Third Quarter 2006 Progress Report
Midwest Roadside Safety Facility
Mid-States Regional Pooled Fund
November 4, 2006

Projects with Full-Scale Crash Tests This Quarter

Evaluation of Transverse Culvert Safety Grate

A full-scale test utilizing a 2000P vehicle was completed on July 20th. As shown in the enclosed sequential, the 2000P vehicle was successfully "launched" and impacted the culvert system as planned. The vehicle safely traversed the grate, meeting all salient criteria. Damage to the system was limited to grate deformation and superficial concrete damage. A second test of the system utilizing an 820C vehicle was completed on August 23rd. As shown in the sequential photographs below, the vehicle traversed the grate, meeting all salient safety criteria.

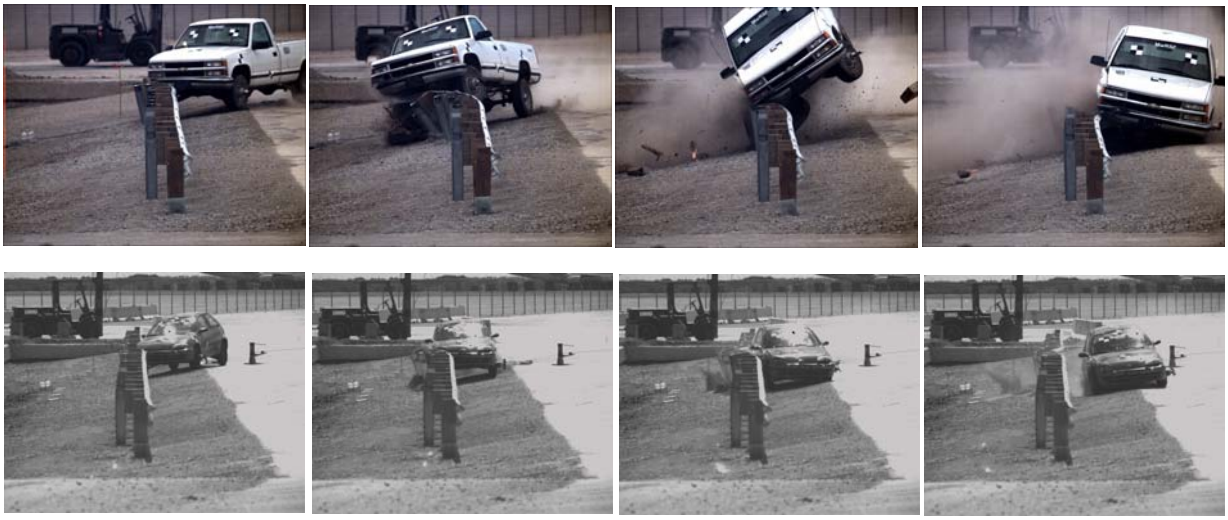
Redesign of Anchors for Temporary Concrete Barriers

A significant number of alternative anchors were tested this Quarter using the jigs shown below for dynamic testing. The results from these tests are currently being analyzed.

Approach Slopes for W-Beam Guardrails Systems

Based on the result of our simulation study, the MGS located 5' from travel way 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 travel way on an 8:1 or flatter slope would be acceptable. Two tests of the system were completed this Quarter. The 2000P test was run on July 27th, as shown in the sequential photos the truck was successfully redirected. All relevant safety criteria were met and test was determined to be a pass. On September 6th, an 820C test was performed on the same

system. Again, as shown in the sequential photos, the vehicle was successfully redirected and all salient criteria were satisfied. Given these two successful tests, the MGS guardrail system can safely be located any offset distance from the travel way on slopes of 8:1 or flatter.



Midwest Guardrail System on Breakpoint of a 2:1 Slope

A final design for the system utilizing 75" post spacing and 9' W6X9 posts was selected for testing. Based on consideration of the NCHRP 350 update criteria that states, "Whenever possible --- light truck tests should be conducted with railings installed at the minimum height", it was decided to perform this test with a top-of-rail-height of 27 ¾". The metric w-beam has been shown to perform satisfactory on flat ground at this height, and successful completion of this test at this height would allow for construction tolerance and future overlays. Our simulation effort has shown that there was a reasonable chance of success. As shown in the accompanying photos, while the truck was mostly redirected, it went over the top of the rail and subsequently landed behind the system. The use of excess funds from the Culvert Grate and MGS Slope projects has been authorized to rerun this test utilizing the same design, but with a guardrail height of 31".

