## Technical Report Documentation Page

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<td>4. Title and Subtitle</td>
<td>TRAFFIC BARRIERS FOR PARKWAYS:</td>
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<td>Performance Evaluation of a Stone Masonry Guardwall</td>
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<td>5. Report Date</td>
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<td>6. Performing Organization Code</td>
<td>RF 7033</td>
</tr>
<tr>
<td>7. Author(s)</td>
<td>Richard A. Zimmer and Wanda L. Campise</td>
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<td>9. Performing Organization Name and Address</td>
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<td>Texas A&amp;M Research Foundation</td>
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<td>Texas A&amp;M University System</td>
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<td>Department of Transportation</td>
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<td></td>
<td>Washington, D.C.</td>
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<tr>
<td>13. Type of Report and Period Covered</td>
<td>FINAL REPORT</td>
</tr>
<tr>
<td></td>
<td>January 1985 - March 1985</td>
</tr>
<tr>
<td>15. Supplementary Notes</td>
<td>Contract Technical Officer: Charles F. McDevitt</td>
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<tr>
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<td>During the next few years the National Park Service plans to install a number of stone masonry guardwalls along its parkways. This study was initiated to evaluate the performance of the stone masonry guardwall under full-scale crash tests. Two crash tests were performed and evaluated according to procedures and standards set forth in NCHRP Report 230. The first test conducted using a Honda at 60 mi/h and 15 degrees met criteria for the NCHRP Report 230 Test 12. The second test performed using a 4500-lb vehicle at 60 mi/h and 25 degrees is considered a strength test according to NCHRP Report 230 Test 10. In this regard the guardwall performed acceptably to all applicable criteria.</td>
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<tr>
<td>17. Key Words</td>
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<td>18. Distribution Statement</td>
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<td>19. Security Classif. (of this report)</td>
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<td>20. Security Classif. (of this page)</td>
<td>Unclassified</td>
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<td>21. No. of Pages</td>
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INTRODUCTION

During the next few years the National Park Service plans to install a number of stone masonry guardwalls along its parkways. Before beginning these installations the Park Service recognized the need to evaluate the safety performance of these barriers. In order to meet this objective, two full-scale vehicle crash tests were performed and the results evaluated in accordance with procedures and standards set forth in NCHRP Report 230.(1) Reported herein are the findings of these two tests.

TEST INSTALLATION

A 120-ft (37-m) length of stone masonry guardwall was constructed at the TTI Proving Ground for the tests. The barrier consisted of twelve 10-ft (3-m) precast concrete T-sections (shown in figure 1). The precast units were joined by 2 in (5 cm) deep tongue and groove connections. The T-sections were placed in an 8-in (20-cm) deep trench on a 6-in (15-cm) layer of Georgetown crushed limestone base material (NCHRP Report 230 Strong Soil). Decorative stone was applied to the front face and top of the barrier by National Park Service personnel. The finished traffic face of the guardwall was 6 in (15 cm) from the end of the pavement. The stone was placed in a random pattern with respect to the joints in the precast units. The mortar between the stone was pointed to a depth of 1 in (5 cm). The vertical distance in the pointed joints of the stone varied from 1 in (5 cm) to 3 in (8 cm). The area between the pavement and barrier was backfilled with soil. A cross section of the barrier is shown in figure 2, and photographs of the barrier prior to testing are shown in figure 3. Specifications for the stone masonry are given in appendix A.

INSTRUMENTATION AND DATA ANALYSIS

The vehicle was equipped with triaxial accelerometers mounted near the center of gravity. In addition, yaw, pitch, and roll rates were measured by on-board gyroscopic instruments. The electronic signals 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
Figure 1. T-sections of stone masonry guardwall.
Figure 2. Cross section of the test installation.
Figure 3. Test installation prior to testing.
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 by the vehicle to indicate the elapsed time over a known distance to provide measurement of impact velocity. The initial contact also produced an "event" mark on the data record to establish the instant of impact.

Two anthropomorphic dummies (Alderson Hybrid II) were positioned in the front seat of the vehicle. The driver dummy was restrained, with original equipment lap and shoulder belt, while the passenger dummy was unrestrained. The dummies were equipped with triaxial accelerometers mounted in the head and chest for determination of injury indices. Signals from these accelerometers were also telemetered to the base station and recorded on magnetic tape.

