Development of a Low-Profile Portable Concrete Barrier

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A low-profile portable concrete barrier (PCB) has been developed for use in low-speed [approximately 45 mph (73 km/hr) or less] work zones. The purpose of the low-profile barrier is to shield the work zone and redirect errant vehicles while improving visibility. The low-profile barrier has a total height of only 20 in. (50.8 cm), whereas most current PCBs have a total height of 32 in. (81.28 cm). The primary advantage of the reduced height of the low-profile PCB is that driver visibility is significantly increased. This enhanced visibility should provide drivers with safer conditions and reduce the number of accidents. The performance of the barrier was demonstrated through the results of two full-scale crash tests. Based on the results of these crash tests, the low-profile barrier is recommended for immediate use under appropriate conditions.

As many cities show continued growth, so do their existing roadway systems. As a result, roadway work zones have become commonplace. The work zones disrupt the continuity of traffic flow and thus introduce a hazard for both motorists and workers. As such, work zones are often segregated and delineated by longitudinal barriers capable of redirecting errant vehicles.

Boundaries of work zones are often defined by the use of reflective barrels or portable concrete barriers (PCBs). These systems work well for vehicles traveling along the major roadway through the work zone. However, if cross-traffic access is required, sight-distance problems often occur. A typical example of this problem would occur where openings in the longitudinal barrier are provided to allow cross-traffic access from parking lots and intersecting roads. The heights of typical longitudinal barriers reduce the ability the cross-traffic visibility. This is especially a problem at night, when the barrier obstructs the ability of drivers to see oncoming headlights.

In many cases, the driver of the cross-traffic vehicle must pull into the mainstream of the roadway before being able to see the headlights of oncoming vehicles. This situation has led to many accidents. The objective of this research was to develop a low-profile PCB short enough to alleviate the sight-distance problem while still maintaining a credible redirective ability. This was accomplished by first studying the geometrics of the situation. Studies were then conducted to establish theoretical barrier performance limits for low-profile barriers of various heights. This information was integrated into the workable low-profile barrier design discussed in this report.

The remainder of this report deals with the development, full-scale testing, and recommendations for the use of the new low-profile PCB.

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DEVELOPMENT OF LOW-PROFILE PCB

The purpose of this research was to develop a low-profile segmented PCB for use in low-speed [45 mph (73 km/hr) or less] applications. The design goals for the low-profile PCB are as follows. The low-profile barrier should be short enough so that the barrier does not cause a sight-distance problem for cross traffic. The new low-profile PCB should be capable of redirecting errant vehicles over an appropriate range of vehicle weights, speeds, and impact angles. Texas Department of Transportation (TxDOT) engineers requested that the maximum lateral deflection of the barrier should be held to a minimum. These issues are addressed in the remainder of this section.

It was decided that an unobstructed line of sight between the cross-traffic driver's eye and the center of the headlight of the oncoming vehicle provides the boundary for acceptable barrier performance. To study the sight-distance problem, it was necessary to define headlight heights and other related geometric constraints as described below.

A random survey of 100 vehicles was conducted to establish the range of typical headlight heights. In this study, the headlight height was defined as the measured distance between roadway surface and the center of the headlight. The headlight heights varied for different makes and models of vehicles. Of importance, however, is the range that encompassed most of the vehicle headlights heights and the minimum headlight height. Most of today's cars have headlight heights between 24 and 28 in. (61 cm and 71 cm). None of the vehicles measured had headlight heights less than 24 in. (61 cm). In addition, AASHTO's *A Policy on Geometric Design of Highways and Streets, 1990* suggests that the minimum allowable headlight height is 24 in. (61 cm) (*1*). Therefore, the minimum headlight height of 24 in. (61 cm) was used in the sight-distance analysis.

In addition to the headlight height, it was necessary to know the eye height of the driver of the cross-traffic vehicle. AASHTO requires a driver's design eye height of 42 in. (107 cm) (*1*). Hence, this value was used to generate the results discussed here.

Many other variables affect the sight-distance problem, including the offset of the oncoming vehicle and the offset of the cross-traffic vehicle to the barrier, as shown in Figure 1. Further, the situation depicted in Figure 1 can occur in conjunction with three different geometric conditions: (a) constant slope—flat terrain, (b) sag curve, and (c) crest curve. These geometric conditions are shown in Figure 2.

Simplified geometric analyses were conducted for each of these geometric conditions and a wide range of offset con-

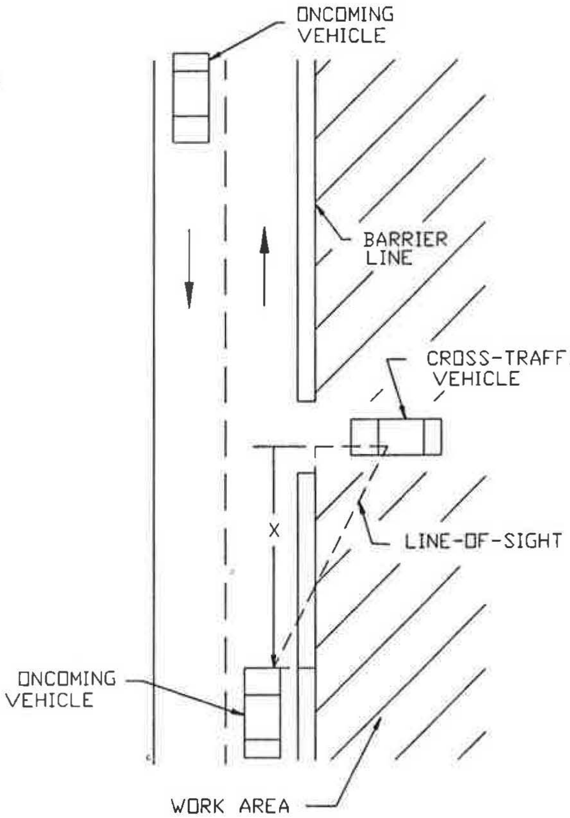


FIGURE 1 Geometry of sight-distance problem.

