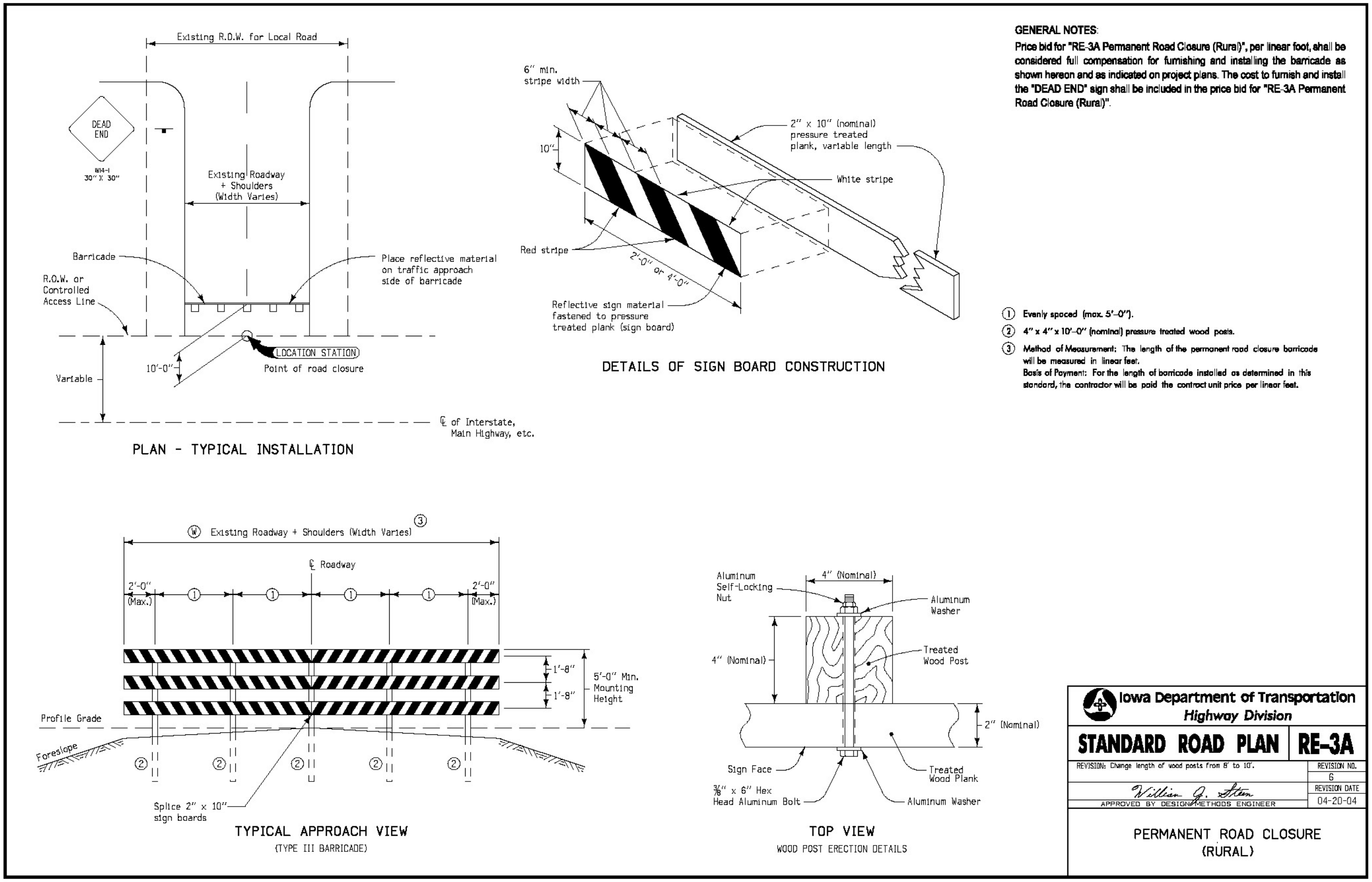


Figure 6. Permanent Road Closure Barricade

Problem # 4 – IaDOT Questions – Part II

State Question:

Ron,

I have attached details of our W-Beam bullnose system. We would like to be able to utilize half of the existing installation (shown as the “T” distance on RE-67) when traffic is head-to-head on the side of the roadway near the top of the page. I am unsure whether we would need to leave the 5-foot radius end section attached, or if we would need to replace that with some other type of end terminal.

Let me know if you have any questions.

Thanks,

Chris Poole, P.E.
Litigation/Roadside Safety Engineer
Office of Design
Iowa Department of Transportation

MwRSF Response:

Chris:

I have reviewed the materials that you have provided. Based on this review, I offer the following comments. First, I understand that two-way traffic will be utilizing the lanes provided at the top of the page (page RE-67), while the bridge at the bottom of the page is being replaced. As such, the hazard between the twin bridges still requires shielding. As I see it, you have two basic options.

Option 1 consists of removing the bullnose buffer end and guardail sections that connect the bullnose barrier to the lower bridge end. Once that material is removed, a crashworthy guardrail end terminal and anchorage system would be connected to the guardrail system shown at the top of the page. The flared guardrail length would be selected such that the system provides adequate shielding of the median hazard.

Option 2 consists of removing a portion of the lower approach guardrail transition (i.e., the section connecting the bullnose guardrail to the lower bridge end). The “STS” segment, measuring approximately 18.75’ in length, could be removed to allow construction of the new bridge. Then, in the first two spans of remaining rail, an approved anchorage system could be installed such that anchorage is provided in both directions, thus simulating a rigid attachment to the bridge end. If this option is desirable, we could assist with this detail.

The basic design consists of a standard foundation tube with soil plate at the last two wood BCT posts. A standard steel channel strut is connected between the two posts/steel sleeves. No impact head would be needed in this region as no crashes would be expected at this far end and since the bridge/road is closed. Standard anchor cable hardware would be placed between the two wood posts and in both directions (reverse cables in first span). You would need to drill an extra set of holes to place the second cable anchor bracket on the rail close to the top of post 1, similar to that near the top of post 2. Now the rail would be anchored in both directions – tension and compression, thus simulating a rigid attachment to the bridge end. We have done this in our thrie beam bullnose testing as well as in recent box beam testing when we were unsure with load direction would occur.

I am enclosing CAD details for a new MnDOT bullnose R&D project currently within MwRSF. For this effort, we have placed both the standard and reverse direction cable anchorages on the downstream end. In prior bullnose testing efforts, we switched the direction of the single cable anchorage from one test to another. In future testing, we will place two anchor cables on the downstream end – one in each direction.

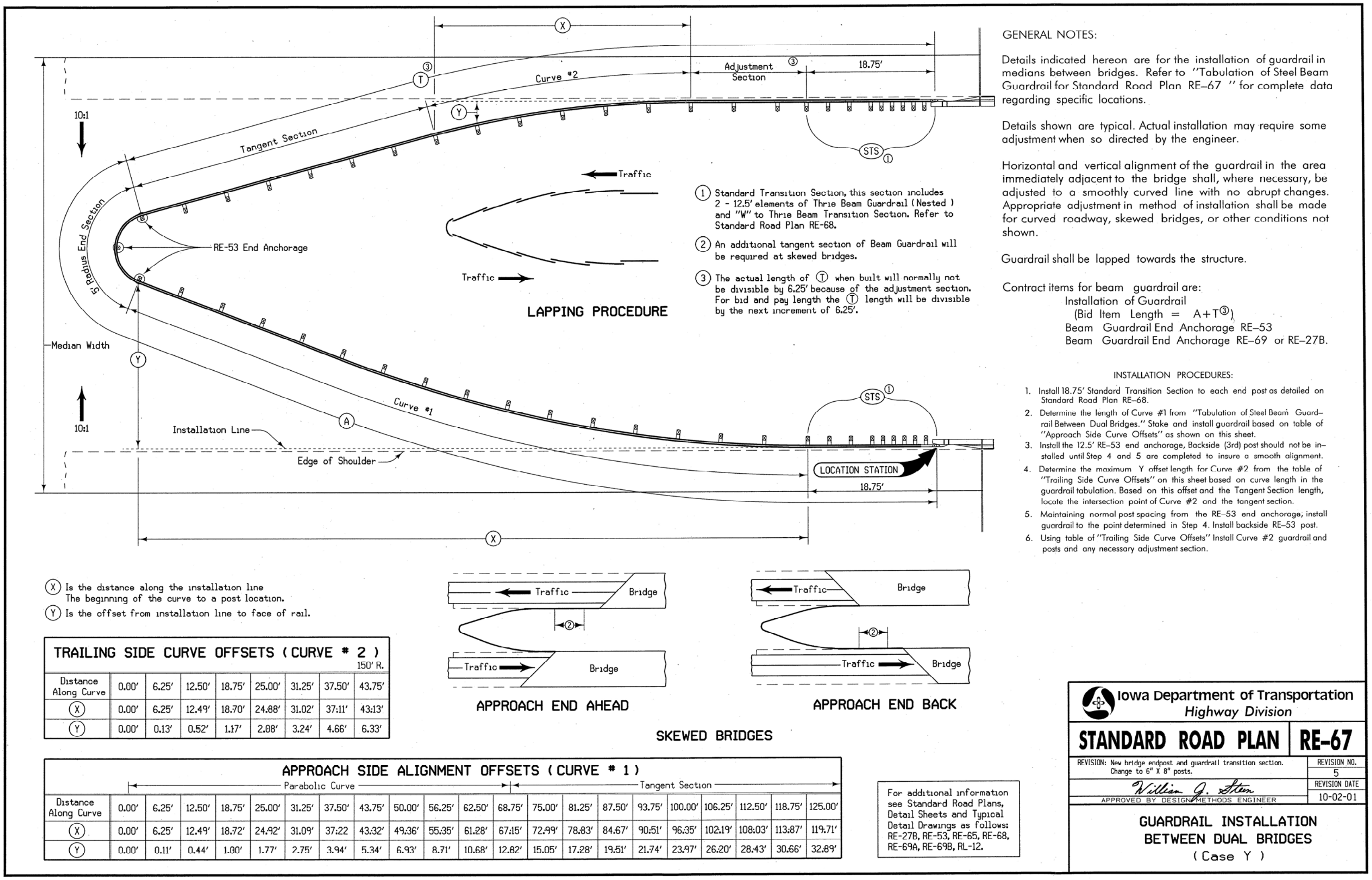
It should be noted that this double anchorage should be used on any bullnose design that incorporates a free end that requires anchorage.

