Fourth Quarter 2005 Progress Report
Midwest Roadside Safety Facility
Mid-States Regional Pooled Fund
January 24, 2006

For improved organization we are arranging the Pooled Fund projects in the following order:

1. Projects with Pending Full-Scale Crash Tests
2. Paper Studies not Involving FS Crash Tests
3. Projects waiting for final Reporting
4. Final Report References for Completed Projects will be maintained on our web site (www.mwrsf.unl.edu)

Projects with Pending Full-Scale Crash Tests

Development of a Guardrail Treatment at Intersecting Roadways-Year 3

After discussion at the April Pooled Fund meeting, a design change was developed to eliminate the trigger mechanism in front of the rail system. Bogie testing of the new anchor system was completed and information regarding the change was distributed to the States and found acceptable to the majority. A full-scale 820C test (SR-6) was performed on 10/7/05. While the vehicle was captured in the system, there was substantial damage. The test was determined to be a marginal pass. We are going to rebuild the system and perform a test with an update 2270P vehicle to evaluate the changes made in the system. That test is anticipated early in the 2nd Quarter of 2006.

Three-Cable Guardrail

Based on responses from the States, we are going to proceed with this test utilizing an offset distance of 48" from a 1.5:1 slope and 4' post spacing. This test will follow culvert testing.

Development of a Four-Strand, High-Performance Cable Barrier

This research plan will focus on two primary issues facing application of the system. The first will involve evaluation of the system at the base of a V-ditch and at other potential locations along the slope to determine critical locations. LS-DYNA modeling will be utilized to evaluate the influence of moderate roadside slopes on system performance. Results of crash tests on flat ground will be used to refine the barrier model and improve its accuracy. The modeling will be utilized to determine the maximum ditch slope and depth at which the barrier can be expected to perform adequately. The second objective is the design of an anchorage system to provide long term maintenance of cable tension. This design effort will by necessity consider a variety of potential soil conditions and provide guidance for design of anchorage based on in situ conditions that may be encountered a various sites. Two full-scale crash tests of the new system (1 @ 820C and 1 @ 2000P) are budgeted herein to verify performance in a V-ditch. Additional funding will be required at the completion of this effort to evaluate system compliance at TL-4.

Evaluation of Transverse Culvert Safety Grate

Full-scale testing is anticipated in the 1st or 2nd Quarter of 2006 depending on the weather. We have completed a test pit and are currently constructing the 20' X 20' culvert grate system which will be tested on a 3:1 slope.

Flare Rates for MGS W-Beam Guardrail

The first full-scale test with a 2000P vehicle was performed on May 24th. The system was constructed at a nominal flare of 13:1. The vehicle was safely redirected with all salient criteria being satisfied. Based on the actual impact angle of the vehicle with the system, and the relatively high velocity of the impacting vehicle, the effective impact severity in this test reflects a system with a flare of approximately 8.4:1. Subsequent to this result a second test was completed on August 2nd, this test utilized the MGS system at a 7:1 flare. Considering vehicle speed and angle, the effective impact severity of this test was 5.75:1. The vehicle was safely redirected with all salient criteria being satisfied. To confirm performance of the system, an 820C test was performed on August 17th. Again, this test satisfied all salient criteria with an effective flare angle considering actual speed and impact angle of 6.06:1. To establish a maximum acceptable flare rate, the final test funded under this contract will be performed utilizing a 5:1 flare. This 2000P test is planned as early next year as weather will allow.

Approach Slopes for W-Beam Guardrails Systems

Based on the result of our simulation study and feedback from States we will initially test an MGS system located 5' from travelway on an 8:1 slope. This offset distance was deemed critical during the simulation study, so success at this offset would indicate that locating an MGS system at any distance from the travelway on an 8:1 or flatter slope would be acceptable. If this test is successful, a steeper slope will be investigated.

Concept Development of a Bridge Pier Protection System for Longitudinal Barrier

Plans for the proposed system were distributed to the States in the 3rd Quarter. We are anticipating beginning construction of the system in the 4th Quarter and testing in the Spring.

New TL-5 Median Barrier and Anchor

The literature review for this project is nearing completion. Design and subsequent requests for review from Pooled Fund States is anticipated in the 1st Quarter.

Long Span Design for the MGS Guardrail System

The design of this system has been submitted to the States and comments have been returned to MwRSF. We are currently finalizing the design based on feedback from the States. A system drawing is in preparation and will be distributed in the next Quarterly report.

