The purpose of this study is to crash test and evaluate new or modified roadside safety hardware and, where necessary, redesign the devices to improve their impact performance. The three major areas addressed in this study are the impact performance of bridge railings, transitions from guardrails to bridge railings, and end treatments for guardrails and median barriers.

This report presents the results of four crash tests conducted on a swing-away mailbox support design by the Minnesota Department of Transportation in accordance with guidelines set forth in the 1985 American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals and National Cooperative Highway Research Program (NCHRP) Report 350. The first two tests corresponded to NCHRP Report 350 test designation 3-60 and 3-61, involving an 820-kg passenger car impacting the vertical mailbox support head-on at speeds of 35 km/h and 100 km/h, respectively. The mailbox support was aligned with the right front quarter point of the vehicle so that the interaction between the cantilevered arm and the mailbox assembly with the windshield of the vehicle can be evaluated. The third and fourth tests involved an 820-kg passenger car impacting the mailbox assembly head-on at a nominal speed of 100 km/h and zero (0) degree with the centerline of the mailbox assembly aligned with the centerline of the vehicle. These two tests are not required in NCHRP Report 350, but are included because of the cantilever design of the mailbox support. The Minnesota swing-away mailbox support was judged to have successfully met all evaluation criteria for a single mailbox assembly, but not for a triple mailbox assembly.

PREFACE

Because of specific needs or constraints of individual states, new or modified roadside safety hardware are being designed and developed on a continuing basis. To ensure that these new or modified designs perform according to established guidelines, full-scale crash testing and evaluation were deemed necessary. The objective of this study is to crash test and evaluate these roadside safety hardware and, where necessary, redesign the devices to improve their impact performance. The three major areas addressed in this study are the impact performance of bridge railings, transitions from guardrails to bridge railings, and end treatments for guardrails and median barriers.

This is Volume VII of a 14-volume series of final reports for this study. The 14 volumes are as follows:

<table>
<thead>
<tr>
<th>Volume</th>
<th>Appendix</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>B</td>
<td>Crash Testing and Evaluation of a Michigan Thrie-Beam Transition Design.</td>
</tr>
<tr>
<td>III</td>
<td>C</td>
<td>Crash Testing and Evaluation of a Guardrail System for Low-Fill Culvert.</td>
</tr>
<tr>
<td>V</td>
<td>E</td>
<td>Crash Testing and Evaluation of a Washington, DC, PL-1 Bridge Rail.</td>
</tr>
<tr>
<td>VI</td>
<td>F</td>
<td>Crash Testing and Evaluation of a Modified Breakaway Cable Terminal (BCT) Design.</td>
</tr>
<tr>
<td>VIII</td>
<td>H</td>
<td>Crash Testing and Evaluation of the Single Slope Bridge Rail.</td>
</tr>
<tr>
<td>IX</td>
<td>I</td>
<td>Crash Testing and Evaluation of the NETC PL-2 Bridge Rail Design.</td>
</tr>
<tr>
<td>X</td>
<td>J</td>
<td>Crash Testing and Evaluation of a Mini-MELT for a W-Beam, Weak-Post (G2) Guardrail System.</td>
</tr>
<tr>
<td>XII</td>
<td>L</td>
<td>Crash Testing and Evaluation of the MELT.</td>
</tr>
<tr>
<td>XIII</td>
<td>M</td>
<td>Crash Testing and Evaluation of the Modified MELT.</td>
</tr>
<tr>
<td>XIV</td>
<td></td>
<td>Laboratory and Pendulum Testing of Modified Breakaway Wooden Posts.</td>
</tr>
</tbody>
</table>
### APPROXIMATE CONVERSIONS TO SI UNITS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>When You Know</th>
<th>Multiply By</th>
<th>To Find</th>
</tr>
</thead>
<tbody>
<tr>
<td>in</td>
<td>inches</td>
<td>25.4</td>
<td>mm</td>
</tr>
<tr>
<td>ft</td>
<td>feet</td>
<td>0.305</td>
<td>m</td>
</tr>
<tr>
<td>yd</td>
<td>yards</td>
<td>0.914</td>
<td>m</td>
</tr>
<tr>
<td>mi</td>
<td>miles</td>
<td>1.61</td>
<td>km</td>
</tr>
<tr>
<td><strong>AREA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in²</td>
<td>square inches</td>
<td>645.2</td>
<td>mm²</td>
</tr>
<tr>
<td>ft²</td>
<td>square feet</td>
<td>0.093</td>
<td>m²</td>
</tr>
<tr>
<td>yd²</td>
<td>square yards</td>
<td>0.836</td>
<td>m²</td>
</tr>
<tr>
<td>ac</td>
<td>acres</td>
<td>0.405</td>
<td>ha</td>
</tr>
<tr>
<td>mi²</td>
<td>square miles</td>
<td>2.59</td>
<td>km²</td>
</tr>
<tr>
<td><strong>VOLUME</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fl oz</td>
<td>fluid ounces</td>
<td>29.57</td>
<td>mL</td>
</tr>
<tr>
<td>gal</td>
<td>gallons</td>
<td>3.785</td>
<td>L</td>
</tr>
<tr>
<td>ft³</td>
<td>cubic feet</td>
<td>0.028</td>
<td>m³</td>
</tr>
<tr>
<td>yd³</td>
<td>cubic yards</td>
<td>0.765</td>
<td>m³</td>
</tr>
</tbody>
</table>

**NOTE**: Volumes greater than 1000 L shall be shown in m³.

### APPROXIMATE CONVERSIONS FROM SI UNITS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>When You Know</th>
<th>Multiply By</th>
<th>To Find</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>millimeters</td>
<td>0.039</td>
<td>in</td>
</tr>
<tr>
<td>m</td>
<td>meters</td>
<td>3.28</td>
<td>ft</td>
</tr>
<tr>
<td>m</td>
<td>meters</td>
<td>1.09</td>
<td>yd</td>
</tr>
<tr>
<td>km</td>
<td>kilometers</td>
<td>0.621</td>
<td>mi</td>
</tr>
<tr>
<td><strong>AREA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mm²</td>
<td>square millimeters</td>
<td>0.0016</td>
<td>square inches</td>
</tr>
<tr>
<td>m²</td>
<td>square meters</td>
<td>10.764</td>
<td>square feet</td>
</tr>
<tr>
<td>m²</td>
<td>square meters</td>
<td>1.195</td>
<td>square yards</td>
</tr>
<tr>
<td>ha</td>
<td>hectares</td>
<td>2.47</td>
<td>acres</td>
</tr>
<tr>
<td>km²</td>
<td>square kilometers</td>
<td>0.386</td>
<td>square miles</td>
</tr>
<tr>
<td><strong>VOLUME</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mL</td>
<td>milliliters</td>
<td>0.034</td>
<td>fluid ounces</td>
</tr>
<tr>
<td>L</td>
<td>liters</td>
<td>0.264</td>
<td>gallons</td>
</tr>
<tr>
<td>m³</td>
<td>cubic meters</td>
<td>35.71</td>
<td>cubic feet</td>
</tr>
<tr>
<td>m³</td>
<td>cubic meters</td>
<td>1.307</td>
<td>cubic yards</td>
</tr>
</tbody>
</table>

**MASS**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>When You Know</th>
<th>Multiply By</th>
<th>To Find</th>
</tr>
</thead>
<tbody>
<tr>
<td>oz</td>
<td>ounces</td>
<td>28.35</td>
<td>g</td>
</tr>
<tr>
<td>lb</td>
<td>pounds</td>
<td>0.454</td>
<td>kg</td>
</tr>
<tr>
<td>T</td>
<td>short tons (2000 lb)</td>
<td>0.907</td>
<td>(or &quot;metric ton&quot;)</td>
</tr>
<tr>
<td>g</td>
<td>grams</td>
<td>0.035</td>
<td>ounces</td>
</tr>
<tr>
<td>kg</td>
<td>kilograms</td>
<td>2.202</td>
<td>pounds</td>
</tr>
<tr>
<td>Mg</td>
<td>megagrams (or &quot;metric ton&quot;)</td>
<td>1.103</td>
<td></td>
</tr>
</tbody>
</table>

**TEMPERATURE (exact)**

<table>
<thead>
<tr>
<th>℉</th>
<th>Fahrenheit 5(F-32)/9</th>
<th>℃</th>
<th>Celcius (or F-32)/1.8</th>
</tr>
</thead>
</table>

**ILLUMINATION**

<table>
<thead>
<tr>
<th>fc</th>
<th>foot-candies 10.76</th>
<th>lx</th>
<th>lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>fl</td>
<td>foot-Lamberts 3.428</td>
<td>cd/m²</td>
<td>candela/m²</td>
</tr>
</tbody>
</table>

**FORCE and PRESSURE or STRESS**

<table>
<thead>
<tr>
<th>lbf</th>
<th>poundforce 4.45</th>
<th>N</th>
<th>newtons</th>
</tr>
</thead>
<tbody>
<tr>
<td>lbf/in²</td>
<td>poundforce per square inch 6.89</td>
<td>kPa</td>
<td>kilopascals</td>
</tr>
</tbody>
</table>