Our CAD details show the use of a 6-ft long tube without a soil plate but with a channel strut between two tubes. An alternative would be to use the shorter BCT tubes that incorporate soil plates and use the channel strut.

Please let me know if you have any questions or comments regarding the information provided herein.

Ron

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



TRAILING SIDE CURVE OFFSETS (CURVE # 2)

150' R.

Distance Along Curve	0.00'	6.25'	12.50'	18.75'	25.00'	31.25'	37.50'	43.75'
X	0.00'	6.25'	12.49'	18.70'	24.88'	31.02'	37.11'	43.13'
Y	0.00'	0.13'	0.52'	1.17'	2.88'	3.24'	4.66'	6.33'

APPROACH SIDE ALIGNMENT OFFSETS (CURVE # 1)

	Parabolic Curve												Tangent Section								
Distance Along Curve	0.00'	6.25'	12.50'	18.75'	25.00'	31.25'	37.50'	43.75'	50.00'	56.25'	62.50'	68.75'	75.00'	81.25'	87.50'	93.75'	100.00'	106.25'	112.50'	118.75'	125.00'
X	0.00'	6.25'	12.49'	18.72'	24.92'	31.09'	37.22	43.32'	49.36'	55.35'	61.28'	67.15'	72.99'	78.83'	84.67'	90.51'	96.35'	102.19'	108.03'	113.87'	119.71'
Y	0.00'	0.11'	0.44'	1.00'	1.77'	2.75'	3.94'	5.34'	6.93'	8.71'	10.68'	12.82'	15.05'	17.28'	19.51'	21.74'	23.97'	26.20'	28.43'	30.66'	32.89'

