Neighborhood Delivery and Collection Box Units (NDCBU) and Cluster Box Units (CBU) present a special challenge to the highway engineer due to their large physical size, mass, and tall mounting height. Efforts expended in the past by TTI researchers and others have demonstrated the hazards of mounting various types of mailbox installations within the clear zone. In addition, TTI and the Texas Department of Transportation, having performed full-scale crash tests, concluded that the rigid mounting of CBU's using 13 mm (0.5 in) studs or bolts into a concrete footing was unacceptable for installation in the clear zone of high-speed roadways. To this end, TTI concluded from the study that impact performance of CBU type installations could be improved by the inclusion of a breakaway feature(s) such as a slip-base, breakaway welds at the post to base connection, a weakened support, or a combination of these. In addition, even with a frangible or slip connection, the CBU mounted at windshield height presents an additional hazard that must be addressed.

The United States Postal Service (USPS), recognizing that a potential hazard to the errant motorist may exist where CBU's are installed, contracted with Texas Transportation Institute (TTI) to: (1) evaluate the potential crash performance of pedestal mounted Neighborhood Delivery and Collection Box Units (NDCBU) and Cluster Box Units (CBU) currently being used in the field, (2) design a prototype retrofit breakaway mount for these units, and (3) provide initial laboratory testing of the new frangible mounting system. The end objective of the study was to investigate the development of a frangible retrofit system for mounting existing and new CBU installations that would satisfy the crash performance criteria presented in the NCHRP Report 350 and the 1994 AASHTO "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals."
**SI* (MODERN METRIC) CONVERSION FACTORS**

### APPROXIMATE CONVERSIONS TO SI UNITS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>When You Know</th>
<th>Multiply By</th>
<th>To Find</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LENGTH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in</td>
<td>inches</td>
<td>25.4</td>
<td>millimeters</td>
<td>mm</td>
</tr>
<tr>
<td>ft</td>
<td>feet</td>
<td>0.305</td>
<td>meters</td>
<td>m</td>
</tr>
<tr>
<td>yd</td>
<td>yards</td>
<td>0.914</td>
<td>meters</td>
<td>m</td>
</tr>
<tr>
<td>mi</td>
<td>miles</td>
<td>1.61</td>
<td>kilometers</td>
<td>km</td>
</tr>
<tr>
<td><strong>AREA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>in(^2)</td>
<td>square inches</td>
<td>645.2</td>
<td>square millimeters</td>
<td>mm(^2)</td>
</tr>
<tr>
<td>ft(^2)</td>
<td>square feet</td>
<td>0.093</td>
<td>square meters</td>
<td>m(^2)</td>
</tr>
<tr>
<td>yd(^2)</td>
<td>square yards</td>
<td>0.836</td>
<td>square meters</td>
<td>m(^2)</td>
</tr>
<tr>
<td>ac</td>
<td>acres</td>
<td>0.405</td>
<td>hectares</td>
<td>ha</td>
</tr>
<tr>
<td>mi(^2)</td>
<td>square miles</td>
<td>2.59</td>
<td>square kilometers</td>
<td>km(^2)</td>
</tr>
<tr>
<td><strong>VOLUME</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fl oz</td>
<td>fluid ounces</td>
<td>29.57</td>
<td>milliliters</td>
<td>mL</td>
</tr>
<tr>
<td>gal</td>
<td>gallons</td>
<td>3.785</td>
<td>liters</td>
<td>L</td>
</tr>
<tr>
<td>ft(^3)</td>
<td>cubic feet</td>
<td>0.028</td>
<td>cubic meters</td>
<td>m(^3)</td>
</tr>
<tr>
<td>yd(^3)</td>
<td>cubic yards</td>
<td>0.765</td>
<td>cubic meters</td>
<td>m(^3)</td>
</tr>
</tbody>
</table>

**NOTE:** Volumes greater than 1000 L shall be shown in m\(^3\).

### APPROXIMATE CONVERSIONS FROM SI UNITS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>When You Know</th>
<th>Multiply By</th>
<th>To Find</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LENGTH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mm</td>
<td>millimeters</td>
<td>0.039</td>
<td>inches</td>
<td>in</td>
</tr>
<tr>
<td>m</td>
<td>meters</td>
<td>3.28</td>
<td>feet</td>
<td>ft</td>
</tr>
<tr>
<td>yd</td>
<td>yards</td>
<td>1.09</td>
<td>meters</td>
<td>m</td>
</tr>
<tr>
<td>km</td>
<td>kilometers</td>
<td>0.621</td>
<td>miles</td>
<td>mi</td>
</tr>
<tr>
<td><strong>AREA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mm(^2)</td>
<td>square millimeters</td>
<td>0.0016</td>
<td>square inches</td>
<td>in(^2)</td>
</tr>
<tr>
<td>m(^2)</td>
<td>square meters</td>
<td>10.764</td>
<td>square feet</td>
<td>ft(^2)</td>
</tr>
<tr>
<td>yd(^2)</td>
<td>square yards</td>
<td>1.195</td>
<td>square meters</td>
<td>m(^2)</td>
</tr>
<tr>
<td>ha</td>
<td>hectares</td>
<td>2.47</td>
<td>acres</td>
<td>ac</td>
</tr>
<tr>
<td>km(^2)</td>
<td>square kilometers</td>
<td>0.386</td>
<td>square miles</td>
<td>mi(^2)</td>
</tr>
<tr>
<td><strong>VOLUME</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mL</td>
<td>milliliters</td>
<td>0.034</td>
<td>fluid ounces</td>
<td>fl oz</td>
</tr>
<tr>
<td>L</td>
<td>liters</td>
<td>0.264</td>
<td>gallons</td>
<td>gal</td>
</tr>
<tr>
<td>m(^3)</td>
<td>cubic meters</td>
<td>35.71</td>
<td>cubic feet</td>
<td>ft(^3)</td>
</tr>
<tr>
<td>yd(^3)</td>
<td>cubic yards</td>
<td>1.307</td>
<td>cubic meters</td>
<td>m(^3)</td>
</tr>
<tr>
<td><strong>MASS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g</td>
<td>grams</td>
<td>0.035</td>
<td>ounces</td>
<td>oz</td>
</tr>
<tr>
<td>kg</td>
<td>kilograms</td>
<td>2.202</td>
<td>pounds</td>
<td>lb</td>
</tr>
<tr>
<td>Mg</td>
<td>megagrams</td>
<td>1.103</td>
<td>short tons (2000 lb)</td>
<td>T</td>
</tr>
<tr>
<td><strong>TEMPERATURE (exact)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>°F</td>
<td>Fahrenheit temperature</td>
<td>5(°F-32)/9</td>
<td>Celcius temperature</td>
<td>°C</td>
</tr>
<tr>
<td>or (°F-32)/1.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ILLUMINATION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fc</td>
<td>foot-candles</td>
<td>10.76</td>
<td>lux</td>
<td>lx</td>
</tr>
<tr>
<td>fl</td>
<td>foot-Lamberts</td>
<td>3.426</td>
<td>candela/m(^2)</td>
<td>cd/m(^2)</td>
</tr>
<tr>
<td><strong>FORCE and PRESSURE or STRESS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>lbf</td>
<td>poundforce</td>
<td>4.45</td>
<td>newtons</td>
<td>N</td>
</tr>
<tr>
<td>lbf/in(^2)</td>
<td>poundforce per square inch</td>
<td>6.89</td>
<td>kilopascals</td>
<td>kPa</td>
</tr>
</tbody>
</table>

### FORCE and PRESSURE or STRESS

| N | newtons | 0.225 | poundforce | lbf |
| kPa | kilopascals | 0.145 | poundforce per square inch | lbf/in\(^2\) |

* SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.

