**MIDWEST POOLED FUND PROGRAM**

**Progress Report**
**First Quarter 2009**
**January 1st to March 31st (Actually Through April 20th)**
Midwest Roadside Safety Facility
Nebraska Transportation Center
University of Nebraska-Lincoln

April 20, 2009

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

### Phase I & II Development of a TL-3 MGS Bridge Rail – Program Years 18 and 19

On January 20, 2009, one dynamic bogie test (test no. MGSBRB-7) was performed on a weak-post bridge railing concept attached to a short section of reinforced concrete deck. During the test, the under-reinforced concrete deck fractured and allowed to post hardware to release prematurely. Although the full design load was not imparted into the hardware, the research team determined that the prototype hardware was ready for full-scale testing and evaluation. Following the result, minor design modifications were made in terms of shimming within the steel tubular post socket. New post and connection hardware has been fabricated. Construction of the MGS guardrail, MGS bridge rail, and reinforced concrete bridge deck is underway and planned for completion in May 2009. Two full-scale vehicle crash tests are planned for the Second Quarter of 2009.


**Standardizing Posts and Hardware for MGS Transition – Program Years 18 and 19**

In 2008, two crash tests, using a 2270P and an 1100C vehicle, were successfully performed on a simplified, steel-post, stiffness transition to a nested thrie beam transition using the MGS. An internal draft research report has been completed on the two crash tests. With the completion of the full-scale crash testing program, a simplified, steel post transition option is now available for attaching the MGS to crashworthy approach guardrail transition systems.

In the first quarter, dynamic bogie testing of wood posts embedded in soil was initiated in order to determine a simplified wood post transition alternative. In February 2009, four bogie tests were performed – two on W6x15 steel posts and two on 8-in. x 8-in. wood posts. From this testing, it was revealed that the wood posts were unable to provide comparable performance to the existing steel posts as wood post fracture occurred prior to reaching the targeted peak load capacity. As a result, alternative wood post sizes were selected for evaluation and for use as a substitute for the W6x15 steel transition posts. Both 8-in. x 10-in. and 10-in. x 10-in. wood posts have been ordered. Dynamic component testing of the new wood posts embedded in soil is planned for the Second Quarter of 2009.

**Midwest Guardrail System Placed at the Breakpoint of a 2:1 Slope – Bogie Testing Project Using Year 14 Contingency Funds**

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 published in TRR No. 2060.

During the report review process, it was noted some states desired a wood-post alternative for the MGS placed on a 2:1 slope. As such, a very limited dynamic bogie testing program was initiated in order to determine the appropriate length of a 6-in. x 8-in. wood post for placement at the slope breakpoint of a 2:1 fill slope. On March 6, 2009, one dynamic test (test no. MGS2-1PT22) was performed using an 8-ft wood post. During the test, wood post fracture occurred with limited post rotation. Using limited contingency funds, two or three bogie tests are planned in the Second Quarter of 2009 in order to finalize the wood post length for this MGS application.

**Performance Limits for a 6-in. High, AASHTO Type B Curb Placed in Advance of the MGS – Program Year 17**

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.

On April 8, 2009, a 2270P crash test (test no. MGSC-5) was performed using the TL-3 conditions and requirements found in the MASH-08 guidelines. During the test, the pickup truck impacted the MGS with a slight upward trajectory of the right-front corner of the vehicle which later began to be redirected with moderate roll toward the barrier system. In this sequence, the right-front wheel was also removed and propelled along and under the truck. As the vehicle was traveling along the barrier system, the vehicle roll toward the barrier increased as well as the upward pitch of the truck's rear end. The vehicle's angular motions, combined with the wheel release and truck travel over an upright loose wheel, likely contributed to the vehicular instabilities and vehicle rollover upon exiting the MGS barrier. With vehicle rollover, the results from test MGSC-5 were deemed unsatisfactory.

The results from this crash test will be documented and reported in the Second Quarter of 2009, as part of a Phase II report. At this time, there are insufficient funds to conduct a re-test using a reduced lateral offset. However, a more accurate indication of the remaining project funds will be available after the March and April labor charges have been posted.

A Phase I draft research report was prepared and submitted in late 2008. Limited comments were received for the Phase I report in the First Quarter. The Phase I report will be made final in the Second Quarter of 2009.

## 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 small car 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 continued in 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 of the simplified bracket was initiated in this First Quarter of 2009. In addition, draft CAD details for various concepts were prepared and forwarded to the Bennett Bolt Co. for seeking feedback on the constructability of the cable attachment prototypes. It is anticipated that prototype hardware will be obtained in May or June for use in the dynamic component testing and evaluation program. If those tests show promising results, the 1100C small car re-test should be conducted in the Third Quarter of 2009.

### Testing of End Terminal for Four-Cable, High-Tension Barrier (1100C & 2270P) – Program Year 17

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. A Year 20 proposal has been prepared in order to obtain additional funding to complete the compliance testing program.

## Paper Studies

### Cost-Effective Measures for Roadside Design on Low-Volume Roads – Program Year 16

Documentation of the culvert treatments and tree analyses was completed during the Fourth Quarter of 2008 and First Quarter of 2009. During a field investigation of 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.

Additionally, a fourth hazard category was initialized, consisting of safety treatments for low-volume bridges. MwRSF researchers are gathering actual cost number to use in the RSAP analysis for slopes and bridge rails. Aside from the cost numbers, all analysis runs have been compiled. Results from the slope and bridge analyses should be completed during the Second Quarter of 2009.

**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.

**Cost-Effective Upgrading of Existing Guardrail Systems – Program Year 17**

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 field investigation in the summer of 2009 in order to document selected guardrail installations.

**Evaluation of Safety Performance of Vertical and Safety Shaped Concrete Barriers – Program Year 16**

The preliminary data analysis indicated that there was little correlation between barrier shape and rollover propensity. However, after a more careful analysis, it became apparent that there was a relationship, but it was being masked by other factors such as traffic volume and operating speeds. In order to control for these complicating factors and determine the effects of barrier shape on rollover rate, some additional data will be needed. MwRSF Is currently working to obtain the additional crash data to allow for a more detailed evaluation.

**MGS Implementation – Program Year 18**

In the Fall of 2007, consulting funds were used to assist states with the MGS implementation effort. MwRSF began the effort with a review of CAD details from the Illinois and Washington DOTs. Project correspondence occurred via email with a pre-determined Technical Working group. To date, three subject areas were covered and are as follows: (1) Standard, Half, and Quarter Post Spacing; (2) MGS w/ Curbs and MGS on 2:1 Slopes; and (3) MGS w/ Culvert Applications. A fourth category, MGS Stiffness Transition, will be initiated after the simplified, wood-post transition project is completed. It is estimated that the MGS implementation effort will commence in the Third Quarter of 2009.

## 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. Due to many factors, existing project funds are insufficient to complete the research study. MwRSF-UNL researchers have been seeking funds to complete this research from alternative sources. In March 2009, an NCHRP IDEA proposal was submitted to seek additional project funds. A proposal was also submitted to the Year 20 Pooled Fund Program. In addition, documentation and reporting of the Phase I R&D program was continued in the First Quarter of 2009.

**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. In 2008, a continuation project was approved to provide new funding for an additional crash testing program. Three 2270P and one 1100C crash tests were performed. The reporting and documentation for the last four crash tests has been added to the original test report, The combined, internal draft report is currently being reviewed and will be submitted to New York for comment in May 2009. In early 2009, a follow-on crash testing program was recently approved, which includes two additional crash tests. Initial planning for this effort is underway.

**Universal Breakaway Steel Post for Guardrail (Minnesota DOT)**

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 thrie beam bullnose system. After the failed test, MwRSF researchers studied the results. In February 2009, MwRSF provided recommendations on how to proceed with the project using two different plans. MwRSF is currently waiting for confirmation as to which plan to follow and whether approximately $10,000 in additional funding is available. Documentation and report of this research study occurred in the First Quarter of 2009 and will continue in the Second Quarter.

**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 has been completed. A draft research report was submitted to the West Virginia DOT in the First Quarter of 2009. A final report is anticipated in the Second Quarter. In addition, a formal request seeking FHWA acceptance will be prepared in the Second Quarter.

**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 edited by MwRSF researchers in the First Quarter of 2009. Documentation and reporting of the research project was also initiated in First Quarter. Completion of the draft report is expected in the Second Quarter of 2009. A request seeking FHWA acceptance should also be completed in the Second Quarter of 2009.

**Dynamic Testing and Evaluation of a New TCB for FRP Bridge Deck Applications (Kansas DOT)**

The project consisted of the crash testing and evaluation of a vertical-face, precast concrete parapet attached to an FRP composite bridge deck system. The research effort was performed according to the Test Level 3 safety performance guidelines found in the Manual for Assessing Safety Hardware 2008 (MASH-08). On March 13, 2009, one 2270P pickup truck test (test no. KSFRP-1) was successfully performed at the target impact conditions of 62 mph and 25 degrees. For this test, the vehicle was safely contained and smoothly redirected in a stable manner. Documentation and reporting of this crash test will be continued in the Second Quarter of 2009.


**Dynamic Evaluation of New York State's Pinned Temporary Concrete Barrier (New York DOT)**

The project consisted of the crash testing and evaluation of New York State Department of Transportation's New Jersey shape, temporary concrete barriers attached to a concrete slab using vertical pins on the back-side face. The research effort was performed according to the Test Level 3 safety performance guidelines found in the Manual for Assessing Safety Hardware 2008 (MASH-08). On January 9, 2009, one 2270P pickup truck test (test no. NYTCB-4) was successfully performed at the target impact conditions of 62 mph and 25 degrees. For this test, the vehicle was contained and redirected. However, it should be noted that significant barrier deflections were observed in two segments. In addition, one barrier joint ruptured after the vehicle's rear end impacted the barrier and had exited the region. An internal draft report was initiated in the First Quarter of 2009. A draft report should be completed and submitted to the NYDOT in the Second Quarter of 2009.

## Awaiting Reporting

**Development of a Temporary Concrete Barrier Transition – Program Year 16**

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. Limited progress was made on the draft report this quarter. As such, the draft report should be submitted to the Pooled Fund members for review and comment in the Second Quarter of 2009.

**Termination of Temporary Concrete Barrier – Program Year 16**

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. A draft report should be submitted to the Pooled Fund members in the Second Quarter of 2009.

## Draft Pooled Fund Reports Completed

Not applicable this quarter.

## Final Pooled Fund Reports Completed

Not applicable this quarter.

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

Rosenbaugh, S.K., Benner, C.D., Faller, R.K., Bielenberg, R.W., Reid, J.D., and Sicking, D.L., *Development of a TL-1 Timber, Curb-Type, Bridge Railing for Use on Transverse, Nail-Laminated, Timber Bridges*, Draft Report to the West Virginia Department of Transportation, Transportation Research Report No. TRP-03-211-09, Project No.: SPR-3(017) Supplement No. 53, Project Code: WV-09-2007-B1, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, Nebraska, March 13, 2009.