Projects with Pending Full-Scale Crash Tests

Three-Cable Guardrail

The system, utilizing non-tensioned cable would utilize an offset distance of 48" from the breakpoint of the slope and 4' post spacing has been constructed and will be tested in the 4th Quarter (the test passed, details to follow in the 4th Quarter report).

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

Critical impact locations for the 1100C and 2270P were determined this Quarter based on 4:1 slopes. With the completion of the three-cable system, excavation work on the v-ditch will commence during the 4th Quarter. Proposed design and installation guidelines will be distributed to the States prior to installation of the system for comments.

Three full-scale crash tests of the new system utilizing update vehicles (1 @ 1100C, 1 @ 2270P and 1 @ 10,000S) are budgeted (utilizing contingency money for the added vehicle costs) herein to verify performance in a V-ditch.

Concept Development of a Bridge Pier Protection System for Longitudinal Barrier

We anticipate beginning construction of the system after completion of the testing of the MGS on a 2:1 fill slope.

New TL-5 Median Barrier and Anchor

The initial design has been completed; after the system is drafted feedback from the States will be solicited.

Termination of Temporary Concrete Barrier

A simulation study has been undertaken based on previous work with free-standing barriers and different restraint systems previously developed.

Development Temporary Concrete Barrier Transition

Based on the results of the survey, a median transition from temporary barrier to permanent barrier will be developed for this study. Initial design work is anticipated in the 4th Quarter.

Development of a Guardrail Treatment at Intersecting Roadways-Year 3

The last full-scale angled hit on the nose with a 2270P vehicle was performed on June 27th. During deceleration, the vehicle yawed and when nearly stopped, rolled when the rear wheels struck the thrie-beam. We are currently in the process of evaluating this test and looking at options to mitigate this yaw induced by the geometry of the current system utilizing LS-DYNA with a significantly improved model.

Paper Studies

Cost-Effective Measures for Roadside Design on Low Volume Roads

The first field trip was completed during the 3rd Quarter. We are currently looking at a second study site. Work on this project will continue during the 4th Quarter.

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

We have submitted the various perturbations of the MGS system to TF-13. We are continuing to work on the backlog of past developments over the next year.

Awaiting Reporting

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

Utilizing the fabricated 10-gauge welded asymmetrical thrie-beam section, two full-scale crash tests of this system were performed; a 2000P test and an 820C test. Both tests performed well, meeting all salient criteria. We have prepared a paper for the 2007 TRB meeting based on this project.

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

Comments for the draft report sent to the States were due 9/11/06, a final report is being prepared.

Evaluation of Rigid Hazards in Zone of Intrusion

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

Comments for the draft report sent to the States were due 10/27/06, a final report is being prepared.

Long Span Design for the MGS Guardrail System

This system incorporates a 25' clear span, three BCT posts with standard 12" MGS blockouts adjacent to the free span in either direction, and no nested rail. Two successful tests of this system provide evidence of structural capacity and the applicability of the system location with the back of the posts in-line with the traffic side face of the head wall. A report on this project will be initiated. We have prepared a paper for the 2007 TRB meeting based on this project.

Flare Rates for MGS W-Beam Guardrail

This testing has shown that the MGS can be installed at up to a 5:1 flare rate to the travel way. A report on this project will be initiated. We have prepared a paper for the 2007 TRB meeting based on this project.

Pooled Fund Consulting Summary

Midwest Roadside Safety Facility
August 2006 – October 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 – Florida Temporary Barrier Questions

State Question:

Hi Bob,

Haven't talked with you lately, hope all is well. I need to ask you a few questions about FTB's:

1. Can ASTM A706 rebar be substituted for all the A615 rebar in FTB's, and if so, can the A706 rebars be tack welded together without compromising the crashworthiness of the design?

A fabricator down here wants to tack weld pre-tied rebar cages together to make them more rigid and easier to handle when they are placed into the forms. It appears he wants to fabricate his own homemade "welded wire fabric". I am concerned about doing this in a precast yard and not a factory environment. If we mandate that the welders be certified and that AWS welding procedures be used, I think we would also need to require A706 rebar. Currently we require A706 rebar for the connector loops only as it is a more ductile steel and can better accommodate the tight bend radius.