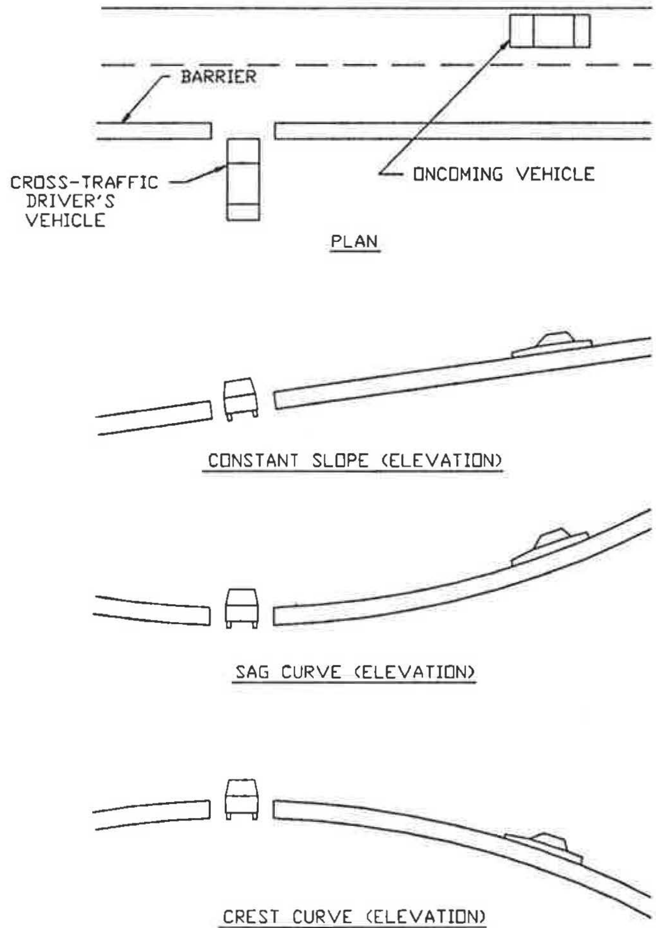


FIGURE 2 Categories of study.

ditions. It was found that the sight distance of cross-traffic drivers is unlimited as long as the barrier height is less than 24 in. (61 cm) (the minimum headlight height) for both constant slope and sag vertical curves. However, in the case of crest vertical curves it was found that the sight distance of cross-traffic drivers is significantly increased by the use of barrier heights less than 24 in. (61 cm). The degree of limitation in this latter case depends to a large extent on the geometric conditions assumed. AASHTO sets limits for crest vertical curve design parameters based on driver comfort, visibility, and stopping sight distance (*1*). These limiting parameters result in minimum curve radii for given design speeds. Cross-traffic driver analyses were done for 45 mph (73 km/hr) AASHTO requirements. In addition, headlight offsets of 2, 14, and 26 ft (0.61, 4.3, and 7.9 m) were examined to represent one, two, and three lanes of oncoming traffic. The AASHTO design stopping sight-distance for a vehicle traveling at 45 mph (73 km/hr) is 325 ft (99 m) (*1*). Results from this analysis showed that a barrier height of 20 in. (51 cm) provided sufficient vision of one or both headlights for the above conditions. Therefore, an overall barrier height of 20 in. (51 cm) is acceptable for 45 mph (73 km/hr) applications. Although the 20 in. (51 cm) barrier meets AASHTO requirements, the cross-traffic driver's visibility is further improved if the barrier height is reduced. On the basis of this sight-distance analysis it was determined to develop a low-profile barrier that is 20 in. (51 cm) tall or shorter.

The first step in the design process was to define appropriate collision criteria for the low-profile barrier in cooperation with TxDOT engineers. After discussion with TxDOT engineers, test conditions were established. Since the low-profile barrier is intended for use in urban work zones where speeds are limited to 45 mph (73 km/hr), it was determined that 45 mph (73 km/hr) provides a reasonable test speed for all conditions. Because of the potentially hazardous consequences associated with failure to redirect, the remainder of the crash test parameters were selected to reflect relatively severe conditions. Therefore, the strength test was established to be a ¾-ton pickup impacting at 45 mph (73 km/hr) at an angle of 25 degrees. It is believed that this test represents a severe set of impact conditions for the proposed application. The stability test was determined to be a 1,800-lb (817-kg) small automobile impacting at 45 mph (73 km/hr) at an angle of 20 degrees. These angles are consistent with current strength and stability tests for full-service barriers.

After the test criteria were established, the research was focused on determining the minimum barrier height that is required to achieve the desired goal.

Preliminary barrier analyses were conducted using computer simulations. The computer program used was HVOSM (Highway-Vehicle-Object-Simulation-Model) (*2*). The RD-2 version of HVOSM was used in the study; modifications developed by researchers at the Texas Transportation Institute (TTI) were incorporated in this version. The TTI modifications permit the structure of the vehicle to interact with the sloped faces of a multifaced rigid barrier. Studies of rigid New

Jersey concrete median barriers (CMBs) made with this modified version of HVOSM have been reasonably successful.

A ¾-ton-pickup computer model was not available at the outset of the project; consequently, a large car model was used in its place for the HVOSM simulations. The simulation results suggested that the minimum acceptable barrier height is 18 in. (46 cm) for the impact criteria discussed above. At 18 in. (46 cm), the large automobile remained stable. At a barrier height of 16 in. (41 cm), the large automobile rolled over the barrier. Since a ¾-ton pickup has a higher center of gravity than a large automobile, it was judged that the barrier should be taller than 18 in. (46 cm). In addition, a barrier height of 20 in. (51 cm) is acceptable for previously mentioned visibility requirements. Therefore, a barrier height of 20 in. (51 cm) was established on the basis of these results and engineering judgment. The authors believe that a barrier height of 20 in. (51 cm) is close to the minimum acceptable height for this application.

In reviewing previous automobile tests on the New Jersey CMB and the single-slope CMB it can be seen that the stability of an impacting vehicle is significantly affected by the shape of the barrier face (*3–5*). Both the New Jersey and single-slope CMBs have sloped sides. The sloped sides induce upward-acting vertical forces on the impact side of the vehicle. These forces, in combination with tire interaction, cause the impact side of the vehicle to rise. This vertical rise imparts a roll motion to the vehicle. The severity of the roll motion depends on the vehicle properties and impact conditions. If the roll motion is severe enough, the vehicle will experience full rollover.

Results of full-scale crash tests show that the impact sides of automobiles, pickups, and suburban-type vehicles do not have a tendency to rise if the barrier face is vertical (*4*). This is the case because the impact forces have relatively small vertical components, and the tire-barrier interaction forces alone are not sufficient to force the impact side of the vehicle to rise. The result is little or no roll motion away from the barrier.

