EVALUATION OF THE CRASH WORTHINESS OF
THE FLORIDA THIN WALLED ALUMINUM TUBE
AND STEEL U-CHANNEL SIGN SUPPORTS

Prepared by
D. Lance Bullard, Jr.

Prepared for
Florida Department of Transportation
605 Suwannee Street
Tallahassee, Florida 32399-0450

SAFETY DIVISION
TEXAS TRANSPORTATION INSTITUTE
THE TEXAS A&M UNIVERSITY SYSTEM
COLLEGE STATION, TEXAS 77843
EVALUATION OF THE CRASH WORTHINESS OF
THE FLORIDA THIN WALLED ALUMINUM TUBE
AND STEEL U-CHANNEL SIGN SUPPORTS

by

D. Lance Bullard, Jr.
Engineering Research Associate

Research Report RF 7185-1F

Sponsored by

Florida Department of Transportation
605 Suwannee Street
Tallahassee, Florida 32399-0450

February 1992

Safety Division
Texas Transportation Institute
Texas A&M University System
College Station, Texas 77843
DISCLAIMER

This document is disseminated under the sponsorship of the State of Florida Department of Transportation. The contents of this report reflect the views of the author who is solely responsible for the opinions, findings, and conclusions presented herein. The report does not necessarily reflect the official views or policies of the Florida Department of Transportation. This report does not constitute a standard, specification, or regulation. The Florida Department of Transportation assumes no liability for its contents or use thereof. The Florida Department of Transportation does not endorse products or manufacturers. Trade or manufacturers names appear herein only to facilitate communication.
ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation for the guidance and expertise of Dr. J. R. Morgan throughout this project. In addition, special thanks goes to the TII Proving Ground personnel for their excellent job in setting up and conducting the crash tests.
PREFACE

The Florida Department of Transportation (herein referred to as the Department) contracted with the Texas Transportation Institute (TTI) in 1985 to conduct full-scale crash tests on round-tube aluminum sign support installations installed in strong soil (TTI Project No. 0314F) (1), as defined in National Cooperative Highway Research Program (NCHRP) Report 230 (2). The objective of these tests was to assess the impact characteristics of aluminum single-support sign installations when impacted by 1,800 pound automobiles traveling 20 and 60 mile per hour. Standards set forth in 1975 AASHTO "Standards Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals" (3) and NCHRP Report 230 were used for analysis and evaluation of these tests. The sign supports tested were the 3/16 in x 4 in, 3/16 in x 4-1/2 in and 1/4 in x 5 in 6061-T6 aluminum tubes. Of the tests conducted, the 3/16 in x 4 in aluminum tube sign support was the only installation that successfully complied with all the safety performance criteria of NCHRP Report 230 and 1975 AASHTO.

The Department is currently using the 3/16 in x 4 in aluminum tube sign supports. As previously mentioned, this installation was found to meet NCHRP Report 230 strong soil (S-1) test criteria. However, the Department was aware of the importance of soil strength and the need to test the safety appurtenance in the most appropriate soil type consistent with potential applications. The Department therefore sought to evaluate the impact performance of 3/16 in x 4 in aluminum tube sign supports weak soil (S-2) criteria in NCHRP Report 230.

To this end, the Department contracted with TTI on February 14, 1991 to (1) conduct crash tests on the 3/16 in x 4 in aluminum tube sign support installed in weak soil and (2) conduct static and crash tests on 4 lb/ft steel u-channel sign supports. Initially the project consisted of 20 full-scale vehicular crash tests and nine static load tests. The first two crash tests were conducted on the aluminum tube support and the remainder of the crash tests were to be conducted on the steel u-channel. Upon completion of crash testing, however, performance of the aluminum tube support was found to be unacceptable, and, thereof, it became apparent that a retrofit of this design, and additional crash tests, would be necessary. Accordingly, the project was modified September 25, 1991 to include
pendulum tests and additional crash tests. In addition, 3/16 in x 3-1/2 in aluminum tube sign supports were added to the test matrix of pendulum and crash tests.
TABLE OF CONTENTS

I. INTRODUCTION ................................................................. 1

II. STATIC LOAD TESTS ......................................................... 2
      Objective ................................................................. 2
      Static Test Procedure ................................................. 2
      Static Test Description .............................................. 2

III. PENDULUM TESTS .......................................................... 7
      Objective ................................................................. 7
      Pendulum Instrumentation ............................................ 7
      Pendulum Test Procedure ............................................ 7
      Pendulum Test Discussion ............................................ 11

IV. FULL-SCALE CRASH TESTS ................................................. 13
      Objective ................................................................. 13
      Description of Test Installations ................................. 13
      Aluminum Tube Sign Installations .................................. 13
      Steel U-Channel Sign Installations .................................. 13
      Description of Crash Test Procedures ............................ 16
      Data Analysis Procedures ............................................ 18
      Evaluation Criteria .................................................. 19
      CRASH TEST RESULTS .................................................. 21
      Test 7185-1 ............................................................... 21
      Test 7185-2 ............................................................... 35
      Test 7185-3 ............................................................... 43
      Test 7185-4 ............................................................... 53
      Test 7185-5 ............................................................... 64
      Test 7185-6 ............................................................... 88
<table>
<thead>
<tr>
<th>TABLE OF CONTENTS (continued)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test 7185-7 .................. 101</td>
</tr>
<tr>
<td>Test 7185-8 .................. 108</td>
</tr>
<tr>
<td>Test 7185-9 .................. 121</td>
</tr>
<tr>
<td>Test 7185-10 ................ 143</td>
</tr>
<tr>
<td>Test 7185-11 ................ 156</td>
</tr>
<tr>
<td>Test 7185-12 ................ 164</td>
</tr>
<tr>
<td>Test 7185-13 ................ 173</td>
</tr>
<tr>
<td>Test 7185-14 ................ 186</td>
</tr>
<tr>
<td>Test 7185-15 ................ 210</td>
</tr>
<tr>
<td>Test 7185-16 ................ 224</td>
</tr>
<tr>
<td>Test 7185-17 ................ 234</td>
</tr>
<tr>
<td>Test 7185-18 ................ 244</td>
</tr>
<tr>
<td>Test 7185-19 ................ 255</td>
</tr>
<tr>
<td>Test 7185-20 ................ 279</td>
</tr>
</tbody>
</table>

V. FINDINGS AND CONCLUSIONS ........................... 291
   Aluminum Tube Sign Installations .................. 291
   Steel U-Channel Sign Installations ................ 291

REFERENCES ............................................. 294
APPENDIXES ............................................ 295
   A. Force vs Displacement Graphs of Static Load Tests ........ 295
   B. Longitudinal Accelerometer Traces for Pendulum Tests .... 305
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>T.T.I. Small Sign Support Station before test</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>T.T.I. Small Sign Support Station after completed test</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>Details of 3/16” x 4” aluminum tube retrofits</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>Details of 3/16” x 4” aluminum tube retrofits (Continued)</td>
<td>9</td>
</tr>
<tr>
<td>4</td>
<td>Typical pretest pendulum configuration</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>Aluminum Tube Sign Installation</td>
<td>14</td>
</tr>
<tr>
<td>6</td>
<td>Steel U-channel Sign Installation</td>
<td>15</td>
</tr>
<tr>
<td>7</td>
<td>Details of U-channel splice configurations</td>
<td>17</td>
</tr>
<tr>
<td>8</td>
<td>Vehicle before test 7185-1</td>
<td>22</td>
</tr>
<tr>
<td>9</td>
<td>Vehicle/Sign geometrics (test 7185-1)</td>
<td>23</td>
</tr>
<tr>
<td>10</td>
<td>Florida thin walled aluminum tube sign installation before test 7185-1</td>
<td>24</td>
</tr>
<tr>
<td>11</td>
<td>Test vehicle properties (7185-1 &amp; 2)</td>
<td>25</td>
</tr>
<tr>
<td>12</td>
<td>Sequential photographs of test 7185-1</td>
<td>26</td>
</tr>
<tr>
<td>12</td>
<td>Sequential photographs of test 7185-1 (Continued)</td>
<td>27</td>
</tr>
<tr>
<td>13</td>
<td>Florida thin walled aluminum tube installation after test 7185-1</td>
<td>28</td>
</tr>
<tr>
<td>13</td>
<td>Florida thin walled aluminum tube installation after test 7185-1 (Continued)</td>
<td>29</td>
</tr>
<tr>
<td>14</td>
<td>Summary of results for test 7185-1</td>
<td>30</td>
</tr>
<tr>
<td>15</td>
<td>Vehicle angular displacement for test 7185-1</td>
<td>31</td>
</tr>
<tr>
<td>16</td>
<td>Longitudinal accelerometer trace (7185-1)</td>
<td>32</td>
</tr>
<tr>
<td>17</td>
<td>Lateral accelerometer trace (7185-1)</td>
<td>33</td>
</tr>
<tr>
<td>18</td>
<td>Vertical accelerometer trace (7185-1)</td>
<td>34</td>
</tr>
<tr>
<td>19</td>
<td>Florida thin walled aluminum tube sign installation before test 7185-2</td>
<td>36</td>
</tr>
<tr>
<td>20</td>
<td>Sequential photographs of test 7185-2</td>
<td>37</td>
</tr>
<tr>
<td>20</td>
<td>Sequential photographs of test 7185-2 (Continued)</td>
<td>38</td>
</tr>
<tr>
<td>21</td>
<td>Florida thin walled aluminum tube installation after test 7185-2</td>
<td>39</td>
</tr>
<tr>
<td>22</td>
<td>Vehicle after test 7185-2</td>
<td>40</td>
</tr>
<tr>
<td>23</td>
<td>Summary of results for test 7185-2</td>
<td>41</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>24</td>
<td>Vehicle angular displacement for 7185-2</td>
<td>42</td>
</tr>
<tr>
<td>25</td>
<td>Longitudinal accelerometer trace (7185-2)</td>
<td>44</td>
</tr>
<tr>
<td>26</td>
<td>Lateral accelerometer trace (7185-2)</td>
<td>45</td>
</tr>
<tr>
<td>27</td>
<td>Vertical accelerometer trace (7185-2)</td>
<td>46</td>
</tr>
<tr>
<td>28</td>
<td>Vehicle before test 7185-3</td>
<td>47</td>
</tr>
<tr>
<td>29</td>
<td>Vehicle/sign geometric (test 7185-3)</td>
<td>48</td>
</tr>
<tr>
<td>30</td>
<td>Sign installation before test 7185-3</td>
<td>49</td>
</tr>
<tr>
<td>31</td>
<td>Test vehicle properties (7185-3 &amp; 4)</td>
<td>50</td>
</tr>
<tr>
<td>32</td>
<td>Sequential photographs of test 7185-3</td>
<td>51</td>
</tr>
<tr>
<td>33</td>
<td>Sequential photographs of test 7185-3 (Continued)</td>
<td>52</td>
</tr>
<tr>
<td>34</td>
<td>Sign installation after test 7185-3</td>
<td>53</td>
</tr>
<tr>
<td>35</td>
<td>Vehicle after test 7185-3</td>
<td>54</td>
</tr>
<tr>
<td>36</td>
<td>Summary of results for test 7185-3</td>
<td>55</td>
</tr>
<tr>
<td>37</td>
<td>Vehicle angular displacement for test 7185-3</td>
<td>56</td>
</tr>
<tr>
<td>38</td>
<td>Longitudinal accelerometer trace (7185-3)</td>
<td>57</td>
</tr>
<tr>
<td>39</td>
<td>Lateral accelerometer trace (7185-3)</td>
<td>58</td>
</tr>
<tr>
<td>40</td>
<td>Vertical accelerometer trace (7185-3)</td>
<td>59</td>
</tr>
<tr>
<td>41</td>
<td>Vehicle before test 7185-4</td>
<td>60</td>
</tr>
<tr>
<td>42</td>
<td>Vehicle/sign geometric (test 7185-4)</td>
<td>61</td>
</tr>
<tr>
<td>43</td>
<td>Sign installation before test 7185-4</td>
<td>62</td>
</tr>
<tr>
<td>44</td>
<td>Sequential photographs of test 7185-4</td>
<td>63</td>
</tr>
<tr>
<td>45</td>
<td>Sequential photographs of test 7185-4 (Continued)</td>
<td>64</td>
</tr>
<tr>
<td>46</td>
<td>Sign installation after test 7185-4</td>
<td>65</td>
</tr>
<tr>
<td>47</td>
<td>Vehicle after test 7185-4</td>
<td>66</td>
</tr>
<tr>
<td>48</td>
<td>Summary of results for test 7185-4</td>
<td>67</td>
</tr>
<tr>
<td>49</td>
<td>Vehicle angular displacement for test 7185-4</td>
<td>68</td>
</tr>
<tr>
<td></td>
<td>Longitudinal accelerometer trace (7185-4)</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>Lateral accelerometer trace (7185-4)</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>71</td>
</tr>
<tr>
<td></td>
<td></td>
<td>72</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>------------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>50</td>
<td>Vertical accelerometer trace (7185-4)</td>
<td>73</td>
</tr>
<tr>
<td>51</td>
<td>Vehicle before test 7185-5</td>
<td>74</td>
</tr>
<tr>
<td>52</td>
<td>Vehicle/sign geometrics (test 7185-5)</td>
<td>75</td>
</tr>
<tr>
<td>53</td>
<td>Sign installation before test 7185-5</td>
<td>76</td>
</tr>
<tr>
<td>54</td>
<td>Test vehicle properties (7185-5 &amp; 6)</td>
<td>78</td>
</tr>
<tr>
<td>55</td>
<td>Sequential photographs for test 7185-5</td>
<td>79</td>
</tr>
<tr>
<td>55</td>
<td>Sequential photographs for test 7185-5 (Continued)</td>
<td>80</td>
</tr>
<tr>
<td>56</td>
<td>Sign installation after test 7185-5</td>
<td>81</td>
</tr>
<tr>
<td>57</td>
<td>Vehicle after test 7185-5</td>
<td>82</td>
</tr>
<tr>
<td>58</td>
<td>Summary of results for test 7185-5</td>
<td>83</td>
</tr>
<tr>
<td>59</td>
<td>Vehicle angular displacement for test 7185-5</td>
<td>84</td>
</tr>
<tr>
<td>60</td>
<td>Longitudinal accelerometer trace (7185-5)</td>
<td>85</td>
</tr>
<tr>
<td>61</td>
<td>Lateral accelerometer trace (7185-5)</td>
<td>86</td>
</tr>
<tr>
<td>62</td>
<td>Vertical accelerometer trace (7185-5)</td>
<td>87</td>
</tr>
<tr>
<td>63</td>
<td>Vehicle before test 7185-6</td>
<td>89</td>
</tr>
<tr>
<td>64</td>
<td>Sign installation before test 7185-6</td>
<td>90</td>
</tr>
<tr>
<td>65</td>
<td>Vehicle/sign geometrics (test 7185-6)</td>
<td>91</td>
</tr>
<tr>
<td>66</td>
<td>Sequential photographs for test 7185-6</td>
<td>92</td>
</tr>
<tr>
<td>66</td>
<td>Sequential photographs for test 7185-6 (Continued)</td>
<td>93</td>
</tr>
<tr>
<td>67</td>
<td>Sign installation after test 7185-6</td>
<td>94</td>
</tr>
<tr>
<td>68</td>
<td>Vehicle after test 7185-6</td>
<td>95</td>
</tr>
<tr>
<td>69</td>
<td>Summary results for test 7185-6</td>
<td>96</td>
</tr>
<tr>
<td>70</td>
<td>Vehicle angular displacement for test 7185-6</td>
<td>97</td>
</tr>
<tr>
<td>71</td>
<td>Longitudinal accelerometer trace (7185-6)</td>
<td>98</td>
</tr>
<tr>
<td>72</td>
<td>Lateral accelerometer trace (7185-6)</td>
<td>99</td>
</tr>
<tr>
<td>73</td>
<td>Vertical accelerometer trace (7185-6)</td>
<td>100</td>
</tr>
<tr>
<td>74</td>
<td>Vehicle before test 7185-7</td>
<td>102</td>
</tr>
<tr>
<td>75</td>
<td>Sign installation before test 7185-7</td>
<td>103</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>76</td>
<td>Vehicle/sign geometrics (test 7185-7)</td>
<td>104</td>
</tr>
<tr>
<td>77</td>
<td>Test vehicle properties (7185-7 &amp; 8)</td>
<td>105</td>
</tr>
<tr>
<td>78</td>
<td>Sequential photographs for test 7185-7</td>
<td>106</td>
</tr>
<tr>
<td>78</td>
<td>Sequential photographs for test 7185-7 (Continued)</td>
<td>107</td>
</tr>
<tr>
<td>79</td>
<td>Vehicle after test 7185-7</td>
<td>109</td>
</tr>
<tr>
<td>80</td>
<td>Sign installation after test 7185-7</td>
<td>110</td>
</tr>
<tr>
<td>81</td>
<td>Summary of results for test 7185-7</td>
<td>111</td>
</tr>
<tr>
<td>82</td>
<td>Vehicle angular displacement for test 7185-7</td>
<td>112</td>
</tr>
<tr>
<td>83</td>
<td>Longitudinal accelerometer trace (7185-7)</td>
<td>113</td>
</tr>
<tr>
<td>84</td>
<td>Lateral accelerometer trace (7185-7)</td>
<td>114</td>
</tr>
<tr>
<td>85</td>
<td>Vertical accelerometer trace (7185-7)</td>
<td>115</td>
</tr>
<tr>
<td>86</td>
<td>Vehicle before test 7185-8</td>
<td>116</td>
</tr>
<tr>
<td>87</td>
<td>Sign installation before test 7185-8</td>
<td>117</td>
</tr>
<tr>
<td>88</td>
<td>Vehicle/sign geometrics (test 7185-8)</td>
<td>118</td>
</tr>
<tr>
<td>89</td>
<td>Sequential photographs for test 7185-8</td>
<td>119</td>
</tr>
<tr>
<td>89</td>
<td>Sequential photographs for test 7185-8 (Continued)</td>
<td>120</td>
</tr>
<tr>
<td>90</td>
<td>Sign installation after test 7185-8</td>
<td>122</td>
</tr>
<tr>
<td>91</td>
<td>Vehicle after test 7185-8</td>
<td>123</td>
</tr>
<tr>
<td>92</td>
<td>Summary of results for test 7185-8</td>
<td>124</td>
</tr>
<tr>
<td>93</td>
<td>Vehicle angular displacement for test 7185-8</td>
<td>125</td>
</tr>
<tr>
<td>94</td>
<td>Longitudinal accelerometer trace (7185-8)</td>
<td>126</td>
</tr>
<tr>
<td>95</td>
<td>Lateral accelerometer trace (7185-8)</td>
<td>127</td>
</tr>
<tr>
<td>96</td>
<td>Vertical accelerometer trace (7185-8)</td>
<td>128</td>
</tr>
<tr>
<td>97</td>
<td>Vehicle before test 7185-9</td>
<td>129</td>
</tr>
<tr>
<td>98</td>
<td>Sign installation before test 7185-9</td>
<td>130</td>
</tr>
<tr>
<td>99</td>
<td>Vehicle/sign geometrics 7185-9</td>
<td>131</td>
</tr>
<tr>
<td>100</td>
<td>Test vehicle properties (7185-9 &amp; 10)</td>
<td>133</td>
</tr>
<tr>
<td>101</td>
<td>Sequential photographs of test 7185-9</td>
<td>134</td>
</tr>
</tbody>
</table>
**LIST OF FIGURES (continued)**

