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DEVELOPMENT OF A CRASWORTHY SUPPORT SYSTEM FOR LARGE TEMPORARY GUIDE SIGNS

by R. P. Bligh and D. R. Arrington

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ABSTRACT

A common issue during phased highway construction projects is the need to temporarily relocate large guide signs on the roadside or install new guide signs for temporary use. The conventional concrete foundations used for these signs are costly and time consuming to install and remove after construction is completed.

A temporary direct embed wood post support system for large guide signs was developed and successfully crash tested in accordance with MASH guidelines. The design considers wind loads, foundation requirements, and impact performance. The direct embedded support posts eliminate the need for reinforced concrete foundations.

The results of the research can be used to establish acceptance of other less critical design configurations for other sizes of temporary guide signs. Variations include different post size, grade, and spacing.

INTRODUCTION

A common issue during phased highway construction projects is the need to temporarily relocate large guide signs on the roadside or install new guide signs for temporary use. Many of these signs are larger than 100 square feet in size. The conventional concrete foundations used for these signs are costly and time consuming to install. They are equally costly to remove after construction is completed and, consequently, they are often left in place. This creates a problem during mowing and other maintenance operations. There is a need for something more temporary and more cost effective to install and remove than conventional steel reinforced drilled concrete shafts for the temporary placement or relocation of large guide signs during construction projects.

The objective of this research was to develop design details for temporary guide signs. There are various types of guide signs commonly used along highway roadsides including destination signs, advance exit signs, logo signs, etc. In Texas, a standard work zone sign is the “Give Us a Brake” sign, which is part of a work zone safety campaign. This sign is 16 ft wide x 8 ft tall with an area of 128 square feet. It was noted by Texas Department of Transportation (TxDOT) personnel that this sign is relocated often and would serve as a good sign configuration that should be considered under the research project.

The support system developed under the research described herein incorporates wood supports that are directly embedded into the ground. The evaluation of the wood support system included consideration of factors such as support member size, length, grade, availability, spacing, and cost. The analysis process included consideration of wind load, foundation requirements, and impact performance.

BACKGROUND

Wood supports are often used for both permanent and temporary sign applications. Federal Highway Administration (FHWA) letter HNG-14/SS-25 states that signs may be supported by various size wood posts in single and dual support configurations ([1]). Previous
research has shown that weakening wood posts through the use of drilled holes at strategic locations has enhanced crashworthiness without sacrificing a significant percentage of their wind load capacity. Numerous wood sign support configurations were crash tested and evaluated as part of a national pooled-fund study entitled “Testing of Small and Large Sign Supports” performed in the early 1990s (2). The testing was conducted at the Federal Highway Administration’s (FHWA’s) Federal Outdoor Impact Laboratory (FOIL) using an 1,800-lb passenger car following National Cooperative Highway Research Program (NCHRP) Report 350 guidelines (3).

FHWA letter HNG-14/SS-36 summarizes the testing conducted under the pooled-fund study (4). Most posts were Southern Yellow Pine (SYP) species. The size, number of supports installed, and number of posts impacted varied. Support posts were tested in single and multiple configurations. Some tests involved impacting one or two posts in dual or multiple support installations. This is an important distinction because the behavior of the sign support system is different depending on whether or not all posts in an installation are impacted. If all posts (e.g., two posts in a dual post installation) are impacted, the wood posts fracture at the ground and the released sign support system rotates above the vehicle. If only one post is impacted in a dual or multiple post installation, the sign support system remains attached to the ground through the other support posts and the interaction with the vehicle can be substantially different.

Supports successfully tested and considered eligible for use on the National Highway System (NHS) include:

1. A single, unmodified 4 inch x 6 inch SYP post,
2. Dual 4 inch x 6 inch SYP posts with 1 ½-inch diameter holes drilled through the post along its strong axis at heights of 4 inches and 18 inches above grade,
3. A single 5-inch diameter round SYP post with 2-inch diameter weakening holes at 4 inches and 18 inches above grade, and
4. One post of a dual post system using 6-inch x 8-inch SYP posts with 3-inch diameter weakening holes at 4 inches and 18 inches above grade.