Figure 7. IaDOT Bullnose

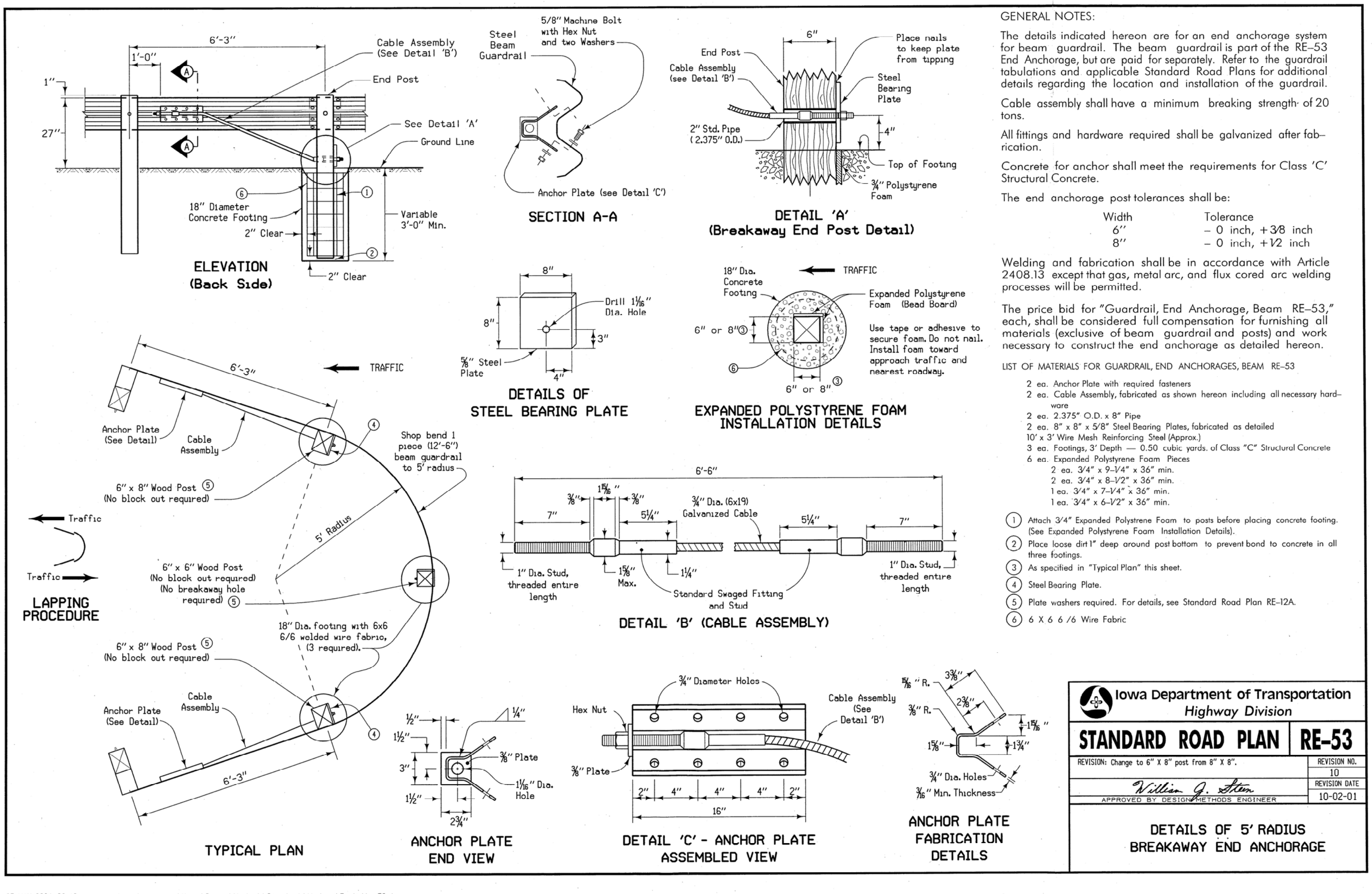


Figure 7. IaDOT Bullnose

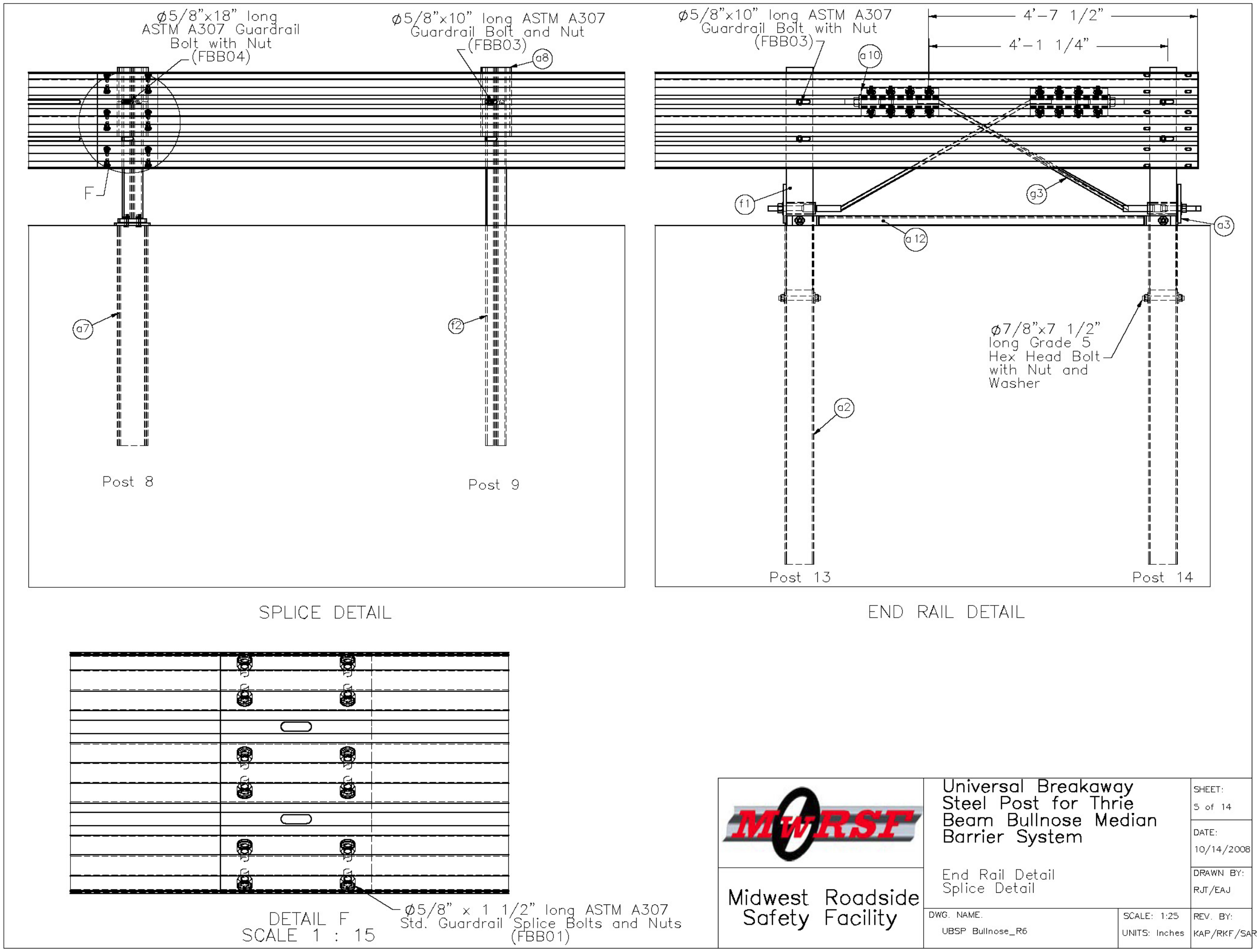
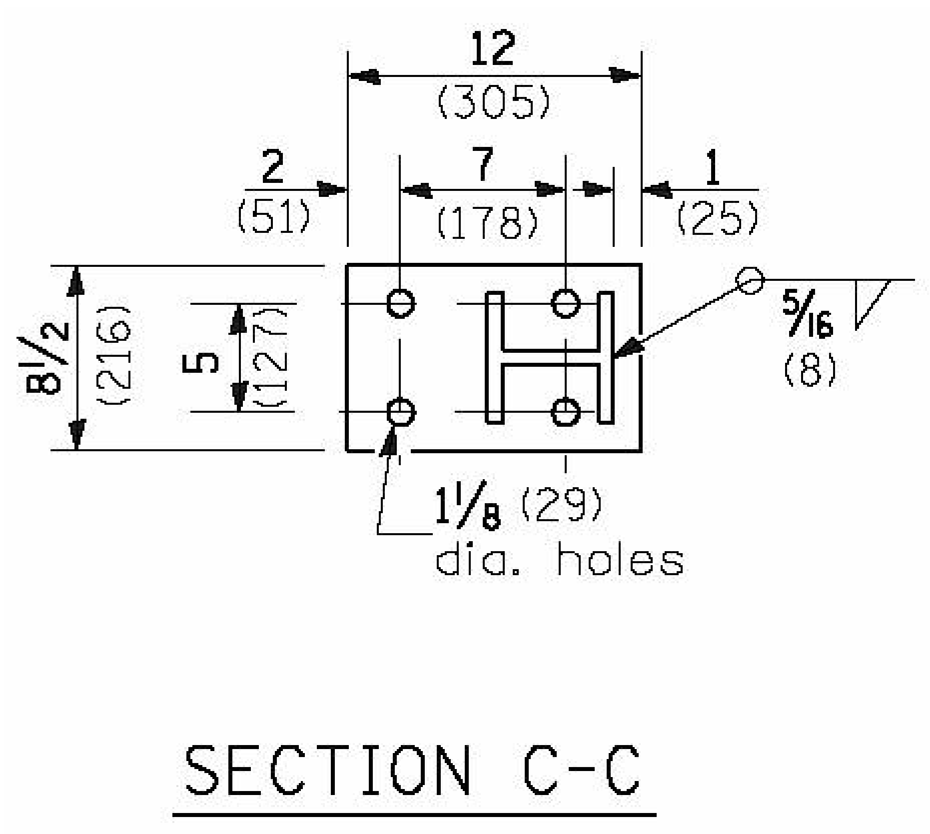


Figure 8. Dual Anchorage for Bullnose

Problem # 5 – Weld Detail for Guardrail Attached to the Top Slab of a Culvert

State Question:

After review of the crash testing report, and discussions between our Bureaus of Design and Bridges and Structures, here is what we have come up with for a weld detail between the post and plate for this application. Does this appear appropriate?



David L. Piper, P.E.
Safety Design Engineer
Bureau of Safety Engineering

MwRSF Response:

Dave,

During testing of the W-beam system attached to the top slab of a culvert, it was found that a 3 pass weld was necessary on the front and back sides of the front flange of the post. If this 3 pass weld was not completed, the post tore away from the base plate which compromised the performance of the system. Therefore, you would need to change your weld detail on the front flange of the post to be a 5/16" 3 pass weld on the front and back sides of the front flange. It is fine to increase the weld sizes for the back flange and the web of the post and these only need to be a single pass.

We cannot recommend using only a single pass weld on the front flange unless it had been proven to work with testing. Therefore, this would require funding a bogie test in order to prove or disprove its performance capabilities.

If you have any further questions, please feel free to contact me.

Thanks,
Karla

Problem # 6 – Cable Guardrail Next to Slopes

State Question:

Hi Bob,
Thanks for the e-mail sent to me in April regarding cable guardrail adjacent to slopes. I had one additional concern. Since MwRSF did the testing on flat ground with the low tension cable system, would you change your recommendation if the cable was placed on 1V:6H or 1V:8H slopes in front of and up to 4 ft. behind the cable before starting on a 1V:2H fill slope. It would seem the vehicle would strike the barrier higher, so it may be necessary to constrain deflection even more.
-Bill

William B. Wilson, P.E.
Architectural and Highway
Standards Engineer
Wyo. Dept. Of Transportation
5300 Bishop Blvd
Cheyenne, WY 82001-3340

MwRSF Response:

Hi Bill,

I have reviewed you question regarding the use of the CASS adjacent to a steep slope with an 1:6H or 1:8H approach slope.

Previously we had given you guidance for using the CASS adjacent to a steep slope. We had suggested using a 4ft offset to the slope and reducing the post spacing of the CASS to 3 m. Your new question was whether or not these recommendations would hold true when the cable barrier was installed on a 1:6H or 1:8H approach slope. In order to address this issue, I looked into the performance of the CASS system, analysis of bumper trajectories for 2000P pickup trucks encroaching on approach slopes, and previous testing of cable barrier on approach slopes. Based on this analysis I have the following comments.

1. We have concerns with placement of the CASS on a 1:6H approach slope adjacent to a steep slope. This concern is based on effective capture of the vehicle by the CASS system. Previous testing was conducted on 30" high, low-tension cable barrier placed on a 1:6H slope with a 6 ft offset from the edge of shoulder. Two tests were conducted. The first was a test (3569-5) of a 1974 Plymouth sedan that weighed 4500 lbs and impacted the barrier at 59.6 mph and an angle of 24.75 degrees. The second test (3569-6) was a test of a 1974 Chevy Vega that weighed 2250 lbs and impacted the barrier at 58.4 mph and an angle of 17.25 degrees. Both of these tests showed safe redirection of the vehicle. However, the sedan and small car vehicles in this testing had bumper heights of approximately 18". Typical bumper heights for the 2000P and 2270P vehicles are around 26". Thus, there is concern that the capture and redirection of the vehicles observed in these tests would not be as likely with the higher bumper heights of the current test vehicles and vehicle fleet. The RDG recommendations for approach slopes are based on this testing, but do not take into account the higher bumper heights and CG heights of the current vehicle fleet. The reference for this testing is given below.

   Ross, H.E., Smith, D.G., Sicking, D.L., and Hall, P.R., Development of Guidelines for Placement of Longitudinal Barriers on Slopes, Research Report 3659-2 (DOT-FH-11-9343), Texas Transportation Institute, May 1983.

   In addition, I reviewed some analysis that we conducted on bumper trajectories of 2000P vehicles running off slopes and compared these trajectories with the cable heights of the CASS System. A chart is attached. In the chart, the green lines are the cable heights, the pink line is the slope, and the navy blue line is the truck bumper trajectory. You can see from the chart that vehicle encroaching on a 1:6H slope could have bumper heights higher than the top cable height of the CASS system which could lead to the potential for override of the system. Similar analysis performed by TTI on 1:6H slopes with the 2000P vehicle also indicated bumper heights that would exceed the top cable height of the CASS depending on the barrier offset (http://tti.tamu.edu/documents/0-5210-3.pdf).

   Based on the existing test data and analysis of vehicles encroaching on 1:6H slopes, we are concerned about the use of cable barrier adjacent to steep slopes due to uncertainty about the effective capture and redirection of the vehicle.

2. No testing was available with cable barrier on 1:8H slopes. However, I did look at our bumper trajectory relative to the CASS system for an 1:8H slope. See the attached chart. In the case of the 1:8H slope, you can see that the bumper trajectory analysis indicated that there is an improved likelihood of vehicle capture as the bumper does not exceed the height of the top cable. This would indicate potential for capture and redirection. When

> using the CASS on an 1:8H slope adjacent to a steep slope, we would still recommend that you use the 4 ft offset from the cable barrier to the steep slope and also use the reduced CASS post spacing of 3 m.

Hopefully, this helps address your question. Let me know if you have further comments or concerns.