(Revised September 1993)
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>STUDY APPROACH</td>
<td>3</td>
</tr>
<tr>
<td>- DESIGN REQUIREMENTS</td>
<td>3</td>
</tr>
<tr>
<td>- MODELING</td>
<td>6</td>
</tr>
<tr>
<td>- PROTOTYPE REQUIREMENTS</td>
<td>6</td>
</tr>
<tr>
<td>- PROTOTYPE CONSTRUCTION</td>
<td>6</td>
</tr>
<tr>
<td>TESTING</td>
<td>11</td>
</tr>
<tr>
<td>- Crash Testing</td>
<td>11</td>
</tr>
<tr>
<td>- Crash Test Evaluation Criteria</td>
<td>15</td>
</tr>
<tr>
<td>- Crash Test and Data Analysis Procedures</td>
<td>16</td>
</tr>
<tr>
<td>- Laboratory Testing</td>
<td>18</td>
</tr>
<tr>
<td>TEST RESULTS</td>
<td>19</td>
</tr>
<tr>
<td>- STATIC LOAD TESTING</td>
<td>19</td>
</tr>
<tr>
<td>- BOGIE TESTING</td>
<td>19</td>
</tr>
<tr>
<td>- Test 405461-B1</td>
<td>22</td>
</tr>
<tr>
<td>- Test 405461-B2</td>
<td>22</td>
</tr>
<tr>
<td>- Test 405461-B3</td>
<td>33</td>
</tr>
<tr>
<td>- Test 405461-B4</td>
<td>41</td>
</tr>
<tr>
<td>- Test 405461-B5</td>
<td>49</td>
</tr>
<tr>
<td>- Test 405461-B6</td>
<td>54</td>
</tr>
<tr>
<td>SUMMARY OF FINDINGS, CONCLUSIONS &amp; RECOMMENDITIONS</td>
<td>61</td>
</tr>
<tr>
<td>- SUMMARY OF FINDINGS</td>
<td>61</td>
</tr>
<tr>
<td>- CONCLUSIONS</td>
<td>62</td>
</tr>
<tr>
<td>- RECOMMENDATIONS</td>
<td>63</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>65</td>
</tr>
</tbody>
</table>
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Geometric comparison of 820C vehicle and CBU installation</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Typical Type II CBU pedestal</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>Details of TTI CBU slip-base</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Details of revised TTI CBU slip-base</td>
<td>12</td>
</tr>
<tr>
<td>5</td>
<td>Details of Transpo Industries breakaway support coupling for mailboxes</td>
<td>13</td>
</tr>
<tr>
<td>6</td>
<td>TTI 820C (1800 lb) bogie test vehicle</td>
<td>20</td>
</tr>
<tr>
<td>7</td>
<td>Slip-base retrofitted CBU installation prior to test 405461-B1</td>
<td>23</td>
</tr>
<tr>
<td>8</td>
<td>Bogie/slip-base retrofitted CBU geometries for test 405461-B1</td>
<td>24</td>
</tr>
<tr>
<td>9</td>
<td>Vehicle and CBU installation after test 405461-B1</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>Sequential photographs for test 405461-B1</td>
<td>26</td>
</tr>
<tr>
<td>11</td>
<td>CBU installation after test 405461-B1</td>
<td>27</td>
</tr>
<tr>
<td>12</td>
<td>Vehicle crush damage after test 405461-B1</td>
<td>28</td>
</tr>
<tr>
<td>13</td>
<td>Vehicle longitudinal accelerometer trace for test 405461-B1</td>
<td>29</td>
</tr>
<tr>
<td>14</td>
<td>Breakaway support coupling retrofitted CBU installation prior to test 405461-B2</td>
<td>30</td>
</tr>
<tr>
<td>15</td>
<td>Vehicle/breakaway support coupling retrofitted CBU geometries for test 405461-B2</td>
<td>31</td>
</tr>
<tr>
<td>16</td>
<td>Sequential photographs for test 405461-B2</td>
<td>32</td>
</tr>
<tr>
<td>17</td>
<td>Vehicle and CBU installation after test 405461-B2</td>
<td>34</td>
</tr>
<tr>
<td>18</td>
<td>Vehicle crush damage after test 405461-B2</td>
<td>35</td>
</tr>
<tr>
<td>19</td>
<td>Vehicle longitudinal accelerometer trace for test 405461-B2</td>
<td>36</td>
</tr>
<tr>
<td>20</td>
<td>Breakaway support coupling and 3 mm (0.125 in) cable restraint retrofitted CBU installation prior to test 405461-B3</td>
<td>37</td>
</tr>
<tr>
<td>21</td>
<td>Sequential photographs for test 405461-B3</td>
<td>38</td>
</tr>
<tr>
<td>22</td>
<td>Breakaway support coupling and 3 mm (0.125 in) cable restraint retrofitted CBU installation after test 405461-B3</td>
<td>39</td>
</tr>
<tr>
<td>23</td>
<td>Vehicle crush damage after test 405461-B3</td>
<td>40</td>
</tr>
<tr>
<td>24</td>
<td>Vehicle longitudinal accelerometer trace for test 405461-B3</td>
<td>42</td>
</tr>
<tr>
<td>25</td>
<td>Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation prior to test 405461-B4</td>
<td>43</td>
</tr>
<tr>
<td>26</td>
<td>Vehicle and CBU installation after test 405461-B4</td>
<td>44</td>
</tr>
<tr>
<td>27</td>
<td>Sequential photographs for test 405461-B4</td>
<td>45</td>
</tr>
<tr>
<td>28</td>
<td>Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation after test 405461-B4</td>
<td>46</td>
</tr>
<tr>
<td>29</td>
<td>Vehicle crush damage after test 405461-B4</td>
<td>47</td>
</tr>
<tr>
<td>30</td>
<td>Vehicle longitudinal accelerometer trace for test 405461-B4</td>
<td>48</td>
</tr>
<tr>
<td>31</td>
<td>Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation prior to test 405461-B5</td>
<td>50</td>
</tr>
<tr>
<td>32</td>
<td>Sequential photographs for test 405461-B5</td>
<td>51</td>
</tr>
</tbody>
</table>
LIST OF FIGURES (continued)

Figure No. | Description                                                                                                                                 | Page
-----------|---------------------------------------------------------------------------------------------------------------------------------------------|------
33         | Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation after test 405461-B5                                 | 52   
34         | Vehicle crush damage after test 405461-B5                                                                                                | 53   
35         | Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation prior to test 405461-B6                             | 55   
36         | Sequential photographs for test 405461-B6                                                                                                | 56   
37         | Vehicle and CBU installation after test 405461-B6                                                                                         | 57   
38         | Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation after test 405461-B6                             | 58   
39         | Vehicle crush damage after test 405461-B6                                                                                                | 59   

LIST OF TABLES

Table No. | Description                                                                                   | Page
----------|--------------------------------------------------------------------------------------------|------
1         | Summary of data from bogie tests performed on CBU installations                              | 21   
INTRODUCTION

In accordance with the forgiving roadside concept adopted by State and Federal transportation agencies since the late 1960's, safety is designed into the roadway and the immediate surrounding environment. In order to fulfill this concept, the highway engineer and those agencies responsible for placing articles within the roadway environment are charged with the responsibility of providing the safest feature feasible, within given restraints. Motorists do run off the roadway and when these events occur, a safe traversable recovery zone or "clear zone" should be provided. As described in the American Association of State Highway Transportation Officials (AASHTO) Roadside Design Guide, design options for the treatment of these features have generally been considered in the following order of preference:

1. Remove the obstacle or redesign it so it can be traversed safely.
2. Relocate the obstacle to a point where it is less likely to be struck.
3. Reduce the impact severity by using an appropriate breakaway device.
4. Shield the obstacle with a longitudinal traffic barrier and/or crash cushion if it cannot be eliminated, relocated or redesigned.
5. Delineate the obstacle if the above alternatives are not appropriate.

Options 1 and 2 are obviously the most desirable, but not always possible and/or feasible.

Mailboxes are common and abundant in the roadside environment. Neighborhood Delivery and Collection Box Units (NDCBU) and Cluster Box Units (CBU) present a special challenge to the highway engineer due to their large physical size, mass, and tall mounting height (herein after, all generically referred to as CBU's). Additionally, multiple CBU's are often mounted contiguously along the roadway. Efforts expended in the past by TTI researchers and others have demonstrated the hazards of mounting various types of mailbox installations within the clear zone. In addition, TTI and the Texas State Department of Highways and Public Transportation (now Texas Department of Transportation) performed full-scale crash tests concluded that the rigid mounting of CBU's using 13 mm (0.5 in) studs or bolts into a concrete footing was unacceptable for installation in the clear zone of high-speed roadways. The vehicle experienced a marginally acceptable occupant impact velocity of 4.9 m/s (16.1 ft/s) in the longitudinal direction, and subsequent to impact the vehicle rolled six revolutions. To this end, TTI concluded from the study that impact performance of CBU type installations could be improved by the inclusion of a breakaway feature(s) such as a slip-base, breakaway welds at the post to base connection, a weakened support, or a combination of these. In addition, even with a frangible or slip connection, the CBU, because it is mounted at windshield height, presents an additional hazard that must be addressed.

The United States Postal Service (USPS), recognizing that a potential hazard to the errant motorist may exist where CBU's are installed, contracted with Texas Transportation Institute (TTI) to: (1) evaluate the potential crash performance of pedestal mounted Neighborhood Delivery and Collection Box Units (NDCBU) and Cluster Box Units (CBU) currently being used in the field, (2) design a prototype retrofit breakaway mount for these
units, and (3) provide initial laboratory testing of the new frangible mounting system. The end objective of the study was to investigate the development of a frangible retrofit system for mounting existing and new CBU installations that would satisfy the crash performance criteria presented in the National Cooperative Highway Research Program (NCHRP) Report 350 "Recommended Procedures for the Safety Performance Evaluation of Highway Features" and the 1994 American Association of State Highway and Transportation Officials (AASHTO) "Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals." [7, 8]
STUDY APPROACH

The USPS issued a Statement of Work on December 1, 1994, requesting design, prototype, and initial laboratory testing of breakaway mounts for nine (9) types of cluster box units purchased by the USPS. The specification did not include full-scale crash testing.