Midwest Guardrail System on Breakpoint of a 2:1 Slope

Simulation of this system will be continued in the 1st Quarter. Investigation of the effects of eliminating the need for reduced post spacing is the first task that will be undertaken.

Cost Effective Measures for Roadside Design on Low Volume Roads

No progress to date.

Termination of Temporary Concrete Barrier

No progress to date.

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

We are currently producing the MGS and other recent developments for submission, we will work on the backlog of past developments over the next year.

Redesign of Anchors for Temporary Concrete Barriers

No progress to date.

Develop Temporary Concrete Barrier Transition for Highest Priority Problem

This project will wait until the conclusion of Evaluation of Temporary Transition Needs.

Evaluation of the Safety Performance of Vertical and Safety Shaped Concrete Barriers

No progress to date.

Paper Studies not Involving FS Crash Tests

Evaluation of Temporary Transition Needs

A survey of Pooled Fund States is currently being prepared to determine which temporary barrier transitions designs are needed, where the transitions are used, and the importance of each.

Awaiting Reporting

MGS W-Beam to Thrie-Beam Transition Contingency 2000P Test and Additional 820C Test

Utilizing the fabricated 10 gage welded asymmetrical thrie-beam section, two full-scale crash tests of this system were performed this quarter; a 2000P test on 11/10 and an 820C test on 11/22. Both tests performed well, meeting all salient criteria.

Open Railing Mounted on New Jersey Concrete Barrier (2'8")

After two unsuccessful tests of this system, we are planning on preparing a final report on the project.

Evaluation of Rigid Hazards in Zone of Intrusion

The third and final full-scale test in this project, a luminarie pole mounted on the concrete deck behind the barrier was performed on 3/3/05. The interaction of the single axle truck and the luminarie pole were incidental, but maximum intrusion over the barrier occurred before the vehicle reached the pole. All salient criteria were satisfied. In review both TL-3 and TL-4 tests of a luminarie pole mounted on the top of a 32" single slope barrier and behind that same barrier successfully passed full-scale testing with the qualification that the impact condition for the pole mounted behind the rail was not "worst case". A report for this study will be initiated.

Retest of the Cable End Terminal

Based on successful testing of this system a final report of the project will be initiated.

MnDOT Work Zone Sign Testing

Results of additional testing under this project.

Pooled Fund Consulting Summary

Midwest Roadside Safety Facility
October 2005 – January 2006

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 – Long Span and Short-Radius Guardrail

State Question:

Hi Ron,

Yet another question for the MWRSF's designed Ohio Long Span guardrail design. Previously, I asked about increasing the length of the span and about its interaction with a curbed drainage inlet.

Can any portion of the TL-3 long span be installed on a radius?

Ohio, maybe more than the other Midwest Pooled Fund states, have lots of driveways and side roads directly next to streams. As other states do, Ohio uses the radius guardrail to transition to the side road/driveway.

For example, eastern states property frontages are narrow, and this fact usually places driveway access right in the middle of the LON of a guardrail run off of a bridge or culvert. The short radius rail needed. But on the Ohio Long Span design, the system is 100 feet long, meaning 37.5 feet of nested rail is placed in advance of the actual long span portion. Can any portion of this rail be radiused?

I am hoping the last 25 feet (outside of the CRT post area) can be, but I am afraid I know the answer you'll give.

As usual, I appreciate your insight on this.

Thanks,
Dean Focke

MwRSF Response:

The crash testing of the long-span guardrail system was conducted with the entire system installed parallel to the roadway, including the nested and non-nested guardrail segments as well as both anchors. Without further testing, it is difficult to allow or recommend the use of a curve or radius within the upstream or downstream segments of the nested W-beam guardrail adjacent to the long span since a curved or radiused rail could affect the system's overall safety performance near the long-span region due to a change in tensile capacity.

As noted above and at this time, we cannot recommend the use of a radius within the nested guardrail length of 37.5 ft. After that distance, it may be possible to begin the short radius guardrail design which consists of a straight thrie beam guardrail section prior to reaching the curved thrie beam section. A transition region would be needed between the thrie beam section and the W-beam section. Using the existing long-span and short radius guardrail configurations, the culvert would need to be a minimum specified distance away from the curved thrie beam section (and intersecting road or drive) based on the geometry of the two current barrier systems. If the primary side of the short radius guardrail did not attach to a bridge rail (as currently being developed), there may be some possibility to shorten the required thrie beam length downstream of the curved thrie beam segment from that currently used.

Please feel to contact me if you have further questions or comments!