2. On another project, the contractor has proposed using the proprietary 1" diameter high strength (A449) anchor bolts shown on page 11 of the following attachment in lieu of the 1.25" diameter F1554 Grade 36 anchor bolts specified on our standard:

What do you think of using a smaller diameter, higher strength bolt than that used in the crash tests? The contractor is also proposing to use an adhesive that we have not classified as a "high strength" adhesive. We only allow "high strength" adhesives for this application due to the shallow embedment depth of the anchor bolts necessitated by our 7" to 8" deck thicknesses.

I would like to allow this type of proprietary bolt, maybe the same 1.25" diameter as was used in the crash tests though, because the bolts can be easily removed from the bridge deck when the barrier is removed or relocated.

Please let me know what you think. As always, thanks for the help.

Best regards,

Charles E. Boyd, P.E.

Senior Structures Design Engineer
Florida Department of Transportation
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MwRSF Response:

Hi Charles

I have made some comments for you below.
As always, feel free to ask more questions or give comments and concerns.

Thanks

Bob Bielenberg, MSME, EIT
Research Associate Engineer
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-----Original Message-----
From: charles.boyd@dot.state.fl.us [mailto:charles.boyd@dot.state.fl.us]
Sent: Tuesday, August 22, 2006 2:54 PM
To: rbielenberg2@unl.edu
Subject: FTB questions

1. Can ASTM A706 rebar be substituted for all the A615 rebar in FTB's, and if so, can the A706 rebars be tack welded together without compromising the crashworthiness of the design?

I see no reason that you should not be able to substitute the A706 for the A615 as long as long as the grade of steel stays the same or is better and there are no changes in bar sizes or lengths. The A706 should have better ductility and should not pose any other issues.

A fabricator down here wants to tack weld pre-tied rebar cages together to make them more rigid and easier to handle when they are placed into the forms. It appears he wants to fabricate his own homemade "welded wire fabric". I am concerned about doing this in a precast yard and not a factory environment. If we mandate that the welders be certified and that AWS welding procedures be used, I think we would also need to require A706 rebar. Currently we require

A706 rebar for the connector loops only as it is a more ductile steel and can better accommodate the tight bend radius.

With regard to tack welding the rebar, I don't see a huge problem with it either as long as you hold the contractor to similar quality controls as those observed by welded wire fabric manufacturers. It appears from you email that you plan to do that. As long as the tack welds are not compromising the capacity of the rebar or causing stress concentrations, it should not be an issue.

2. On another project, the contractor has proposed using the proprietary 1" diameter high strength (A449) anchor bolts shown on page 11 of the following attachment in lieu of the 1.25" diameter F1554 Grade 36 anchor bolts specified on our standard:

What do you think of using a smaller diameter, higher strength bolt than that used in the crash tests? The contractor is also proposing to use an adhesive that we have not classified as a "high strength" adhesive. We only allow "high strength" adhesives for this application due to the shallow embedment depth of the anchor bolts necessitated by our 7" to 8" deck thicknesses.

I would like to allow this type of proprietary bolt, maybe the same 1.25" diameter as was used in the crash tests though, because the bolts can be easily removed from the bridge deck when the barrier is removed or relocated.

For our design and testing of the bolt through tie-down, we specified a 1.25" dia. A307 threaded rod. The rod was embedded approximately 12" into the concrete with a high strength epoxy. The epoxy and embedment depth were chosen such that the full strength of the threaded rod was developed. In this case the threaded rod ultimate strength was 60 ksi and the threaded area was 0.969 in^2 which yields a maximum load of approximately 58 kips.

The Kelligrout specs you sent suggest that for the A449 1" dia. bolt proposed you need 9.5" of embedment to develop the strength of the bolt. The bolt capacity for the A449 1" dia. bolt corresponds to a ultimate strength of 120 ksi and a threaded area of 0.606. This would correspond to a capacity of 72.72 kips. Therefore the tensile capacity of the bolts is not an issue.

We are concerned with the bending capacity of the anchor rods. The bending section of the 1" diameter rod is approximately 50% less than that of the 1.25" dia. rod. So while the strength of the rods is different, the ultimate bending capacity of the 449 anchor is actually slightly lower than the A307 rod. We did get significant bending of the anchors in the full-scale testing and thus are leery of using the smaller diameter anchor. In addition, the A449 anchor is made of high strength steel that has lower ductility than the A307. This translates to lower energy absorption during the impact and an increased potential for bolt failure. The smaller diameter of the 1" anchor also increases the bending load because of the increased clearances in the holes of the barrier. Because of these concerns, we would not recommend the 1" dia. A449 anchor at this time.