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>Sequential photographs of test 7185-9 (Continued)</td>
<td>135</td>
</tr>
<tr>
<td>102</td>
<td>Sign installation after test 7185-9</td>
<td>136</td>
</tr>
<tr>
<td>103</td>
<td>Vehicle after test 7185-9</td>
<td>137</td>
</tr>
<tr>
<td>104</td>
<td>Summary of results for test 7185-9</td>
<td>138</td>
</tr>
<tr>
<td>105</td>
<td>Vehicle angular displacement for test 7185-9</td>
<td>139</td>
</tr>
<tr>
<td>106</td>
<td>Longitudinal accelerometer trace (7185-9)</td>
<td>140</td>
</tr>
<tr>
<td>107</td>
<td>Lateral accelerometer trace (7185-9)</td>
<td>141</td>
</tr>
<tr>
<td>108</td>
<td>Vertical accelerometer trace (7185-9)</td>
<td>142</td>
</tr>
<tr>
<td>109</td>
<td>Vehicle before test 7185-10</td>
<td>144</td>
</tr>
<tr>
<td>110</td>
<td>Sign installation before test 7185-10</td>
<td>145</td>
</tr>
<tr>
<td>111</td>
<td>Vehicle/sign geometrics (test 7185-10)</td>
<td>146</td>
</tr>
<tr>
<td>112</td>
<td>Sequential photographs of test 7185-10</td>
<td>147</td>
</tr>
<tr>
<td>112</td>
<td>Sequential photographs of test 7185-10 (Continued)</td>
<td>148</td>
</tr>
<tr>
<td>113</td>
<td>Sign installation before test 7185-10 (Continued)</td>
<td>149</td>
</tr>
<tr>
<td>114</td>
<td>Vehicle after test 7185-10</td>
<td>150</td>
</tr>
<tr>
<td>115</td>
<td>Summary of results for test 7185-10</td>
<td>151</td>
</tr>
<tr>
<td>116</td>
<td>Vehicle angular displacement for test 7185-10</td>
<td>152</td>
</tr>
<tr>
<td>117</td>
<td>Longitudinal accelerometer trace (7185-10)</td>
<td>153</td>
</tr>
<tr>
<td>118</td>
<td>Lateral accelerometer trace (7185-10)</td>
<td>154</td>
</tr>
<tr>
<td>119</td>
<td>Vertical accelerometer trace (7185-10)</td>
<td>155</td>
</tr>
<tr>
<td>120</td>
<td>Vehicle before test 7185-11</td>
<td>157</td>
</tr>
<tr>
<td>121</td>
<td>Sign installation before test 7185-11</td>
<td>158</td>
</tr>
<tr>
<td>122</td>
<td>Vehicle/sign geometrics (test 7185-11)</td>
<td>159</td>
</tr>
<tr>
<td>123</td>
<td>Test Vehicle properties (7185-11 &amp; 12)</td>
<td>160</td>
</tr>
<tr>
<td>124</td>
<td>Sequential photographs of test 7185-11</td>
<td>161</td>
</tr>
<tr>
<td>124</td>
<td>Sequential photographs of test 7185-11 (Continued)</td>
<td>162</td>
</tr>
<tr>
<td>125</td>
<td>Sign installation after test 7185-11</td>
<td>163</td>
</tr>
<tr>
<td>126</td>
<td>Summary of results for test 7185-11</td>
<td>165</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES (continued)

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>127</td>
<td>Vehicle angular displacement for test 7185-11</td>
<td>166</td>
</tr>
<tr>
<td>128</td>
<td>Vehicle longitudinal accelerometer trace for test 7185-11</td>
<td>167</td>
</tr>
<tr>
<td>129</td>
<td>Vehicle lateral accelerometer trace for test 7185-11</td>
<td>168</td>
</tr>
<tr>
<td>130</td>
<td>Vehicle vertical accelerometer trace for test 7185-11</td>
<td>169</td>
</tr>
<tr>
<td>131</td>
<td>Vehicle before test 7185-12</td>
<td>170</td>
</tr>
<tr>
<td>132</td>
<td>Sign installation before test 7185-12</td>
<td>171</td>
</tr>
<tr>
<td>133</td>
<td>Vehicle/sign geometrics (test 7185-12)</td>
<td>172</td>
</tr>
<tr>
<td>134</td>
<td>Sequential photographs of test 7185-12</td>
<td>174</td>
</tr>
<tr>
<td>134</td>
<td>Sequential photographs of test 7185-12 (Continued)</td>
<td>175</td>
</tr>
<tr>
<td>135</td>
<td>Sign installation after test 7185-12 (Continued)</td>
<td>176</td>
</tr>
<tr>
<td>136</td>
<td>Details of vehicle damage after test 7185-12</td>
<td>177</td>
</tr>
<tr>
<td>137</td>
<td>Summary of results for test 7185-12</td>
<td>178</td>
</tr>
<tr>
<td>138</td>
<td>Vehicle angular displacement for test 7185-12</td>
<td>179</td>
</tr>
<tr>
<td>139</td>
<td>Vehicle longitudinal accelerometer trace for test 7185-12</td>
<td>180</td>
</tr>
<tr>
<td>140</td>
<td>Vehicle lateral accelerometer trace for test 7185-12</td>
<td>181</td>
</tr>
<tr>
<td>141</td>
<td>Vehicle vertical accelerometer trace for test 7185-12</td>
<td>182</td>
</tr>
<tr>
<td>142</td>
<td>Vehicle before test 7185-13</td>
<td>183</td>
</tr>
<tr>
<td>143</td>
<td>Sign installation before test 7185-13</td>
<td>184</td>
</tr>
<tr>
<td>144</td>
<td>Vehicle/sign geometrics (test 7185-13)</td>
<td>185</td>
</tr>
<tr>
<td>145</td>
<td>Test vehicle properties (7185-13 &amp; 14)</td>
<td>187</td>
</tr>
<tr>
<td>146</td>
<td>Sequential photographs of test 7185-13</td>
<td>188</td>
</tr>
<tr>
<td>146</td>
<td>Sequential photographs of test 7185-13 (Continued)</td>
<td>189</td>
</tr>
<tr>
<td>147</td>
<td>Sign installation after test 7185-13 (Continued)</td>
<td>190</td>
</tr>
<tr>
<td>148</td>
<td>Vehicle after test 7185-13</td>
<td>191</td>
</tr>
<tr>
<td>149</td>
<td>Summary of results for test 7185-13</td>
<td>192</td>
</tr>
<tr>
<td>150</td>
<td>Vehicle angular displacement for test 7185-13</td>
<td>193</td>
</tr>
<tr>
<td>151</td>
<td>Longitudinal accelerometer trace for test 7185-13</td>
<td>194</td>
</tr>
<tr>
<td>152</td>
<td>Lateral accelerometer trace for test 7185-13</td>
<td>195</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>153</td>
<td>Vertical accelerometer trace for test 7185-13</td>
<td>196</td>
</tr>
<tr>
<td>154</td>
<td>Vehicle before test 7185-14</td>
<td>197</td>
</tr>
<tr>
<td>155</td>
<td>Sign installation before test 7185-14</td>
<td>198</td>
</tr>
<tr>
<td>156</td>
<td>Vehicle/sign geometrics (test 7185-14)</td>
<td>200</td>
</tr>
<tr>
<td>157</td>
<td>Sequential photographs of test 7185-14</td>
<td>201</td>
</tr>
<tr>
<td>157</td>
<td>Sequential photographs of test 7185-14 (Continued)</td>
<td>202</td>
</tr>
<tr>
<td>158</td>
<td>Sign installation after test 7185-14</td>
<td>203</td>
</tr>
<tr>
<td>159</td>
<td>Vehicle after test 7185-14</td>
<td>204</td>
</tr>
<tr>
<td>160</td>
<td>Summary of results for test 7185-14</td>
<td>205</td>
</tr>
<tr>
<td>161</td>
<td>Vehicle angular displacement for test 7185-14</td>
<td>206</td>
</tr>
<tr>
<td>162</td>
<td>Longitudinal accelerometer trace for test 7185-14</td>
<td>207</td>
</tr>
<tr>
<td>163</td>
<td>Lateral accelerometer trace for test 7185-14</td>
<td>208</td>
</tr>
<tr>
<td>164</td>
<td>Vertical accelerometer trace for test 7185-14</td>
<td>209</td>
</tr>
<tr>
<td>165</td>
<td>Vehicle before test 7185-15</td>
<td>211</td>
</tr>
<tr>
<td>166</td>
<td>Sign installation before test 7185-15</td>
<td>212</td>
</tr>
<tr>
<td>167</td>
<td>Sign/vehicle geometrics (test 7185-15)</td>
<td>213</td>
</tr>
<tr>
<td>168</td>
<td>Test vehicle properties (7185-15 &amp; 16)</td>
<td>214</td>
</tr>
<tr>
<td>169</td>
<td>Sequential photographs of test 7185-15</td>
<td>215</td>
</tr>
<tr>
<td>169</td>
<td>Sequential photographs of test 7185-15 (Continued)</td>
<td>216</td>
</tr>
<tr>
<td>170</td>
<td>Sign installation after test 7185-15</td>
<td>217</td>
</tr>
<tr>
<td>171</td>
<td>Details of damage to vehicle (test-15)</td>
<td>218</td>
</tr>
<tr>
<td>172</td>
<td>Summary of results for test 7185-15</td>
<td>219</td>
</tr>
<tr>
<td>173</td>
<td>Vehicle angular displacement for test 7185-15</td>
<td>220</td>
</tr>
<tr>
<td>174</td>
<td>Longitudinal accelerometer trace for test 7185-15</td>
<td>221</td>
</tr>
<tr>
<td>175</td>
<td>Lateral accelerometer trace for test 7185-15</td>
<td>222</td>
</tr>
<tr>
<td>176</td>
<td>Vertical accelerometer trace for test 7185-15</td>
<td>223</td>
</tr>
<tr>
<td>177</td>
<td>Vehicle before test 7185-16</td>
<td>225</td>
</tr>
<tr>
<td>178</td>
<td>Sign installation before test 7185-16</td>
<td>226</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>179</td>
<td>Vehicle/sign geometrics (test 7185-16)</td>
<td>227</td>
</tr>
<tr>
<td>180</td>
<td>Sequential photographs of test 7185-16</td>
<td>228</td>
</tr>
<tr>
<td>180</td>
<td>Sequential photographs of test 7185-16 (Continued)</td>
<td>229</td>
</tr>
<tr>
<td>181</td>
<td>Sign installation after test 7185-16</td>
<td>230</td>
</tr>
<tr>
<td>182</td>
<td>Details of damage to vehicle (test 7185-16)</td>
<td>231</td>
</tr>
<tr>
<td>183</td>
<td>Summary of results for test 7185-16</td>
<td>232</td>
</tr>
<tr>
<td>184</td>
<td>Vehicle angular displacement for test 7185-16</td>
<td>233</td>
</tr>
<tr>
<td>185</td>
<td>Longitudinal accelerometer trace for test 7185-16</td>
<td>235</td>
</tr>
<tr>
<td>186</td>
<td>Lateral accelerometer trace for test 7185-16</td>
<td>236</td>
</tr>
<tr>
<td>187</td>
<td>Vertical accelerometer trace for test 7185-16</td>
<td>237</td>
</tr>
<tr>
<td>188</td>
<td>Vehicle before test 7185-17</td>
<td>238</td>
</tr>
<tr>
<td>189</td>
<td>Sign installation before test 7185-17</td>
<td>239</td>
</tr>
<tr>
<td>190</td>
<td>Vehicle/sign geometrics (test 7185-17)</td>
<td>240</td>
</tr>
<tr>
<td>191</td>
<td>Test vehicle properties (7185-17 &amp; 18)</td>
<td>241</td>
</tr>
<tr>
<td>192</td>
<td>Sequential photographs of test 7185-17</td>
<td>242</td>
</tr>
<tr>
<td>192</td>
<td>Sequential photographs of test 7185-17 (Continued)</td>
<td>243</td>
</tr>
<tr>
<td>193</td>
<td>Sign installation after test 7185-17</td>
<td>245</td>
</tr>
<tr>
<td>194</td>
<td>Vehicle after test 7185-17</td>
<td>246</td>
</tr>
<tr>
<td>195</td>
<td>Summary of results for test 7185-17</td>
<td>247</td>
</tr>
<tr>
<td>196</td>
<td>Vehicle angular displacement for test 7185-17</td>
<td>248</td>
</tr>
<tr>
<td>197</td>
<td>Longitudinal accelerometer trace for test 7185-17</td>
<td>249</td>
</tr>
<tr>
<td>198</td>
<td>Lateral accelerometer trace for test 7185-17</td>
<td>250</td>
</tr>
<tr>
<td>199</td>
<td>Vertical accelerometer trace for test 7185-17</td>
<td>251</td>
</tr>
<tr>
<td>200</td>
<td>Sign installation before test 7185-18</td>
<td>252</td>
</tr>
<tr>
<td>201</td>
<td>Vehicle before test 7185-18</td>
<td>253</td>
</tr>
<tr>
<td>202</td>
<td>Vehicle/sign geometrics (test 7185-18)</td>
<td>254</td>
</tr>
<tr>
<td>203</td>
<td>Sequential photographs of test 7185-18</td>
<td>256</td>
</tr>
<tr>
<td>203</td>
<td>Sequential photographs of test 7185-18 (Continued)</td>
<td>257</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>204</td>
<td>Sign installation after test 7185-18</td>
<td>258</td>
</tr>
<tr>
<td>205</td>
<td>Vehicle after test 7185-18</td>
<td>259</td>
</tr>
<tr>
<td>206</td>
<td>Summary of results for test 7185-18</td>
<td>260</td>
</tr>
<tr>
<td>207</td>
<td>Vehicle angular displacement for test 7185-18</td>
<td>261</td>
</tr>
<tr>
<td>208</td>
<td>Vertical accelerometer trace for test 7185-18</td>
<td>262</td>
</tr>
<tr>
<td>209</td>
<td>Lateral accelerometer trace for test 7185-18</td>
<td>263</td>
</tr>
<tr>
<td>210</td>
<td>Longitudinal accelerometer trace for test 7185-18</td>
<td>264</td>
</tr>
<tr>
<td>211</td>
<td>Vehicle before test 7185-19</td>
<td>265</td>
</tr>
<tr>
<td>212</td>
<td>Sign installation before test 7185-19</td>
<td>266</td>
</tr>
<tr>
<td>213</td>
<td>Vehicle/sign geometries (test 7185-19)</td>
<td>268</td>
</tr>
<tr>
<td>214</td>
<td>Test vehicle properties (7185-19 &amp; 20)</td>
<td>269</td>
</tr>
<tr>
<td>215</td>
<td>Sequential photographs of test 7185-19</td>
<td>270</td>
</tr>
<tr>
<td>215</td>
<td>Sequential photographs of test 7185-19 (Continued)</td>
<td>271</td>
</tr>
<tr>
<td>216</td>
<td>Details of damage to the sign installation (test 7185-19)</td>
<td>272</td>
</tr>
<tr>
<td>217</td>
<td>Details of damage to the vehicle (test 7185-19)</td>
<td>273</td>
</tr>
<tr>
<td>218</td>
<td>Sign installation and vehicle after test 7185-19</td>
<td>274</td>
</tr>
<tr>
<td>219</td>
<td>Summary of results for test 7185-19</td>
<td>275</td>
</tr>
<tr>
<td>220</td>
<td>Vehicle angular displacement for test 7185-19</td>
<td>276</td>
</tr>
<tr>
<td>221</td>
<td>Longitudinal accelerometer trace for test 7185-19</td>
<td>277</td>
</tr>
<tr>
<td>222</td>
<td>Lateral accelerometer trace for test 7185-19</td>
<td>278</td>
</tr>
<tr>
<td>223</td>
<td>Vehicle before test 7185-20</td>
<td>280</td>
</tr>
<tr>
<td>224</td>
<td>Sign installation before test 7185-20</td>
<td>281</td>
</tr>
<tr>
<td>225</td>
<td>Vehicle/sign geometries (test 7185-20)</td>
<td>282</td>
</tr>
<tr>
<td>226</td>
<td>Sequential photographs of test 7185-20</td>
<td>283</td>
</tr>
<tr>
<td>226</td>
<td>Sequential photographs of test 7185-20 (Continued)</td>
<td>284</td>
</tr>
<tr>
<td>227</td>
<td>Sign installation after test 7185-20</td>
<td>285</td>
</tr>
<tr>
<td>228</td>
<td>Vehicle after test 7185-20</td>
<td>287</td>
</tr>
<tr>
<td>229</td>
<td>Summary of results for test 7185-20</td>
<td>288</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES (continued)

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>230</td>
<td>Vehicle angular displacement for test 7185-20</td>
<td>289</td>
</tr>
<tr>
<td>231</td>
<td>Longitudinal accelerometer trace for test 7185-20</td>
<td>290</td>
</tr>
<tr>
<td>A-1</td>
<td>Force vs displacement for 4 lb/ft Franklin post (7185-Case A)</td>
<td>296</td>
</tr>
<tr>
<td>A-2</td>
<td>Force vs displacement for 4 lb/ft Franklin post (7185-Case B)</td>
<td>297</td>
</tr>
<tr>
<td>A-3</td>
<td>Force vs displacement for 4 lb/ft Marion post (7185-Case C)</td>
<td>298</td>
</tr>
<tr>
<td>A-4</td>
<td>Force vs displacement for 4 lb/ft Marion post (7185-Case D)</td>
<td>299</td>
</tr>
<tr>
<td>A-5</td>
<td>Force vs displacement for 4 lb/ft for Franklin post (7185-Case E)</td>
<td>300</td>
</tr>
<tr>
<td>A-6</td>
<td>Force vs displacement for 4 lb/ft Marion post (7185-Case F)</td>
<td>301</td>
</tr>
<tr>
<td>A-7</td>
<td>Force vs displacement for 4 lb/ft Franklin post (7185-Case G)</td>
<td>302</td>
</tr>
<tr>
<td>A-8</td>
<td>Force vs displacement for 4 lb/ft Marion post (7185-Case H)</td>
<td>303</td>
</tr>
<tr>
<td>A-9</td>
<td>Force vs displacement for 4 lb/ft Mixed (Franklin stub/Marion support) post</td>
<td>304</td>
</tr>
<tr>
<td></td>
<td>(7185-Case X)</td>
<td></td>
</tr>
<tr>
<td>B-1</td>
<td>Pendulum longitudinal accelerometer trace (7185-P1)</td>
<td>306</td>
</tr>
<tr>
<td>B-2</td>
<td>Pendulum longitudinal accelerometer trace (7185-P2)</td>
<td>307</td>
</tr>
<tr>
<td>B-3</td>
<td>Pendulum longitudinal accelerometer trace (7185-P3)</td>
<td>308</td>
</tr>
<tr>
<td>B-4</td>
<td>Pendulum longitudinal accelerometer trace (7185-P4)</td>
<td>309</td>
</tr>
<tr>
<td>Table</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>---------------</td>
<td>-------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>1</td>
<td>Data Summary of Static Load Test</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>Performance Evaluation Summary - Pendulum Test</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>Performance Evaluation Summary - Crash Tests</td>
<td>293</td>
</tr>
</tbody>
</table>
I. INTRODUCTION

The objective of this study was to provide baseline data for revising the Department standards for single-support, small sign installations. The scope of the study included conducting (1) static load tests using different splice and hardware configurations for potential use in 4 lb/ft steel u-channel sign support installations, (2) full-scale crash tests on 4 lb/ft steel u-channel sign support installations (as determined from static load tests) anchored in NCHRP Report 230 strong and weak soil (S-1 and S-2, respectively), (3) full-scale crash tests on 3/16 in x 3-1/2 in and 3/16 in x 4 in thin walled aluminum sign support installations anchored in NCHRP Report 230 weak soil (S-2 soil), and (4) pendulum tests on 3/16 in x 4 in aluminum tube sign support retrofits.

