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SAFETY PERFORMANCE EVALUATION OF MINNESOTA'S LOW-HEIGHT, TEMPORARY RIGID PANEL SIGN STAND

Submitted by

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Submitted to

MIDWEST STATES' REGIONAL POOLED FUND PROGRAM
Nebraska Department of Roads
1500 Nebraska Highway 2
Lincoln, Nebraska 68502

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16. Abstract (Limit: 200 words)

A wide variety of traffic controlling devices are used in work zones, some of which are not normally found on the roadside or in the traveled way outside of the work zones. These devices are used to enhance the safety of the work zones by controlling the traffic through these areas. Due to the placement of the traffic control devices, the devices themselves may be potentially hazardous to both workers and errant vehicles. The impact performance of many work-zone traffic control devices is mainly unknown and to date limited crash testing has been conducted, under the criteria of National Cooperative Highway Research Program (NCHRP) Report No. 350, *Recommended Procedures for theSafety Performance Evaluation of Highway Features*.

The objective of the study was to evaluate the safety performance of a modified work-zone traffic control devices through dynamic bogie testing according to the Test Level 3 (TL-3) criteria set forth in the NCHRP Report No. 350. Both of the impacts on the low-height, temporary rigid panel sign supports resulted in acceptable safety performances. Following the analysis of these crash tests as well as the test results from other testing programs, it has been found that slight variations in design features of the work-zone traffic control devices can lead to very different performance results. Therefore, extreme care should be taken in applying crash test results from one work-zone traffic control device to similar work-zone traffic control devices with slight variations. The results of the crash tests were documented and the temporay work-zone device were accepted by Federal Highway Administration (FHWA) as a crashworthy device.

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DISCLAIMER STATEMENT

The contents of this report reflect the views of the authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views nor policies of the State Highway Departments participating in the Midwest States' Regional Pooled Fund Research Program nor the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

ACKNOWLEDGMENTS

The authors wish to acknowledge several sources that made a contribution to this project: (1) The Minnesota Department of Transportation for donating the signs; (2) the Midwest States' Regional Pooled Fund Program funded by the Connecticut Department of Transportation, Iowa Department of Transportation, Kansas Department of Transportation, Minnesota Department of Transportation, Missouri Department of Transportation, Montana Department of Transportation, Nebraska Department of Roads, Ohio Department of Transportation, South Dakota Department of Transportation, Texas Department of Transportation, and Wisconsin Department of Transportation for sponsoring this project; and (3) MwRSF personnel for conducting the bogie crash tests.

A special thanks is also given to the following individuals who made a contribution to the completion of this research project.

Midwest Roadside Safety Facility

D.L. Sicking, Ph.D., P.E., Associate Professor and MwRSF Director
J.D. Reid, Ph.D., Associate Professor, Mechanical Engineering Department
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Beth Cannestra, P.E., Chief in Roadway Development

Federal Highway Administration

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1 SUBMISSION REQUESTING FHWA APPROVAL

University of Nebraska Lincoln

MIDWEST ROADSIDE SAFETY FACILITY

September 12, 2002

Mr. Nicholas Artimovich
Federal Highway Administration
Office of Safety
400 Seventh Street, SW
Washington, DC 20590
Phone - 202-366-1331
Fax - 202-366-2249

Subject: Submission for acceptance on one low-height, temporary rigid panel sign stand.

Dear Mr. Artimovich:

Recently, the Midwest Roadside Safety Facility (MwRSF) of the University of Nebraska-Lincoln conducted dynamic bogie testing on a modified temporary work-zone sign stand for the Minnesota Department of Transportation (Mn DOT). This dynamic bogie testing concluded a test program that consisted of full-scale vehicle crash testing of an original system and bogie testing on various temporary sign stand design modifications aimed at improving its overall safety performance. Based on our review of the successful bogie test results and on behalf of the Mn DOT, I am submitting this letter-type report in an effort to seek FHWA approval of the work-zone device according to the Test Level 3 (TL-3) impact conditions and requirements found in NCHRP Report No. 350.

As mentioned previously, one two work-zone device was subjected to a series of bogie tests using our lightweight bogie vehicle which is fitted with a simulated bumper, engine hood, and front windshield frame. The bogie vehicle itself is configured after the FHWA bogie vehicle which was developed in the late 1980's. Additional bogie modifications have been made in order to replicate the geometrical body features of the current small cars, more specifically the Geo Metro. These changes were deemed necessary in order to more accurately simulate the dynamic interaction between the simulated vehicle and the work-zone device.

On June 19, 2002, MwRSF performed two additional dynamic bogie tests on a work-zone sign stand manufactured by the Mn DOT.

Temporary Sign Stand w/ 48" x 48" Aluminum Panel w/ Attached Warning Light

Bogie test nos. MNSB-12 and MNSB-13 were performed at 0 and 90 degrees and 97.5 and 98.8 km/hr, respectively, and on a temporary sign stand which supported a 48-in. by 48-in. aluminum panel. The system description, design details, and test results for the 48-in. by 48-in. sign panel system are included in Attachment No. 1. In addition, bogie test no. MNSB-9 was performed at 0 degrees and on the same sign stand system but without the attached warning light. This additional test demonstrated that the system remains crashworthy when the light is or is not utilized.

