Third Quarter 2005 Progress Report
Midwest Roadside Safety Facility
Mid-States Regional Pooled Fund
October 3, 2005

YEAR 12

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 of the modified system is scheduled for October 6, 2005.

Portable Aluminum Work Zone Signs

The bogie testing for this project has been completed. A submission to FHWA seeking approval was sent and received approval. Polivka, K.A., Faller, R.K., Holloway, J.C.,and Rohde, J.R., ***Safety Performance Evaluation of Minnesota's Low-Height, Temporary Rigid Panel Sign Stand***, Final Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-129-03, Project No. SPR-3(017)-Year 12, Sponsoring Agency Code RPFP-02-04, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, January 23, 2003. Subsequent to this report additional testing was added to the project. This work has been completed and a second final report is pending.

Single-Faced Concrete Barrier

Faller, R.K., Sicking, D.L., Larsen, J., Rohde, J.R., Bielenberg, R.W., and Polivka, K.A., ***TL-5 Development of 42- and 51-In. Tall, Single-Faced, F-Shape Concrete Barriers***, Final Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-149-04, Project No. SPR-3(017)-Year 12, Project Code: RPFP-02-04, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, April 30, 2004.

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

In response to a recent letter, the pooled fund states have elected to fabricate a 10 gage welded asymmetrical thrie-beam section for full-scale testing. The new welded section arrived on site in late September. We are currently completing a simulation study of the system to finalize the post layout and anticipate initiating construction early in the fourth quarter and testing in early November.

Three-Strand Cable Median Barrier

After a significant discussion of all of our cable projects currently in the pooled fund, this project has been significantly modified. These changes include a new attachment for the cable to post connection, employing tension to reduce deflections, and the development anchorage for the tensioned system. During this quarter, we have designed and tested a series of alternative post connections and plan to perform dynamic testing during the fourth quarter. We are also working on design of foundation systems for the tensioned four-cable system. This work represents the completion of the work under this project year. Future work will be funded in Year 14.

Year 13

Generic W-Beam Guardrail with Curb

Polivka, K.A., Faller, R.K., Sicking, D.L., Reid, J.D., Rohde, J.R., Holloway, J.C., Bielenberg, R.W., and Kuipers, B.D., ***Development of the Midwest Guardrail System (MGS) for Standard and Reduced Post Spacing and in Combination with Curbs***, Final Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-139-04, Project No. SPR-3(017)-Years 10, and 12-13, Project Code: RPFP-00-02, 02-01, and 03-05, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, September 1, 2004.

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.

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 described in Year 14.

Non-proprietary Guardrail System – Additional Test

Polivka, K.A., Faller, R.K., Sicking, D.L., Reid, J.D., Rohde, J.R., Holloway, J.C., Bielenberg, R.W., and Kuipers, B.D., ***Development of the Midwest Guardrail System (MGS) for Standard and Reduced Post Spacing and in Combination with Curbs***, Final Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-139-04, Project No. SPR-3(017)-Years 10, and 12-13, Project Code: RPFP-00-02, 02-01, and 03-05, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, September 1, 2004.

Kansas Temporary Barrier Redesign and Test

Polivka, K.A., Faller, R.K., Rohde, J.R., Holloway, J.C., Bielenberg, B.W., and Sicking, D.L., ***Development and Evaluation of a Tie-Down System for the Redesigned F-shape Concrete Temporary Barrier***, Final Report to the Midwest States Regional Pooled Fund Program, Transportation Report No. TRP-03-134-03, Project No. SPR-03(017)-Year 13, Sponsoring Agency Code RPFP-03-06, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, Lincoln, NE, August 22, 2003.

System for Stiffening New Guardrail System

Polivka, K.A., Faller, R.K., Sicking, D.L., Reid, J.D., Rohde, J.R., Holloway, J.C., Bielenberg, R.W., and Kuipers, B.D., ***Development of the Midwest Guardrail System (MGS) for Standard and Reduced Post Spacing and in Combination with Curbs***, Final Report to the Midwest State's Regional Pooled Fund Program, Transportation Research Report No. TRP-03-139-04, Project No. SPR-3(017)-Years 10, and 12-13, Project Code: RPFP-00-02, 02-01, and 03-05, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, September 1, 2004.

YEAR 14

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

A revised description of this project, based on discussion at the April Pooled Fund Meeting, will be submitted with the Year 16 proposal.