Data from the electronic transducers were filtered per SAE J211 except dummy head data which was processed by a -3db at 500 HZ, 5-pole filter. The data were then digitized, using a microcomputer, for analyses and evaluation of performance. Several computer programs were used to process various types of data from the test vehicle and dummies.

The VEHICLE computer program uses data from the three vehicle-mounted linear accelerometers to compute accelerations, areas enclosed by acceleration-time curves, changes in velocity, changes in momentum, instantaneous forces, average forces, and maximum average accelerations over 0.050-sec intervals in each of the three directions. The maximum resultant 0.050-sec average vehicle acceleration was also computed by the VEHICLE program. Several methods exist for computing this resultant value. The one used for the data presented herein may be described as follows: Resultant 0.050-sec average accelerations are computed by taking the vector resultant of 0.050-sec average accelerations at corresponding times in each of the three directions with the 0.050-sec interval beginning at impact. The process is repeated with the time interval shifted 0.001 sec until the duration of impact is covered. The maximum value from these computations is sought and reported as the maximum resultant 0.050-sec average vehicle acceleration. The VEHICLE program also plots acceleration versus time curves for the longitudinal, lateral, and vertical directions.
The PLOTANGLE program uses the digitized data from the yaw, pitch, and roll rate charts to compute angular displacement (degree) at 0.001 sec and then instructs the Versatec Plotter (Model 1200 Electrostatic Plotter) to produce a reproducible plot: yaw, pitch, and roll versus time. It should be noted that these angular displacements are sequence dependent with the sequence being yaw - pitch - roll for the data presented herein. These displacements are in reference to the vehicle-fixed coordinate system with the initial position and orientation of the vehicle-fixed coordinate system being that which existed at initial impact.

The CRASH TEST program computes accelerations at 0.002-sec intervals using digitized data from dummy head or chest X, Y, and Z charts and provides these three accelerations at each interval in printout form. The program computes accelerations for each chart independently and combines accelerations at corresponding time to obtain resultant acceleration of the dummy head or chest.

The INJURY program uses the accelerations assembled in the CRASH TEST program to compute HIC injury indices. Head injury criteria (HIC) approximates the time-dependent effects of acceleration by integrating resultant head acceleration according to the equation:

\[ HIC = \left( \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} A_r \, dt \right)^{2.5} [t_2 - t_1] \]

in which
\[ A_r = \text{Resultant instantaneous acceleration} \]
\[ t_1 = \text{Beginning time of integration} \]
\[ t_2 = \text{Final time of integration} \]

The time interval is variable and chosen to produce a maximum value of HIC.

Still and motion photography were used to document the test, to obtain time-displacement data, and to observe phenomena occurring during the impact. Still photography was used to record conditions of the test vehicle and barrier installation before and after the test. Motion photography was used to record the collision event.
Description of Test

The 1979 Honda CVCC shown in figure 4 was used in the first test. Test inertial mass of the vehicle was 1,820 lb (826 kg) and the vehicle gross static mass was 2,160 lb (981 kg). Vehicle properties are shown in figure 5. The vehicle was directed into the barrier using a cable guidance system. The transmission was in neutral, and the vehicle was released so as to be unrestrained prior to impact. Prior to the test the concrete pavement was wetted to lower the coefficient of friction to about 0.5 to approximate dry soil.

The vehicle impacted the barrier approximately 30 ft (9 m) from the upstream end of the barrier. Velocity of the vehicle at impact was 62.1 mi/h (99.9 km/h) and the approach angle was 14.5 degrees. The vehicle was redirected and remained upright during and after the test. Vehicle loss of contact with the barrier occurred at 0.315 sec after impact. The vehicle exited the barrier traveling at 49.8 mi/h (80.1 km/h) and at 4.0 degrees exit angle. Then the brakes were applied and the vehicle came to rest 205 ft (62 m) downstream and 65 ft (20 m) away from the front of the barrier.

The stone on the front of the barrier were scraped from the impact point to about 8 ft (2.4 m) downstream (see figure 6). There was no sign of stone movement and there were no visible cracks in the barrier or mortar.