1901 'Y' Street, Bldg. C
P.O. Box 880601
Lincoln, NE 68588-0601

Discussion

Based on the successful bogie testing on the temporary sign support system and in lieu of full-scale vehicle crash testing, we believe that the bogie tests are a valid indicator of the sign stands' safety performance. This conclusion is based on the fact that the rigid panel sign support system did not contact the bogie vehicle's front windshield region during the initial impact event. Although it can only be verified through full-scale vehicle crash testing, it is our opinion that the temporary sign support system presented herein would meet the TL-3 safety standards found in NCHRP Report No. 350.

If you have any questions regarding this information, please feel free to contact me at (402) 472-6864.

Sincerely,

Ronald K. Faller

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

Enclosure:

(1) One CD-ROM containing digital still photographs, slow-speed footage, and high-speed footage of the three bogie tests (MNSB-12, MNSB-13, and MNSB-9).

Attachment:

(1) Performance Analysis of Mn DOT's 48" x 48" Rigid Panel Systems (MNSB-12 and 13)

x.c. - Karla Polivka, M.S.M.E., E.I.T., Research Associate Engineer

2 SUBMISSION REPORT ATTACHMENTS

Attachment No. 1

PERFORMANCE ANALYSIS OF MINNESOTA'S DEPARTMENT OF TRANSPORTATION 48" x 48" RIGID PANEL SYSTEMS

Bogie Test MNSB-12 (Head-on device)

1. System:
   - Vertical Upright Masts – 44.5 mm (1.75 in.) sq. galvanized telespar ASTM A-653 Grade 50 steel tubing with 2.67 mm (0.105 in.) wall thickness and a length of 1,524 mm (60 in.).
   - Outside Vertical Upright Tubing – 50.8 mm (2 in.) sq. galvanized telespar ASTM A-653 Grade 50 steel tubing with 2.74 mm (0.108 in.) wall thickness and a length of 911 mm (35.875 in.).
   - Legs, Horizontal Portion – 38.1 mm (1.5 in.) sq. galvanized telespar ASTM A-653 Grade 50 steel tubing with 2.74 mm (0.108 in.) thickness and a length of 1,524 mm (60 in.).
   - Legs, Vertical Stub – 38.1 mm (1.5 in.) sq. galvanized telespar ASTM A-653 Grade 50 steel tubing with 2.74 mm (0.108 in.) wall thickness and a length of 305 mm (12 in.).
   - Vertical stub of the leg is welded to the horizontal portion of the leg on all four sides.
   - Outside vertical upright tubings slide over the vertical upright masts.
   - Vertical portion of legs slide into vertical upright masts – 7.9 mm (0.3125 in.) diameter x 63.5 mm (2.5 in.) long hex head S30400 threaded bolts were used to fasten masts and legs.

   Sign: Rigid
   - Panel – Rigid aluminum, 1,219 mm (48 in.) wide x 1,219 mm (48 in.) long with 2.74 mm (0.108 in.) thickness.
   - Panel fastened to vertical mast supports with four 7.9 mm (0.3125 in.) diameter x 63.5 mm (2.5 in.) long hex head S30400 threaded bolts. A 23.81 mm (0.9375 in.) OID x 1.59 mm (0.0625 in.) thick rubber washer was placed between the head of the bolt and the sign panel.
   - Warning Light – "Toughlite 2000" attached to the sign panel.

   Height to Bottom of Sign: 335 mm (13.1875 in.)
   Height to Top of Outer Tube: 959 mm (37.74 in.)
   Height to the Warning Light Bolt: 1,481 mm (58.3125 in.)

2. Weights of Sign Systems

Legs:	9.072 kg (10 lbs)
Panel, Masts, Outside Tubes, and Lights:	36.741 kg (81 lbs)
Ballast (sandbags):	20.4 kg (45 lbs) – 1 sandbag at end of each leg

3. Bogie Vehicle Weight: 974 kg (2,148 lbs)

4. Impact speed: 97.5 km/hr (60.6 mph)
   Impact orientation: 0 degrees

5. Velocity Change: ≈ 10 km/hr

6. System performance – Minor mast and leg deformations were observed. The sign panel, masts, outer tubes, and legs remained intact. One of the lower panel bolts pulled through the panel. The top of the sign panel and masts rotated toward the vehicle, but no contact nor damage to the windshield area was observed. Throughout the entire test, the system remained in front of the vehicle and never became a potential hazard to the bogie nor the occupant compartment.

Bogie Test MNSB-13 (End-on device)

1. <u>System:</u>
   - Vertical Upright Masts – 44.5 mm (1.75 in.) sq. galvanized telespar ASTM A-653 Grade 50 steel tubing with 2.67 mm (0.105 in.) wall thickness and a length of 1,524 mm (60 in.).
   - Outside Vertical Upright Tubing – 50.8 mm (2 in.) sq. galvanized telespar ASTM A-653 Grade 50 steel tubing with 2.74 mm (0.108 in.) wall thickness and a length of 911 mm (35.875 in.).
   - Legs, Horizontal Portion – 38.1 mm (1.5 in.) sq. galvanized telespar ASTM A-653 Grade 50 steel tubing with 2.74 mm (0.108 in.) thickness and a length of 1,524 mm (60 in.).
   - Legs, Vertical Stub – 38.1 mm (1.5 in.) sq. galvanized telespar ASTM A-653 Grade 50 steel tubing with 2.74 mm (0.108 in.) wall thickness and a length of 305 mm (12 in.).
   - Vertical stub of the leg is welded to the horizontal portion of the leg on all four sides.
   - Outside vertical upright tubings slide over the vertical upright masts.
   - Vertical portion of legs slide into vertical upright masts – 7.9 mm (0.3125 in.) diameter x 63.5 mm (2.5 in.) long hex head S30400 threaded bolts were used to fasten masts and legs.