Data from these full-scale crash tests was reviewed under the current research effort to determine if larger wood posts installed in a large guide sign system have a reasonable probability of complying with the impact performance criteria of American Association of State Highway and Transportation Officials (AASHTO) Manual for Assessing Safety Hardware (MASH) (5). Occupant impact velocity (OIV) was considered to be the most critical criterion for assessment of crashworthiness. The small car low speed impact (Test Designation 3-60) is typically most critical in terms of OIV. In tests of single supports, OIV values were extrapolated to decide if multiple supports could be impacted with a reasonable probability of success.

Based on this review, it was estimated that three 4-inch x 6-inch posts with 2-inch weakening holes near groundline and two 6-inch x 8-inch posts with 4-inch weakening holes near groundline had a high probability of meeting the impact performance requirements of MASH. TTI researchers further investigated weakening of the support posts below the sign panel to facilitate fracture and release of one or more posts from the sign installation in situations where not all posts were simultaneously impacted.
WIND LOAD ANALYSIS

In addition to being crashworthy, sign supports must also meet wind load requirements described in the AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals (6). The basic wind speed is associated with an annual event probability of 0.02 (or a 50-year mean recurrence interval), and is prescribed by isotachs contained in the AASHTO Specification. The basic wind speed is modified by an importance factor based on the recommended minimum design life of a structure. The recommended minimum design life for roadside sign structures is 10 years.

The wind pressure on a sign can be calculated using the following equation (6):

\[ P_z = 0.00256 K_z G (V * C_v)^2 I_r C_d (\text{psf}) \]

where:
- \( P_z = \) Design Wind Pressure (psf)
- \( I_r = \) Wind Importance Factor
- \( C_v = \) Velocity Conversion Factor
- \( K_z = \) Height and Exposure Factor
- \( G = \) Gust Effect Factor
- \( C_d = \) Wind Drag Coefficients
- \( V = \) Basic Wind Speed (mph), from Wind Chart

Since 90 and 100 mph wind speeds cover most of the country (except for some extreme coastal regions subject to hurricanes), and the large guide sign support system is defined to be temporary in nature, 90 and 100 mph wind speeds were evaluated. A 90 mph design wind speed with a 10 year recurrence interval equates to a wind pressure of 11.5 psf, while a 100 mph design wind speed equates to a wind pressure of 14.2 psf. These values were used to determine the required number of support posts and the maximum hole size that can be used to weaken the support to help facilitate fracture during vehicle impacts.

There are many factors involved in determining the minimum number of support posts required. The primary factors include sign size, sign mounting height, post size, and post grade. Post size and grade directly affect the material strength of the post. The researchers evaluated 6-inch x 8-inch and 4-inch x 6-inch posts for application to the large temporary guide signs. These post sizes provide significant flexure capacity to accommodate wind loads for relatively large signs, and were believed to have a reasonable probability of meeting impact performance requirements for multiple post impacts. Both Grade 1 and Grade 2 posts were analyzed.

In Texas, the minimum mounting height for signs is 7 ft measured relative to the pavement surface. Because signs are typically installed on roadside slopes beyond the shoulder, actual mounting height from the local terrain to the bottom of the sign panel is typically larger depending on the roadside terrain and offset distance of the sign from the edge of travelway. Therefore, a range of mounting heights from 7 to 10 feet was considered.

An analysis was performed to determine reasonable support configurations for a 16 ft x 8 ft tall (128 ft²) sign. The results of the analysis are shown in Table 1. A 100 mph design wind
speed, 10 ft mounting height above the local terrain, and Grade 2 post represents the worst case for windload considerations. This configuration requires eight 4-inch x 6-inch posts with a weakening hole no larger than 2.15 inch diameter, or five 6-inch x 8-inch posts with a maximum weakening hole size of 4.33 inch diameter.

*MASH* requires crash testing with both a 2,420-lb passenger car (denoted 1100C) and a 5,000-lb pickup truck (denoted 2270P). Testing houses typically use a Kia Rio for the 1100C design vehicle and a Dodge Ram 1500 pickup truck for the 2270P. The Kia Rio has a maximum width (excluding mirrors) of 67 inches, while the Dodge Ram pickup has a maximum width (excluding mirrors) of 82 inches. Using this data, it was determined that in all of the design cases except one, a maximum of two 6-inch x 8-inch posts would be impacted. The data also shows that on average a 4” hole can be used to weaken the 6-inch x 8-inch support without compromising wind load requirements.