The vehicle sustained extensive damage to the right front quarter as shown in figure 7. The lower control arm, the strut rod, and torsion bar were damaged. The rim on the right front was bent, and the tire was torn. Maximum crush to the frontal plane was 12 in (30.5 cm) and 10.5 in (26.7 cm) to the right side plane. Both occurred on the right front corner at bumper height. Vehicle crush measurements are reported in figure 8.

Shortly after impact, the passenger dummy hit the right side door and pushed the door outward (the window did not break). The driver dummy then shoved the passenger dummy back into the door. The passenger door was
Figure 4. Test vehicle before Test 7033-1.
Date: 2/11/85  Test No.: 7033-1  VIN: SGC5O34821

Make: Honda  Model: CVCC  Year: 1979  Odometer: 73051

Tire Size: 155SR12  Ply Rating: 4  Bias Ply:  
Belted:  
Radial: x

Tire Condition: good x fair  
badly worn  

Vehicle Geometry - inches
- a = 59"  - b = 29"
- c = 87 1/2"  - d = 52"
- e = 27"  - f = 143.5"
- g = ----  - h = 34.1"
- i = ----  - j = 30 3/4"
- k = 14 1/2"  - l = 30 3/4"
- m = 19 3/4"  - n = 5 1/4"
- o = 15"  - p = 51 1/4"
- r = 21 1/2"  - s = 13 1/4"

Engine Type: 4 cyl  
Engine CID: 91  

Transmission Type:  
Automatic or Manual  
(FWD) or RWD or 4WD  

Body Type: 3 DR 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 x drum  

Note any damage to vehicle prior to test:
- Right Rear Fender Around Bumper Slightly Damaged  

4-wheel weight for c.g. det.  
lf 560  rf 550  lr 360  rr 350  

Mass - pounds  Curb  Test Inertial  Gross Static  
M₁  1110  1280  
M₂  710  880  
M₁  1820  2160  

Figure 5. Test vehicle properties before Test 7033-1.
Figure 6. Barrier after Test 7033-1.
Figure 7. Vehicle after Test 7033-1.
FIELD MEASUREMENTS

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<th>Side Damage</th>
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<tr>
<td>Undeformed end width</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>Corner shift: A1</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>A2</td>
<td>___</td>
<td></td>
</tr>
<tr>
<td>End shift at frame (CDC)</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>(check one) &lt;4 inches</td>
<td>___</td>
<td>___</td>
</tr>
<tr>
<td>≥4 inches</td>
<td>___</td>
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Bowing: B1 X1 ___
B2 X2 ___
Bowing constant  
X1 + X2 __

Note: Measure C1 to C6 from Driver to Passenger side in Front or Rear impacts—
Rear to Front in Side impacts.

Specific Impact Number | Plane* of C-Measurements | Direct Damage Width** | Max** Crush | Field L** | C1 | C2 | C3 | C4 | C5 | C6 | ±D |
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<tr>
<td>Front</td>
<td>bumper ht</td>
<td>7</td>
<td>12</td>
<td>55</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>12</td>
<td>+22.5</td>
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<tr>
<td>Rt Side</td>
<td>below beltline, above sill</td>
<td>142</td>
<td>10.5</td>
<td>144.5</td>
<td>0.5</td>
<td>1.5</td>
<td>2</td>
<td>2</td>
<td>10.5</td>
<td>-13.5</td>
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*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).
Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, sill taper, etc. Record the value for each C-measurement and maximum crush.
**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).
***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure 8. Crush measurements for vehicle used in Test 7033-1.
U.S. DEPARTMENT OF TRANSPORTATION
NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION
NATIONAL ACCIDENT SAMPLING SYSTEM—CONTINUOUS SAMPLING SUBSYSTEM: VEHICLE

DAMAGE DESCRIPTION

<table>
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<th>TYPE OF TRANSMISSION</th>
<th>WHEEL STEER ANGLES</th>
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<tr>
<td>RF 1</td>
<td>X Manual</td>
<td>(For locked front wheels or displaced rear axles only)</td>
</tr>
<tr>
<td>LF 2</td>
<td>Automatic</td>
<td>RF 1</td>
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<tr>
<td>RR 2</td>
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<td>LF 1</td>
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<tr>
<td>LR 2</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>LR 1</td>
</tr>
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(1) Yes, (2) No, (8) NA, (9) Unk.

right front tire deflated and rim bent

Average Track: 51.25
Maximum Width: 59.00

NOTE: Measure C1 to C6 from DRIVER to PASSENGER side in FRONT or REAR impacts—REAR to FRONT in SIDE impacts.