Sign: Rigid

- Panel – Rigid aluminum, 1,219 mm (48 in.) wide x 1,219 mm (48 in.) long with 2.74 mm (0.108 in.) thickness.
- Panel fastened to vertical mast supports with four 7.9 mm (0.3125 in.) diameter x 63.5 mm (2.5 in.) long hex head S30400 threaded bolts. A 23.81 mm (0.9375 in.) OID x 1.59 mm (0.0625 in.) thick rubber washer was placed between the head of the bolt and the sign panel.
- Warning Light – "Toughlite 2000" attached to the sign panel.

Height to Bottom of Sign:	333 mm (13.125 in.)
Height to Top of Outer Tube:	959 mm (37.75 in.)
Height to the Warning Light Bolt:	1,480 mm (58.25 in.)

2. Weights of Sign Systems

Legs:	9.072 kg (10 lbs)
Panel, Mast, Outside Tubes and Bars:	36.741 kg (81 lbs)
Ballast (sandbags):	20.4 kg (45 lbs) – 1 sandbag at end of each leg

3. Bogie Vehicle Weight: 974 kg (2,148 lbs)

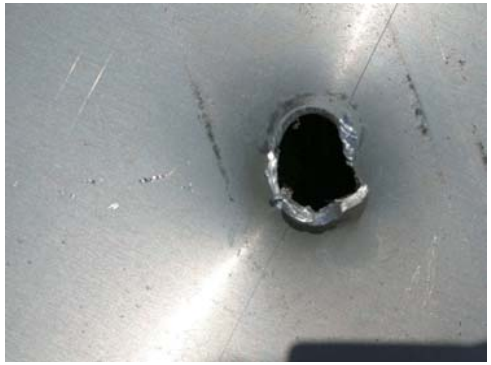
4. Impact speed: 98.8 km/hr (61.4 mph)
   Impact orientation: 90 degrees

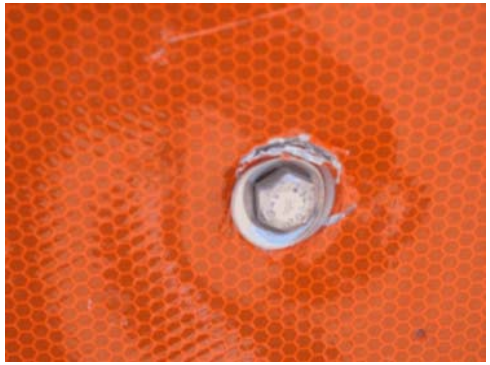
5. Velocity Change: ≈ 10 km/hr

6. System performance – Minor mast and panel deformations were observed. The legs were deformed and fractured. The mast furthest from the vehicle disengaged completely but the leg remained attached. All the panel bolts pulled through the sign panel except for the top one closest to the vehicle. No contact nor damage to the windshield area was observed. The system rotated around toward the passenger side of the vehicle, but never became a potential hazard to the occupant compartment.

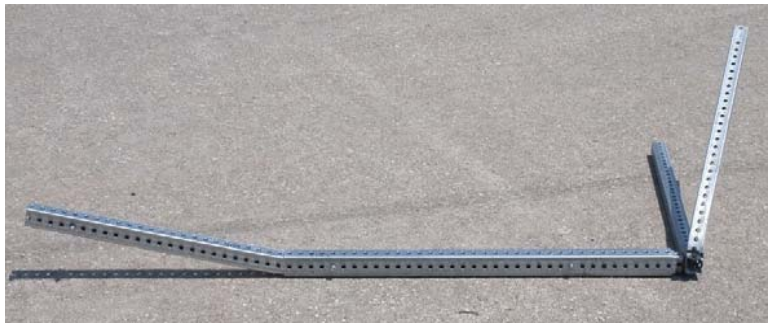
48" x 48" Rigid Panel System, Bogie Tests MNSB-12 and MNSB-13