The steel u-channel test phase was divided into static and crash test phases. The objective of the static phase was to test and evaluate three configurations of steel u-channel splices. The splices tested were the nested lap (normal and reverse oriented) and the back-to-back splice. Figure 7 illustrates the splice geometries crash tested. The splice configurations were evaluated on the ability to transfer design wind loads without splice failure. The objective of the dynamic phase was to determine the impact characteristics of single-support sign installations when impacted by an 1,800 lb vehicle at 20 and 60 mi/h. Franklin Steel Company and Marion Steel Company 4 lb/ft steel u-channel were used. The nominal yield stress for the Franklin and Marion supports were 60 ksi and 80 ksi, respectively.

The aluminum tube test phase consisted of two dynamic phases: crash tests and pendulum tests. The objective of these tests was to determine the impact characteristics of single-support sign installations when impacted by an 1,800 lb vehicle at 20 and 60 mi/h. All sign installations were evaluated on their ability to perform in a safe and predictable manner. The crash tests were conducted and evaluated in accordance with 1985 AASHTO "Standards Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals" and NCHRP Report 230.
II. STATIC LOAD TESTS

Objective

The Department's objective was to develop and test splice configurations for steel u-channel sign installations utilizing inexpensive "off-the-shelf" hardware. Static load tests were conducted to evaluate the relationship between transfer of design wind loads and splice failure. These tests were performed on Franklin Steel Company and Marion Steel Company 4 lb/ft steel u-channel. The nominal yield stress for the Franklin and Marion supports tested were 60 ksi and 80 ksi respectively.

Static Test Procedure

Static load tests were conducted using the TTI small sign support station. This test fixture was recently developed at TTI for the sole purpose of testing static load capabilities of small sign supports. The test fixture is shown in Figures 1 and 2.

Each static load test was conducted on a support securely held vertical and fixed against rotation. A horizontal concentrated load was applied 10 feet above the center of the lower bolt in the lap-splice. Loading was applied perpendicular to the plane of the post flanges by a hydraulic actuator. The applied load was measured using a load cell mounted 10 feet above the center of the lower splice bolt. Sign post angle of rotation was measured near the theoretical ground level. The effective load and angle of rotation were electronically recorded every 0.5 second using a micro-computer. Each post specimen was loaded until a load of 300 pounds was achieved or failure occurred. The load was removed and permanent residual deflection recorded, unless failure had occurred. If the post specimen had successfully sustained the 300 pound load, then loading was resumed until failure of the post or splice connection occurred. The maximum load recorded prior to failure defined the capacity of the support.

Static Test Description

A total of nine static load tests were conducted using different splice configurations, posts and hardware. Three splice configurations were evaluated: (1) normal oriented, nested splice (post mounted rear of ground stub), (2) reverse oriented, nested splice (post mounted
Figure 1. T.T.I. Small Sign Support Station before test.
Figure 2. T.T.I. Small Sign Support Station after completed test.
forward of ground stub), and (3) back to back splice. In addition, bolt spacing, bolt size and splice length were evaluated. All three splice configurations and a mixed-post configuration were tested using a 6 inch bolt spacing and A307 3/8 in x 2 in bolts. Of these tests, the nested lap splice utilized an 8 inch lap. The mixed post combination was tested using a Franklin stub and a Marion support in a normal-splice orientation. Additional static tests were conducted using a 6 inch normal oriented nested lap splice, 4 inch bolt spacing, and A354 5/16 in x 2 in bolts. A summary of the static load test data is presented in Table 1. Appendix A, Figures A1 through A9 show force versus displacement graphs of the static load tests.

Tests were conducted on case samples "A" through "F" initially. Had a splice failure occurred on any of samples "A" through "D" at a loading of 250 pounds or less, then static load tests of samples "G", "H" and "X" would have utilized ASTM A354 Grade BD, 5/16 inch diameter bolts at 4 inch spacing, otherwise 3/8 inch diameter, A307 bolts at a 6 inch spacing were to be used. However, in all test cases a 300 pound load was reached prior to failure. Therefore, test cases "G", "H" and "X" utilized A307-3/8 inch diameter bolts spaced 6 inches apart.

The primary failure mechanism for the majority of these tests were tensile failure of the bolt(s). Test case "F", however, failed by stripping the threads from the bolt. In test cases "G" and "X" the post fractured. Case "G" failed by fracturing the entire cross-section of the post. Case "X" failed by fracturing the post longitudinally along the lower bolt hole.
<table>
<thead>
<tr>
<th>CASE</th>
<th>POST TYPE</th>
<th>BOLT SPACING</th>
<th>BOLT SIZE</th>
<th>ORIENTATION</th>
<th>FAILURE MECHANISM</th>
<th>FORCE AT FAILURE</th>
<th>DISPLACEMENT AT FAILURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Franklin</td>
<td>6 in</td>
<td>A307 - 3/8&quot;</td>
<td>Normal</td>
<td>Bolt</td>
<td>351.4lb</td>
<td>23.1 in</td>
</tr>
<tr>
<td>B</td>
<td>Franklin</td>
<td>6 in</td>
<td>A307 - 3/8&quot;</td>
<td>Reverse</td>
<td>Bolt</td>
<td>343.2lb</td>
<td>19.8 in</td>
</tr>
<tr>
<td>C</td>
<td>Marion</td>
<td>6 in</td>
<td>A307 - 3/8&quot;</td>
<td>Normal</td>
<td>Bolt</td>
<td>356.6lb</td>
<td>16.1 in</td>
</tr>
<tr>
<td>D</td>
<td>Marion</td>
<td>6 in</td>
<td>A307-3/8&quot;</td>
<td>Reverse</td>
<td>Bolt</td>
<td>414.5lb</td>
<td>17.7 in</td>
</tr>
<tr>
<td>E</td>
<td>Franklin</td>
<td>4 in</td>
<td>A354-5/16&quot;</td>
<td>Normal</td>
<td>Bolt</td>
<td>311.7lb</td>
<td>17.9 in</td>
</tr>
<tr>
<td>F</td>
<td>Marion</td>
<td>4 in</td>
<td>A354-5/16&quot;</td>
<td>Normal</td>
<td>Bolt</td>
<td>333.2lb</td>
<td>15.2 in</td>
</tr>
<tr>
<td>G</td>
<td>Franklin</td>
<td>6 in</td>
<td>A307 - 3/8&quot;</td>
<td>Back to Back</td>
<td>Post</td>
<td>419.4lb</td>
<td>54.5 in</td>
</tr>
<tr>
<td>H</td>
<td>Marion</td>
<td>6 in</td>
<td>A307 - 3/8&quot;</td>
<td>Back to Back</td>
<td>Bolt</td>
<td>385.4lb</td>
<td>16.1 in</td>
</tr>
<tr>
<td>X</td>
<td>Mixed</td>
<td>6 in</td>
<td>A307 - 3/8&quot;</td>
<td>Normal</td>
<td>Post</td>
<td>330.7lb</td>
<td>22.5 in</td>
</tr>
</tbody>
</table>

Table 1. Data Summary of Static Load Test
III. PENDULUM TESTS

Objective

This phase of testing was initiated as a consequence of crash tests 7185-1&2. In these crash tests, the 3/16 in x 4 in aluminum tube performed unsatisfactorily. Therefore, the Department decided to pursue developing an economical field retrofit for the 4 in aluminum tube installation installed in weak soil. The purpose of the gravitational pendulum tests was to simulate and evaluate the impact/failure characteristics of a single 3/16 in x 4 in aluminum tube sign support when impacted by a small vehicle at 20 mi/h.

Pendulum Instrumentation

A low impedance, piezoelectric accelerometer was mounted on the rear of the pendulum to measure acceleration in the longitudinal direction. Provision was made for transmission of calibration signals before and after the test, and a accurate time reference signal was simultaneously recorded with the data. A contact switch on the pendulum was actuated just prior to impact by a wooden dowel 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 impact. The electronic signals from the accelerometer and contact switch were telemetered to a base station for recording on magnetic tape and for display on a real-time strip chart.

Pendulum Test Procedure

The aluminum tube retrofits (shown in Figure 3) were tested at the TTI outdoor gravitational pendulum test facility. The facility was equipped with a rigid-nosed, 2,443 pound pendulum and NCHRP Report 230 S-2 soil (weak) pit. Figure 4 shows a typical pretest pendulum configuration. Impact speed was 20 mi/h for all pendulum tests.

Actual full-scale crash testing requires an 1,800 pound vehicle. However, the pendulum facility provided an economical method of simulating low speed impacts and providing a comparison of alternatives. The pendulum tests rely on the principles of conservation of energy for predicting the change in velocity and momentum for the 1,800 lb vehicle. Predicted change in velocity is based on the amount of energy absorbed during
3/16" x 4" 6061-T6 ALUMINUM TUBE

7185-P1  
Unmodified

7185-P2  
1-1/2" dia. hole each side

7185-P3  
1-0" vertical slot each side

7185-P4  
1-1/2" vertical slot each side

Figure 3. Details of 3/16" x 4" aluminum tube retrofits.
Figure 3. Details of 3/16" x 4" aluminum tube retrofits. (Continued)
Figure 4. Typical pretest pendulum configuration.
impact with an installation. This change in energy is:

\[ \frac{1}{2} M V_i^2 = \frac{1}{2} M (V_i - V_f)^2 + \Delta KE \]

For each test, the pendulum mass \( M_p = 2443 \text{ lb/32.2 ft/s}^2 \), the initial \( V_i \) and final \( V_f \) velocities are known. Therefore, the change in kinetic energy \( \Delta KE \) during impact for a single post installation is easily calculated. Predicted velocity change for an 1,800 pound vehicle is calculated using \( \Delta KE \) obtained from the pendulum test and by making the appropriate vehicle mass substitution \( M_v = 1800 \text{ lb/32.2 ft/s}^2 \).

**Pendulum Test Discussion**

A total of four pendulum tests were conducted during the developmental effort. A performance evaluation summary of the pendulum tests is shown in Table 2. Longitudinal accelerometer traces are shown in Appendix B, Figures B1 through B4. It should be noted, if the data shown in Table 2 are interpreted strictly in accordance with NCHRP Report 230, then one may erroneously conclude all the retrofits tested were successful potential solutions. However, in conjunction with data obtained from crash test 7185-1 it was known that the configurations tested in pendulum tests 7185-P1 through 7185-P4 cannot successfully pass the NCHRP criteria. Previous full-scale crash test results dictate that the tube must yield if the test is to be deemed a potential success. A cross-sectional yield failure was never successfully achieved during these tests.
<table>
<thead>
<tr>
<th>Test No.</th>
<th>Installation Description</th>
<th>Occupant Contact Velocity</th>
<th>1,800 lb Vehicle DV Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>7185-P1</td>
<td>3/16&quot; x 4&quot; aluminum tube - unmodified</td>
<td>N/A</td>
<td>3.09 f.p.s.</td>
</tr>
<tr>
<td>7185-P2</td>
<td>3/16&quot; x 4&quot; aluminum tube - modified (1-1/2&quot; dia. hole drilled through the tube cross-section; transverse to the direction of travel).</td>
<td>N/A</td>
<td>5.83 f.p.s.</td>
</tr>
<tr>
<td>7185-P3</td>
<td>3/16&quot; x 4&quot; aluminum tube - modified (vertical slot; three-1&quot; dia. holes drilled through the tube cross-section; transverse to the direction of travel).</td>
<td>N/A</td>
<td>5.22 f.p.s.</td>
</tr>
<tr>
<td>7185-P4</td>
<td>3/16&quot; x 4&quot; aluminum tube - modified (vertical slot; three-1-1/2&quot; dia. holes drilled through the tube cross-section; transverse to the direction of travel.</td>
<td>N/A</td>
<td>5.90 f.p.s.</td>
</tr>
</tbody>
</table>

Table 2. Performance Evaluation Summary - Pendulum Tests
IV. FULL-SCALE CRASH TESTS

Objective

The objective of full-scale crash testing was to determine the impact characteristics of single-support sign installations when impacted by 1,800 lb vehicles at 20 and 60 mi/h. All sign installations were evaluated on their ability to perform in a safe and predictable manner. The crash tests were conducted and evaluated in accordance with 1985 AASHTO "Standards Specifications for Structural Supports for Highway Signs, Luminaries, and Traffic Signals" and NCHRP Report 230.

Description of Test Installations

Aluminum Tube Sign Installations

Single-support sign installations were constructed from 3/16 in x 4 in and 3/16 in x 3-1/2 in 6061-T6 round aluminum tube. The 3-1/2 and 4 inch diameter tubes were tested with a 2 ft x 3 ft and 4 ft x 4 ft aluminum sign panel attached, respectively. The panels were attached to two 1-3/4 in Zee x 1.08 lb/ft wind beams and then to the support with two 3-in extruded sign support clamps (6063-T6 aluminum). Attached 1 ft-0 in below grade was a 3 in extruded sign support clamp. The below grade clamp was added to provide torsional resistance. Each tube was driven 3 ft-9 in into NCHRP Report 230 weak (S-2) soil. Figure 5 illustrates typical aluminum tube sign installation. The bottom of sign mounting height was 7 ft-0 in.

Steel U-Channel Sign Installations

Single-support sign installations were constructed from 4 lb/ft steel u-channel. The specimens tested were manufactured by Franklin Steel Company and Marion Steel Company. All steel u-channel installations were tested with a 2 ft x 3 ft aluminum sign panel bolted directly to the support. The ground stub was driven 36 in into either NCHRP Report 230 S-1 or S-2 soil (strong and weak soil, respectively). The ground stub was installed such that only a 4 in stub height remained above grade. The Franklin and Marion posts were tested using normal and reverse oriented, 8 in nested lap splices. The splices utilized A307 3/8 in x 2 in bolts spaced 6 in on-center. Figure 6 illustrates a typical steel
Figure 5. Aluminum Tube Sign Installation.
Figure 6. Steel U-channel Sign Installation.
u-channel sign installation. Details of the splice configurations are shown in Figure 7. The bottom of sign mounting height was 7 ft-0 in.

**Description of Crash Test Procedures**

According to NCHRP Report 230 guidelines, two crash tests are recommended for the evaluation of single support sign installations:

- **Modified NCHRP Test Designation 62:** 1,800-pound vehicle impacting the sign support at a speed of 20 miles per hour with the quarter point of the vehicle bumper.

- **NCHRP Test Designation 63:** 1,800-pound vehicle impacting the sign support at a speed of 60 miles per hour with the quarter point of the vehicle bumper.

The crash test procedures were in accordance with the guidelines presented in NCHRP Report 230. The test inertia mass of the crash vehicle was 1,800 lb. This weight represents the weight of the test vehicle and all rigidly attached on-board test equipment. In addition, the gross static mass was 1,970±5 lb (varied by test). The gross static mass represents the vehicle inertial mass and an unsecured anthropomorphic dummy.

The test vehicle was instrumented with three rate transducers to measure roll, pitch, and yaw rates and a triaxial accelerometer near the vehicle center of gravity to measure acceleration. The electronic signals from the accelerometers and transducers were telemetered to a base station for recording on magnetic tape and for display on a real-time strip chart. Provision was made for transmission of calibration signals before and after the test, and an accurate time reference signal was simultaneously recorded with the data. 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 impact.

In accordance with NCHRP Report 230, an unrestrained, uninstrumented special-purpose 50th percentile anthropomorphic test dummy was positioned in the front seat of the test vehicle. The dummy was used to create an asymmetrical vehicle mass distribution. The
Figure 7. Details of U-channel splice configurations.
effect of this load configuration was used to evaluate vehicle stability during impact.

Photographic coverage of the tests included two high-speed cameras, one perpendicular to the sign installation and the other located downstream at approximately 45 degrees from the point of impact. The films from these cameras were used to observe phenomena occurring during collision and to obtain time-event, displacement and angular data. A 3/4-inch video camera and 35 mm still cameras were also used for documentary purposes.

**Data Analysis Procedures**

The analog data from the accelerometers and transducers were digitized, using a microcomputer, for analysis and evaluation of performance. The digitized data were then analyzed using two computer programs: DIGITIZE and PLOTANGLE. Brief descriptions 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 0.010-second average ridedown acceleration. The DIGITIZE program also calculates 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-second intervals in each of 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 commercially available software (Quattro Pro 3.0).

The PLOTANGLE program uses the digitized data from the yaw, pitch, and roll rate transducers to compute angular displacement in degrees at 0.001-second intervals and then instructs a plotter to draw a reproducible plot: yaw, pitch, and roll versus time. 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.
Evaluation Criteria

All crash tests were evaluated in accordance with the criteria presented in NCHRP Report 230 and 1985 AASHTO. As stated in NCHRP Report 230, "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". In accordance, the following safety evaluation criteria from Table 6, NCHRP Report 230 were used:

● Structural adequacy

(B) The test article shall readily activate in a predictable manner by breaking away or yielding.
(D) Detached elements, fragments or other debris from the test-article shall not penetrate or show potential for penetrating the passenger compartment or present undue hazard to other traffic.

● Occupant Risk

(E) The vehicle shall remain upright during and after collision although moderate roll, pitching and yawing are acceptable. Integrity of the passenger compartment must be maintained with essentially no deformation or intrusion.
(F) Impact velocity of hypothetical front seat passenger against vehicle interior, calculated from the vehicle accelerations and 24 in (0.61 m) forward and 12 in (0.30 m) lateral displacement, shall be less than:

<table>
<thead>
<tr>
<th>Occupant Impact Velocity - fps</th>
<th>Longitudinal</th>
<th>Lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>N./A.</td>
</tr>
</tbody>
</table>

and vehicle highest 10 ms average accelerations subsequent to instant of hypothetical passenger impact should be less than:

<table>
<thead>
<tr>
<th>Occupant Ridedown Accelerations - g's</th>
<th>Longitudinal</th>
<th>Lateral</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15</td>
<td>N./A.</td>
</tr>
</tbody>
</table>
Vehicle Trajectory

(H) After collision, the vehicle trajectory and final stopping position shall intrude a minimum distance, if at all, into adjacent traffic lanes.
(J) Vehicle trajectory behind the test article is acceptable.

In addition, 1985 AASHTO states:

Satisfactory dynamic performance is indicated when the maximum change in velocity for a standard 1,800 pound (816.5 kg) vehicle, or its equivalent, striking a breakaway support at speeds from 20 mi/h to 60 mi/h (32 km/h to 97 km/h) does not exceed 15 fps (4.57 mps), but preferably does not exceed 10 fps (3.05 mps) or less.
CRASH TEST RESULTS

Test 7185-1

A 1985 Chevrolet Sprint (shown in Figures 8 & 9) impacted a 3/16 in x 4 in aluminum tube sign installation (Figure 10) in weak soil. The impact was conducted at 19.4 miles per hour (31.2 km/h) using a cable reverse tow and guidance system. The point of impact was the front right quarter point of the vehicle bumper with the sign installation. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross static mass was 1,965 lb (891 kg). The height from roadway surface to the lower edge of the vehicle bumper was 13.8 inches (34.9 cm) and 18.5 inches (47.0 cm) to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 11.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to yield at ground level. By approximately 0.223 seconds, the sign support ceased dynamic yielding and the right front tire of the vehicle lost contact with the roadway. As the vehicle attempted to ramp up the support, the right rear tire lost contact with the roadway at 0.327 second. By 0.706 seconds, the vehicle had regained contact with the roadway and forward motion was arrested. The vehicle came to rest at the point of impact and against the sign installation. Sequential photographs of the test are shown in Figure 12.

The installation failed to yield to the vehicle. The sign support was displaced rearward 30 in (76.2 cm) and was leaning at approximately a 45 degree angle. The vehicle sustained only minor damage to the bumper as shown in Figure 13.