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

Not applicable in this quarter.

**<u>Pooled Fund Consulting Summary</u>**

Midwest Roadside Safety Facility
January 2009– March 2009

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 –MwRSF TCB**

State Question:

One of our contractors is in the process of relocating a run of the MwRSF TCB that was pinned through the asphalt with the 38mm dia x 978mm long A36 steel pins. They are having a very difficult time pulling the pins out, most likely due to the extreme cold temperatures we are having. For future installations we would like to consider specifying slightly larger diameter holes, say up to 45mm (1-3/4") diameter holes, to ensure pins could be pulled easier in future. We would also like to consider a threaded top on the pin in order to use double nuts and square plate washer as an alternative to the welded steel top plate. This would allow other devices to be attached to the pin during removal.

Please advise if you and/or contractors using the MwRSF TCB have experienced similar problems during pin removal, and their solution.

Please also advise if it would be advisable to allow larger diameter holes in the asphalt, and/or allow a threaded top on pin for a double nut and washer as an alternative to the welded top plate.

On another matter, have you run a TL-2 crash test or simulation test on the MwRSF TCB? We would be interested to know the approximate deflection distance for a TL-2 freestanding installation for designer information.

Thanks,
Mark Ayton, P. Eng.
Senior Engineer, Highway Design
Design & Contract Standards Office
Ontario Ministry of Transportation

MwRSF Response:

I don't see any issues with threading the top of the pin and using double nuts if that helps you with extraction. I would recommend that the washer plate have the same thickness and dimensions as the plate used on the tested pin.

We can't allow larger holes in the pavement because it could potentially allow larger deflections and more vertical pullout of the pins. Both of these behaviors would be detrimental to the performance of the system.

As far as deflection limits, of the MwRSF TCB under TL-2 impact conditions, we have not explicitly determined those limits. We have however provided some guidance for barrier deflections based on accident data in TRP-03-113-03. The report basically gives guidance for lower barrier deflection expectations based on accident data. Let me know if I can give you any more assistance.

Thanks

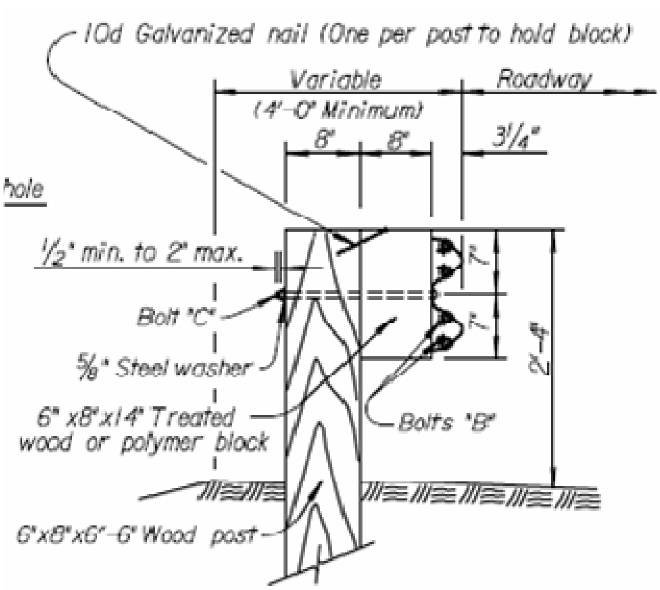
Bob Bielenberg, MSME, EIT
Research Associate Engineer
Midwest Roadside Safety Facility

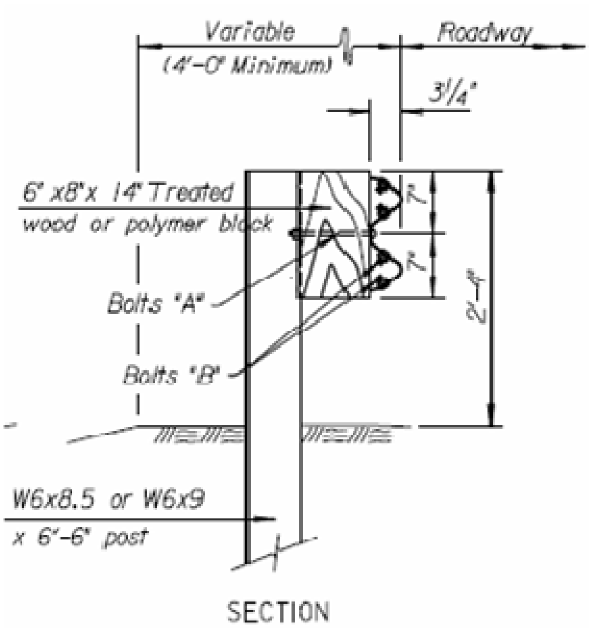
**Problem # 2 –Guardrail – Slope Question**

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






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.

Dean – If you have any additional comments, please feel free to add them in your reply.

Respectively,

Ron

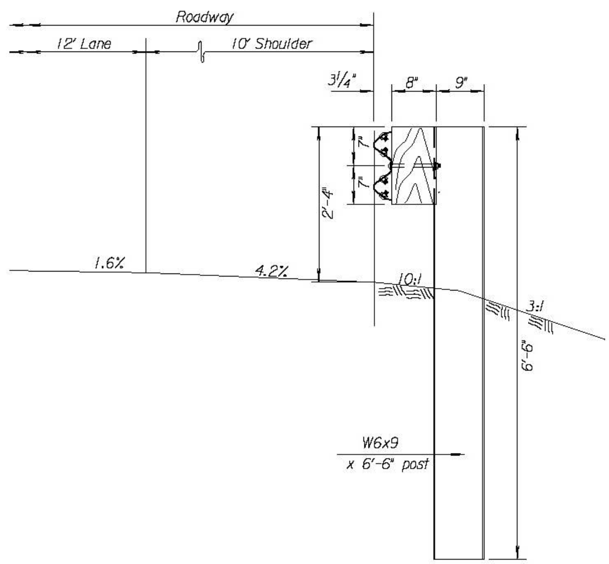
Ronald K. Faller, Ph.D., P.E.
Research Assistant Professor

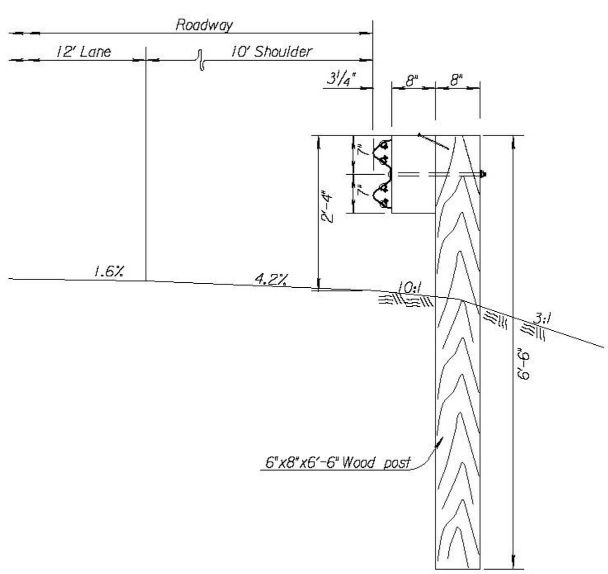
**Problem # 3 –Guardrail – Slope Question – Part II**

State Question:

Thanks Ron for the breakdown, but I am not certain if I told the whole story about the post. I think my situation is close to #3.
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.

See the attached detail for our scenario. We want to avoid different post lengths from our typical 6’6” post in case these posts/guardrail get hit and the maintenance personnel replaces them with our typical 6’ 6” posts. Since we are slightly different than your breakdown of recommendations, would the 6’6” shown in the detail with the 3:1 slope be adequate at normal post spacing?



Thanks,
Scott

MwRSF Response:

Scott:

Based on your new detail that was provided on 12-16-2008, it appears as though you have a 3:1 fill slope starting at the center of the post. This situation is different from what I assumed according to your previous email which showed a greater region of somewhat level terrain behind the posts. Your situation now appears to be closer to case 4 below for standard W-beam guardrail. For case 4, we have recommended the use of 7-ft long posts at a half-post spacing. However, as noted in the previous email, we tested standard height w-beam rail at the break point of a 2:1 slope with ½ post spacing and 7' long posts. For your installation, you are requesting to use 6'-6" long posts at ½ post spacing at the break point of a 3:1 slope. Based on our understanding of soil behavior with respect to embedment depths and slopes, we believe that this is this installation will have similar stiffness to the 7' posts at ½ post spacing on the 2:1 slope. Thus, we would recommend this configuration.

Please note that case 4 utilized metric height guardrail.

Ron

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

**Problem # 4 –Guardrail and 1.5:1 Slope**

State Question:

Hi Ron,

We have a pavement overlay project where the district wants to add 6 inches of pavement, which causes a sliver 1.5:1 slope at the guardrail. The district is bulking at expending additonal funds needed to extend the shoulder is this fill segment. See attached sheet, and refer to the outside shoulders.

The design currently calls for standard 6 foot post to be installed at the breakpoint of the slope, and not our standard installation of having 2 foot of shoulder behind the post before the break point. The existing guardrail would be raised 6 inches as shown on the sheet, but we are concerned about the sliver fill at that point and the 1.5:1 slope to catch the existing 2:1 embankment slope. Since the 6" fill at the guardrail would probably be just dumped and not compacted, I want to ensure we have sufficient post embedment for the 27 guardrail height.

I've reviewed MWRSF recommendations for W-beam system on a 2:1 slope and was wondering if the use of 9 foot posts (at half post spacing) on this project would compensate for the sliver? And could wood posts be substituted for the steel, even with the longer post lengths?

Dean Focke, P.E.
Roadway Standards Engineer

MwRSF Response:

Dean:

MwRSF has performed two studies involving W-beam guardrail placed on 2:1 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.

Both MwRSF efforts, in cooperation with the Midwest States Pooled Fund Program, were successful.

Later and using available crash test data as well as engineering judgment, Dr. Dean Sicking and Mr. Bob Bielenberg prepared the preliminary guidance for guardrail placed on slopes, subject to refinement in the future. It was 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.

In 2008, TTI researchers evaluated 27” tall, standard W-beam guardrail with half-post spacing placed 1ft off of a 2:1 fill slope using TL-3 of NCHRP 350. For this evaluation, the pickup truck rolled over in front of the barrier.

Based on the information provided above as well as the proposed OHDOT design detail, I recommend using one of two options. First and assuming a portion of the 6 in. of fill would be effective and remain in place over the years, it would be acceptable to use the Case 4 option for standard W-beam guardrail which consists of 7-ft long steel posts at half-post spacing although preferred to be at the metric height of 27-3/4 in. Alternatively, it would be acceptable to use the Case 4 option for MGS guardrail which consists of 9-ft long steel posts at full post spacing. The overall preferred option would be to use the MGS with 9-ft steel posts spaced on 75-in. centers. For the wood post option, MwRSF would need to evaluate longer posts in a 2:1 foreslope using dynamic bogie testing before recommending a suitable post length.