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E390.*

(Revised September 1993)
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>II. STUDY APPROACH</td>
<td>3</td>
</tr>
<tr>
<td>2.1 TEST ARTICLE</td>
<td>3</td>
</tr>
<tr>
<td>2.2 CRASH TEST CONDITIONS</td>
<td>5</td>
</tr>
<tr>
<td>2.3 CRASH TEST AND DATA ANALYSIS PROCEDURES</td>
<td>7</td>
</tr>
<tr>
<td>2.3.1 Electronic Instrumentation and Data Processing</td>
<td>7</td>
</tr>
<tr>
<td>2.3.2 Anthropomorphic Dummy Instrumentation</td>
<td>8</td>
</tr>
<tr>
<td>2.3.3 Photographic Instrumentation and Data Processing</td>
<td>8</td>
</tr>
<tr>
<td>2.3.4 Test Vehicle Propulsion and Guidance</td>
<td>8</td>
</tr>
<tr>
<td>III. RESULTS OF CRASH TESTS</td>
<td>9</td>
</tr>
<tr>
<td>3.1 TEST NO. 471470-11</td>
<td>9</td>
</tr>
<tr>
<td>3.1.1 Test Description</td>
<td>15</td>
</tr>
<tr>
<td>3.1.2 Damage to Test Installation</td>
<td>15</td>
</tr>
<tr>
<td>3.1.3 Vehicle Damage</td>
<td>15</td>
</tr>
<tr>
<td>3.1.4 Occupant Risk Values</td>
<td>15</td>
</tr>
<tr>
<td>3.2 TEST NO. 471470-12</td>
<td>22</td>
</tr>
<tr>
<td>3.2.1 Test Description</td>
<td>22</td>
</tr>
<tr>
<td>3.2.2 Damage to Test Installation</td>
<td>32</td>
</tr>
<tr>
<td>3.2.3 Vehicle Damage</td>
<td>32</td>
</tr>
<tr>
<td>3.2.4 Occupant Risk Values</td>
<td>32</td>
</tr>
<tr>
<td>3.3 TEST NO. 471470-13</td>
<td>46</td>
</tr>
<tr>
<td>3.3.1 Test Description</td>
<td>46</td>
</tr>
<tr>
<td>3.3.2 Damage to Test Installation</td>
<td>52</td>
</tr>
<tr>
<td>3.3.3 Vehicle Damage</td>
<td>52</td>
</tr>
<tr>
<td>3.3.4 Occupant Risk Values</td>
<td>52</td>
</tr>
<tr>
<td>3.4 TEST NO. 471470-14</td>
<td>63</td>
</tr>
<tr>
<td>3.4.1 Test Description</td>
<td>63</td>
</tr>
<tr>
<td>3.4.2 Damage to Test Installation</td>
<td>63</td>
</tr>
<tr>
<td>3.4.3 Vehicle Damage</td>
<td>74</td>
</tr>
<tr>
<td>3.4.4 Occupant Risk Values</td>
<td>74</td>
</tr>
<tr>
<td>IV. SUMMARY OF FINDINGS AND CONCLUSIONS</td>
<td>83</td>
</tr>
<tr>
<td>4.1 SUMMARY OF FINDINGS</td>
<td>83</td>
</tr>
<tr>
<td>4.2 RECOMMENDATIONS AND DISCUSSION</td>
<td>84</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>91</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
</tr>
<tr>
<td>--------</td>
<td>-------------</td>
</tr>
<tr>
<td>1</td>
<td>Schematic of Minnesota swing-away mailbox support design</td>
</tr>
<tr>
<td>2</td>
<td>Minnesota swing-away mailbox installation before test 7147-11.</td>
</tr>
<tr>
<td>3</td>
<td>Mounting bracket and post attachment before test 7147-11.</td>
</tr>
<tr>
<td>4</td>
<td>Vehicle/mailbox geometrics for test 7147-11.</td>
</tr>
<tr>
<td>5</td>
<td>Vehicle prior to test 7147-11.</td>
</tr>
<tr>
<td>6</td>
<td>Vehicle properties for tests 7147-11, 12, and 13.</td>
</tr>
<tr>
<td>7</td>
<td>Sequential photographs for test 7147-11 (perpendicular and side views).</td>
</tr>
<tr>
<td>8</td>
<td>Test site after test 7147-11.</td>
</tr>
<tr>
<td>9</td>
<td>Mailbox and upper support arm after test 7147-11.</td>
</tr>
<tr>
<td>10</td>
<td>Support post and lower support arm after test 7147-11.</td>
</tr>
<tr>
<td>11</td>
<td>Vehicle after test 7147-11.</td>
</tr>
<tr>
<td>12</td>
<td>Summary of results for test 7147-11.</td>
</tr>
<tr>
<td>13</td>
<td>Vehicle angular displacement for test 7147-11.</td>
</tr>
<tr>
<td>14</td>
<td>Vehicle longitudinal accelerometer trace for test 7147-11.</td>
</tr>
<tr>
<td>15</td>
<td>Vehicle lateral accelerometer trace for test 7147-11.</td>
</tr>
<tr>
<td>16</td>
<td>Vehicle vertical accelerometer trace for test 7147-11.</td>
</tr>
<tr>
<td>17</td>
<td>Minnesota swing-away mailbox installation before test 7147-12.</td>
</tr>
<tr>
<td>18</td>
<td>Mounting bracket and post attachment before test 7147-12.</td>
</tr>
<tr>
<td>19</td>
<td>Vehicle/mailbox geometrics for test 7147-12.</td>
</tr>
<tr>
<td>20</td>
<td>Vehicle prior to test 7147-12.</td>
</tr>
<tr>
<td>21</td>
<td>Sequential photographs for test 7147-12 (perpendicular and side views).</td>
</tr>
<tr>
<td>22</td>
<td>Mailbox and tube after test 7147-12.</td>
</tr>
<tr>
<td>23</td>
<td>Mounting base and upper support arm after test 7147-12.</td>
</tr>
<tr>
<td>24</td>
<td>Support post and lower support arm after test 7147-12.</td>
</tr>
<tr>
<td>25</td>
<td>Vehicle after test 7147-12.</td>
</tr>
<tr>
<td>26</td>
<td>Vehicle A-pillar and side window after test 7147-12.</td>
</tr>
<tr>
<td>27</td>
<td>Undercarriage and rear tire after test 7147-12.</td>
</tr>
<tr>
<td>28</td>
<td>Summary of results for test 7147-12.</td>
</tr>
<tr>
<td>29</td>
<td>Vehicle angular displacement for test 7147-12.</td>
</tr>
<tr>
<td>30</td>
<td>Vehicle longitudinal accelerometer trace for test 7147-12.</td>
</tr>
<tr>
<td>31</td>
<td>Vehicle lateral accelerometer trace for test 7147-12.</td>
</tr>
<tr>
<td>32</td>
<td>Vehicle vertical accelerometer trace for test 7147-12.</td>
</tr>
<tr>
<td>33</td>
<td>Minnesota swing-away mailbox installation before test 7147-13.</td>
</tr>
<tr>
<td>34</td>
<td>Vehicle/mailbox geometrics for test 7147-13.</td>
</tr>
<tr>
<td>35</td>
<td>Vehicle prior to test 7147-13.</td>
</tr>
<tr>
<td>36</td>
<td>Sequential photographs for test 7147-13 (perpendicular and side views).</td>
</tr>
<tr>
<td>37</td>
<td>Test site after test 7147-13.</td>
</tr>
<tr>
<td>38</td>
<td>Mailbox and tube after test 7147-13.</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES (continued)

<table>
<thead>
<tr>
<th>Figure</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>39</td>
<td>55</td>
</tr>
<tr>
<td>40</td>
<td>56</td>
</tr>
<tr>
<td>41</td>
<td>57</td>
</tr>
<tr>
<td>42</td>
<td>58</td>
</tr>
<tr>
<td>43</td>
<td>59</td>
</tr>
<tr>
<td>44</td>
<td>60</td>
</tr>
<tr>
<td>45</td>
<td>61</td>
</tr>
<tr>
<td>46</td>
<td>62</td>
</tr>
<tr>
<td>47</td>
<td>64</td>
</tr>
<tr>
<td>48</td>
<td>65</td>
</tr>
<tr>
<td>49</td>
<td>66</td>
</tr>
<tr>
<td>50</td>
<td>67</td>
</tr>
<tr>
<td>51</td>
<td>68</td>
</tr>
<tr>
<td>52</td>
<td>69</td>
</tr>
<tr>
<td>53</td>
<td>71</td>
</tr>
<tr>
<td>54</td>
<td>72</td>
</tr>
<tr>
<td>55</td>
<td>73</td>
</tr>
<tr>
<td>56</td>
<td>75</td>
</tr>
<tr>
<td>57</td>
<td>76</td>
</tr>
<tr>
<td>58</td>
<td>77</td>
</tr>
<tr>
<td>59</td>
<td>78</td>
</tr>
<tr>
<td>60</td>
<td>79</td>
</tr>
<tr>
<td>61</td>
<td>80</td>
</tr>
<tr>
<td>62</td>
<td>81</td>
</tr>
<tr>
<td>Table</td>
<td>Assessment of results of test 471470-11 (according to NCHRP 350)</td>
</tr>
<tr>
<td>-------</td>
<td>-------------------------------------------------</td>
</tr>
<tr>
<td>1</td>
<td>Assessment of results of test 471470-12 (according to NCHRP 350)</td>
</tr>
<tr>
<td>2</td>
<td>Assessment of results of test 471470-13 (according to NCHRP 350)</td>
</tr>
<tr>
<td>3</td>
<td>Assessment of results of test 471470-14 (according to NCHRP 350)</td>
</tr>
<tr>
<td>4</td>
<td>Assessment of results of test 471470-14 (according to NCHRP 350)</td>
</tr>
</tbody>
</table>
I. INTRODUCTION

Because of specific needs or constraints of individual states, new or modified roadside safety hardware have been designed and developed recently. To ensure that these new or modified designs perform according to established performance guidelines, full-scale crash testing and evaluation was deemed necessary. The objective of this study is to crash test and evaluate these roadside safety hardware and, where necessary, redesign the tested devices to improve their performance. The major areas addressed in this study include the impact performance of bridge rails, transitions from guardrails to bridge rails, end treatments for guardrails and median barriers, and other roadside safety appurtenances.

The Minnesota Department of Transportation (MnDOT) has designed a swing-away mailbox support for use in locales where snow and ice removal during the wintertime presents a problem. The Minnesota swing-way mailbox support design utilizes a cantilevered arm for attachment of the mailbox assembly. The cantilever design is intended to allow for snowplow operation beyond the shoulder or curbline, thus reducing snowdrifting on the roadway and minimizing the potential for damaging the mailbox support, which could present a maintenance problem. It is easily installed using existing highway agency equipment, can be salvaged and reinstalled, and costs considerably less than current mailbox designs approved by MnDOT.