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 initiated a contract to dig the pit for this test and are currently completing the design of a 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 late in the upcoming Quarter or 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. This test is anticipated late in the 4th Quarter. 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.

YEAR 15

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 4th Quarter.

Retest of the Cable End Terminal

Based on successful testing of this system a final report of the project will be initiated in the 1st Quarter of 2006.

Long Span Design for the MGS Guardrail System

Barrier VII simulation is being undertaken to evaluate the design of the system. Currently a 25' clear span without nested rail is being investigated.

Midwest Guardrail System on Breakpoint of a 2:1 Slope

Simulation of this system will be undertaken in the 4th Quarter. Investigation of the effects of eliminating the need for reduced post spacing is the first task that will be undertaken.

Pooled Fund Consulting Summary

Midwest Roadside Safety Facility
April 2005 – October 2005

This is a brief summary of the consulting problems presented to the Midwest Roadside Safety Facility over the past two quarters and the solutions we have proposed.

Problem # 1 – Type F Barrier Height Transitions

State Question:

There has been a question raised about the concrete height transitions that are connected to the temporary type F barriers. MoDOT is using and has used a 20-foot long concrete height transition for at least 6-8 years. Located on page 3 of 6 at the attached email address http://www.modot.org/business/standards_and_specs/documents/61720b.pdf

We use the transition for road ways where the posted speeds are less than 35 mph. Other states use a 12.5-foot long concrete height transition. There are two questions:

1. Are there any concerns between the two different transition lengths of 12.5 and 20 feet?

2. Has the height transitions been crash tested at the lower speeds and how did they perform? If not, are there any approved crashed tested concrete height transitions?

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MwRSF Response:

Question #1:

Although the full-scale vehicle crash testing program was conducted on the approximately 20-ft long sloped segments, HVOSM computer simulation modeling was also performed on the conventional sloped end treatment. Several small car simulation results were provided based on impact angle, impact speed, and impact location.

For end on impacts, the simulation results showed that vehicle overturn was likely at the 30, 37, and 45 mph speeds for taper lengths of 10 and 15 ft. For 20 and 25 ft length, vehicle rollover was only predicted at 45 mph and with the 20 ft long sloped end.

For oblique impacts (15 degrees), vehicle rollover was not predicted for the 20 and 25 ft section lengths and at any of the three speeds.

For oblique impacts (30 degrees), vehicle rollover was predicted for the 10, 15, 20, and 25 ft section lengths and at all three speeds.

The TTI researchers recommended the use of 20 ft sloped sections over 25 ft sloped sections due to the insignificant benefit observed with using 25% longer section. The longer lengths were also noted to provide measurable improvement over the shorter segment lengths.

Question #2:

Six full-scale vehicle crash tests were conducted to evaluate two sloped end treatment configurations, as report in NCHRP Report No. 358. A conventional sloped end treatment and the New York sloped end treatment were evaluated. The CSET was 20 ft long while the NYSET was 19-ft 11 1/2-in. long. The sloped end treatments were anchored along their length during the test program.

The CSET was evaluated with three tests:

(a) small car impacting end at 45 mph and 0 degrees with left wheels aligned on barrier centerline - marginal stability observed - overturn possibly adverted by steel guide flag attached to front wheel assembly [test 8]

(b) small car impacting 2 ft from end at 45 mph and 30 degrees with left wheel contacting side slope - vehicle overturn - failure [test 9]

(c) small car impacting 2 ft from end at 30 mph and 30 degrees with left wheel contacting side slope - vehicle overturn - failure [test11]

The NYSET was evaluated with three tests:

(a) small car impacting end at 45 mph and 0 degrees with left wheels aligned on barrier centerline - marginal stability observed - overturn possibly adverted by steel guide flag attached to front wheel assembly [test 5]

(b) small car impacting 2 ft from end at 45 mph and 30 degrees with left wheel contacting side slope - vehicle overturn - failure [test 6]

(c) small car impacting 2 ft from end at 30 mph and 30 degrees with left wheel contacting side slope - vehicle overturn - failure [test12]

As shown above, crash tests have been performed on 20-ft long, anchored sloped end treatments with small cars. At 45 mph. end-on impacts were mariginal. For oblique impacts at 30 and 45 mph, test results were unsuccessful with vehicle rollover observed.