Thanks

Bob Bielenberg, MSME, EIT
Research Associate Engineer
Midwest Roadside Safety Facility
527 Nebraska Hall
Lincoln NE, 68588-0529
402-472-9064
rbielenberg2@unl.edu

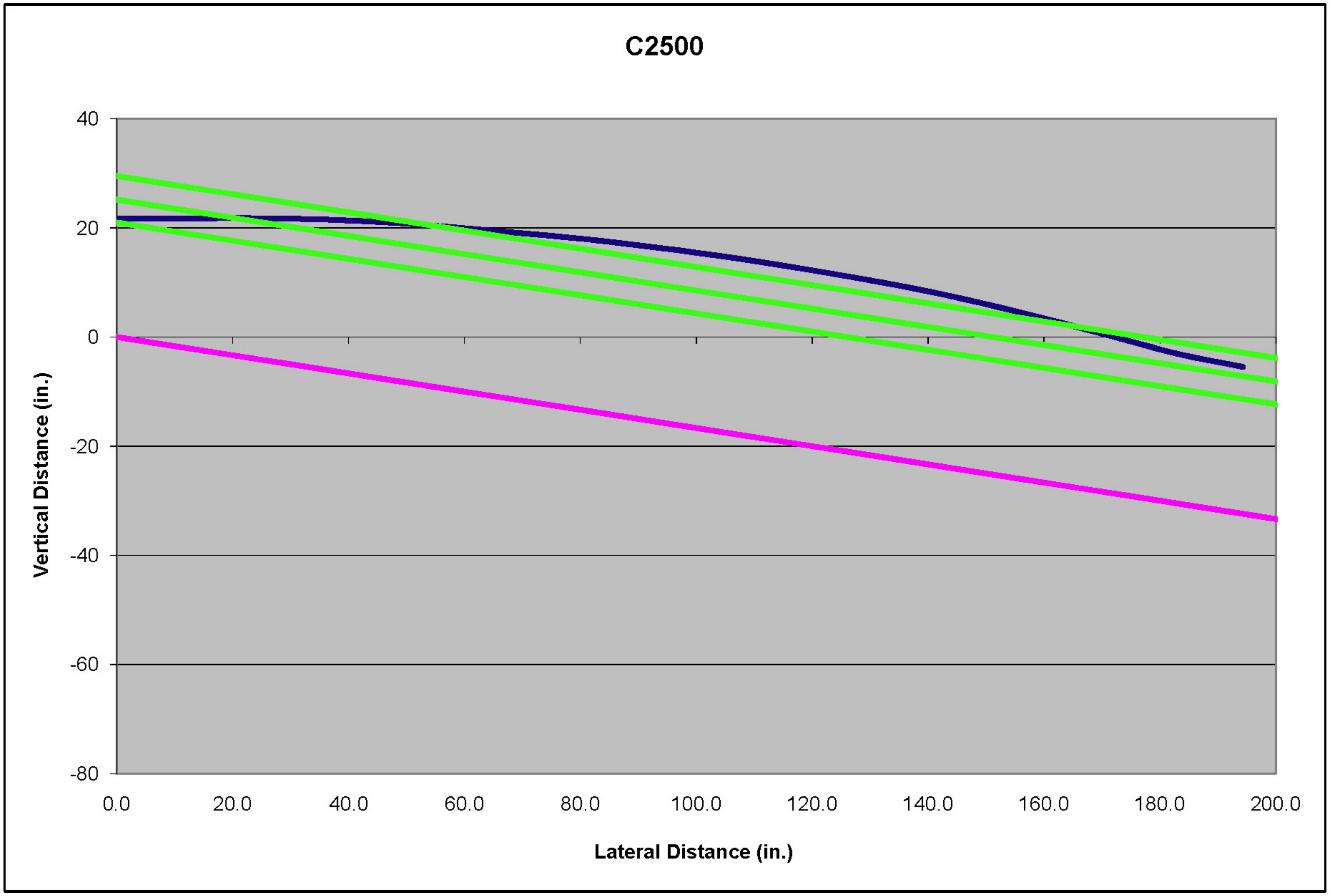


Figure 9. C2500 Bumper Trajectory Relative to CASS Cable Height – 6:1 Slope

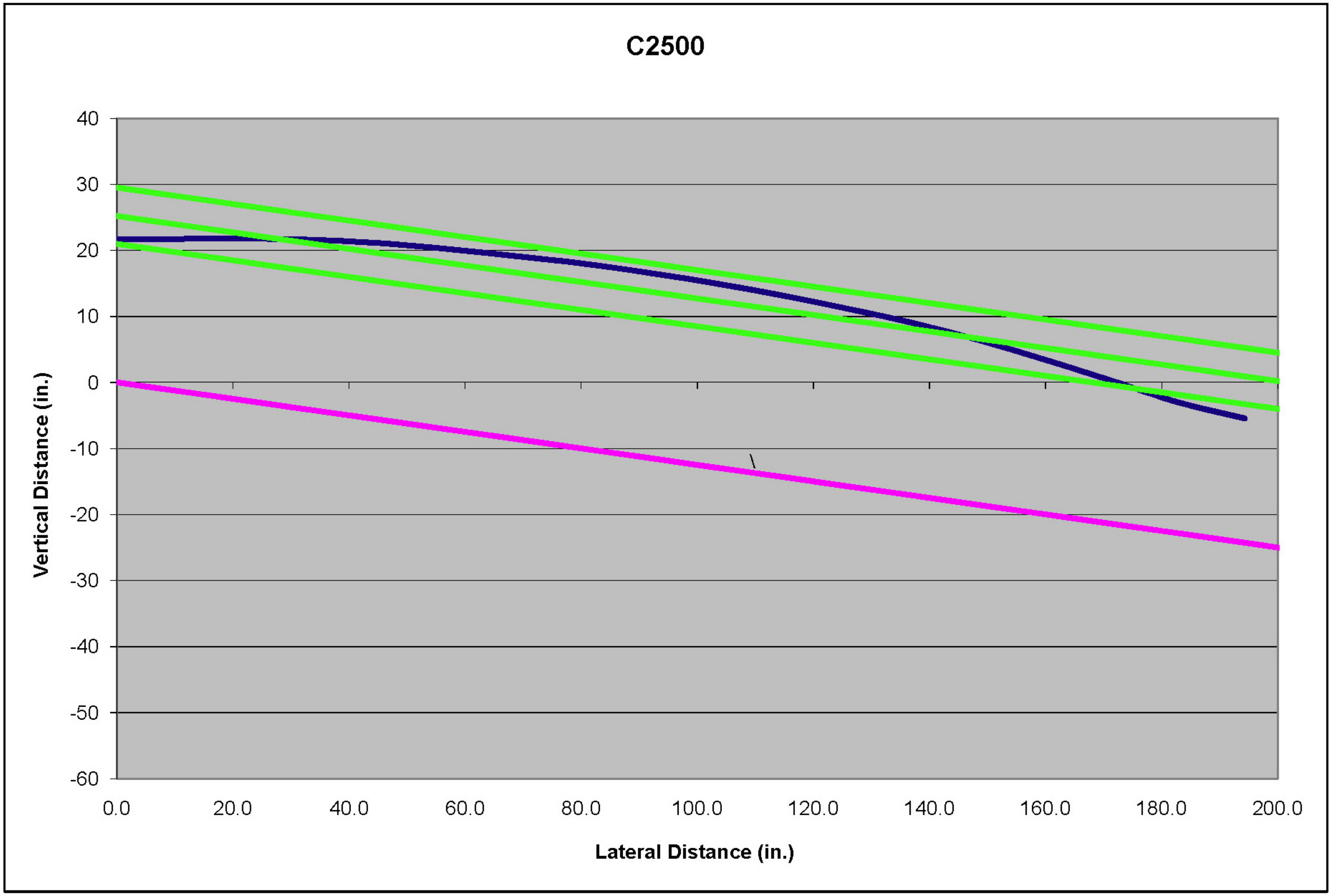


Figure 10. C2500 Bumper Trajectory Relative to CASS Cable Height – 8:1 Slope

Problem # 7 – A Guide to Standardized Highway Barrier Hardware, 2nd Edition

State Question:

Dear MwRSF,
Is there a more current version of the Guide to Standardized Highway Barrier Hardware? The on-line version is from 1995 and AASHTO list 1995 as the publishing date for the paper version of the guide.
I know that MwRSF has submitted items to be place into the guide, and they have been approved. However, I don't know if someone has been keeping the on-line version up to date or if a updated paper copy exist elsewhere.

Sincerely,

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

MwRSF Response:

Erik:

The 1995 AASHTO Hardware Guide is the latest in print. However, AASHTO Task Force 13 has been updating the CAD details for new components over the last several years. Old or existing parts are receiving little to no attention. Yes, MwRSF has been providing new CAD details for those roadside safety developments and components that were generated over a prior period through a prior Pooled Fund project. However, that effort is nearing completion and will need to be renewed if that effort is to continue. There is a web location where these details are being housed and where comments are added for consideration. The proboards site is as follows:

http://barrierguide.proboards31.com/index.cgi

Also, the final electronic CAD details will eventually be located on a TTI FTP site. That site is as follows:

http://www.aashtotf13.org/Barrier-Hardware.asp

Thanks!

Ron

Problem # 8 – Caltrans Barrier Request

State Question:

Dear MwRSF,

Has MwRSF looked into :

1. TL-3 Working widths for various heights of caltrans barrier?
2. A recommendation on what to do near fixed objects (e.g. go with taller barrier, go with vertical barrier, go with taller and vertical barrier) in areas where working width is reduced?

Sincerely,

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

MwRSF Response:

Erik:

MwRSF has reviewed available information on the working widths and zone-of-intrusion (ZOI) values for the single-slope, concrete barriers evaluated by MwRSF and CALTRANS. Based on this information, the working width and zone-of-intrusion measures for the 32-in. tall, single-slope barrier are approximately 27 and 21 in., respectively. The published ZOI value for the prior TL-3 impacts into 32" tall, sloped-face barriers is 18", while 24" was provided for vertical-face barriers. Actually, the single-slope barrier would likely fall between the two noted ZOI values, thus substantiating the 21" measurement from test no. ZOI-2. The maximum effective height for this lateral extent was nearly 42 in. As such, a conservative approximation would be to use the 27-in. working width value from 32 to 42 in. Beyond the 42-in. barrier height, the ZOI would be approximately zero for TL-3 conditions and valid through the 56-in. barrier height. Thus, the working width for 42 to 56-in. tall, single-slope barriers would be the base barrier width or 24 in.