This report presents the results of four full-scale crash tests conducted on this Minnesota swing-away mailbox support and the evaluation of its impact performance. Testing and evaluation was performed in accordance with guidelines outlined in National Cooperative Highway Research Program (NCHRP) Report 350 and the 1985 American Association of State Highway and Transportation Officials (AASHTO) Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals.\(^1\,^2\)
II. STUDY APPROACH

2.1 TEST ARTICLE

The Minnesota swing-away mailbox support, a schematic diagram of which is shown in figure 1, consists of four major components:

- U-channel base post,
- Vertical support,
- Cantilever arm, and
- Mailbox assembly.

A 2.13-m- (7-ft-) long, 4.46-kg/m (3-lb/ft) U-channel sign post is driven into the ground as a base post, leaving a stub height of approximately 0.46 m (18 in) above ground level. The minimum specified embedment depth of the post is 1.22 m (4 ft) so that either a 1.83-m- (6-ft-) or a 2.13-m- (7-ft-) long post may be used with the installation. A post length of 2.13 m (7 ft) was used in the crash tests since it was considered to be a more critical condition from a base bending standpoint. Note that the strong axis of the U-channel post is aligned with the direction of vehicle travel.

A vertical support, made from 42.2-mm- (1.66-in-) outside diameter, 35-mm- (1.38-in-) inside diameter standard-weight pipe, is bolted to the post stub with two 9.5-mm x 63.5-mm (3/8-in x 2.5-in) grade 5 bolts. The two bolts are spaced 0.31 m (12 in) apart, with the bottom bolt located 102 mm (4 in) above ground level. The top 0.31 m (12 in) of the pipe is bent at a 45-degree angle. A 0.41-m- (16-in-) long, 33.4-mm- (1.315-in-) outside diameter, 26.6-mm- (1.049-in-) inside diameter standard-weight pipe is inserted into the bent end of the vertical support and welded in place. The insert pipe extends 203 mm (8 in) beyond the end of the vertical support for attachment of the cantilever arm. A groove, 12.7-mm (1/2-in) wide and 3.2-mm (1/8-in) deep, is cut into the insert pipe 76.2 mm (3 in) above the end of the vertical support for use with a 6.4-mm- (1/4-in-) diameter set screw to attach the cantilever arm. The set screw and groove configuration renders removal of the cantilever arm more difficult so as to discourage vandalism. The set screw still allows the cantilever arm to rotate freely about the insert pipe and to separate readily from the vertical support upon impact, and is not expected to have any appreciable effect on the impact performance of the support.

A cantilever arm, also made from 42.2-mm- (1.66-in-) outside diameter, 35-mm- (1.38-in-) inside diameter standard-weight pipe, connects the vertical support to the mailbox assembly. The cantilever arm is 1.22 m (48 in) in length, 0.31 m (12 in) of which is bent at 45 degrees for attachment to the insert pipe. Two 3.2-mm- (1/8-in-) thick, 127-mm- (5-in-) long, 25.4-mm- (1-in-) wide metal straps, one at the end of the cantilever arm and the other spaced 0.31 m (12 in) apart, are welded to the top of the pipe. Two 7.9-mm (5/16-in) holes, spaced 102 mm (4 in) center to center, are drilled on the straps for attachment of the mailbox assembly to the cantilever arm.
Figure 1. Schematic of Minnesota swing-away mailbox support design.
An alternative design shortens the metal strap to only 63.5 mm (2.5 in) in length, with a single 7.9-mm-(5/16-in-) diameter hole drilled through the center of the pipe and strap. The purpose of the shorter strap is to minimize the potential of the straps penetrating the windshield if they should become exposed during an impact. It was decided to use the longer metal strap attachments for the test installation since that would be the more critical design from the safety standpoint.

For the triple mailbox assembly, the cantilever arm consists of standard-weight pipe for the bent portion of the arm that attaches to the insert arm and the first 127 mm (5 in) of the horizontal arm. The remainder of the horizontal arm is constructed of thin-wall pipe (such as muffler pipe) welded to the standard-weight pipe to reduce the weight of the cantilever arm. The horizontal arm forks out into three branches, spaced 0.31 m (12 in) apart, one for each of the three mailbox assemblies.

A 0.41-m- (16-in-) long, 0.20-m- (8-in-) wide (nominal), 25.4-mm- (1-in-) thick (nominal) wood board is bolted to the straps on the cantilever arm with four 6.35-mm-(1/4-in-) diameter, 38.1-mm- (1.5-in-) long carriage bolts. A size 1-A standard mailbox is attached to the wood board with sheetrock (drywall) screws.

A standard plastic newspaper tube is also attached to one side of the mailbox assembly using a 16-gauge metal bracket. The plastic newspaper tube is attached to the metal bracket using two 6.35-mm × 12.7-mm (1/4-in × 1/2-in) bolts, and the metal bracket is attached to the bottom of the wood board with four 25.4-mm- (1-in-) long sheetrock (drywall) screws. Note that the plastic newspaper tube is approved by the U.S. Postal Service for attachment to either side of the mailbox assembly. For the test installations, the plastic newspaper tubes were installed on the nonimpact side of the mailbox assemblies to allow direct contact of the mailbox with the windshield of the vehicle. However, given the light weight and crushable nature of the plastic newspaper tube and the attachment hardware, the positioning of the plastic newspaper tube is not expected to have any appreciable effect on the impact performance of the mailbox installation.

The attachment of the mailboxes to the cantilever arm for the triple mailbox assembly was similar to that of the single mailbox assembly. For each mailbox assembly, a wood board was bolted to the cantilever arm and the mailbox was attached to the wood board with sheetrock (drywall) screws. A single plastic newspaper tube was attached to one end (nonimpact end) of the triple mailbox assembly.

2.2 CRASH TEST CONDITIONS

A total of four full-scale crash tests were conducted to evaluate the impact performance of the Minnesota swing-away mailbox support. The four crash tests conducted are as follows:

1. Test no. 471470-11 (NCHRP Report 350 test designation 3-60). An 820-kg (1808-lb) passenger car impacting the vertical mailbox support head-on at a
nominal speed of 35 km/h (21.7 mi/h) and zero (0) degree. The mailbox support was aligned with the right front quarter point of the vehicle.

2. Test no. 471470-12 (NCHRP Report 350 test designation 3-61). An 820-kg (1808-lb) passenger car impacting the mailbox support head-on at a nominal speed of 100 km/h (62.2 mi/h) and zero (0) degree. The mailbox support was aligned with the right front quarter point of the vehicle.

3. Test no. 471470-13. An 820-kg (1808-lb) passenger car impacting a single mailbox assembly head-on at a nominal speed of 100 km/h (62.2 mi/h) and zero (0) degree. The centerline of the mailbox assembly was aligned with the centerline of the vehicle.

4. Test no. 471470-14. This test was identical to test no. 471470-13 except for the mailbox assembly, which had three mailboxes attached instead of a single mailbox. The test conditions again were for an 820-kg (1808-lb) passenger car impacting the triple mailbox assembly head-on at a nominal speed of 100 km/h (62.2 mi/h) and zero (0) degree with the centerline of the mailbox assembly aligned with the centerline of the vehicle.

In accordance with the crash test matrix for support structures outlined in NCHRP Report 350, two crash tests (designations 3-60 and 3-61) are required for evaluation of the mailbox support. The objective of the low-speed test (test designation 3-60) is to evaluate the breakaway, fracture, or yielding mechanism of the support, while the objective of the high-speed test (test designation 3-61) is to evaluate the vehicle and test article trajectory. The right front quarter point of the vehicle was selected as the point of impact so that the interaction between the cantilevered arm and the mailbox assembly with the windshield of the vehicle can be evaluated.

The third (test nos. 471470-13) and fourth (test no. 471470-14) tests in which the mailbox assembly directly impacts the windshield of the vehicle are not specifically required according to guidelines set forth in NCHRP Report 350, but are included because of the cantilever design of the mailbox support. Previous crash tests have shown that the mailbox assembly has the potential to impact the windshield and intrude into the passenger compartment. This potential is minimized by designing the support structure so that the front of the vehicle will contact and engage the support structure first. This allows the mailbox assembly to be pushed forward and downward or thrown up and over the vehicle, thus avoiding impact of the mailbox assembly with the windshield.

In the case of the Minnesota swing-away mailbox support, the mailbox assembly is attached to a cantilevered arm so that the mailbox assembly could impact the windshield of the vehicle without the front of the vehicle impacting the support. The cantilever design is intended to allow for snowplow operation without damaging the mailbox support, which presents a maintenance problem. Since the mailbox assembly has the potential of directly impacting the windshield of the vehicle, crash tests 3 and 4 were included in the crash test matrix to evaluate the potential of the mailbox assembly to penetrate or intrude into the occupant compartment.
2.3 CRASH TEST AND DATA ANALYSIS PROCEDURES

All crash tests and data analysis were conducted in accordance with guidelines contained in NCHRP Report 350. Brief descriptions of the crash test and data analysis procedures are presented as follows.

2.3.1 Electronic Instrumentation and Data Processing

Each test vehicle was instrumented with three solid-state angular rate transducers to measure roll, pitch, and yaw rates; a triaxial accelerometer near the vehicle center of gravity to measure longitudinal, lateral, and vertical acceleration levels; and a backup biaxial accelerometer in the rear of the vehicle to measure longitudinal and lateral acceleration levels. The accelerometers were strain-gauge type with a linear millivolt output proportional to acceleration.

The electronic signals from the accelerometers and transducers were transmitted to a base station by means of constant bandwidth FM/FM telemetry link for recording on magnetic tape and for display on a real-time strip chart. Provision was made for the transmission of calibration signals before and after the test, and an accurate time reference signal was simultaneously recorded with the data. Pressure-sensitive contact switches on the bumper were actuated just prior to impact by wooden dowels to indicate the elapsed time over a known distance to provide a measurement of impact velocity. The initial contact also produced an "event" mark on the data record to establish the exact instant of contact with the mailbox support system.