No crash testing on concrete sloped end treatments has been performed to date in accordance with the NCHRP Report No. 350 requirements. However, the end-on impact would likely qualify as one of the TL-2 test conditions.

Problem # 2 – Concrete Barrier Orientation

State Question:

Good Morning, Dick (Powers) and Ron (Faller),

A question came up already this morning about the orientation of concrete barriers on superelevated roadsides. One thought is that they are installed vertical with respect to a flat surface, while the other thought is they should be rotated so that the vertical axis is perpendicular to the slope of the roadway.

A 1997 NHI course "Design and Construction of Highway Safety Features and Appurtenances" (section 4.1.7) states that "...when CSS barriers are installed on superelevated curves, the preferred orientation is for barrier on the high side f the curve to be installed with its axis perpendicular to the roadway, and on the low side of the curve with the axis vertical."

I say this recommendation still applies, and it also applies to the single slope design. But, I've been requested to ask you whether or not this recommendation still applies, and more specifically, if it also applies to the single slope barrier shape. What are your opinions on this?

As usual, thanks!

Dean Focke
Ohio DOT

MwRSF Response:

In the early 1980's, Maurice Bronstad, et al, formerly of Southwest Research Institute, conducted a series of full-scale vehicle crash tests on three curved bridge railing configurations using three different test vehicles. The report references are as follows:

(1) Bronstad, M.E. and Kimball, C.E., Jr., *Bridge Rail Retrofit for Curved Structures - Volume I: Executive Summary*, Report No. FHWA/RD-85/040, Final Report Prepared for the Offices of Research and Development, Federal Highway Administration, Washington, D.C., September 1986.

(2) Bronstad, M.E. and Kimball, C.E., Jr., *Bridge Rail Retrofit for Curved Structures - Volume 2: Technical Report*, Report No. FHWA/RD-81/, Final Report Prepared for the Offices of Research and Development, Federal Highway Administration, Washington, D.C., June 1981.

The three test vehicles included an 1,800-lb mini-compact car, a 2,250-lb subcompact car, and a 20,000-lb school bus. All crash tests were performed at the target impact conditions of 40 mph and 15 degrees.

The three bridge railing configurations included:

(1) a New Jersey concrete safety shape bridge installed **vertical** to a super-elevated bridge deck surface,
(2) a New Jersey concrete safety shape bridge installed **perpendicular** to a super-elevated bridge deck surface, and
(3) a tubular thrie beam/collapsing tube retrofit bridge railing installed **perpendicular** to a super-elevated bridge deck surface.

The results and conclusions are as follows:

All three barrier systems contained and redirected the full range of test vehicles. In terms of stability and acceleration, the tubular thrie beam retrofit with a more vertical front face was superior but installed perpendicular to the superelevated deck.

For the safety shape testing, there was not a dramatic difference in performance for the two safety shape orientations. The preferred orientation, as determined from a 1976 concrete median barrier research program and from the later research results noted above, was to place the barrier perpendicular to the superelevation when the vehicle approach is up the superelevation. It was noted that vehicle climb was reduced by this preferred orientation in the car tests although only in the bus test was this significant. The authors stated that the school bus test was noticeably less severe in terms of vehicle redirection with the preferred perpendicular orientation. It was also observed that the small car was at the threshold of riding on top of the barrier for the barrier placed vertical to the earth and not perpendicular to the superelevated deck.

Finally, for barriers placed on the downside of the superelevation, I agree with Dick Powers that those barriers are preferred to be placed vertical or perpendicular with respect to the earth and not with the superelevated deck.

If you have any additional questions regarding the enclosed information, please feel to call or email me to discuss. Overall, I believe that the information that I have provided is consistent with that provided by Dick (Powers). Thanks!

Respectfully,

Ronald K. Faller

FHWA Response:

This topic was discussed in the 1977 AASHTO Barrier Guide where it was concluded that the "optimum" orientation was vertical on the low side and perpendicular to the roadway surface on the high side. However, that Guide also indicated the best "compromise" (or practical) orientation was vertical at both locations. A vertical wall (not NJ, F-, or single slope shape) would limit vehicular climb better than any shaped design. No significant difference in crash performance between a NJ and a constant slope shape.