Determine L, D1, D2, C1, C2, C3, C4, C5, C6, D1

Figure 8. Crush measurements for vehicle used in Test 7033-1 (continued).
Figure 9. Anthropomorphic dummies before and after Test 7033-1.
bent outward 2 in (5 cm). Final resting positions of the dummies are shown in figure 9.

Results of Test

The results of this test are summarized in figure 10. Injury indices for the anthropomorphic dummies used in the test are reported in table 1. Sequential photographs and the various plots are displayed in figures 11 to 20.

Safety evaluation criteria described in NCHRP Report 230 were used to evaluate the results of this test. The barrier smoothly redirected the vehicle and there were no detached elements, fragments, or debris to present undue hazard. This meets with the structural adequacy evaluation factors. The first requirement for occupant risk evaluation, that the vehicle remain upright during and after impact, was also met. The occupant impact velocity and occupant ridedown accelerations shown in figure 11 were within the limits specified for occupant risk as were the dummy responses reported in table 1. The change in vehicle speed at loss of contact was 12.6 mi/h (20.3 km/h) and the exit angle was 4 degrees which meets vehicle trajectory requirements. Therefore, the stone masonry guardwall meets the criteria set forth in NCHRP Report 230, Test 12.
Test No. ............... 7033-1
NCHRP 230 Test No. ...... 12
Date ..................... 2/11/85
Barrier .................. Stone Masonry Guardwall
Length of Installation ... 120 ft (37 m)
Barrier Deflection
   Permanent ............. 0 ft (0 m)
   Maximum ............... 0 ft (0 m)
Vehicle .................. 1979 Honda CVCC
Vehicle Weight
   Test Inertia .......... 1,820 lb (826 kg)
   Gross Static ......... 2,160 lb (981 kg)
Vehicle Damage Classification
   TAD. ................. O1FR3 & O1RD3
   SAE. .................. O1FREK3
                      O1RDES3
Impact Speed ............. 62.1 mi/h (99.9 km/h)
Impact Angle ............ 14.5 degrees
Exit Speed .............. 49.5 mi/h (79.7 km/h)
Exit Angle ............... 4.0 degrees
Change in Momentum ..... 1045 lb/s (474 kg/s)
Vehicle Accelerations (Max. 0.050-sec Avg)
   Longitudinal .......... -6.2 g
   Lateral ............... 10.6 g
   Vertical .............. 1.3 g
   Resultant ............. 12.3 g
Occupant Impact Velocity
   Longitudinal .......... 15.6 fps (4.8 m/s)
   Lateral ............... 18.5 fps (5.6 m/s)
Occupant Ridedown Accelerations
   Longitudinal .......... -1.1 g
   Lateral ............... 6.4 g

Figure 10. Summary of results for Test 7033-1.
Table 1. Injury indices for anthropomorphic dummies used in Test 7033-1.

**Driver Head**

HIC: 233 between 0.146 and 0.150 sec

**Driver Chest**

Highest 3-ms sustained acceleration 15 g from 0.124 to 0.127 sec

**Passenger Head**

HIC: 54 between 0.078 and 0.094 sec

**Passenger Chest**

Highest 3-ms sustained acceleration 17 g from 0.088 to 0.091 sec
Figure 11. Sequential photographs for Test 7033-1.
Figure 11. Sequential photographs for Test 7033-1 (continued).
Figure 12. Interior sequential photographs for Test 7033-1.
Figure 13. Vehicle longitudinal accelerometer trace for Test 7033-1.
Figure 14. Vehicle lateral accelerometer trace for Test 7033-1.
Figure 15. Vehicle vertical accelerometer trace for Test 7033-1.
Axes are vehicle fixed. Sequence for determining orientation is:
1. Yaw
2. Pitch
3. Roll