Because of the reduced height of the low-profile barrier, it is important to control the upward vertical displacement of the impact side of the vehicle so that the vehicle does not vault over the barrier. Therefore, a negative slope was cast into the impact surface of the low-profile barrier to prevent vertical displacement of the impact side of the vehicle. The negative slope significantly changes the tire barrier interaction, thus reducing the tendency for the vehicle to rise because of this mechanism. In addition, the vertical component of the impact force acts in a downward direction on the vehicle, which further restricts the tendency for the impact side of the vehicle to rise. Using engineering judgment and simplified analyses it was determined that a negative slope of 1:20 would provide the desired effect.

Keeping the lateral deflections of the barrier to a minimum required an adequate combination of barrier weight and connection moment capacity. The effects of barrier weight and connection moment capacity on the lateral deflections of the low-profile barrier were studied using a simulation program called Simulation of Articulated Barrier Systems (SABS) (*6*). SABS yields deflections of segmented PCBs based on force versus time data derived from similar crash tests. For this study, deflections were determined for barrier segment lengths of 20, 25, and 30 ft (6.1 m, 7.6 m, and 9.1 m). The weight of the barrier was somewhat constrained to be in the 500 to 600 lb/ft (745 to 894 kg/m) range, given the geometric constraints discussed previously. For barrier weights in this range, and a 100,000 ft-lb (136,000 N-M) connection moment capacity, the deflections are approximately the same for all three segment lengths. Therefore, no significant advantage is given by using 25 or 30 ft (7.6 or 9.1 m) segments over the 20 ft (6.1 m) segment for this connection moment capacity. In addition, using a shorter segment allows a reduced turning radius while enhancing barrier maneuverability. Although barrier segments shorter than 20 ft (6.1 m) were not examined (because TxDOT criteria were met with 20 ft lengths), it is believed that shorter segments would probably work in other applications.

These barrier segments are moved by using adequate steel rebar placed though holes located 4 ft from the end of each segment. Chains can be connected to the rebar and the segment can be moved by forklift or light crane. On the basis of these results it was concluded that a combination of a barrier weight of approximately 550 lb/ft (819 kg/m) for a 20-ft (6.1-m) segment and a 100,000-ft.-lb (136,000-N-M) moment connection capacity would appropriately limit lateral deflections to less than 6 in. (15.2 cm). The barrier segment moment capacity is in excess of 100,000 ft-lb (136,000 N-M). As such, maximum lateral barrier deflections are forced to occur at the system's weakest points (i.e., at the barrier segment connections).

On the basis of the previous discussions, the barrier height was established at 20 in. (51 mm), the minimum barrier weight was set at 550 lb/ft (819 kg/m), and the slope of the barrier face was set at a negative 1:20. The resulting barrier cross section is shown in Figure 3. The outline of the New Jersey PCB is also presented in Figure 3 for comparison purposes. The low-profile barrier shape yields an actual weight of approximately 560 lb/ft (834 kg/m).

Several different connection schemes were considered for the new low-profile PCB, including those previously used on many conventional PCBs. However, none of these existing connection details was appropriate. Therefore, a new con-

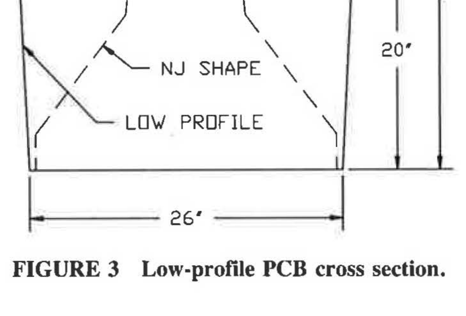


FIGURE 3 Low-profile PCB cross section.

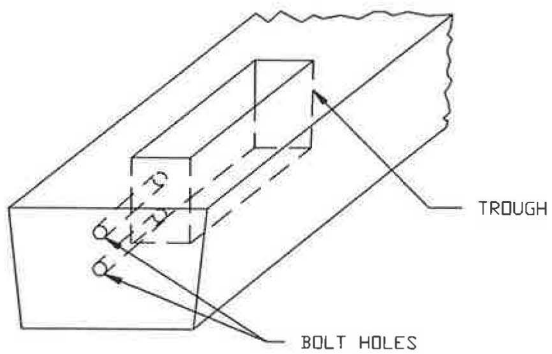


FIGURE 4 Connection details.

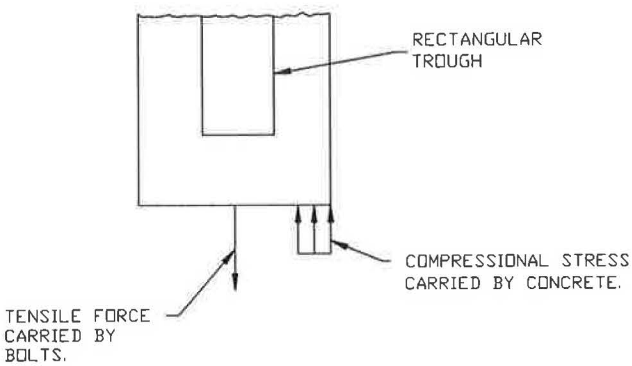


FIGURE 5 Connection loading.

nection detail was developed, as shown in Figure 4. The connection is accomplished by aligning the ends of two barrier segments and inserting two ASTM A36 bolts through the connection holes that are recessed into a rectangular trough that is cast into the end of each segment. This trough allows the bolts to be removed and inserted freely. Drainage in the trough is provided by a hole 1 in. (2.54 cm) in diameter that runs from the bottom of the trough to the barrier drainage slot. When the connection is loaded, a moment develops between the tensile force in the bolts and the compressive force in the extreme concrete fibers, as shown in Figure 5. This connection results in a moment capacity slightly in excess of 100,000 ft-lb (136,000 N-M).

The tolerances in the connection holes were set so that the barrier can be assembled on roadways with moderate vertical and horizontal curves. The barrier connection can tolerate angles up to 4 degrees in both the horizontal and vertical directions. This means that barrier segments 20 ft. (6.1 m) in length can be used to turn horizontal curves with radii of curvature of 150 ft. (46 m).

Complete fabrication details for the new low-profile barrier are shown in Figure 6.

FULL-SCALE CRASH TESTS

Two full-scale crash tests were conducted on the low-profile PCB to evaluate its performance relative to structural adequacy, occupant risk, and vehicle exit trajectory. The first test involved a 4,500-lb (2,043-kg), ¾-ton pickup that impacted the PCB at 45 mph (73 km/hr) at an encroachment angle of 25 degrees. The second test involved a 1,800-lb (817-kg) compact car that impacted the PCB at 45 mph (73 km/hr) at an encroachment angle of 20 degrees.