Dick Powers

Problem # 3 – Wisconsin Barrier Design

State Problem:

Wisconsin began by asking MwRSF to check the adequacy of a concrete barrier they had designed to meet the TL-4 impact condition. Initial calculations performed by MwRSF found that the barrier did not posses sufficient capacity to meet TL-4 as designed, MwRSF suggested some changes. After the suggested changes were determined to cost too much, they requested a new concrete barrier design. The concrete barrier was designed to be capable of being slip formed and attached to an existing roadway or shoulder using tie bars that could be inserted during the paving of the roadway. These bars are currently used in a similar manner to connect shoulder pavement to mainline pavement by WiDOT.

A TL-4 barrier designed was presented to Wisconsin, but it proved to be too costly. WiDOT then sought and received federal approval to lower their concrete barrier design to TL-3. It was still desired that the TL-3 version of the barrier be slip-formable and be capable to attachment to an existing roadway or shoulder with tie bars. The first TL-3 barrier was completed, but there were issues with the stirrups and the slip forming capabilities. The stirrups were then redesigned, allowing slip forming capabilities, but once again the design was too costly and it was abandoned by Wisconsin in favor of a past design.

MwRSF Response:

Wisconsin Barrier Design Summary

Figure 1:

Design 1 – TL-4

42 in. high, 9 in. wide Concrete single faced F-shape barrier with 13 in. slab footing. Slab footing attaches to neighboring roadway or shoulder. Stirrups are continuous between slab and wall.

Figure 2:

Design 2 – TL-4

42 in. high, 9 in. wide Concrete single faced F-shape barrier with 24 in. square torsion footing. Torsion footing does not need to attach to neighboring roadways or shoulders.

Figure 3:

Design 3 – TL-3

42 in. high, 9 in. wide Concrete single faced F-shape barrier with 13 in. slab footing. Slab footing attaches to neighboring roadway or shoulder. Stirrups are not continuous

between slab and wall allowing for easier slip forming in two phases.

Figure 4:

Rebar and stirrup details for Design 3.

