Minnesota Bridge Rail–Guardrail Transition Systems

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Summarized are the results of crash testing and evaluation of two W-beam guardrail-to-concrete safety-shaped bridge-rail transition designs developed by the Minnesota Department of Transportation. The first, integral end-post design, is intended for use with new construction and reconstruction in which replacement of bridge railings is required. The second, separate end-post design, is intended for use as retrofits to existing bridge railings on 3R and 4R projects. Three crash tests were used to evaluate the integral end-post design. Results of the crash tests indicated that the integral end-post design met all impact performance evaluation criteria according to guidelines outlined in NCHRP Report 230. Two versions of the separate end-post transition design were evaluated, each with one crash test. Results of the first crash test indicated that the initial separate end-post design did not meet the impact performance evaluation criteria according to guidelines outlined in NCHRP Report 230. The vehicle pocketed and impacted the end of the concrete bridge end post, resulting in an unacceptable level of longitudinal occupant ridedown acceleration. The design was then modified and the improved transition design was successfully crash tested.

The primary functions of a bridge rail are to prevent errant vehicles from going over the side of the bridge and to prevent the wheels of an impacting vehicle from falling between the bridge rail and the edge of the bridge deck. Thus, bridge rails must be either rigid or semirigid in construction. The most common types of bridge rails are reinforced concrete walls or metal rails on concrete parapets. If improperly treated, the exposed ends of these railings can present a serious safety hazard to errant vehicles.

In most instances, an approach guardrail is used to shield the exposed end of the bridge railing and to prevent errant vehicles from getting behind the railing and encountering underlying hazards. These approach guardrails are typically much more flexible than the bridge rails to which they are attached and thus have the potential for deflecting sufficiently to allow an errant vehicle to impact the end of the rigid or semi-rigid bridge railing. A transition section is therefore used whenever there is a significant change in lateral strength from the approach guardrail to the bridge railing.

The purpose of a transition section is to provide continuity of protection where an approach guardrail joins a bridge rail. In order to achieve this continuity of protection, the lateral stiffness of the transition section should be increased smoothly and continuously from the more flexible to the less flexible system. This required increase in lateral barrier strength can be achieved by varying one or more key design parameters, including increasing guardrail beam strength, reducing post spacing, and increasing post size or embedment depth. An effective transition design is one that limits dynamic deflection and minimizes vehicle pocketing or snagging on the end of the bridge railing.

Two W-beam guardrail-to-concrete safety-shaped bridge-rail transition designs were developed by the Minnesota Department of Transportation (MnDOT). The designs were the product of an MnDOT committee and were based on review of literature and FHWA-approved transition designs and on existing field conditions, including bridge railing, curb, and approach guardrail designs. Another consideration in the design was the use of only standard in-stock components to minimize maintenance and inventory problems.

MnDOT contracted with the Texas Transportation Institute to crash test and evaluate the impact performance of these two Minnesota transition designs (*1*,*2*). These two transition designs are referred to herein as integral end-post design and separate end-post design. The integral end-post design is intended for use with new construction and reconstruction in which replacement of bridge railings is required. The separate end-post design is intended for use as retrofits to existing bridge railings on 3R and 4R projects on roadways with speed limits above 40 mph and average daily traffic (ADT) volume of more than 1,500 vehicles. The impact performance of these two transition designs is summarized and presented here.

INTEGRAL END-POST TRANSITION DESIGN

The integral end-post transition design incorporates special steel reinforcements near the end of the standard concrete safety-shaped bridge rail so that the W-beam guardrail transition can be attached directly to the bridge rail, and thus the term "integral end post". The transition from the standard concrete safety-shaped bridge rail to the standard G4(2W) W-beam guardrail spans a length of 25.0 ft (7.6 m). The major features of the transition design are as follows:

- The first 12.5-ft- (3.8-m-) long section of W-beam is nested (i.e., one W-beam is placed on another). The nested W-beams are attached to a standard W-beam terminal connector and anchored to the concrete parapet with four ⅞-in. × 12.0-in. (2.22-cm × 30.5-cm) high-strength bolts and nuts and 2-in. × 3-in. × ¼-in. (5.08-cm × 7.62-cm × 0.64-cm) plate wash-

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ers. A single W-beam is used for the second 12.5-ft (3.8-m) guardrail section.