Please note that these ZOI values provide conservative results for the placement of fixed objects on and nearby the barrier system. Actually, a fixed object could be placed closer to the top-front corner of the barrier as long as acceptable crash performance was obtained.

Previously, MwRSF provided guidance for selecting the top geometry of taller vertical, or near vertical barriers, in an effort to prevent head contact with tall barriers. A head ejection envelope was provided. However, guidance was not provided for sloped-face barriers in terms of the recommended top-barrier geometry or head ejection envelope.

In summary, here are my suggestions:

SS Barrier Height	WW	ZOI

32"	27	21
36"	27 (assumed)	?? (measured from top front corner but unknown)
42" (≤)	27 (assumed)	?? (measured from top front corner but unknown)
42" (>)	24 (barrier width)	0
51"	24 (barrier width)	0
56"	24 (barrier width)	0

<u>Vertical Barrier Height</u>
32" 24 24 (vertical barrier has toe and front corner at same position)

Please let me know if you have any questions or comments regarding the information provided herein. Thanks!

Ron

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

Problem # 9 – Concrete barrier questions-ZOI for SSB and use of taller or vertical walls

State Question:

Dear MwRSF,

As Part of WisDOTs process to develop a new set of standard detail drawings for concrete barrier, WisDOT requires some additional assistance developing some details.

Issue 1: ZOI for various heights of Single Slope Concrete Barrier:

Reviewing the crash test report on the Single Slope Caltrans barrier did not indicate a ZOI. Discussions with Caltrans indicated that they have performed some crash test, but the report is not final. Not knowing when Caltrans will release the report, WisDOT is in proposing to do the following:

1. Because the slope of the Single slope barrier wall is constant, a vehicle should "ride up" the barrier regardless of wall height the same amount (e.g. if the truck rides up 3" during an impact to a 32" single slope barrier it should ride up 3" during an impact on a 56" barrier). This would allow someone to interpolate working width between two known working widths. In fact taller walls may have less deflection because vehicle contacts the upper part of the barrier, prevents the vehicle from lean on top of the wall.

2. Use the 27" working width of ZOI-2 crash test from MwRSF Research Report No. TRP-03-151-07 as the working width for the Caltrans 32" concrete barrier. Although there are

differences between the 32" Caltrans barrier and the barrier used in the ZOI-2 test (ZOI-2 barrier has a narrower top and a flatter front face), WisDOT believes that these differences are small considering the variability of real world crash test.

3. It appears that in the Caltran's crash test of a 56" wall that the pickup truck did not lean over the barrier (i.e. 0 working width).

4. Therefore if one were to use a linear interpolation between working width of the 32" ZOI-2 crash test and the 56" Caltrans, WisDOT could calculate working widths for intermediate barrier heights of 36, 42 and 51.

WisDOT understands that crash testing would be the preferred method to determine working width. However, given MwRSF's experience in crash testing does this procedure sound reasonable? Or, does MwRSF have an alternative suggestion on how WisDOT can determine working width for the various barrier heights?

Issue 2 Use of taller walls or vertical barrier in confined locations:

There are going to be situations were designers, have limited space to install a barrier wall (typically near structures). In these locations, designer cannot get the require working width for a given barrier height or shape. Currently WisDOT allows designers to either install a taller barrier wall or vertical barrier.

Given MwRFS's experience in crash testing, is there a preferred alternative (e.g. install the vertical wall of same height, install a taller single slope wall, install a taller vertical wall...). If there is no general preferred alternative, what other factors should a designer consider when selection a barrier wall in these situations.

Sincerely,
<<barrier differences.pdf>> <<working width.pdf>> Erik Emerson P.E.
Wisconsin Department of Transportation
Standards Development Engineer

MwRSF Response:

My responses to your questions are provided below in red.

Ron

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

-----Original Message-----
From: Emerson, Erik [mailto:erik.emerson@dot.state.wi.us]

Sent: Thursday, September 18, 2008 7:57 AM
To: Bob Bielenberg (E-mail); Dean L. Sicking (E-mail); Karla Polivka (E-mail); Ron Faller (E-mail)
Cc: Emerson, Erik
Subject: Concrete barrier questions-ZOI for SSB and use of taller or verit cal walls.

Dear MwRSF,

As Part of WisDOTs process to develop a new set of standard detail drawings for concrete barrier, WisDOT requires some additional assistance developing some details.

Issue 1: ZOI for various heights of Single Slope Concrete Barrier:

Reviewing the crash test report on the Single Slope Caltrans barrier did not indicate a ZOI. Discussions with Caltrans indicated that they have performed some crash test, but the report is not final. Not knowing when Caltrans will release the report, WisDOT is in proposing to do the following:

** CALTRANS has several published reports on various crash testing of single-slope concrete and steel barriers using different test levels.

1. Because the slope of the Single slope barrier wall is constant, a vehicle should "ride up" the barrier regardless of wall height the same amount (e.g. if the truck rides up 3" during an impact to a 32" single slope barrier it should ride up 3" during an impact on a 56" barrier). This would allow someone to interpolate working width between two known working widths. In fact taller walls may have less deflection because vehicle contacts the upper part of the barrier, prevents the vehicle from lean on top of the wall.

** Two terms have been noted above – zone of intrusion (ZOI) and working width. The ZOI was termed by MwRSF researchers in a Pooled Fund study and refers to the maximum vehicle extent behind the top front corner of the barrier. ZOI was reported to vary by barrier shape/type and Test Level. Working width is the lateral distance from the original front face/toe of barrier to the greatest of vehicle extent, barrier deflection, or barrier width.

** Using the same test level and identical barriers, the taller barriers have the potential for reduced ZOI. However, the height where this reduction occurs may not be known. Even though the maximum vehicle extent may be reduced with increases in barrier height, the working width could technically increase since the barrier base would be wider.

2. Use the 27" working width of ZOI-2 crash test from MwRSF Research Report No. TRP-03-151-07 as the working width for the Caltrans 32" concrete barrier. Although there are differences between the 32" Caltrans barrier and the barrier used in the ZOI-2 test (ZOI-2 barrier has a narrower top and a flatter front face), WisDOT believes that these differences are small considering the variability of real world crash test.

** The working width for the single-face, single-slope, concrete barrier was approximately 27”, as observed for Test ZOI-2 by MwRSF. Recall that this measurement was taken from the front toe of the barrier. Thus, an effective TL-3 ZOI measurement would have been about 21” for this test. The published ZOI value for the prior TL-3 impacts into 32” tall, sloped-face barriers is 18”, while 24” was provided for vertical-face barriers. Actually, the single-slope barrier would likely fall between the two noted ZOI values, thus substantiating the 21” measurement from test no. ZOI-2.

3. It appears that in the Caltran's crash test of a 56" wall that the pickup truck did not lean over the barrier (i.e. 0 working width).

** If no truck lean over the top-front corner of the barrier was observed for pickup truck vehicle, then the ZOI would be zero. However, the working width would be the base width of the rigid parapet.

4. Therefore if one were to use a linear interpolation between working width of the 32" ZOI-2 crash test and the 56" Caltrans, WisDOT could calculate working widths for intermediate barrier heights of 36, 42 and 51.

** I am not sure whether you are seeking working widths or ZOIs for the varying height, single-slope barriers. Also, ZOI may not vary linearly as a sudden change may occur at a height sufficient to prevent vehicle extent over the top of the barrier. We would need to review all of the CALTRANS single-slope barrier tests to determine (estimate) the ZOI for each test and then provide a ZOI guide value for a given test level. In addition, MwRSF has shown how crash testing was used to demonstrate that fixed objects could be allowed within the ZOI. Please note that the original ZOI guidance was conservative and based on the premise that fixed objects would not be contacted if outside of the ZOI. However, fixed objects could be placed within the ZOI if proven to not cause undue risk to occupants or pedestrians nearby. Also, it should be noted that the ZOI concept has not been adopted by AASHTO but serves as a could guide to use to improve motorist safety.

** Are you seeking TL-3 or TL-4 ZOI values?

** Does the WsDOT desire to keep all fixed objects outside of the ZOI?

WisDOT understands that crash testing would be the preferred method to determine working width. However, given MwRSF's experience in crash testing does this procedure sound reasonable? Or, does MwRSF have an alternative suggestion on how WisDOT can determine working width for the various barrier heights?

** A preferred procedure would be to first review the single-slope, crash testing reports published by CALTRANS to determine whether the linear approach is reasonable. If it is, then no additional work would be needed. However, it there are concerns with this approach, then

MwRSF would need to acquire film/video from CALTRANS to determine more accurate ZOI and/or working width values. This secondary effort may require considerable resources, that of which may quickly utilize a moderate portion of the Year 19 Pooled Fund consulting funding. If this level of effort is required, then we would first need to obtain Pooled Fund approval to proceed.

Issue 2 Use of taller walls or vertical barrier in confined locations:

There are going to be situations were designers, have limited space to install a barrier wall (typically near structures). In these locations, designer cannot get the require working width for a given barrier height or shape. Currently WisDOT allows designers to either install a taller barrier wall or vertical barrier.