A summary of the test results and other information pertinent to this test are given in Figure 14. The maximum 0.050 second average acceleration experienced by the vehicle was -4.6 g in the longitudinal direction and -1.6 g in the lateral direction. Vehicle angular displacements are plotted in Figure 15 and vehicle accelerometer traces are displayed in Figures 16 through 18. Occupant impact velocity was 17.9 ft/s (5.5 m/s) in the longitudinal direction and 4.8 ft/s (1.5 m/s) in the lateral direction. Occupant ridedown accelerations in the longitudinal and lateral directions were -3.1 g's and 0.5 g's respectively. Change in vehicle velocity was 19.4 mi/h (31.2 km/h) and change in momentum was 1591 lb-s.
Figure 8. Vehicle before test 7185-1.
Figure 9. Vehicle/Sign geometrics (test 7185-1).
Figure 10. Florida thin walled aluminum tube sign installation before test 7185-1.
Date: 05/09/91  Test No.: 7185-1 & 2  VIN: JG1N90BN0FK729457

Make: Chevrolet  Model: Sprint  Year: 1985  Odometer: 96662


Tire Condition: good _ fair _X badly worn _

Vehicle Geometry - inches
a 60"   b 27"
"c 88½"   d* 52"
e 24"   f 139 3/4"
g h 34 1/2"
i j 27½"
k 13½"   l 43"
m 18½"   n 4½"
o 13 3/4"   p 52½"
r 20½"   s 13"

Engine Type: 3 Cylinder
Engine CID: 993 CC
Transmission Type: Automatic or M XXXXX
FWD or RWD or 4WD

Body Type: Hatch

Steering Column Collapse Mechanism:
Behind wheel units
Convoluted tube
Cylindrical mesh units
Embedded ball
NOT collapsible
Other energy absorption
Unknown

Brakes:
Front: disc X drum
Rear: disc _ drum

4-wheel weight for c.g. det.  LF 570  RF 538  LR 356  RR 336

Mass - pounds  Curb  Test Inertial  Gross Static
M₁  964  1108  1187
M₂  520  692  778
M₄  1484  1800  1965

Note any damage to vehicle prior to test:
___ Dent in left rear fender ___

*d = overall height of vehicle

Figure 11. Test vehicle properties (7185-1 & 2).
Figure 12. Sequential photographs of test 7185-1.
Figure 12. Sequential photographs of test 7185-1. (Continued)
Figure 13. Florida thin walled aluminum tube installation after test 7185-1.
Figure 13. Florida thin walled aluminum tube installation after test 7185-1. (Continued)
<table>
<thead>
<tr>
<th>Test No.</th>
<th>7185-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>05/09/91</td>
</tr>
<tr>
<td>Test Article</td>
<td>Sign installation</td>
</tr>
<tr>
<td>Support</td>
<td>Thin walled aluminum tube 3/16&quot; x 4&quot; x 14'-5&quot;</td>
</tr>
<tr>
<td>Embedment</td>
<td>3'-9&quot; driven (weak soil)</td>
</tr>
<tr>
<td>Vehicle</td>
<td>1985 Chevrolet Sprint</td>
</tr>
<tr>
<td>Vehicle Weight</td>
<td>1,800 lb (817 kg)</td>
</tr>
<tr>
<td>Gross Static</td>
<td>1,965 lb (891 kg)</td>
</tr>
<tr>
<td>Vehicle Damage Classification</td>
<td>TAD: 12FC-1</td>
</tr>
<tr>
<td></td>
<td>SAE: 12FRLN1</td>
</tr>
<tr>
<td>Impact Speed</td>
<td>19.4 mi/h (31.2 km/h)</td>
</tr>
<tr>
<td>Change in Velocity</td>
<td>19.4 mi/h (31.2 km/h)</td>
</tr>
<tr>
<td>Change in Momentum</td>
<td>1590.6 lb-s</td>
</tr>
<tr>
<td>Vehicle Accelerations</td>
<td>(Max. 0.050-sec Avg)</td>
</tr>
<tr>
<td></td>
<td>Longitudinal: -4.6 g</td>
</tr>
<tr>
<td></td>
<td>Lateral: -1.6 g</td>
</tr>
<tr>
<td>Occupant Impact Velocity</td>
<td>Longitudinal: 17.9 ft/s (5.5 m/s)</td>
</tr>
<tr>
<td></td>
<td>Lateral: 4.8 ft/s (1.5 m/s)</td>
</tr>
<tr>
<td>Occupant Ridedown Accelerations</td>
<td>Longitudinal: -3.1 g</td>
</tr>
<tr>
<td></td>
<td>Lateral: 0.5 g</td>
</tr>
</tbody>
</table>

Figure 14. Summary of results for test 7185-1.
Axes are vehicle fixed.
Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 15. Vehicle angular displacement for test 7185-1.
Figure 16. Longitudinal accelerometer trace (7185-1).
Figure 18. Vertical accelerometer trace (7185-1).
In summary, the sign installation failed to yield to the vehicle. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was no deformation or penetration into the occupant compartment. However, Occupant impact velocity in the longitudinal direction (17.9 ft/s) was above the recommended limit of 15 ft/s as specified in NCHRP 230. This sign installation in "weak soil" is not acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

Test 7185-2

The same 1985 Chevrolet Sprint used in the 20 mile per hour crash test (7185-1) was used for the 60 mile per hour test. The vehicle impacted a 3/16 in x 4 in aluminum tube sign installation (shown in Figure 19) in weak soil. The impact was conducted at 60.2 miles per hour (96.9 km/hr) using a cable reverse tow and guidance system. The point of impact was the front left quarter point of the vehicle bumper with the sign installation.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to yield at ground level and at bumper height. At approximately 0.055 seconds, the rear wheels of the vehicle lost contact with the roadway. The vehicle continued to travel forward experiencing a tremendous amount of pitch and yaw due to excessive change in vehicle velocity. Shortly after the sign post pulled out of the soil, the vehicle's front right wheel dug into the soil (approximately 55 ft (16.8 m) from the point of impact) causing the vehicle to begin to roll. The vehicle rolled over four times coming to rest approximately 95 ft (29.0 m) from the point of impact. Sequential photographs of the test are shown in Figure 20.

The installation yielded to the vehicle. The sign support pulled from the soil. Primary damage experienced to the post was bending at approximately bumper height (shown in Figure 21). The vehicle sustained severe damages due to rollover. The extent of vehicle damage severity is shown in Figure 22.

A summary of the test results and other information pertinent to this test are given in Figure 23. The maximum 0.050 second average acceleration experienced by the vehicle was -7.3 g in the longitudinal direction and -2.5 g in the lateral direction. Vehicle angular displacements are plotted in Figure 24 and vehicle accelerometer traces are displayed in
Figure 19. Florida thin walled aluminum tube sign installation before test 7185-2.
Figure 20. Sequential photographs of test 7185-2.
Figure 20. Sequential photographs of test 7185-2. (Continued)
Figure 21. Florida thin walled aluminum tube installation after test 7185-2.
Figure 22. Vehicle after test 7185-2.
<table>
<thead>
<tr>
<th>Test No.</th>
<th>7185-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>05/09/91</td>
</tr>
<tr>
<td>Test Article</td>
<td>Sign installation</td>
</tr>
<tr>
<td>Support</td>
<td>Thin walled aluminum tube 3/16&quot; x 4&quot; x 14'-5&quot;</td>
</tr>
<tr>
<td>Embedment</td>
<td>3'-9&quot; driven (weak soil)</td>
</tr>
<tr>
<td>Vehicle</td>
<td>1985 Chevrolet Sprint</td>
</tr>
</tbody>
</table>

- **Vehicle Weight**
  - Test Inertia: 1,800 lb (817 kg)
  - Gross Static: 1,965 lb (891 kg)

- **Vehicle Damage Classification**
  - TAD: 12FC-1 and 12L&T-4
  - SAE: 12FRLNI

- **Impact Speed**: 60.2 mi/h (96.9 km/h)
- **Change in Velocity**: N/A
- **Change in Momentum**: N/A
- **Vehicle Accelerations**
  - Longitudinal: -7.3 g
  - Lateral: -2.5 g
- **Occupant Impact Velocity**
  - Longitudinal: 22.2 ft/s (6.8 m/s)
  - Lateral: 10.6 ft/s (3.2 m/s)
- **Occupant Ridedown Accelerations**
  - Longitudinal: -3.3 g
  - Lateral: -2.4 g

**Figure 23.** Summary of results for test 7185-2.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll
Figures 25 through 27. Occupant impact velocity was 22.2 ft/s (6.8 m/s) in the longitudinal direction and 10.6 ft/s (3.2 m/s) in the lateral direction. Occupant ridedown accelerations in the longitudinal and lateral directions were -3.3 g's and -2.4 g's respectively. Change in vehicle velocity and change in momentum was indeterminate.

In summary, the sign installation yielded to the vehicle. The vehicle sustained severe damage and presented undue hazard to other traffic. There was excessive deformation and penetration into the occupant compartment due to vehicle rollover. In addition, occupant impact velocity in the longitudinal direction (22.2 ft/s) was above the recommended limit of 15 ft/s as specified in NCHRP 230. This sign installation in "weak soil" is not acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

Test 7185-3

A 1987 Chevrolet Sprint (shown in Figures 28 & 29) impacted a 4 lb/ft Marion steel u-channel, reverse splice orientation, sign installation (shown in Figure 30) in weak soil. The impact was conducted at 18.4 miles per hour (29.6 km/h) using a cable reverse tow and guidance system. The point of impact was the front left quarter point of the vehicle bumper with the sign installation. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross static mass was 1,971 lb (894 kg). The height from roadway surface to the lower edge of the vehicle bumper was 9.0 inches (22.9 cm) and 19.3 inches (48.9 cm) to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 31.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. By approximately 0.244 seconds, the splice bolts had failed and the sign installation was in contact with the roadway. As the vehicle continued to travel forward and over the installation, the dummy impacted the windshield at 0.274 seconds. Shortly thereafter, the brakes were applied and the vehicle came to rest approximately 90.0 ft (27.4 m) from the point of impact. Sequential photographs of the test are shown in Figure 32.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts. The sign support ground stub was displaced rearward 6.0 in (15.2 cm). The
CRASH TEST 7185-2
Class 180 Filter

Figure 27. Vertical accelerometer trace (7185-2).
Figure 28. Vehicle before test 7185-3
Figure 29. Vehicle/sign geometries (test 7185-3).
Figure 30. Sign installation before test 7185-3.
Figure 31. Test vehicle properties (7185-3 & 4).
Figure 32. Sequential photographs of test 7185-3.
Figure 32. Sequential photographs of test 7185-3 (continued).
sign installation came to rest at the point of impact (shown in Figure 33). The vehicle sustained only minor damages to the bumper and windshield as shown in Figure 34.

A summary of the test results and other information pertinent to this test are given in Figure 35. The maximum 0.050 second average acceleration experienced by the vehicle was -2.0 g in the longitudinal direction and -0.3 g in the lateral direction. Vehicle angular displacements are plotted in Figure 36 and vehicle accelerometer traces are displayed in Figures 37 through 39. Occupant impact velocity was 0.9 ft/s (0.3 m/s) in the longitudinal direction. Occupant ridedown acceleration in the longitudinal direction was -0.6 g's and no contact was experienced in the lateral direction. Change in vehicle velocity was 6.9 mi/h (11.1 km/h) and change in momentum was 565 lb-s.

In summary, the sign installation yielded to the vehicle by failing the post splice bolts. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was no deformation or penetration into the occupant compartment. Occupant impact velocities and ridedown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "weak soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

Test 7185-4

The same 1987 Chevrolet Sprint (shown in Figure 40) and sign installation configuration used in the 20 mile per hour crash test (7185-3) was used for the 60 mile per hour test. The vehicle impacted the sign installation at 61.8 miles per hour (99.4 km/hr) using a cable reverse tow and guidance system. The point of impact (shown in Figure 41) was the front right quarter point of the vehicle bumper with the sign installation (shown in Figure 42).

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. At approximately 0.020 second, the sign support fractured at bumper height and the splice bolts failed. Shortly thereafter, the installation lost contact with the vehicle. As the vehicle continued to move forward, the installation passed over the vehicle. At approximately 0.117 seconds, the sign blank impacted the roof of the vehicle.
Figure 33. Sign installation after test 7165-3.
Figure 34. Vehicle after test 7185-3.
Figure 35. Summary of results for test 7185-3.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 36. Vehicle angular displacement for test 7185-3.
CRASH TEST 7185-3
Class 180 Filter

Figure 37. Longitudinal accelerometer trace (7185-3).
Figure 38. Lateral accelerometer trace (7185-3).
Figure 39. Vertical accelerometer trace (7185-3).
Figure 40. Vehicle before test 7185-4.
Figure 41. Vehicle/sign geometrics (test 7185-4).
Figure 42. Sign installation before test 7185-4.
and bounced off. Shortly thereafter, the brakes were applied and the vehicle came to rest approximately 252.0 ft (76.8 m) from the point of impact. Sequential photographs of the test are shown in Figure 43.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts and sign support. The sign support ground stub was displaced rearward 3.0 in (7.6 cm). The sign installation came to rest 100.0 ft (30.5 m) from the point of impact. The damage sustained to the installation is shown Figure 44. The vehicle sustained only minor damage to the bumper, hood, grill and right rear corner of the roof as shown in Figure 45.

A summary of the test results and other information pertinent to this test are given in Figure 46. The maximum 0.050 second average acceleration experienced by the vehicle was -2.7 g in the longitudinal direction and 1.3 g in the lateral direction. Vehicle angular displacements are plotted in Figure 47 and vehicle accelerometer traces are displayed in Figures 48 through 50. Occupant impact velocity was 4.2 ft/s (1.3 m/s) in the longitudinal direction and -5.7 ft/s (-1.7 m/s) in the lateral direction. Occupant ridedown accelerations in the longitudinal and lateral directions were -1.1 g's and 1.6 g's respectively. Change in vehicle velocity was 1.9 mi/h (3.1 km/h) and change in momentum was 158 lb-s.

In summary, the sign installation yielded to the vehicle by fracturing the post at bumper height and failing the splice bolts. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was minimal deformation and no penetration into the occupant compartment. Occupant impact velocities and ridedown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "weak soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

Test 7185-5

A 1986 Chevrolet Sprint (shown in Figures 51 & 52) impacted a 4 lb/ft Marion steel u-channel, reverse splice orientation, sign installation in strong soil (shown in Figure 53). The impact was conducted at 19.3 miles per hour (31.1 km/h) using a cable reverse tow and guidance system. The point of impact was the front left quarter point of the vehicle bumper with the sign installation. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross
Figure 43. Sequential photographs of test 7185-4.
Figure 43. Sequential photographs of test 7185-4 (continued).
Figure 44. Sign installation after test 7185-4.
Figure 45. Vehicle after test 7185-4.
Figure 46. Summary of results for test 7185-4.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 47. Vehicle angular displacement for test 7185-4.
CRASH TEST 7185-4
Class 180 Filter

Figure 48. Longitudinal accelerometer trace (7185-4).
CRASH TEST 7185-4
Class 180 Filter

Figure 49: Lateral accelerometer trace (7185-4).
CRASH TEST 7185-4
Class 180 Filter

Figure 50. Vertical accelerometer trace (7185-4).

Vertical Acceleration (g's)

Time (seconds)
Figure 51. Vehicle before test 7185-5.
Figure 52. Vehicle/sign geometrics (test 7185-5).
Figure 53. Sign installation before test 7185-5.
static mass was 1,970 lb (894 kg). The height from roadway surface to the lower edge of the vehicle bumper was 13.0 inches (33.0 cm) and 18.5 inches (47.0 cm) to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 54.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. At approximately 0.062 second, the sign support fractured at bumper height and the splice bolts failed. Shortly thereafter, the installation lost contact with the vehicle. As the vehicle continued to move forward and the installation attempted to pass over, the sign blank impacted the roof line at the top of the windshield. At approximately 0.523 seconds, the sign support impacts the hood of the vehicle. Shortly thereafter, the brakes were applied and the vehicle came to rest approximately 98.0 ft (29.9 m) from the point of impact. Sequential photographs of the test are shown in Figure 55.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts and sign support. The sign support ground stub was displaced rearward 3.5 in (8.9 cm). The sign installation came to rest 68.0 ft (20.7 m) from the point of impact. The damage sustained by the installation is shown in Figure 56. The vehicle sustained only minor damage to the bumper, hood, grill, windshield and front section of the roof as shown in Figure 57.

A summary of the test results and other information pertinent to this test are given in Figure 58. The maximum 0.050 second average acceleration experienced by the vehicle was -3.0 g in the longitudinal direction and 0.4 g in the lateral direction. Vehicle angular displacements are plotted in Figure 59 and vehicle accelerometer traces are displayed in Figures 60 through 62. Occupant impact velocity was -3.6 ft/s (-1.1 m/s) in the lateral direction and no contact was recorded in the longitudinal direction. Occupant ridedown acceleration was -0.3 g's in the lateral direction. Change in vehicle velocity was 4.1 mi/h (6.6 km/h) and change in momentum was 336 lb-s.

In summary, the sign installation yielded to the vehicle by fracturing the post at bumper height and failing the splice bolts. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was minimal deformation and no penetration into the occupant compartment. Occupant impact velocities and ridedown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in
Date: 06/13/91  Test No.: 7185-5 & 6  VIN: 1GIMB08S4GK708461
Make: Chevrolet  Model: Sprint  Year: 1986  Odometer: 09340
Tire Condition: good  ___  fair  ___  badly worn  ___
Vehicle Geometry - inches
a  60"  b  26½"  c  87"  d*  52"  e  25½"  f  130 3/4"  g  ___  h  34.9"  i  ___  j  27½"  k  14"  l  43½"  m  18½"  n  3 3/4"  o  13"  p  52 3/4"  r  21"  s  13"
Engine Type: 3 Cylinder  Engine CID: __________
Transmission Type: XXXX or Manual
FWD or XXX or 4WD
Body Type: hatch
Steering Column Collapse Mechanism:
- Behind wheel units
- Convoluted tube
- Cylindrical mesh units
- Embedded ball
- NOT collapsible
- Other energy absorption
- Unknown
Brakes:
Front: disc X drum
Rear: disc ___ drum X

4-wheel weight for c.g. det.  lf 544  rf 534  lr 379  rr 343
Mass - pounds Curb Test Inertial Gross Static
M1  982  1078  1165
M2  562  722  805
Mf  1544  1800  1970
Note any damage to vehicle prior to test:

* = overall height of vehicle

Figure 54. Test vehicle properties (7185-5 & 6).
Figure 55. Sequential photographs for test 7185-5.
Figure 55. Sequential photographs for test 7185-5 (continued).
Figure 56. Sign installation after test 7185-5.
Figure 57. Vehicle after test 7185-5.
Figure 58. Summary of results for test 7185-5.

Test No. .......... 7185-5
Date .......... 06/13/91
Test Article .......... Sign Installation
Support .......... One Marion 80 ksi,
4 lb/ft Steel U-Channel
Embedment .......... 3'-9" driven
(NCHRP S-1 soil)
Vehicle .......... 1986 Chevrolet Sprint
Vehicle Weight
Test Inertia .......... 1,800 lb (817 kg)
Gross Static .......... 1,970 lb (894 kg)
Vehicle Damage Classification
TAD .......... [2FL-1]
SAE .......... [2FLLN1]

Impact Speed .......... 19.3 mi/h (31.1 km/h)
Change in Velocity .......... 4.1 mi/h (6.6 km/h)
Change in Momentum .......... 236.1 lb-s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal .......... -3.0 g
Lateral .......... 0.4 g
Occupant Impact Velocity
Longitudinal .......... N/A
Lateral .......... -3.6 ft/s (-1.1 m/s)
Occupant Ridedown Accelerations
Longitudinal .......... No Contact
Lateral .......... -0.3 g
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 59. Vehicle angular displacement for test 7185-5.
Figure 60. Longitudinal accelerometer trace (7185-5).
Figure 61. Lateral accelerometer trace (7185-5).
CRASH TEST 7185-5
Class 180 Filter

Figure 62. Vertical accelerometer trace (7185-5).
NCHRP 230. This sign installation in "strong soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHO Standards.