48" x 48" Rigid Panel System, Bogie Tests MNSB-12 and MNSB-13



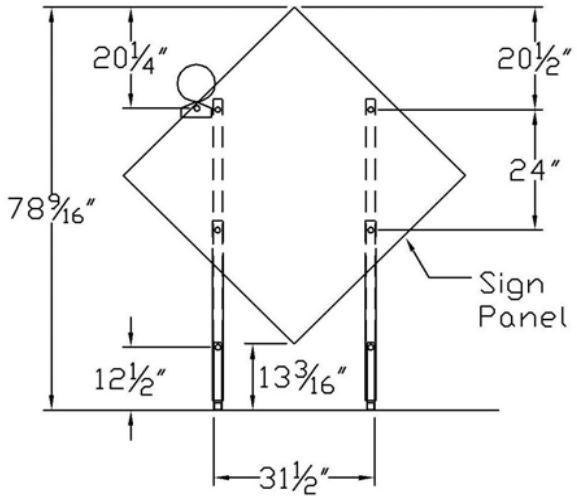


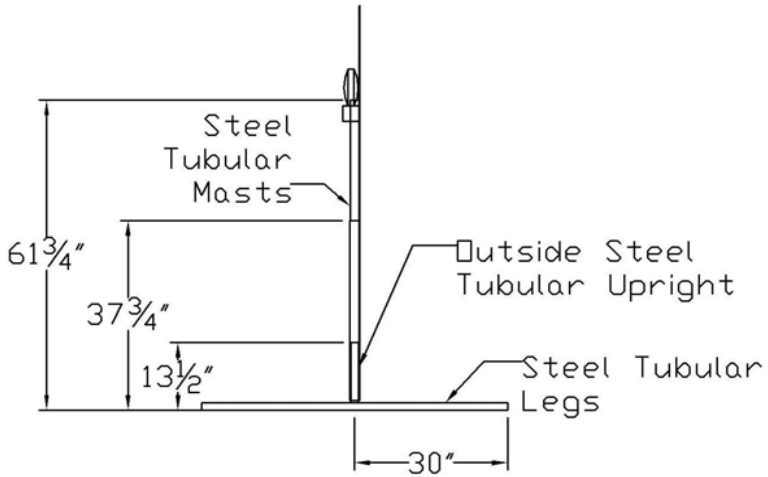
System Damage, Bogie Test MNSB-12 (0 degrees)

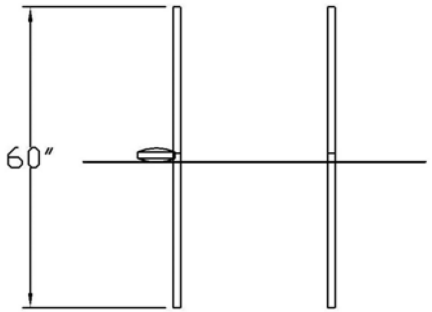


System Damage, Bogie Test MNSB-13 (90 degrees)

System: MNSB-12





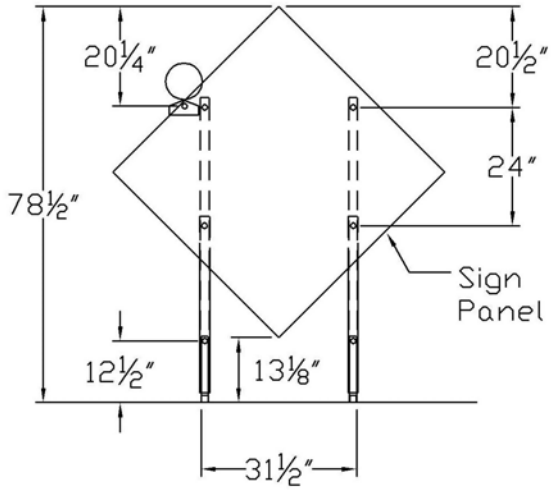


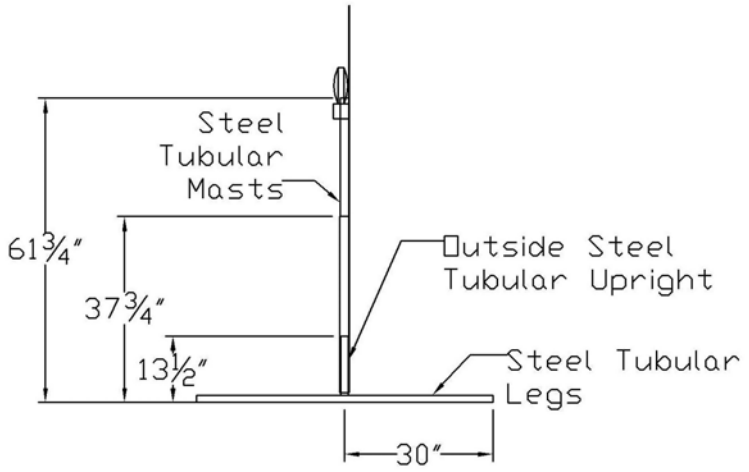
48" x 48" Rigid Panel System

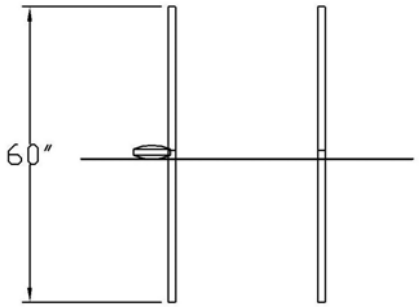
- Vertical Upright Masts – 1.75" sq. x 0.105" wall x 60" long galvanized telespar ASTM A–653 Grade 50 steel tubing
- Outside Vertical Upright Tubing – 2" sq. x 0.108" wall x 35.875" long galvanized telespar ASTM A–653 Grade 50 steel tubing
- Legs, Horizontal Portion – 1.5" sq. x 0.108" wall x 60" long galvanized telespar ASTM A–653 Grade 50 steel tubing
- Legs, Vertical Stub – 1.5" sq. x 0.108" wall x 12" long galvanized telespar ASTM A–653 Grade 50 steel tubing
- Vertical stub of the leg is welded to the horizontal portion of the leg on all four sides
- Outside vertical upright tubings slide over the vertical upright masts
- Vertical stub of legs slide into vertical upright masts – 0.3125" diameter x 2.5" long hex head S30400 threaded bolts were used to fasten the masts and legs
- Sign Panel – Relfective aluminum, 48" wide x 48" long with a 0.108" thickness
- Panel fastened to vertical mast supports with four 0.3125" diameter x 2.5" long hex head S30400 threaded bolts. A 0.9375" OID x 0.0625" thick washer was placed between the head of the bolt and the sign panel
- Light – "Toughlite 2000" flashing warning light attached to the sign panel
- Ballast – 45–lb sandbag at end of each leg