The tests were conducted using six 20-ft- (6.1-m-) long low-profile concrete segments connected together to form a 120 ft (36.4 m) longitudinal barrier. The segments were placed on the existing concrete surface at the TTI Proving Ground with no positive attachment to the roadway surface.

In both full-scale crash tests, the vehicles impacted the 120 ft (36.4 m) longitudinal barrier at a point located approximately 5 ft (1.5 m) upstream of the middle barrier segment joint. This impact point was chosen to provide the most critical impact situation with respect to both strength and snagging. Test statistics for the two crash tests are summarized in Table 1.

Results from Test 1

In this test, a 1984 GMC Sierra 2500 pickup was directed into the PCB. The test inertia weight of the vehicle was 4,500 lb (2,043 kg), and its gross static weight was also 4,500 lb (2,043 kg). The height to the lower edge of the vehicle bumper was 17.5 in. (44.4 cm), and the height to the upper edge was 26.5 in. (67.3 cm). The vehicle was directed into the barrier using a reverse cable tow and guidance system. The vehicle was freewheeling and unrestrained just before impact.

The vehicle was traveling at a speed of 44.4 mph (71.4 km/hr) when it impacted the barrier. The impact angle was 26.1 degrees. Immediately after impact, the bumper of the vehicle rode up on top of the barrier. At approximately 23 msec after impact, the left front tire impacted the barrier. The barrier began to move laterally at 66 msec, and the vehicle began to redirect at 71 msec after initial impact. The right front tire became airborne at 117 msec, the left front at 133 msec, and the right rear at 217 msec. At approximately 357 msec, the vehicle was traveling parallel to the barrier with a speed of 37.0 mph (59.5 km/hr), and the rear of the vehicle impacted the barrier shortly thereafter. The vehicle exited the barrier at 768 msec, traveling virtually parallel with the barrier at a speed of 34.8 mph (56 km/hr). Sequential photographs of the test are presented elsewhere (7).

Damage to the barrier is shown in Figure 7. The maximum lateral movement of the barrier was 5 in. (12.7 cm) at the impacted (center) joint. At the impacted connection, vehicle bumper interaction resulted in slight damage to the upper edge of the barrier. One segment downstream experienced a shallow delamination. These damages exposed no reinforcing steel and are not considered to be structurally significant.

The vehicle (shown in Figure 8) sustained minimal damage to the left side; however, the floorpan and frame were bent, and the A-arms were damaged. There was also damage to the front bumper, left front quarter panel, left door, left rear quarter panel, and rear bumper. The wheelbase on the left side was shortened from 131.5 in. (3.3 m) to 120.75 in. (3.1 m).

Data from the electronic instrumentation were digitized for evaluation and posttest processing. As stated previously, the impact speed was 44.4 mph (73 km/hr), and the angle of impact was 26.1 degrees. Occupant risk evaluation criteria are described in *NCHRP Report 230*, and limits are placed on these criteria for acceptable performance for tests conducted with 1,800-lb (817-kg) vehicles (*8*). These limits do not apply to tests conducted with 4,500-lb (2,043-kg) vehicles, but they were computed for information purposes. The occupant impact velocity was 21.2 ft/sec (6.5 m/sec) in the longitudinal direction and 16.0 ft/sec (4.9 m/sec) in the lateral direction. The highest 0.010 sec average occupant ridedown accelerations were −6.0 *g* (longitudinal) −11.4 *g* (lateral). These and other pertinent data from this test are presented in Figure 9. Angular displacement data and vehicular accelerations versus time data are presented elsewhere (*7*). The maximum 0.050-sec average accelerations measured near the center of gravity of the vehicle were −5.6 *g* (longitudinal) and −7.7 *g* (lateral).

After impact, the vehicle redirected and did not penetrate, vault, or roll over the barrier. The barrier moved laterally 5 in. (12.7 cm). There were no detached elements or debris to show potential for penetration of the occupant compartment or to present undue hazard to other vehicles. The vehicle remained upright and stable during contact with the barrier and after exiting the test installation. The vehicle trajectory at loss of contact indicates minimum intrusion into adjacent traffic lanes.

Results from Test 2

In this test a 1981 Honda Civic was directed into the low-profile PCB deployed in a temporary configuration. The test inertia weight of the vehicle was 1,800 lb (817 kg), and its gross static weight was 1,965 lb (892 kg). The height to the lower edge of the vehicle bumper was 14.0 in. (35.6 cm), and the height to the upper edge was 19.5 in. (49.5 cm). The vehicle was directed into the barrier using a cable reverse tow and guidance system. The vehicle was freewheeling and unrestrained just before impact.

The vehicle was traveling at a speed of 45.7 mph (73.5 km/hr) when it impacted the barrier. The impact angle was 21.3 degrees. At approximately 27 msec after impact, the left front

