

**Fourth Quarter 2004 Progress Report**  
Midwest Roadside Safety Facility  
Mid-States Regional Pooled Fund  
January 28, 2005

## **YEAR 12**

### **Development of a Guardrail Treatment at Intersecting Roadways-Year 3**

The system, augmented by an anchor placed near the center of the radiused section, will utilize a release mechanism similar to the cable terminal currently being tested under Year 14. This anchor will significantly reduce system deflection during impacts on the side of the radiused section and should still allow the system to capture a vehicle impacting on the "nose". The system is fully constructed waiting for Spring to come to Nebraska.



### **Portable Aluminum Work Zone Signs**

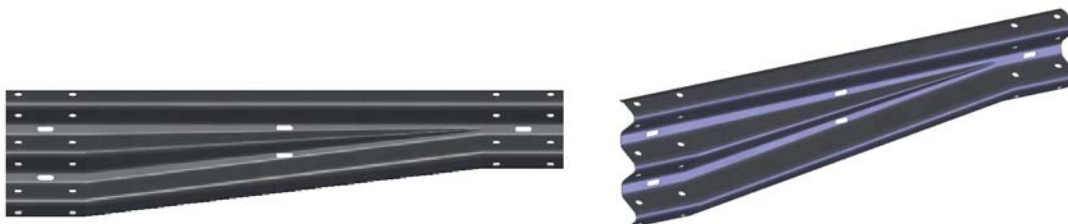
The bogie testing for this project has been completed. A submission to FHWA seeking approval was sent and received approval. Polivka, K.A., Faller, R.K., Holloway, J.C., and Rohde, J.R., ***Safety Performance Evaluation of Minnesota's Low-Height, Temporary Rigid Panel Sign Stand***, Final Report to the 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.

### **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**

A full-scale test of this system was conducted on July 29, 2004. This test demonstrated that the current welded, asymmetrical W-beam to Thrie-beam section had inadequate capacity. During this Quarter, two manufacturers have committed to producing 10-gauge transitions for this work. We anticipate having materials in house to begin construction late in the 1<sup>st</sup> Quarter of 2005. Funding for this test will be proposed at the upcoming annual pooled fund meeting.



### **Three-Strand Cable Median Barrier**

A full-scale small car test was performed on the new 4-cable median barrier on November 10, 2004. As shown in the sequential photos below, the vehicle was redirected and ultimately stopped in the system. While the test passed all salient criteria, the performance of the system was considered less than optimal. While the cable load was transferred into the posts by the new cable attachment system, the cables showed a tendency to come out of the top of the hooks prematurely. Currently, a retainer system is being developed for future testing. This enhancement should reduce deflection of the system by providing prolonged connectivity between the posts and thus forcing the posts to rotate in the soil.



## **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")**

Currently, there is not additional funding for further development so our plan is to report on the two unsuccessful tests and look for recommendations during the next year's annual meeting.

### **Evaluation of Rigid Hazards in Zone of Intrusion**

Previous full-scale TL-3 and TL-4 crash tests of a luminaire pole mounted on top of a single-slope concrete barrier have been acceptable. The final TL-4 test will incorporate a luminaire pole mounted on the concrete deck behind the barrier and is planned for the 1<sup>st</sup> Quarter of 2005.

### **Three-Cable Guardrail**

This project is on hold pending results of the post bogie testing being performed under the median cable barrier project in Year 12.

### **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**

Follows work under Year 12.

### **Evaluation of Transverse Culvert Safety Grate**

Full-Scale testing is anticipated late in the 2<sup>nd</sup> or early in the 3<sup>rd</sup> Quarter of 2005.

### **Flare Rates for W-Beam Guardrail**

The objectives of this research are to evaluate the effect of increased flare rates on impact performance and identify optimal flare rates that minimize total crash costs. A literature review of flare rates, including relevant crash testing and standards, is complete. Additionally, baseline Barrier VII models for the standard W-beam guardrail and for the MGS W-Beam guardrail system have been performed. This effort has resulted in the determination of an impact angle for the initial evaluation of 29.4°. This test is planned for late in the 1<sup>st</sup> Quarter of 2005. A great deal of the initial research for this project was funded under NCHRP 17-20(3), Critical Flare Rates for W-beam Guardrail Determining Maximum Capacity Using Computer Simulation. Copies of the final report for that research has been sent to each of the member states for review.