48" x 48" Rigid Panel System Design Details, Bogie Test MNSB-12

System: MNSB-13







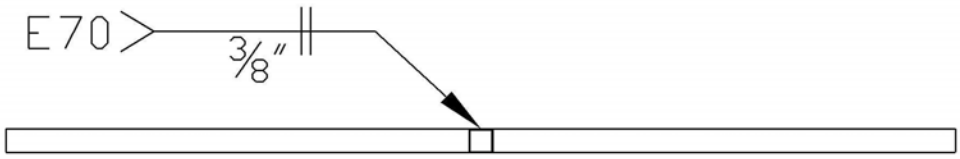
48" x 48" Rigid Panel System

- Vertical Upright Masts – 1.75" sq. x 0.105" wall x 60" long galvanized telespar ASTM A-653 Grade 50 steel tubing
- Outside Vertical Upright Tubing – 2" sq. x 0.108" wall x 35.875" long galvanized telespar ASTM A-653 Grade 50 steel tubing
- Legs, Horizontal Portion – 1.5" sq. x 0.108" wall x 60" long galvanized telespar ASTM A-653 Grade 50 steel tubing
- Legs, Vertical Stub – 1.5" sq. x 0.108" wall x 12" long galvanized telespar ASTM A-653 Grade 50 steel tubing
- Vertical stub of the leg is welded to the horizontal portion of the leg on all four sides
- Outside vertical upright tubings slide over the vertical upright masts
- Vertical stub of legs slide into vertical upright masts – 0.3125" diameter x 2.5" long hex head S30400 threaded bolts were used to fasten the masts and legs
- Sign Panel – Relfective aluminum, 48" wide x 48" long with a 0.108" thickness
- Panel fastened to vertical mast supports with four 0.3125" diameter x 2.5" long hex head S30400 threaded bolts. A 0.9375" OID x 0.0625" thick washer was placed between the head of the bolt and the sign panel
- Light – "Toughlite 2000" flashing warning light attached to the sign panel
- Ballast – 45-lb sandbag at end of each leg

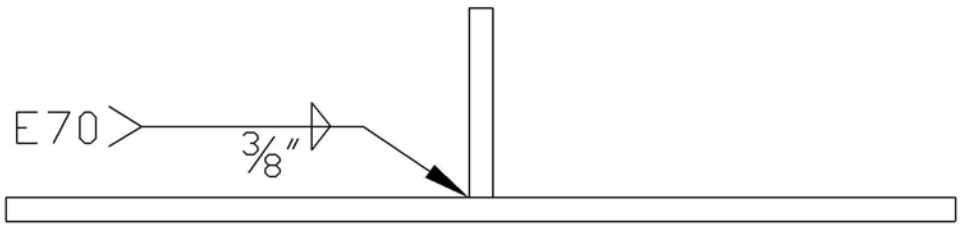
48" x 48" Rigid Panel System Design Details, Bogie Test MNSB-13

System: MNSB-12 & MNSB-13

Top View (Legs)



Side View (Legs)



48" x 48" Rigid Panel System Leg Fabrication Details, Bogie Tests MNSB-12 and MNSB 13

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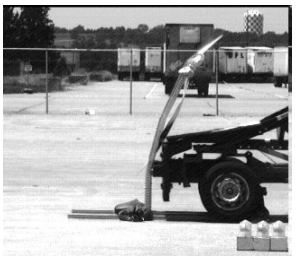

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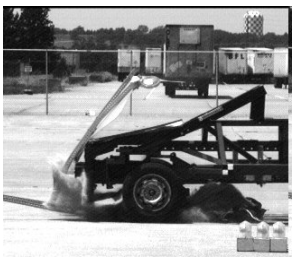

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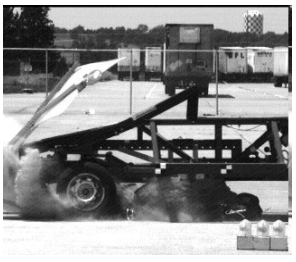

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0 degree orientation – Bogie Test MNSB-12

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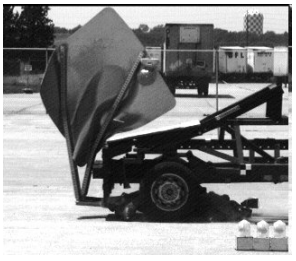

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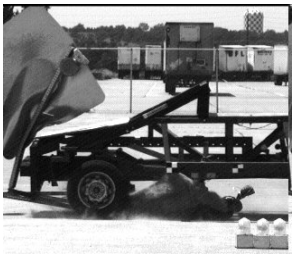