The USPS engineers, in coordination with TTI engineers, made modifications to the work plan throughout the contract to strive to accomplish the development of a successful retrofit for CBU's while working within the financial constraints of the study. The refined work plan provided for the crash performance evaluation of the worst-case CBU installation rather than incomplete evaluation of all nine types of CBU's. A retrofit solution for the worst-case CBU installation would also be applicable to other CBU types with performance predicted better than the worst-case. The CBU installation investigated as worst-case for this study was the Type II CBU. The Type II CBU installation had the highest center of gravity and presented the greatest hazard for occupant compartment intrusion. The following sections contain reprints of the pertinent specifications from the *USPS Statement of Work* with TTI commentary and amendments to the scope of the study.

DESIGN REQUIREMENTS

The performance of a highway safety appurtenance is evaluated based on three factors, according to NCHRP Report 350: (1) structural adequacy, (2) occupant risk values, and (3) vehicle trajectory. Support structures such as the CBU pedestal must first be structurally adequate to support the CBU, and resist ice, wind and service loads. Breakaway mechanisms, such as slip-bases and frangible couplings, may be incorporated into the design to permit the structure to be structurally sound when subjected to bending moments, but are weak in shear when struck and loaded transversely by an errant vehicle. In addition, the AASHTO Roadside Design Guide provides the following guidelines for basic mailbox support installations:

- Mailbox supports which should be considered are nominal 102-mm by 102-mm (4-in by 4-in) or 114-mm (4.5-in) diameter wood posts, or a metal post with a strength no greater than a 51-mm (2-in) diameter standard strength pipe, embedded no more than 610 mm (24 in) into the ground. For example, a single 3-kg per meter (2 ft/1b) U-channel support would be acceptable under this structural limitation. Mailbox supports should not be set in concrete unless the support design has been shown to be safe by crash tests.

- Mailbox to post attachments should ideally prevent mailboxes from separating from their support under vehicle impacts. The mailbox guide contains information on attachments that prevent separation.

- Multiple mailbox installations should meet the same criteria as single mailbox installations. Multiple support installations should have their supports separated
a minimum distance equal to three-fourths their heights above ground. This will reduce interaction between adjacent mailboxes and supports.

- Neighborhood delivery and collection box units are owned by the postal service and are a specialized type of multiple mailbox installation that should be located outside the clear zone, particularly on high-speed or heavily traveled highways.

When a mailbox installation is struck by an errant motorist, the risk of serious injury to the occupants of the vehicle should be minimized. The risk of injury is dependent on the crashworthiness of the vehicle and the design of the highway safety appurtenance. The risk to the occupant is assessed by a flail space model. As described in NCHRP Report 350, “the flail space model uses a hypothetical, unrestrained front seat occupant whose motion relative to the occupant compartment is dependent on vehicular accelerations. The “point mass” occupant is assumed to move through space until striking a hypothetical instrument panel, windshield, or side structure and subsequently is assumed to experience the remainder of the vehicular acceleration pulse by remaining in contact with the interior surface. The two performance factors of occupant risk factors are (1) the lateral and longitudinal component of occupant velocity at impact with the interior surface, and (2) the highest lateral and longitudinal component of resultant vehicular acceleration averaged over any 10-ms interval for the collision pulse subsequent to occupant impact. Performance factor two is referred to as occupant ridedown.” The maximum occupant impact velocity permissible for support structures is 5 m/s (16 ft/s) in the longitudinal direction. The maximum permissible occupant ridedown acceleration limit is 20 g’s in both the longitudinal and lateral directions. Additionally, detached elements or fragments from the mailbox installation should not show potential for penetrating the occupant compartment or present an undue hazard to other traffic, pedestrians, or workers in traffic zones, if applicable.

Subsequent to impact with a mailbox installation or any highway safety appurtenance, the potential of post-impact trajectory of the vehicle to cause a subsequent multi-vehicle accident or collision with other fixed objects should not exist. In addition, for mailboxes and other support type structures, vehicular trajectory behind the installation is acceptable.

The primary objective of the study was to investigate the development of a safe, crashworthy retrofit for USPS CBU type installations and was described in the USPS Statement of Work as follows:

1) Mount or mounts shall be designed to meet the crash test requirements of NCHRP Report 350 when impacted by a 700 kg (1550 lb), a 820 kg (1800 lb) passenger vehicle and a 2000 kg (4400 lb) pickup truck.

NCHRP Report 350 states: “Although tests with the 700C vehicle are desirable, they are optional because (1) this vehicle type represents only a very small portion of the vehicular mix, and (2) there is no assurance that an existing feature will meet the recommended performance criteria or that new features can be found that will fully meet the recommended
performance criteria for these tests. In the interim until sufficient testing experience is acquired with the 700C type vehicle, the test article should perform acceptably with all appropriate tests using the 820C and 2000P type vehicles and preferably should perform acceptably during tests with the 700C type vehicle."

To date, TTI is not aware of any tests performed or to be performed with the 700C (1550 lb) vehicle. The current standard vehicle for crash testing support structures is the 820C (1800 lb) vehicle. TTI recommended designing for and testing with the 820C (1800 lb) vehicle with the option of crash testing the optional lighter 700C (1550 lb) vehicle after compliance is met with the 820C (1800 lb) vehicle. The 2000P (4400 lb pickup) test vehicle is utilized primarily to evaluate the potential for penetration of the support system, cluster box units, and/or any parts or fragments thereof into the occupant compartment, and is typically not used as a test vehicle in the evaluation of support structures.

All evaluation and testing was performed with the objective of complying with the safety guidelines presented in NCHRP Report 350 “Recommended Procedures for the Safety Performance Evaluation of Highway Features” and the 1994 American Association of State Highway and Transportation Officials (AASHTO) “Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals.”

2) **Design the mount in such a way that, if possible, it requires minimal modification to the existing CBU or NDCBU pedestal design.** Design requirements for the cluster box mount(s) to be met were as follows:

- The mount shall be designed in such a way that, minimal modification to the existing CBU or NDCBU pedestal design is required.
- The mount shall be designed for easy installation.
- The mount shall be designed for minimal production cost.
- The mount shall be designed for a 20 year usable life.
- The mount shall be designed such that, if the cluster box is knocked over, it cannot be set back up without proper repair or replacement of the pedestal and mount.

TTI has performed many crash tests on similar types of support structures and utilized this experience to select a mount design that has historically performed well in other applications. TTI's experience with this type of installation indicates shearing or permitting the mount(s) to fail in a controlled manner is a fairly academic exercise. The difficulty in complying with NCHRP Report 350 comes in preventing the cluster box unit from penetrating the occupant compartment. The dynamic characteristics of the mount and attached cluster box installation after yielding to the impacting vehicle was the primary focus.
MODELING

1) Mathematical modeling shall be performed to prove out the design. If necessary and accurate, a computer generated model shall be made of the crash scenario.

TII exercised the option to not perform computer simulations on the retrofit designs for the following reasons: (1) A validated computer model for this type of application was not readily available; (2) Developing a computer model of the CBU installation would have been prohibitively time consuming and not within the budgetary constraints of this project; (3) Any computer model simulations would need validating with full-scale crash tests; and (4) More cost effective and accurate bogie tests were available for purposes of dynamic analyses.

PROTOTYPE REQUIREMENTS

1) Two prototypes of each design shall be built for lab testing. After lab testing and design revisions, if any, four additional prototypes shall be built as deliverables to the USPS.

The cost to produce a prototype of any type device is high due to the hand fabrication often necessary in developmental type work. Prototypes were constructed for the purpose of performing impact tests and static load tests. The decision was made to not construct redundant prototypes, but rather use the funding to perform the research needed to derive a solution to the problem. Prototypes constructed for crash testing will be supplied to the USPS.

PROTOTYPE CONSTRUCTION

As previously discussed, the safety performance of CBU type installations can be improved by the inclusion of a breakaway feature(s) such as a slip-base, breakaway welds or bolts at the post-to-base connection, a weakened support, or a combination of these. Constructing a mechanism to allow the installation to passively yield to a vehicle, while maintaining the structural integrity of the installation has become a fairly straightforward process over years of testing. However, controlling the trajectory of the struck CBU installation is a more arduous task. The physical size of CBU's and mounting height restrictions (1575 mm ± 6 (62 in ± 0.25)) implemented for human ergonomics place an enormous impediment on the design for crash performance. The center of mass of the "worst case" (Type II) CBU is at the same height as the center of the windshield on the 820 kg (1800 lb) test vehicle. When struck by an errant vehicle traveling at a high rate of speed, the high vertical center of gravity results in a center of rotation that presents the potential for intrusion into the occupant compartment through the windshield. Figure 1 illustrates the center-of-gravity of the Type II CBU installation relative to the frontal profile of a typical 820 kg (1800 lb) passenger vehicle. In addition, the current methodology of anchoring the pedestal to a concrete footing with four 13 mm (0.5 in) diameter bolts was shown to perform
Notes:

(1) "*" Denotes Heights With Transpo Industries Pole-Safe Frangible Coupling

(2) Vertical Center-Of-Gravity Of Standard Type II CBU Installation is 1081 mm.