### **Approach Slopes for W-Beam Guardrails Systems**

Initial simulation efforts are underway to predict the effect of slope angle, slope length and barrier height on the performance of W-beam systems. Conclusions of this work will be utilized to establish parameters for full-scale tests.

### **Concept Development of a Bridge Pier Protection System for Longitudinal Barrier**

The literature review for this project has been started. This review consists of an overview of the current pier protection standards utilized by the member states.

### **Retest of Cable End Terminal**

A modified system with additional breakaway posts has been fabricated. Testing of the system is planned for early 2005 dependent on the weather.

## **SUPPLEMENTAL PROJECTS:**

### **Transitions and Deflection Limiting Modifications for the Kansas Type F3 Concrete Temporary Barrier**

This project was initiated with two goals. First, it was necessary to develop a tie-down system to limit the deflection of the barrier system when placed on an asphalt concrete surface with some sort of restraint mechanism. Second, it was deemed necessary to transition from free standing barrier to barrier bolted to a bridge deck.

On September 27<sup>th</sup>, 2004, a full-scale test of the pinned barrier was performed. The barrier was placed on a 2" asphalt pad 6" in front of a vertical drop off, with the barrier restrained utilizing the three existing holes on the impact face with 1.5" diameter, 3' long A36 pins. The full-scale test met all salient criteria and was deemed a pass. The maximum permanent deflection of the barrier was approximately 12". Before and after photos are shown below. A design concept for transitioning from free standing barrier to a bolted bridge section has been developed. As of early December, discussions with FHWA based on this design concept have cleared the way for testing of this system which is planned late 1<sup>st</sup> or early in the 2<sup>nd</sup> Quarter of 2005 depending on weather.



### **Minnesota Sound Wall Rail**

Polivka, K.A., Rohde, J.R., Faller, R.K., Holloway, J.C., and Sicking, D.L., *Design and Evaluation of Minnesota's Timber Rub-Rail for Noise Barriers*, Draft Report to Minnesota Department of Transportation, Transportation Research Report No. TRP-03-156-04, Midwest Roadside Safety Facility, University of Nebraska-Lincoln, November 30, 2004.

### **NCHRP 22-14(2) – Update of NCHRP Report No. 350**

An update on the progress of NCHRP 22-14(2), the update of NCHRP Report No. 350, was given at the 2005 Transportation Research Board Annual Meeting. The presentation reviewed seven full-scale crash tests that were conducted at MwRSF over the past year in support of NCHRP 22-14(2). The presentation has been attached to this progress report in order to keep the states informed on the development of NCHRP 22-14(2).

**Pooled Fund Consulting Summary**

Midwest Roadside Safety Facility  
October 2004 – January 19, 2005

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 – Unsupported W-beam Guardrail Lengths Greater than 6'-3"**

State Question:

MnDOT asked MwRSF to comment on strong post W-beam guardrail systems with unsupported spans greater than 6'-3". This question related to options for W-beam guardrail installations where a post needed to be left out or could not be installed.

MwRSF Response:

I am sending you an email response that I had sent to Dick Powers of FHWA, Washington, D.C., in October 2003. I hope that this new information will help answer your question on unsupported guardrail spans greater than 6 ft - 3 in. Please note that the question raised to us by Dick related to long span guardrail systems in general and the associated nesting requirements for the W-beam rail adjacent to the unsupported span. Your question was very similar in that you desired comment on a strong-post, W-beam guardrail system where one post was left out. For a quick answer, you may want to jump to the last paragraph. In summary, with current W-beam systems, we believe that you will need to nest the W-beam guardrail over the unsupported length and carrying the nesting into adjacent regions. At this time, the length of this nested rail for spans less than 25 ft is undetermined nor optimized for impacts with pickup trucks at the TL-3 conditions. In the future, we believe that the use of the MGS, in combination with long-span systems, may actually allow us to significantly reduce and/or eliminate the need for nested W-beam rail.