Figure 16. Vehicle angular displacements for Test 7033-1.
Figure 17. Driver head accelerometer traces for Test 7033-1.
Figure 17. Driver head accelerometer trace for Test 7033-1 (continued).
Figure 18. Driver chest accelerometer traces for Test 7033-1.
Figure 19. Passenger head accelerometer traces for Test 7033-1.
Figure 19. Passenger head accelerometer trace for Test 7033-1 (continued).
Figure 20. Passenger chest accelerometer traces for Test 7033-1.
Description of Test

This test was conducted using a 1980 Dodge with a test inertial mass (TIM) of 4,300 lb (1,952 kg) and a gross static mass (GSM) of 4,640 lb (2,107 kg). Photographs of the vehicle prior to testing are shown in figure 21, and vehicle properties are shown in figure 22. The vehicle was directed into the barrier using a cable guidance system. The transmission was in neutral, and the vehicle was released so as to be unrestrained prior to impact. Prior to the test the concrete pavement was wetted to lower the coefficient of friction to about 0.5 to approximate dry soil.

The vehicle impacted the barrier approximately 40 ft (12 m) from the upstream end of the barrier. Vehicle velocity at impact was 58.4 mi/h (94.0 km/h) and the approach angle was 24.5 degrees. The vehicle was redirected and remained relatively stable during and after the test. Vehicle velocity at loss of contact (0.498 sec) was 45.0 mi/h (72.4 km/h), and the departure angle was 5.0 degrees. Shortly after loss of contact the brakes were applied. The vehicle subsequently came to rest approximately 160 ft (49 m) downstream of impact and 8 ft (2 m) behind the barrier.

The barrier received some scrapes and hairline cracks. The mortar was cracked above the stone on the second row from the top. The crack extended from 5 in (15 cm) upstream of impact (impact occurred 1 ft upstream of the 4th joint) for approximately 16 ft (5 m) downstream. Another crack in the mortar extended across the top of the barrier just downstream of the 6th joint. The cap stone at the point of impact was dislodged but remained in place. Maximum dynamic deflection of the top of the barrier was 2.30 in (5.8 cm) and maximum permanent deflection was 0.75 in (1.9 cm). Photographs of the barrier after testing are shown in figure 23.

The vehicle sustained extensive damage to the front and right side as shown in figure 24. Suspension damage to the right front included damage to the upper and lower control arms, the uniframe, the strut rod, and torsion bar. Both rims and tires on the right side were damaged. The front bumper was cracked and severely bent. Maximum crush to the frontal
Figure 21. Test vehicle before Test 7033-2.
Date: 2/13/85  Test No.: 7033-2  VIN: EH 42LAA138968
Make: Dodge  Model: St. Regis  Year: 1980  Odometer: 67068
Tire Size: HR 70-15  Ply Rating: 4  Bias Ply:  Belted:  Radial: x
Tire Condition: good _  fair x  badly worn _

Vehicle Geometry - inches
a 77 3/4"  b 40 1/4"  c 55 1/4"  d 68 1/4"  e 214 1/2"  f 214 1/2"
g _ h 57.0"  i _ j 36"  k 15 1/4"  l 43"  m 22 1/2"  n 6"  o 13 3/4"  p 61 3/4"
r 28"  s 16 1/4"

Engine Type: 8 cyld
Engine CID: 360
Transmission Type: Automatic or Manual
FWD or RWD or 4WD

Body Type: 4 DR Sedan
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

Figure 22. Test vehicle properties before Test 7033-2.
Figure 23. Barrier after Test 7033-2.
Figure 24. Vehicle after Test 7033-2.
FIELD MEASUREMENTS

<table>
<thead>
<tr>
<th>End Damage</th>
<th>Side Damage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Undeformed end width</td>
<td>Bowing: B1 X1</td>
</tr>
<tr>
<td>Corner shift: A1</td>
<td>B2 X2</td>
</tr>
<tr>
<td>A2</td>
<td>Bowing constant</td>
</tr>
<tr>
<td>End shift at frame (CDC) (check one)</td>
<td>X1 + X2 =</td>
</tr>
<tr>
<td>&lt; 4 inches</td>
<td>2</td>
</tr>
<tr>
<td>≥ 4 inches</td>
<td></td>
</tr>
</tbody>
</table>

Note: Measure C1 to C6 from Driver to Passenger side in Front or Rear impacts—Rear to Front in Side impacts.