1 mm = 0.039 in

Figure 1. Geometric comparison of 820C vehicle and CBU installation.
poorly in a crash test of a similar type of mailbox installation. A typical Type II pedestal is shown in figure 2.

Given the constraints previously mentioned and in compliance with the guidelines presented in NCHRP Report 350, the approach, in order of importance, to the retrofit design for the CBU installation was to: (1) provide a design that produced acceptable occupant risk values and did not allow penetration into the occupant compartment, (2) minimize hazards produced by debris from the CBU installation, and (3) provide an installation that was structurally adequate to carry the required wind, ice, and service loads.

Two types of frangible mechanisms were designed and investigated in the study. A slip-base and frangible support couplings were the subjects of investigation and testing. Transpo Industries, Inc. designed and provided to TTI and the USPS for testing, a new product in their Pole-Safe coupling line of hardware (herein referred to as coupling). Both frangible mechanisms were designed as a retrofit for existing CBU installations. Installation of the retrofit hardware in both cases consists of simply unbolting the existing CBU pedestal from the concrete anchor bolts, bolting down either the slip-base unit or the frangible coupling using the existing concrete anchor bolts and nuts, and then reattaching the CBU installation atop the new yielding connection with standard nuts and washers.

The CBU slip-base was designed to (1) activate safely and readily when struck by an errant vehicle, (2) be easily adaptable to the retrofit of CBU installations, (3) require no special machining and thus be simple to fabricate, (4) consist of a single inventory base component, (5) be as heavy as possible while maintaining a practical level of economy, and (6) be capable of withstanding a 2034 Nm (1500 ft-lb) moment at ground level. Details of the slip-base design and fabrication, as tested, are shown in figure 3.

The slip-base is constructed such that the bottom and top components (ground base plate and slip-base) are identical. The slip-base was constructed of A36 steel, which is a heavy material, to aid in reducing the height of the vertical center of mass of the CBU installation. The slip planes of the base were constructed from 13 mm (0.5 in) thick plate steel that was 229 mm (9 in) wide by 381 mm (15 in) long. These plates were fabricated with a 60 degree notch at each corner to accommodate a 16 mm (0.625 in) diameter by 51 mm (2 in) long grade 8 steel bolt, nut and two washers. The notches were cut into the slip plate corners at 60 degrees to facilitate omni-directional impact performance of the installation while maintaining the maximum bearing surface for each of the four bolts connecting the two slip planes together. A 28 gage galvanized bolt keeper plate, 229 mm (9 in) wide by 381 mm (15 in) long, was placed between the slip planes. The holes in the keeper plate were each 19 mm (0.75 in) in diameter and placed in the plate for the purpose of preventing the bolts from “walking” or vibrating out of the slots in the slip plates. Attaching the slip plane plate to the anchoring plate, by fillet welding, was a 67 mm (2.625 in) long TS203mm×102mm×5mm (TS 8×4×0.188). The anchoring plate was constructed from C152×12 (C6×8) that approximated the appearance and physical dimensions of the channel shape currently used at the base ends of pedestals. The CBU installation was anchored to the slip-base anchoring plate using 13 mm (0.5 in) diameter by 25 mm (1 in) long grade 8 steel bolts and nuts.
Figure 2. Typical Type II CBU pedestal.

1 mm = 0.039 in
Figure 3. Details of TTI CBU slip-base.
Subsequent to performing the bogie tests, the slip-base design was modified to make the outside dimensions of the slip plates the same size as the channel shape (152 mm by 305 mm (6 in by 12 in)). The details of the proposed slip-base design and fabrication are shown in figure 4.

Texas Transportation requested that Transpo Industries, Inc. design and provide to TTI and the USPS for testing, a product from their Pole-Safe coupling line of hardware (herein referred to as coupling) for retrofitting CBU installations. The Transpo Industries frangible coupling was designed to (1) activate safely and readily when struck by an errant vehicle, (2) break as close to the ground as possible to avoid possible snagging of vehicle’s undercarriage, (3) be easily adaptable to the retrofit of CBU installations, (4) consist of a single inventory base component, (5) be capable of withstanding a 2034 Nm (1500 ft-lb) moment at ground level, and (6) be economical. Details of the frangible coupling design, fabrication and installation, as tested, are shown in figure 5.

The Transpo Industries Pole Safe Breakaway Support Couplings Model No. 4050, when installed in sets of four, are capable of withstanding a 2034 Nm (1500 ft-lb) moment while maintaining their ability to be frangible and weak in shear. The coupling is constructed from material per AMS 6378D*, HDG per ASTM A153 (*with exception to decarburization and macrostructure clauses). The couplings are 29 mm (1.125 in) in diameter and 127 mm (5 in) long. Along the length of each coupling are two 21 mm (0.825 in) long sections that are tapered down to a diameter of 6 mm (0.25 in) at the center of each section. The base end of the coupling is tapped to accept a 13 mm (0.5 in) diameter bolt. Additionally, the top end of the coupling is threaded 38 mm (1.5 in) down its length to accept a standard 13 mm (0.5 in) nut. The retrofit for the CBU installation is performed by simply unbolting the pedestal from the concrete anchor bolt, threading the couplings onto the existing concrete anchor bolts, and reattaching the CBU installation atop the couplings using washers and nuts. If the installation is not plumb, galvanized steel shims may be used to correct any errors.

TESTING

Crash Testing

1) Laboratory testing of the mount shall be performed to simulate crash testing conditions and behaviors as recommended by TTI.

In lieu of full-scale crash tests and for developmental purposes, a surrogate vehicle was used to perform “bogie tests.” The TTI surrogate, or bogie test vehicle, is a sprung structure mounted on four wheels with the same mass (820 kg (1800 lb)) as the NCHRP Report 350 test vehicle. In addition, a ten-stage crushable nose was mounted on the bogie vehicle to emulate the frontal crush characteristics of the 820C (1800 lb) test vehicle. The vehicle was then instrumented with accelerometers, as the 820C (1800 lb) vehicle would be. A simulated windshield frame was mounted to evaluate the potential for occupant compartment intrusion. The bogie vehicle provides a more economical alternative to full-scale crash testing for evaluating the dynamic impact characteristics of a safety appurtenance.
Figure 4. Details of revised TTI CBU slip-base.

1 mm = 0.039 in
**SPECIFICATIONS**

Breakaway Support Coupling conforms to 1985 AASHTO standards for breakaway supports for light poles and mailboxes.

Ultimate Tensile Strength: 35.6kN (30.0 kips) min.

Restrained Shear: 0.9kN (0.20 kips) min.

3.1kN (0.70 kips) max.

Allowable Pole Mass: Not Applicable

**Installation Note:**

a) Shims are provided for leveling and can be used on top and/or bottom of coupling.

b) Coupling should be tightened onto the anchor bolt as tight as possible using conventional wrench and the top nut should be tightened using turn of the nut method.

c) Do not place torque across necked down portions of coupling. Wrench flats are provided on either side for proper tightening.

**INTENDED USE**

The breakaway support coupling is used with base plate equipped poles and mailboxes installed using 13mm (1/2") dia. externally threaded anchor bolts in locations exposed to vehicular collisions.

**BREAKAWAY SUPPORT COUPLINGS FOR MAIL BOXES**

**MODEL NO. 4050**

---

Figure 5. Details of Transpo Industries breakaway support coupling for mailboxes.
INSTALLATION INSTRUCTIONS FOR
TRANSPO POLE-SAFE BREAKAWAY SUPPORT COUPLING
(MODEL 4125, 4100, 4062, 4050)

CAUTION: CORRECT INSTALLATION IS VERY IMPORTANT TO
THE PROPER FUNCTIONING OF THE BREAKAWAY COUPLING.

1. Area around the anchor bolt must be free of debris or dirt and must be even and flat.
2. Projection of Hot Dip Galv. (HDG) anchor bolt should be as shown on the specification
   sheet (see the reverse) and its threads must be free of dirt and other foreign material.
3. Install the washer, then thread the coupling onto the anchor bolt.
   NOTE: The coupling must be tightened onto the anchor bolt as tight as possible using a
   conventional wrench (not a pipe wrench as it may damage the part's coating).
   Use additional washer underneath the coupling if the anchor bolt height hinders
   the proper seating of the part.
   CAUTION: Use lower wrench flats to tighten the part so that the necked section is not
   stressed and the coupling sits squarely on the washer.
4. Remove the nut, top washer and cardboard sleeve from the other end of the coupling.
5. Level all four couplings using shims.
   CAUTION: Adjustments over 3mm (1/8 in), for any one coupling, should be done using
   additional washers. Sufficient threaded length should be available after
   adjustment for proper tightening of the nut.
6. Set the pole on top of the couplings.
7. Install the washers and nuts on top of the pole's base-plate.
   NOTE: The nuts do not have specific torque requirement. They should be tightened
   using turn of the nut method.
   CAUTION: While tightening the nut, the coupling should be held in place by using the
   upper wrench flats so as to protect the necked section from being stressed.
8. Make sure the pole is plumb. If not, correction can be made by inserting shims
   underneath the couplings.
   CAUTION: Do not use more than 2 shims underneath any one coupling.