Table 1 also shows that in most configurations with 4-inch x 6-inch support posts, three posts will be impacted by the Kia Rio and up to four can possibly be impacted by the Dodge Ram pickup. The analysis shows that on average, a 2” hole can be used to weaken the 4-inch x 6-inch support.

**POST ACTIVATION BELOW SIGN PANEL**

The researchers considered it necessary to weaken the posts below the sign panel to facilitate fracture and release of a post in a multiple support system during impacts that do not engage all posts. Steel post systems use fuse plates to create hinge or release points below the sign panel that permit an impacted post to rotate out of the path of the vehicle. Wood support posts can be weakened using saw cuts or holes drilled through the cross section of the post.

There are several options available for weakening the post at the location just below the bottom of the sign. These include various size holes or saw cuts applied along the strong or weak axes of the post. A minimum section modulus of 16.15 in$^3$ is required to accommodate wind load just below the sign panel. The selected weakening option was a 3 5/8-inch diameter hole drilled along the weak axis of the post approximately 4 inches below the bottom of the sign panel. The section modulus of the post at this weakened section is 25.5 in$^3$. This option provides a reasonable balance between meeting wind load requirements and selecting a hole size that is not too large to be reliably and cleanly drilled through the 6 inch width of the post.

**FOUNDATION DESIGN**

The AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals* (6) suggests use of Brom’s method for design of foundations for sign support structures. This method has two complimentary models for analyzing foundation requirements. One model is for the design of foundations in cohesionless soils such as sand, and the other is intended to be used for cohesive soils such as clay.
Table 1. Sign Support Requirement Analysis

<table>
<thead>
<tr>
<th>Wind Velocity (mph)</th>
<th>Sign Mounting Height (ft)</th>
<th>Post Size (in)</th>
<th>Max Hole Size (in)</th>
<th>Number of Posts</th>
<th>Minimum Post Spacing (ft)</th>
<th>Number of Posts Impacted</th>
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</thead>
<tbody>
<tr>
<td>100</td>
<td>10</td>
<td>4x6</td>
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<td>7</td>
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<td>6x8</td>
<td>5.39</td>
<td>3</td>
<td>5.33</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>10</td>
<td>4x6</td>
<td>2.39</td>
<td>5</td>
<td>3.20</td>
<td>2,3</td>
</tr>
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<td>5.26</td>
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<tr>
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<td>3.8</td>
<td>3</td>
<td>5.33</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1 is a representation of the foundation analysis model for cohesive soils. In this analysis, the suggested safety factor (SF) can range from 3 to 4. The more conservative value of 4 was used in the foundations analyses performed under this research. Shear (V) and Moment (M) were taken from the wind load analysis. The equations below determine the minimum embedment depth (L) for the foundation. A “c” value of 3,100 psf was used when calculating the minimum embedment depth for the in-situ clay found at the Texas A&M Transportation Institute (TTI) Proving Ground at which the system was tested.

\[
V_f = V_{req} \times SF \\
M_f = M_{req} \times SF \\
L = 1.5 \times D + q \left[ 1 + \sqrt{2 + \frac{4 \times H + 6 \times D}{q}} \right] \\
H = \frac{M_f}{V_f} \\
q = \frac{V_f}{9 \times c \times D}
\]

The results of this analysis can be found in Table 2. It can be seen that the required embedment depth for a 4-inch x 6-inch post varies from 4.0 - 4.9 feet. The embedment depth for a 6-inch x 8-inch post varies between 3.6 - 4.3 feet. Given the factor of safety in the analysis, it
was recommended that the foundation embedment depth be standardized at 4 feet. This will reduce the complexity of the design and installation of the temporary sign support system. If the supports are to be placed in non-cohesive soils, it is recommended that the foundation embedment depth be reanalyzed using Brom’s method for cohesionless soils. If soils are known to be stronger than the values used herein, the analysis can be repeated using actual soil values to take advantage of the stronger soil conditions to reduce the required embedment depth.