*Per my original email to Dick Powers:*

Recently, you had asked me to consider what reduced nested guardrail lengths would be acceptable for long-span guardrail systems placed over shorter culverts (i.e., with only one post (12.50-ft span) or two posts (18.75-ft span) left out).

Currently, we use 100 ft of nested rail for the 25-ft long-span system which resulted in 37.50 ft of nested rail on each side of the unsupported span. Obviously, shorter nested rail lengths will be acceptable when the unsupported span is reduced from 25 ft to either 12.50 or 18.75 ft. Three general approaches could be utilized for considering the shorter span alternatives. They are as follows:

Option 1 - A very conservative approach, which results in significant overkill in the design, would use 100 ft of nested rail for all long-span systems (i.e., 25 ft or shorter spans) in the absence of any new research (crash testing or computer simulation modeling). Personally, I would not recommend this approach since excess nested rail would be used for systems not requiring it. However, some states may choose to be very conservative and employ this solution. For clarity, this approach would consist of the following:

25.00-ft span: 100.00-ft nested rail

18.75-ft span: 100.00-ft nested rail

12.50-ft span: 100.00-ft nested rail

Option 2 - A moderately conservative approach would use the same length of nested rail on each side of the unsupported span or 37.50 ft. For shorter spans, this would result in a total nested rail length equal to 75.00 ft plus the length of the unsupported span. Prior MwRSF testing showed that the 37.50 ft of nested rail on each side of the span would be adequate for reducing and/or eliminating the potential for rail rupture when used in combination with a 25-ft span. As such, I believe that this same nested requirement would also be more than adequate for the 12.50 and 18.75-ft spans. For clarity, this approach would consist of the following:

25.00-ft span: 100.00-ft nested rail

18.75-ft span: 93.75-ft nested rail

12.50-ft span: 87.50-ft nested rail

Option 3 - A slightly more aggressive approach would use a reduced nested rail requirement on each side as shorter unsupported rail spans are encountered since it is recognized that dynamic deflections and critical rail stresses will likely be contained within a shorter region. In the absence of a BARRIER VII computer simulation effort or any compliance testing, I am personally unwilling to recommend this option. Please note that I am not stating that this option, or even one more aggressive yet, will not perform in an acceptable manner. I am just unwilling to recommend such a leap without further validation/verification. However, I will provide it for clarity below:

25.00-ft span: 100.00-ft nested rail (37.50 ft of nested rail on each side)

18.75-ft span: 81.25-ft nested rail (31.25 ft of nested rail on each side)

12.50-ft span: 62.50-ft nested rail (25.00 ft of nested rail on each side)

Finally, it should be noted that the relocation of the rail splice and/or implementation of the MGS guardrail system for culvert applications may help to reduce the nesting requirements from what is shown in all three options above. However, those nesting reductions can only be verified with full-scale crash testing according to the NCHRP Report No. 350 criteria, computer simulation modeling, and/or combinations thereof. It should be noted that several Pooled Fund States have inquired about this same topic in the past, that of which must be resolved in a future funded research study. If you have any questions regarding this matter, please feel free to call or email

me at your convenience. Dean would also concur that options 1 and 2 are too conservative and even the final option (option 3) may be actually over designed.

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

## **Problem # 2 – Rectangular Washers and Reduced Post Spacing**

State Question:

Illinois no longer uses the rectangular plate washers behind the bolt holding guardrail to blockouts for the 6'-3" post spacing. However, it has been pointed out that we still use this on the double face guardrail, and I have noted that we still use this washer on guardrail installations with 3'-1½" post spacing.

The inquiry regarding the double faced guardrail was referred to Dick Powers at FHWA before coming to me, and he has suggested that it would probably be better to eliminate it from that application.