<table>
<thead>
<tr>
<th>Specific Impact Number</th>
<th>Plans* of C Measurements</th>
<th>Direct Damage Width** (CDC)</th>
<th>Field L**</th>
<th>Max*** Crush</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>C5</th>
<th>C6</th>
<th>±D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>bumper ht</td>
<td>27</td>
<td>21</td>
<td>65</td>
<td>1</td>
<td>1</td>
<td>6</td>
<td>12</td>
<td>21</td>
<td>+25.4</td>
<td></td>
</tr>
<tr>
<td>Rt side</td>
<td>above sill</td>
<td>213</td>
<td>14.5</td>
<td>214</td>
<td>0.5</td>
<td>2</td>
<td>1</td>
<td>4.5</td>
<td>10</td>
<td>14.5</td>
<td>-49.5</td>
</tr>
</tbody>
</table>

*Identify the plane at which the C-measurements are taken (e.g., at bumper, above bumper, at sill, above sill, at beltline, etc.) or label adjustments (e.g., free space).

Free space value is defined as the distance between the baseline and the original body contour taken at the individual C locations. This may include the following: bumper lead, bumper taper, side protrusion, side taper, etc. Record the value for each C-measurement and maximum crush.

**Measure and document on the vehicle diagram the beginning or end of the direct damage width and field L (e.g., side damage with respect to undamaged axle).

***Measure and document on the vehicle diagram the location of the maximum crush.

Note: Use as many lines/columns as necessary to describe each damage profile.

Figure 25. Crush measurements for vehicle used in Test 7033-2.
Figure 25. Crush measurements for vehicle used in Test 7033-2 (continued).
plane of the vehicle at bumper height was 21 in (53 cm). Maximum crush to the right side of the vehicle at bumper height was 14.5 in (37 cm). Crush measurements are reported in figure 25.

Shortly after impact, the passenger dummy hit the right side door and pushed the window glass outward. The glass then shattered releasing the passenger dummy to protrude out the window from the chest upward. The passenger dummy remained partially out the window until shortly before the vehicle stopped. The driver dummy hit the instrument panel with its face about 0.141 sec after impact and then hit the seat very abruptly with the back of its head. Final resting positions of the dummies are shown in figure 26.

Results of Test

The results of this test are summarized in figure 27. Injury indices for the anthropomorphic dummies used in this test are reported in table 2. Sequential photographs and various plots are presented in figures 28 to 37.

According to NCHRP Report 230, Test 10 is considered a strength test of the barrier. In this regard the barrier performed acceptably to all applicable criteria. The barrier contained and redirected the vehicle with no detached elements or debris to present undue hazard. The vehicle remained upright during and after the test and vehicle trajectory did not intrude into adjacent traffic lanes. Occupant risk factors do not apply to this test but were computed and reported in figure 27 for information only.
Figure 26. Anthropomorphic dummies before and after Test 7033-2.
Figure 27. Summary of results for Test 7033-2.
Table 2. Injury indices for anthropomorphic dummies used in Test 7033-2.

Driver Head
HIC: 176 between 0.116 and 0.234 sec

Driver Chest
Highest 3-ms sustained acceleration
22 g from 0.118 to 0.121 sec

Passenger Head
HIC: 303 between 0.100 and 0.264 sec

Passenger Chest
Highest 3-ms sustained acceleration
22 g from 0.130 to 0.133 sec
Figure 28. Sequential photographs for Test 7033-2.
Figure 28. Sequential photographs for Test 7033-2 (continued).
Figure 29. Interior sequential photographs for Test 7033-2.
Figure 30. Vehicle longitudinal accelerometer trace for Test 7033-2.
Figure 31. Vehicle lateral accelerometer trace for Test 7033-2.
Figure 32. Vehicle vertical accelerometer trace for Test 7033-2.
Axes are vehicle fixed. Sequence for determining orientation is:
1. Yaw
2. Pitch
3. Roll