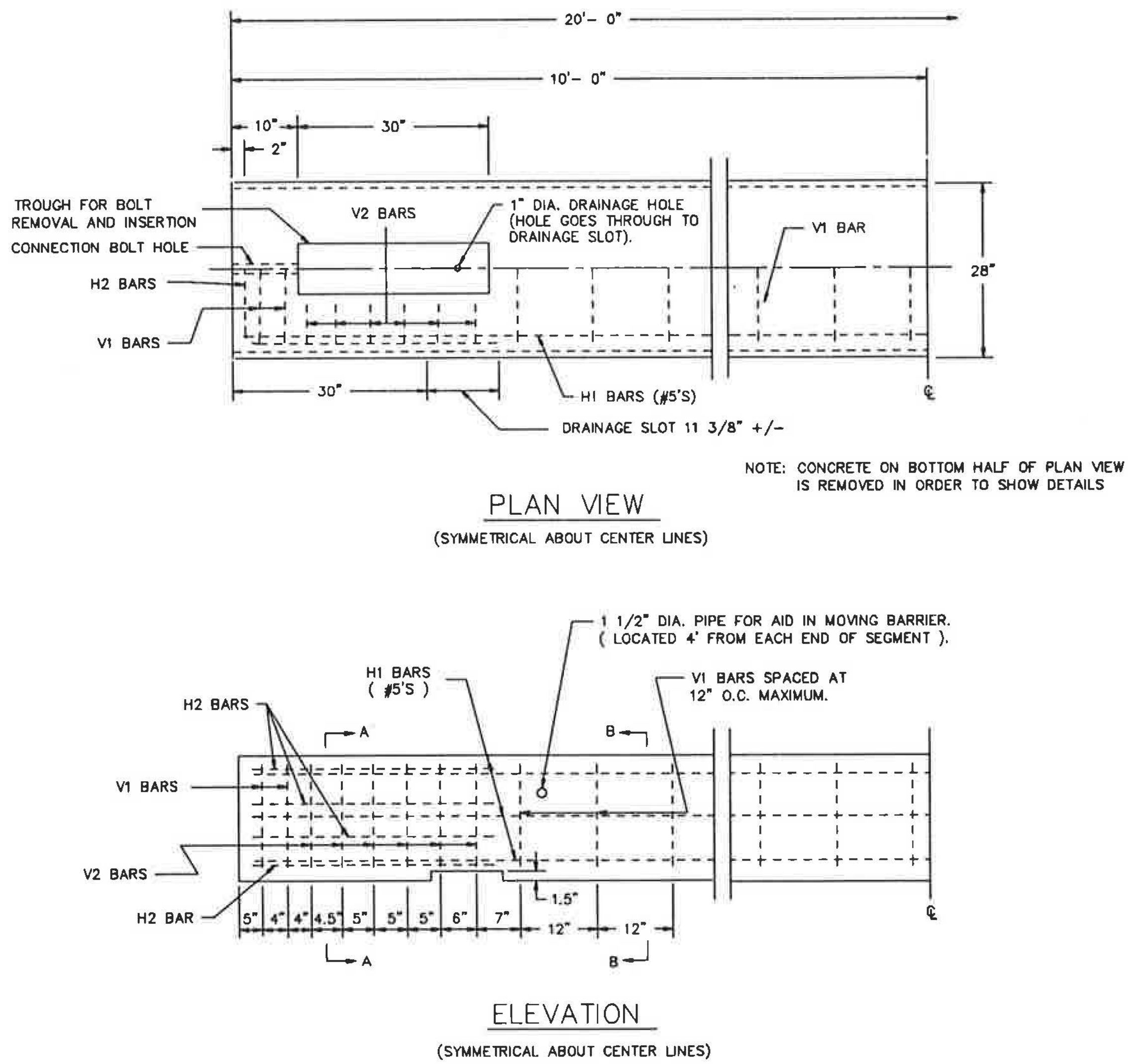
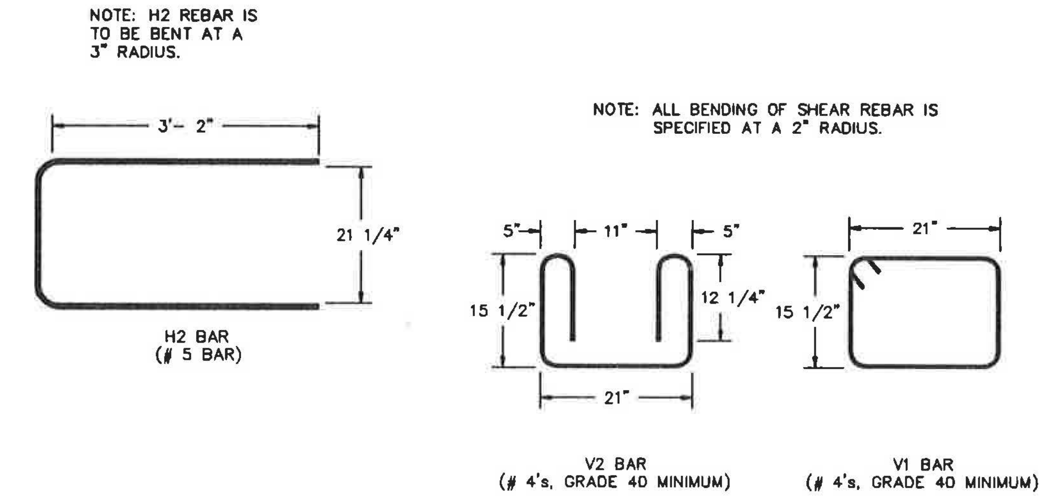
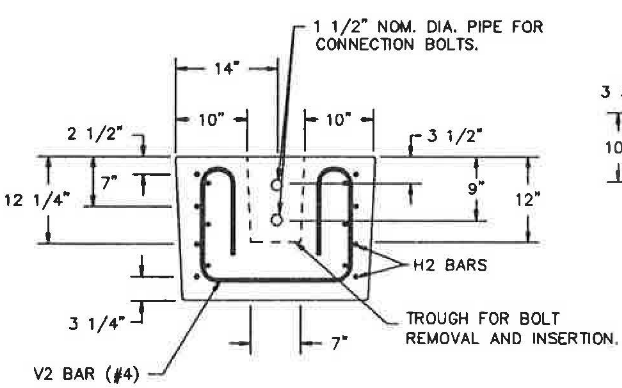


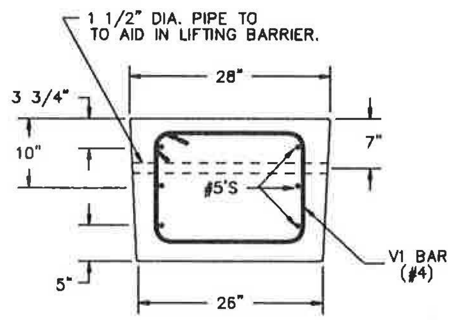
FIGURE 6 Low-profile construction details (*continued on next page*).



REINFORCING STEEL DETAILS



SECTION A–A

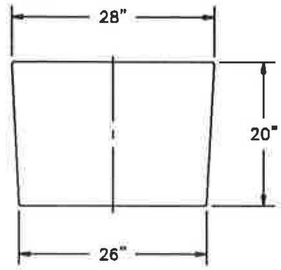


SECTION B–B

GENERAL NOTES

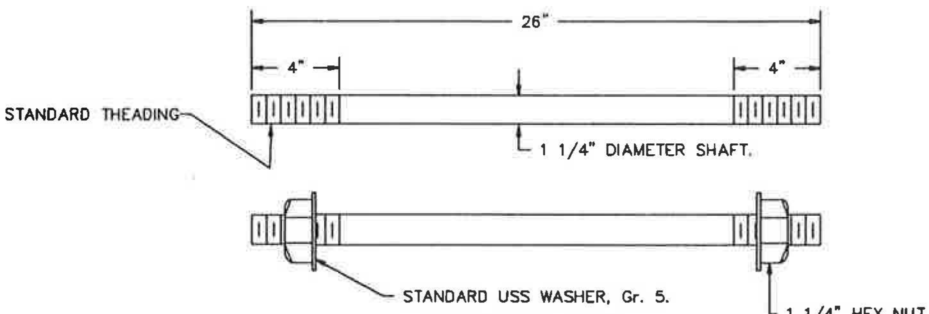
1. ALL CONCRETE SHALL BE CLASS A, C, OR H, UNLESS OTHERWISE SPECIFIED.
2. ALL REINFORCING STEEL SHALL BE GRADE 60, UNLESS OTHERWISE SPECIFIED.
3. CHAMFER END EDGES 3/4".