Ron

Problem # 2 – Long Span Guard Rail over Low Fill Culverts, and Curbs

State Question:

With the completion of NCHRP Report 537 on Recommended Guidelines for Curb and Curb Barrier Combinations, would you have any concerns with allowing a sloped mountable curb (height less than 100mm) to be installed with the sloped portion of the curb directly under the W-beam for the long span system? Based on my review of Report 537 recommendations for roads with speeds greater than 90km/h (p86), I think this combination would be OK for the long span system as well. Would you have any concerns?

If you respond by e-mail, send me your phone number as well which I seem to have lost from my Contacts list.

Thanks,

Mark Ayton, P. Eng.
Senior Engineer, Highway Design
Highway Design Office
Ontario Ministry of Transportation
Garden City Tower, 2nd Floor North
301 St. Paul Street
St. Catharines, Ontario
L2R 7R4

MwRSF Response:

With regard to long-span W-beam guardrail systems, we believe that there exists a reasonable chance that the standard long-span guardrail system would perform in an acceptable manner when placed over a 4-in. tall curb.
This opinion also would correspond to the toe of the curb being positioned at the face of the guardrail. However, it should be noted that the long-span guardrail system with a lower 4-in. tall curb has not been evaluated according to the NCHRP Report No. 350 impact safety standards. In summary, we are reasonably confident that the long-span guardrail with noted curb would be okay to use on high-speed, high volume roadways.

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

Problem # 3 – Median Cable Guardrail / Bullnose

State Question:

Dean,
I think Missouri requested an informed opinion on how to place high tension
cable guardrail in the median.
When to terminate it prior to bullnoses, or tied in behind W-beam End Treatments?
Do any of the high tension cables allow placement on slopes greater than 10:1?

Thanks

Phil TenHulzen P.E.
Design Standards Engineer,
Roadway Design Division,
Nebraska Dept. of Roads
ph. (402) 479 - 3951

MwRSF Response:

Dr Sicking asked me to respond to you regarding you questions on high-tension cable guardrail systems. I will answer you questions as best we can, while keeping in mind that we have limited information on these systems because they were designed and tested elsewhere.

1. When to terminate it prior to bullnoses, or tied in behind W-beam End Treatments?

I reviewed the full-scale crash tests for the major high tension cable systems. All of the reviewed systems had dynamic deflections between 6.5 and 8.9 ft when impacted with the 2000P vehicle under TL-3 impact conditions. Keeping in mind that these tests where conducted on relatively short installations, we can expect slightly higher levels of dynamic deflection in longer installations. As such we would recommend at least a 10-ft lateral offset between the high tension cable barrier systems and the bullnose. In addition, we would recommend termination of the high tension cable barrier at least 31’ downstream of the first post of the bullnose. This distance should be sufficient to allow the bullnose to provide redirection of a vehicle if it impacts near the cable end terminal and gates through the terminal. See the attached pdf file for a schematic. Another alternative might be to not use a bullnose at all, but rather an end terminal appropriate for median use with a similar offset for the cable.

As far as tying the high tension cable behind W-beam end terminals, we cannot give much guidance. We have successfully tested two low-tension cable guardrail to W-beam end terminal end treatments in the past. These are the FLEAT cable transition and the South Dakota cable transition. However, we cannot predict how these designs will perform when used with high-tension cable barrier systems and thus cannot recommend their use. We would recommend that you contact the individual high tension system manufactures for their recommendations.

2. Do any of the high tension cables allow placement on slopes greater than 10:1?

Based on our current knowledge, none of the high-tension cable guardrail systems have been tested on a slope at this time. As such, we would be forced to recommend that they be used on slopes of 10:1 or less for the time being. We do believe that the cable barrier manufactures are starting to attempt to address this issue. Again we would recommend that you contact them in order to get the most up to date information on their system for applications on slopes. We would be interested to see what they have to say.

Let me know if you have further questions or comments Phil.