NOTE: Pole-Safe Model 4100 can be used as a replacement for Pole-Safe Model 201. (Old
anchor bolts must be cut down to the height shown on the specification sheet (see
the reverse) or a nut must be turned down tight onto the foundation so that the
anchor bolt height does not hinder the proper seating of the coupling. Old anchor
bolts must also be cleaned and sprayed with cold galvanization before re-use.)

Transpo Industries, Inc. 20 Jones Street, New Rochelle, NY 10801
Phone: (914) 636-1000        Fax: (914) 636-1282

August, 94

Figure 5. Details of Transpo Industries breakaway support couplings
for mailboxes (continued).
To assure that new and existing designs perform according to the established performance guidelines, NCHRP Report 350 requires a minimum of two full-scale crash tests to evaluate the impact characteristics of a support structure such as the CBU installation, to the basic test level three (TL3) evaluation criteria. The full-scale crash tests required by NCHRP Report 350 are as follows:

NCHRP Report 350 Test Designation 3-60: 820C (1800 lb) vehicle impacting the support structure at a speed of 35 km/h (20 mi/h) with the vehicle bumper at an impact angle between 0 and 20 degrees. The primary purpose of this test is to evaluate the breakaway, fracture, or yielding mechanism of the support as well as occupant risk.

NCHRP Report 350 Test Designation 3-61: 820C (1800 lb) vehicle impacting the support structure at a speed of 100 km/h (60 mi/h) with the vehicle bumper at an impact angle between 0 and 20 degrees. The main objective of this test is to evaluate occupant risk, and vehicle and test article trajectory.

The CBU installations were anchored to a Portland Cement Concrete (PCC) pavement and bogie tested in accordance with NCHRP Report 350 test designations 3-60 and 3-61.

Crash Test Evaluation Criteria

The crash tests performed were evaluated in accordance with the criteria presented in NCHRP Report 350 and the 1994 AASHTO Standards. As previously discussed and stated in NCHRP Report 350, “Safety performance of a highway appurtenance cannot be measured directly but can be judged on the basis of three factors: structural adequacy, occupant risk, and vehicle trajectory after collision.” Accordingly, the following safety evaluation criteria from table 5.1 of NCHRP Report 350 were used in this study:

- **Structural Adequacy**
  
  B. The test article should readily activate in a predictable manner by breaking away, fracturing, or yielding.

- **Occupant Risk**
  
  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. Deformation of, or intrusions into, the occupant compartment that could cause serious injuries should not be permitted.
F. The vehicle should remain upright during and after collision although moderate roll, pitching and yawing are acceptable.

H. Occupant impact velocity should satisfy the following:

<table>
<thead>
<tr>
<th>Longitudinal Occupant Impact Velocity - m/s</th>
<th>Preferred</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3 (10 ft/s)</td>
<td>5 (16 ft/s)</td>
</tr>
</tbody>
</table>

I. Occupant ridedown accelerations should satisfy the following:

<table>
<thead>
<tr>
<th>Longitudinal Occupant Ridedown Accelerations - g's</th>
<th>Preferred</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>20</td>
</tr>
</tbody>
</table>

- Vehicle Trajectory

K. After collision it is preferable that the vehicle’s trajectory not intrude into adjacent traffic lanes.

N. Vehicle trajectory behind the test article is acceptable.

In addition, the 1994 AASHTO standards states:

"Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1800 pound (820 kg) vehicle, or its equivalent, striking a breakaway support at speeds from 20 mi/h to 60 mi/h (35 km/h to 100 km/h) does not exceed 16 ft/s (4.9 m/s), but preferably does not exceed 10 ft/s (3.1 m/s) or less."

Crash Test and Data Analysis Procedures

The crash test and data analysis procedures were in accordance with guidelines presented in NCHRP Report 350. Brief descriptions of these procedures are presented as follows.

Electronic Instrumentation and Data Processing

The test vehicle was instrumented with a biaxial accelerometer near the vehicle center of gravity to measure longitudinal acceleration levels, and a back-up biaxial accelerometer in the rear of the vehicle to measure longitudinal acceleration levels. The accelerometers were strain gage 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. Calibration signals were recorded before and after the test, and an accurate time reference signal was simultaneously recorded with the data. Pressure sensitive switches on the bumper of the impacting vehicle 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 installation.

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

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 10-ms 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 50-ms intervals in each of the three directions are computed. For reporting purposes, the data from the vehicle-mounted accelerometers were then filtered with a 60 Hz digital filter and acceleration versus time curves for the longitudinal direction was plotted using a commercially available software package (QUATTRO PRO). The accelerations 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.

Photographic Instrumentation and Data Processing

Photographic coverage of the test included one high-speed camera placed to have a field of view perpendicular to the installation. A flash bulb activated by a pressure sensitive tape switch was positioned on the impacting vehicle to indicate the instant of contact with the installation and was visible from the camera. The film from the high-speed camera was analyzed on a computer-linked Motion Analyzer to observe phenomena occurring during the collision and to obtain time-event, displacement and angular data. A Betacam, a 3/4-inch video camera and recorder, and still cameras were used to record and document conditions of the test vehicle and installation before and after each test.
Test Vehicle Propulsion and Guidance

The test vehicle was towed into the test installation using a steel cable guidance and reverse tow system. A steel cable for guiding the test vehicle was tensioned along the path, anchored at each end, and threaded through an attachment to the front spindle of the test vehicle. An additional steel cable was connected to the test vehicle, 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. For the high speed test, a 2 to 1 speed ratio between the test and tow vehicle existed with this system. A 1 to 1 speed ratio between the test and tow vehicle was used for the low speed tests performed. Just prior to impact with the installation, 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.

Laboratory Testing

2) The USPS required that a static load test be performed in accordance with USPS-B-1118E on the installation by applying a 112.4 N (25.3 lbf) horizontal load at a distance of 0.9 m (3.0 ft) from the base of the installation.

Static load tests were performed to evaluate the structural adequacy of the retrofitted pedestal and CBU installation. A load cell was attached to a rigidly mounted structure and a cable attached from the load cell to the pedestal at a mounting height of 0.9 m (3 ft) from the base of the installation. A horizontal load was applied to the pedestal incrementally until a structural failure was achieved or the required bending moment of 2034 Nm (1500 ft-lb) was exceed. The ultimate load was recorded when failure occurred, when applicable.

3) Testing shall include a Salt Spray Test in accordance with USPS-B-1118E paragraph 3.5.11.

TTI and the USPS chose to not perform the salt spray test in this phase of the study. This type of test is prudent after all developmental tests, including full-scale crash testing, are complete. The type of retrofits investigated would be galvanized according to ASTM A525-90 “Standard Specifications for General Requirements for Steel Sheet, Zinc Coated (Galvanized) by the Hot Dip Process.” Corrosion resistance is not expected to be a problem and the expected life of the retrofit is anticipated to exceed the twenty year minimum, as required by the USPS.
TEST RESULTS

STATIC LOAD TESTING

As previously discussed, static load tests were performed to evaluate the structural adequacy for wind and service loads of retrofitted pedestal and CBU installations using the TTI slip-base design and Transpo Industries Pole Safe Breakaway Support Coupling Model No. 4050.

A load cell was attached to a rigidly mounted structure and a cable attached from the load cell to the pedestal at a mounting height of 0.9 m from the base of the installation. A horizontal load was applied to the pedestal incrementally until a structural failure was achieved or the required bending moment of 2034 Nm (1500 ft-lb) was exceeded.

The TTI slip-base was only tested to a maximum static bending moment of 2441 Nm (1800 lb-ft) rather than trying to establish an absolute maximum and unnecessarily destroying limited research hardware (i.e. the pedestal). The Transpo Industries couplings failed at a bending moment of 2441 Nm (1800 lb-ft). The maximum bending moment of the Transpo Industries coupling equates to a factor of safety of 20 percent.

BOGIE TESTING

A total of six full-scale crash tests were performed on the Type II CBU installation. Four low-speed tests were performed to quantitatively evaluate the retrofitted CBU installation for occupant risk values (occupant impact velocity and occupant ridedown accelerations). Additionally, two high-speed tests were performed to evaluate the risk of occupant compartment penetration, post-impact vehicle stability, and test article and vehicle trajectory. In all tests performed, the instrumented bogie vehicle (shown in figure 6), equipped with a 10-stage crushable nose, was used. Shown in table 1 is a summary of the data from the six tests performed. The bogie vehicle was towed into the CBU installations and released prior to impact. At the time of impact the bogie vehicle was unrestrained and free wheeling.