In the future, we recommend that the OHDOT begin to implement the MGS along with its crashworthy design variations, including systems for placement across culverts, adjacent to slopes, etc.

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

Ron

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

**Problem # 5 –Butterfly Delineators**

State Question:

Hey Ron,

I wanted to get your opinion on the use of butterfly delineators (metal or plastic) that slip under the bolt on guardrail. We have contended that slipping these delineators under the bolt will cause this to act like a washer. Do you have any comments about this (performance, any study, etc)?

Below is a link to a website for our approved delineators along with the KDOT specification. KDOT uses a plastic type delineators as mentioned in the spec. We do state in our spec that these delineators need to be 350 approved. KDOT is placing these guardrail delineators on the maintenance side. However, I have attached our standard drawing that shows them to be riveted and these are being placed in the construction plans on the design side.

http://www.aktinc.com/guardraildelineators.htm

If you read down the email chain, FHWA checked with their office and said that there were no 350 approval letters. Also, they indicated that there is not a concern with the use of these delineators (assuming under a guardrail bolt). Anyway, I want to make sure that there is not a performance issue since we are saying it should be 350 compliant. Typically the maintenance personnel install these by sliding the plastic delineators under the guardrail bolt. It appears alot of states use these but I have no firm documentation from anyone that there will not be an issue and they are 350 compliant. I have not agreed with everyone yet that these delineators should be used because of this concern. I would think installing a metal delineator under the guardrail bolt would be a concern too. Anyway, please give me your thoughts on this and thanks a lot for your help on this issue.

Thanks,
Scott

MwRSF Response:

Scott:

The delineators should not be a concern for becoming a projectile and posing risk to oncoming traffic or to the occupants of the vehicle impacting the barrier. However, the delineators may imitate the behavior of the old steel washers and allow the rail to remain attached to the post and possibly become pulled down during impact events. The steel variety may seem to be a greater concern than those made with polycarbonate material. As an alternative, would KsDOT be willing to place the devices on the rail at non-post locations, on posts, or even glue/bond them to the rail?

Ron

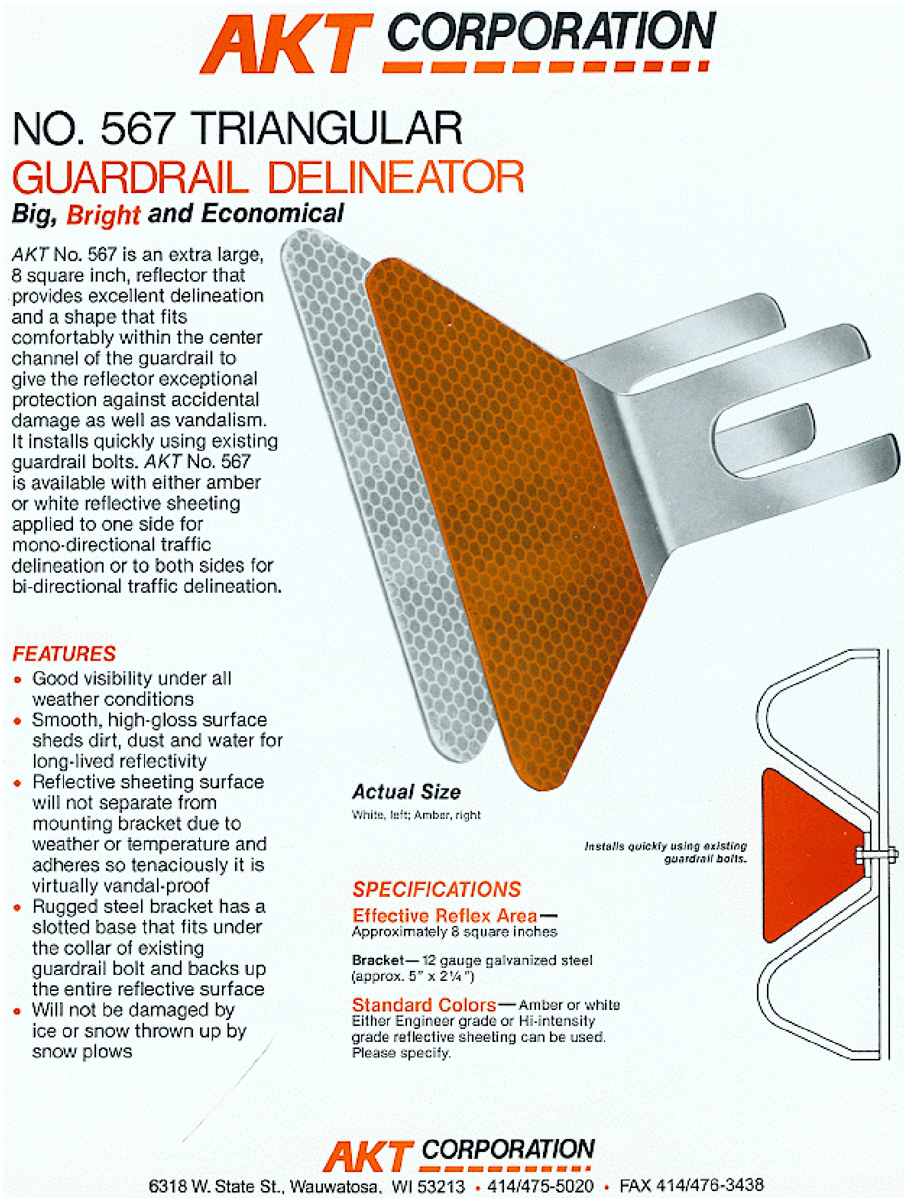
Ronald K. Faller, Ph.D., P.E.
Research Assistant Professor

**Problem # 5 –Butterfly Delineators – Part II**

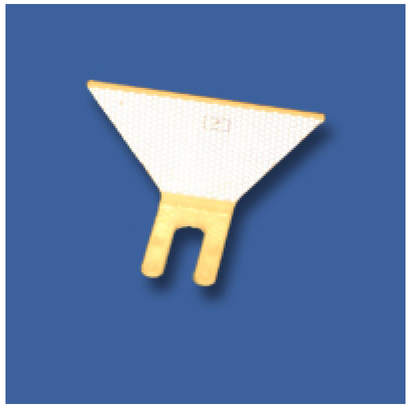
State Question:

The location could be discussed internally again but I believe the easiest for maintenance folks (probably installing under guardrail bolt) will prevail if there are not any issues. We tried the glue years ago and it did not work. First snow, the delineators were knocked off. We found the rivet option worked.

I think there are many manufactures that describe placing these under the guardrail bolts like the link I sent you. The picture below from this manufacturer's site states "install quickly using existing guardrail bolts" by the detail showing the guardrail and delineator. (this is for the steel version) The attached email has further comments from the FHWA. I appreciate everyone weighing in on this and can you explain the effects of using a washer too in order to pass this along.




Here is the plastic version. Again, they indicate to install under guardrail bolts. No mention of performance or 350 compliance.



http://www.interwestsafety.com/store/265.aspx

I called the supplier about specific details and they are checking into it. The only thing they could give me is listed on the product sheets below and I summarized this. Also, I asked this supplier for any testing or 350 compliance but I don't think they had a clue about what that meant (checking into it though). I did not see any mention of compliance on any website for these things. Thanks, Scott

AKT Plastic version (717):
- 5 ¼" x 3"
- approx. 0.085" thick
- High impact polycarbonate

AKT Steel version (567):
- 5 ¼" x 2 ¼"
- 12 guage galvanized steel

Thanks,
Scott

MwRSF Response:

Sorry for the delay in getting back to you regarding the use of Flexible Guardrail Delineators. Please note that the slot dimensions or washer plate size are not shown below. I have considered this issue more and still have concerns with the 12-gauge, steel galvanized component when used under the head of a guardrail bolt. As you are aware, the use of 3/16" rectangular guardrail plate washers have been highly discouraged with the use of strong-post guardrails. Although this component is thinner, 0.105 vs. 0.188", and has one end open, the potential remains for it to increase rail to block/post attachment. At rail splice locations, this device would add another rail thickness. At non-splice locations, it would simulate a two-ply splice. As such, I would not recommend the use of the steel device at rail splice locations. In addition, I am concerned about effectively adding plate washers, although thinner than prior designs, to the non-rail-splice locations. If crash testing demonstrates that the use of the steel components provide an acceptable safety performance, then use them as needed.

With regard to the thin polymer version, I believe that the head of the guardrail bolt would easily pull through the washer region.

Ron

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

**Problem # 6 –Butterfly Delineators – Part III**

State Question:

MwRSF, FHWA, and KsDOT discussed the issue of the butterfly delineators further. It was noted that there were concerns with regards to the metal delineators acting similar to rectangular washers on guardrail which has been shown to have detrimental effects on barrier performance.

MwRSF Response:

After review of the plastic and steel butterfly delineator designs, MwRSF, FHWA and KsDOT agreed that the plastic delineators posed little concern for adversely affecting guardrail performance due to their low thickness and material strength. However, there concern with the steel design acting like a washer could not be eliminated. Thus, the group recommended use of the plastic butterfly delineator designs until further research or testing verified the steel butterfly delineator performance.

**Problem # 7 – 4" Mountable Curb and Standard Beam Guard**

State Question:

Jeff Shaw from FHWA resource center is asking for the report that MwRSF ran that involved 4" mountable curb and standard beam guard. Jeff also was wondering why NCHRP Report 537 indicates that standard barrier can be installed at a zero offset and MwRSF's failed crash tests with standard beam guard.

If MwRSF could get me the report number and title and MwRSF's opinion on NCHRP 537 recommendation.

Sincerely,

Erik

MwRSF Response:

Erik:

MwRSF performed two research studies for the Midwest Pooled Fund Program regarding standard strong-post W-beam guardrail installed over 4" concrete curbs. The research results from these studies are published in the following reports: TRP-03-83-99 and TRP-03-105-00. I will email you these reports in separate emails using the UNL DROPBOX SYSTEM.

MwRSF found that a steel post, wood-blockout, w-beam guardrail would rupture when placed over a 4-in. wedge-shaped, concrete curb. TTI found that a wood post, w-beam guardrail would redirect a pickup truck when placed over a 4-in. asphalt dike. MwRSF later obtained a successful test result when the single rail was replaced with a nested guardrail.

NCHRP 537 makes the statement regarding 4-in. curbs being placed flush with the guardrail face based on prior crash test data noted above, LS-DYNA simulations performed in the study, and the lower speed validation crash tests performed for NCHRP 537. As such, NCHRP 537 is silent on the issue of which W-beam rail system modified G4(1s) or G4(2W) can be used with single rail or nested rail.

Later, MwRSF demonstrated that the Midwest Guardrail System (MGS) could be used with a 6-in. curb placed slightly forward of the rail face.