Thanks

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

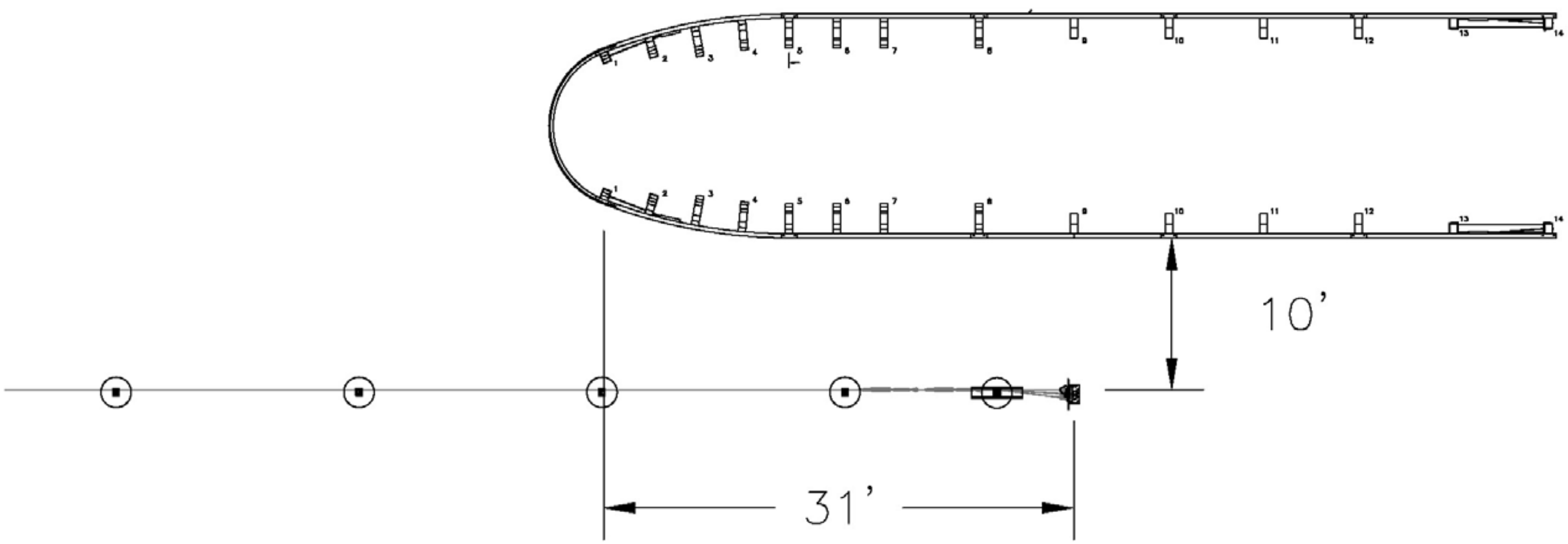

Figure 1. Bullnose – High Tension Cable Offset

Problem # 4 – F-Shape PCB Transition to Rigid Barrier – Thrie Beam Splice

State Question:

Hi Bob,

I'm working on our FTB to rigid barrier thrie beam splice drawings and I need to ask you a few questions about the design. I've attached PDF's of our preliminary drawings:

(See attached file: 0715s08 2.pdf)(See attached file: 0715s08 1.pdf)

When you get time, please take a look at these drawings and the following questions:

1. What size and type of bolts are used to attach the thrie beam terminal connectors to the barriers? In our drawing 8 of 9 above we've shown a through bolted connection using five 7/8" dia. HS bolts (ASTM A449 Type 1) with hex nuts and washers under the nuts and heads. This is what we use for permanent attachments of thrie beam to our concrete traffic railings. In the attached photo you sent me, it looks like some kind of big lag screw (3/4" dia.?) was used for the test installation:

(See attached file: DSCN2687.JPG)

Can you give me any specs or the name of a manufacturer for these lag screws/bolts? Do these screws/bolts require the use of an expansion sleeve? If we wanted to use through bolting only, do you see any problems other than fit up of the bolts and the terminal connectors on the two opposite sides of the barriers?

2. Proper lateral positioning of the FTB relative to the end of the permanent barrier is proving to be a challenge with all the different shape barriers and end transitions we currently use or have used in the past - 32" F shape (shoulder and median), 42" F shape, 32" Jersey shape (shoulder and median), 32" and 42" vertical face, corral shape, 8' F shape / soundbarrier, etc. On drawing 8 of 9 above we show two combinations: 1) FTB to permanent median barrier and 2) FTB to an old FDOT style shoulder barrier transition.

Depending on the shape and overall thickness of the permanent barrier and lateral positioning of the FTB, potential snag points could be created. We're still looking at all our possible combinations of approach and trailing end configurations. One combination with a possible snag point is shown on the upper right corner of drawing 8 of 9. If the direction of adjacent traffic is right to left on this plan view, the exposed lower end of the FTB could be a snag point. To reduce this potential I'm thinking of filling the cross hatched area with miscellaneous asphalt. If the direction of adjacent traffic is left to right on the plan view, the potential for a snag looks to be minimal.

Another problem seen in this same plan view is bending and fit up of the thrie beam guardrail on the back side of the barrier. I'm thinking of using offset blocks on the back side of the FTB between the FTB and the terminal connector so the thrie beam doesn't have to be bent as shown. A second offset block may be needed at the end of the FTB to engage the middle portion of the thrie beam.