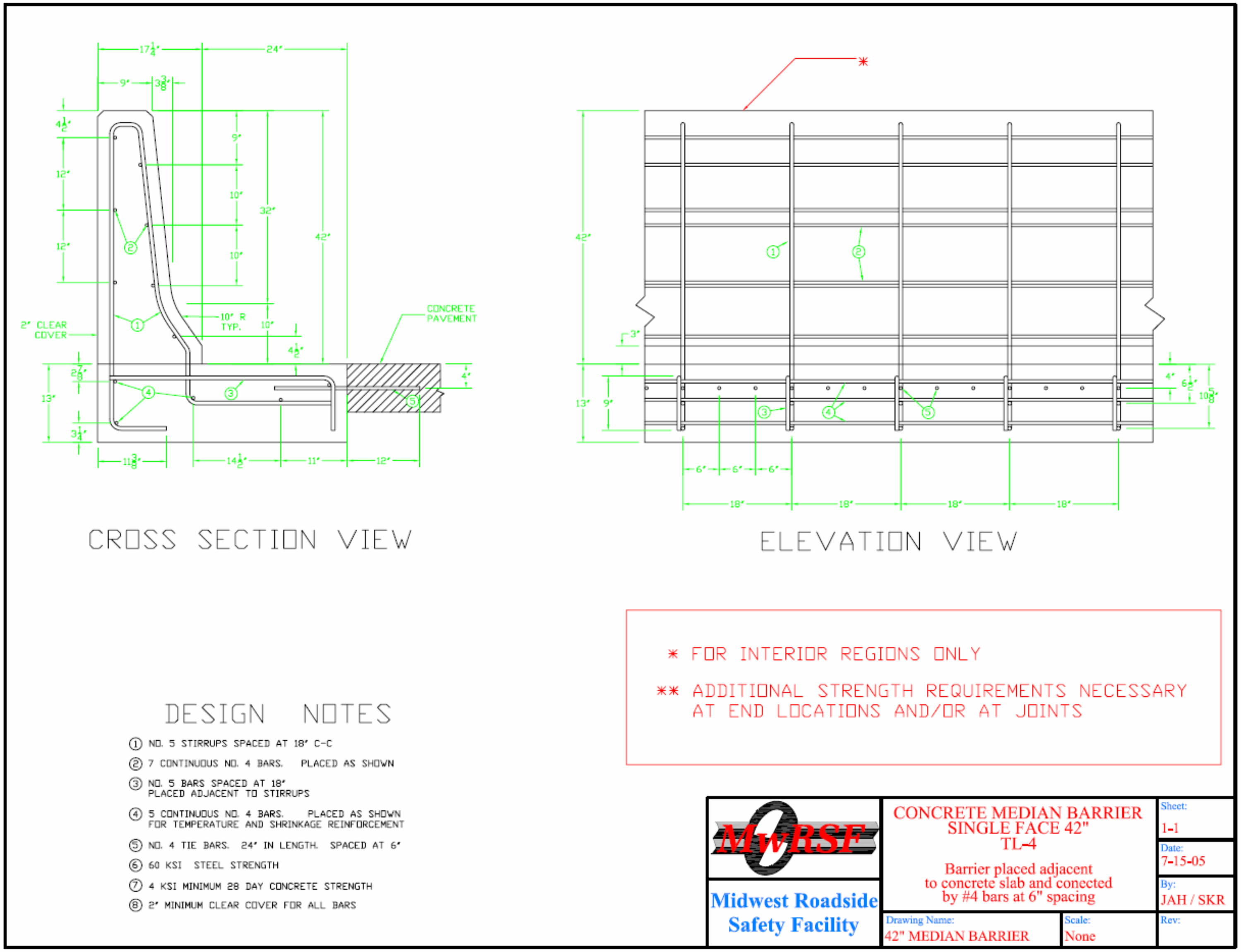

Figure 1. Design 1 – TL-4

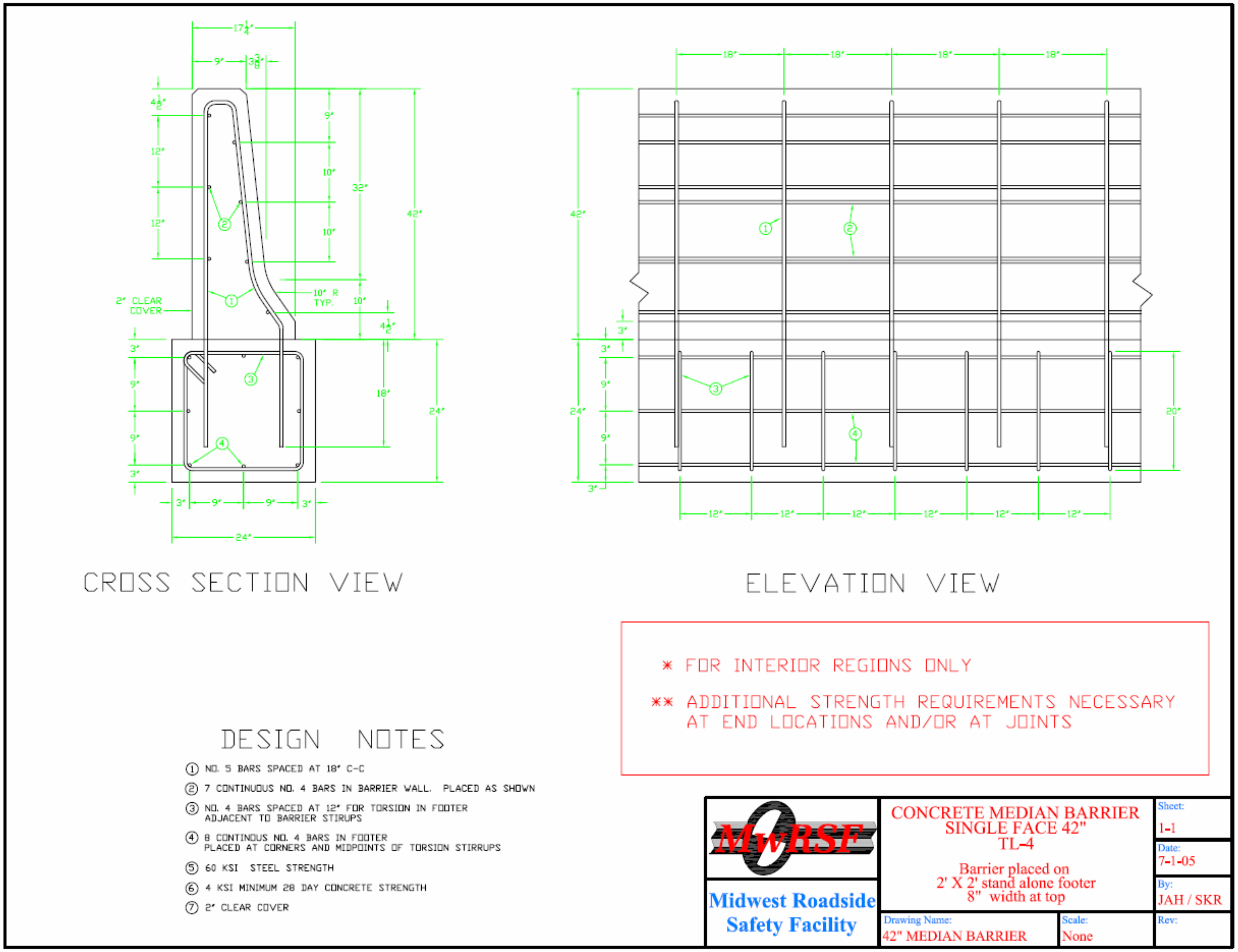