The multiplex of data channels, transmitted on one radio frequency, was received at a data acquisition station, and demultiplexed into separate tracks of Intermediate Range Instrumentation Group (I.R.I.G.) tape recorders. After the test, the data were played back from the tape machines, filtered with a SAE J211 Class 180 filter, and digitized using a microcomputer, for analysis and evaluation of impact performance. The digitized data were then processed using two computer programs: DIGITIZE and PLOTANGLE. Brief descriptions of the functions of these two computer programs are given below.

The DIGITIZE program uses digitized data from vehicle-mounted linear accelerometers to compute occupant-compartment impact velocities, time of occupant-compartment impact after vehicle impact, and the highest 0.010-s average ridedown acceleration. The DIGITIZE program also calculates a vehicle impact velocity and the change in vehicle velocity at the end of a given impulse period. In addition, maximum average accelerations over 0.050-s intervals in each of the three directions are computed. Acceleration versus time curves for the longitudinal, lateral, and vertical directions are then plotted from the digitized data of the vehicle-mounted linear accelerometers using a commercially available software package.

The PLOTANGLE program uses the digitized data from the yaw, pitch, and roll rate charts to compute angular displacement in degrees at 0.00067-s intervals and then instructs a plotter to draw a reproducible plot of yaw, pitch, and roll versus time. It should be noted that
these angular displacements are sequence dependent, with the sequence being yaw-pitch-roll for the data presented herein. These displacements are in reference to the vehicle-fixed coordinate system, with the initial position and orientation of the vehicle-fixed coordinate system being that which existed at initial impact.

2.3.2 Anthropomorphic Dummy Instrumentation

An Alderson Research Laboratories Hybrid II, 50th-percentile male anthropomorphic dummy, restrained with lap and shoulder belts, was placed in the driver’s position of the vehicle. The dummy was uninstrumented; however, a high-speed onboard camera recorded the motions of the dummy during the test.

2.3.3 Photographic Instrumentation and Data Processing

Photographic coverage of each test included two high-speed cameras: one perpendicular and one placed at 45 degrees to the vehicle direction of travel. A flashbulb activated by pressure-sensitive tape switches was positioned on the impacting vehicle to indicate the instant of contact with the mailbox support system and was visible from each camera. The films from these high-speed cameras were analyzed on a computer-linked Motion Analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement, and angular data. A 16-mm movie cine and a professional videocamera and 19-mm (3/4-in) video recorder along with still cameras were used for documentary purposes and to record conditions of the test vehicle and the mailbox support system before and after the test. The high-speed and 16-mm documentary films were transferred to 19-mm (3/4-in) videotape and a composite videotape of the crash tests was prepared.

2.3.4 Test Vehicle Propulsion and Guidance

The test vehicles were towed into the mailbox support system using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicles was stretched along the impact path, anchored at each end, and threaded through an attachment to the front wheel of the test vehicle. Another steel cable was connected to the test vehicles, passed around a pulley near the impact point, through a pulley on the tow vehicle, and then anchored to the ground such that the tow vehicle moved away from the test site. A 1 to 1 speed ratio between the test and tow vehicle was used for the low-speed test and a 2 to 1 speed ratio was used for the high-speed tests. Just prior to impact with the mailbox support system, the test vehicle was released to be free-wheeling and unrestrained. The vehicle remained free-wheeling (i.e., no steering or braking inputs) until the vehicle cleared the immediate area of the test site, at which time brakes on the vehicle were activated to bring the vehicle to a safe and controlled stop.
III. RESULTS OF CRASH TESTS

As mentioned previously, the following four crash tests were conducted to evaluate the performance of this Minnesota swing-away mailbox support design:

1. Test no. 471470-11 (NCHRP Report 350 test designation 3-60). An 820-kg (1808-lb) passenger car impacting the vertical mailbox support head-on at a nominal speed of 35 km/h (21.7 mi/h) and zero (0) degree. The mailbox support was aligned with the right front quarter point of the vehicle.

2. Test no. 471470-12 (NCHRP Report 350 test designation 3-61). An 820-kg (1808-lb) passenger car impacting the mailbox support head-on at a nominal speed of 100 km/h (62.2 mi/h) and zero (0) degree. The mailbox support was aligned with the right front quarter point of the vehicle.

3. Test no. 471470-13. An 820-kg (1808-lb) passenger car impacting a single mailbox assembly head-on at a nominal speed of 100 km/h (62.2 mi/h) and zero (0) degree. The centerline of the mailbox assembly was aligned with the centerline of the vehicle.

4. Test no. 471470-14. This test was identical to test no. 471470-13 except for the mailbox assembly. The mailbox assembly in this test had three mailboxes instead of a single mailbox. The test conditions again were for an 820-kg (1808-lb) passenger car impacting the triple mailbox assembly head-on at a nominal speed of 100 km/h (62.2 mi/h) and zero (0) degree with the centerline of the mailbox assembly aligned with the centerline of the vehicle.

Results of these crash tests are summarized in the following sections.

3.1 TEST NO. 471470-11

The first crash test (test no. 471470-11) corresponded to NCHRP Report 350 test designation 3-60. It consisted of an 820-kg (1808-lb) passenger car impacting the vertical mailbox support head-on at the nominal speed of 35 km/h (21.7 mi/h) and zero (0) degree. The mailbox support was aligned with the right front quarter point of the vehicle. Photographs of the mailbox test installation and details of the mounting bracket and post attachment are shown in figures 2 and 3, respectively.

A 1986 Yugo GV, shown in figures 4 and 5, was used for the crash test. Test inertia weight of the vehicle was 820 kg (1808 lb) and its gross static weight was 895 kg (1971 lb). The height to the lower edge of the vehicle bumper was 0.34 m (13.4 in) and it was 0.47 m (18.3 in) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in figure 6. The vehicle was directed into the Minnesota swing-away
Figure 2. Minnesota swing-away mailbox installation before test 7147-11.
Figure 3. Mounting bracket and post attachment before test 7147-11.
Figure 4. Vehicle/mailbox geometrics for test 7147-11.
Figure 5. Vehicle prior to test 7147-11.
Figure 6. Vehicle properties for tests 7147-11, 12, and 13.
mailbox test installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

3.1.1 Test Description

The vehicle impacted the mailbox support at a speed of 35.1 km/h (21.8 mi/h). Upon impact, the vertical support and the U-channel base post began to lean forward and, at approximately 0.022 s after impact, the cantilever arm and mailbox assembly began to rotate toward the vehicle. By 0.148 s, the cantilever arm and mailbox assembly had rotated 90 degrees. The cantilever arm separated from the vertical support at 0.179 s. The vehicle lost contact with the cantilever arm and mailbox assembly at 0.230 s, traveling at a speed of 25.9 km/h (16.1 mi/h). However, the vertical support remained in contact with the undercarriage of the vehicle until approximately 0.634 s, at which time the vehicle had slowed to a speed of 24.8 km/h (15.4 mi/h). Brakes on the vehicle were applied at 3.8 s after impact and the vehicle subsequently came to rest approximately 24 m (80 ft) downstream from the point of impact. Sequential photographs of the test sequence are presented in figure 7.

3.1.2 Damage to Test Installation

The cantilever arm and mailbox assembly came to rest approximately 17 m (55 ft) downstream and 5 m (15 ft) to the right of the impact point, as shown in figure 8. The cantilever arm was only scraped and the mailbox assembly was deformed, as shown in figure 9. The vertical support was scraped and the U-channel base post was bent and pushed back 180 mm (7 in) at ground level, as shown in figure 10.

3.1.3 Vehicle Damage

The vehicle (shown in figure 11) sustained minimal damage. There was 80-mm (3.2-in) permanent deformation to the bumper where contact with the vertical support and U-channel base post occurred. There were dents in the oil pan and gas tank and scrape marks along the floor pan on the right side caused by contact with the vertical support of the mailbox test installation.

3.1.4 Occupant Risk Values

Data from the electronic instrumentation were digitized for evaluation, and occupant risk factors were computed as follows. In the longitudinal direction, occupant impact velocity was 1.9 m/s (6.1 ft/s) at 0.411 s; the highest 0.010-s average ridedown acceleration was 0.9 g’s from 0.470 to 0.480 s; and the 0.050-s average acceleration was -1.6 g’s between 0.008 and 0.058 s. No occupant contact occurred in the lateral direction. The maximum 0.050-s average acceleration in the lateral direction was 0.4 g’s between 0.409 and 0.459 s. The change in vehicle velocity at loss of contact was 9.2 km/h (5.7 mi/h) and the change in momentum was 2086 N-s (469 lb-s).
Figure 7. Sequential photographs for test 7147-11 (perpendicular and side views).
Figure 7. Sequential photographs for test 7147-11 (perpendicular and side views) (continued).
Figure 8. Test site after test 7147-11.
Figure 9. Mailbox and upper support arm after test 7147-11.
Figure 10. Support post and lower support arm after test 7147-11.
Figure 11. Vehicle after test 7147-11.
A summary of pertinent data from the electronic instrumentation, high-speed film and field measurements is given in figure 12. Vehicle angular displacements are displayed in figure 13, and vehicular accelerations versus time traces filtered at Class 180 are presented in figures 14 through 16.

In summary, the mailbox installation yielded to the impacting vehicle through bending of the U-channel base post. The cantilever arm and mailbox assembly rotated upward and toward the vehicle upon impact and subsequently separated from the vertical support as designed. The detached cantilever arm and mailbox assembly were thrown forward of the vehicle and did not impact the vehicle. The vehicle sustained very minor damage to the front bumper. There was contact between the vertical support and the undercarriage of the vehicle, but the resulting damage to the vehicle was minor and did not pose a hazard. Also, the vehicle remained stable throughout the collision without exhibiting any tendency of rollover or instability. Neither the vehicle nor detached elements from the mailbox installation presented any undue hazard to adjacent traffic after the impact. The occupant impact velocities and ride-down accelerations were well below the current recommended limits of 4.6 m/s (15 ft/s) and 20 g's, respectively.