FIGURE 6 ***(continued).***



TYPICAL PROFILE

NOTE: BOLT MATERIAL IS
ASTM A36 ROUND BAR.



CONNECTION BOLT

ALTERNATE WIRE MESH REINFORCING
SCHEME FOR THE LOW-PROFILE PCB

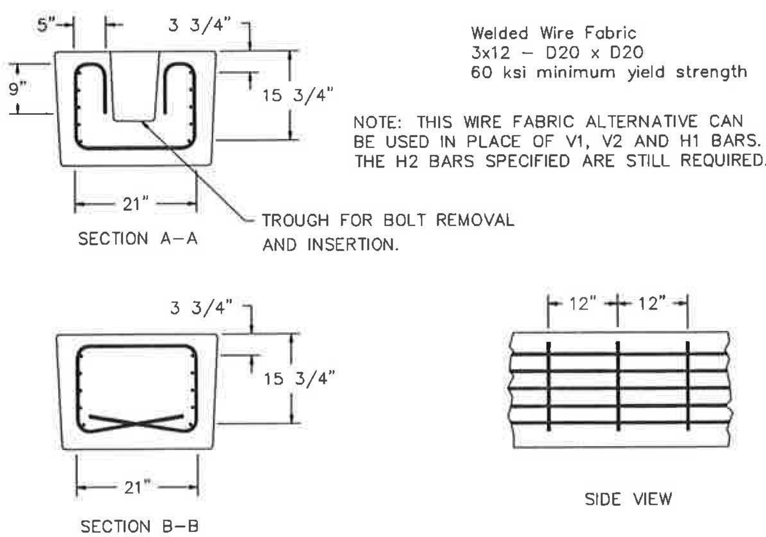


FIGURE 6 ***(continued).***

TABLE 1 Summary of Crash Test Results

Test No.	9901F-1	9901F-2
Vehicle Weight, lb (kg)	4500(2043)	1800(817)
Impact Speed, mph (km/hr)	44.4(71.4)	45.7(73.5)
Impact Angle, degrees	26.1	21.3
Exit Angle, degrees	0.0	7.4
Displacement, in (cm)	5.0(12.7)	0.0(0.0)
Occupant Impact Velocity ft/s (m/s)		
Longitudinal	21.2(6.5)	11.7(3.6)
Lateral	16.0(4.9)	18.6(5.7)
Occupant Ridedown Acceleration g's		
Longitudinal	-6.0	-1.1
Lateral	-11.4	-8.7
Vehicle Damage Classification		
TAD	11FL1	11LD3
CDC	11FLLK1 & 11LDLW1	11FLEK2 & 11LDEW3

tire impacted the barrier, and at 40 msec the vehicle began to redirect. The right side of the vehicle began to lift at 125 msec. At approximately 174 msec, the vehicle was traveling parallel to the barrier at a speed of 39.6 mph (63.7 km/hr). The rear of the vehicle impacted the barrier at 202 msec, and the vehicle exited the barrier at 366 msec, traveling 7.4 degrees away from the barrier at a speed of 38.2 mph (61.5 km/hr). Sequential photographs of the test are presented elsewhere (*7*).

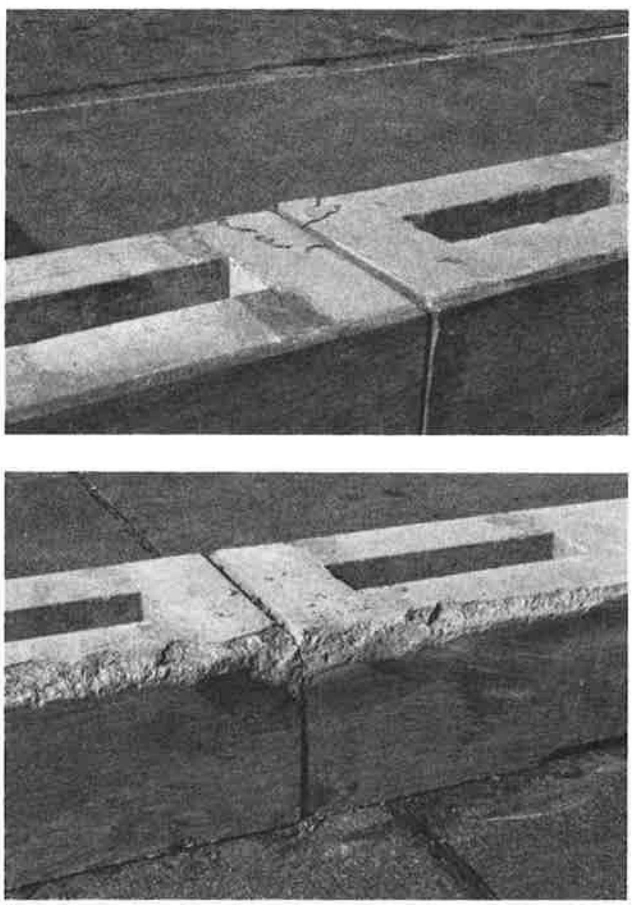


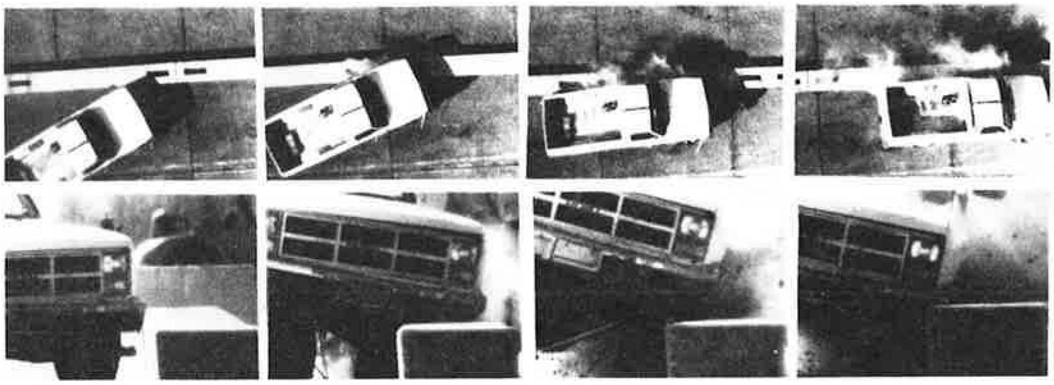
FIGURE 7 Damage at joints, Test 1.