Figure 2. Design 2 – TL-4

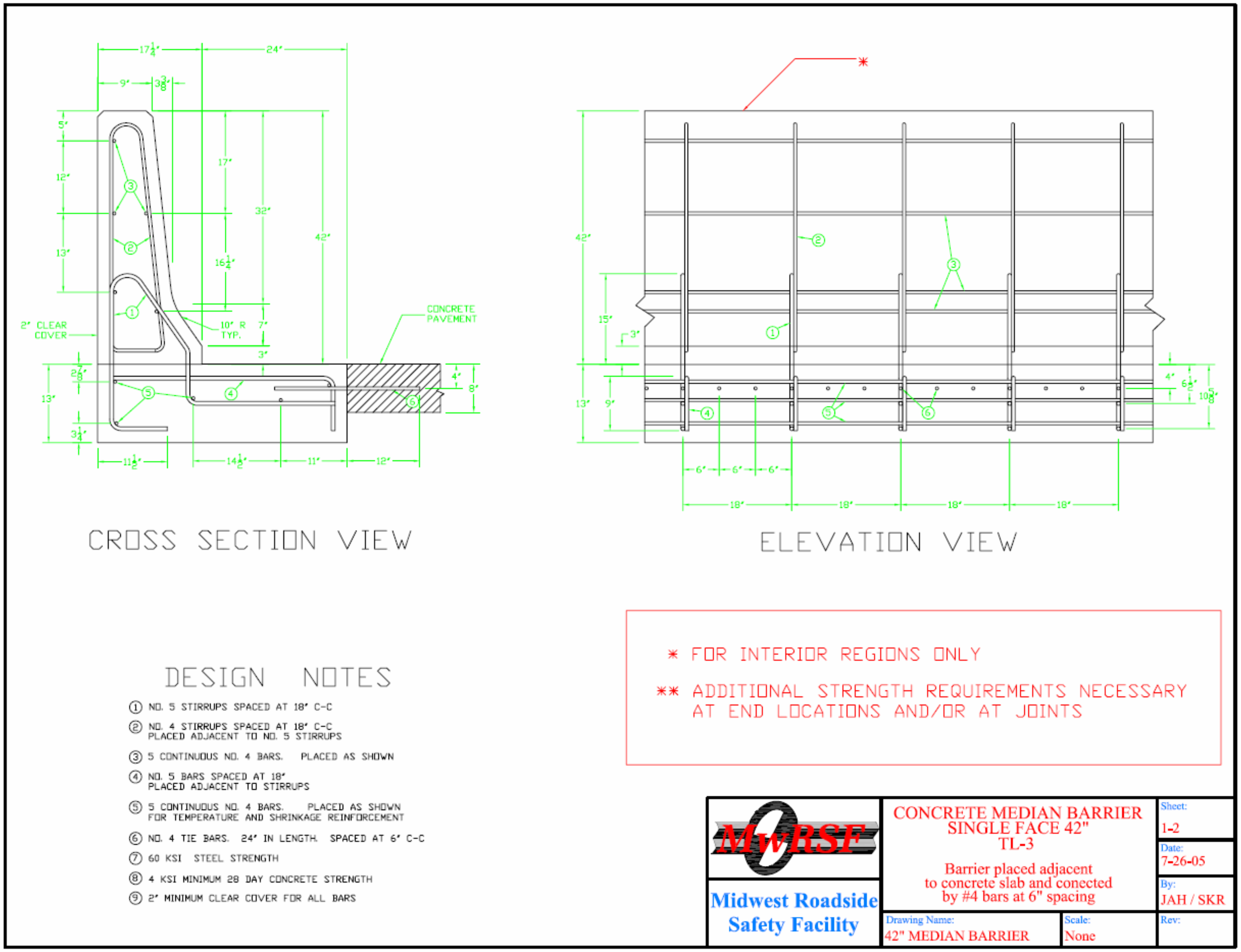

Figure 3. Design 3 – TL-3