Test 7185-6

The same 1986 Chevrolet Sprint (shown in Figure 63) and sign installation configuration (shown in Figure 64) used in the 20 mile per hour crash test (7185-5) was used for the 60 mile per hour test. The vehicle impacted the sign installation at 61.1 miles per hour (98.3 km/hr) using a cable reverse tow and guidance system. The point of impact (shown in Figure 65) was the front right quarter point of the vehicle bumper with the sign installation.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. At approximately 0.017 second, the sign support fractured at bumper height and the splice bolts failed. Shortly thereafter, the installation lost contact with the vehicle. As the vehicle continued to move forward, the installation passed over the vehicle. At approximately 0.130 seconds, the sign blank impacted the right rear corner of the roof of the vehicle and bounced off. Shortly thereafter, the brakes were applied and the vehicle came to rest approximately 263.0 ft (80.2 m) from the point of impact. Sequential photographs of the test are shown in Figure 66.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts and sign support. The sign support ground stub was displaced rearward 4.0 in (10.2 cm). The sign installation came to rest 35.0 ft (10.7 m) from the point of impact. Damage sustained to the installation is shown in Figure 67. The vehicle sustained only minor damage to the bumper, hood, grill and right rear corner of the roof as shown in Figure 68.

A summary of the test results and other information pertinent to this test are given in Figure 69. The maximum 0.050 second average acceleration experienced by the vehicle was -2.5 g in the longitudinal direction and 1.5 g in the lateral direction. Vehicle angular displacements are plotted in Figure 70 and vehicle accelerometer traces are displayed in Figures 71 through 73. Occupant impact velocity was 7.6 ft/s (2.3 m/s) in the lateral direction and no contact was recorded in the longitudinal direction. Occupant ridedown
Figure 63. Vehicle before test 7185-6.
Figure 64. Sign installation before test 7185-6.
Figure 65. Vehicle/sign geometrics (test 7185-6).
Figure 66. Sequential photographs for test 7185-6.
Figure 66. Sequential photographs for test 7185-6 (continued).
Figure 67. Sign installation after test 7185-6.
Figure 68. Vehicle after test 7185-6.
Test No. .......... 7185-6
Date ............. 06/13/91
Test Article ...... Sign Installation
Support .......... One Marion 80 ksi, 4 lb/ft Steel U-Channel
Embedment ........ 3'-9" driven (NCHRP S-1 soil)
Vehicle .......... 1986 Chevrolet Sprint
Vehicle Weight
Test Inertia ........ 1,800 lb (817 kg)
Gross Static .......... 1,970 lb (894 kg)
Vehicle Damage Classification
TAD ............... 12FR-1
SAE .......... 12FREN1
Impact Speed ........ 61.1 mi/h (98.3 km/h)
Change in Velocity .... 3.8 mi/h (6.1 km/h)
Change in Momentum .... 312.4 lb-s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal ........ -2.5 g
Lateral .......... 1.5 g
Occupant Impact Velocity
Longitudinal ........ N/A
Lateral .......... 7.6 ft/s (2.3 m/s)
Occupant Ridedown Accelerations
Longitudinal ........ No Contact
Lateral .......... -1.63 g

Figure 60. Summary of results for test 7185-6.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 70. Vehicle angular displacement for test 7185-6.
Figure 72. Lateral accelerometer trace (7185-6).
Figure 73. Vertical accelerometer trace (7185-6).
acceleration was -1.6 g's in the lateral direction. Change in vehicle velocity was 3.8 mi/h (6.1 km/h) and change in momentum was 312.4 lb-s.

In summary, the sign installation yielded to the vehicle by fracturing the post at bumper height and failing the splice bolts. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was minimal deformation and no penetration into the occupant compartment. Occupant impact velocities and ridedown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "strong soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

Test 7185-7

A 1988 Yugo (shown in Figure 74) impacted a 4 lb/ft Franklin steel u-channel, reverse splice orientation, sign installation in weak soil (shown in Figure 75). The impact was conducted at 20.3 miles per hour (32.7 km/h) using a cable reverse tow and guidance system. The point of impact (shown in Figure 76) was the front left quarter point of the vehicle bumper with the sign installation. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross static mass was 1,965 lb (891 kg). The height from roadway surface to the lower edge of the vehicle bumper was 13.8 inches (34.9 cm) and 19.0 inches (48.3 cm) to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 77.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. Shortly thereafter, the sign installation pulled from the soil. By 0.259 seconds, the installation was in contact with the roadway. As the vehicle passed over the installation, the sign installation temporarily snagged the undercarriage of the vehicle and was dragged approximately 6.0 ft (1.8 m). Shortly thereafter, the brakes were applied and the vehicle came to rest approximately 63.0 ft (19.2 m) from the point of impact. Sequential photographs of the test are shown in Figure 78.

The installation yielded to the vehicle. The mode of failure was the entire installation pulling from the soil. The splice bolts did not fail. The sign support was bent 18.0 in (45.7 cm) from ground level. Damage sustained to the installation is shown in
Figure 74. Vehicle before test 7185-7.
Figure 75. Sign installation before test 7185-7.
Figure 76. Vehicle/sign geometrics (test 7185-7).
Date: 06/20/91    Test No.: 7185-7 & 8    VIN: VX1BE1228JK393090

Make: Yugo    Model: ________    Year: 1988    Odometer: 32173


A  good    B  fair X    C  badly worn

Tire Condition: ________

Vehicle Geometry - inches
a  60½"    b  28"

c  84 3/4"    d*  55"
e  26"    f  ________
g  ________    h  31.6"
i  ________    j  28½"
k  14½"    l  31½"
m  19"    n  3"
o  13 3/4"    p  51½"
r  22"    s  14¼"

Engine Type: __ 4 Cylinder
Engine CID: ___ 1.1 Litre
Transmission Type:
A  Automatic or Manual
FWD or 4WD or 4x4

Body Type: 3 Door

Steering Column Collapse Mechanism:
- Behind wheel units
- Convoluted tube
- Cylindrical mesh units
- Embedded ball
- NOT collapsible
- Other energy absorption
- Unknown

Brakes:
Front: disc X drum __
Rear: disc ____ drum X

4-wheel weight for c.g. det.  LF  567    RF  562    LR  348    RR  323

Mass - pounds  Curb  Test Inertial  Gross Static
M₁  1131    1129    1205
M₂  646    671    760
M₃  1777    1800    1965

Note any damage to vehicle prior to test:

*d = overall height of vehicle

Figure 77. Test vehicle properties (7185 - 7 & 8)
Figure 78. Sequential photographs for test 7185-7.
Figure 78. Sequential photographs for test 7185-7 (continued).
Figure 79. The sign installation came to rest 6.0 ft (1.8 m) from the point of impact. The vehicle sustained only minor damage to the bumper as shown in Figure 80.

A summary of the test results and other information pertinent to this test are given in Figure 81. The maximum 0.050 second average acceleration experienced by the vehicle was -1.9 g in the longitudinal direction and -0.5 g in the lateral direction. Vehicle angular displacements are plotted in Figure 82 and vehicle accelerometer traces are displayed in Figures 83 through 85. Occupant impact velocity was 6.3 ft/s (1.9 m/s) in the longitudinal direction and no contact was recorded in the lateral direction. Occupant ridersdown acceleration was -0.7 g's in the longitudinal direction. Change in vehicle velocity was 5.3 mi/h (8.6 km/h) and change in momentum was 437 lb-s.

In summary, the sign installation yielded to the vehicle by pulling the post anchor stub from the soil. The vehicle sustained minor damage to the bumper and did not present undue hazard to other traffic. There was no deformation or penetration into the occupant compartment. Occupant impact velocities and ridersdown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "weak soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

Test 7185-8

The same 1988 Yugo and sign installation configuration (shown in Figures 86 & 87, respectively) used in the 20 mile per hour crash test (7185-7) was used for the 60 mile per hour test. The vehicle impacted the sign installation at 61.5 miles per hour (98.6 km/hr) using a cable reverse tow and guidance system. The point of impact (shown in Figure 88) was the front right quarter point of the vehicle bumper with the sign installation.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. As the vehicle continued forward, the support formed a pocket around the bumper of the vehicle. Shortly thereafter, the support stub pulled from the soil. The installation remained in front of the vehicle. The brakes were applied and the vehicle came to rest approximately 215.0 ft (65.5 m) from the point of impact. Sequential photographs of the test are shown in Figure 89.
Figure 79. Vehicle after test 7185-7.
Figure 80. Sign installation after test 7185-7.
Test No. ............... 7185-7
Date ............... 06/20/91
Test Article .......... Sign Installation
Support ............. One Franklin 60 ksi,
4 lb/ft Steel U-Channel
Embedment .......... 3'-9" driven
(NCHRP S-2 soil)
Vehicle .............. 1988 Yugo
Vehicle Weight
Test Inertia ........... 1,800 lb (817 kg)
Gross Static ........... 1,965 lb (891 kg)
Vehicle Damage Classification
- TAD .................. I2FL-1
- SAE ................. 12FRLN1
Impact Speed .......... 20.3 mi/h (32.7 km/h)
Change in Velocity ... 5.3 mi/h (8.6 km/h)
Change in Momentum .. 437 lb-s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal ........ -1.9 g
Lateral .............. -0.5 g
Occupant Impact Velocity
Longitudinal ......... 6.3 ft/s (1.9 m/s)
Lateral .............. N/A
Occupant Ridedown Accelerations
Longitudinal ......... -0.7 g
Lateral .............. No Contact

Figure 81. Summary of results for test 7185-7.
Aaxes are vehicle fixed.
Sequence for determining orientation is:
1. Yaw
2. Pitch
3. Roll

Figure 82. Vehicle angular displacement for test 7185-7.
CRASH TEST 7185-7
Class 180 Filter

Figure 83. Longitudinal accelerometer trace (7185-7).
CRASH TEST 7185-7
Class 180 Filter

![Graph showing lateral acceleration (g's) over time (seconds)](image)

---

Figure 84. Lateral accelerometer trace (7185-7).
Figure 85. Vertical accelerometer trace (7185-7).
Figure 86. Vehicle before test 7185-8.
Figure 87. Sign installation before test 7185-8.
Figure 88. Vehicle/sign geometrics (test 7185-8).
Figure 89. Sequential photographs for test 7185-8.
Figure 89. Sequential photographs for test 7165-8 (continued).
The installation yielded to the vehicle. The mode of failure was the entire installation pulling from the soil. The splice bolts did not fail. The sign support was bent 21.0 in (53.3 cm) from ground level. The sign installation came to rest 88.0 ft (26.8 m) from the point of impact. Damage sustained to the sign installation is shown in Figure 90. The vehicle sustained only minor damages to the bumper, hood and grill as shown in Figure 91.

A summary of the test results and other information pertinent to this test are given in Figure 92. The maximum 0.050 second average acceleration experienced by the vehicle was -3.0 g in the longitudinal direction and -1.4 g in the lateral direction. Vehicle angular displacements are plotted in Figure 93 and vehicle accelerometer traces are displayed in Figures 94 through 96. Occupant impact velocity was 7.6 ft/s (2.3 m/s) in the longitudinal direction and 6.3 ft/s (1.9 m/s) in the lateral direction. Occupant ridedown accelerations in the longitudinal and lateral directions were -2.1 g's and -2.3 g's respectively. Change in vehicle velocity was 4.4 mi/h (7.1 km/h) and change in momentum was 364 lb-s.

In summary, the sign installation yielded to the vehicle by pulling the post anchor stub from the soil. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was no deformation or penetration into the occupant compartment. Occupant impact velocities and ridedown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "weak soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

Test 7185-9

A 1988 Yugo (shown in Figure 97) impacted a 4 lb/ft Franklin steel u-channel, reverse splice orientation, sign installation in strong soil (shown in Figure 98). The impact was conducted at 17.0 miles per hour (27.4 km/h) using a cable reverse tow and guidance system. The point of impact (shown in Figure 99) was the front right quarter point of the vehicle bumper with the sign installation. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross static mass was 1,970 lb (894 kg). The height from roadway surface to the lower edge of the vehicle bumper was 14.0 inches (35.6 cm) and 19.3 inches (48.9 cm) to the top of the bumper. Other dimensions and information on the vehicle are given in Figure
Figure 90. Sign installation after test 7185-8.
Figure 91. Vehicle after test 7185-8.
Test No. ............... 7185-8
Date ............... 06/20/91
Test Article ............... Sign Installation
Support ............... One Franklin 60 ksi, 4 lb/ft Steel U-Channel
Embedment ............... 3'-9" driven (NCHRP 5-2 soil)
Vehicle ............... 1988 Yugo
Vehicle Weight
Test Inertia ............... 1,800 lb (817 kg)
Gross Static ............... 1,965 lb (891 kg)
Vehicle Damage Classification
TAD ............... 12FR-2
SAE ............... 12FREN2
Impact Speed ............... 61.5 mi/h (98.6 km/h)
Change in Velocity ............... 4.4 mi/h (7.1 km/h)
Change in Momentum ............... 364.0 lb-s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal ............... -3.0 g
Lateral ............... -1.4 g
Occupant Impact Velocity
Longitudinal ............... 7.6 ft/s (2.3 m/s)
Lateral ............... 6.3 ft/s (1.9 m/s)
Occupant Ridedown Accelerations
Longitudinal ............... -2.1 g
Lateral ............... -2.3 g

Figure 92. Summary of results for test 7185-8.
Axes are vehicle fixed. Sequence for determining orientation is:
1. Yaw
2. Pitch
3. Roll

Figure 33. Vehicle angular displacement for test 7185-8.
CRASH TEST 7185-8
Class 180 Filter

Figure 94. Longitudinal accelerometer trace (7185-8).
Figure 95. Lateral accelerometer trace (7185-8).
Figure 96. Vertical accelerometer trace (7185-8).
Figure 97. Vehicle before test 7185-9.
Figure 98. Sign installation before test 7185-9.
Figure 99. Vehicle/sign geometrics 7185-9.
The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. As the post deformed, the vehicle began to climb the sign support. By approximately 0.159 seconds, the right front wheel of the vehicle had lost contact with the roadway. Shortly thereafter, the splice bolts failed. The sign post and blank impacted the roadway at 0.239 second allowing the vehicle to pass over the sign installation. Shortly thereafter, the brakes were applied and the vehicle came to rest approximately 40.0 ft (12.2 m) from the point of impact. Sequential photographs of the test are shown in Figure 101.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts. The sign support ground stub was displaced rearward 6.0 in (15.2 cm). The sign support was bent 24.0 in (6.0 cm) from ground level. The sign installation came to rest directly behind the vehicle. Damage sustained to the sign installation is shown in Figure 102. The vehicle sustained only minor damage to the bumper as shown in Figure 103.

A summary of the test results and other information pertinent to this test are given in Figure 104. The maximum 0.050 second average acceleration experienced by the vehicle was -4.4 g in the longitudinal direction and 1.3 g in the lateral direction. Vehicle angular displacements are plotted in Figure 105 and vehicle accelerometer traces are displayed in Figures 106 through 108. Occupant impact velocity was 15.7 ft/s (4.8 m/s) in the longitudinal direction and -5.9 ft/s (1.8 m/s) in the lateral direction. Occupant riddenown accelerations in the longitudinal and lateral directions were 1.4 g and 1.6 g respectively. Change in vehicle velocity was 7.5 mi/h (12.0 km/h) and change in momentum was 612 lb-s.

In summary, the sign installation yielded to the vehicle by failing the splice bolts. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was no deformation or penetration into the occupant compartment. Occupant impact velocities and riddenown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "strong soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.
Date: 06/27/91  Test No.: 7185-9 & 10  VIN: VX1BAYJ912JK390205
Make: Yugo  Model: GV  Year: 1988  Odometer: 433457
Tire Size: 155 SR13  Ply Rating:  Tire Condition: good
Bias Ply:  Belted:  Radial: X
Tire of rear: badly worn  accelerometer
26 3/4"
Vehicle Geometry - inches

a  60"  b  28"
c  85"  d*  55 3/4"
e  23 1/2"  f  136 1/2"
g  ----  h  30.9"
i  ----  j  30"
k  15"  l  31"
m  19 1/2"  n  3"
o  14"  p  51 1/2"
r  23"  s  14 1/2"

Engine Type: 3 cylinder  Engine CID:  __________
Transmission Type: 
AXXXXXXXX or Manual  FWD or XXXX or XXXX
Body Type: Hatch
Steering Column Collapse Mechanism: 

Behind wheel units  Convoluted tube
Cylindrical mesh units  Embedded ball
H01 collapsible  Other energy absorption
Unknown

Brakes:
Front: disc X drum
Rear: disc drum X

4-wheel weight for c.g. det.

\[ M_1 = 1161 \quad M_2 = 549 \quad M_T = 1710 \]

Note any damage to vehicle prior to test:

---

* d = overall height of vehicle

Figure 100. Test vehicle properties (7185-9 and 10).
Figure 101. Sequential photographs of test 7185-9.
Figure 101. Sequential photographs of test 7185-9 (continued).
Figure 102. Sign installation after test 7185-9.
Figure 103. Vehicle after test 7185-9.
Figure 104. Summary of results for test 7185-9.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 105. Vehicle angular displacement for test 7185-9.
CRASH TEST 7185-9
Class 180 Filter

Figure 106. Longitudinal accelerometer trace (7185-9).
CRASH TEST 7185-9
Class 180 Filter

Figure 107. Lateral accelerometer trace (7185-9).
Test 7185-10

The same 1988 Yugo and sign installation configuration (shown in Figures 109 & 110, respectively) used in the 20 mile per hour crash test (7185-9) was used for the 60 mile per hour test. The vehicle impacted the sign installation at 60.8 miles per hour (97.8 km/hr) using a cable reverse tow and guidance system. The point of impact (shown in Figure 111) was the front left quarter point of the vehicle bumper with the sign installation.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. As the vehicle continued forward, the support began to pocket around the bumper of the vehicle. At approximately 0.040 seconds, the sign support fractured at bumper height and the splice bolts failed. As the vehicle continued forward, the sign installation attempted to pass over the vehicle. However, the sign blank struck the front left side of the roof, near the top of the windshield (over the drivers compartment). Shortly thereafter, the brakes were applied and the vehicle came to rest approximately 250.0 ft (76.2 m) from the point of impact. Sequential photographs of the test are shown in Figure 112.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts and sign support. The sign support ground stub was displaced rearward 6.0 in (15.2 cm). The sign installation came to rest 176.0 ft (53.7 m) from the point of impact. Damage sustained to the installation is shown in Figure 113. The vehicle sustained only minor damages to the bumper and hood. However, severe damage was sustained to the roof section over the driver compartment area. Post-test vehicle damage is shown in Figure 114.