All tests installations were erected with an aluminum Type II CBU and a 787 mm (31 in) tall pedestal. The CBU installations were mounted to 13 mm (0.5 in) studs anchored in the portland cement concrete road surface. The pedestals were not shortened to accommodate the now current 1575 mm (62 in) maximum mounting height. In the event that currently installed CBU installations are truly retrofitted and the overall height of the CBU installation is increased, the tests performed are believed to represent the worst-case scenario.
Figure 6. TTI 820C (1800 lb) bogie test vehicle.
Table 1. Summary of data from bogie tests performed on CBU installations.

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Base</th>
<th>Impact Speed</th>
<th>Angular Velocity</th>
<th>Longitudinal Occupant Impact Velocity</th>
<th>Longitudinal Occupant Ridedown</th>
</tr>
</thead>
<tbody>
<tr>
<td>405461-B1</td>
<td>Slip-base</td>
<td>35.5 km/h</td>
<td>508.01 deg/s</td>
<td>No contact</td>
<td>No contact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(22.1 mi/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>405461-B2</td>
<td>Transpo Industries*</td>
<td>34.8 km/h</td>
<td>582.41 deg/s</td>
<td>No contact</td>
<td>No contact</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(21.6 mi/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>405461-B3</td>
<td>Transpo Industries*</td>
<td>35.5 km/h</td>
<td>570.94 deg/s</td>
<td>No contact</td>
<td>No contact</td>
</tr>
<tr>
<td></td>
<td>with 3-mm (0.125 in) cable</td>
<td>(22.1 mi/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>405461-B4</td>
<td>Transpo Industries*</td>
<td>33.7 km/h</td>
<td>Not Attainable</td>
<td>No contact</td>
<td>No contact</td>
</tr>
<tr>
<td></td>
<td>with 6-mm (0.25 in) cable</td>
<td>(20.9 mi/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>405461-B5</td>
<td>Transpo Industries*</td>
<td>100.3 km/h</td>
<td>632.70 deg/s</td>
<td>Not Available</td>
<td>Not Available</td>
</tr>
<tr>
<td></td>
<td>with 6-mm (0.25 in) cable</td>
<td>(62.3 mi/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>405461-B6</td>
<td>Slip-base</td>
<td>102.3 km/h</td>
<td>Not Attainable</td>
<td>Not Available</td>
<td>Not Available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(63.6 mi/h)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Transpo Industries Pole Safe Breakaway Support Coupling Model No. 4050.
Test 405461-B1

The slip-base design was crash tested at a nominal speed of 35 km/h (20 mi/h). The slip-base was anchored to the pavement by nuts and washers on the existing 13 mm (0.5 in) diameter anchors bolts. The CBU installation prior to testing is shown in figures 7 and 8.

The bogie was traveling at a speed of 35.5 km/h (22.1 mi/h) at the time of contact with the pedestal. Pedestal movement began at 0.017 s after impact and the pedestal separated at the base at 0.048 s. The bogie lost contact with the pedestal at 0.087 s. At 0.154 s the lower left side of the mailbox contacted the hood of the bogie and at 0.229 s the upper left side of the mailbox contacted the hood close to the windshield area. The mailbox continued moving upward and contacted the windshield area at 0.260 s. The bogie lost contact with the mailbox at 0.334 s. The mailbox and pedestal continued to rotate and came to rest inverted on the hood area of the bogie as shown in figure 9. Sequential photographs of the test are shown in figure 10.

As can be seen in figure 11, the pedestal was dented from impact with the bumper of the bogie. The keeper plate and the two trailing bolts remained on the lower part of the base. The nose of the bogie was crushed slightly as shown in figure 12.

There was no occupant contact in the longitudinal direction. Longitudinal vehicle accelerations filtered at 60 Hz are plotted in figure 13. The average angular velocity of the CBU installation during the test was 508.0 deg/s. The change in velocity of the bogie at loss of contact was 1.4 m/s (4.6 ft/s). The slip-base performed well in the low-speed test and demonstrated a low probability of allowing the CBU installation to intrude into the occupant compartment and cause serious injury to an occupant in the vehicle.

Test 405461-B2

Transpo Industries Pole Safe Breakaway Support Coupling Model No. 4050 was crash tested at a nominal speed of 35 km/h (20 mi/h). The couplings were anchored to the pavement by threading the couplings to the existing 13 mm (0.5 in) diameter anchor bolts and then attaching the base of the pedestal to the top of the four couplings with 13 mm (0.5 in) nuts and washers. The completed installation is shown in figures 14 and 15.

The bogie was traveling at a speed of 34.8 km/h (21.6 mi/h) at the time of contact with the pedestal. The pedestal began to move at 0.007 s and then separated from the bolts at 0.012 s. The bogie lost contact with the pedestal at 0.077 s and the lower left side of the mailbox impacted the hood of the bogie at 0.139 s. At 0.163 s the upper left side of the mailbox impacted the hood and at 0.192 s it contacted the lower left windshield area. The mailbox moved upward and the top right corner contacted the upper windshield area at 0.214 s. At 0.295 s, the bogie lost contact with the mailbox. The mailbox and pedestal went over the bogie with no further contact. Sequential photographs of the test are shown in figure 16.
Figure 7. Slip-base retrofitted CBU installation prior to test 405461-B1.
Figure 8. Bogie/slip-base retrofitted CBU geometrics for test 405461-B1.
Figure 9. Vehicle and CBU installation after test 405461-B1.
Figure 10. Sequential photographs for test 405461-B1.
Figure 11. CBU installation after test 405461-B1.
Figure 12. Vehicle crush damage after test 405461-B1.
Crash Test 405461-B1
Accelerometer at center of gravity

Test Article: Rect. slip base
Test Vehicle: Bogie vehicle
Test Inertia Weight: 820 kg
Gross Static Weight: 820 kg
Test Speed: 35.5 km/h
Test Angle: 0 deg

Figure 13. Vehicle longitudinal accelerometer trace for test 405461-B1.
Figure 14. Breakaway support coupling retrofitted CBU installation prior to test 405461-B2.
Figure 15. Vehicle/breakaway support coupling retrofitted CBU geometrics for test 405461-B2.
Figure 16. Sequential photographs for test 405461-B2.
The pedestal was dented slightly by impact with the bumper of the bogie. The couplings on the base of the mailbox unit sheared at all shear control points as shown in figure 17. The nose of the bogie was crushed slightly and the simulated windshield was dented (see figure 18), indicating possible glass breakage.

No occupant contact occurred in the longitudinal direction. Longitudinal vehicle accelerations filtered at 60 Hz are plotted in figure 19. The average angular velocity of the CBU installation was 582.4 deg/s. The change in velocity of the bogie at loss of contact was 0.6 m/s (2.0 ft/s). The couplings performed well in the low-speed test and demonstrated a low probability of allowing the CBU installation to intrude into the occupant compartment and cause serious injury to an occupant in the vehicle.

Test 405461-B3

A Type II CBU installation was installed with Transpo Industries Pole Safe Breakaway Support Couplings Model No. 4050 and modified with a 3 mm (0.125 in) diameter steel restraint cable. The installation was crash tested at a nominal speed of 35 km/h (20 mi/h). A 3 mm (0.125 in) diameter steel restraint cable, 305 mm (12 in) long was attached between the base of one of the couplings, and bolted to the base of the pedestal using a 6 mm (0.25 in) bolt, nut and washer. The couplings were anchored to the pavement by threading the couplings to the existing 13 mm (0.5 in) diameter anchor bolts and then attaching the base of the pedestal to the top of the four couplings with 13 mm (0.5 in) nuts and washers (see figure 20).

The bogie was traveling at a speed of 35.5 km/h (22.1 mi/h) at the time of contact with the pedestal. Pedestal movement began at 0.005 s after impact and the pedestal separated from the base shortly thereafter. As the bogie pushed the pedestal forward, the cable became taut and shortly thereafter sheared on the edge of the pedestal. The bogie lost contact with the pedestal at 0.065 s. At 0.142 s the lower right side of the mailbox contacted the hood and at 0.161 s the upper right side contacted the hood. As the mailbox moved upward the top contacted the lower section of the windshield area at 0.202 s and then the top left side contacted the upper windshield area at 0.231 s. The bogie lost contact with the mailbox at 0.281 s. When the cable caught the pedestal it reduced the angular velocity of the mailbox unit and the installation did not go over the bogie. The mailbox and pedestal continued to move in front of the bogie and was impacted several more times before the bogie came to a stop. Sequential photographs of the test are shown in figure 21.