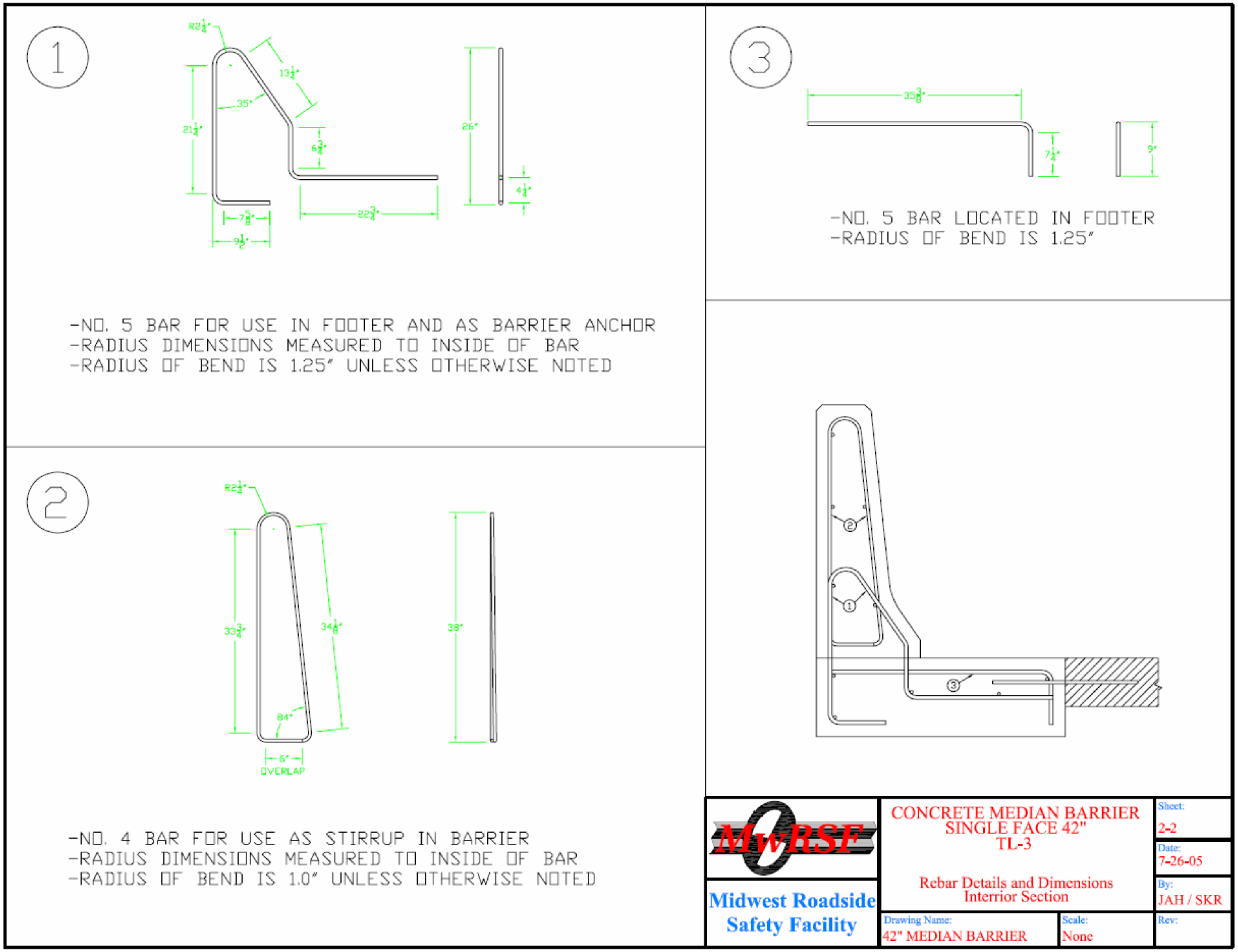

Figure 4. Rebar and Stirrup Details for Design 3