Given MwRFS's experience in crash testing, is there a preferred alternative (e.g. install the vertical wall of same height, install a taller single slope wall, install a taller vertical wall...). If there is no general preferred alternative, what other factors should a designer consider when selection a barrier wall in these situations.

** The ZOI and working width measures for a rigid barrier system are generally of little concern when used in medians to prevent cross-median crashes. However, values for ZOI and working width may be more of concern when placed very close to rigid, fixed objects. Before I can answer the question above, it would be helpful to understand the type of hazards that are anticipated to be shielded by the family of single-slope barrier systems. In addition, it is imperative to know what test level is being considered for each barrier variation. Thanks!

** Of course, other factors that warrant consideration when placing these barriers include: end and interior anchorage for the barrier base, safety treatment for the barrier ends, propensity for head ejection out of side windows and head slap against rigid parapets and objected mounted on top or close behind.

Ron

If you have any questions please call or email me. As always MwRSF's help is always appreciated.

Sincerely,
<<barrier differences.pdf>> <<working width.pdf>> Erik Emerson P.E.
Wisconsin Department of Transportation
Standards Development Engineer

Problem # 10 – Cut Slopes

State Question:

Ron:

What I see from the 1996 RDG is in Chapter 6, Subsection 6.4.1.9 Earth Berm (P. 6-8,9), which says that "slope rates should not exceed 1:2, although steeper slopes can be used if they are smooth and liberally rounded at the base."

But I don't see any such information in the 2002 RDG, so it apparently got removed in that revision. Also don't see that there are any references identified for this information in the 1996 RDG.

Dave

MwRSF Response:

Dave:

I have reviewed the results presented in NCHRP Report No. 158 which was also discussed at the spring Pooled Fund meeting. I have also reviewed the guidance in prior RDGs. Basically, the NCHRP authors do not recommend using slopes beyond a 2:1 back slope when the foreslope is flat. Front end bumper/vehicle snag into the slope was a noted concern. Dean and I are also concerned with a 1:1 slope as it would be the worst situation for causing vehicle rollover, especially for higher center of mass vehicles found on the roads today and as compared to the test vehicles used in the early 70s.

Therefore, we recommend treating the 1:1 back slope situation by one of the following options. First, as you mentioned, a reinforced concrete parapet could be installed close to the base of the back slope but actually cut into it to match the wall height slightly above the soil grade. A vertical parapet would be preferred, although single slope or other approved shapes could be used. Alternatively, a smooth MSE or block type wall could be constructed at the same cut back location, thus producing a smooth vertical parapet for redirecting vehicles. Both of the barrier options would be backed up (i.e., supported) with soil over most of the vertical height.

Please let me know if you have any further questions or comments. Thanks!

Ron

Problem # 11 – Mounting Flexible Markers on Post 1 of EAT

State Question:

Dear MwRSF,

I've got a hold of a detail that one of our regions is using to install flexible markers on to post 1. (see attached)

From reading manufactures data, we would be looking to install

- Any one of the flat or single curvature Carsonite models
- Either the 400 or 500 series Davidson models
- The FlexStake EZ Drive model (without the
-

The information form each manufacture is attached.

Does MwRSF see an issue with mounting any of theses product to the 1st post of the EAT? Most of these post would have a half circle cross section.

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

MwRSF Response:

Erik:

We do not have actual impact experience for these devices placed on guardrail end terminals. However, I do not believe that they pose significant safety concerns to impacting vehicles since they are light-weight and attached to the first post along its side. For end-on hits into the terminal, the lower delineator would be in front of the vehicle, potentially with a light-weight broken stub low to the ground.

Ron

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

Problem # 12 – Plastic Block-Outs for W-beam Guardrail

State Question:

All,

In our role as General Engineering Consultant to the Illinois Tollway, we are tasked with keeping the Tollway Standards up to date. The Tollway has adopted the Illinois Department of Transportation's Highway Standard for standard w-beam guardrail. IDOT recently revised their

standard to use the Midwest Guardrail System, which has the higher rail and 12" block-outs. IDOT allows the use of plastic block-outs and considers them equivalent and interchangeable with wood. They also allow plastic and wood to be intermixed within a run of guardrail.
According to Nick Artimovich the FHWA also considers the "crashworthy" plastic block-outs to be interchangeable with wood. That means they need a FHWA acceptance letter before they can be used.

The Tollway does not have tort immunity, and therefore is very cautious about safety devices. Currently, the Tollway does not mix and match and does not allow plastic block-outs. The Tollway's policy is to only replace in kind when guardrail is in need of repair. There is concern with UV deterioration and stocking of many types of blocks because all maintenance is done by Tollway forces.

Has there been any concern over UV deterioration for plastic blocks?

Nick sent me an approval letter for the "Monroeville 12 inch MGS Composite Offset Block" dated April 16, 2008. To your knowledge has any other product been approved or crash-tested using the larger 12" plastic block-out?

I appreciate your help.

Thanks,
Tracy Borchardt
CTE Engineers, Inc.
Chicago, IL
312-823-5005

MwRSF Response:

Tracy:

Thank you for your inquiry regarding the use of plastic blockouts. For many years now, several companies have developed various compositions of recycled blockouts for use in strong-post, W-beam guardrail systems. Based on my understanding of these blockouts, most would contain additives that inhibit UV degradation, such as the use of carbon black in tires. However, if you were concerned with UV degradation, it would be recommended that you ask a potential supplier/manufacturer whether resistance to UV deterioration is provided.

With regard to the use of plastic and wood blockouts in standard, W-beam guardrail systems, I am not concerned with using multiple, approved blockouts within the same longitudinal barrier system. Although this type of configuration may be rare in new construction, it may be more common during guardrail maintenance operations over time. In any event, the safety performance of the barrier system should not be affected with the use of different blockout materials that have been approved for use in the barrier system.

I am familiar with the research report which documents the crash testing of the MGS using a 12" deep composite blockout. Unfortunately, I am not aware of any other 12" deep plastic blockout that has been tested, evaluated, and approved for use with the MGS. However, there is new variation of the MGS which utilizes round wood posts with 12" deep wood blocks adapted to the round posts.

Finally, other 31" tall W-beam guardrail systems have been developed to date and have included options for use with and without blockouts. If further information is required on these systems, I recommend that you review the FHWA website for approved crashworthy hardware as well as the corporate websites for NUCOR-Marion, Trinity Industries, and Gregory Industries.

Please let me know if you have any additional questions or comments. Thanks again!

Ron

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

Problem # 13 – Tie-Down Temporary Barrier with Asphalt Overlay

State Question:

Dear MwRSF,

I was ask by a construction engineer, if it O.K. to bolt the 12.5-foot temporary concrete barrier to a bridge deck that has an asphalt overlay.
Currently, our detail (see attached) does not allow this. Why does the barrier need to rest on concrete? If there is an asphalt overlay on the bridge deck, is there some other modification to the design that we should do?

Your help as always is greatly appreciated.

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

MwRSF Response:

Hi Eric,

Our concern with installation the bolt-through tie-down in asphalt is that the asphalt increases the moment arm on the bolt and the corresponding bending stresses. We have come up with a retrofit using a pipe sleeve in the asphalt and concrete that should eliminate this issue. See the attached schematic.

Contact me with any questions or concerns.