Again the pedestal was dented slightly by impact of the bumper of the bogie. As shown in figure 22, all couplings except the left front sheared off at all shear control points. The left front coupling sheared off only at the lower shear point. The cable sheared at its connection to the base of the pedestal. The nose of the bogie was crushed slightly and the simulated windshield was dented, indicating possible glass breakage (see figure 23).
Figure 17. Vehicle and CBU installation after test 405461-B2.
Figure 18. Vehicle crush damage after test 405461-B2.
Crash Test 405461-B2
Accelerometer at center of gravity

Test Article: Transpo Industries w/3 mm cable
Test Vehicle: Bogie vehicle
Test Inertia Weight: 820 kg
Gross Static Weight: 820 kg
Test Speed: 34.8 km/h
Test Angle: 0 deg

Figure 19. Vehicle longitudinal accelerometer trace for test 405461-B2.
Figure 20. Breakaway support coupling and 3 mm (0.125 in) cable restraint retrofitted CBU installation prior to test 405461-B3.
Figure 21. Sequential photographs for test 405461-B3.
Figure 22. Breakaway support coupling and 3 mm (0.125 in) cable restraint retrofitted CBU installation after test 405461-B3.
Figure 23. Vehicle crush damage after test 405461-B3.
There was no occupant contact during the test. Longitudinal vehicle accelerations filtered at 60 Hz are plotted in figure 24. The average angular velocity of the CBU installation was 570.9 deg/s before the restraint cable became taut. The change in velocity of the bogie at loss of contact was 1.3 m/s (4.3 ft/s). The couplings performed well in the low-speed test and demonstrated a low probability of allowing the CBU installation to intrude into the occupant compartment and cause serious injury to an occupant in the vehicle.

Test 405461-B4

A Type II CBU installation was installed with Transpo Industries Pole Safe Breakaway Support Couplings Model No. 4050, and modified with a 6 mm (0.25 in) diameter steel restraint cable. The installation was crash tested at a nominal speed of 35 km/h (20 mi/h). A 6 mm (0.25 in) diameter steel restraint cable, 305 mm (12 in) long was attached between the base of one of the couplings and bolted to the base of the pedestal using a 11 mm (0.4 in) bolt, nut and washer. The couplings were anchored to the pavement by threading the couplings to the existing 13 mm (0.5 in) diameter anchor bolts, and then attaching the base of the pedestal to the top of the four couplings with 13 mm (0.5 in) nuts and washers. The completed installation is shown in figure 25.

The bogie was traveling at a speed of 33.7 km/h (20.9 mi/h) at the time of contact with the pedestal. At 0.002 s after impact, the pedestal began to move and at 0.012 s the pedestal separated from the base. The cable caught the bottom of the pedestal at 0.033 s causing the pedestal to deform around the bumper of the bogie. The cable broke at 0.096 s. At 0.105 s the bottom left corner of the mailbox contacted the hood of the bogie and at 0.213 s the left side of the mailbox contacted the hood. The bogie lost contact with the mailbox at 0.287 s and the mailbox contacted the hood again at 0.464 s, bounced up and then came to rest on the hood as shown in figure 26. Sequential photographs of the test are shown in figure 27.

As seen in figure 28, the pedestal was deformed at bumper height. All couplings except the right front sheared off at the shear control points. The upper shear point on the right front coupling did not shear. The nose of the bogie received moderate crush as shown in figure 29.

No occupant contact occurred during the test period. Longitudinal vehicle acceleration filtered at 60 Hz are plotted in figure 30. The change in velocity of the bogie at loss of contact was 1.5 m/s (4.9 ft/s). The couplings performed well in the low-speed test and demonstrated a low probability of allowing the CBU installation to intrude into the occupant compartment and cause serious injury to an occupant in the vehicle.
Crash Test 405461-B3

Accelerometer at center of gravity

Test Article: Transpo Industries w/3 mm cable
Test Vehicle: Bogie vehicle
Test Inertia Weight: 820 kg
Gross Static Weight: 820 kg
Test Speed: 35.5 km/h
Test Angle: 0 deg

Figure 24. Vehicle longitudinal accelerometer trace for test 405461-B3.
Figure 25. Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation prior to test 405461-B4.
Figure 26. Vehicle and CBU installation after test 405461-B4.
Figure 27. Sequential photographs for test 405461-B4.
Figure 28. Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation after test 405461-B4.
Figure 29. Vehicle crush damage after test 405461-B4.
Crash Test 405461-B4
Accelerometer at center of gravity

- Test Article: Transpo Industries w/6 mm cable
- Test Vehicle: Bogie vehicle
- Test Inertia Weight: 820 kg
- Gross Static Weight: 820 kg
- Test Speed: 33.7 km/h
- Test Angle: 0 deg

Figure 30. Vehicle longitudinal accelerometer trace for test 405461-B4.
A Type II CBU installation was installed with Transpo Industries Pole Safe Breakaway Support Couplings Model No. 4050 and modified with a 6 mm (0.25 in) diameter steel restraint cable. The installation was crash tested at a nominal speed of 100 km/h (60 mi/h). A 6 mm (0.25 in) diameter steel restraint cable, 305 mm (12 in) long was attached between the base of one of the couplings and bolted to the base of the pedestal using a 11 mm (0.4 in) bolt, nut and washer. The couplings were anchored to the pavement by threading the couplings to the existing 13 mm (0.5 in) diameter anchor bolts and then attaching the base of the pedestal to the top of the four couplings with 13 mm (0.5 in) nuts and washers. The Type II CBU installation prior to test 405461-B5 is shown in figure 31.

The bogie was traveling at a speed of 100.3 km/h (62.3 mi/h) at the time of contact with the pedestal. The pedestal began to move at 0.002 s after impact and the pedestal separated from the base at 0.007 s. At 0.010 s the pedestal began to separate from the mailbox and at 0.026 s the pedestal and mailbox were only attached at the bottom right corner of the mailbox. The restraint cable pulled taut causing the pedestal to deform around the bumper and shortly thereafter the cable broke. The bogie lost contact with the pedestal at 0.046 s. At 0.051 s the left side of the mailbox contacted the windshield area of the bogie, and at 0.053 s the windshield shattered. The bogie lost contact with the mailbox at 0.140 s. The mailbox and pedestal went up and to the side of the bogie with no further contact. Sequential photographs of the test are shown in figure 32.

The pedestal was deformed at bumper height and the mailbox unit separated into several pieces as seen in figure 33. The upper shear control point on the left rear coupling sheared and the left rear concrete anchor bolt was pulled up. The right front concrete anchor bolt sheared off at ground level where the restraint cable was attached. All other couplings sheared at the shear control points. There was minimal crush to the nose of the bogie; however, the simulated windshield was broken and the frame surrounding the windshield was severely deformed as shown in figure 34.

Quantitative occupant risk data were unobtainable due to the CBU installation striking the data telemetry hardware on the bogie. The average angular velocity of the CBU installation was 632.7 deg/s. The change in velocity of the bogie at loss of contact was 2.8 m/s (9.2 ft/s). The couplings performed well in the high-speed test. However, this test demonstrated a propensity for the CBU installation to intrude into the occupant compartment and present the potential for injury to an occupant in the vehicle.
Figure 31. Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation prior to test 405461-B5.
Figure 32. Sequential photographs for test 405461-B5.
Figure 33. Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation after test 405461-B5.
Figure 34. Vehicle crush damage after test 405461-B5.
The slip-base design was crash tested at a nominal speed of 100 km/h (60 mi/h). The slip-base was anchored to the pavement by nuts and washers on the existing 13 mm (0.5 in) diameter anchors bolts as shown in figure 35.

The bogie was traveling at a speed of 102.3 km/h (63.6 mi/h) at the time of contact with the pedestal. Movement of the pedestal began at 0.007 s, and the pedestal began to separate from the base of the mailbox and the bolts mounting the base of the slip-base began to come up out of the concrete at 0.010 s. At 0.026 s, the pedestal and mailbox were attached only at the bottom left corner. As the bogie continued moving forward, the pedestal deformed around the bumper. By 0.034 s, the bottom of the pedestal base separated from the slip-base and the concrete anchor bolts were completely pulled from the roadway. The cable added additional resistance before it broke. As the installation continued to rotate, the top right corner of the mailbox contacted the top section of the windshield area of the bogie at 0.048, and the windshield shattered at 0.050 s. At 0.053 s the pedestal completely separated from the mailbox and at 0.062 s the mailbox began to move upward and out of the windshield cavity area. The bogie lost contact with the pedestal at 0.110 s. Loss of contact with the mailbox occurred at 0.130 s. Sequential photographs of the test are shown in figure 36.

The pedestal was deformed at bumper height and the mailbox unit was separated into many pieces (see figure 37). All bolts in the base connection sheared or pulled out at the ground (see figure 38). The nose of the bogie received moderate crush, and the simulated windshield was broken and the windshield frame deformed as shown in figure 39.