Figure 33. Vehicle angular displacements for Test 7033-2.
Figure 34. Driver head accelerometer traces for Test 7033-2.
Figure 34. Driver head accelerometer trace for Test 7033-2 (continued).
Figure 35. Driver chest accelerometer traces for Test 7033-2.
Figure 35. Driver chest accelerometer traces for Test 7033-2.
Figure 36. Passenger head accelerometer traces for Test 7033-2.
Figure 36. Passenger head accelerometer trace for Test 7033-2 (continued).
Figure 37. Passenger chest accelerometer traces for Test 7033-2.
SUMMARY AND CONCLUSIONS

Two crash tests were conducted to evaluate the safety performance of a stone masonry guardwall. The tests were conducted in accordance with NCHRP Report 230 for longitudinal barriers over the length-of-need and did not address the problem of end impacts. The barrier was constructed of embedded, reinforced concrete cores faced and capped with decorative stone. The stone was placed in a random pattern with respect to the joints in the concrete core and exhibited a fairly smooth finished surface.

The first crash test used a 1,800-lb (817-kg) vehicle to assess the potential risk or hazard to vehicle occupants during collision with the test article. The second test used a 4,500-lb (2,043-kg) vehicle to assess the strength and containment capability of the guardwall.

Analysis of the first test results revealed the following:
1. The barrier smoothly redirected the vehicle.
2. The vehicle remained upright throughout the collision.
3. Occupant risks based on vehicle and occupant accelerations were within the limits specified.
4. The exit angle was 4 degrees which meets trajectory requirements.

Analysis of the second test results revealed the following:
1. The barrier contained and redirected the vehicle.
2. The vehicle remained upright during and after the test.
3. The vehicle trajectory did not intrude into adjacent traffic lanes.
4. Occupant risk factors were high but do not apply to this test.

Based on the above results each test was acceptable in terms of nationally recognized criteria for a length-of-need barrier.

These tests did not address the problem of the guardwall end treatment. For an end-on impact, a terminal will be required to perform as either a crash cushion, in which case the vehicle is brought to a controlled stop, or a deflective device that directs the vehicle back to the pavement or to a path safely behind the installation as described in reference 2.
These tests were conducted on flat and level terrain. Should a guardwall of this type be installed on a side slope, i.e., lower than the roadway, the same performance may not be achieved. Should a side slope installation be considered, careful consideration should be given to impacting vehicles vaulting over the top of the barrier as described in reference 2.

The height of the guardwall test installation was 24 in (61 cm) and performance was acceptable in both full-scale crash tests. However, the installation was used under "ideal" conditions with standard test vehicles that do not represent all of the variations that frequently occur in automobiles. This and other crash test data coupled with field experience strongly indicate that the minimum barrier height should be 27 in (69 cm).
REFERENCES


PART 1: GENERAL

1-1 DESCRIPTION: The work of this section consists of providing stone for the construction of stone masonry traffic barriers in Bryan, Texas.

1-2 PRODUCT HANDLING: The contractor is responsible to transport the stone from the source/quarry to: Texas A&M University System, Bldg. 7757, Bryan Research and Extension Center, Texas Transportation Institute, Highway 21 West, Bryan, Texas 77801; Point of Contact: Dr. Gene Buth (409) 845-6159.

PART 2: MATERIALS

2-1 STONE: Native Mica Schist having a blend of colors, saw cut --~) -5"(40%) -7-3/4(40%) height, with random lengths of 18" to 30" (inches), with varying sizes to insure a random pattern. The stone shall be 20,000 to 22,000 lbs per square in compression and free of cracks and spouts.

2-2 CAP STONE: The cap stone to be used will be 4"(height) x 24" (width), natural crust surface, with one natural long edge, and a saw cut back.

PART 3: EXECUTION

3-1 LOCATION: Provide stone to construct a 150 L.F. 2'-6" x height x2'-0 width traffic barrier at Bryan, Texas. Stone to be transported to project site by Contractor.

PART 4: MEASUREMENT AND PAVEMENT

4-1 The measurement of stone will be weighed by a state certified scale and paid for by the ton. Transportation of stone will be a lump sum one-way from the local area to Bryan, Texas.
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