A summary of the test results and other information pertinent to this test are given in Figure 115. The maximum 0.050 second average acceleration experienced by the vehicle was -3.7 g in the longitudinal direction and -1.4 g in the lateral direction. Vehicle angular displacements are plotted in Figure 116 and vehicle accelerometer traces are displayed in Figures 117 through 119. Occupant impact velocity was 9.2 ft/s (2.8 m/s) in the longitudinal direction and no contact was recorded in the lateral direction. Occupant ridedown acceleration was -1.8 g in the longitudinal direction. Change in vehicle velocity was 5.8 mi/h (9.3 km/h) and change in momentum was 473 lb-s.
Figure 109. Vehicle before test 7185-10.
Figure 110. Sign installation before test 7185-10.
Figure 111. Vehicle/sign geometrics (test 7185-10).
Figure 112. Sequential photographs of test 7185-10.
Figure 112. Sequential photographs of test 7185-10 (continued).
Figure 113. Sign installation after test 7185-10.
Figure 114. Vehicle after test 7185-10.
Test No. .................. 7185-10
Date ...................... 06/27/91
Test Article ................ Sign Installation
Support .................... One Franklin 60 ksi
4 lb/ft Steel U-Channel
Embedment ................ 3'-9" driven
(NCHRP S-1 soil)
Vehicle .................... 1988 Yugo
Vehicle Weight
Test Inertia ................ 1,200 lb (817 kg)
Gross Static ................ 1,970 lb (894 kg)
Vehicle Damage Classification
TAD ...................... 12FR-1
SAE ....................... J2FLEK1 & 12FLGN3
Impact Speed ................ 60.8 mi/h (97.8 km/h)
Change in Velocity ........ 5.8 mi/h (9.3 km/h)
Change in Momentum .......... 473.0 lb-s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal ................ -3.7 g
Lateral ........................ -1.4 g
Occupant Impact Velocity
Longitudinal ................ 9.2 ft/s (2.8 m/s)
Lateral ........................ N/A
Occupant Ridedown Accelerations
Longitudinal ................ -1.8 g
Lateral ........................ No Contact

Figure 115. Summary of results for test 7185-10.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 116. Vehicle angular displacement for test 7185-10.
CRASH TEST 7185-10
Class 180 Filter

Figure 117. Longitudinal accelerometer trace (7185-10).
CRASH TEST 7185-10
Class 180 Filter

Time (seconds)
Vertical Acceleration (g's)

Figure 119. Vertical accelerometer trace (7185-10).
In summary, the sign installation yielded to the vehicle by fracturing the post at bumper height and failing the splice bolts. The vehicle sustained minor damage to the frontal area of the vehicle. However, an unacceptable amount of deformation was sustained to the roof over the driver compartment. Occupant impact velocities and ride-down accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. Due to the amount of intrusion into the driver compartment, this sign installation in "strong soil" is unacceptable according to the evaluation criteria recommended in NCHRP Report 230.

Test 7185-11

A 1986 Chevrolet Sprint (shown in Figure 120) impacted a 4 lb/ft Marion steel u-channel, normal splice orientation, sign installation in weak soil (shown in Figure 121). The impact was conducted at 19.2 miles per hour (30.9 km/h) using a cable reverse tow and guidance system. The point of impact (shown in Figure 122) was the front left quarter point of the vehicle bumper with the sign installation. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross static mass was 1,970 lb (894 kg). The height from roadway surface to the lower edge of the vehicle bumper was 13.0 inches (33.0 cm) and 18.5 inches (47.0 cm) to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 123.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. At approximately 0.047 second, the sign support fractured at approximately bumper height. Shortly thereafter, the upper post section lost contact with the vehicle and impacts roadway. The vehicle passed over the post stub and remaining appendage, the brakes were applied and the vehicle came to rest approximately 60.0 ft (18.3 m) from the point of impact. Sequential photographs of the test are shown in Figure 124.

The installation yielded to the vehicle. The mode of failure was fracturing of the sign support at approximately 17.0 in (43.2 cm). The sign support ground stub was displaced rearward. The sign installation came to rest 20.0 ft (6.1 m) from the point of impact. Damage sustained to the sign installation is shown in Figure 125. The vehicle sustained only minor damage to the bumper.
Figure 120. Vehicle before test 7185-11.
Figure 121. Sign installation before test 7185-11.
Figure 122. Vehicle/sign geometrics (test 7185-11).
Date: 09/10/91  Test No.: 7185-11 & 12  VIN: 1G1NB08546K708451

Make: Chevrolet  Model: Sprint  Year: 1986  Odometer: __________


Height of rear accelerometer: 29½"  Tire Condition: good __  fair __  badly worn __

Vehicle Geometry - inches
a 60"  b 26½"  c 87"  d* 52"  e 25½"  f 138 3/4"  g ___  h 34.9
i ___  j 27½"  k 14"  l 43½"  m 18½"  n 3 3/4"  o 13"  p 52 3/4"
q 21"  r 13"  s ___

Engine Type: 3 cyl.  Engine CID: ________  Transmission Type: ANXXXXXX or Manual
FWD or RWD or 4WD

Body Type: Hatch

Steering Column Collapse Mechanism:
- Behind wheel units
- Convoluted tube
- Cylindrical mesh units
- Embedded ball
- NOT collapsible
- Other energy absorption
- Unknown

Brakes:
Front: disc X drum __
Rear: disc ___ drum X

Note any damage to vehicle prior to test:

4-wheel weight for c.g. det.  \( \ell_f \) 544  \( \ell_r \) 379  \( \ell_r \) 544

Mass - pounds
Curb  Test Inertial  Gross Static
\( M_1 \) 982  1078  1165
\( M_2 \) 562  722  805
\( M_T \) 1544  1800  1970

\*d = Overall height of vehicle

Figure 123. Test Vehicle properties (7185-11 & 12).
Figure 124. Sequential photographs of test 7185-11.
Figure 124. Sequential photographs of test 7185-11 (continued).
Figure 125. Sign installation after test 7185-11.
A summary of the test results and other information pertinent to this test are given in Figure 126. The maximum 0.050 second average acceleration experienced by the vehicle was -1.8 g in the longitudinal direction and 0.4 g in the lateral direction. Vehicle angular displacements are plotted in Figure 127 and vehicle accelerometer traces are displayed in Figures 128 through 130. Occupant impact velocity was 2.8 ft/s (0.8 m/s) in the longitudinal direction; and no contact was recorded in the lateral direction. Occupant ridedown acceleration was -0.3 g's in the longitudinal direction. Change in vehicle velocity was 4.3 mi/h (7.0 km/h) and change in momentum was 355 lb-s.

In summary, the sign installation yielded to the vehicle by fracturing the post at bumper height. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was no deformation or penetration into the occupant compartment. Occupant impact velocities and ridedown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "weak soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

Test 7185-12

The same 1986 Chevrolet Sprint and sign installation configuration (shown in Figures 131 & 132, respectively) used in the 20 mile per hour crash test (7185-11) was used for the 60 mile per hour test. The vehicle impacted the sign installation at 61.9 miles per hour (99.5 km/hr) using a cable reverse tow and guidance system. The point of impact (shown in Figure 133) was the front right quarter point of the vehicle bumper with the sign installation.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. At approximately 0.012 second, the sign support fractured at bumper height and the splice bolts failed. Shortly thereafter, the installation lost contact with the vehicle. As the vehicle continued to move forward, the installation passed over the vehicle. At approximately 0.109 seconds, the sign blank impacted the right rear of the roof of the vehicle and bounced off. Shortly thereafter, the brakes were applied and the vehicle came to rest approximately 275.0 ft (83.8 m) from the point of impact. Sequential
Test No. .......... 7185-11
Date .......... 09/10/91
Test Article .......... Sign Installation
Support .......... One Marion 80 ksi,
4 lb/ft Steel U-Channel
Embedment .......... 3'-9" driven
(NCHRP S-2 soil)
Vehicle .......... 1986 Chevrolet Sprint
Vehicle Weight
Test Inertia .......... 1,800 lb (817 kg)
Gross Static .......... 1,970 lb (894 kg)
Vehicle Damage Classification
TAD .......... 12FLO
SAE .......... 12FLLUO
Impact Speed .......... 19.2 mi/h (30.9 km/h)
Change in Velocity .......... 4.3 mi/h (7.0 km/h)
Change in Momentum .......... 355.0 lb-s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal .......... -1.8 g
Lateral .......... 0.4 g
Occupant Impact Velocity
Longitudinal .......... 2.8 ft/s (0.8 m/s)
Lateral .......... N/A
Occupant Ridedown Accelerations
Longitudinal .......... -0.3 g
Lateral .......... No Contact

Figure 126. Summary of results for test 7185-11.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 127. Vehicle angular displacement for test 7185-11.
Figure 128. Vehicle longitudinal accelerometer trace for test 7185-11.
Figure 129. Vehicle lateral accelerometer trace for test 7185-11.
CRASH TEST 7185-11
Class 180 Filter

Figure 130. Vehicle vertical accelerometer trace for test 7185-11.
Figure 131. Vehicle before test 7185-12.
Figure 132. Sign installation before test 7185-12.
Figure 133. Vehicle/sign geometrics (test 7185-12).
photographs of the test are shown in Figure 134.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts and sign support. The sign support ground stub was displaced rearward 3.5 in (8.9 cm). The sign installation came to rest 120.0 ft (36.6 m) from the point of impact. Damage sustained to the sign installation is shown in Figure 135. The vehicle sustained damage to the bumper, hood, grill and rear most section of the roof as shown in Figure 136.

A summary of the test results and other information pertinent to this test are given in Figure 137. The maximum 0.050 second average acceleration experienced by the vehicle was \(-1.2\) g in the longitudinal direction and \(0.7\) g in the lateral direction. Vehicle angular displacements are plotted in Figure 138 and vehicle accelerometer traces are displayed in Figures 139 through 141. Occupant impact velocity and ridedown was not applicable for this test. Change in vehicle velocity was 3.7 mi/h (6.0 km/h) and change in momentum was 303 lb-s.

In summary, the sign installation yielded to the vehicle by fracturing the post at bumper height and failing the splice bolts. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was minimal deformation and no penetration into the occupant compartment. Occupant impact velocities and ridedown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "weak soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

**Test 7185-13**

A 1988 Yugo (shown in Figure 142) impacted a 4 lb/ft Marion steel u-channel, normal splice orientation, sign installation in strong soil (shown in Figure 143). The impact was conducted at 20.1 miles per hour (32.4 km/h) using a cable reverse tow and guidance system. The point of impact (shown in Figure 144) was the front left quarter point of the vehicle bumper with the sign installation. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross static mass was 1,970 lb (894 kg). The height from roadway surface to the lower edge of the vehicle bumper was 14.3 inches (36.2 cm) and 19.5 inches (49.5 cm) to the top of the bumper. Other dimensions and information on the vehicle are given in Figure
Figure 134. Sequential photographs of test 7185-12.
Figure 134. Sequential photographs of test 7185-12 (continued).
Figure 135. Sign installation after test 7185-12.
Figure 136. Details of vehicle damage after test 7185-12.
Test No. ..................... 7185-12
Date ......................... 09/10/91
Test Article ................... Sign Installation
Support ....................... One Marion 80 ksi,
4 lb/ft Steel U-Channel
3'-9" driven
(NCHRP S-2 soil)
Embedment ......................
Vehicle ....................... 1986 Chevrolet Sprint
Vehicle Weight
Test Inertia ................... 1,800 lb (817 kg)
Gross Static ................... 1,970 lb (894 kg)
Vehicle Damage Classification
TAD ......................... 12FR-1
SAE ......................... 12FREN1
Impact Speed .................. 61.9 mi/h (99.5 km/h)
Change in Velocity ........... 3.7 mi/h (6.0 km/h)
Change in Momentum .......... 303.0 lb-s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal ................. -1.2 g
Lateral ...................... 0.7 g
Occupant Impact Velocity
Longitudinal ................... N/A
Lateral ...................... N/A
Occupant Ridedown Accelerations
Longitudinal ................... No Contact
Lateral ...................... No Contact

Figure 137. Summary of results for test 7185-12.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 138. Vehicle angular displacement for test 7185-12.
Figure 4.1. Vehicle vertical accelerometer trace for test 7185-12.
Figure 142. Vehicle before test 7185-13.
Figure 143. Sign installation before test 7185-13.
Figure 144. Vehicle/sign geometrics (test 7185-13).
The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. At approximately 0.028 second, the sign support fractured just above bumper height and the splice bolts failed. Shortly thereafter, the installation temporarily lost contact with the vehicle. As the vehicle continued to move forward, the installation laid over on the hood area, allowing the sign panel to impact the windshield. Shortly thereafter, the brakes were applied and the vehicle came to rest approximately 90.0 ft (27.4 m) from the point of impact. Sequential photographs of the test are shown in Figure 146.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts and sign support. The sign installation came to rest 43.0 ft (13.1 m) from the point of impact. Damage sustained to the sign installation is shown in Figure 147. The vehicle sustained damage to the bumper, hood, and windshield as shown in Figure 148.

A summary of the test results and other information pertinent to this test are given in Figure 149. The maximum 0.050 second average acceleration experienced by the vehicle was -1.1 g in the longitudinal direction and 0.4 g in the lateral direction. Vehicle angular displacements are plotted in Figure 150 and vehicle accelerometer traces are displayed in Figures 151 through 153. Occupant impact velocity and ride-down is not applicable to this test. Change in vehicle velocity was 1.0 mi/h (1.6 km/h) and change in momentum was 84 lb-s.

In summary, the sign installation yielded to the vehicle by fracturing the post at bumper height and failing the splice bolts. The vehicle sustained minor damage and did not present undue hazard to other traffic. The impact sustained to the windshield did not penetrate the occupant compartment. Occupant impact velocities and ride-down accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "strong soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

Test 7185-14

The same 1988 Yugo and sign installation configuration (shown in Figures 154 & 155,
Figure 145 Test vehicle properties (7185-13 & 14).
Figure 146. Sequential photographs of test 7185-13.
Figure 146. Sequential photographs of test 7185-13 (continued).
Figure 147. Sign installation after test 7185-13.
Figure 148. Vehicle after test 7185-13.
<table>
<thead>
<tr>
<th>Test No.</th>
<th>7185-13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>09/12/91</td>
</tr>
<tr>
<td>Test Article</td>
<td>Sign Installation</td>
</tr>
<tr>
<td>Support</td>
<td>One Marion 80 ksi, 4 lb/ft Steel U-Channel</td>
</tr>
<tr>
<td>Embedment</td>
<td>3'-9&quot; driven (NCHRP S-1 soil)</td>
</tr>
<tr>
<td>Vehicle</td>
<td>1988 Yugo</td>
</tr>
<tr>
<td>Vehicle Weight</td>
<td>Test Inertia: 1,800 lb (817 kg)</td>
</tr>
<tr>
<td>Gross Static</td>
<td>1,970 lb (894 kg)</td>
</tr>
</tbody>
</table>

| Impact Speed  | 20.1 mi/h (32.4 km/h) |
| Change in Velocity | 1.0 mi/h (1.6 km/h) |
| Change in Momentum | 84.0 lb-s |

**Vehicle Accelerations**
(Max. 0.050-sec Avg)
- Longitudinal: -1.1 g
- Lateral: 0.4 g

**Occupant Impact Velocity**
- Longitudinal: N/A
- Lateral: N/A

**Occupant Ridedown Accelerations**
- Longitudinal: No Contact
- Lateral: No Contact

Figure 149. Summary of results for test 7185-13.
Figure 150. Vehicle angular displacement for test 7185-13.
CRASH TEST 7185-13
Class 180 Filter

Figure 151. Longitudinal accelerometer trace for test 7185-13.
Figure 153. Vertical accelerometer trace for test 7185-13.
Figure 154. Vehicle before test 7185-14.
Figure 155. Sign installation before test 7185-14.
respectively) used in the 20 mile per hour crash test (7185-13) was used for the 60 mile per hour test. The vehicle impacted the sign installation at 61.8 miles per hour (99.4 km/hr) using a cable reverse tow and guidance system. The point of impact (shown in Figure 156) was the front right quarter point of the vehicle bumper with the sign installation.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. At approximately 0.010 second, the sign support fractured at approximately bumper height and the splice bolts failed. Shortly thereafter, the installation lost contact with the vehicle. As the vehicle continued to move forward, the installation attempted to pass over the vehicle. At approximately 0.118 seconds, the sign panel impacted the right rear of the roof of the vehicle and bounced off. Shortly thereafter, the brakes were applied and the vehicle came to rest approximately 310.0 ft (94.5 m) from the point of impact. Sequential photographs of the test are shown in Figure 157.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts and sign support. The sign installation came to rest 73.0 ft (22.3 m) from the point of impact. Damage sustained to the sign installation is shown in Figure 158. The vehicle sustained damage to the bumper, hood, grill and roof as shown in Figure 159. A summary of the test results and other information pertinent to this test are given in Figure 160. The maximum 0.050 second average acceleration experienced by the vehicle was -1.4 g in the longitudinal direction and -0.8 g in the lateral direction. Vehicle angular displacements are plotted in Figure 161 and vehicle accelerometer traces are displayed in Figures 162 through 164. Occupant impact velocity and ridedown was not applicable to this test. Change in vehicle velocity was 3.1 mi/h (4.9 km/h) and change in momentum was 437 lb-s.

In summary, the sign installation yielded to the vehicle by fracturing the post at bumper height and failing the splice bolts. The vehicle sustained minor damage and did not present undue hazard to other traffic. The impact sustained to the roof did not penetrate or cause excessive deformation to the occupant compartment. Occupant impact velocities and ridedown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "strong soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985
Figure 156. Vehicle/sign geometrics (test 7185-14).
Figure 157. Sequential photographs of test 7185-14.
Figure 157. Sequential photographs of test 7185-14 (continued).
Figure 158. Sign installation after test 7185-14.
Figure 159. Vehicle after test 7185-14.
Test No.: 7185-14
Date: 09/12/91
Test Article: Sign Installation
Support: One Marion 80 ksi,
4 lb/ft Steel U-Channel
Embedment: 3' - 9" driven
(NCHRP S-1 soil)
Vehicle: 1988 Yugo
Vehicle Weight: 1,800 lb (817 kg)
Gross Static: 1,970 lb (894 kg)
Vehicle Damage Classification:
TAO: 12FR-1
SAE: 12FRAN1
Impact Speed: 61.8 mi/h (99.4 km/h)
Change in Velocity: 3.1 mi/h (4.9 km/h)
Change in Momentum: 251.0 lb-s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal: -1.4 g
Lateral: -0.8 g
Occupant Impact Velocity
Longitudinal: N/A
Lateral: N/A
Occupant Rideown Accelerations
Longitudinal: No Contact
Lateral: No Contact

Figure 160. Summary of results for test 7185-14.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 161. Vehicle angular displacement for test 7185-14.
Figure 162. Longitudinal accelerometer trace for test 7185-14.
CRASH TEST 7185-14
Class 180 Filter

Figure 163. Lateral accelerometer trace for test 7185-14.
Figure 164. Vertical accelerometer trace for test 7185-14.
AASHTO Standards.

Test 7185-15

A 1987 Yugo (shown in Figure 165) impacted a 4 lb/ft Franklin steel u-channel, normal splice orientation, sign installation in strong soil (shown in Figure 166). The impact was conducted at 19.4 miles per hour (31.2 km/h) using a cable reverse tow and guidance system. The point of impact (shown in Figure 167) was the front left quarter point of the vehicle bumper with the sign installation. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross static mass was 1,970 lb (894 kg). The height from roadway surface to the lower edge of the vehicle bumper was 14.5 inches (36.8 cm) and 20.0 inches (50.8 cm) to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 168.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. By approximately 0.042 second, the splice bolts had failed. Shortly thereafter, the sign installation strikes the roadway. The vehicle passed over the installation, the brakes were applied and the vehicle came to rest approximately 70.0 ft (21.3 m) from the point of impact. Sequential photographs of the test are shown in Figure 169.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts. The sign support ground stub was displaced rearward 0.8 in (2.0 cm). The sign installation came to rest 42.0 ft (12.8 m) from the point of impact. Damage sustained to the sign installation is shown in Figure 170. The vehicle sustained only minor damage to the bumper and hood as shown in Figure 171.