Quantitative occupant risk data were unobtainable due to the CBU installation striking the data telemetry hardware on the bogie. In addition, the average angular velocity of the CBU installation was not attainable due to damage to the high-speed film. The change in velocity of the bogie at loss of contact was 3.6 m/s (11.8 ft/s). The slip-base performed poorly in the high-speed test, and demonstrated a propensity for the CBU installation to intrude into the occupant compartment and present the potential for injury to an occupant in the vehicle.
Figure 35. Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation prior to test 405461-B6.
Figure 36. Sequential photographs for test 405461-B6.
Figure 37. Vehicle and CBU installation after test 405461-B6.
Figure 38. Breakaway support coupling and 6 mm (0.25 in) cable restraint retrofitted CBU installation after test 405461-B6.
Figure 39. Vehicle crush damage after test 405461-B6.
SUMMARY OF FINDINGS

Two types of frangible mechanisms were designed and investigated in this study to retrofit Cluster Box Units (CBU) to a crashworthy condition that would be capable of complying with the safety performance guidelines set forth in NCHRP Report 350. The study approach, in order of importance, to the retrofit design for the CBU installation was to: (1) provide a design that produced acceptable occupant risk values and did not allow penetration into the occupant compartment, (2) minimize hazards produced by debris from the struck CBU installation, and (3) provide an installation that was structurally adequate to carry the required wind, ice, and service loads. The two retrofits investigated were a TTI designed slip-base and Transpo Industries Pole Safe Breakaway Support Coupling Model No. 4050. Both frangible mechanisms were designed as a retrofit for existing CBU installations. Installation of the retrofit hardware in both cases consisted of simply unbolting the existing CBU pedestal from the concrete anchor bolts, bolting down either the slip-base unit or the frangible coupling using the existing concrete anchor bolts, and nuts and then reattaching the CBU installation atop the new yielding connection with standard nuts and washers.

In low-speed bogie crash tests, the slip-base and the coupling both satisfied the occupant risk and vehicle/installation trajectory criteria outlined in NCHRP Report 350. In addition, when a 6 mm (0.25 in) steel restraint cable was added to the coupling, the performance was enhanced. The same enhanced performance is expected by the slip-base, if tested with the restraint cable. The cable provides restraining force to allow the pedestal to be engaged further and permit the pedestal to pocket and deform around the front of the vehicle. As the pedestal deforms around the front of the vehicle, (1) the angular velocity of the installation is reduced, (2) the mailbox is brought down and into contact with the hood, and (3) more time is created for the CBU installation to accelerate to the speed of the impacting vehicle. If these three conditions can be met in the correct proportions, the vehicle will not sustain excessive deceleration and the struck installation will not be propelled into the occupant compartment. In addition, because ductility and mass are desirable material properties of the pedestal, the bent plate steel pedestal may show some advantages over its extruded aluminum counterpart in full-scale crash testing. The steel pedestal demonstrated a propensity to more readily permit the pedestal to deform around the front of the vehicle. In addition, the additional mass of the steel pedestal lowers the vertical center of gravity of the CBU installation.

In both high-speed bogie crash tests, quantitative occupant risk data were unobtainable due to the CBU installation striking the data telemetry hardware on the bogie. The slip-base and coupling were both installed and crash tested with the 6 mm (0.5 in) steel restraint cable. In both tests, the installations demonstrated a propensity for intrusion into the occupant compartment by striking the windshield and bending the windshield frame. The Transpo couplings performed as intended. The TTI slip-base activated, but only after the concrete anchor bolts were pulled from the roadway first. The performance of the slip-base was poor.
in the high-speed test. In both high-speed tests, the pedestal, when struck, pulled out the bottom of the mailbox. The detached mailbox may present a hazard to other motor vehicles and pedestrians in the area.

Static load tests were performed on the TTI slip-base and Transpo Industries Pole Safe Breakaway Support Coupling Model No. 4050. Both retrofit devices were successfully capable of sustaining a minimum static bending moment of 2441 Nm (1800 ft-lb).

CONCLUSIONS

The TTI slip-base and Transpo Industries Pole Safe Breakaway Support Coupling Model No. 4050 are both viable solutions for retrofitting existing CBU installations and for new construction. However, before implementation, a number of unresolved issues must first be addressed. In all tests performed, the vehicle accelerations and occupant impact velocities were acceptable. In low-speed applications, the retrofits described in this study would provide safe solutions for the USPS. However, the installations should be full-scale crash tested with a 820 kg (1800 lb) passenger vehicle at high-speed (100 km/h (60 mi/h)) to evaluate more precisely the extent of intrusion into the occupant compartment. The fact still remains that CBU installations are dimensionally large units and may not intrude far enough into the occupant compartment to cause serious injury to the occupants of the vehicle. In addition, a larger restraint cable warrants investigation. The activation forces in the low-speed crash tests were sufficiently low and a large margin in the safety performance exists at low-speed. Therefore, by increasing the restraint cable size, the impact severity will be incrementally more severe in low-speed impacts but may yield great benefits in high-speed impacts. However, the benefit of a larger restraint cable may only be realized if the structural connection between the CBU and pedestal can be maintained. A strap retrofitted around the CBU and anchored to the pedestal may be necessary to fully develop the connection.

The design of the TTI slip-base was modified subsequent to the conduct of the tests in this study. The new design is shown in figure 4. The design modification was prompted by the poor performance of the slip-base in the high-speed bogie test. The concrete anchor bolts pulled from the pavement prior to the slip-base activating. This event may have occurred because of excessive moment between the pedestal and the slip bolts. Therefore, the slip plane size was reduced to minimize the moment introduced in the connection.

The estimated cost of the TTI slip-base is approximately $100.00 and the cost for four Transpo Industries Pole Safe Breakaway Support Couplings, Model No. 4050, is $80.00. These cost estimates are for the systems only and do not include installation costs.
RECOMMENDATIONS

As recommended by AASHTO, CBU installations should not be erected within the clear zone of roadways. This is especially true of high-speed roadways. When a CBU installation can not be relocated or erection must occur along a high-speed roadway, the CBU installation(s) should be crash tested in accordance with the criteria presented in NCHRP Report 350. In addition, guidelines must be provided for properly spacing multiple CBU installations so that the crash performance of the installation is not compromised.

When existing CBU installations can not be relocated and retrofitting is the only solution, then full-scale crash tests should be conducted to validate the performance of the retrofitted CBU installation. The TTI slip-base and the Transpo Industries Pole Safe Breakaway Support Coupling Model No. 4050 are good candidates for the CBU retrofit. The low-speed bogie test results already indicate the retrofits are suitable for residential areas where travel speeds are typically low. However, full-scale vehicular crash testing is needed to fully understand the trajectory dynamics and the severity of the impact with the CBU installation at high speeds (100 km/h (60 mi/h)). To this end, high-speed crash tests should be performed to evaluate the occupant compartment intrusion prior to any further low-speed testing.

Where available and in cooperation with municipalities, the rear of luminaire supports may be considered as a potential mounting location of CBU’s. The taller and greater mass of luminaires may offer a viable solution to the occupant compartment intrusion problem. Luminaires mounted along high-speed roadways have normally been crash tested and their performance is proven. Typically when struck at high speeds, the luminaire will travel up and over the errant vehicle. The retrofit of a CBU to a luminaire support however would still require additional crash testing.

The Federal Highway Administration allows the installation of proprietary roadside hardware. The USPS should consider requiring their vendors in the future to provide crash-test approved hardware for USPS purchases of CBU installations. If the USPS, however, should decide to proceed with full-scale crash testing, an estimate of what testing might be required to determine the acceptability of these pieces of equipment is possible. Specifically, the following should be considered:

- The USPS requested a retrofit for nine types of central delivery equipment, (1) the three types of NDCBU, including pedestal, which are fabricated of steel only, (2) the three types of CBU, including pedestal, which are made of aluminum, and (3) the three types of CBU, including pedestal, which are made of plastic.

- The pedestals and boxes of each of these three groups of central delivery equipment are never mixed and matched with pedestals or boxes from the other two groups.
• Types I and III of the plastic CBU's and of the aluminum CBU's may be close enough in design/weight/crash response that only a Type I or a Type III in aluminum and plastic could require full-scale crash testing.

• Lastly, the NDCBU features a unique design feature that virtually eliminates it from consideration in high-speed clear zones. In particular, the poor performance of the box-to-pedestal bolts, under crash conditions, are very similar to that of a break-away device. This is not acceptable since the box could not be consistently counted on to behave in such a way as to take full advantage of the installation of a break-away device at the pedestal base.

Based on this, it is estimated that, as a minimum, five low-speed tests and four high-speed tests would be required. The low-speed tests may only be needed for one of the steel NDCBU’s. This would most likely be for the largest of the three sizes since it might have greatest chance of having crash debris penetrate the windshield. In addition, two aluminum CBU’s would need low-speed testing; a Type II and either a Type I or III. The same set of low-speed testing would be required for the plastic CBU. Only CBU’s are considered potential candidates for high-speed crash locations and, because of this, the same set of CBU tests would be required as for the low-speed test. Once again, the recommendation would be to keep NDCBU’s out of high-speed clear zone locations.

In the bogie tests performed, aluminum and steel pedestals were mixed with aluminum CBU’s due to a shortage of available test pieces. While the steel pedestals did in fact have a more desirable performance characteristic, the performance of the aluminum pedestals with the aluminum CBU’s was acceptable. The steel pedestal more readily deformed around the front of the vehicle, allowing the CBU to translate more and rotate less. With both configurations, however, it was clearly established that full-scale crash testing is mandatory to ultimately determine the true clear zone acceptability of roadside CBU installations.

It is recommended that the USPS continue to strive for hardware standardization to reduce the effort and expense necessary to provide crashworthy CBU installations.
REFERENCES


