Second Quarter 2006 Progress Report
Midwest Roadside Safety Facility
Mid-States Regional Pooled Fund
August 14, 2006

Projects with Pending Full-Scale Crash Tests

Development of a Guardrail Treatment at Intersecting Roadways-Year 3

A full-scale angled hit on the nose with a 2270P vehicle was performed on June 27th. As shown in the sequential photos below, the vehicle was captured by the slotted rail. 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.




Three-Cable Guardrail

Based on discussion with the States during the April pooled fund meeting, we are requesting your input on the system that we performing this test on. Several States expressed interest in testing a tensioned cable system to reduce the offset from the planned 1.5:1 slope. Our current plan utilizing non-tensioned cable would utilize an offset distance of 48” from the breakpoint of the slope and 4’ post spacing. If there is majority consensus to utilize tensioned cable for this system, it is anticipated that offset distance and post spacing could be reduced. This test will follow culvert testing, which should be completed mid-3rd Quarter if the second test is successful, so we need to receive your feedback as soon a possible. Please email jrohde@unl.edu with your comments and questions in the next two weeks.

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

Designs for foundation systems involving driven steel piles, cylindrical reinforced concrete piles, and reinforced concrete blocks have been developed this quarter. The design approach has involved consideration of a range of soil conditions and the related anchor size to control anchor deflection. This design process will provide a rational design tool for appropriately sizing foundations to reflect soil bearing capacity under a range of soil conditions. Static testing of these foundation designs is anticipated in the 3rd Quarter. Also, during the Quarter we have completed design of the cable mounting clips and commenced a series of bogie tests to finalize S3X5.7 post length and spacing. After completion of culvert testing and the 1.5:1 cable slope testing, the pit will be filled to provide the slopes for testing the cable system in a depressed median. An LS-DYNA or HVOSM modeling study will be utilized to evaluate the influence of moderate roadside slopes on system performance. This modeling will be utilized to determine the maximum ditch slope and depth at which the barrier can be expected to perform adequately.

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.

Evaluation of Transverse Culvert Safety Grate

The culvert system, pictured herein, was completed this Quarter. A full-scale test utilizing a 2000P vehicle was completed on July 20th. While this test is early in the third Quarter, it was completed during the development of the 2nd Quarter progress report so it is included. 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. The system is currently being repaired for the subsequent 820C test which is anticipated in the next few weeks.

Flare Rates for MGS W-Beam Guardrail

As previously discussed, three successful crash tests have shown the MGS system to perform well at a 7:1 flare rate. With the one additional test budgeted in the project, we constructed a system with a 5:1 flare. This system was tested on May 17th with a 2000P vehicle, sequential photos are shown below. The system passed all salient criteria. To certify the system, an additional 820C test was performed on July 7th. Again as shown below, all salient criteria were met. Given these two tests, the MGS guardrail system can be installed at up to a 5:1 flare rate to the travel way.

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 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. This test is anticipated in the 3rd Quarter.

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 of 2005. We are anticipating beginning construction of the system in the 3rd Quarter after completion of the testing of the MGS on a 2:1 fill slope.

New TL-5 Median Barrier and Anchor

The literature review for this project is completed. Several barrier configurations have been developed for both slop-formed and cast-in-place construction methods Upper barrier geometries were developed based on head ejection considerations. In terms of cost and constructability, feedback was sought from slip-formers with regard to these proposed barrier cross sections. Final barrier design and subsequent requests for review from the Pooled Fund States are anticipated in the 3rd Quarter.

Long Span Design for the MGS Guardrail System

Two tests of the long-span MGS were performed during the 2^{nd} Quarter. 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. The first test with an impact point selected to maximize rail stress was performed with a 2270P vehicle on April 21^{st}. Given the success of this test, we decided with the agreement of the States to move the system so that the back of the posts were in line with the traffic-side face of the headwall. An impact point was selected based on maximum displacement adjacent to the downstream wing wall end. This test was performed with a 2270P vehicle on June 7^{th}. As shown in the two sequential photo sets below, the system performed well.