3.2 TEST NO. 471470-12

The second crash test (test no. 471470-12) corresponded to NCHRP Report 350 test designation 3-61. It consisted of an 820-kg (1808-lb) passenger car impacting the vertical mailbox support head-on at the nominal speed of 100 km/h (62.2 mi/h) and zero (0) degree. The mailbox support was aligned with the right front quarter point of the vehicle. Photographs of the mailbox test installation and details of the mounting bracket and post attachment are shown in figures 17 and 18.

The 1986 Yugo GV used in the first test (test 471470-11) was repaired and used for this crash test. The test inertia weight, the gross static weight, and dimensions of the vehicle remained unchanged from the first test. Photographs of the test vehicle prior to the test are shown as figures 19 and 20. The vehicle was directed into the Minnesota swing-away mailbox test installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

3.2.1 Test Description

The vehicle impacted the mailbox vertical support at a speed of 104.9 km/h (65.2 mi/h). Upon impact, the vertical support and the U-channel base post began to lean forward and, at approximately 0.015 s after impact, the cantilever arm and mailbox assembly began to rotate toward the vehicle. At this time, the mailbox also began to separate from the wood board that was attached to the cantilever arm. The mailbox became completely detached from the wood board at 0.041 s. By 0.042 s, the mailbox contacted the A-pillar on the driver's side of the vehicle. The mailbox lost contact with the vehicle at 0.075 s while the vehicle was traveling at 98.0 km/h (60.9 mi/h). The vertical support and U-channel base post...
### Summary of results for test 7147-11

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test No.</td>
<td>7147-11</td>
</tr>
<tr>
<td>Date</td>
<td>02/02/93</td>
</tr>
<tr>
<td>Test Installation</td>
<td>Minnesota</td>
</tr>
<tr>
<td>Mounting Height</td>
<td>1016 mm (40 in)</td>
</tr>
<tr>
<td>Installation Depth</td>
<td>1575 mm (62 in)</td>
</tr>
<tr>
<td>Soil Type</td>
<td>Strong Soil (S-1)</td>
</tr>
<tr>
<td>Test Vehicle</td>
<td>1986 Yugo GV</td>
</tr>
<tr>
<td>Vehicle Weight</td>
<td>820 kg (1806 lb)</td>
</tr>
<tr>
<td>Gross Static</td>
<td>895 kg (1971 lb)</td>
</tr>
<tr>
<td>Vehicle Damage Classification</td>
<td>TAD 12FR1</td>
</tr>
<tr>
<td>CDC</td>
<td>12FREN1</td>
</tr>
<tr>
<td>Maximum Vehicle Crush</td>
<td>80 mm (3.2 in)</td>
</tr>
<tr>
<td>Impact Speed</td>
<td>35.1 km/h (21.8 mi/h)</td>
</tr>
<tr>
<td>Impact Angle</td>
<td>0 deg-381 mm (15 in) Offset</td>
</tr>
<tr>
<td>Exit Speed</td>
<td>25.9 km/h (16.1 mi/h)</td>
</tr>
<tr>
<td>Change in Velocity</td>
<td>9.2 km/h (5.7 mi/h)</td>
</tr>
<tr>
<td>Change in Momentum</td>
<td>2086 N-s (469 lb-s)</td>
</tr>
<tr>
<td>Vehicle Accelerations</td>
<td>(Max. 0.050-s avg)</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>-1.6 g's</td>
</tr>
<tr>
<td>Lateral</td>
<td>0.4 g's</td>
</tr>
<tr>
<td>Occupant Impact Velocity</td>
<td>1.9 m/s (6.1 ft/s)</td>
</tr>
<tr>
<td>Lateral</td>
<td>No Contact</td>
</tr>
<tr>
<td>Occupant Ridedown Accelerations</td>
<td>Longitudinal 0.9 g's</td>
</tr>
<tr>
<td></td>
<td>Lateral N/A</td>
</tr>
</tbody>
</table>

**Figure 12.** Summary of results for test 7147-11.
Figure 13. Vehicle angular displacement for test 7147-11.
TEST 7147-11
Accelerometer at center of gravity

Figure 14. Vehicle longitudinal accelerometer trace for test 7147-11.
Figure 15. Vehicle lateral accelerometer trace for test 7147-11.
TEST 7147-11
Accelerometer at center of gravity

Test Article: Minnesota Mailbox
Test Vehicle: 1986 Yugo GV
Test Inertia Weight: 1,800 lb
Gross Static Weight: 1,971 lb
Test Speed: 21.8 mi/h
Test Angle: 0 deg - 15 in offset

Figure 16. Vehicle vertical accelerometer trace for test 7147-11.
Figure 17. Minnesota swing-away mailbox installation before test 7147-12.
Figure 18. Mounting bracket and post attachment before test 7147-12.
Figure 19. Vehicle/mailbox geometrics for test 7147-12.
Figure 20. Vehicle prior to test 7147-12.
remained in contact with the undercarriage of the vehicle until approximately 0.146 s, at which time the vehicle had slowed to a speed of 97.3 km/h (60.5 mi/h). Brakes on the vehicle were applied at 1.2 s after impact and the vehicle subsequently came to rest 134 m (441 ft) downstream from the point of impact. Sequential photographs of the test sequence are presented in figure 21.

3.2.2 Damage to Test Installation

The mailbox installation separated into several pieces, as shown in figures 22 through 24. The plastic newspaper tube landed 15 m (48 ft) downstream and 8 m (25 ft) to the left of the point of impact. The deformed mailbox landed 18 m (60 ft) downstream and 5 m (18 ft) to the left of point of impact. The cantilever arm and wood board were found 22 m (72 ft) downstream and 12 m (38 ft) to the left of the point of impact. The vertical support arm was only scraped and the U-channel base post was bent and pushed back 150 mm (6 in) at ground level.

3.2.3 Vehicle Damage

The vehicle sustained minimal damage, as shown in figures 25 through 27. There was 120-mm (4.7-in) permanent deformation to the bumper where contact with the vertical support and the U-channel base post occurred. The A-pillar on the driver’s side was deformed from impact by the mailbox and the windshield was cracked around the point of impact. The door post on the driver side was bent and the glass broken out. There was also damage to the hood and grill and the right rear tire and rim. There was a dent in the gas tank, and scrape marks and a dent along the floor pan on the right side of the undercarriage caused by contact with the vertical support.

3.2.4 Occupant Risk Values

Data from the electronic instrumentation were digitized for evaluation, and occupant risk factors were computed as follows. In the longitudinal direction, occupant impact velocity was 1.3 m/s (4.3 ft/s) at 0.548 s; the highest 0.010-s average ridedown acceleration was -2.7g’s from 0.975 to 0.985 s; and the 0.050-s average acceleration was -1.9 g’s between 0.005 and 0.055 s. In the lateral direction, occupant impact velocity was 1.4 m/s (4.5 ft/s) at 0.532 s; the highest 0.010-s average ridedown acceleration was 4.6 g’s from 0.976 to 0.986 s; and the maximum 0.050-s average acceleration was 1.0 g’s between 0.095 and 0.145 s. The change in vehicle velocity at loss of contact was 6.9 km/h (4.3 mi/h) and the change in momentum was 1573 N-s (354 lb-s).

A summary of pertinent data from the electronic instrumentation, high-speed film, and field measurements is given in figure 28. Vehicle angular displacements are displayed in figure 29, and vehicular accelerations versus time traces filtered at Class 180 are presented in figures 30 through 32.
Figure 21. Sequential photographs for test 7147-12 (perpendicular and side views).
Figure 21. Sequential photographs for test 7147-12 (perpendicular and side views) (continued).
Figure 22. Mailbox and tube after test 7147-12.
Figure 23. Mounting base and upper support arm after test 7147-12.
Figure 24. Support post and lower support arm after test 7147-12.
Figure 25. Vehicle after test 7147-12.
Figure 26. Vehicle A-pillar and side window after test 7147-12.
Figure 27. Undercarriage and rear tire after test 7147-12.
Figure 28. Summary of results for test 7147-12.
Axes are vehicle fixed. Sequence for determining orientation is:
1. Yaw
2. Pitch
3. Roll

Figure 29. Vehicle angular displacement for test 7147-12.
Figure 30. Vehicle longitudinal accelerometer trace for test 7147-12.
TEST 7147-12
Accelerometer at center of gravity

Test Article: Minnesota Mailbox
Test Vehicle: 1986 Yugo GV
Test Inertia Weight: 1,800 lb
Gross Static Weight: 1,971 lb
Test Speed: 65.2 mph
Test Angle: 0 deg - 15 in offset

Figure 31. Vehicle lateral accelerometer trace for test 7147-12.
TEST 7147-12
Accelerometer at center of gravity

![Graph showing vertical acceleration over time for Test 7147-12.]

Test Article: Minnesota Mailbox
Test Vehicle: 1986 Yugo GV
Test Inertia Weight: 1,800 lb
Gross Static Weight: 1,971 lb
Test Speed: 65.2 mi/h
Test Angle: 0 deg - 15 in offset

---

Figure 32. Vehicle vertical accelerometer trace for test 7147-12.
In summary, the mailbox installation yielded to the impacting vehicle through bending of the U-channel base post. The cantilever arm and mailbox assembly separated from the vertical support shortly after impact. The mailbox assembly impacted the driver-side A-pillar, resulting in some slight deformation to the A-pillar and the door post, cracking of the windshield, and breaking of the glass on the driver's side door. However, there was no intrusion into the occupant compartment. The vehicle also sustained minor damage to the front and undercarriage. The vehicle remained stable throughout the collision without exhibiting any tendency of rollover or instability. Neither the vehicle nor detached elements from the mailbox installation presented any undue hazard to adjacent traffic after the impact. The occupant impact velocities and ridedown accelerations were well below the current recommended limits of 4.6 m/s (15 ft/s) and 20 g's, respectively.

3.3 TEST NO. 471470-13

The third test (test no. 471470-13) involved an 820-kg (1808-lb) passenger car impacting a single mailbox assembly head-on at a nominal speed of 100 km/h (62.2 mi/h) and zero (0) degree. The centerline of the mailbox assembly was aligned with the centerline of the vehicle. A photograph of the test installation is shown in figure 33.

