Assessment of Weathering Steel Overhead Sign Structures in West Virginia

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Extended Abstract
Weathering steel overhead sign structures are widely used in interstate highways and at traffic intersections. They are susceptible to fatigue, cracking and lateral buckling under wind loads because of their high span-to-weight ratio and relatively small cross-sectional area. State Departments of Transportation (DOTs) need to consider rational and viable decisions regarding preservation and replacement alternatives of weathering steel sign structures. The decision-making and prioritization of maintenance and replacement plans can be executed more objectively when a representative framework is developed. The ultimate goal of this project is to assist the West Virginia Department of Highways (WVDOH) in managing its weathering steel sign structures inventory through appropriate periodic inspection and evaluation of their current condition. To achieve this goal, the researchers developed an element condition rating system and an overall sign structure inspection framework. This framework was then applied to the WVDOH inventory in its Charleston Interstate System, which includes 82 weathering steel overhead sign structures. Twenty-six comprehensive inspection forms were developed to evaluate the current condition of the inventory, which includes the following sign structure types:

1) Type 1.1: Double Armed Ground Mount Cantilever
2) Type 1.2: Single Armed Ground Mount Cantilever
3) Type 2.1: Bridge Superstructure Mount Cantilever
4) Type 2.2: Bridge Parapet Wall Mount Cantilever
5) Type 3.1: Dual Shoulder Mount Two-Dimensional Overhead Truss, Closed Type Column Design
6) Type 3.2: Dual Shoulder Mount Two-Dimensional Overhead Truss, Open Type Column Design
7) Type 3.3: Dual Shoulder Mount Three-Dimensional Overhead Truss
8) Type 3.4: Dual Shoulder Mount Single Chord Truss
9) Type 4.1: Shoulder/Median Barrier Mount Two-Dimensional Truss
10) Type 4.2: Shoulder/Median Barrier Mount Three-Dimensional Truss
11) Type 5: Dual Shoulder & Median Barrier Mount Two-Dimensional Truss
12) Type 6.1.1: Bridge Mount Truss, Type A Column Connection with Type A Superstructure Connection Bracket Left & Right, Closed Columns
13) Type 6.1.2: Bridge Mount Truss, Type A Column Connection with Type B Superstructure Connection Bracket Left & Right, Closed Columns
14) Type 6.2.1: Bridge Mount Truss, Type A Column Connection with Type A Superstructure Connection Bracket Left & Right, Open Columns
15) Type 6.2.2: Bridge Mount Truss, Type A Column Connection with Type B Superstructure Connection Bracket Left & Right, Open Columns
16) Type 6.3: Bridge Mount Truss, Type B Column Connection Left & Right, Open Columns
17) Type 6.4: Bridge Mount Truss, Type C Column Connection Left & Right, Open Columns
18) Type 6.5: Bridge Mount Truss, Type D Column Connection Left & Right, Open Columns
19) Type 6.6: Bridge Mount Truss, Type E Column Connection Right, Median Barrier Column Connection Left, Open Columns
20) Type 7: Retaining Wall Mount Cantilever
21) Type 8: Retaining Wall/Parapet Wall Mount Truss
22) Type 9: Shoulder/Retaining Wall Mount Truss
23) Type 10.1: Bridge Frame Mount - Steel Girder Attached
24) Type 10.2: Bridge Frame Mount - Concrete Box Girder Attached
25) Type 11.1: Shoulder/Parapet Wall Mount Truss, Open Columns
26) Type 11.2: Shoulder/Parapet Wall Mount Truss, Closed Columns

The project included extensive field inspections of the structural elements of the 82 sign structures. A reliable ultrasonic testing technique was used to examine critical components of the sign structures (e.g. column base, anchor bolts, base plates, and connection plates) while the other components were inspected by visual inspection technique. Below is a list of sign structure elements that were inspected:

- Foundation/superstructure bracket
- Drainage issues
- Grout pad under the base plate
- Base plate/mounting plate
- Nuts/washers
- Anchor bolts (using visual inspection and ultrasonic testing)
- Connections between base plate/mounting plate and vertical column
- Section loss of the vertical column near the base plate/mounting plate
- Weld lines between vertical columns and supplemental bracing
- Vertical weld lines between tubes constituting the vertical column
- Vertical column, internal and external condition
- Connections between the vertical column and horizontal chords
- Horizontal chords and secondary vertical posts
- Attachments: vertical sign supports, horizontal light arms, vertical sign support to horizontal chord connection bracket, sign panels, electric distribution boxes, conduits, traffic control devices, cameras, etc.