Midwest Guardrail System on Breakpoint of a 2:1 Slope

A final design for the system utilizing 75" post spacing and 9' W6X9 posts has been shown to have a reasonable chance of success. The system is currently under construction and should be tested in the 3^{rd} Quarter.

Cost-Effective Measures for Roadside Design on Low Volume Roads

Study of rural highways with <500 ADT and ≥55 mph speed limit. This study will initially consider one State. Currently, we are beginning to plan the travel to review the site where field data will be acquired.

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.

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.

Redesign of Anchors for Temporary Concrete Barriers

A set of jigs for dynamic testing of various anchor systems was constructed this Quarter. We anticipate bogie testing other anchoring options during the 3^{rd} Quarter.

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.

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 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 draft 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.

<u>Pooled Fund Consulting Summary</u>

Midwest Roadside Safety Facility
April 2006 – August 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 – F-shape Barrier Strap Tie-Down Bolt Size

State Question:

Dr. Faller,

I am trying to finalize our standard details for the strap anchor option on the F3 barrier system. While working on the details for the RED HEAD Multi-SET II anchor I noticed a discrepancy in the bolt length. All of the details I have received to date show a 2.25" Grade 5 bolt through the strap and into the anchor. However, when I look at the anchor specifications, the threading inside of the anchor is only 1.25 inches deep. So, if the anchor is embedded the 3 3/16", which is also the length of the anchor, and it is threaded for 1.25" with 1/2" of plate steel for the strap, the bolt could not be any longer than 1.75", unless the anchor is embedded at least 3 11/16" (the top of the anchor is ½" below the top of the pavement).

Can you shed some light on this issue, or some additional details on how the anchor was installed for the test?

Thank you in advance for any help you can provide.

Sincerely,

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MwRSF Response:

KsDOT has brought an issue to our attention regarding the bolt length used in the F-shape PCB Strap Tie-Down design. This design uses the RedHead Multi-Set II Drop-In anchor to anchor the steel retainer straps to the concrete bridge deck. We used a ¾" dia. drop-in during our testing that had an embedment of 3 3/16" and a threaded depth of 1 ¼". When we tested the system, MwRSF used a 2 ¼" long x ¾" dia. Grade 5 hex bolt. The system test was successful, and we specified that bolt size for our final plans. When looking at the anchor geometry, KsDOT noticed that we had ½" more length on our bolt than the threaded length of the anchor and wondered if that was an issue. MwRSF contacted engineers at RedHead about this question. The response from RedHead was that they did not advise using bolts that threaded farther into the anchor than the 1 ¼" thread depth. Their concern was that using bolts with longer lengths could cause excess expansion of the base of the anchor and potential fracture of the tabs at the base of the anchor. This would cause a possible reduction in anchor capacity.

Based on this new information, we are recommending that the states revise their details for this system to reflect the use of 1 ¾" long x ¾" dia. Grade 5 hex bolts with the drop-in anchors to eliminate any potential problems with the anchors.

Thank you

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Problem # 2 – Bullnose Questions

State Question:

See Figure 2 below.

MwRSF Response:

Hello Joe,

I have looked at your bullnose barrier question regarding the distance from the nose of the system to the hazard. Based on a somewhat less conservative approach than our original guidelines, we believe you can reduce the 69.5' minimum distance shown in your drawing to 50'. We do not recommend that you shorten the distance any more than that as it may allow larger vehicles impacting the end of the system to impact your sign supports with significant velocity. The new 50' distance should shorten your installation 19.5' on the narrow side of your median.

As for your second question regarding the red area in your drawings, I am afraid I do not understand. The red area in your drawing is not a critical number. The critical number is the distance from the nose of the system to the rigid hazard. This distance is based on the amount of system deflection we saw in tests of a pickup truck impacting the end of the barrier system under NCHRP Report 350 impact conditions. We do believe that this distance can be safely reduced to 50' if need be as stated above.

Please feel free to contact me with any further questions you have.