Ron

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

**Problem # 8 – Summary of Maximum Deflections for Beam Guard and Thrie Beam**

State Question:

Dear MwRSF,

I was looking at the deflection values in Table 5.4 of the RDG (page 5-25). I'm confused where these deflection values are measured from. Are they deflection values or working width (e.g. barrier width plus deflection). If they are just deflection do I just and the width of the system to get working width?

Sincerely,

Erik

MwRSF Response:

Erik:

The values in the table come from several sources. To the best of my knowledge, the simulations were performed by Kitty Hancock using the NARD code. At the time of this analysis, our industry was not yet using the working width terminology. As such, I believe that the simulation results just depict dynamic deflections. Some crash test results are also referenced in the table. These MwRSF tests were also very dated. As such, dynamic deflections were likely used as well.

Ron

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

**Problem # 9 – SSCB Thrie Beam Transition**

State Question:

MwRSF,

Below is a draft copy of our thrie beam anchorage. If MwRSF has any comments, please let me know.

Erik

MwRSF Response:

Hello Erik!

For your new detail, I briefly glanced through the pages but did not see anything glaringly out of order. However, please note that I did not check dimensions, bar sizes, bar locations, or bar quantities. It appears that you have adapted transition details from a wood post variation of the Iowa Pooled Fund design from the mid- to late 90s. It is also recognized that you utilized the steel adaptor plate from a prior Missouri Pooled Fund design from the mid 90s. Various cross sectional views are also provided. However, I do not see where they are shown on the plans. In addition, it may be worth considering the use of some vertical bars over the first 4-5 ft to the left of the cold joint since a significant change in geometry occurs here when considering the loss of the foundation system.

At the present time, Bob is looking into alternatives for attaching the thrie beam end shoe and adaptor plate to the single slope barrier face. It should be noted that the embedded anchors utilized in the research study may no longer be available. For roadside applications, through bolts may be used as an option. We should wait to see what Bob comes up with for other anchorage options.

On another point, will the WsDOT be implementing the MGS guardrail in the future. If you anticipate this, you may consider the fact that modifications to the transition will be forthcoming after the project reports are completed.

Ron

Ronald K. Faller, Ph.D., P.E.

Research Assistant Professor

Hi Erik,

I have been looking into your question on the anchorage of the approach transition and I have some comments.

First, the original transition that was tested anchored the thrie beam to the single slope barrier using 7/8” diameter A325 bolts with “self-drilling” Redhead anchors. These anchors had a listed capacity of 20.5 kips in pullout/tension and 24.32 kips in shear. The higher grade bolt was required to address bending of the bolt. The issue that arises is that this anchorage is no longer made. Thus, we looked through the available alternatives.

1. There are not currently available drop-ins or wedge bolt type anchors that are 7/8” diameter nor are any made in high grade steel. It is possible to get 3/4” diameter anchors the meet the 20.5 and 24.32 kip anchor loads, but the bolts will not handle the same bending loads as those in the original design.
2. There are 7/8” diameter mechanical stud anchors available, but neither is available in high grade steel. Thus, they may not be strong enough for the bending loads. Also, studs are not as easy to use as the original anchors and there is some snag potential on the heads.
3. Bolting through is a potential option and is likely the best option for a roadside installation. For median installations, the ends of the bolt present a snag potentials similar to the stud anchors mentioned above.
4. Another option for attachment would be epoxied threaded rod. 7/8” diameter, B7 threaded rod would be stronger than the bolts in the original design and could be epoxied into the concrete. Based on a review of the available epoxies from Powers Fasteners and RedHead, it appears that they would require approximately 7 7/8” of embedment. This may be difficult to embed based on the width of the barrier. Also, there would be potential for snag on the threaded rod similar to the stud option.
5. Dayton Richmond and Williams Form engineering produce and design cast-in-place anchors. It is likely that they could help you develop a template to cast anchors with similar shear and tensile capacities to the originally tested anchors and that would work with 7/8” A325 bolts.
6. An alternative to all of these options would be to cast a vertical face on the end of the single-slope that matches the mounting plate used in the testing. This would eliminate the bolt bending and allow for the use of drop-ins with 3/4" diameter A325 bolts. These anchors exist and we have good experience with them. You could also use a wedge-bolt mechanical anchor in this type of option.

Please look through these options and let me know what you think.

Thanks

Bob Bielenberg, MSME, EIT
Research Associate Engineer

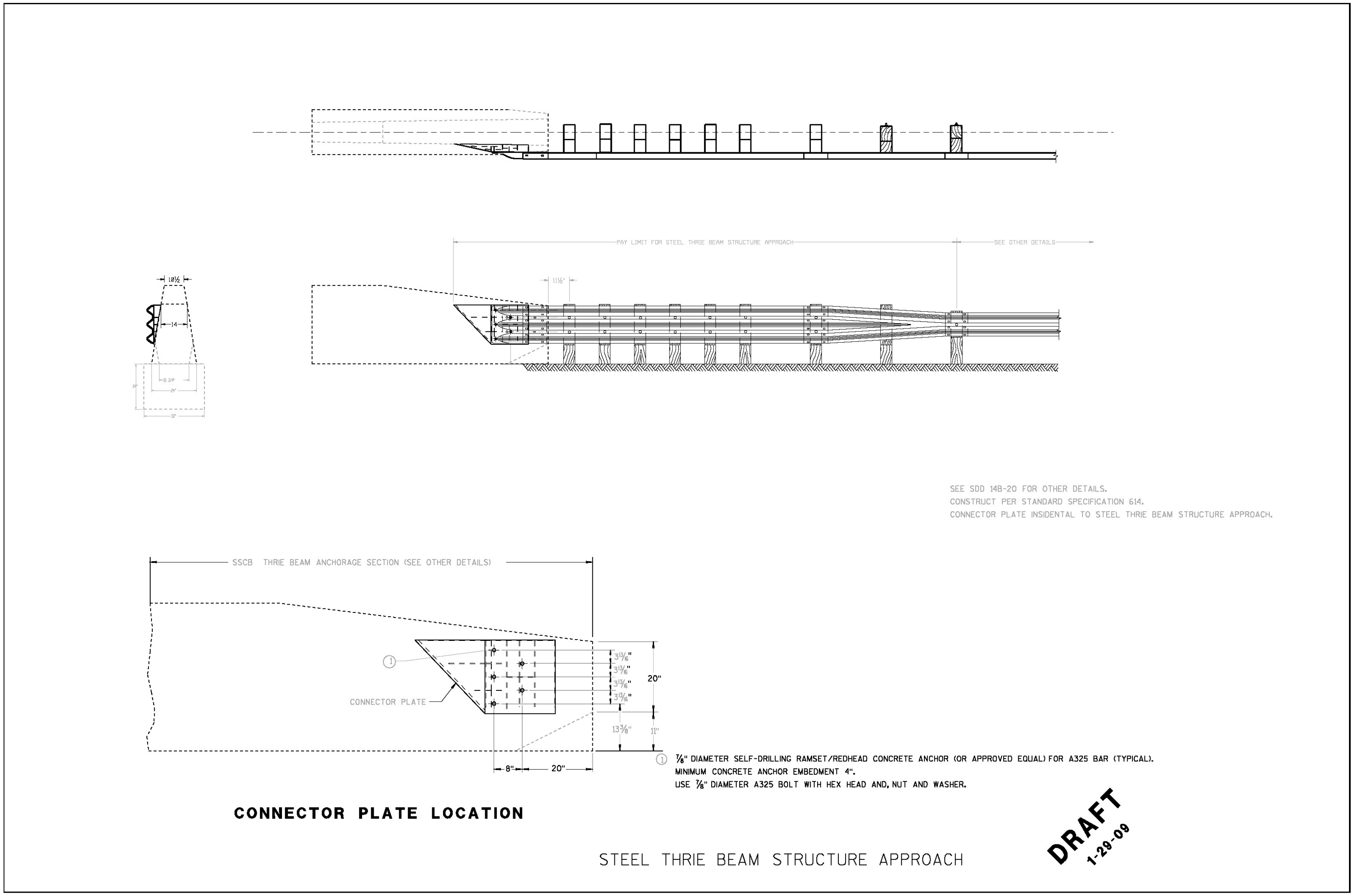



Figure 1. Wisconsin Single-Slope Concrete Barrier Thrie Beam Transition

## GENERAL NOTES

COVER PLATE PANELS ARE 3/16" THICK.

ALL STIFFENERS ARE 1/4" THICK.

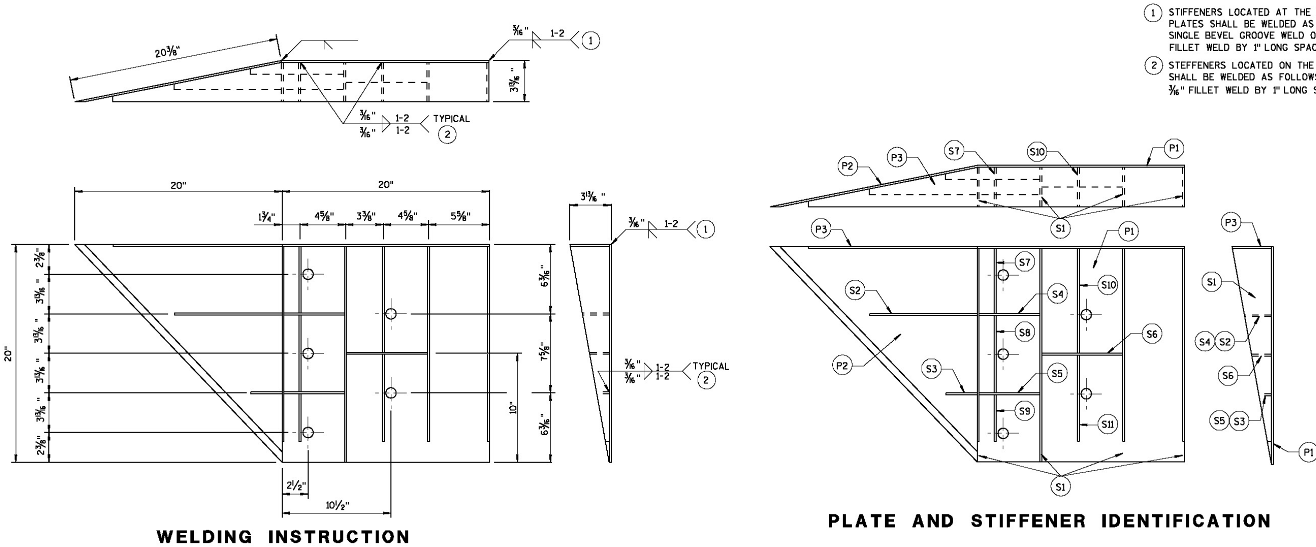
CONNECTOR PLATE SHALL BE FABRICATED FROM ASTM GRADE A36 STEEL AND GALVANIZED.

FOR GALVANIZED REQUIREMENTS, SEE SECTION 614 OF THE STANDARD SPECIFICATIONS.

ALL HOLE DIAMETERS SHALL BE 1".