Thanks

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

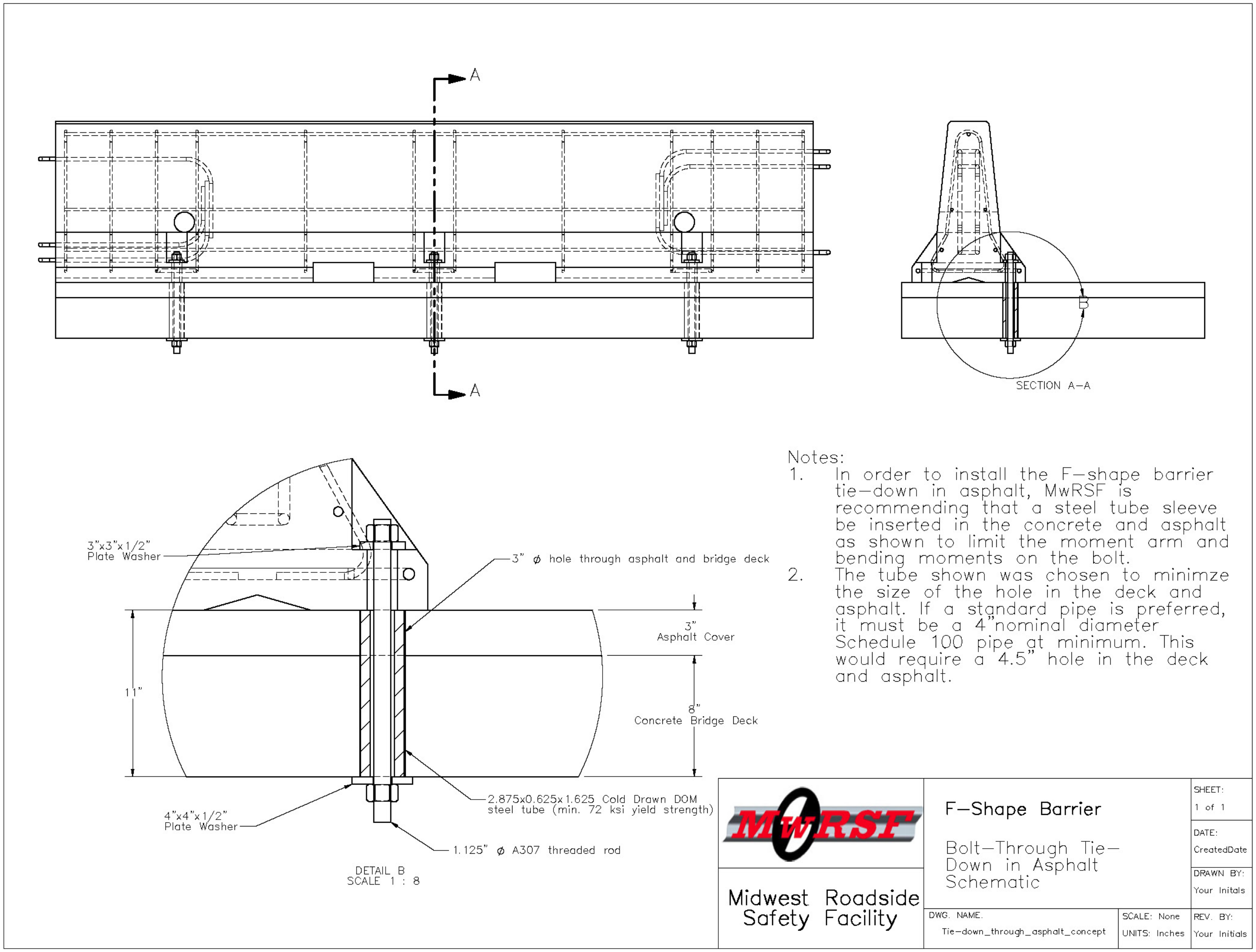


Figure 11. TCB Tie-Down through 3" Asphalt Overlay.

Problem # 14 – Tie-Down Temporary Barrier with Asphalt Overlay – Additional Options

State Question:

Hi Bob - I recently received a copy through AASHTO TCRS of the Progress Report for Third Quarter of the Midwest States Regional Pooled Fund Program dated September 15/08. I note your answer and detail for a pipe sleeve under Problem #10 to address the asphalt overlay issue we had discussed previously. Is a 3" asphalt overlay the absolute maximum thickness for this detail or could the thickness of the overlay be increased at least to 4", or even 6"?

Thanks, Mark.

MwRSF Response:

Hi Mark,

Glad to hear you are using the Pooled Fund Consulting summaries!

The bolt through tie-down in asphalt retrofit we came up with should work for deeper asphalt depths if needed. The issue is that the pipe size needed and thus the hole in the concrete becomes larger. I have come up with tube specs for larger asphalt depths. There is a spec for the smallest tube size I could make work as well as the smallest standard schedule pipe I could find. These pipes were sized based on expected maximum shear an bending loads expected.

For 4" asphalt

1. 4" Schedule 100 pipe (yield strength = 35 ksi) 2. 3.25" OD x 0.625" thick x 2.00" ID 1026 CD round tube (yield strength = 72 ksi)

For 6" asphalt

1. 5" Schedule 100 pipe (yield strength = 35 ksi) 2. 3.75" OD x 0.625" thick x 2.5" ID DOM (Drawn Over Mandrel) round tube (yield strength = 75 ksi)

Another thing to note is that the larger tube sizes shown here will require a corresponding increase in the plate washers used in the system.

Let me know if you have further questions.

Thanks

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

Problem # 15 – Sloped End Treatment for a Raised Median

State Question:

Hi Bob,

We are requesting guidance on the use of a sloped end treatment for concrete barrier installed on a raised median.

Attached is a PDF file containing all the geometric information you wanted. This file has 3 pages, showing different information. Page one (35 MPH) and page two (50 MPH) are the locations we need recommendations for. Page three is the entire project.

FYI - Curbs are vertical faced and 4 to 6 inches tall.

Thanks
Mohammad

Mohammad Dehdashti, P.E.
Design Engineer
Metropolitan District

MwRSF Response:

Hi Mohammad,

Thanks for the layout drawings and median barrier drawings. Based on what I have seen, I have some recommendations.

1. Given you installation speeds and median barrier type, we cannot recommend that you use a sloped concrete end terminal for the installations you have shown. Previous computer simulations of the sloped end treatment, as shown in NCHRP Report 358, found that the sloped end treatment for a 32" high barrier can cause overturn of the vehicle for impact speeds of 30 mph or greater. Both of your installations have designs speeds over 30 mph, so this is not likely to be a good alternative for you. In addition, used of the sloped end would have required removal of the median curb in front of the end treatment for approximately 65' in order to prevent interaction with the curb front affecting the terminal performance. This would have placed an significant gap between the end terminal and the median curb that I don't believe you would like.
2. One alternative option would be to install the available low height TL-2 barriers rather than your current 32" design. These systems have available sloped end terminals that have been tested to TL-2.We can help get you details on these systems if you would like them.

3. The only other alternative that we have is to install a crash cushion on the end of the barrier. However, you would need to consult with the manufacturer with regards to there use with you median layout.