When you get time, please take a look at these issues and let me know what you think.

Thanks again,

Charles E. Boyd, P.E.
Senior Structures Design Engineer
Florida Department of Transportation
Structures Design Office

MwRSF Response:

I got a chance to go through your PCB transition questions this morning. I have written my responses and comments below. Please respond with any further questions and comments you have for us.

1. The bolts used in the full-scale test were 3/4” dia. by 6” long Powers Fasteners Wedge Bolt Anchors. We have been using these anchors quite a bit lately and have been happy with them. We use them to attach the SAFER barrier to the concrete walls of the race tracks. It does not use a sleeve. On important note on these anchors is that we used the anchors with a minimum 8” spacing between anchors. The performance of the anchors can degrade under smaller spacings. As such, you may need to change the anchor layout shown on you drawing to use the three outer holes in the end shoe and the two inner holes. This is shown in the picture you emailed me. This layout gives the 8” spacing.

As far as through-bolting the end shoe, that is fine as well. You may encounter issues hitting rebar as you mentioned.

2. Charles, as you mentioned, the snag risk at this location is not significant unless the potential for two way traffic and reverse hits is present. However, we would recommend that the potential be reduced in this situation. Ron and I discussed you suggestion to use asphalt to fill in the hatched area. We believed that this should reduce snag, but we have a couple of concerns. First, it would be important to use the fill asphalt to make a smooth and complete fill of the hatched area. The fill should completely cover the area and any gaps would be undesirable. Second, we are a little concerned about the ability of the asphalt to prevent rim and wheel of an impacting vehicle from gouging or digging into the asphalt and creating a snag hazard or exposing a corner of the barrier. A better method may be to make a simple form and place a concrete fill in the hatched area. This will be more resistant to gouging during the impact and provide better reduction of snag potential.

You can use offset blocks to eliminate the need for the bending the thrie beam in this situation, but there are some things to consider. First, you will want to offset the beam from the barrier at two locations at a minimum and more would be preferable. You would want to block the area near the joint between the barriers as well as the of the end shoe connection at minimum. It should also be noted that the use of the blockouts may introduce bending loads into the bolts or anchors used in the end connection with the blockout. Thus you may want to check and possibly increase the capacity of these anchors. I would not recommend using the Wedge Bolt anchors in this installation due to lack of bolt embedment and the potential for bending loads. Instead I would require the through-bolt option here.

I have a couple of other comments about your CAD with the four types of installations. On the top installation, the median installation, there may be some issues with reverse hits on the non-staked side of the transition barriers downstream of the permanent barrier. I think we have discussed before that impacts with the stakes on the back side of the barrier are very likely to result in increased rotation of the barrier sections and thus increased potential for vehicle instability. As such, we are not very excited about the use of the transition in the median area. However, we realize that you may have no better options at this time. Until we have investigated this issue more thoroughly, the best recommendation I can give is that we are concerned about reverse hits in this installation due to the potential increase in barrier rotation and resulting increase in vehicle instability. Another thing to keep in mind with the median installation is slopes. Do you know what kind of slopes you will be installing the barriers on??

My last comment concerns the fourth installation detail at the bottom of the page. This trailing end transition should be fine for installations only dealing with one way traffic, but on narrow highways with two way traffic, the potential for reverse hits on this installation is significant. In that case we would recommend you install the approach transition here.