I am aware that the Midwest Roadside Safety Facility has conducted testing of the reduced post spacing of W-beam guardrail on 2:1 slope breaks. (October 2000 report entitled "Development of a W-Beam Guardrail System for Use on a 2:1 Slope.")

Did that application use the washers at the posts? From the photos you sent me on disk earlier, it appears that these washers were not used.

Based on Mr. Powers comments and pending your reply, we are considering removing these washers from our applications of both the double faced guardrail, and from the reduced post spacing design.

David L. Piper, P.E.  
Highway Policy Engineer

MwRSF Response:

Hello David!

For the strong-post, W-beam guardrail system installed at the slope break point on a 2H:1V fill slope, you are correct in stating that the system utilized a reduced or half-post spacing. In addition, the noted guardrail system was designed and installed **without** the use of any rectangular washers on the traffic-side face of the rail element. Rectangular washers are no longer recommended on guardrail systems as their use can lead to the rail being pulled down to the ground during system deformation and post rotation, thus resulting in an increased potential for override of semi-rigid barrier systems. The use of these washers are obviously more critical



in guardrail systems that are subjected to higher deformations and where guardrail release from the posts is desired. For stiffer guardrail systems, such as the three beam approach guardrail transition system, their use is much less of a concern since large barrier deflections generally do not occur.

Over the last several years, MwRSF researchers have been involved in the development, testing, and evaluation of many corrugated steel beam guardrail systems, including those using both standard and reduced post spacing designs. For all of these guardrail systems, MwRSF has **not** implemented the use of rectangular washers on the rail face and has no plans to do so in the future. As such, we concur with the suggestion made by Dick Powers of FHWA.

Respectfully,

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

### **Problem # 3 – USH 12 Lake Delton Vertical Concrete Barrier**

State Question:

Peter,

Ron and I reviewed your question and came up with the following response. Before I comment on the proposed system, it should be noted that MwRSF has a new Pooled Fund project to develop, test, and evaluate a concrete barrier for use in protecting bridge piers.

The proposed vertical concrete barrier is 15.75-in thick by 42-in. tall and reinforced by three longitudinal No. 4 rebars and anchored to an edge slab with No. 8 vertical dowel bars (10.5 in. in barrier and 7.5 in. in slab). The vertical dowel bars are spaced on 18-in. centers. It is my understanding that the Wisconsin DOT desires to use this barrier to protect bridge piers and needs the barrier to meet Test Level 3 of NCHRP Report 350.

From a very brief review, it is noted that the cross-sectional area of the thick barrier is 661.50 sq. in. Therefore, the approximate shrinkage and temperature steel requirements for longitudinal reinforcement is a minimum of 1.19 sq. in. Thus, approximately six No. 4 longitudinal bars, versus three, would be required for this large cross section in order to prevent significant cracking and gaps from forming in the barrier. Although not determined, it is very likely that a 15.75-in. wide barrier measuring 42-in. tall would be capable of meeting the TL-3 requirements when reinforced with six longitudinal No. 4 bars for interior locations. In addition, if designed using the yield-line analysis procedures, it is believed possible to further reduce the thickness and still not require crash testing. At the present, there exists no vertical reinforcement in the barrier. Although it has been shown on occasion that concrete barriers with limited or no reinforcement have met crash testing guidelines, it is reasonable to utilize a minimum amount of vertical reinforcement for temperature and shrinkage considerations as well as to tie the wall to the dowel bars. Steel reinforcement for the barrier located away from the interior regions, such as

at gaps, joints, or end sections, must also be considered since a reduced redirective capacity exists in those regions.

For 42-in. tall vertical walls, it is becoming more known that new designs should address or consider the potential for an occupant's head to extend out of the side window and impact the concrete barrier above the 32-in. height. Thus, setbacks near the top of the wall should be considered although they are not required.

I have provided a few comments and considerations on the proposed design. Please feel free to contact me at your convenience!