Structural elements of each sign structure were evaluated using an element condition rating system. The element condition rating system includes a sequential rating score (i.e. '0', '1', '2', '3', '4') and an importance weight for each structural element. The descriptions of the sequential rating scores range, in severity, from “Not Applicable” (0) to “Element does not perform intended function with any degree of reliability” (4). The overall condition of each sign structure was then evaluated using an overall condition rating system. The overall condition rating is estimated based on the ratio between the total score recorded for each structure (S) and its maximum possible total score (S_{max}). Sign structures with ratios between S/S_{max} < 0.43 are categorized as “good condition”. Sign structures with ratios between 0.43 ≤ S/S_{max} < 0.62 are categorized as “fair condition”. Sign structures with ratios between 0.62 ≤ S/S_{max} < 0.8 are categorized as “poor condition”. Sign structures with ratios between 0.8 ≤ S/S_{max} ≤ 1.0 are categorized as “severe condition”. Table 1 shows the overall condition rating for type 4.1 (Shoulder/Median Barrier Mount Two-Dimensional Truss) and type 4.2 (Shoulder/Median Barrier Mount Three-Dimensional Truss) sign structures, which have the most deficient conditions. Rating results for the other sign structure types were published by the authors in the WVDOH final report on “Evaluation of Weathering Steel Overhead Sign Structures in West Virginia”. The sign structures in Table 1 are sorted in the order of largest to smallest S/S_{max} ratio (i.e. most deficient condition to least deficient condition). Ultrasonic testing results of anchor/connection bolts and maximum section loss of vertical columns near base plates are also included in Table 1. The maximum section loss was calculated by a fraction between the minimum UT thickness reading of the vertical columns near the base plates and an assumed initial thickness of the vertical columns. It can be seen from Table 1 that out of nine types 4.1 and 4.2 sign structures, seven structures were found to be in poor condition with the S/S_{max} ratio ranging from 0.63 to 0.77 and two remaining structures were determined to be in fair condition with the S/S_{max} ratio ranging from 0.55 to 0.60. Six of the seven structures with a poor condition rating are structure type #4.1. The remaining sign structure with a poor condition rating is structure type 4.2. Average maximum section loss near base plate for sign structure types 4.1 & 4.2 are 37% and 41%, respectively. Ultrasonic inspection of anchor bolts shows that all the anchor bolts are in a good shape with no significant deficiencies (ultrasonic testing of anchor bolts shows Non-Relevant Indication (NRI) as seen in Table 1). Major deficiencies for sign structure types 4.1 & 4.2 are: (1) deterioration/corrosion, surface pitting, possible cracks, and warping/buckling of the base plates; (2) anchor bolts/nuts/washers are corroded and some anchor
bolts are cut short; (3) corrosion of weld lines connecting the base plate and the vertical column; (4) corrosion/deterioration/distress of the vertical columns; (5) pack rust between plates/members at splice connections between the vertical column and the horizontal chords; (6) some U-bolt connections are loose or broken; (7) delamination in several surface areas of the horizontal chords; (8) corrosion/twist of horizontal light arms; (9) pack rust between light arm JBs and the lower chord; and (10) corrosion of electrical box, conduit, and washers. Sample deficiencies of types 4.1 and 4.2 sign structures are shown in Figure 1.

The element and overall condition rating systems are intended to assist the WVDOH in making rational decisions on whether there is a need to repair or replace at-risk elements or connections. To detect any serious defects which may endanger the structure or the traveling public, in-depth evaluations are recommended for the sign structures with the most deficient condition. Further evaluations are recommended for the sign structures with a fair condition rating. Normal periodic inspections are recommended for the sign structures with a good condition rating.

Table 1. Overall Condition Rating for Types 4.1 & 4.2 Sign Structures

<table>
<thead>
<tr>
<th>Form Number</th>
<th>Structure Number</th>
<th>UT Signal Indication</th>
<th>Max. Section Loss (%)</th>
<th>Min. Score ($S_{\text{min}}$)</th>
<th>Max. Score ($S_{\text{max}}$)</th>
<th>Total Score ($S$)</th>
<th>$S/S_{\text{max}}$</th>
<th>Rating Condition</th>
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<tr>
<td>4.1</td>
<td>01-20-064-57.53</td>
<td>NRI</td>
<td>51</td>
<td>41</td>
<td>164</td>
<td>127</td>
<td>0.774</td>
<td>Poor</td>
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<td>41</td>
<td>164</td>
<td>122</td>
<td>0.744</td>
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<td>39</td>
<td>41</td>
<td>164</td>
<td>121</td>
<td>0.738</td>
<td>Poor</td>
</tr>
<tr>
<td>4.2</td>
<td>01-20-077-101.84</td>
<td>NRI</td>
<td>41</td>
<td>41</td>
<td>164</td>
<td>121</td>
<td>0.738</td>
<td>Poor</td>
</tr>
<tr>
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<td>41</td>
<td>164</td>
<td>120</td>
<td>0.732</td>
<td>Poor</td>
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<td>41</td>
<td>164</td>
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<td>0.671</td>
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<td>41</td>
<td>164</td>
<td>104</td>
<td>0.634</td>
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<td>41</td>
<td>164</td>
<td>99</td>
<td>0.604</td>
<td>Fair</td>
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<td>41</td>
<td>164</td>
<td>90</td>
<td>0.549</td>
<td>Fair</td>
</tr>
</tbody>
</table>

Note: UT = Ultrasonic Testing; NRI = Non-Relevant Indication.

(a) Corrosion/deterioration of anchor bolts, base plates, and weld connections between vertical column and base plate

Figure 1. Sample deficiencies of Shoulder/Median Barrier Mount Truss (types 4.1 & 4.2) sign structures

Keywords: Weathering steel, overhead sign structures, visual inspection, ultrasonic testing, element/overall condition rating systems, management and preservation