FIGURE 8 Vehicle after Test 1.

The barrier received no significant damage, as shown in Figure 10. There was no measurable lateral movement of the barrier. The vehicle sustained moderate damage to the left side, as shown in Figure 11. The left strut and stabilizer bar were damaged. The front bumper, grill, left front quarter panel, left door, left rear quarter panel, and rear bumper were also damaged.

Data from the electronic instrumentation were digitized for evaluation and posttest processing. As stated previously, the impact speed was 45.7 mph (73.5 km/hr), and the angle of impact was 21.3 degrees. Occupant risk evaluation criteria are described in *NCHRP Report 230,* and limits are placed on these criteria for acceptable performance for tests conducted with 1,800-lb (817 kg) vehicles impacting at 15-degree angles (*8*). These limits do not apply to this set of test conditions; they were computed for information only. The occupant impact velocity was 11.7 ft/sec (3.6 m/sec) in the longitudinal direction and 18.6 ft/sec (5.7 m/sec) in the lateral direction. The highest 0.010-sec average occupant ridedown accelerations were $-1.1\ g$ (longitudinal) and $-8.7\ g$ (lateral). These and other pertinent data from this test are presented in Figure 12.

Vehicle angular displacements and vehicular accelerations versus time traces filtered at 300 Hz are presented elsewhere (*7*). The maximum 0.050-sec average accelerations measured near the center of gravity of the vehicle were $-4.5\ g$ (longitudinal) and $-9.1\ g$ (lateral).



Test No 9901F-1
Date. 01/17/91

Test Installation . . . . . Low Profile Barrier
Installation Length . . . . 120 ft (37 m)
Maximum movement. . . . . . 5 in. (12.7 cm)

Vehicle . . . . 1984 GMC Pickup
Vehicle Weight
  Test Inertia. . . . . . . 4,500 lb (2,043 kg)
  Gross Static. . . . . . . 4,500 lb (2,043 kg)
Vehicle Damage Classification
  TAD 11FL1
  CDC . . . . 11FLLK1 & 11LDLW1
Maximum Vehicle Crush . . . 3.0 in. (7.6 cm)

Impact Speed . . . . 44.4 mi/h (71.4 km/h)
Impact Angle . . . . 26.1 degrees
Speed at Parallel. . . . . . 37.0 mi/h (59.5 km/h)
Exit Speed . . . . 34.8 mi/h (56.0 km/h)
Exit Trajectory. . . . . . . 0 degrees
Vehicle Accelerations
  (Max. 0.050-sec Avg)
  Longitudinal . . . . -5.6 g
  Lateral. . . . . -7.7 g
Occupant Impact Velocity
  Longitudinal . . . . 21.2 ft/s (6.5 m/s)
  Lateral. . . . . 16.0 ft/s (4.0 m/s)
Occupant Ridedown Accelerations
  Longitudinal . . . . -6.0 g
  Lateral. . . . .-11.4 g

FIGURE 9 Summary of results for Test 1.

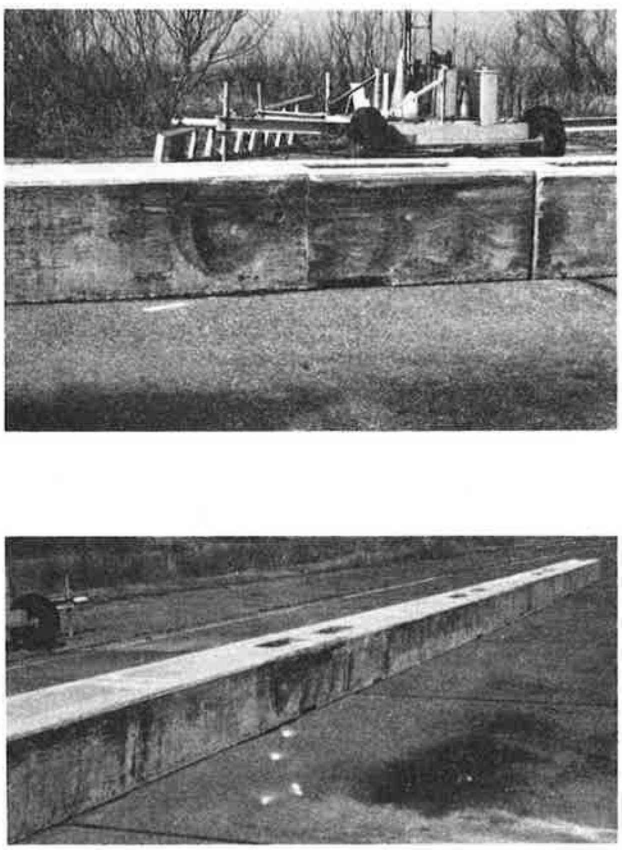


FIGURE 10 Barrier after Test 2.