Thanks

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

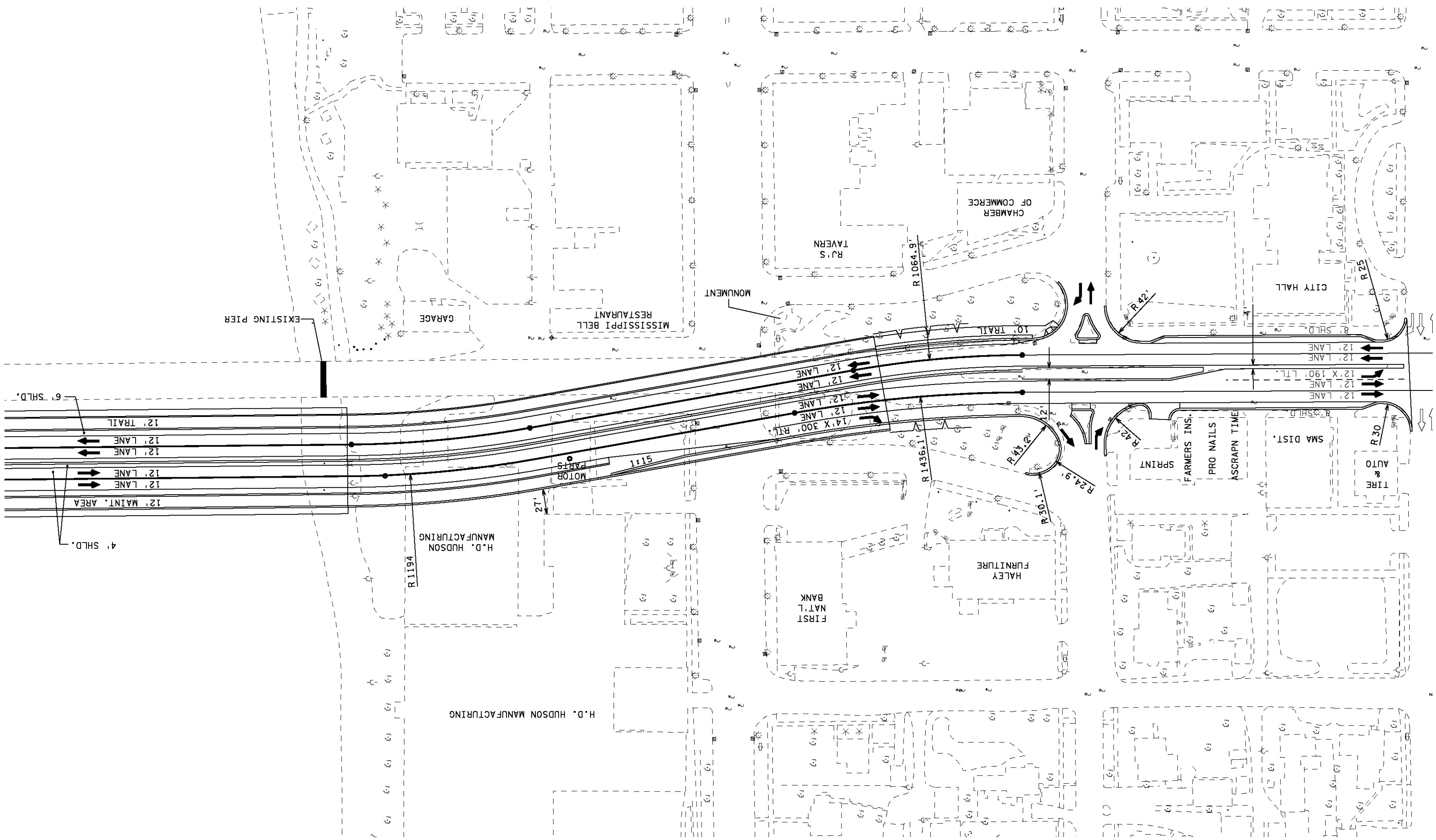


Figure 12. MnDOT Raised Median Site – Page 1

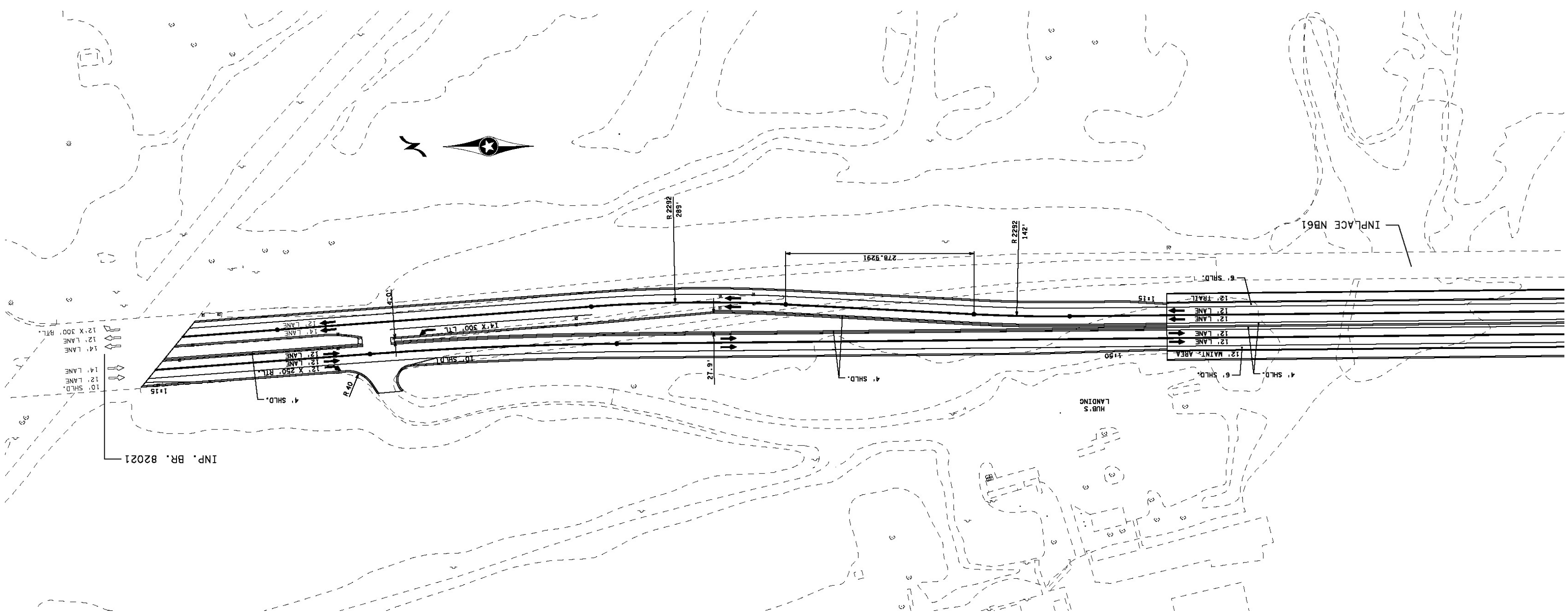


Figure 12. MnDOT Raised Median Site – Page 2

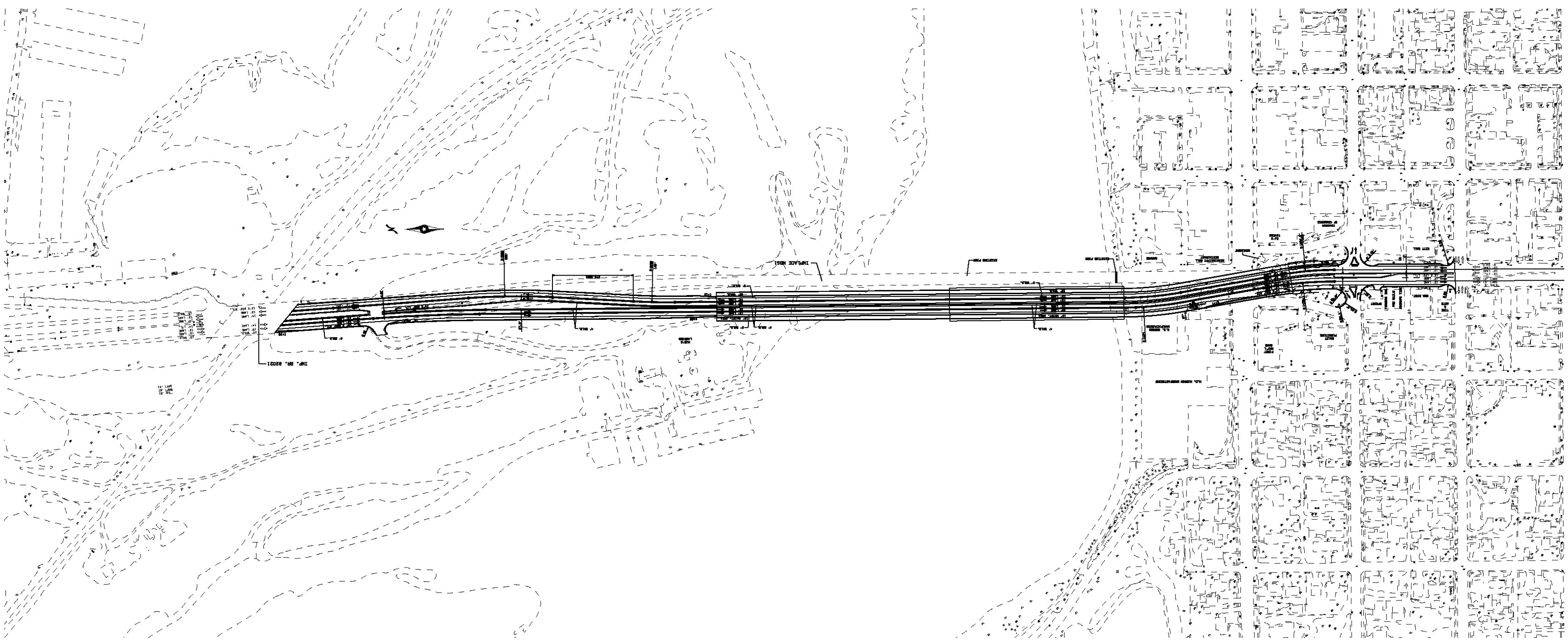


Figure 12. MnDOT Raised Median Site – Page 3

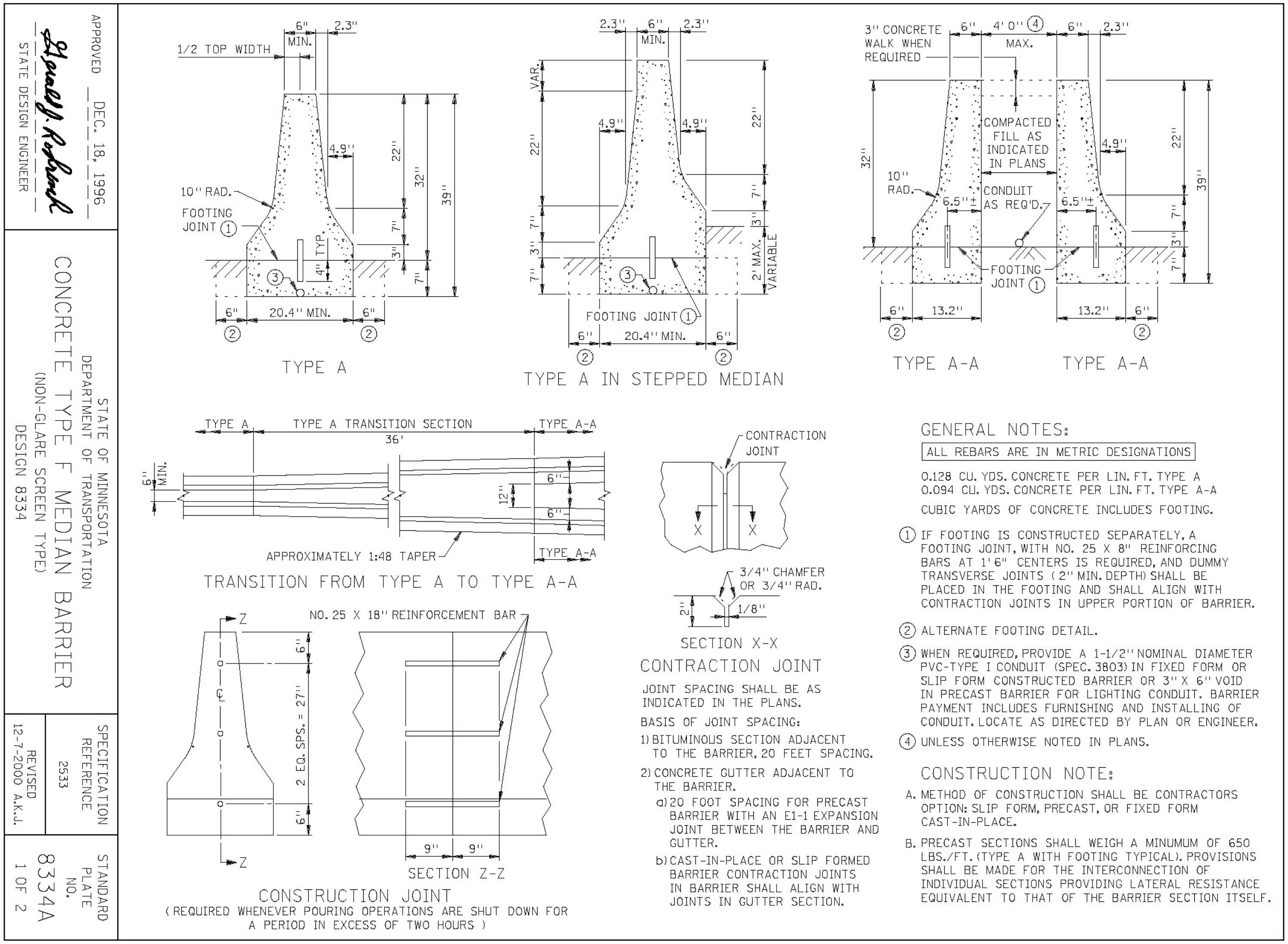


Figure 12. MnDOT Median Barrier Design