![Figure 1. Brom’s Cohesive Soil Foundation Model (6)](image)

Table 2. Calculated Foundation Embedment Depth

<table>
<thead>
<tr>
<th>Design Wind Speed, V (mph)</th>
<th>Sign Mounting Height, Zbs (ft)</th>
<th>Post Size (inches)</th>
<th>Embedment Depth (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>10</td>
<td>4 x 6</td>
<td>4.8</td>
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<tr>
<td></td>
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<td>6 x 8</td>
<td>3.6</td>
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</table>
SIGN SUBSTRATE CONNECTION

TxDOT uses extruded aluminum signs almost exclusively on its permanent roadside guide signs. Plywood is a commonly used substrate for temporary sign support systems. After discussion with TxDOT personnel, it was decided that both extruded aluminum and plywood substrates would be considered in the design of the temporary large guide sign support systems. This will give contractors more flexibility to choose a sign substrate that is most economical based on factors such as material cost, fabrication cost, weight (handling), durability, etc. If an existing guide sign is being relocated, it would be cost-effective to use the existing extruded aluminum sign panel. If a new sign is being deployed in the work zone, it may be more economical to use a plywood sign substrate.

Connection details exist for attaching an extruded aluminum sign panel to a steel support post. The standard connection used in Texas for permanent guide signs involves inserting the square head of a bolt into a channel fabricated into the back side of the extruded aluminum panel. A cast clamp is inserted onto the bolt and secured with a nut. The clamp is positioned to extend over the flange of the steel support post. When the connection bolt is tightened, the extruded aluminum sign panel is clamped to the steel sign post.

A connection between an extruded aluminum sign panel and wood support post was developed using standard clamp connection hardware. A 3-inch x 2-inch x ¼-inch steel angle is attached to each side of the wood support member. The length of the angle matches the vertical dimension of the extruded aluminum sign panel. One leg of each angle is placed flush with the sides of the wood support and attached using ½-inch diameter, 3-inch long lag screws spaced at approximately 2 ft intervals. The other leg of the angles is placed flush with the front face of the wood support post and extends perpendicularly outward from the post. The clamp connection hardware is used to clamp the extruded aluminum sign panel to the steel angle in a similar manner to the front flange of a steel post.

The recommended thickness for a plywood substrate sign panel is 5/8 inch. Aluminum wind beams should run horizontally along the width of the plywood sign panel approximately 5-6 inches from the top and bottom edges. Interior wind beams should be placed at maximum 4 ft spacing. The wind beams are secured to the plywood substrate using 5/16-inch diameter x 1 ¼-inch long hex bolts. Aluminum plates measuring 3-inch wide x 1/8-inch thick are placed along joints in the plywood sign substrate and secured using #10 x 5/8-inch long pan head screws. The 3-inch x 2-inch x ¼-inch steel angles are attached to the sides of each wood support member as described above. Square head bolts slide into a channel fabricated into the back side of the aluminum wind beams. The top bolt slides into a ½-inch wide x ¾-inch long slot cut into the edge of the outside edge of the angle and is secured with a nut. The remaining bolts are clamped to the edges of the angle in the same manner described above for the extruded aluminum sign substrate. The top bolt has a more positive connection because there are fewer clamps to attach the plywood substrate to the supports than the extruded aluminum substrate.

The important variables for evaluating the activation and/or release of the sign support from the sign substrate are the stiffness of the sign substrate and the connection strength between the support posts and the sign substrate. If the weakening mechanism built into the post below
the sign panel is to activate as designed, the sign substrate must be stiff enough to develop the required moment in the support post. If the sign panel lacks sufficient stiffness to generate this moment, the support can simply rotate without activation of the weakening mechanism and cause the sign substrate to twist. This twisting stores energy in the sign substrate and will result in the support post eventually rotating back toward the vehicle as it is passing beneath the sign. Therefore, the less stiff the sign substrate, the more critical it is in terms of activation of the weakening mechanism in the support post.

An alternative behavior to activation of the post weakening mechanism is to have the post release from the sign substrate and rotate as a rigid body up and away from the vehicle. The stronger connection, the more difficult it is for the support post to release from the sign substrate. Therefore, the stronger connection would constitute a more critical condition from an impact standpoint.

After analyzing the relative stiffness of the sign substrates and the strength of the respective connections, the extruded aluminum was considered to be worse case from both perspectives compared to the plywood. Due to the reduced number of clamps on the plywood substrate connection, the plywood substrate has an increased chance of releasing from the wood sign supports during a vehicular impact errant. Further, the increased stiffness of the plywood substrate will enhance activation of the weakening mechanism incorporated into the support below the sign panel. Therefore, it was decided to conduct the compliance testing of the temporary large guide sign support system with an extruded aluminum sign panel.