The grout itself seems acceptable. I looked at the specs for the grout on their web page and it appears that they can achieve the full strength of the 1.25" dia. A307 rod with 12" of embedment.

As an alternative, we did develop a bolt through option that bolts through the bridge deck with washers and nuts underneath. This system is easier to remove than the epoxy system.

Problem # 2 – Guard Rail Transition to a Bridge

State Question:

Dean,

We have a guard fence transition to a bridge that was recently hit. This will be repaired per our maintenance policy.

My question is:

1. Can we use double blockouts in the portion where the curb is in front of the guard fence for the full length of the guard fence to bridge rail transition section? How many posts can have more than one blockout and is there a limit, ie some may want to use three blocks on several posts. I am looking into the height of the bridge rail to see if we can get thrie beam on it.

Rod Lacy, PE
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Email: rlacy@ksdot.org

MwRSF Response:

Hi Rod,

Dr Sicking asked me to look at your transition issue from the email below with regards to blockout depth and the addition of some thrie beam guardrail. I have reviewed the photos you sent and I believe we can retrofit your installation to improve it significantly. I have attached a schematic of our proposed modifications. We are basically proposing that you blockout the existing system using 24" deep spacer blocks (basically three standard 8" deep blocks in series). We have used 16" blocks on several systems in the past with no problems and we believe that 24" of spacer block is okay as well. We are also recommending that you replace the first 12'-6" section of w-beam with nested 12-gauge thrie beam. Then a W-thrie transition section would be placed between the nested thrie and the standard w-beam. This layout would make you

installation very similar to the Iowa transition developed by the Pooled Fund and would increase the safety of the installation greatly. After the W-thrie transition section, the spacer blocks could be reduced incrementally to taper the w-beam to meet the existing installation.

Please look over the attached schematic and let me know if you have any questions.

Thanks

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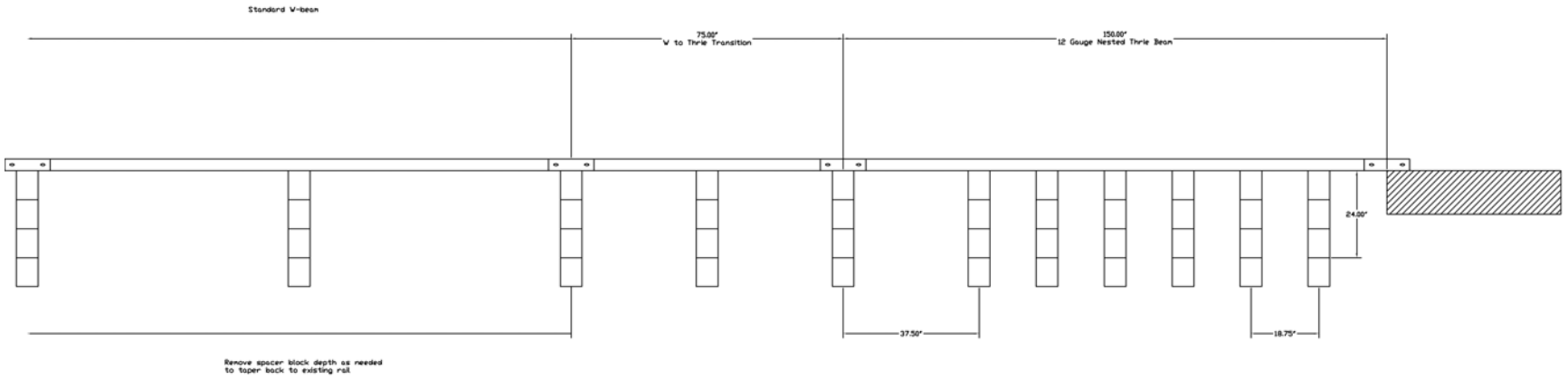
Standard W-beam
75.00"
W to Thrie Transition
150.00"
12 Gauge Nested Thrie Beam
24.00"
37.50"
18.75"
Remove spacer block depth as needed
to taper back to existing rail

Problem # 3 – F-Shape Temporary Concrete Barrier

State Question:

We have a requirement to anchor the temporary concrete barrier if is closer than a specified distance to a 2-foot or greater dropoff. A question has come up on how to define the maximum steepness of dropoff. What is the maximum steepness of dropoff slope that wouldn't require anchoring?