Thanks

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

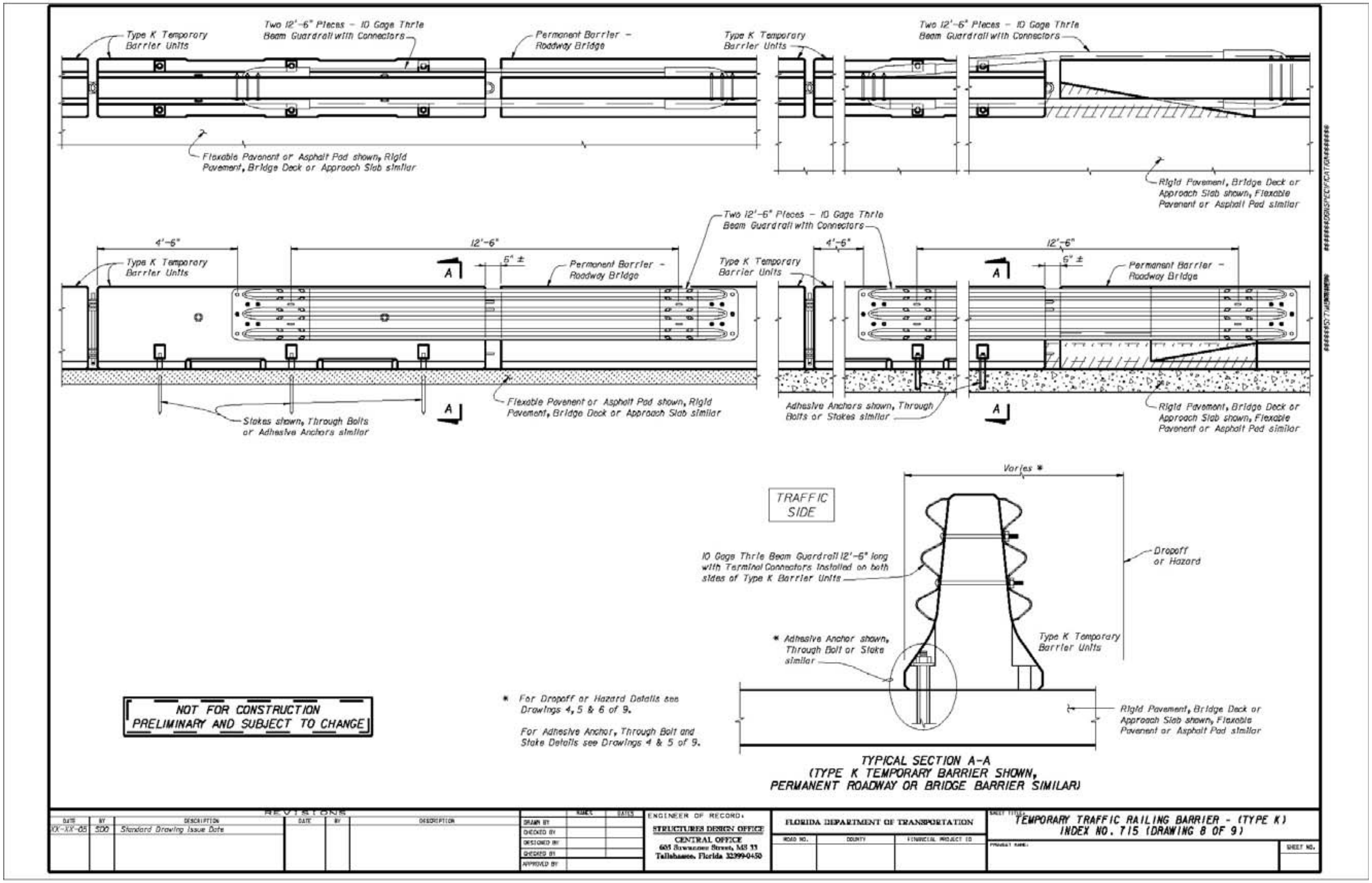

Figure 2. Florida PCB Transition Splice

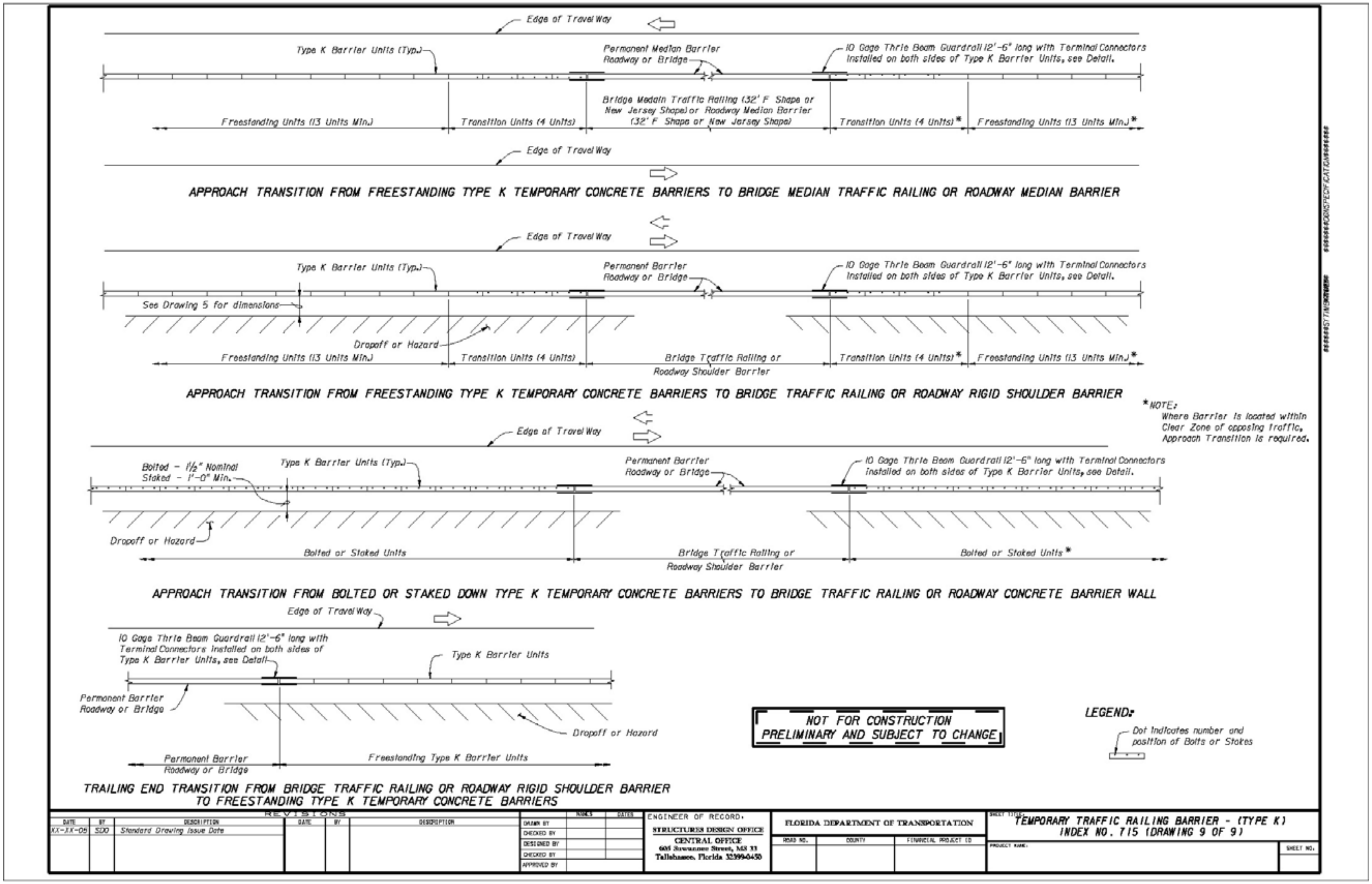

Figure 3. Florida PCB Transition Splice

Figure 4. MwRSF Tested PCB Transition Splice

Problem # 5 – F-Shape PCB Transition to Rigid Barrier – Thrie Beam Splice – Part 2

State Question:

Hi Bob,

Here is a sketch that shows our old F and NJ shape traffic railing transition, an FTB and a Thrie Beam Splice:

(See attached file: Old Transition.pdf)

This section of traffic railing is supported by the wing wall that is part of the end bent. The bridge would be at the far left side of the sketch.

The old W beam guardrail end shoe would have bolted up to the 2'-6" long "End Post" section. We plan to fill in the recess at the bottom of this section with concrete to reduce the snag potential for traffic moving left to right. For traffic moving right to left, we plan to leave the recess open. The Offset Blocks at the back of the FTB are there to keep the Thrie Beam straight (unbent).

The "Varies" dimension is drawn at 1'-0" but could be any length from 0' to many feet. Our problem shows up at the left end of the "Varies" dimension where the Thrie Beam Terminal Connector straddles the deck expansion joint.