A summary of the test results and other information pertinent to this test are given in Figure 172. The maximum 0.050 second average acceleration experienced by the vehicle was -2.0 g in the longitudinal direction and -0.3 g in the lateral direction. Vehicle angular displacements are plotted in Figure 173 and vehicle accelerometer traces are displayed in Figures 174 through 176. Occupant impact velocity was 5.8 ft/s (1.8 m/s) in the longitudinal direction and no contact was recorded in the lateral direction. Occupant ridedown acceleration was 0.1 g's in the longitudinal direction. Change in vehicle velocity was 4.3
Figure 165. Vehicle before test 7185-15.
Figure 166. Sign installation before test 7285-15.
Figure 167. Sign/vehicle geometrics (test 7185-15).
Date: 10/03/91  Test No.: 7185-15 & 16  VIN: VX1BA121XH347581
Make: Yugo  Model: GV  Year: 1987  Odometer: 9624
Height of rear accelerometer: 26½"  Vehicle Geometry - inches
  a  60"  b  26½"  
c  45"  d*  55½"  
e  25½"  f  137"  
g  32.3"  h  31½"  
i  ---  j  31½"  
k  15½"  l  31½"  
m  20"  n  3"  
o  14½"  p  51½"  
r  22"  s  14½"
Engine Type: 4 cyl.  Engine CID: 1100 cc
Transmission Type: XXXXXX or Manual  FWD or RWD or AWD
Body Type: hatch back
Steering Column Collapse Mechanism:  
  __ Behind wheel units  
  __ Convoluted tube  
  __ Cylindrical mesh units  
  __ Embedded ball  
  NOT collapsible  
  Other energy absorption  
  Unknown
Brakes:
  Front: disc  X  drum  
  Rear:  disc  __  drum X

4-wheel weight for c.g. det.  ef  558  rf  558  lr  330  rr  354
Mass - pounds  Curb  Test Inertial  Gross Static
M₁  573/1137/564  1116  1202
M₂  303/607/304  684  768
M₇  876/1744/868  1800  1970

Note any damage to vehicle prior to test:
  Crack in windshield (marked)

*d = overall height of vehicle

Figure 168. Test vehicle properties (7185-15 & 16).
Figure 169. Sequential photographs of test 7185-15.
Figure 169. Sequential photographs of test 7185-15 (continued).
Figure 170. Sign installation after test 7185-15.
Figure 171. Details of damage to vehicle (test-15).
Test No. .......... 7185-15
Date ............ 10/03/91
Test Article ....... Sign Installation
Support .......... One Franklin 60 ksi,
                4 lb/ft Steel U-Channel
Embedment ...... 3'-9" driven
(NCHRSP S-1 soil)
Vehicle ........... 1987 Yugo
Vehicle Weight
Test Inertia ...... 1,800 lb (817 kg)
Gross Static ..... 1,970 lb (994 kg)
Vehicle Damage Classification
TAD ............. 12FL-1
SAE ............. 12FLM1

Impact Speed ........ 19.4 mi/h (31.2 km/h)
Change in Velocity .. 4.3 mi/h (6.9 km/h)
Change in Momentum .. 356.0 lb-s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal ....... -2.0 g
Lateral ............ -0.3 g
Occupant Impact Velocity
Longitudinal ....... 5.8 ft/s (1.8 m/s)
Lateral ............ N/A
Occupant Ridedown Accelerations
Longitudinal ....... 0.1 g
Lateral ............ No Contact

Figure 172. Summary of results for test 7185-15.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 173. Vehicle angular displacement for test 7185-15.
Figure 174. Longitudinal accelerometer trace for test 7185-15.
Figure 175. Lateral accelerometer trace for test 7185-15.
Figure 176. Vertical accelerometer trace for test 7185-15.
mi/h (6.9 km/h) and change in momentum was 356 lb-s.

In summary, the sign installation yielded to the vehicle by fracturing the splice bolts. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was no deformation or penetration into the occupant compartment. Occupant impact velocities and ride-down accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "strong soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

Test 7185-16

The same 1987 Yugo and sign installation configuration (shown in Figures 177 & 178, respectively) used in the 20 mile per hour crash test (7185-15) was used for the 60 mile per hour test. The vehicle impacted the sign installation at 62.4 miles per hour (100.4 km/hr) using a cable reverse tow and guidance system. The point of impact (shown in Figure 179) was the front right quarter point of the vehicle bumper with the sign installation.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. By approximately 0.013 second, the splice bolts had failed. Shortly thereafter, the sign installation strikes the roadway. The vehicle passed over the installation, the brakes were applied and the vehicle came to rest approximately 295.0 ft (89.9 m) from the point of impact. Sequential photographs of the test are shown in Figure 180.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts. The sign support ground stub was displaced rearward 0.3 in (0.6 cm). The sign installation came to rest 160.0 ft (48.8 m) from the point of impact. Damage sustained to the sign installation is shown in Figure 181. The vehicle sustained minor damage to the bumper, hood, grill and roof as shown in Figure 182.

A summary of the test results and other information pertinent to this test are given in Figure 183. The maximum 0.050 second average acceleration experienced by the vehicle was -2.3 g in the longitudinal direction and -0.7 g in the lateral direction. Vehicle angular displacements are plotted in Figure 184 and vehicle accelerometer traces are displayed in
Figure 177. Vehicle before test 7185-16.
Figure 178. Sign installation before test 7185-16.
Figure 179. Vehicle/sign geometrics (test 7185-16).
Figure 180. Sequential photographs of test 7185-16.
Figure 180. Sequential photographs of test 7185-16 (continued).
Figure 181. Sign installation after test 7185-16.
Figure 182. Details of damage to vehicle (test 7185-16).
Test No. .................. 7185-16
Date ...................... 10/03/91
Test Article .............. Sign Installation
Support ................... One Franklin 60 ksi,
4 lb/ft Steel U-Channel
Embedment ............... 3'-9" driven
(NCHRP S-1 soil)
Vehicle .................... 1987 Yugo
Vehicle Weight
Test Inertia ............... 1,800 lb (817 kg)
Gross Static ............... 1,970 lb (894 kg)
Vehicle Damage Classification
TAD ....................... 12FR-2
SAE ....................... 12FRAN2
Impact Speed .............. 62.4 mi/h (100.4 km/h)
Change in Velocity ........ 4.2 mi/h (6.8 km/h)
Change in Momentum ....... 344.0 lb-s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal ............ -2.3 g
Lateral .................. -0.7 g
Occupant Impact Velocity
Longitudinal ............ 5.7 ft/s (1.7 m/s)
Lateral .................. -3.3 ft/s (1.0 m/s)
Occupant Ridedown Accelerations
Longitudinal ............ 2.5 g
Lateral .................. -1.1 g

Figure 183. Summary of results for test 7185-16.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 184. Vehicle angular displacement for test 7185-16.
Figures 185 through 187. Occupant impact velocity was 5.7 ft/s (1.7 m/s) in the longitudinal direction and -3.3 ft/s (1.0 m/s) in the lateral direction. Occupant ridedown accelerations were 2.5 g's longitudinal and -1.1 g's lateral. Change in vehicle velocity was 4.2 mi/h (6.8 km/h) and change in momentum was 344.0 lb-s.

In summary, the sign installation yielded to the vehicle by fracturing the splice bolts. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was minimal deformation and no penetration into the occupant compartment. Occupant impact velocities and ridedown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. This sign installation in "strong soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.

Test 7185-17

A 1987 Yugo (shown in Figure 188) impacted a 4 lb/ft Franklin steel u-channel, normal splice orientation, sign installation in weak soil (shown in Figure 189). The impact was conducted at 20.0 miles per hour (32.2 km/h) using a cable reverse tow and guidance system. The point of impact (shown in Figure 190) was the front left quarter point of the vehicle bumper with the sign installation. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross static mass was 1,970 lb (894 kg). The height from roadway surface to the lower edge of the vehicle bumper was 14.0 inches (35.6 cm) and 19.5 inches (49.5 cm) to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 191.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to deform. By approximately 0.186 second, the splice bolts had failed and the installation had lost contact with the vehicle. Shortly thereafter, the sign installation strikes the roadway. The vehicle passed over the installation, the brakes were applied and the vehicle came to rest approximately 40.0 ft (12.2 m) from the point of impact. Sequential photographs of the test are shown in Figure 192.

The installation yielded to the vehicle. The mode of failure was fracturing of the splice bolts. The sign support ground stub was displaced rearward 16.0 in (40.6 cm). The
Figure 185. Longitudinal accelerometer trace for test 7185-16.
CRASH TEST 7185-16
Class 180 Filter

Figure 186. Lateral accelerometer trace for test 7185-16.
Figure 187. Vertical accelerometer trace for test 7185-16.
Figure 188. Vehicle before test 7185-17.
Figure 190. Vehicle/sign geometrics (test 7185-17).
Date: 10/08/91    Test No.: 7185-17 & 18    VIN: VX18A1219JK388239
Make: Yugo    Model: GV    Year: 1987    Odometer: 2243
Tire Condition: good
Height of    fair X    rear accelerometer
26 1/2"
Vehicle Geometry - inches
a 60 1/2"    b 26 1/2"
c 85"    d* 55 3/4"
e 26"    f 137 1/4"
g    h 33.8"
i    j 31"
k 16"    l 32"
m 19 1/2"    n 2 3/4"
o 14"    p 53"
r 22"    s 14 1/2"

Engine Type: 4 cyl
Engine C10: 1100 cc
Transmission Type: Automatic or Manual
FWD or 4WD or XW

Body Type: hatchback

Steering Column Collapse Mechanism:
Behind wheel units
Convoluted tube
Cylindrical mesh units
Embedded ball
NOT collapsible
Other energy absorption
Unknown

Brakes:
Front: disc X drum
Rear: disc__ drum X

4-wheel weight for c.g. det.  lf 552    rf 533    lr 355    rr 360

Mass - pounds    Curb    Test Inertial    Gross Static
M₁ 582/1149/567    1085    1170
M₂ 309/616/307    715    800
Mₜ 891/1765/874    1800    1970

Note any damage to vehicle prior to test:
Crack in windshield (marked)

*d = overall height of vehicle

Figure 191. Test vehicle properties (7185-17 & 18).

241
Figure 192. Sequential photographs of test 7185-17.
Figure 192. Sequential photographs of test 7185-17 (continued).
sign installation came to rest 15.0 ft (4.6 m) from the point of impact. Damage sustained
to the sign installation is shown in Figure 193. The vehicle sustained minor damage to the
bumper as shown in Figure 194.

A summary of the test results and other information pertinent to this test are given
in Figure 195. The maximum 0.050 second average acceleration experienced by the vehicle
was -1.8 g in the longitudinal direction and -0.3 g in the lateral direction. Vehicle angular
displacements are plotted in Figure 196 and vehicle accelerometer traces are displayed in
Figures 197 through 199. Occupant impact velocity was 7.1 ft/s (2.2 m/s) in the longitudinal
direction and no contact was recorded in the lateral direction. Occupant ridedown
acceleration was 0.3 g's longitudinal. Change in vehicle velocity was 5.6 mi/h (9.0 km/h)
and change in momentum was 459.0 lb-s.

In summary, the sign installation yielded to the vehicle by fracturing the splice bolts.
The vehicle sustained minor damage and did not present undue hazard to other traffic.
There was no deformation or penetration into the occupant compartment. Occupant impact
velocities and ridedown accelerations were within the recommended limits of 15 ft/s and
15 g's respectively, as specified in NCHRP 230. This sign installation in "weak soil" is
acceptable according to the evaluation criteria recommended in NCHRP Report 230 and
the 1985 AASHTO Standards.

Test 7185-18

The same 1987 Yugo and sign installation configuration (shown in Figures 200 & 201,
respectively) used in the 20 mile per hour crash test (7185-17) was used for the 60 mile per
hour test. The vehicle impacted the sign installation at 62.4 miles per hour (100.4 km/hr)
using a cable reverse tow and guidance system. The point of impact (shown in Figure 202)
was the front right quarter point of the vehicle bumper with the sign installation.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact,
the sign support began to deform, forming a pocket around the bumper. At approximately
0.047 second, the sign support fractured at bumper height. Shortly thereafter, the sign
support ground stub and remaining attached post appendage was pulled from the soil. As
the vehicle continued forward, the sign panel struck the right side of the roof directly above
Figure 193. Sign installation after test 7185-17.
Figure 194. Vehicle after test 7185-17.
Test No. .............. 7185-17
Date .............. 10/08/91
Test Article .............. Sign Installation
Support. .............. One Franklin 60 ksi, 4 lb/ft Steel U-Channel
Embedment. .............. 3'9" driven (NCHRP S-2 soil)
Vehicle .............. 1987 Yugo
Vehicle Weight
   Test Inertia .............. 1,800 lb (817 kg)
   Gross Static .............. 1,970 lb (894 kg)
Vehicle Damage Classification
   TAD .............. 12FL-1
   SAE .............. 12FLLN1
Impact Speed .............. 20.0 mi/h (32.2 km/h)
Change in Velocity .............. 5.6 mi/h (9.0 km/h)
Change in Momentum .............. 459.0 lb-s
Vehicle Accelerations
   (Max. 0.050-sec Avg)
      Longitudinal .............. -1.8 g
      Lateral .............. -0.3 g
Occupant Impact Velocity
   Longitudinal .............. 7.1 ft/s (2.2 m/s)
   Lateral .............. N/A
Occupant Ridedown Accelerations
   Longitudinal .............. 0.3 g
   Lateral .............. No Contact

Figure 195. Summary of results for test 7185-17.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 196. Vehicle angular displacement for test 7185-17.
CRASH TEST 7185-17
Class 180 Filter

Figure 197. Longitudinal accelerometer trace for test 7185-17.
Figure 198. Lateral accelerometer trace for test 7185-17.
CRASH TEST 7185-17
Class 180 Filter

Figure 199. Vertical accelerometer trace for test 7185-17.
Figure 200. Sign installation before test 7185-18.
Figure 201. Vehicle before test 7185-18.
Figure 202. Vehicle/sign geometrics (test 7185-19).
the windshield. The vehicle exited, the brakes were applied and the vehicle came to rest approximately 285.0 ft (86.9 m) from the point of impact. Sequential photographs of the test are shown in Figure 203.

The installation yielded to the vehicle. The mode of failure was fracturing of the sign support. The upper post section and attached sign panel came to rest 260.0 ft (79.3 m) from the point of impact. The sign support ground stub and attached post fragment came to rest 178 ft (54.3 m). Damage sustained to the sign installation is shown in Figure 204. The vehicle sustained damage to the bumper, hood, right front area of the roof and windshield. However, severe damage was sustained to the roof section over the driver compartment area. Post-test vehicle damage is shown in Figure 205. A summary of the test results and other information pertinent to this test are given in Figure 206. The maximum 0.050 second average acceleration experienced by the vehicle was -2.9 g in the longitudinal direction and 1.0 g in the lateral direction. Vehicle angular displacements are plotted in Figure 207 and vehicle accelerometer traces are displayed in Figures 208 through 210. Occupant impact velocity was 5.3 ft/s (1.6 m/s) in the longitudinal direction and 5.7 ft/s (1.7 m/s) in the lateral direction. Occupant ridedown accelerations were 0.6 g's longitudinal and 0.3 lateral. Change in vehicle velocity was 5.5 mi/h (8.9 km/h) and change in momentum was 454 lb-s.

In summary, the sign installation yielded to the vehicle by fracturing the post at bumper height. The vehicle sustained minor damage to the frontal area of the vehicle. However, an unacceptable amount of deformation was sustained to the roof over the passenger compartment. Occupant impact velocities and ridedown accelerations were within the recommended limits of 15 ft/s and 15 g's respectively, as specified in NCHRP 230. Due to the amount of intrusion into the passenger compartment, this sign installation in "weak soil" is unacceptable according to the evaluation criteria recommended in NCHRP Report 230.

Test 7185-19

A 1986 Yugo (shown in Figure 211) impacted a 3/16 in x 3-1/2 in aluminum tube sign installation in weak soil (shown in Figure 212). The impact was conducted at 19.0 miles per hour (30.6 km/h) using a cable reverse tow and guidance system. The point of impact
Figure 203. Sequential photographs of test 7185-18.
Figure 203. Sequential photographs of test 7185-18 (continued).
Figure 204. Sign installation after test 7185-18.
Figure 205. Vehicle after test 7185-18.
Test No. .......................... 7185-18
Date ............................. 10/08/91
Test Article ...................... Sign Installation
Support ......................... One Franklin 60 ksi, 4 lb/ft Steel U-Channel
Embedment ...................... 3'-9" driven (NCHRP S-2 soil)
Vehicle ........................... 1987 Yugo
Vehicle Weight ....................
Test Inertia ...................... 1,800 lb (817 kg)
Gross Static ...................... 1,970 lb (894 kg)
Vehicle Damage Classification
TAD .............................. 12FR-2
SAE ............................. 12FREK2 & 12FRGN3

Impact Speed ...................... 62.4 mi/h (100.4 km/h)
Change in Velocity .............. 5.5 mi/h (8.9 km/h)
Change in Momentum ............. 454.0 lb-s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal ..................... -2.9 g
Lateral ......................... 1.0 g
Occupant Impact Velocity
Longitudinal ..................... 5.3 ft/s (1.6 m/s)
Lateral ......................... 5.7 ft/s (1.7 m/s)
Occupant Ridedown Accelerations
Longitudinal ..................... 0.6 g
Lateral ......................... 0.3 g

Figure 206. Summary of results for test 7185-18.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 207 Vehicle angular displacement for test 7185-18.
Figure 208. Vertical accelerometer trace for test 7185-18.
CRASH TEST 7185-18
Class 180 Filter

Figure 209. Lateral accelerometer trace for test 7185-18.
Figure 211. Vehicle before test 7185-19.
Figure 212. Sign installation before test 7185-19.
(shown in Figure 213) was the front left quarter point of the vehicle bumper with the sign installation. Test inertia mass of the vehicle was 1,800 lb (817 kg) and its gross static mass was 1,970 lb (894 kg). The height from roadway surface to the lower edge of the vehicle bumper was 13.0 inches (33.0 cm) and 18.3 inches (46.4 cm) to the top of the bumper. Other dimensions and information on the vehicle are given in Figure 214.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to yield. The support displaced over 69 degrees, allowing the vehicle to climb the support. Upon climbing the support, the front wheels and left rear wheel lost contact with the roadway. By approximately 0.481 seconds, the vehicle had climbed the support making contact with the sign panel. At 0.703 second, the sign panel arrested forward motion of the vehicle. The support laid over and the vehicle contacted the roadway at 0.863 second. The vehicle came to rest over the sign installation. Sequential photographs of the test are shown in Figure 215.

The installation failed to yield sufficiently to the vehicle. The sign support was displaced rearward 34 in (86.4 cm) prior to coming to rest on the roadway. Damage sustained to the sign installation is shown in Figure 216. The vehicle sustained only minor damage to the bumper, grill and hood as shown in Figures 217 and 218.

A summary of the test results and other information pertinent to this test are given in Figure 219. The maximum 0.050 second average acceleration experienced by the vehicle was -2.5 g in the longitudinal direction and 1.8 g in the lateral direction. Vehicle angular displacements are plotted in Figure 220 and vehicle accelerometer traces are displayed in Figures 221 and 222. Occupant impact velocity was 10.0 ft/s (3.0 m/s) in the longitudinal direction and -7.8 ft/s (2.4 m/s) in the lateral direction. Occupant riddenown accelerations in the longitudinal and lateral directions were -2.2 g's and 1.0 g's respectively. Change in vehicle velocity was 19.0 mi/h (30.6 km/h) and change in momentum was 1,558 lb-s.