Bob Bielenberg, MSME, EIT  
Research Associate Engineer



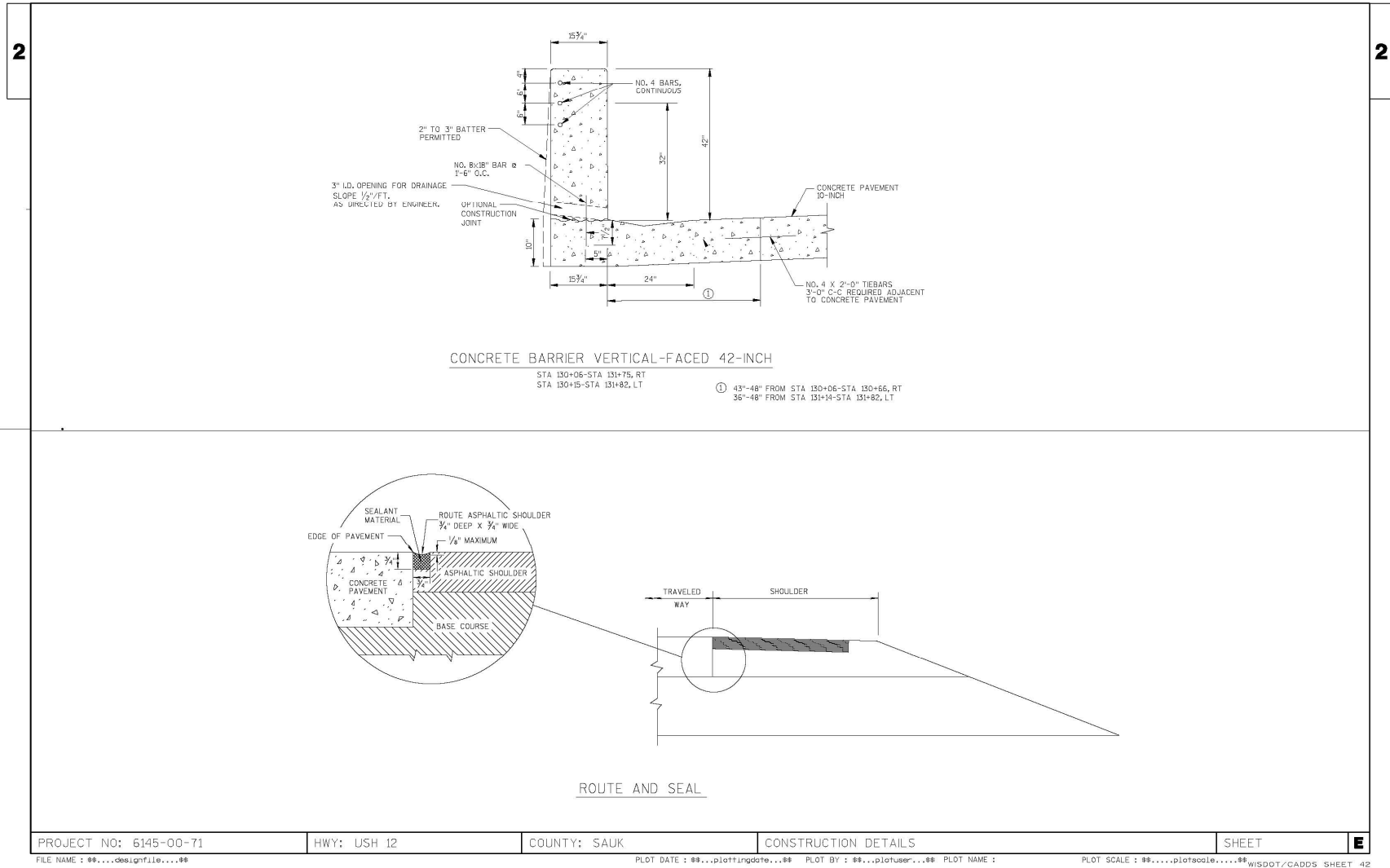


Figure 2. Vertical Shape Concrete Barrier



## Exploration of Crash Test Conditions Proposed for the Update to NCHRP Report 350

**Karla A. Polivka**  
University of Nebraska-Lincoln  
Midwest Roadside Safety Facility

January 11, 2005

## Vehicle and Impact Conditions

- Vehicle weights have increased
  - 6% of all vehicles sold in 2002 weigh more than 2270 kg (5000 lbs)
  - Large SUV c.g. heights range from 28 - 29.5 in.
  - 98% of all vehicles sold in 2002 weigh more than 1100 kg (2425 lbs)
- Crash data indicates
  - 100 km/h is 85<sup>th</sup> percentile crash speed
  - 25° represents 85<sup>th</sup> percentile impact angle
  - Impact angles for small cars & SUV are similar

## Preliminary Recommendations

- Test Vehicles
  - Light truck test vehicle should weigh 2270 kg (5000 lbs)
    - ¾-ton regular cab pickup (2WD), c.g. ≈ 27 in.
    - 4-door ½-ton full-size pickup (2WD), c.g. ≈ 28 in.
  - Small car test vehicle should weigh 1100 kg (2425 lbs)
- Recommend 100 km/h, 25° impact for both vehicles

## Testing Program

- Identify effects of proposed changes in the guidelines
  - How will our safety hardware perform under the new guidelines?
  - What are the expected benefits of updating the guidelines?
- Provide information needed for developing an implementation plan

## Full-Scale Tests


- Standard W-Beam
  - 2002 GMC Pickup @ 100 km/h & 25°
- Midwest Guardrail System
  - 2002 GMC Pickup @ 100 km/h & 25°
  - 2002 Dodge Quad Pickup @ 100 km/h & 25°
  - 2002 Kia Rio @ 100 km/h & 25°

## Full-Scale Tests

- Free-Standing Temporary Barrier