- In addition to the nested W-beams, a reduced post spacing is used to transition the lateral stiffness between the systems. The first post is 8½ in. (21.6 cm) from the end of the concrete parapet. The post spacings are 1 ft 6¾ in. (0.48 m) center to center (3 spaces) for Posts 1 through 4, 3 ft 1½ in. (0.95 m) center to center (4 spaces) for Posts 5 through 8, and 6 ft 3 in. (1.91 m) for Post 9 and beyond. All posts used in the transition are standard 6-in. × 8-in. × 6-ft (15.2-cm × 20.3-cm × 1.83-m) timber posts. The W-beam sections are attached to the posts with ⅝-in button head bolts and recess nuts with rectangular washers.
- A 7-ft- (2.1-m-) long curb transition is used from the top of the lower slope of the concrete safety-shaped barrier at 13 in. (33.0 cm) above ground to a 4-in. (10.2-cm) high roll curb, which then continues throughout the remainder of the 25-ft (7.6-m) transition area. The curb section facilitates drainage and reduces the potential of wheel snagging by an impacting vehicle on the posts.
- The upper corner of the concrete parapet is tapered from a height of 32 in. (81.3 cm) to 27 in. (68.6 cm) so that it is level with the top of the W-beam to minimize the potential of snagging on the exposed corner.

The test installation in this study consisted of a simulated concrete bridge parapet that incorporated both the integral end-post and the separate end-post designs. To simplify construction, a single foundation, 14.1 ft (4.3 m) in length, was designed and constructed for use with both transition designs. A 12.0-ft- (3.7-m-) long section of the integral end-post bridge railing and a 2.0-ft- (0.61-m-) long separate end post, separated by a construction joint, were attached to the foundation. The guardrail installation consisted of the 25-ft (7.6-m) transition area, 25 ft (7.6 m) of standard G4(2W) W-beam guardrail, and a 25-ft (7.6-m) W-beam turndown terminal anchor for a total length of 75 ft (22.9 m). Photographs of the completed test installation are shown in Figure 1.

Three crash tests were conducted for the integral end-post transition design:

- A 4,500-lb (2,041-kg) passenger car impacting the transition at a speed of 60 mph (96.5 km/hr) and an angle of 25 degrees. The point of impact was midspan between guardrail Posts 6 and 7, 13 ft 5½ in. (4.1 m) upstream from the end of the bridge parapet. This is the required test for a transition installation, according to NCHRP Report 230 (*3*).
- A 1,800-lb (817-kg) passenger car impacting the transition at a speed of 60 mph (96.5 km/hr) and an angle of 20 degrees. The point of impact was just downstream from guardrail Post 5, 8 ft 6¼ in. (2.6 m) from the end of the bridge parapet. This test is intended to assess the potential for wheel snagging on the posts or for the tire to wedge in the area between the W-beam and the curb transition section.
- A 4,500-lb (2,041-kg) passenger car impacting the transition at a speed of 60 mph (96.5 km/hr) and an angle of 25 degrees. The point of impact was 1 ft (0.3 m) downstream from guardrail Post 9, 23 ft 4¾ in. (7.1 m) from the end of the bridge parapet. This test was intended to assess the effect of the curb section on impact performance and the potential for snagging or pocketing at the end of the nested W-beam section.