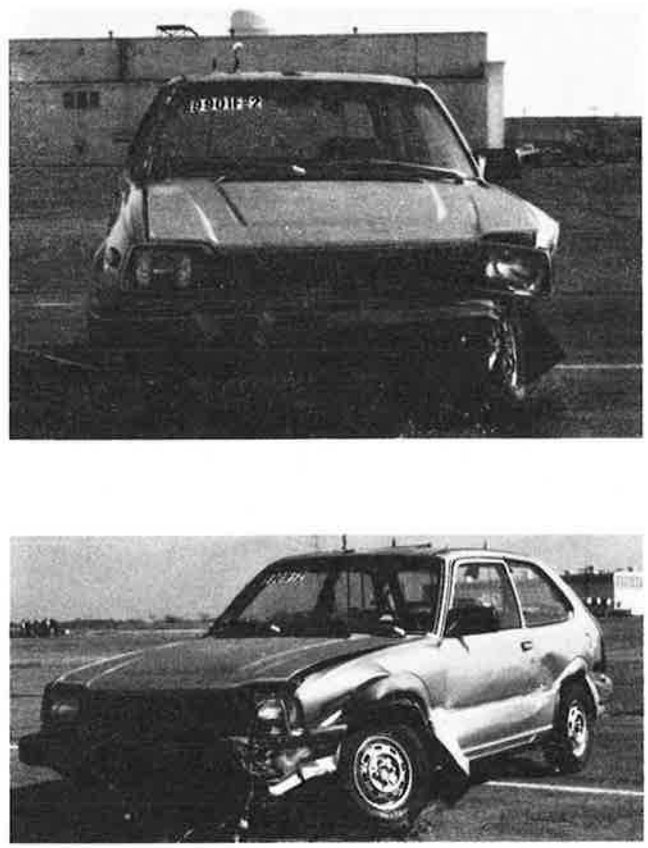
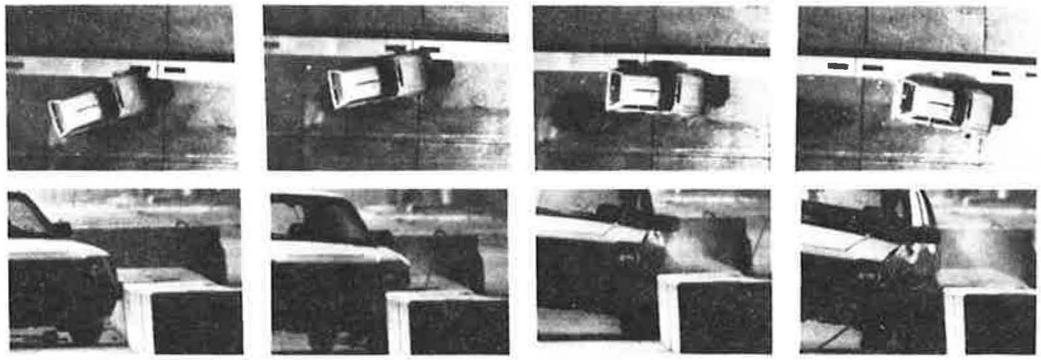


FIGURE 11 Vehicle after Test 2.



Test No 9901F-2
Date. 01/25/91

Test Installation . . . . . Low Profile Barrier
Installation Length . . . . 120 ft (37 m)
Maximum movement. . . . . . 0 in. (0 cm)

Vehicle . . . . 1981 Honda Civic
Vehicle Weight
Test Inertia. . . . . . . 1,800 lb (817 kg)
Gross Static. . . . . . . 1,965 lb (892 kg)
Vehicle Damage Classification
TAD 11LD3
CDC . . . . 11FLEK2 & 11LDEW3
Maximum Vehicle Crush . . . 8.0 in. (20.3 cm)

Impact Speed . . . . 45.7 mi/h (73.5 km/h)
Impact Angle . . . . 21.3 degrees
Speed at Parallel. . . . . . 39.6 mi/h (63.7 km/h)
Exit Speed . . . . 38.2 mi/h (61.5 km/h)
Exit Trajectory. . . . . . . 7.4 degrees
Vehicle Accelerations
(Max. 0.050-sec Avg)
Longitudinal . . . . -4.5 g
Lateral. . . . . -9.1 g
Occupant Impact Velocity
Longitudinal . . . . 11.7 ft/s (3.6 m/s)
Lateral. . . . . 18.6 ft/s (5.7 m/s)
Occupant Ridedown Accelerations
Longitudinal . . . . -1.1 g
Lateral. . . . . -8.7 g

FIGURE 12 Summary of results for Test 2.

After impact, the vehicle redirected and did not penetrate, vault, or roll over the barrier. There was no measurable movement of the barrier. There were no detached elements or debris to show potential for penetration of the occupant compartment or to present undue hazard to other vehicles. The vehicle remained upright and stable during impact with the barrier and after exiting the test installation. There was no deformation or intrusion into the occupant compartment. The vehicle exited the barrier traveling 7.4 degrees away from the barrier. The vehicle trajectory at loss of contact indicates minimum intrusion into the adjacent traffic lanes.

CONCLUSIONS

A low-profile PCB has been developed; it is designed for impacts ranging from 1,800-lb (817-kg) compact automobiles to 4,500-lb (2,043-kg), ¾-ton pickups. The test conditions for the ¾-ton pickup were 45 mph (73 km/hr) at a 25-degree encroachment angle. The test conditions for the small car were 45 mph (73 km/hr) at a 20-degree encroachment angle. It is believed that these are severe test conditions for the urban application in which vehicle speeds are limited to 45 mph (73 km/hr). The tests prove that the barrier can withstand these impacts without any vaulting or rolling of the vehicle and without any significant damage to the barrier.

In both full-scale crash tests, the vehicles were smoothly redirected. The largest deflection of the barrier was 5 in. (12.7 mm), which resulted from the impact of the ¾-ton pickup. No measurable deflection occurred in the small-car test. All test results fell within acceptable limits of occupant and vehicle accelerations according to *NCHRP Report 230* (*8*). Therefore, the low-profile PCB is recommended for immediate use.

The primary advantage of the low-profile PCB is that it significantly improves the site distance situation for the drivers attempting to enter or exit a work zone delineated with PCB barriers. The critical site-distance situation was judged to be the lateral visibility of a cross-traffic driver attempting to enter the work zone at night. Specifically, the new low-profile PCB was designed to not interfere with the sighting of headlights of oncoming traffic at night. In addition, the daytime visibility is significantly improved. The improved visibility provided by the use of the low-profile PCB will allow drivers to see oncoming vehicles at night and during the day and to avoid a potentially hazardous situation. In addition to this advantage, a reasonable level of safety in the work zone is maintained by preventing the intrusion of errant vehicles into the work area.

TxDOT engineers believe there are also permanent uses for the low-profile barrier in urban situations and in some areas adjacent to freeways. The PCB can be easily converted to permanent use including slip forming the shape without connections or permanently anchoring the barrier to the roadway.

The new low-profile barrier presents a major advance for urban work zones in which vehicle speeds are limited to 45 mph or less. It is perceived that there is a need for a similar low-profile barrier for higher speed applications. Although the redirective capabilities of the 20-in. (51-cm) low-profile PCB may not be sufficient for use in high-speed work zones, it is believed that a 24-in. (61-cm) version of the low-profile barrier would be able to redirect a 4,500-lb (2,043-kg) vehicle impacting at an angle of 25 degrees and a speed of 60 mph (96 km/hr). Therefore, it is suggested that future research efforts be directed toward the development and testing of a 24-in. (61-cm), full-service, low-profile barrier. In addition, a significant effort is ongoing to develop an end treatment for the new low-profile PCB that will not inhibit required cross-traffic visibility.

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