FULL-SCALE CRASH TESTING

In addition to being able to accommodate service loads, sign support systems placed within the clear zone on a highway roadside must also be crashworthy. The design impact requirements for roadside hardware are performance based and consist of a prescribed crash test matrix with impact conditions defined in terms of vehicle type, vehicle mass, impact speed, and impact angle.

Current guidance on the impact performance evaluation of sign support structures is contained in the AASHTO Manual for Assessing Safety Hardware (MASH) (5). According to MASH, a matrix of 3 tests is recommended to evaluate the impact performance of a new sign support system. This includes two small car tests (low speed and high speed) and one pickup truck test. The tests were performed at the Texas A&M Transportation Institute (TTI) Proving Ground. The TTI Proving Ground is an International Standards Organization (ISO) 17025 accredited laboratory.

Test Article Design and Construction

The required size and number of support posts for a temporary guide sign will vary based on size of the sign panel, sign panel mounting height, and design wind speed. Obviously, not all possible design configurations can be crash tested. The approach used under this research was to select a critical configuration from among those considered practical. A successful test of the critical configuration will provide acceptance for other less critical configurations.
The test installation involved an 8-ft tall × 16-ft wide (128 square ft) extruded aluminum sign panel supported by three 6-inch × 8-inch, Grade 1, Southern Yellow Pine wood support posts at a mounting height of 7 ft from the ground to the bottom of the sign panel.

The spacing of the wood support posts was 33 inches center to center. This is closer than the spacing that would typically be used in a field installation of this sign, but was selected to permit two of the three supports to be simultaneously impacted by the test vehicle. Since other larger sign configurations may require the closer post spacing to accommodate wind loads, it was desired to evaluate two posts in the path of the vehicle to provide more design flexibility. The reduction in post spacing does not affect the overall performance of the temporary guide sign, and precedence exists for this type of modification for full-scale crash testing (4).

The wood support posts were directly embedded 48 inches below grade. The supports were weakened with 4-inch diameter holes drilled along the strong axis of the post (i.e., parallel to the orientation of the sign panel) at heights of 4 inches and 18 inches above the ground line. These holes facilitate fracture of the supports during a vehicle impact while still accommodating the required wind load capacity for a 90 mph design wind speed. Additionally, the supports were weakened below the sign panel with a 3 5/8-inch diameter hole drilled along the weak axis of the post (i.e., perpendicular to the orientation of the sign panel). These holes permit the wood post to fracture and release from the sign panel in a manner analogous to the fuse plates that are used with standard steel supports.

A 3×2×1/4 steel angle was secured to each side of each wood support member using ½-inch diameter × 3-inch long lag bolts at 24-inch spacing. The length of the angles matched the height of the extruded aluminum sign panel. Standard clamp connection hardware similar to that shown on TxDOT standard drawing SMD (2-1)-08 (7) was used to clamp the extruded aluminum sign panel to the steel angle in a similar manner to the front flange of a steel post. Figure 2 shows photographs of the test installation prior to testing, and Figure 3 provides construction details for the system.

**MASH Test 3-60**

Test 3-60 involved an 1100C passenger car impacting two of three supports head-on at a nominal speed of 19 mph. Actual impact speed was 18.8 mph. This test evaluates the breakaway mechanism and is typically the most critical test in terms of occupant risk.

Upon impact, the two wood supports fractured at the weakening holes near the groundline. The interior (middle) support also fractured at the weakening hole below the sign panel. After fracture of the two wood supports, the sign panel rotated about the remaining support. The rotation caused the sign panel to pry off and release from the remaining support post and fall down on top of the test vehicle. The test vehicle subsequently came to a stop a short distance downstream from the sign support installation.
Figure 2. Direct Embedded Wood Support Temporary Guide Sign System
Figure 3. Details of Direct Embedded Wood Support Temporary Guide Sign System
Figure 3. Details of Direct Embedded Wood Support Temporary Guide Sign System (cont.)