Thanks

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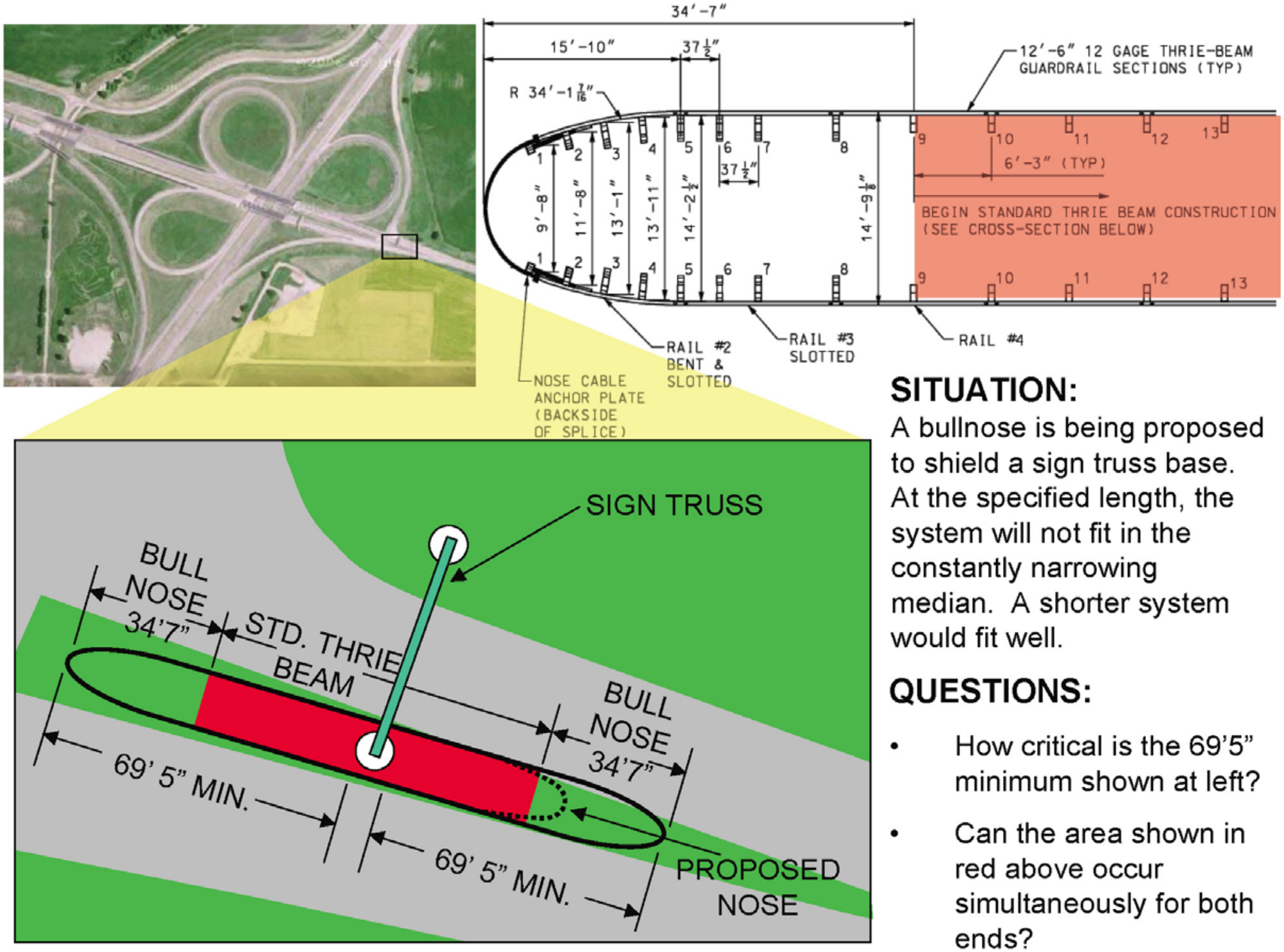

Figure 2. Bullnose Question

Problem # 3 – Safety Shape Barriers

State Question:

The meeting earlier this week has stirred a few questions around here. I'll put each in a separate e-mail to keep the tracking simple. I did not have Prof. Sicking's e-mail address, so you may wish to forward this.