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90 degree orientation – Bogie Test MNSB-13

3 FHWA APPROVAL LETTER

U.S. Department
of Transportation
**Federal Highway
Administration**

NOV 26 2002

400 Seventh St., S.W.
Washington, D.C. 20590

Refer to: HSA-10/WZ-133

Mr. Ron Faller
Midwest Roadside Safety Facility
1901 "Y" Street, Bldg. C
P.O. Box 880601
Lincoln, Nebraska 68588-0601

Dear Dr. Faller:

Thank you for your September 12, 2002, letter requesting Federal Highway Administration (FHWA) acceptance of the Minnesota Department of Transportation (DOT) temporary work zone sign stand as a crashworthy traffic control device for use in work zones on the National Highway System (NHS). Accompanying your letter was a report of crash testing you conducted and a CD of the tests. You requested that we find these devices acceptable for use on the NHS under the provisions of National Cooperative Highway Research Program (NCHRP) Report 350 "Recommended Procedures for the Safety Performance Evaluation of Highway Features."

Introduction

The FHWA guidance on crash testing of work zone traffic control devices is contained in two memoranda. The first, dated July 25, 1997, titled "INFORMATION: Identifying Acceptable Highway Safety Features", established four categories of work zone devices: Category I devices were those lightweight devices which could be self-certified by the vendor, Category II devices were other lightweight devices which needed individual crash testing, Category III devices were barriers and other fixed or massive devices also needing crash testing, and Category IV devices were trailer mounted lighted signs, arrow panels, etc. The second guidance memorandum was issued on August 28, 1998, and is titled "INFORMATION: Crash Tested Work Zone Traffic Control Devices." This later memorandum lists devices that are acceptable under Categories I, II, and III.

A description of the device follows:

The Minnesota DOT rigid panel portable sign support is a stiffened perforated square steel tube "H-Footprint" device:

- Vertical upright masts are 44.5 mm (1.75 inch) square galvanized Telespar ASTM A-653 Grade 50 steel tubing with 2.67 mm (0.105 inch) wall thickness and a length of 1524 mm (60 inches.)
- Outside vertical upright tubing is 50.8 mm (2 inch) square galvanized Telespar ASTM A-653 Grade 50 steel tubing with 2.74 mm (0.108 inch) wall thickness and a length of 911 mm (33.875 inches.)

- Horizontal legs are 38.1 mm (1.5 inch) square galvanized Telespar ASTM A-653 Grade 50 steel tubing with 2.74 mm (0.108 inch) wall thickness and a length of 1524 mm (60 inches.)
- Vertical stubs from the legs are 38.1 mm (1.5 inch) square galvanized Telespar ASTM A-653 Grade 50 steel tubing with 2.74 mm (0.108 inch) wall thickness and a length 305 mm (12 inches.) It is welded to the horizontal leg on all four sides.
- The outside vertical upright tubes slide over the vertical uprights and the vertical portion of the legs slide into the vertical upright masts with 7.9 mm (0.3125 inch) diameter x 63.5 mm (2.5 inch) long hex head S30400 threaded bolts used to fasten the masts and legs.
- The solid, 2.74 mm (0.108 inch) aluminum sign panel was 1219 mm (48 inch) diamond shaped and fastened to the stand with four 7.9 mm (0.3125 inch) x 63.5 mm (2.5 inch) long hex head S30400 threaded bolts.
- Height to bottom of sign: 335 mm (13.1875 inches) Height to top of outer tube 959 mm (37.74 inches). Height to the Warning Light bolt, 1,481 mm (58.3125 inches).
- The legs have a mass of 9.1 kg (10 pounds) and the panel, masts, outside tubes, and light have a mass of 36.75 lg (81 pounds.) One 20 kg (45 pound) sandbag was placed at the end of each leg.

Testing

This crash-testing program used a hard-nosed bogie vehicle of a mass larger than the standard 820C test vehicle. There are significant constraints involved in using such a non-standard testing device, some of which are:

1. The potential vehicle velocity change must be considered insignificant.
2. The crush characteristics of an automobile bumper must not be expected to have a significant affect on the trajectory of the test article.
3. The profile of the bogie vehicle must be configured to replicate the outline of a production vehicle. The MWRSF bogie was configured to replicate the outline of a Geo Metro, a vehicle commonly used in testing of work zone devices.
4. No part of the test article may intrude into the windshield area of the vehicle after impact.

The two tests and their results summarized below were within these constraints.

Stand-alone examples of the devices were tested in separate tests, one head-on and one turned at 90 degrees, as called for in our guidance memoranda. The complete device, as tested is shown in Enclosure 1. The crash test is summarized in the table below:

Test Number	MNSB-12	MNSB-13
Test Article	Head-on	End-On
Flags or lights	One lightweight warning light on each stand	
Test Article Mass (each)	45.8 kg (91 pounds) plus ballast	
Bogie Inertial Mass	974 kg (2148 pounds)	

Impact Speed	97.5 km/hr (60.6 mph)	98.8 km/hr (61.4 mph)
Approx. Velocity Change	10 km/hr, 2.78 m/s	10 km/hr, 2.78 m/s

Findings

The rigid frame of these stands caused them to be pushed ahead of the bogie, or knocked to one side. Neither showed any potential for approaching the windshield or causing any other passenger compartment intrusion. The trajectory of the sign stands in these tests indicate that the bogie vehicle, even though it was not within the specification range of an NCHRP Report 350 820C test vehicle, was acceptable for establishing the crashworthiness of the stands. The results of the testing met the FHWA requirements and, therefore, the devices described above and shown in the enclosed drawings for reference are acceptable for use on the NHS under the range of conditions tested, when proposed by a State.