(1) STIFFENERS LOCATED AT THE OUTSIDE EDGES OF THE COVER PLATES SHALL BE WELDED AS FOLLOWS: SINGLE BEVEL GROOVE WELD ON EXTERNAL SIDES AND 3/16" FILLET WELD BY 1" LONG SPACED AT 2" ON INTERNAL SIDES.

(2) STEFFENERS LOCATED ON THE INSIDE OF THE COVER PLATE SHALL BE WELDED AS FOLLOWS: 3/16" FILLET WELD BY 1" LONG SPACED AT 2".




| PLATE | QTANTITY | SHAPE | SIZE (A × B × C × D) | THICKNESS |
|---|---|---|---|---|
| P1 | 1 | | 20" × 20" | 3/16" |
| P2 | 1 | | 20" × 20" × 28 9/16" | 3/16" |
| P3 | 1 | | 39" × 3 5/8" × 20" × 19 5/16" | 3/16" |
| S1 | 4 | | 18 7/16" × 3 5/8" × 18 3/4" | 1/4" |
| S2 | 1 | | 10 1/4" × 2 7/16" × 10 3/8" × 1/2" | 1/4" |
| S3 | 1 | | 3" × 1 1/16" × 3 1/8" × 1/2" | 1/4" |
| S4 | 1 | | 6 1/8" × 2 7/16" | 1/4" |
| S5 | 1 | | 6 1/8" × 1 1/16" | 1/4" |
| S6 | 1 | | 7 3/4" × 1 3/4" | 1/4" |
| S7 | 1 | | 2 9/16" × 6" × 3 5/8" × 5 7/8" | 1/4" |
| S8 | 1 | | 1 5/32" × 7 1/2" × 2 1/2" × 7 3/8" | 1/4" |
| S9 | 1 | | 6 1/16" × 6 3/16" × 1 3/32" | 1/4" |
| S10 | 1 | | 1 7/8" × 9 7/8" × 3 5/8" × 9 11/16" | 1/4" |
| S11 | 1 | | 8 1/2" × 8 3/4" × 1 13/16" | 1/4" |

CONNECTOR PLATE DIMENSION (PER ASSEMBLY)