Our first question relates to an issue I believe Prof Sicking raised. If I recall correctly, he stated that he prefers other systems to a rigid barrier for safety performance, and also, I think he made reference to some study or documentation showing that lateral offset increases the likelihood of a more direct angle of impact.

We are discussing with one of our District Offices the location of a concrete barrier in a Freeway median. They are building a 6-lane section through an interchange area for inclusion in a future (maybe far in the future) add lanes project on the corridor. Ultimately, the permanent median barrier will be located at the center of the median, about 8 feet off the edge of the inside lane. Until the corridor lane addition is achieved only four lanes will be present and a barrier at the center of the median would be about 20 feet from the edge of the through lane. Another option for them would be to place two lines of temporary concrete barrier, each about 12 from the edge of an inside lane.

We all prefer a concrete barrier in this location due to the high truck traffic (9600 multiple units, and 1600 single unit trucks out of a total ADT of 34700 (2005)). We would like the reference to documentation of the increased likelihood of more direct impacts with increasing offset to the barrier, and also any comments.

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MwRSF Response:

David,

Unfortunately, it is apparent that I confused many people with the discussion of the relationship between lateral offset and impact angle and another discussion of my concerns over the safety of safety shaped concrete barrier. I will recap my comments below in an attempt to clarify the now very muddy water.

HISTORY

Through the 1970's and into the 1980's, FHWA strongly discouraged the use of concrete barriers in medians more than 30 ft wide. The concern was that impact angles would increase as the barrier was placed further from the traffic. As a result of a number of truck penetrations of its W-beam median barrier, the New Jersey Turnpike Authority contracted with TTI, in the mid-1980's to develop a flexible barrier that could be used in wider medians and still provide TL-5 performance. During the process of trying to design a metal barrier that could contain a tractor-trailer truck, it became obvious that the resulting, "flexible" barrier would be rigid with respect to passenger cars. Based upon the results of this study, FHWA realized that it had a choice, either continue to require W-beam and Thrie-beam median barriers in wide medians and accept that heavy trucks will sometimes penetrate the barrier, or allow rigid barriers to be used in wide medians and accept the assumed increase I risk associated with higher impact angles. About this same time, King Mak completed a study of pole and narrow bridge crashes that indicated a modest increase in impact angle as the hazard was placed further from the travelway. Due to the extreme severity and high visibility of some of the cross-median truck crashes, (one such crash involving a gasoline tanker killed or seriously injured 33 people) the FHWA concluded that stopping such crashes on high volume freeways was very important. Hence, FHWA's restrictions against the use of concrete barriers in wide medians were dropped.

The safety shape concrete barrier was developed by GM to prevent sheet metal damage during low angle impacts. The GM Shape as it was called incorporated a 13" high lower curb that would allow an impacting vehicle's tires to climb the barrier without any sheet metal contact for impact angles up to 3 or 4 degrees. Because GM used this barrier only on test tracks where the potential for traffic conflicts are low, most of their crashes were caused by inattention rather than avoidance maneuvers. Hence, the barrier was able to redirect impacting vehicles without damaging the sheet metal during most crashes. When this barrier was introduced onto the highway, it was found to cause large numbers of rollovers. In recognition of this problem, the state of New Jersey reduced the lower curb to a height of 10" and produced the widely used New Jersey Shape. In the 1970's, the Southwest Research Institute (SWRI) conducted a parametric study to examine changes in the NJ shape that would reduce rollovers. They studied a number of revisions to the NJ shape, the first configuration was labeled Shape A. SWRI looked at a number of different versions, finally arriving at what they deemed to be the best, Shape F. This is the origin of the F Shape barrier and it basically involved reducing the height of the lower curb by another 3 inches.

During the 1980's, King Mak and I studied rollovers associated with concrete safety shaped barriers and found that safety shapes are not very safe. This study concluded that concrete safety shaped barriers are the most dangerous barriers along our roadsides. Clearly part of this increased danger is related to the rigidity of the barrier. However, Mak's findings appear to indicate that the greatest portion of the increased risk was related to rollover frequency.