Please note the following standard provisions that apply to FHWA letters of acceptance:

- Our acceptance is limited to the crashworthiness characteristics of the devices and does not cover their structural features, nor conformity with the Manual on Uniform Traffic Control Devices.
- Any changes that may adversely influence the crashworthiness of the device will require a new acceptance letter.
- Should the FHWA discover that the qualification testing was flawed, that in-service performance reveals unacceptable safety problems, or that the device being marketed is significantly different from the version that was crash tested, it reserves the right to modify or revoke its acceptance.
- You will be expected to supply potential users with sufficient information on design and installation requirements to ensure proper performance.
- You will be expected to certify to potential users that the hardware furnished has essentially the same chemistry, mechanical properties, and geometry as that submitted for acceptance, and that they will meet the crashworthiness requirements of FHWA and NCHRP Report 350.
- To prevent misunderstanding by others, this letter of acceptance, designated as number WZ-133 shall not be reproduced except in full. This letter, and the test documentation upon which this letter is based, is public information. All such letters and documentation may be reviewed at our office upon request.

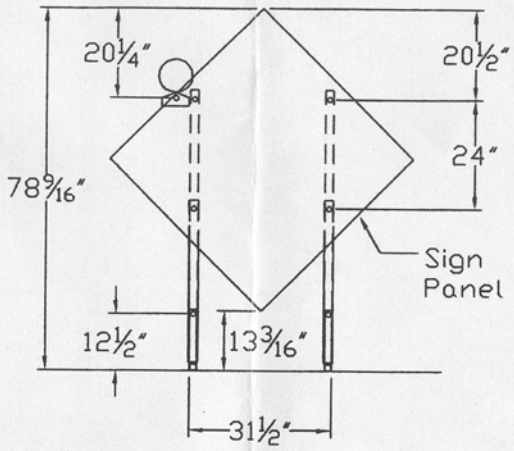
Sincerely yours,

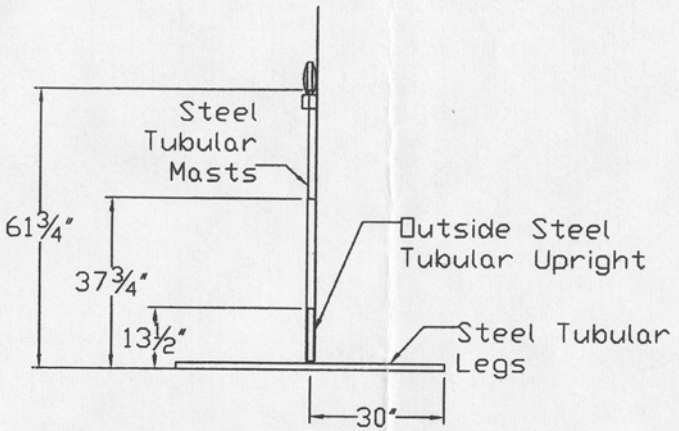
Harry W. Taylor

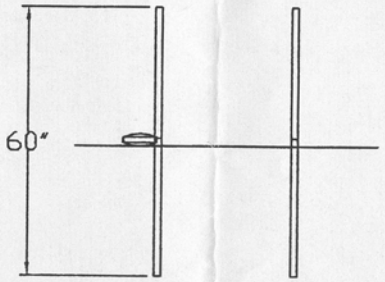
for Carol H. Jacoby, P.E.
Director, Office of Safety Design