The 1986 Yugo GV used in the first two tests (shown in figures 34 and 35) was repaired and used for the third crash test. The test inertia weight, the gross static weight, and dimensions of the vehicle remained unchanged from the first two tests. The vehicle was directed into the Minnesota swing-away mailbox test installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

3.3.1 Test Description

The vehicle impacted the mailbox assembly at a speed of 103 km/h (64.0 mi/h). Upon impact, the mailbox shattered the windshield. At approximately 0.007 s after impact, the cantilever arm contacted the A-pillar on the passenger's side of the vehicle and the mailbox assembly started to rotate away from the windshield. At 0.034 s after impact, the cantilever arm and mailbox assembly separated from the vertical support. The mailbox assembly and the cantilever arm then went up and over the vehicle. Loss of contact between the mailbox assembly and vehicle occurred at 0.061 s as the vehicle was traveling at 99.6 km/h (61.9 mi/h). The windshield, which was held in place by a rubber grommet, separated from the vehicle at approximately 0.044 s after initial impact. The detached windshield first went outward and upward, reaching its maximum outward displacement at 0.208 s after initial impact. The detached windshield contacted the roof of the vehicle at approximately 0.375 s and was partially on the roof of the vehicle before eventually sliding back inside the occupant compartment at 1.208 s. The brakes on the vehicle were applied at 0.640 s after impact and the vehicle subsequently came to rest 100 m (327 ft) downstream from the point of impact. Sequential photographs of the test sequence are presented in figure 36.
Figure 33. Minnesota swing-away mailbox installation before test 7147-13.
Figure 34. Vehicle/mailbox geometrics for test 7147-13.
Figure 35. Vehicle prior to test 7147-13.
Figure 36. Sequential photographs for test 7147-13 (perpendicular and side views).
Figure 36. Sequential photographs for test 7147-13 (perpendicular and side views) (continued).

0.049 s

0.073 s

0.097 s

0.121 s
3.3.2 Damage to Test Installation

The mailbox installation separated into several pieces, as shown in figures 37 through 39. The cantilever arm and part of the wood board landed 54 m (177 ft) downstream and 1.4 m (4.5 ft) to the right of the point of impact. The severely deformed mailbox, part of the wood board, and plastic newspaper tube came to rest 55 m (182 ft) downstream and 0.3 m (1 ft) to the left of the point of impact. The vertical support was only scraped and the U-channel base post was not damaged or pushed back.

3.3.3 Vehicle Damage

The vehicle (shown in figures 40 and 41) sustained moderate damage. There was 30-mm (1.2-in) permanent deformation to the A-pillar on the passenger’s side of the vehicle and the door post on the passenger’s side was deformed at the location where the cantilever arm made contact. The windshield was broken out and lying on the floorboard of the vehicle. However, it should be noted that the windshield actually went outward and upward after separation from the vehicle and was partially on the roof of the vehicle before falling back into the occupant compartment. There was also a scratch located on the left rear section of the roof from contact by the detached cantilever arm as it went over the vehicle.

3.3.4 Occupant Risk Values

Data from the electronic instrumentation were digitized for evaluation, and occupant risk factors were computed as follows. There was no occupant contact in the longitudinal direction. The longitudinal 0.050-s average acceleration was -1.0 g’s between 0.096 and 0.146 s. In the lateral direction, occupant impact velocity was 1.2 m/s (3.9 ft/s) at 0.535 s; the highest 0.010-s average ridedown acceleration was 1.0 g’s from 0.951 to 0.961 s; and the maximum 0.050-s average acceleration was 0.5 g’s between 0.049 and 0.099 s. The change in vehicle velocity at loss of contact was 3.4 km/h (2.1 mi/h) and the change in momentum was 768 N-s (172 lb-s).

A summary of pertinent data from the electronic instrumentation, high-speed film, and field measurements is given in figure 42. Vehicle angular displacements are displayed in figure 43, and vehicular accelerations versus time traces filtered at Class 180 are presented in figures 44 through 46.

In summary, the mailbox assembly directly contacted the windshield of the impacting vehicle, resulting in a shattered and cracked windshield. The windshield, which was held in place only by a rubber grommet, separated from the vehicle shortly after impact. However, the windshield did manage to keep the mailbox assembly from intruding or penetrating into the occupant compartment. The cantilever arm impacted the A-pillar on the passenger side and caused the mailbox assembly to rotate away from the windshield, thus further reducing the potential for the mailbox assembly to intrude or penetrate into the occupant compartment. The cantilever arm and mailbox assembly subsequently separated from the vertical support and went up and over the vehicle. The vehicle remained stable throughout the collision.
Figure 37. Test site after test 7147-13,
Figure 38. Mailbox and tube after test 7147-13.
Figure 39. Post and support arms after test 7147-13.
Figure 40. Vehicle after test 7147-13.
Figure 41. Vehicle interior after test 7147-13.
Vehicle came to rest 327 ft down from point of impact.

Test No. .................. 7147-13
Date ...................... 02/03/93
Test Installation ........ Minnesota
Swing-Away Mailbox
Mounting Height ........ 1016 mm (40 in)
Installation Depth ....... 1575 mm (62 in) Driven
Soil Type .................. Strong Soil (S-1)
Test Vehicle ............... 1986 Yugo GV
Impact Speed .............. 103.0 km/h (64.0 mi/h)
Impact Angle .............. 0 deg-Offset to Impact Box
Exit Speed ................ 99.6 km/h (61.9 mi/h)
Change in Velocity ....... 3.4 km/h (2.1 mi/h)
Change in Momentum ...... 768 N-s (172 lb-s)
Vehicle Accelerations
(Longitudinal (Max. 0.050-s avg) -1.0 g's
Lateral 0.5 g's
Occupant Impact Velocity
(Longitudinal No Contact
Lateral 1.2 m/s (3.9 ft/s)
Occupant Ridedown Accelerations
(Longitudinal N/A
Lateral 1.0 g's
Figure 42. Summary of results for test 7147-13.
Figure 43. Vehicle angular displacement for test 7147-13.

Axes are vehicle fixed.
Sequence for determining orientation is:
1. Yaw
2. Pitch
3. Roll
Figure 44. Vehicle longitudinal accelerometer trace for test 7147-13.
Figure 43 Vehicle lateral accelerometer trace for test 7147-13.
TEST 7147-13
Accelerometer at center of gravity

Test Article: Minnesota Mailbox
Test Vehicle: 1986 Yugo GV
Test Inertia Weight: 1,800 lb
Gross Static Weight: 1,971 lb
Test Speed: 64.0 mi/h
Test Angle: 0 deg - mailbox

Figure 46. Vehicle vertical accelerometer trace for test 7147-13.
without exhibiting any tendency of rollover or instability. Neither the vehicle nor detached elements from the mailbox installation presented any undue hazard to adjacent traffic after the impact. The occupant impact velocities and ridedown accelerations were well below the current recommended limits of 4.6 m/s (15 ft/s) and 20 g's, respectively.

3.4 TEST NO. 471470-14

The fourth test (test no. 471470-14) involved an 820-kg (1808-lb) passenger car impacting a triple mailbox assembly head-on at a nominal speed of 100 km/h (62.2 mi/h) and zero (0) degree. The centerline of the mailbox assembly was aligned with the centerline of the vehicle. Photographs of the test installation and the mounting attachments are shown in figures 47 and 48.

A 1989 Yugo GVL, shown in figures 49 and 50, was used for this crash test. Test inertia weight of the vehicle was 820 kg (1806 lb) and its gross static weight was 895 kg (1971 lb). The height to the lower edge of the vehicle bumper was 0.35 m (13.8 in) and it was 0.49 m (19.1 in) to the upper edge of the bumper. Additional dimensions and information on the vehicle are given in figure 51. The vehicle was directed into the Minnesota swing-away mailbox installation using the cable reverse tow and guidance system, and was released to be free-wheeling and unrestrained just prior to impact.

3.4.1 Test Description

The vehicle impacted the triple mailbox assemblies at a speed of 101.0 km/h (62.8 mi/h). Upon impact, the mailbox assemblies shattered the windshield and, at approximately 0.010 s after impact, the first mailbox assembly bounced up and contacted the edge of the roof just above the windshield. By 0.015 s after impact, the cantilever arm contacted the A-pillar on the passenger’s side of the vehicle. The cantilever arm and mailbox assemblies separated from the vertical support at 0.041 s after impact. The cantilever arm and mailbox assemblies intruded into the occupant compartment of the vehicle and rode along partially in the compartment and partially on the hood of the vehicle. Brakes on the vehicle were applied at 1.04 s after impact and the vehicle subsequently came to rest 121 m (397 ft) downstream from the point of impact. Sequential photographs of the test sequence are presented in figure 52.

3.4.2 Damage to Test Installation

Photographs of the test site and components of the mailbox test installation after the test are shown in figures 53 through 55. The mailbox assemblies were deformed but remained attached to the cantilever arm, and remained with the vehicle through final rest. The vertical support was only scraped and the U-channel base post was bent slightly.
Figure 47. Minnesota swing-away mailbox installation before test 7147-14.
Figure 48. Mounting attachment before test 7147-14.
Figure 49. Vehicle/mailbox geometrics for test 7147-14.
Figure 50. Vehicle prior to test 7147-14.
DATE: 2-3-93  TEST NO.: 471470-14  VIN NO.: VX1BB122KK439587
YEAR: 1989  MAKE: Yugo  MODEL: CVL
TIRE INFLATION PRESSURE:  ODOMETER: 22973  TIRE SIZE: 155 R13

MASS DISTRIBUTION (kg)  LF 242  RF 278  LR 170  RR 130

DESCRIBE ANY DAMAGE TO VEHICLE PRIOR TO TEST:

ACCELEROMETERS

ENGINE TYPE: 4 cyl, gas
ENGINE CID: 1.1 l
TRANSMISSION TYPE:
X AUTO

OPTIONAL EQUIPMENT:

DUMMY DATA:
TYPE: 50th male
MASS: 75 kg
SEAT POSITION: Driver’s

GEOMETRY - (mm)

A 1481  E 630  J 760  N 1316  R 376
B 691  F 3485  K 485  O 589  T 770
C 2164  G 833  L 61  P 166  U 805
D 1400  H 351  M 185  Q 3485  S 159

MASS - (kg)  CURB  TEST INERTIAL  GROSS STATIC
M1 543 282  825  520 300 820 556 339 805

Figure 51. Vehicle properties for test 7147-14.
Figure 52. Sequential photographs for test 7147-14 (perpendicular and side views).
Figure 52. Sequential photographs for test 7147-14 (perpendicular and side views) (continued).
Figure 53. Test site after test 7147-14.
Figure 54. Mailbox and tube after test 7147-14.
Figure 55. Post and lower support arm after test 7147-14.
3.4.3 Vehicle Damage

The vehicle sustained moderate damage around the windshield area and in the occupant compartment, as shown in figures 56 and 57. The mailbox assemblies intruded into the occupant compartment through the windshield and remained partially in the compartment throughout the test period. The roof of the vehicle was deformed upward from the inside of the vehicle approximately 50 mm (2 in). The passenger's side door was pushed out 40 mm (1.6 in) and the glass was shattered. The A-pillar and door post on the passenger's side were also deformed. The windshield was inside the vehicle.