In summary, the sign installation failed to yield to the vehicle. The vehicle sustained minor damage and did not present undue hazard to other traffic. There was no deformation or penetration into the occupant compartment. However, the change in vehicle velocity was (27.9 ft/s) was above the recommended limit of 15 ft/s as specified in 1985 AASHTO. Although the NCHRP Report 230 safety criteria was satisfied, this sign installation in "weak
Figure 213. Vehicle/sign geometrics (test 7185-19).
Date: 11/14/91       Test No.: 7185-19 & 20       VIN: VX1BA1217GK337430

Make: Yugo        Model: GV        Year: 1986        Odometer: 


Tire Condition: good       
rear accelerometer badly worn       

Vehicle Geometry - inches
a  60 1/4"   b  28"

Vehicle Geometry - inches
c  84 1/2"   d* 55"
e  24 1/2"   f 137"
g       h 28.5"
i     j 29 3/4"
k  15 1/4"   l  31 1/2"
m  19 1/4"   n  2 1/2"
o  13"   p 53"
r  22 1/2"   s 14 1/4"

Engine type: 4 cyl

Engine CID: 1100 cc

Transmission Type: Automatic or XXXX

Body type: Hatch

Steering Column Collapse Mechanism:
- Behind wheel units
- Convoluted tube
- Cylindrical mesh units
- Embedded ball
- NOL collapsible
- Other energy absorption
- Unknown

Brakes:
Front: disc X drum
Rear: disc drum X

4-wheel weight for c.g. det.  \( \ell_f \) 597  \( \ell_r \) 595  \( \ell_r \) 307  \( \ell_r \) 301

Mass - pounds  Curb  Test Inertial  Gross Static
\( \ell_f \) 605/1208/603  1192  1277

\( \ell_f \) 313/605/292  608  693

\( \ell_f \) 918/1813/895  1800  1970

Note any damage to vehicle prior to test:

* \( \ell_f \) = overall height of vehicle

Figure 214. Test vehicle properties (7185 - 19 & 20).
Figure 215. Sequential photographs of test 7185-19.
Figure 215. Sequential photographs of test 7185-19, continued.
Figure 216. Details of damage to the sign installation (test 7185-19).
Figure 217. Details of damage to the vehicle (test 7185-19).
Figure 21a. Sign installation and vehicle after test 7125-19.
Test No. ............... 7185-19
Date .................. 11/19/91
Test Article ............ Sign Installation
Support ............... 3/16" x 3'-1/2" x 13'-5" 6061-T6 aluminum tube
Embedment .......... 3'-9" driven (NCHRP S-2 soil)
Vehicle .................. 1986 Yugo GV
Vehicle Weight
Test Inertia .......... 1,800 lb (817 kg)
Gross Static .......... 1,970 lb (894 kg)
Vehicle Damage Classification
TAD .................... 12FL-1
SAE .................... 12FLEN1

Impact Speed ............. 19.0 mi/h (30.6 km/h)
Change in Velocity ........ 19.0 mi/h (30.6 km/h)
Change in Momentum ........ 1,558 lb·s
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal ............. -2.5 g
Lateral .................. 1.8 g
Occupant Impact Velocity
Longitudinal ............. 10.0 ft/s (3.0 m/s)
Lateral ................. -7.8 ft/s (-2.4 m/s)
Occupant Ridedown Accelerations
Longitudinal ............. 2.2 g
Lateral .................. 1.0 g

Figure 219. Summary of results for test 7185-19.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 220. Vehicle angular displacement for test 7185-19.
Figure 221. Longitudinal accelerometer trace for test 7185-19.
soil" is not acceptable according to the evaluation criteria recommended in the 1985 AASHTO Standards.

**Test 7185-20**

The same 1986 Yugo (shown in Figure 223) used in the 20 mile per hour crash test (7185-19) was used for the 60 mile per hour test (shown in Figure 224). The vehicle impacted a 3/16 in x 3-1/2 in aluminum tube sign installation in weak soil. The impact was conducted at 61.1 miles per hour (98.3 km/hr) using a cable reverse tow and guidance system. The point of impact (shown in Figure 225) was the front right quarter point of the vehicle bumper with the sign installation.

The vehicle was free wheeling and unrestrained just prior to impact. Upon impact, the sign support began to yield at ground level and just above bumper height. The post pocketed around the front of the vehicle. Shortly thereafter, the support pulled from the soil. As the vehicle attempted to pass over the installation, the support dug into the ground causing the vehicle to experience a tremendous amount of pitch and yaw. The brakes were applied and the vehicle came to rest approximately 175.0 ft (53.4 m) from the point of impact. Sequential photographs of the test are shown in Figure 226.

The installation yielded to the vehicle. The sign support pulled from the soil. The post was bent just below the soil plate and fractured 27.0 in above grade. The installation came to rest 140.0 ft (42.7 m) from the point of impact. Damage sustained to the sign installation is shown in Figure 227. The vehicle sustained damage to the bumper, hood, grill, right front fender and left front tire. Post-test vehicle damage is shown in Figure 228.

A summary of the test results and other information pertinent to this test are given in Figure 229. The maximum 0.050 second average acceleration experienced by the vehicle was -4.5 g in the longitudinal direction. Vehicle angular displacements are plotted in Figure 230 and the vehicle accelerometer trace is displayed in Figure 231. Occupant impact velocity was 10.9 ft/s (3.3 m/s) in the longitudinal direction. Occupant ridedown acceleration in the longitudinal direction was 2.7 g's. Change in vehicle velocity was approximately 8.4 mi/h (13.5 km/h) and change in momentum was 690 lb-s.

In summary, the sign installation yielded to the vehicle. The vehicle exhibited some
Figure 223. Vehicle before test 7185-20.
Figure 224. Sign installation before test 7195-20.
Figure 225. Vehicle/sign geometrics (test 7185-20).
Figure 226. Sequential photographs of test 7185-20.
Figure 226. Sequential photographs of test 7195-20, continued.
Figure 227. Sign installation after test 7185-20.
instability but did not present undue hazard to other traffic. Damage sustained to the vehicle was minor. There was minimal deformation and no penetration into the occupant compartment. This installation in "weak soil" is acceptable according to the evaluation criteria recommended in NCHRP Report 230 and the 1985 AASHTO Standards.
Figure 228. Vehicle after test 7185-20.
<table>
<thead>
<tr>
<th>Test No.</th>
<th>7185-20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>11/19/91</td>
</tr>
<tr>
<td>Test Article</td>
<td>Sign Installation</td>
</tr>
<tr>
<td>Support.</td>
<td>3/16&quot; x 3-1/2&quot; x 13'-5&quot; 6061-T6 aluminum tube</td>
</tr>
<tr>
<td>Embedment.</td>
<td>3'-9&quot; driven (NCHRP S-2 soil)</td>
</tr>
<tr>
<td>Vehicle.</td>
<td>1986 Yugo GV</td>
</tr>
<tr>
<td>Vehicle Weight</td>
<td></td>
</tr>
<tr>
<td>Test Inertia</td>
<td>1,800 lb (817 kg)</td>
</tr>
<tr>
<td>Gross Static</td>
<td>1,970 lb (894 kg)</td>
</tr>
<tr>
<td>Vehicle Damage Classification</td>
<td></td>
</tr>
<tr>
<td>TAD</td>
<td>12FR-2</td>
</tr>
<tr>
<td>SAE</td>
<td>12FREN2</td>
</tr>
<tr>
<td>Impact Speed.</td>
<td>61.1 mi/h (93.3 km/h)</td>
</tr>
<tr>
<td>Change in Velocity.</td>
<td>8.4 mi/h (13.5 km/h)</td>
</tr>
<tr>
<td>Change in Momentum.</td>
<td>690 lb-s</td>
</tr>
<tr>
<td>Vehicle Accelerations (Max. 0.050-sec Avg)</td>
<td></td>
</tr>
<tr>
<td>Longitudinal</td>
<td>-4.5 g</td>
</tr>
<tr>
<td>Lateral</td>
<td>N/A</td>
</tr>
<tr>
<td>Occupant Impact Velocity</td>
<td></td>
</tr>
<tr>
<td>Longitudinal</td>
<td>10.9 ft/s (3.3 m/s)</td>
</tr>
<tr>
<td>Lateral</td>
<td>N/A</td>
</tr>
<tr>
<td>Occupant Ridedown Accelerations</td>
<td></td>
</tr>
<tr>
<td>Longitudinal</td>
<td>2.7 g</td>
</tr>
<tr>
<td>Lateral</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Figure 229. Summary of results for test 7185-20.
Axes are vehicle fixed. Sequence for determining orientation is:

1. Yaw
2. Pitch
3. Roll

Figure 230. Vehicle angular displacement for test 7185-20.
Figure 731. Longitudinal Accelerometer trace for test 7185-20.
V. FINDINGS AND CONCLUSIONS

Aluminum tube (3/16" x 3-1/2" and 3/16" x 4") and Franklin Steel Company and Marion Steel Company 4 lb/ft steel u-channel, single support sign installations were crash tested and evaluated in this study. A performance evaluation summary of all the crash tests conducted is presented in Table 3.

Aluminum Tube Sign Installations

The aluminum tube supports performed unsatisfactorily in three of the four crash tests conducted. Tests 7185-1&2 (3/16 in x 4 in aluminum tube installed in weak soil) failed the occupant impact criterion of 15 ft/s in both the 20 and 60 mi/h tests (17.9 ft/s and 22.2 ft/s, respectively). In addition, the high speed test resulted in the vehicle rolling over multiple times and the subsequent destruction of the integrity of the passenger compartment. Pendulum tests were conducted thereafter to evaluate the impact performance of simple and economical field retrofit for the 3/16 in x 4 in tube, as developed by the Department. A successful retrofit was not found. Test 7185-19 (3/16 in x 3-1/2 in aluminum tube installed in strong soil; 20 mi/h) satisfied the criteria outlined in NCHRP Report 230. However, the installation failed the 1985 AASHTO change in vehicle velocity criterion of 15 ft/s. The support displaced over allowing the vehicle to climb and decelerate. The upward projection of the vehicle allowed occupant impact velocities to remain acceptable while violating vehicle change in velocity criterion. The use of 3/16 in x 3-1/2 in and 3/16 in x 4 in 6061-T6 aluminum tubes for new and replacement sign support installations is not recommended.

Steel U-Channel Sign Supports

The Franklin and Marion steel u-channel posts were tested using both a normal and reverse oriented, 8 inch nested lap splice. The splice utilized A307 3/8 in x 2 in bolts spaced 6 inch on-center. In addition, all installations were tested in both strong and weak soil.

The Marion single support, 4 lb/ft steel u-channel sign installations tested in strong and weak soil utilizing both the reverse and normal oriented nested lap splice, met all applicable impact performance evaluation criteria presented in NCHRP Report 230 and
The Franklin single support, 4 lb/ft steel u-channel sign installations tested in weak soil utilizing the reverse oriented nested lap splice, and installations tested in strong soil utilizing the normal oriented nested lap splice, met all applicable impact performance criteria presented in NCHRP Report 230 and 1985 AASHTO.

The Franklin sign installation (test 7185-10; 60 mi/h) tested in strong soil utilizing the reverse oriented nested lap splice failed the occupant risk criterion of NCHRP. The integrity of the occupant compartment was violated due to the support impacting the roof. It should be noted, it is permissible for the support to strike the roof as the vehicle passes. However, excessive deformation or intrusion that may present risk to the occupants is unacceptable. The damage sustained to the roof of the vehicle in test 7185-10 was located over the driver flail space area, thereby presenting a severe hazard to the driver (See Figure 114). The occupant accelerations and ridedowns were all within the acceptable limits of 15 g's and 15 ft/s, respectively. The prior low speed test (7185-9; 20 mi/h) appears to have failed due to marginally excessive occupant impact velocity (15.7 ft/s). However, the actual impact velocity was only 17 mi/h, possibly accounting for the high occupant impact velocity. Therefore, test 7185-9 should not be discounted a failure.

The Franklin sign installation (test 7185-18; 60 mi/h) tested in weak soil utilizing the normal oriented nested lap splice failed the occupant risk criterion of NCHRP. Similar to test 7185-10, the integrity of the occupant compartment was violated due to the support impacting the roof. The damage sustained to the roof of the vehicle in test 7185-18 was located over the passenger flail space area, thereby presenting a severe hazard to the passenger (See Figure 205). The occupant accelerations and ridedowns were all within the acceptable limits of 15 g's and 15 ft/s, respectively. The low speed test (7185-17; 20 mi/h) met all applicable impact performance evaluation criteria presented in NCHRP Report 230 and 1985 AASHTO.
<table>
<thead>
<tr>
<th>SPICE ORIENTATION</th>
<th>POST TYPE</th>
<th>SOIL TYPE</th>
<th>SPEED (mi/h)</th>
<th>TEST NO.</th>
<th>VEHICLE ACCEL. (Max 50 msec. avg.) X</th>
<th>Y</th>
<th>OCC. IMPACT VELOCITY X</th>
<th>Y</th>
<th>OCC. RUIDEDOWN ACCELERATIONS X</th>
<th>Y</th>
<th>ΔV mi/h</th>
<th>PASS / FAIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A</td>
<td>3/16&quot; x 4&quot; Aluminum tube</td>
<td>Weak</td>
<td>19.4</td>
<td>1</td>
<td>-4.6 g</td>
<td>-1.6 g</td>
<td>17.9 ft/s</td>
<td>4.8 ft/s</td>
<td>-3.1 g</td>
<td>0.5 g</td>
<td>19.4</td>
<td>Fail</td>
</tr>
<tr>
<td>N/A</td>
<td>3/16&quot; x 3-1/2&quot; Aluminum tube</td>
<td>Weak</td>
<td>19.0</td>
<td>19</td>
<td>-2.5 g</td>
<td>1.8 g</td>
<td>10.0 ft/s</td>
<td>-7.8 ft/s</td>
<td>-2.2 g</td>
<td>1.0 g</td>
<td>19.0</td>
<td>Fail</td>
</tr>
<tr>
<td>Reverse</td>
<td>4 lb/ft Marion Steel U-Channel</td>
<td>Weak</td>
<td>18.4</td>
<td>3</td>
<td>-2.0 g</td>
<td>-0.3 g</td>
<td>0.9 ft/s</td>
<td>N/A</td>
<td>-0.6 g</td>
<td>No Contact</td>
<td>6.9</td>
<td>Pass</td>
</tr>
<tr>
<td>Reverse</td>
<td>4 lb/ft Franklin Steel U-Channel</td>
<td>Weak</td>
<td>26.3</td>
<td>7</td>
<td>-1.3 g</td>
<td>-0.5 g</td>
<td>6.3 ft/s</td>
<td>N/A</td>
<td>-0.7 g</td>
<td>No Contact</td>
<td>5.3</td>
<td>Pass</td>
</tr>
<tr>
<td>Reverse</td>
<td>4 lb/ft Marion Steel U-Channel</td>
<td>Strong</td>
<td>19.3</td>
<td>5</td>
<td>-3.0 g</td>
<td>0.4 g</td>
<td>N/A</td>
<td>-3.6 ft/s</td>
<td>No Contact</td>
<td>-0.3 g</td>
<td>4.1</td>
<td>Pass</td>
</tr>
<tr>
<td>Reverse</td>
<td>4 lb/ft Franklin Steel U-Channel</td>
<td>Strong</td>
<td>17.0</td>
<td>9</td>
<td>-4.4 g</td>
<td>1.3 g</td>
<td>15.7 ft/s</td>
<td>5.9 ft/s</td>
<td>1.4 g</td>
<td>1.6 g</td>
<td>7.5</td>
<td>Pass</td>
</tr>
<tr>
<td>Normal</td>
<td>4 lb/ft Marion Steel U-Channel</td>
<td>Weak</td>
<td>19.2</td>
<td>11</td>
<td>-1.8 g</td>
<td>0.4 g</td>
<td>2.8 ft/s</td>
<td>N/A</td>
<td>-0.3 g</td>
<td>No Contact</td>
<td>4.3</td>
<td>Pass</td>
</tr>
<tr>
<td>Normal</td>
<td>4 lb/ft Franklin Steel U-Channel</td>
<td>Weak</td>
<td>20.0</td>
<td>17</td>
<td>-1.8 g</td>
<td>-0.3 g</td>
<td>7.1 ft/s</td>
<td>N/A</td>
<td>0.3 g</td>
<td>No Contact</td>
<td>5.6</td>
<td>Pass</td>
</tr>
<tr>
<td>Normal</td>
<td>4 lb/ft Marion Steel U-Channel</td>
<td>Strong</td>
<td>19.4</td>
<td>15</td>
<td>-2.0 g</td>
<td>-0.3 g</td>
<td>5.8 ft/s</td>
<td>N/A</td>
<td>0.1 g</td>
<td>No Contact</td>
<td>4.3</td>
<td>Pass</td>
</tr>
<tr>
<td>Normal</td>
<td>4 lb/ft Franklin Steel U-Channel</td>
<td>Strong</td>
<td>62.4</td>
<td>16</td>
<td>-2.3 g</td>
<td>-0.7 g</td>
<td>5.7 ft/s</td>
<td>-3.3 ft/s</td>
<td>2.5 g</td>
<td>-1.1 g</td>
<td>4.2</td>
<td>Pass</td>
</tr>
</tbody>
</table>

Table 3. Performance Evaluation Summary - Crash Tests
REFERENCES


Figure A-1. Force vs displacement for 4 lb/ft Franklin post (7185-Case A).
Figure A-2. Force vs displacement for 4 lb/ft Franklin post (7185-CASE B).
STATIC LOAD TEST - STEEL U-CHANNEL
Project 7185 - Case C

TEST CONDITIONS
Post Type: 4 lb Marion
Bolt Type: A307-3/8" Dia.
Bolt Spacing: 6 in. O.C.
Orientation: Normal
Failure Type: Bolt failure

(16.1 in, 356.6 lbs)

Figure A-3. Force vs displacement for 4 lb/ft Marion post (7185-Case C).
Figure A-4. Force vs displacement for 4 lb/ft Marion post (7185 Case D).

STATIC LOAD TEST - STEEL U-CHANNEL
Project 7185 - Case D

TEST CONDITIONS
Post Type: 4 lb Marion
Bolt Type: A307-3/8" Dia.
Bolt Spacing: 6 in. O.C.
Orientation: Reverse
Failure Type: Bolt failure

Displacement (inches)
0 5 10 15 20 25

Force (pounds)
450 400 350 300 250 200 150 100 50

(177 in, 414.5 lbs)
Figure A-5. Force vs displacement for 4 lb/ft for Franklin post (7185-Case E).
STATIC LOAD TEST - STEEL U-CHANNEL
Project 7185 - Case F

TEST CONDITIONS
Post Type: 4 lb Marion
Bolt Type: A354-5/16" Dia.
Bolt Spacing: 4 in. O.C.
Orientation: Normal
Failure Type: Bolt failure (threads)

(15.2 in, 333.2 lbs)

Figure A-6. Force vs displacement for 4 lb/ft Marion post (7185-Case F).
Figure A-7. Force vs displacement for 4 lb/ft Franklin post (7185-Case G).
Figure A-8. Force vs displacement for 4 lb/ft Marion post (7185-Case H).
Figure A-9. Force vs displacement for 4 lb/ft Mixed (Franklin stub/ Marion support) post (7185-Case X).
APPENDIX B
Figure B-1. Pendulum longitudinal accelerometer trace (7185-P1).
Figure B-2. Pendulum longitudinal accelerometer trace (7185-P2).
Figure B-3. Pendulum longitudinal accelerometer trace (7185-P3).
Figure B-4. Pendulum longitudinal accelerometer trace (7185-P4).