DRAFT 1-22-09

STEEL THRIE BEAM STRUCTURE APPROACH

Figure 2. Wisconsin Single-Slope Concrete Barrier Thrie Beam Transition

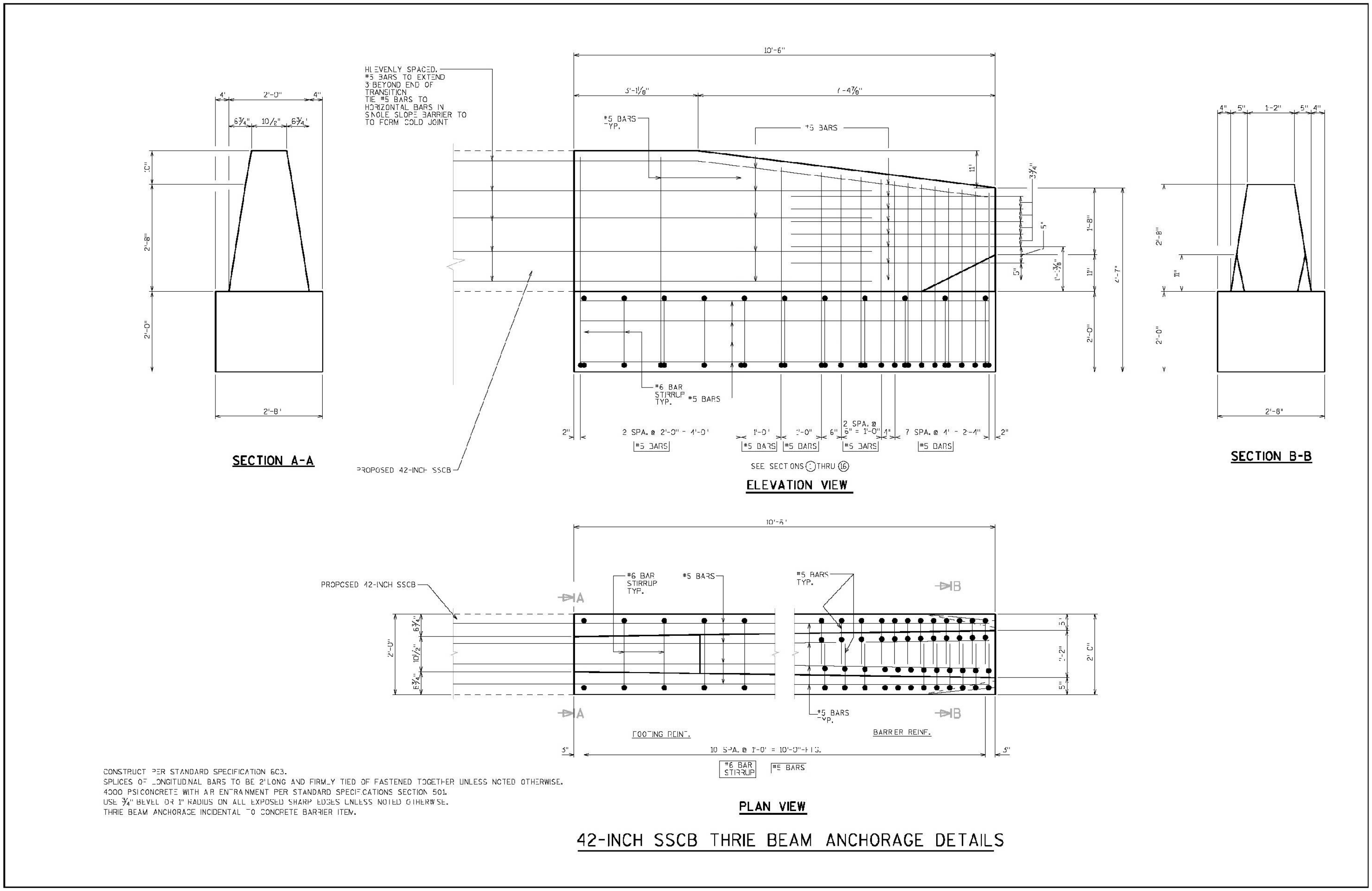



Figure 3. Wisconsin Single-Slope Concrete Barrier Thrie Beam Transition

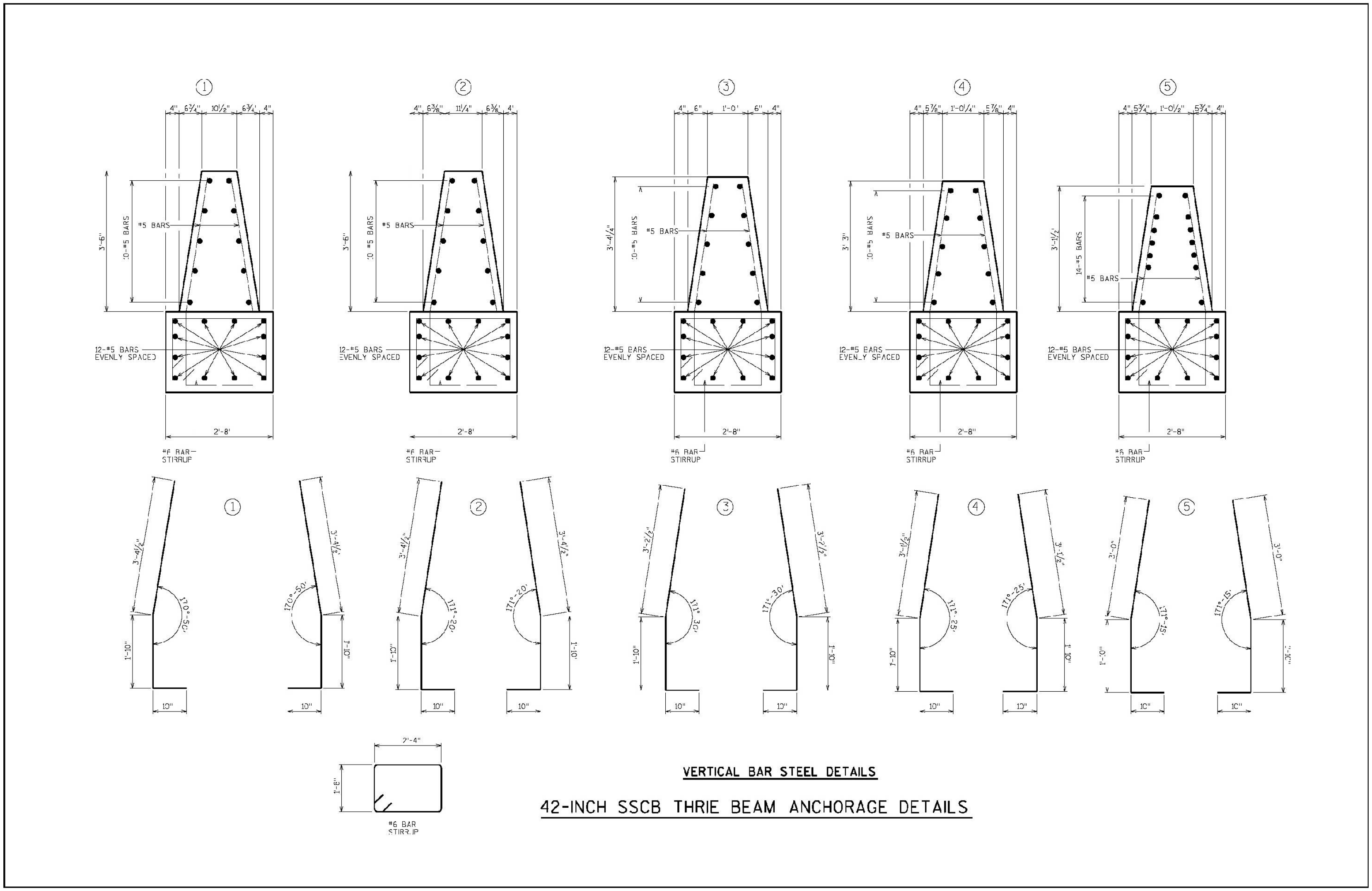



Figure 4. Wisconsin Single-Slope Concrete Barrier Thrie Beam Transition

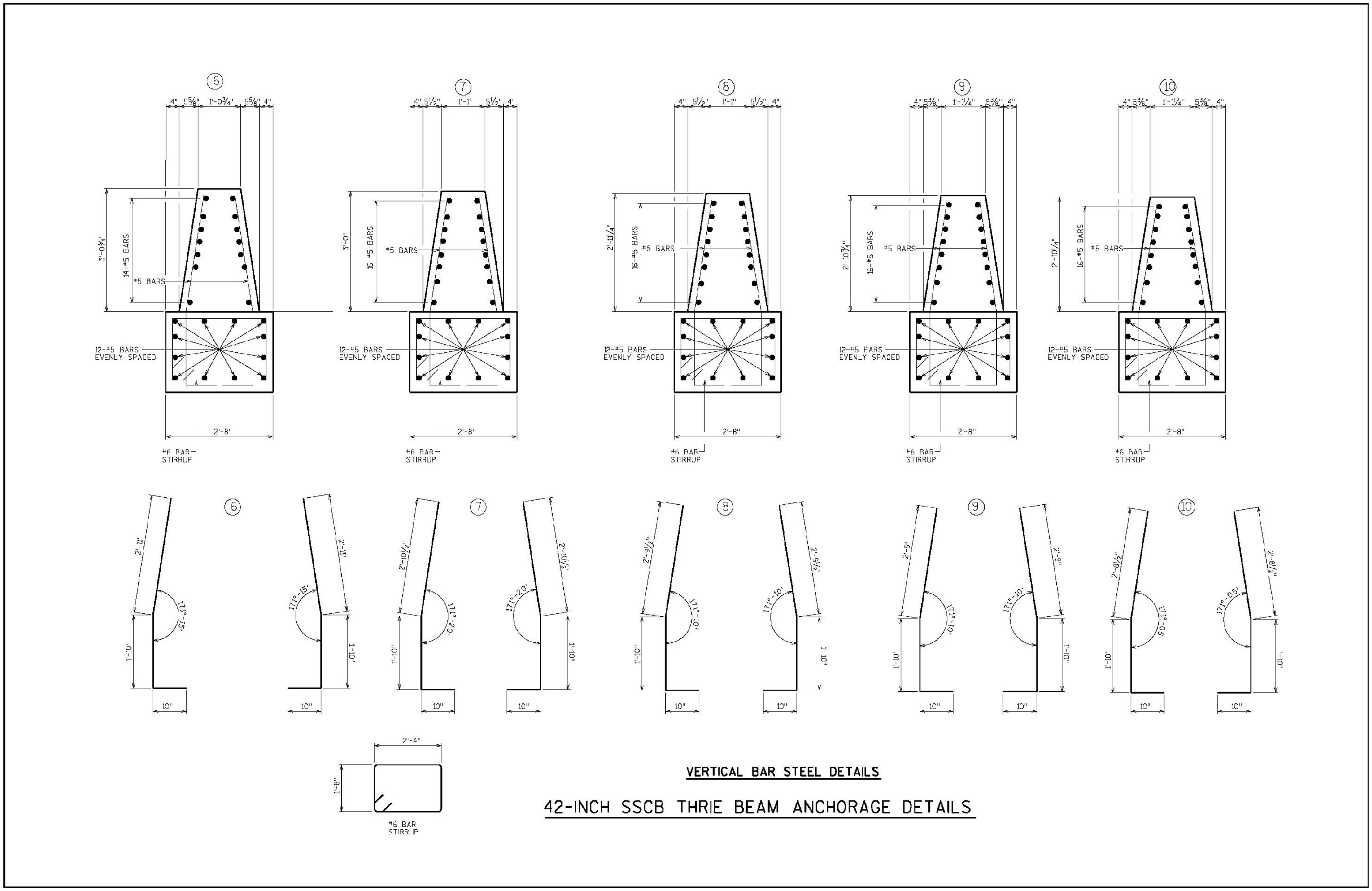



Figure 5. Wisconsin Single-Slope Concrete Barrier Thrie Beam Transition

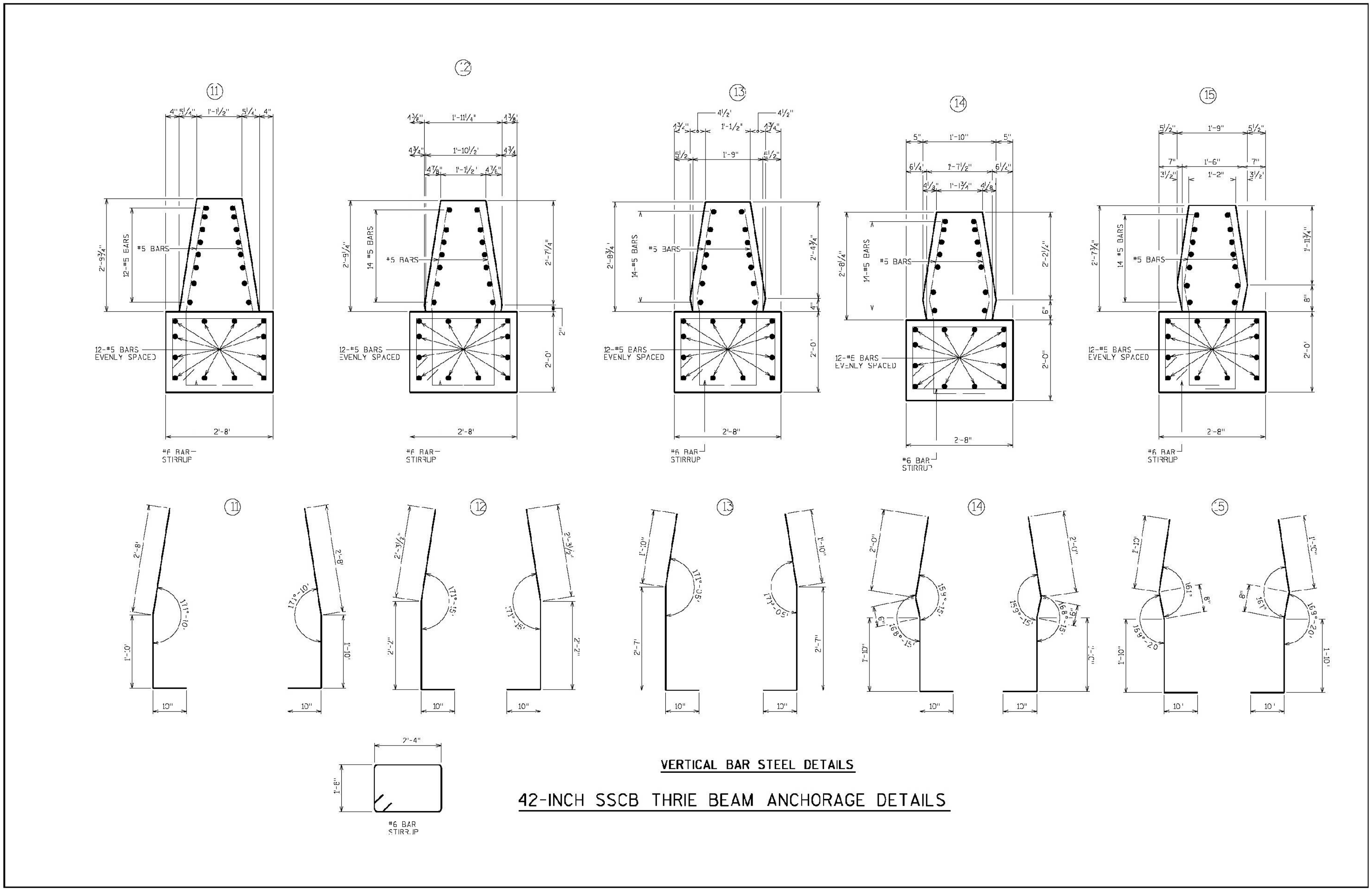



Figure 6. Wisconsin Single-Slope Concrete Barrier Thrie Beam Transition

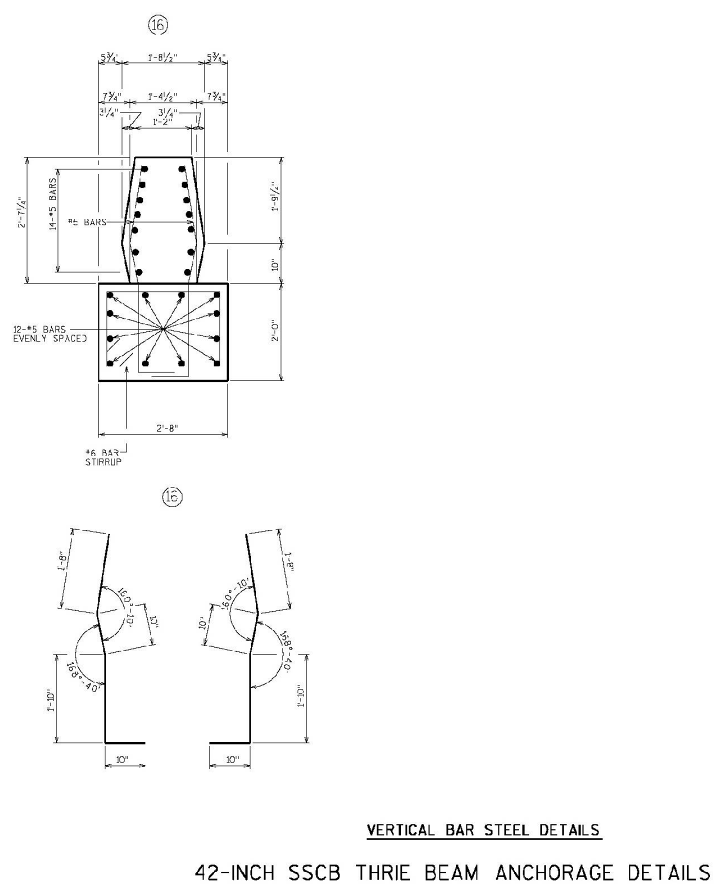



Figure 7. Wisconsin Single-Slope Concrete Barrier Thrie Beam Transition

**Problem # 10 – SSCB Thrie Beam Transition**

State Question:

Wisconsin DOT had a question regarding the Missouri single-slope approach guardrail transition developed at MwRSF (TRP-03-47-95). In that report, the thrie beam end shoe is anchored to the single-slope with "self-drilling" RedHead anchors and 7/8" A325 bolts. Wisconsin could not find similar anchors available from RedHead, and asked what their potential alternatives would be.

MwRSF Response:

Here is a quick summary of the alternatives for this problem.

The original single slope approach guardrail transition used 7/8" diameter A325 bolts with "self-drilling" Redhead anchors. These anchors had a listed capacity of 20.5 kips in pullout/tension and 24.32 kips in shear. The higher grade bolt was required to address bending of the bolt.

The issue that arises is that this anchorage is no longer made. Thus, we looked through the available alternatives.

1. There are not currently available drop-ins or wedge bolt type anchors that are 7/8" diameter or are any made in high grade steel. I can get 3/4" diameter anchors the meet the 20.5 and 24.32 kip anchor loads, but the bolts will not handle the same bending loads as those in the original design.
2. There are 7/8" diameter mechanical stud anchors available, but neither is available in high grade steel. Thus, they may not be strong enough for the bending loads. Also, studs are not as easy to use as the original anchors and there is some snag potential on the heads.
3. Bolting through is a potential option.
4. Another option for attachment would be epoxied threaded rod. 7/8" diameter, B7 threaded rod would be stronger than the bolts in the original design and could be epoxied into the concrete. Based on a review of the available epoxies from Powers Fasteners and RedHead, it appears that they would require approximately 7 7/8" of embedment. This may be difficult to embed based on the width of the barrier. Also, there would be potential for snag on the threaded rod similar to the bolt through option.
5. Anchors could also be cast into the barrier as long as they had similar or greater capacity to the 7/8" A325 bolts used in the original design.