<table>
<thead>
<tr>
<th>#</th>
<th>PART NAME</th>
<th>DETAILS</th>
<th>QTY.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Aluminum Sign Panel, 12'' x 16''</td>
<td>see TxDOT Drawing SMD (2-1) -08</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>Bolt, 3/8 x 3/4 hex</td>
<td>grade 2</td>
<td>56</td>
</tr>
<tr>
<td>3</td>
<td>Washer, 3/8 flat</td>
<td></td>
<td>112</td>
</tr>
<tr>
<td>4</td>
<td>Nut, 3/8 hex</td>
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</tr>
<tr>
<td>6</td>
<td>Angle Stiffener</td>
<td>sheet 3</td>
<td>6</td>
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<tr>
<td>7</td>
<td>Bolt, 3/8 x 1-3/4 square head</td>
<td>see TxDOT Drawing SMD (2-1) -08</td>
<td>54</td>
</tr>
<tr>
<td>8</td>
<td>Sign Clip</td>
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<tr>
<td>9</td>
<td>Nut, 3/8 flange</td>
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<td>54</td>
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<tr>
<td>10</td>
<td>1/2 x 3 Leg Bolt</td>
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Figure 3. Details of Direct Embedded Wood Support Temporary Guide Sign System (cont.)

3a. Timber Post is rough-cut treated #1 yellow pine.
Figure 4 shows sequential images of the test and damage to the sign support system and the 1100C vehicle after the test. The windshield damage and roof deformation that resulted from the sign falling on top of the vehicle were found to satisfy MASH criteria. The maximum occupant compartment deformation at the rear of the roof at the back window was 3.5 inches, which is less than the 4 inch allowable limit. Although the windshield was cracked, there were no holes or tears through the safety liner and the deformation was below the 3-inch allowable threshold.

All occupant risk criteria were within MASH requirements for breakaway support structures. The occupant impact velocity, which was the primary concern for this test, was 11.2 ft/sec. This is less than the acceptable threshold of 16 ft/sec. The direct embedded wood support temporary guide sign system met all applicable MASH evaluation criteria for Test 3-60.

**MASH Test 3-61**

With the success of Test 3-60, Test 3-61 was performed. This test involved an 1100C car impacting two of the 6-inch x 8-inch wood supports head-on at a nominal speed of 62 mph. Actual impact speed was 61.6 mph.

Upon impact, the wood supports fractured at ground line and below the sign panel as designed. However, the released support members rotated into the windshield of the test vehicle. Figure 5 shows sequential images of the test and damage to the sign support system and the 1100C vehicle after the test. The sign remained standing and attached to the remaining wood support. Both of the fractured support posts penetrated through the windshield and into the occupant compartment. The windshield had two holes measuring 7 inches × 14 inches on the driver side and 7 inches × 8 inches on the passenger side.

The direct embedded wood support temporary guide sign system failed to meet MASH impact performance requirements for Test 3-61 due to windshield penetration resulting from secondary contact with the fractured wood supports.
<table>
<thead>
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<th>Time (s)</th>
<th>Image Description</th>
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<tbody>
<tr>
<td>0.000 s</td>
<td>Installation after Test 3-60</td>
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<tr>
<td>0.378 s</td>
<td>Vehicle after Test 3-60</td>
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<tr>
<td>0.756 s</td>
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<tr>
<td>1.134 s</td>
<td>After Impact Trajectory for Test 3-60</td>
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<td>1.512 s</td>
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<tr>
<td>1.890 s</td>
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</tbody>
</table>

**Figure 4.** Test 3-60.
After Impact Trajectory for Test 3-61

Installation after Test 3-61

Vehicle after Test 3-61

Figure 5. Test 3-61.
Design Modification

After analysis of the unacceptable high-speed test, TTI research engineers modified the design of the temporary large guide sign support system to address the identified problem. The objective was to change the rotation of the fractured support posts in high-speed impacts to permit the impacting vehicle to travel beneath the sign system without secondary windshield or roof contact.

Figure 6 illustrates the design modification. It involves drilling a small hole through the wood support parallel to the sign panel above and below the weakening hole. A \( \frac{1}{4} \)-inch diameter cable is used to form a loop through the holes. Upon fracture of the support through the upper weakening hole, the cable will restrict rotation of the support toward the impacting vehicle.

![Diagram of design modification](image)

**Figure 6. Modified Direct Embedded Wood Support Temporary Guide Sign System**

Crash testing was performed to evaluate the impact performance of the modified design. It was concluded that the low-speed car test (Test 3-60) did not need to be rerun. During the low-speed test, only one of the two impacted wood supports fractured at the upper weakening hole, and the other did not interact with the vehicle. When the two wood supports fractured at groundline, the sign rotated around the third support. The only interaction with the vehicle was the sign falling on top of the vehicle after being pried off the third support post. This behavior will not change by adding a hinge point for the fractured support post at the bottom of the sign. Therefore, the test matrix for the modified design consisted of two tests: test 3-61 (high-speed small car test) and test 3-62 (high-speed pickup truck test).