We can't bolt across this joint with the Terminal Connector as thermal movements of the bridge would likely tear the connection apart. Thus we're thinking of using a 25' stick of thrie beam to get the left Terminal Connector (as seen in the sketch) up on the bridge beyond this problem area. The right Terminal Connector would be attached to the FTB at the same location as is currently shown.

Let me know what you think. Thanks!

Charles E. Boyd, P.E.
Senior Structures Design Engineer
Florida Department of Transportation

MwRSF Response:

Hi Charles

Dr Faller and I have looked over your temporary barrier transition problem and have come up with some guidance.

1. The schematic you sent me is acceptable even with a 12" gap between the final PCB and the bridge transition piece as long as the there is only one way traffic on the roadway. If traffic is moving from the PCB's towards the bridge in your schematic, then the chance for snagging on

the end of the bride is minimal, and the thrie beam sections should possess sufficient capacity to hold the joint between the bridge transition and the PCB together even with the larger gap.

If the traffic is moving the other direction, you said you planned to fill the overlap area with concrete to reduce the snag potential. We agree that this is necessary and quite critical. It may be your best option to fill that area for now, but you may want to think about a redesigned transition section in the future to reduce the snag potential. In general, we would recommend not running two way traffic in this type of installation unless the snag issues can be sufficiently eliminated.