Enclosure

System: MNSB-12





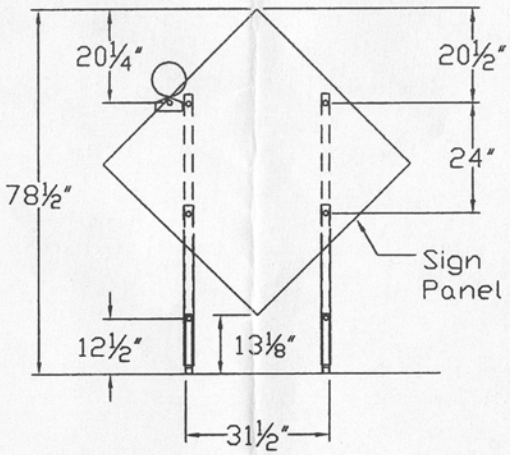


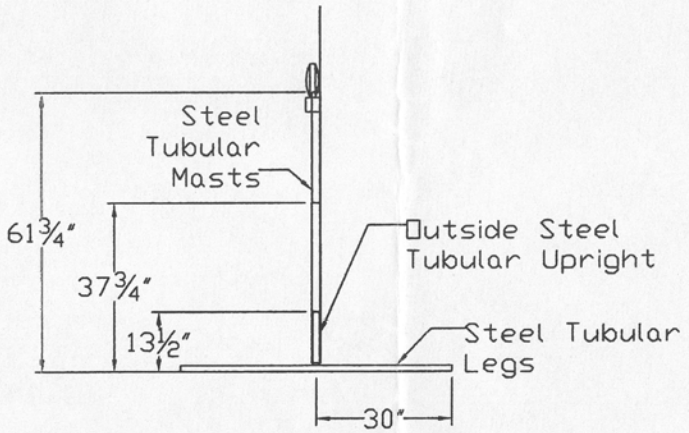
48" x 48" Rigid Panel System

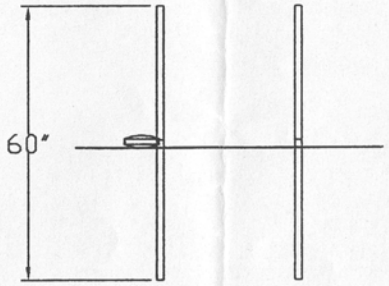
- Vertical Upright Masts – 1.75" sq. x 0.105" wall x 60" long galvanized telespar ASTM A–653 Grade 50 steel tubing
- Outside Vertical Upright Tubing – 2" sq. x 0.108" wall x 35.875" long galvanized telespar ASTM A–653 Grade 50 steel tubing
- Legs, Horizontal Portion – 1.5" sq. x 0.108" wall x 60" long galvanized telespar ASTM A–653 Grade 50 steel tubing
- Legs, Vertical Stub – 1.5" sq. x 0.108" wall x 12" long galvanized telespar ASTM A–653 Grade 50 steel tubing
- Vertical stub of the leg is welded to the horizontal portion of the leg on all four sides
- Outside vertical upright tubings slide over the vertical upright masts
- Vertical stub of legs slide into vertical upright masts – 0.3125" diameter x 2.5" long hex head S30400 threaded bolts were used to fasten the masts and legs
- Sign Panel – Reflective aluminum, 48" wide x 48" long with a 0.108" thickness
- Panel fastened to vertical mast supports with four 0.3125" diameter x 2.5" long hex head S30400 threaded bolts. A 0.9375" OID x 0.0625" thick washer was placed between the head of the bolt and the sign panel
- Light – "Toughlite 2000" flashing warning light attached to the sign panel
- Ballast – 45–lb sandbag at end of each leg

48" x 48" Rigid Panel System Design Details, Bogie Test MNSB-12

System: MNSB-13







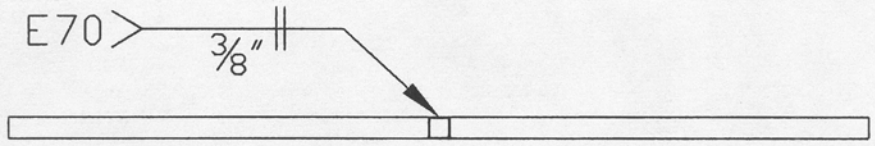
48" x 48" Rigid Panel System

- Vertical Upright Masts – 1.75" sq. x 0.105" wall x 60" long galvanized telespar ASTM A-653 Grade 50 steel tubing
- Outside Vertical Upright Tubing – 2" sq. x 0.108" wall x 35.875" long galvanized telespar ASTM A-653 Grade 50 steel tubing
- Legs, Horizontal Portion – 1.5" sq. x 0.108" wall x 60" long galvanized telespar ASTM A-653 Grade 50 steel tubing
- Legs, Vertical Stub – 1.5" sq. x 0.108" wall x 12" long galvanized telespar ASTM A-653 Grade 50 steel tubing
- Vertical stub of the leg is welded to the horizontal portion of the leg on all four sides
- Outside vertical upright tubings slide over the vertical upright masts
- Vertical stub of legs slide into vertical upright masts – 0.3125" diameter x 2.5" long hex head S30400 threaded bolts were used to fasten the masts and legs
- Sign Panel – Reflective aluminum, 48" wide x 48" long with a 0.108" thickness
- Panel fastened to vertical mast supports with four 0.3125" diameter x 2.5" long hex head S30400 threaded bolts. A 0.9375" OID x 0.0625" thick washer was placed between the head of the bolt and the sign panel
- Light – "Toughlite 2000" flashing warning light attached to the sign panel
- Ballast – 45-lb sandbag at end of each leg

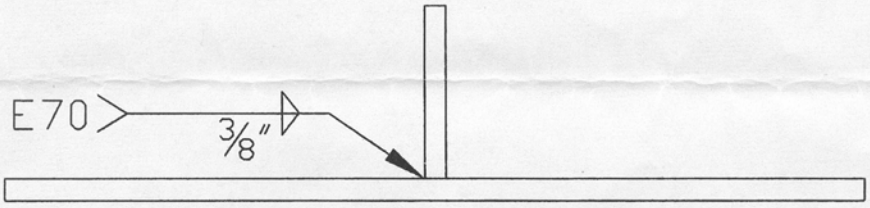
48" x 48" Rigid Panel System Design Details, Bogie Test MNSB-13

System: MNSB-12 & MNSB-13

Top View (Legs)



Side View (Legs)



48" x 48" Rigid Panel System Leg Fabrication Details, Bogie Tests MNSB-12 and MNSB 13