  - 2002 GMC Pickup @ 100 km/h & 25°
  - 2002 Dodge Quad Pickup @ 100 km/h & 25°
- Permanent New Jersey Barrier
  - 2002 Kia Rio @ 100 km/h & 25°

**Midwest Roadside Safety Facility**


## Standard W-beam



Test: 2214WB-1    2002 GMC    98.3 km/h    25.6°

**Midwest Roadside Safety Facility**


## Standard W-beam



IS = 158 kJ  
(350: 138 kJ)

**Midwest Roadside Safety Facility**


## Midwest Guardrail System



Test: 2214MG-1    2002 GMC    100.7 km/h    25.2°

**Midwest Roadside Safety Facility**


## Midwest Guardrail System



IS = 161 kJ  
(350: 138 kJ)

**Midwest Roadside Safety Facility**


## Midwest Guardrail System



Test: 2214MG-2    2002 Dodge Quad    101.1 km/h    25.5°

**Midwest Roadside Safety Facility**


## Midwest Guardrail System



IS = 166 kJ  
(350: 138 kJ)

Midwest Roadside Safety Facility


## Midwest Guardrail System



Test: 2214MG-3    2002 Kia Rio    97.8 km/h    25.4°

Midwest Roadside Safety Facility

## Midwest Guardrail System



IS = 80 kJ  
(350: 37 kJ)

Midwest Roadside Safety Facility

## Free-Standing Temporary Barrier



Test: 2214TB-1    2002 GMC    99.5 km/h    25.7°

Midwest Roadside Safety Facility


## Free-Standing Temporary Barrier



IS = 163 kJ  
(350: 138 kJ)

Midwest Roadside Safety Facility

## Free-Standing Temporary Barrier



Test: 2214TB-2    2002 Dodge Quad    99.7 km/h    25.4°

Midwest Roadside Safety Facility

## Free-Standing Temporary Barrier




IS = 161 kJ  
(350: 138 kJ)



**Midwest Roadside Safety Facility**


## Permanent New Jersey Barrier



Test: 2214NJ-1    2002 Kia Rio    97.9 km/h    26.1°

**Midwest Roadside Safety Facility**

## Permanent New Jersey Barrier



IS = 84 kJ  
(350: 37 kJ)