The ¾" anchors may potentially be sufficient, but we could not guarantee the same capacity as the originally tested system. Thus, they would require additional research or testing.

Bob Bielenberg, MSME, EIT
Research Associate Engineer

**Problem # 11 – Road Closure Gate**

State Question:

In February, Wisconsin DOT asked for assistance in analyzing variations of a previously designed and tested road closure gate. The gate system was tested at TTI and is reported in TRR 1528 article titled "Wyoming Road Closure Gate." The luminaire pole used to support the gate arm was equipped with a four bolt slip base design and an 8-ft long mast arm (with light) at the top. The article stresses the importance of a high center of gravity and large mass moment of inertia to prevent the pole / gate system from crushing the top of the vehicle after impact.

Wisconsin wanted to use a variation of this closure gate system in future projects. Some of these variations are listed below:

- Eliminate the light / mast from the top of the pole
- Replace the slip bolt base with another breakaway mechanism
- Adding an electric powered winch to operate the gate
- Addition of solar panels near top
- Addition of control cabinet / battery near base

MwRSF Response:

Alterations would only be allowable if the C.G. height and the mass moment of inertia values met or exceeded the values of the tested system. MwRSF was asked to analyze multiple different luminaire pole types and sizes along with various attachments to the pole for this comparison.

The last design that came from Wisconsin DOT is attached in PDF form. It incorporates a slightly larger pole, solar panel, control cabinet, and a steel collar near the top to replace the light. However, in order to satisfy the C.G. height requirement the weight of the collar must be increased from 83 pounds (as shown) to 141 pounds. The mass moment of inertia is satisfactory. More details are available upon request.

The additional weight of the collar brings the total weight of the pole / gate system to 750 pounds. The originally tested pole had a weight of 543 pounds. This corresponds to a 38% increase in weight. Now, the ORD and OIV values from the tests were low, so it is unlikely that the increased weight will cause detrimental decelerations to the vehicle. Also, the solar panel is mounted high enough that it should fall behind the vehicle when impacted and not cause and damage to the occupant compartment.

The breakaway mechanism at the base of the pole was also being changed. The behavior of the pole/gate may be significantly altered after changing the breakaway mechanism and adding over 200 pounds. Wisconsin was going to run this new design by FHWA to see if the closure gate would still be approved with the different breakaway mechanism as well as the added components.

Scott Rosenbaugh
Midwest Roadside Safety Facility (MwRSF)