Could an impacting vehicle penetrate or vault the barrier as a result of a barrier deflecting beyond the edge of a dropoff?

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MwRSF Response:

John:

The through-bolt tie-down system provided in TRP-03-134-03 was designed, tested, and evaluated for use with barrier placement on rigid concrete pavement adjacent to a vertical drop off. For this 2000P test, part of a barrier was pushed back slightly, thus extending over the drop off edge but without concern. Certainly, this same barrier and tie-down system could be used at similar locations where shallower roadside slopes exist.

Now, if you do not want to use the tie-down system near drop-offs and roadside slopes, it would be necessary to provide level pavement, or nearly level pavement (say 10:1/12:1 or flatter), on the back side of the barrier. These conditions would allow the impacted barrier to deflect backward without dropping over an edge or slope break point. If a free-standing barrier drops over an edge or modest roadside slope, then there exists and increased propensity for vehicle climb up the barrier, vaulting, and rollover. If a barrier is positioned on soil, then the barrier can sink into the soil. Then, when it is impacted, it may actually dig into the soil and result in increased barrier rotation and vehicle climb, vaulting, and rollover.

In summary, anchoring a TCB to a rigid pavement would not be required as long as you provide adequate space for barrier deflection on a level surface during impact events. For such a situation, a vertical drop-off could be accommodated beyond that distance.

Please call or email if you have additional questions or comments!

Respectfully,

Ron

Ronald K. Faller, Ph.D., P.E.
Research Associate Engineer

Problem # 4 – Pier Protection

State Question:

Dr. Faller,

I would like your professional opinion about a proposed median bridge pier protection design a local city is asking to use.

This suburb is reconstructing a freeway interchange. The mainline freeway will be on a structure over the 45 mph 4-lane divided arterial underneath, with bridge piers in the center median. This will be a modified diamond interchange, with a low speed roundabout along the arterial on each side of the overhead structure. This concept is shown on the attached sheet 4. The city originally proposed a 16 foot wide 6" high curbed median through the center bridge pier location. We recommended the city provide concrete barrier in lieu of the curbed median island to shield the piers. The city has agreed to this, but they still want the curbed median outside of the bridge pier protection length and in between the roundabouts, as this design is typical for their arterial street system.

On the ODOT network the ends of this concrete barrier would be protected by impact attenuators, but the city wants the median curb to run directly to the concrete barrier, meaning the impact attenuator would have to be installed on a curbed island. This is counter to the attenuator manufacturers recommendations. Since this, and other standard solutions are not attractive to the city, it is asking for a different design.

Thus, the city's engineer, through its consultant, has proposed the attached draft design. In it the concrete barrier (labeled as Type D on the second attachment) is flared to the center of the median and a mounded median is used to cover the barrier end, thus eliminating the need, in the city's opinion, for crash cushions. One can assume all of the barrier taper rates and median slopes used in the design are allowable, so there are no snag points for a motorist to encounter. In similar situations, ODOT would not allow a tapered end section to the concrete, but the city believes this design is safe, because none of the earth slopes violate any geometric standard.

I have my doubts about the design, but the AASHTO RDG does give the designer some leeway in lower speed urban locations. After considerable discussion, I did inform the city and consultant I would run the idea past your group at the Midwest Roadside Safety Facility for your comments on the city's proposed design from a roadside safety point of view.

Dean Focke
Ohio DOT

MwRSF Response:

Dean:

Thanks for the opportunity to review the proposed hazard mitigation design. From my review of the attached discussion and details, I assume that the authors are planning to allow impacting vehicles to travel up and over the sloped berm and onto the top of a single-slope concrete median barrier. This action would result in vehicles rolling off of the top of the barrier or traveling forward and entering the separated median barrier and bridge pier region. Second, angled impacts near the nose of the berm but slightly down the side could result in the vehicle being tripped and launched over the barrier system, potentially rolling over as well. As such, I do not recommend that the Ohio DOT nor any municipality use the sloped berm concept described below to treat the tall, single-slope concrete median barrier. Please feel free to discuss this matter with me at your convenience!

Ron

Ronald K. Faller, Ph.D., P.E.
Research Associate Engineer

Problem # 5 – MGS in a Median

State Question:

Hi Ron,

I have a project where I'd like to utilize the Midwest Guardrail System, if possible. Unfortunately, it would be a two-sided median application. Last week, I sent the e-mail below to Dr. Sicking asking in slightly more detail about the use of the MGS (in the last paragraph). He might not have seen it, so I am sending the question on the MGS again, this time to you.