3.4.4 Occupant Risk Values

Data from the electronic instrumentation were digitized for evaluation, and occupant risk factors were computed as follows. In the longitudinal direction, occupant impact velocity was 0.9 m/s (2.8 ft/s) at 0.874 s; the highest 0.010-s average ridedown acceleration was -0.3 g's from 0.901 to 0.911 s; and the 0.050-s average acceleration was -1.3 g's between 0.009 and 0.059 s. There was no occupant contact in the lateral direction, and the maximum 0.050-s average acceleration was -0.3 g's between 0.028 and 0.078 s. Change in velocity at loss of contact was not applicable since the mailbox assemblies and the cantilever arm remained in contact with the vehicle throughout the test period. For information purposes, the velocity change for the vehicle at 1.0 s after impact was 3.2 km/h (2.0 mi/h).

A summary of pertinent data from the electronic instrumentation, high-speed film, and field measurements is given in figure 58. Vehicle angular displacements are displayed in figure 59, and vehicular accelerations versus time traces filtered at Class 180 are presented in figures 60 through 62.

In summary, the triple mailbox assemblies directly contacted the windshield of the impacting vehicle. The windshield was shattered and pushed back into the occupant compartment and the mailbox assemblies intruded substantially into the occupant compartment. The cantilever arm impacted the A-pillar on the passenger side, resulting in minor deformation to the A-pillar and door post and breaking of the glass on the passenger side door. The cantilever arm and mailbox assembly subsequently separated from the vertical support and stayed with the vehicle throughout the post-impact trajectory and final rest. The vehicle remained stable throughout the collision without exhibiting any tendency of rollover or instability. Neither the vehicle nor detached elements from the mailbox installation presented any undue hazard to adjacent traffic after the impact. The occupant impact velocities and ridedown accelerations were well below the current recommended limits of 4.6 m/s (15 ft/s) and 20 g's, respectively.
Figure 56. Vehicle after test 7147-14.
Figure 57. Vehicle interior after test 7147-14.
<table>
<thead>
<tr>
<th>Test No.</th>
<th>7147-14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>02/03/93</td>
</tr>
<tr>
<td>Test Installation</td>
<td>Minnesota</td>
</tr>
<tr>
<td>Mounting Height</td>
<td>1016 mm (40 in)</td>
</tr>
<tr>
<td>Installation Depth</td>
<td>1575 mm (62 in) Driven</td>
</tr>
<tr>
<td>Soil Type</td>
<td>Strong Soil (S-1)</td>
</tr>
<tr>
<td>Test Vehicle</td>
<td>1989 Yugo GV</td>
</tr>
<tr>
<td>Vehicle Weight</td>
<td>820 kg (1806 lb)</td>
</tr>
<tr>
<td>Test Inertia</td>
<td>895 kg (1971 lb)</td>
</tr>
<tr>
<td>Vehicle Damage Classification</td>
<td>None Applicable</td>
</tr>
<tr>
<td>TAD</td>
<td>12FRGN7</td>
</tr>
<tr>
<td>Maximum Vehicle Crush</td>
<td>Penetrated Windshield</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact Speed</th>
<th>101.0 km/h (62.8 mi/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact Angle</td>
<td>0 deg-Offset to Impact Box</td>
</tr>
<tr>
<td>Exit Speed</td>
<td>Remained In and On Vehicle</td>
</tr>
<tr>
<td>Change in Velocity</td>
<td>N/A</td>
</tr>
<tr>
<td>Change in Momentum</td>
<td>N/A</td>
</tr>
<tr>
<td>Vehicle Accelerations</td>
<td>(Max. 0.050-s avg)</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>-1.3 g's</td>
</tr>
<tr>
<td>Lateral</td>
<td>-0.3 g's</td>
</tr>
<tr>
<td>Occupant Impact Velocity</td>
<td>0.9 m/s (2.8 ft/s)</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>No Contact</td>
</tr>
<tr>
<td>Lateral</td>
<td>No Contact</td>
</tr>
<tr>
<td>Occupant Ridedown Accelerations</td>
<td>-0.3 g's</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>N/A</td>
</tr>
<tr>
<td>Lateral</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Figure 58. Summary of results for test 7147-14.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 59. Vehicle angular displacement for test 7147-14.
TEST 7147-14
Accelerometer at center of gravity

---

Test Article: Minnesota Mailbox
Test Vehicle: 1989 Yugo GVL
Test Inertia Weight: 1,800 lb
Gross Static Weight: 1,971 lb
Test Speed: 62.8 mi/h
Test Angle: 0 deg - 3 mailboxes

Figure 60. Vehicle longitudinal accelerometer trace for 7147-14.
TEST 7147-14
Accelerometer at center of gravity

Figure 61. Vehicle lateral accelerometer trace for test 7147-14.
TEST 7147-14
Accelerometer at center of gravity

Figure 62. Vehicle vertical accelerometer trace for test 7147-14.
IV. SUMMARY OF FINDINGS AND CONCLUSIONS

4.1 SUMMARY OF FINDINGS

Results of the four full-scale crash tests (test nos. 471470-11 through 471470-14) to evaluate the impact performance of the Minnesota swing-away mailbox support are summarized in tables 1 through 4, respectively. The Minnesota swing-away mailbox support with a single mailbox assembly was judged to have successfully met all evaluation criteria set forth in NCHRP Report 350 and the 1985 AASHTO Standard Specifications for Structural Supports for Highway Signs, Luminaries and Traffic Signals.

The first two crash tests (test nos. 471470-11 and 471470-12) involving impacts with the vertical supports of the mailbox installations with single mailbox assemblies showed occupant impact velocities and ridedown accelerations that were well below the limiting values of 4.57 m/s (15 ft/s) and 20 g’s, respectively. There was no penetration or intrusion into the occupant compartment. Debris from the test installation, which consisted of the cantilever arm and the mailbox assembly, remained close to the approximate path of the vehicle and did not pose any potential hazard to adjacent traffic. The vehicle remained stable during and after the impact sequence.

The third crash test (test no. 471470-13) with the single mailbox assembly directly impacting the windshield resulted in a shattered and cracked windshield, but the windshield managed to keep the mailbox assembly from intruding or penetrating into the occupant compartment. Damage to the windshield is normally not considered a desirable outcome since it could obstruct the driver’s vision or otherwise cause the driver to lose control of the vehicle. However, given the need for a cantilever design because of snowplow operations, damage to the windshield is considered an acceptable tradeoff provided that there is no intrusion or penetration into the occupant compartment.

The fourth crash test (test no. 471470-14) with triple mailbox assemblies was judged to have failed the evaluation criteria set forth in NCHRP Report 350. The mailbox assemblies shattered the windshield and substantially intruded and penetrated into the occupant compartment, which was judged unacceptable. It appeared that two factors contributed to the unsatisfactory performance: (1) the combined weight of the triple mailbox assemblies and the cantilever arm was 19 kg (42 lb), which was more than double the weight of 8.8 kg (19.5 lb) for the single mailbox assembly; and (2) the width of the triple mailbox assemblies allowed the mailbox assemblies to impact and penetrate the windshield prior to the cantilever arm impacting the A-pillar of the vehicle, which would have partially counteracted against the force of the mailbox assemblies into the windshield.
4.2 RECOMMENDATIONS AND DISCUSSION

- The cantilever design allows the mailbox assembly to come into direct contact with the windshield of the vehicle without the front of the vehicle contacting the vertical support. While the crash test results indicate that a single box assembly performed satisfactorily without penetrating the windshield and intruding into the occupant compartment, it did shatter and crack the windshield. It would be desirable to keep the combined weight of the mailbox assembly and the cantilever arm to a minimum.

- Attachments to the cantilever arm and mailbox assembly, such as a plastic newspaper tube or a crushable light-gauge metal rural fire number or address plate, should be of such construction and location that they will not contribute to the potential of fracturing the windshield or intruding into the passenger compartment. The test installation had a plastic newspaper tube attached to the mailbox assembly and its presence did not appear to adversely affect the safety performance of the mailbox assembly and support.

- Another consideration is the size of the mailbox itself. There are three commonly used sizes for mailboxes: 1, 1-A, and 2. The crash tests were conducted with the size 1-A mailbox, which is 0.53 m (21 in) long, 0.25 m (10 in) high, and 0.20 m (8 in) wide and weighs approximately 2.5 kg (5.5 lb). The smaller size 1 mailbox is 0.48 m (19 in) long, 0.23 m (9 in) high, and 0.16 m (6-1/4 in) wide and weighs approximately 1.6 kg (3.5 lb). The larger size 2 mailbox is 0.60 m (23.5 in) long, 0.38 m (15 in) high, and 0.28 m (11 in) wide and weighs approximately 4.5 kg (10 lb). The smaller and lighter size 1 mailbox should work well with the support. However, there are insufficient data at this time to determine how well the larger and heavier size 2 mailbox would work with the support.