2. As far as the connection to the bridge rail on the downstream end, I agree that you don not want to straddle the expansion joint. A simple fix for this problem would be to shift the thrie beam sections upstream or downstream as needed to prevent straddling the deck joint. Shifting the thrie beam 12"-18" in either direction should not have a large effect on performance, and it would be simpler and cheaper than using a 25' long section to guarantee that you extend past the joint. For the installation in the schematic, you could shift the thrie beam sections upstream a few inches until the end shoe was positioned on the flat face of the end post/transition piece. We would probably prefer this shifting of the thrie beam rather than using the longer section.

Hope this helps with your questions. Let me know if you need anything else.

Thanks

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

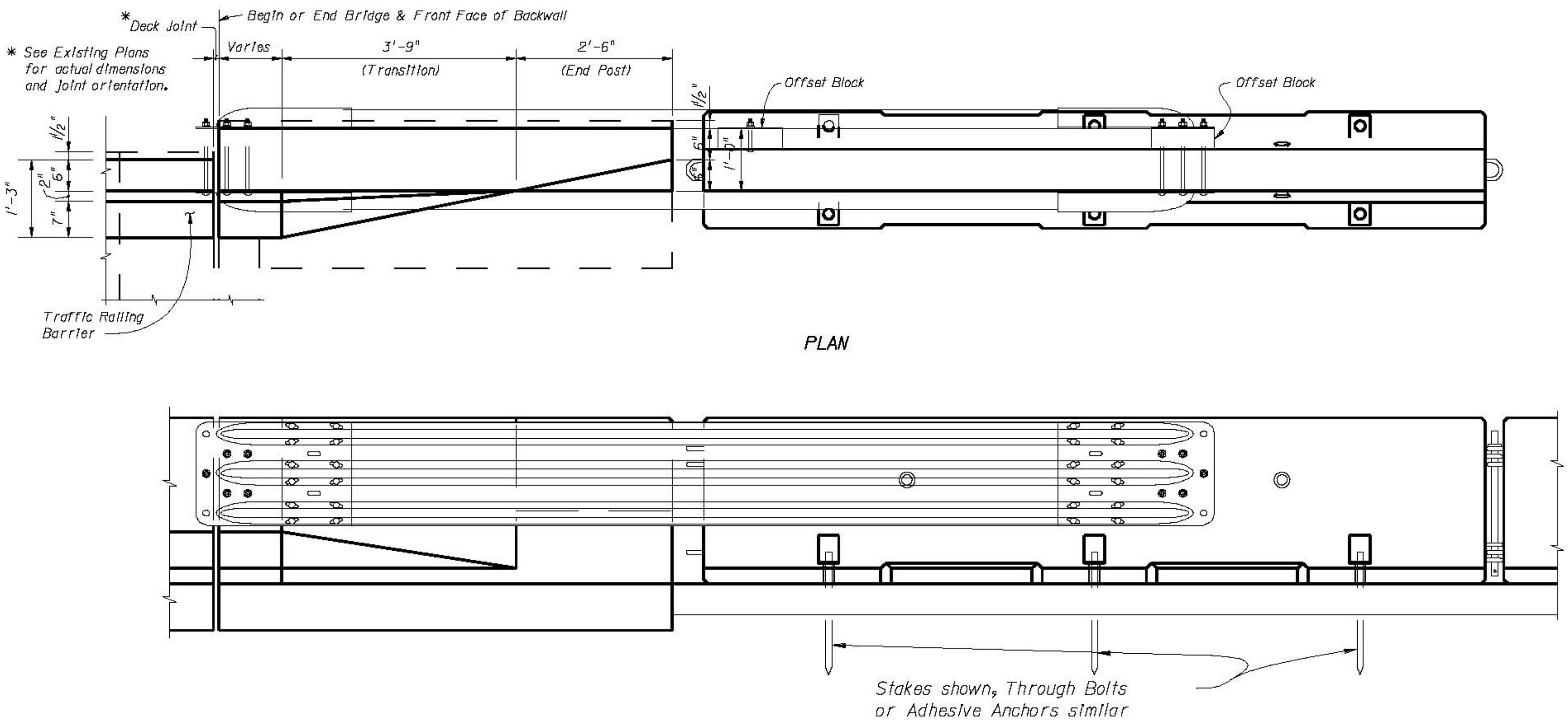

Figure 5. Old FLDOT Transition Schematic