**MASH Test 3-61 (Modified Design)**

Test 3-61 was repeated on the modified direct embedded wood support temporary guide sign system. This test involved an 1100C car impacting two of the 6-inch x 8-inch wood supports head-on at a nominal speed of 62 mph. Actual impact speed was 61.2 mph.

Upon impact, the wood supports fractured at ground line, at bumper height, and below the sign panel as designed. The fractured supports rotated upward about the restraining cables,
and the test vehicle past underneath the sign installation without any secondary contact. The inertia of the fractured rotating supports caused the sign to begin to rotate about the third support post. When the fractured rotating supports contacted the back of the sign panel, the resulting force caused a bending moment that fractured the third support post at the weakening hole below the extruded aluminum sign panel. Figure 7 shows sequential images of the test and damage to the sign support system and the 1100C vehicle after the test.

The occupant impact velocity was 6.9 ft/sec, which is below the preferred value in MASH. The modified direct embedded wood support temporary guide sign system with restraining cable met all applicable MASH evaluation criteria for Test 3-61.

**MASH Test 3-62**

With the success of Test 3-61, Test 3-62 was performed. This test involved a 2270P pickup truck impacting two of the 6-inch x 8-inch wood supports head-on at a nominal speed of 62 mph. Actual impact speed was 64.0 mph.

Upon impact, the wood supports fractured at ground line, at bumper height, and below the sign panel as designed. The fractured supports rotated upward about the restraining cables. As the test vehicle past underneath the sign installation, pieces of wood projecting from the fractured end of the support post contacted the roof of the pickup truck. The inertia of the fractured rotating supports caused the sign to rotate about the third support post. The rotation caused the sign panel to pry off and release from the remaining support post. Figure 8 shows sequential images of the test and damage to the sign support system and the 2270P vehicle after the test.

The modified direct embedded wood support temporary guide sign system with restraining cable met all applicable MASH evaluation criteria for Test 3-62. Occupant impact velocity was 4.6 ft/sec, which is below the preferred value. The roof deformation resulting from secondary contact with pieces of wood projecting from the fractured supports was minor in nature and did not result in any occupant compartment deformation.

**SUMMARY AND CONCLUSIONS**

A temporary support system for large guide signs was developed and successfully crash tested in accordance with MASH guidelines. This system provides a cost-effective option for highway construction projects in which there exists a need to temporarily relocate large guide signs on the roadside or install new guide signs for temporary use. The wooden support posts are directly embedded in the ground, thus eliminating the need for reinforced concrete foundations that are costly and time consuming to both install and remove at the completion of the construction project.
Figure 7. Test 3-61 on the Modified Design.
Figure 8. Test 3-62 on the Modified Design.
The results of the crash tests reported herein can be used to establish acceptance of other less critical design configurations for other sizes of temporary guide signs. For example, testing with the stronger Grade 1 wood posts provides the basis for acceptance of weaker Grade 2 material that may have better availability at reduced cost. Similarly, successfully impacting two wood support posts simultaneously allows for acceptance of other wood post configurations with larger post spacing in which only one 6-inch x 8-inch post can be impacted. Additionally, testing the more critical extruded aluminum sign substrate provides the basis for use of plywood substrates with the temporary support system.

Engineering calculations can be used as the basis for acceptance of other wood support post types as well. The full-scale crash testing establishes an upper limit on post strength. Therefore, various combinations of 4-inch x 6-inch wood posts with appropriately sized weakening holes would be acceptable provided the combined flexural strength (as defined by section modulus) of the number of posts within the vehicle path is less than or equal to the combined strength of the dual 6-inch x 8-inch posts with 4-inch weakening holes that were successfully tested.

REFERENCES


DISCLAIMER

The contents of this paper reflect the views of the authors who are solely responsible for the facts and accuracy of the data, and the opinions, findings and conclusions presented herein. The contents do not necessarily reflect the official views or policies of the Texas A&M
Transportation Institute, the Texas Department of Transportation, or the U.S. Department of Transportation, Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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