CURRENT RECOMMENDATIONS

It is generally accepted that there is a modest increase in impact angle as a barrier is placed farther from the travelway. However, the increase in severity with higher impact angles does not outweigh the attendant reduction in crash frequency as the barrier is moved farther from traffic. Hence, agencies are urged to place barriers as far from the travel way as possible within the available geometric limitations (considering roadside and median slope limitations). Therefore, we strongly recommend that median barriers be placed in the center of the median whenever possible. Further, our primary concern regarding the use of concrete safety shaped barriers is that the shape was originally designed to limit sheet metal damage and as a result, doesn't provide the maximum level of safety possible for a rigid barrier. Under a currently funded pooled fund project we are attempting to verify the findings from Mak's study of barrier shape. If that study proves Mak to be correct, we will begin recommending that agencies abandon the safety shaped barriers in favor of more vertical designs.

If this doesn't clarify the situation to your satisfaction, please reply with questions or call me.

Thanks

Dean

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Problem # 4 – Asphalt Pin Tie-Down in Median Applications

State Question:

Hi Bob,

It doesn't look like we should tie down the Kansas/Iowa/Minnesota Temporary Portable Precast Concrete F Barrier with steel pins and use it for semi- permanent application when it is in the Median?

The steel pins for Tie-Down application you specify in the report are only for when this barrier is going to have traffic on one side, correct?

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MwRSF Response:

We are not recommending the use of the asphalt tie-down in median installations at this time. Our concern is that pins on the backside of the barrier would create a pivot point and induce rotation of the barrier segments. This action could increase the propensity for impacting vehicles to climb the barrier face and vault over the top. We have entertained the idea of placing pins on both sides of the barrier, but we are concerned about vehicle instability with this type of installation for the same barrier rotation issue mentioned above.

If you have any further questions, please let me know.

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Problem # 5 – Thrie Beam Blockouts

State Question:

Ron,

We would like some guidance on the appropriate blockout to use for a standard thrie beam, both for wood posts and steel posts.

WisDOT is working on developing a thrie beam bullnose terminal based on the MwRSF design(report TRP-03-95-00, 6-1-2000) that was approved by FHWA (11-8-2000 letter, HSA-1/HSA-cc68). The blockout for the standard thrie beam construction from posts 9 to 12 is shown as 360 mm (14.17 in) high.

Sheet 2 of Minnesota DOT's Standard No. 5-297.611 "Thrie Beam Bullnose Guardrail for Medians" (dated 8-20-2001), which is based on the approved MwSRF design uses a 22-inch high blockout.

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MwRSF Response:

John:

Per your inquiry, I have summarized several of the successful thrie beam transition tests that have been conducted according to the NCHRP Report No.
350 requirements. They are as follows:

No. 1 - Wood Post - Wood Blockout
550 mm center rail height
804 mm top rail height
150 mm by 200 mm by 554 mm blockouts
150 mm by 200 mm by 1.9 m posts
0.68 m dynamic deflection
TL-3 pickup truck test (404211-11)

No. 2 - Steel Post - Modified Steel Blockout
610 mm center rail height
864 mm top rail height
W360x33 tapered blockouts
W150 x14 posts
0.71 m dynamic deflection
TL-4 single-unit truck test (404211-5a)

610 mm center rail height
864 mm top rail height
M14x18 tapered blockouts
W6 x9 posts
1.02 m dynamic deflection
TL-3 pickup truck test (471470-30)

No. 3 - Steel Posts - Routed Wood Blockout
550 mm center rail height
804 mm top rail height
150 mm by 200 mm by 554 mm routed blockouts
W150 x14 posts
0.58 m dynamic deflection
TL-3 pickup truck test (404211-10)

In summary, you can use either the long wood blocks, shortened wood blocks, or even the tapered steel blocks in combination with the standard thrie beam guardrail systems after post no. 9. See our prior email response at the bottom of this email for further discussion.

Respectfully,

Ron

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