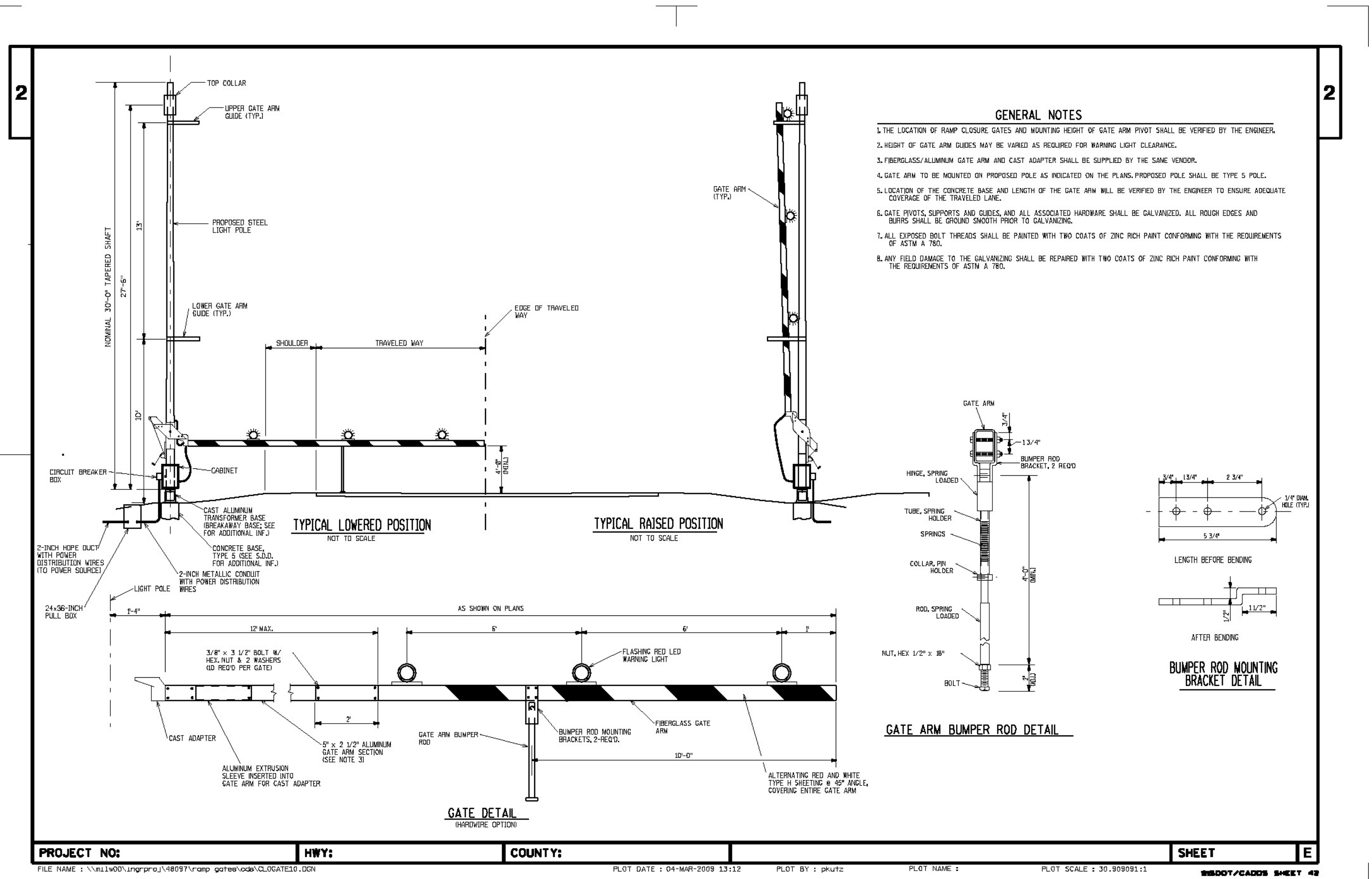



Figure 8. Wisconsin Road Closure Gate

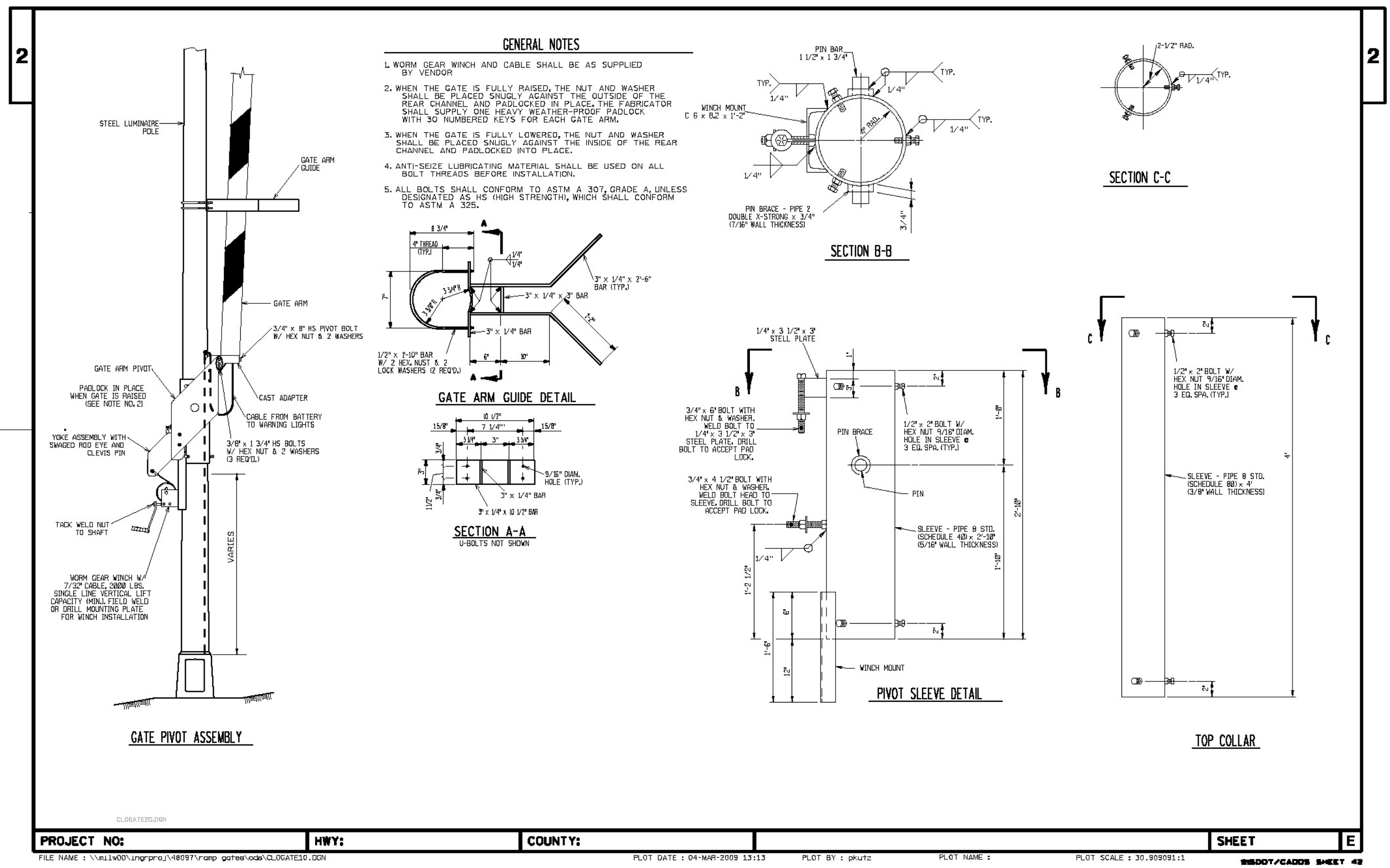



Figure 9. Wisconsin Road Closure Gate

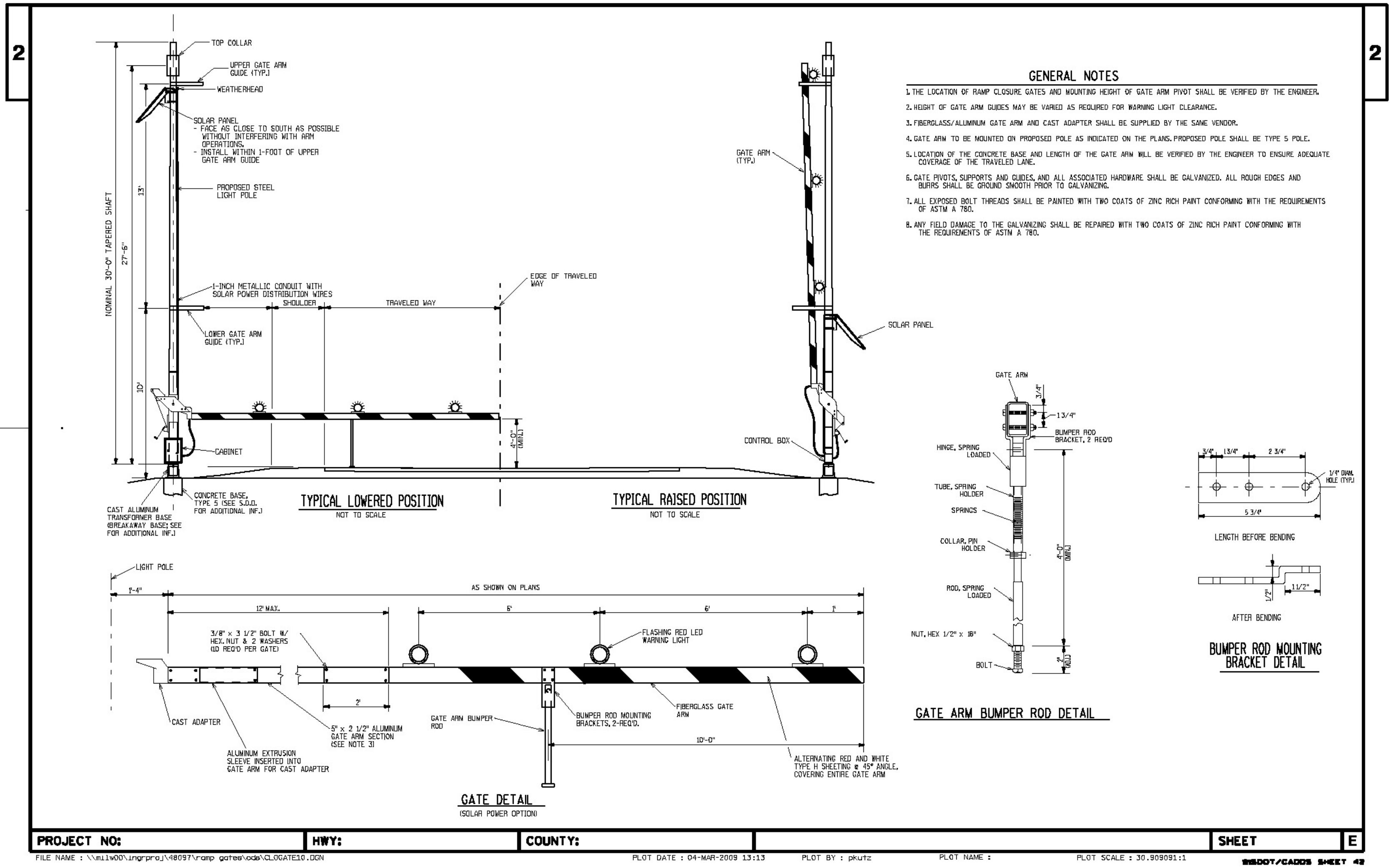



Figure 10. Wisconsin Road Closure Gate

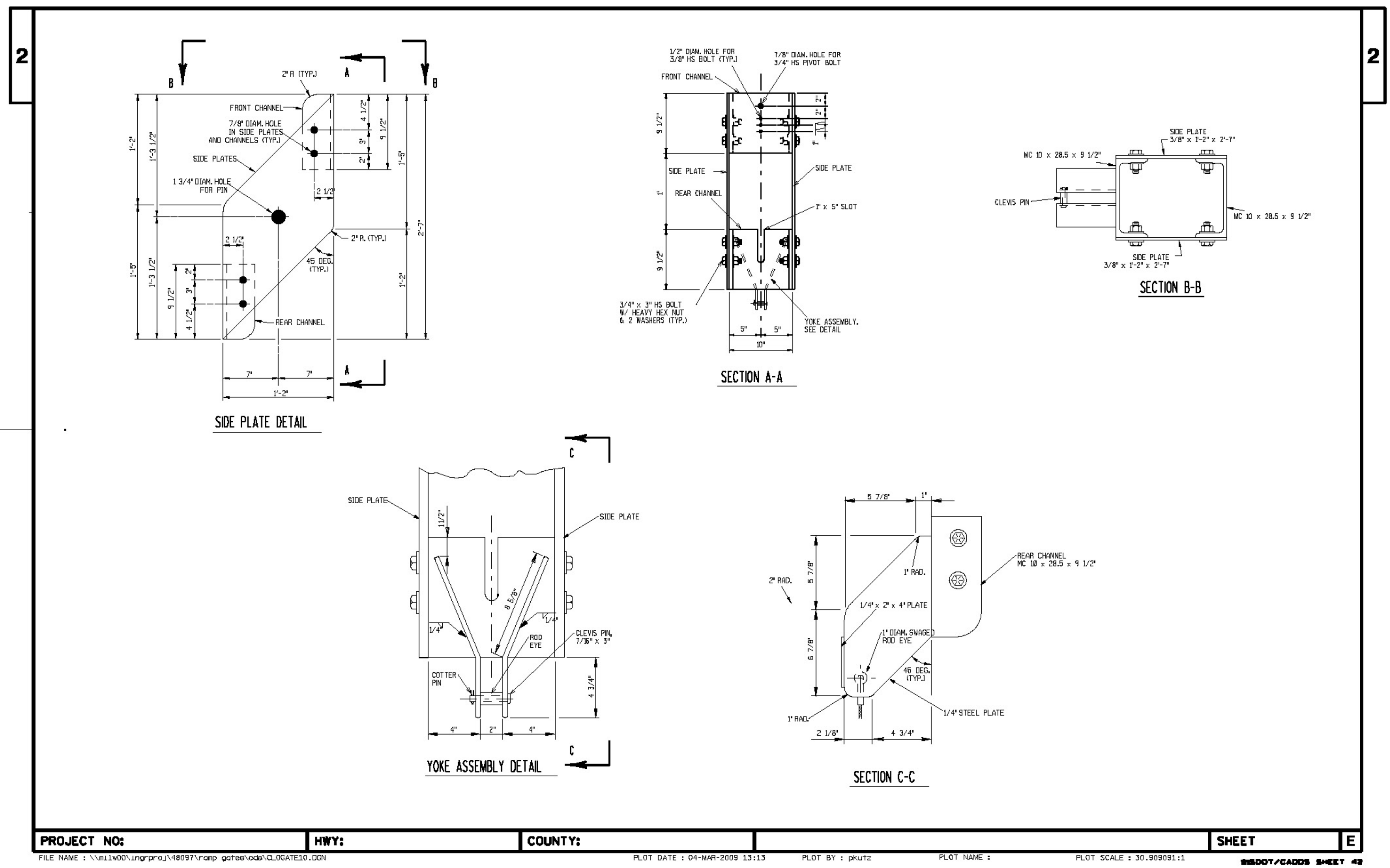



Figure 11. Wisconsin Road Closure Gate

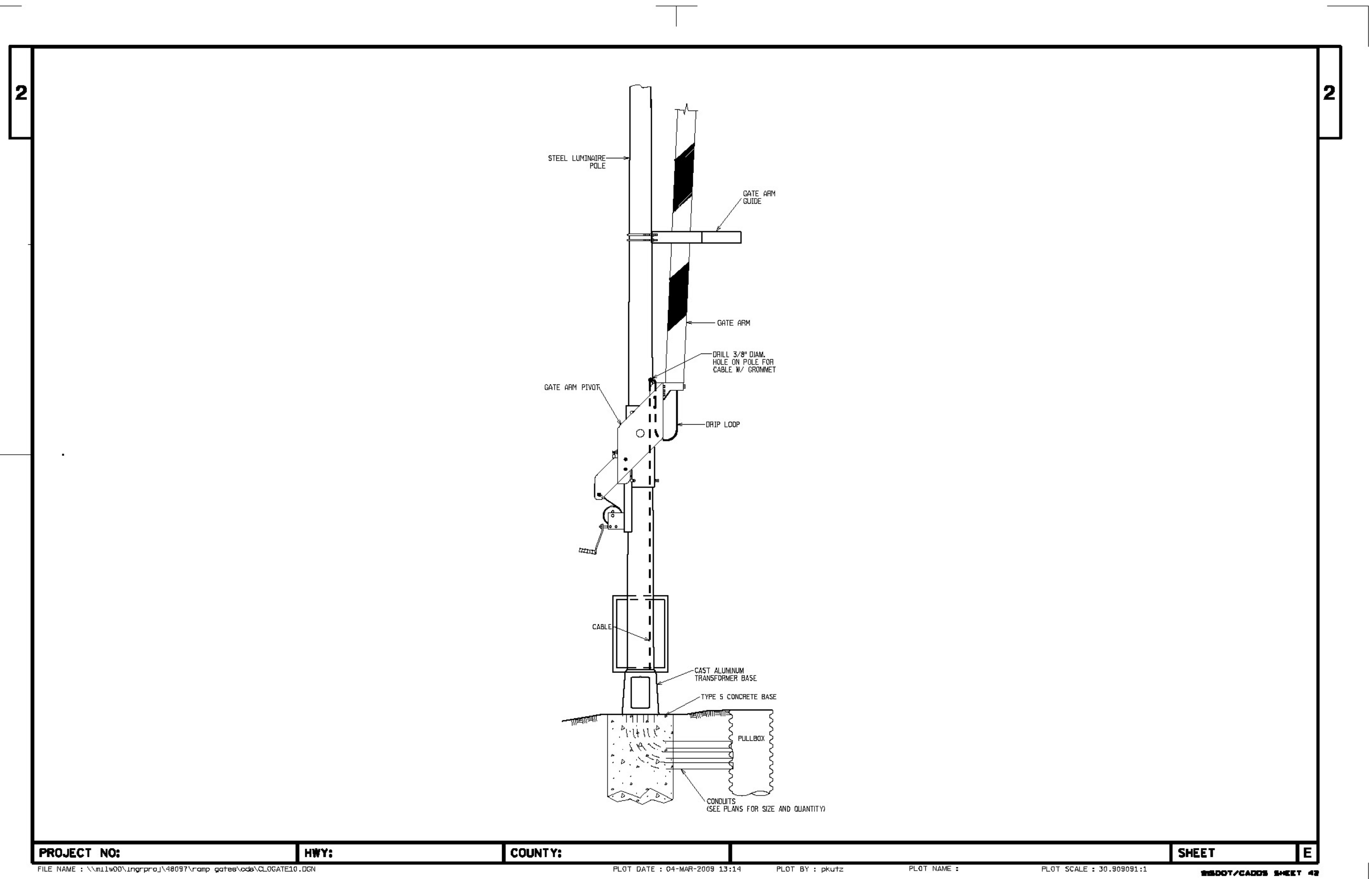


Figure 12. Wisconsin Road Closure Gate