Thanks,
Dean
Ohio DOT

----- Forwarded by Dean Focke/RoadwayEng/CEN/ODOT on 09/26/2006 07:51 AM -----

Hi Dean,

It was nice to see you in Ohio yesterday. As usual when I am with you, I learn quite a bit - this time about the FLEAT system. Thanks.

With regards to our conference next month, your presentation on the MGS is scheduled for Wednesday, October 25, 2006 at 8:50 am in the Columbus Convention Center, downtown Columbus. You are on second, after John Durkos opens the session at 8:30 and talks about the rewrite of 350, After him. you'll have 30 minutes. By now you should have a speaker's packet. Let me know if you don't. And presentations are due on a CD by Oct. 6.

As I said, I would like to announce at the meeting that we will use the MGS. And with that in mind, I have a project where I think I can get the MGS installed. However it would be a two-sided run on one side of a median. The barrier guardrail would be on the top of the slope on one side of the median, and the backside would be at the top of a 6:1 median slope and about 24 feet from the other side travelled lanes. Can the MGS be used in a two-sided barrier situation? Would the median side rail require a rub rail?

Thanks,
Dean
Ohio DOT

MwRSF Response:

Dean:

Thanks for your inquiry on the MGS for median applications. I have discussed your question with Dr. Sicking and Bob Bielenberg. Based on our discussion, we believe that it would be acceptable to use the MGS in a median situation with the W-beam rail blocked out on both sides of the posts. Although the additional W-beam rail may provide some limited stiffening of the guardrail design, we do not believe that stiffening to be significant nor do we have evidence that suggesting that it would degrade MGS safety performance.

For your specific median geometry, are you referring to a situation that resembles “Illustration 2 or 4” on page 6-15 of the roadside design guide? Please clarify your median situation for us.

Second and based on my understanding of your specific application, it is our recommendation that you not use a rubrail with the MGS in a median application. Please call or email to discuss if you have any questions regarding the enclosed recommendations.

I am also copying both Bob and Dr. Sicking on this email so that they can add any others points that they feel are pertinent.

Respectfully,

Ron

Ronald K. Faller, Ph.D., P.E.
Research Associate Engineer

State Question:

Hi Ron,

The situation in which I would like to use the Midwest Guardrail (MGS) on GRE-35 resembles Illustration 2 in the RDG, with both slopes being 6H:1V with the ditch squarely in the center of the median for most of the project length.

The project is on a limited access expressway with a 30 foot wide median that now has sufficient ADT to move it up into the barrier warranted section of RDG Figure 6-1 on page 6.2. The project now has a history of cross median accidents so we would like to protect it. I have ruled out cable in favor of more typical protection (w-beam). The project length is about 7 miles, with some remaining intersections. Most of the median slopes are 6:1 but there are about 20 existing drainage inlets that have a localized depression up to maybe 3:1. When barrier guardrail at the top of one side of the median was proposed, the thought was to level out those depressions so that no slope would be greater than 6:1.

Some pictures are attached.

I've talked to Dick Powers about using double sided guardrail in this situation (as ODOT only uses double sided guardrail with 10:1 slopes on both sides of the barrier run). With one of the sides on our proposed run to be at the top of a 6:1 slope, he suggested using a rub rail on that guardrail face.

Any comments would be appreciated.

Dean
Ohio DOT

MwRSF Response:

Dean:

Thanks for the clarification. I had originally assumed that you were dealing with a situation that resembled “Illustration 2.” For the 30-ft wide median with 6H:1V side slopes, it is only necessary to consider median crossovers since the noted median slopes are relatively flat and clear. As such and using Illustration 2, one would place the median barrier system on the top side of either of the 6H:1V slopes. With the barrier system at the top of the slope, vehicles traversing the centerline ditch would not be expected to underride the barrier on the upslope 15-ft away or so from the ditch center. Therefore, we do not believe that it would be appropriate to use a rubrail in combination with the MGS at this location. In addition, rubrails, used in combination with thrie beam transitions, have not been met with a high degree of success when evaluated by large pickup truck impacts.

Respectfully,

Ron

Ronald K. Faller, Ph.D., P.E.
Research Associate Engineer