- The metal strap and wood board mechanism for attaching the mailbox assembly to the cantilever arm appeared to function satisfactorily in the crash tests. As discussed previously under Section 2.1, “Test Article,” there are two alternative lengths for the metal straps: 127 mm (5 in) or 63.5 mm (2.5 in). The longer metal straps were considered more critical from the safety standpoint and were thus used with the test installations. While the design with the shorter metal straps was not tested, there is reason to believe that it would perform just as well from the standpoint of impact performance. Thus, either length of metal straps may be used for field installation at the discretion of the highway agency provided that two 6.35-mm- (1/4-in-) diameter, 38.1-mm- (1.5-in-) long carriage bolts are used with each strap (a total of four bolts for the two straps) to attach the wood board.

- It should be noted that TTI has recently completed a study for the Texas Department of Transportation (TxDOT) to crash test and evaluate a mailbox support design with an adjustable retaining bracket for mounting the mailbox assembly. The MnDOT has indicated some interest in possibly adapting the new TxDOT adjustable retaining bracket design to the Minnesota swing-away mailbox support design. Based on review
of the crash test results on both mailbox support and retaining systems, it is believed that the Texas adjustable retainer bracket design will work well with the Minnesota swing-away mailbox support design from the impact performance standpoint.

- In light of the unsatisfactory performance of the triple mailbox assemblies, use of the swing-away mailbox support design should be limited to only a single mailbox assembly. In situations where multiple mailboxes are to be installed at the same location, each mailbox assembly should be installed on its own support rather than multiple mailbox assemblies on a single support. Also, it may be desirable to have the mailbox installations spaced far enough apart to separate out the effects of individual impacts. Based on the time between initial impact and separation of the cantilever arm and mailbox assembly from the vertical support, a spacing of roughly 1.07 m (3.5 ft) between installations is suggested. However, it should be noted that this is only a suggestion based on limited information and engineering judgment.

- A question was raised by MnDOT on the potential effect of the length of the cantilever arm or overhang since MnDOT is currently using a shorter cantilever arm of 0.61 m (2 ft) for some older design mailbox supports mounted in concrete bases. Based on review of the crash tests, it appears that the length of the cantilever arm would likely have some effect on the impact performance of the mailbox support. For instance, a shorter cantilever arm may result in the mailbox assembly impacting the windshield in test 471470-12 instead of impacting the A-pillar. On the other hand, a shorter cantilever arm would reduce the potential of a vehicle impacting the mailbox assembly with the windshield without the front of the vehicle first impacting the vertical support. There really is not sufficient information at this time to analyze the potential effects of the cantilever arm length in a more definitive manner.
Table 1. Assessment of results of test 471470-11 (according to NCHRP 350).

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Test Results</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural Adequacy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.</td>
<td>The U-channel base post yielded to the impacting vehicle, allowing the vehicle to traverse over the vertical support and base post.</td>
<td>Pass</td>
</tr>
<tr>
<td><strong>Occupant Risk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td>
<td>The mailbox assembly and cantilever arm separated from the vertical support and base post and were thrown forward of the vehicle. The separated elements did not show potential for penetration of the occupant compartment or hazard to other traffic.</td>
<td>Pass</td>
</tr>
<tr>
<td>F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.</td>
<td>The vehicle remained upright and stable throughout the test sequence.</td>
<td>Pass</td>
</tr>
<tr>
<td><strong>H. Occupant impact velocities should satisfy the following:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Occupant Velocity Limits (m/s)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Component</td>
<td>Preferred</td>
</tr>
<tr>
<td></td>
<td>Longitudinal</td>
<td>3</td>
</tr>
<tr>
<td>I. Occupant ridedown accelerations should satisfy the following:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Occupant Ridedown Acceleration Limits (g's)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Component</td>
<td>Preferred</td>
</tr>
<tr>
<td></td>
<td>Longitudinal and lateral</td>
<td>15</td>
</tr>
<tr>
<td><strong>Vehicle Trajectory</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K. After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.</td>
<td>The vehicle trajectory and final rest position did not indicate any potential of intrusion into adjacent traffic lanes.</td>
<td>Pass</td>
</tr>
<tr>
<td>N. Vehicle trajectory behind the test article is acceptable.</td>
<td>Vehicle maintained a straight path behind the test article and came to rest directly downstream of the point of impact.</td>
<td>Pass</td>
</tr>
</tbody>
</table>
Table 2. Assessment of results of test 471470-12 (according to NCHRP 350).

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Test Results</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural Adequacy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.</td>
<td>The U-channel base post yielded to the impacting vehicle, allowing the vehicle to traverse over the vertical support and base</td>
<td>Pass</td>
</tr>
<tr>
<td><strong>Occupant Risk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td>
<td>The mailbox assembly and cantilever arm separated from the vertical support and base post. The mailbox assembly impacted the driver side A-pillar, resulting in some minor damage to the vehicle. The separated elements did not show potential for intrusion into the occupant compartment and presented minimal hazard to other traffic.</td>
<td>Pass</td>
</tr>
<tr>
<td>F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.</td>
<td>The vehicle remained upright and stable throughout the test sequence.</td>
<td>Pass</td>
</tr>
<tr>
<td>H. Occupant impact velocities should satisfy the following:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupant Velocity Limits (m/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Preferred</td>
<td>Maximum</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>I. Occupant ridedown accelerations should satisfy the following:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupant Ridedown Acceleration Limits (g’s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Preferred</td>
<td>Maximum</td>
</tr>
<tr>
<td>Longitudinal and lateral</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td><strong>Vehicle Trajectory</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K. After collision it is preferable that the vehicle's trajectory not intrude into adjacent traffic lanes.</td>
<td>The vehicle trajectory and final rest position did not indicate any potential of intrusion into adjacent traffic lanes.</td>
<td>Pass</td>
</tr>
<tr>
<td>N. Vehicle trajectory behind the test article is acceptable.</td>
<td>Vehicle maintained a straight path behind the test article and came to rest directly downstream of the point of impact.</td>
<td>Pass</td>
</tr>
</tbody>
</table>
Table 3. Assessment of results of test 471470-13 (according to NCHRP 350).

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Test Results</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural Adequacy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.</td>
<td>The mailbox assembly and cantilevered arm separated readily from the vertical support and base post shortly after impact. The vehicle did not directly impact the vertical support of the mailbox installation</td>
<td>Pass</td>
</tr>
<tr>
<td><strong>Occupant Risk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td>
<td>The mailbox assembly impacted the windshield of the vehicle directly, resulting in a shattered and cracked windshield. However, the windshield managed to keep the mailbox assembly from intruding or penetrating into the occupant compartment. The cantilever arm impacted the A-pillar on the passenger side, resulting in some minor damage to the vehicle. The mailbox assembly and cantilever arm separated from the vertical support and base post and went up and over the vehicle. The separated elements showed minimal potential hazard to other traffic.</td>
<td>Pass - Marginal</td>
</tr>
<tr>
<td>F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.</td>
<td>The vehicle remained upright and stable throughout the test sequence.</td>
<td>Pass</td>
</tr>
<tr>
<td><strong>H. Occupant impact velocities should satisfy the following:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupant Velocity Limits (m/s)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Preferred</td>
<td>Maximum</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td><strong>I. Occupant ridedown accelerations should satisfy the following:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupant Ridedown Acceleration Limits (g's)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Preferred</td>
<td>Maximum</td>
</tr>
<tr>
<td>Longitudinal and lateral</td>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td><strong>Vehicle Trajectory</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After collision it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes.</td>
<td>The vehicle trajectory and final rest position did not indicate any potential of intrusion into adjacent traffic lanes.</td>
<td>Pass</td>
</tr>
<tr>
<td>N. Vehicle trajectory behind the test article is acceptable.</td>
<td>Vehicle maintained a straight path behind the test article and came to rest directly downstream of the point of impact.</td>
<td>Pass</td>
</tr>
</tbody>
</table>
Table 4. Assessment of results of test 471470-14 (according to NCHRP 350).

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Test Results</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural Adequacy</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.</td>
<td>The triple mailbox assemblies and cantilever arm separated readily from the vertical support and base post shortly after impact. The vehicle did not directly impact the vertical support of the mailbox installation.</td>
<td>Pass</td>
</tr>
<tr>
<td><strong>Occupant Risk</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D. Detached elements, fragments or other debris from the test article should not penetrate or show potential for penetrating the occupant compartment, or present an undue hazard to other traffic, pedestrians, or personnel in a work zone. Deformations of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.</td>
<td>The triple mailbox assemblies impacted the windshield of the vehicle directly, shattering the windshield and pushing it back into the occupant compartment. The mailbox assemblies intruded substantially into the occupant compartment. The cantilever arm impacted the A-pillar on the passenger side, resulting in some minor damage to the vehicle. The triple mailbox assemblies and cantilever arm separated from the vertical support and base post and stayed with the vehicle throughout the post-impact trajectory and final rest and did not present any hazard to other traffic.</td>
<td>Fail</td>
</tr>
<tr>
<td>F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.</td>
<td>The vehicle remained upright and stable throughout the test sequence.</td>
<td>Pass</td>
</tr>
<tr>
<td>H. Occupant impact velocities should satisfy the following:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Occupant Velocity Limits (m/s)</td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Preferred</td>
<td>Maximum</td>
</tr>
<tr>
<td>I. Occupant ridedown accelerations should satisfy the following:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Occupant Ridedown Acceleration Limits (g’s)</td>
<td></td>
</tr>
<tr>
<td>Component</td>
<td>Preferred</td>
<td>Maximum</td>
</tr>
<tr>
<td>K. After collision it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes.</td>
<td>The vehicle trajectory and final rest position did not indicate any potential of intrusion into adjacent traffic lanes.</td>
<td>Pass</td>
</tr>
<tr>
<td>N. Vehicle trajectory behind the test article is acceptable.</td>
<td>Vehicle maintained a straight path behind the test article and came to rest directly downstream of the point of impact.</td>
<td>Pass</td>
</tr>
</tbody>
</table>
REFERENCES