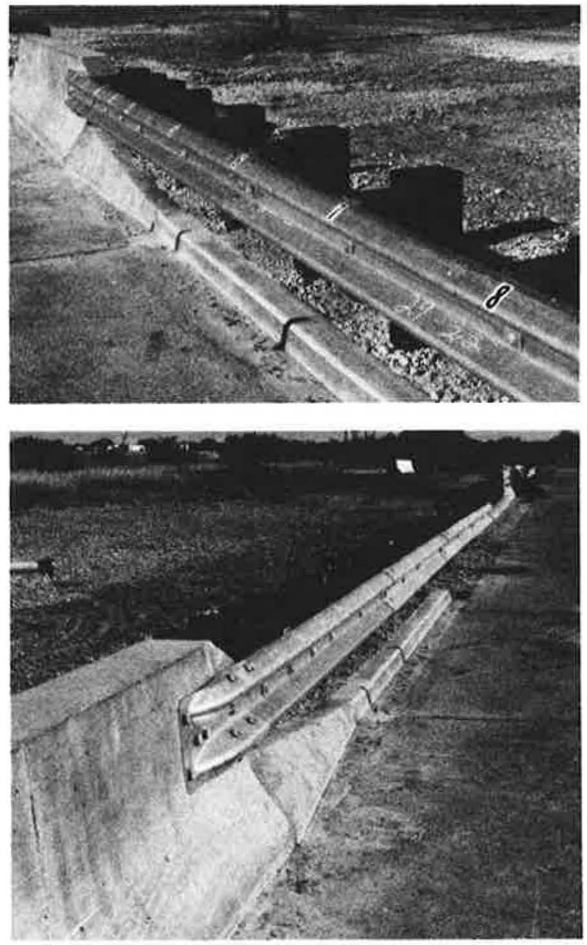

FIGURE 1 Photographs of integral end-post transition design test installation.

The crash test procedures and evaluation of the impact performance were in accordance with the guidelines in NCHRP Report 230. A summary of the test results is presented in Table 1. Following are brief descriptions of the tests and discussions of the results.

Test 1

A 1982 Oldsmobile Ninety-Eight hit the midspan between guardrail Posts 6 and 7, 13 ft 5½ in. (4.1 m) upstream from the end of the bridge parapet, at 59.8 mph (96.2 km/hr) and an angle of 25.4 degrees. The test weight of the vehicle was 4,500 lb (2041 kg). The transition successfully contained and redirected the vehicle. The vehicle remained upright and stable during the initial test period and after leaving the installation.

The transition installation received moderate damage, as shown in Figure 2. There was residual deformation to the nested rail in the area of the first seven posts. In addition,

TABLE 1 Summary of Test Results, Integral End-Post Transition Design

Description	Test 1 (7163-1)	Test 2 (7163-3)	Test 3 (7163-4)
Test Vehicle	1982 Oldsmobile Ninety-Eight	1987 Chevrolet Sprint	1981 Pontiac Bonneville
Test Weight, lb (kg)	4500 (2041)	1969 (894)	4500 (2041)
Impact Speed, mi/h (km/h)	59.8 (96.2)	61.5 (99.0)	61.8 (99.4)
Impact Angle, deg.	25.4	20.5	25.2
Exit Speed, mi/h (km/h)	40.0 (64.4)	43.4 (69.8)	39.7 (63.9)
Exit Angle, deg.	10.2	3.0	7.5
Velocity Change[1], mi/h (km/h)	19.8 (31.8)	18.1 (29.2)	22.1 (35.5)
Occupant Impact Velocity[2]			
Longitudinal, ft/s (m/s)	29.5 (9.0)	28.6 (8.7)	27.5 (8.4)
Lateral, ft/s (m/s)	-25.0 (7.6)	-26.5 (8.1)	-21.3 (6.5)
Occupant Ridedown Acceleration[2]			
Longitudinal, g	-11.4	1.6	-12.4
Lateral, g	12.5	13.2	12.4
Length of Rail Contact, ft (m)	16.3 (5.0)	13.5 (4.1)	19.2 (5.9)
Maximum Dynamic Rail Deflection, in (cm)	13.7 (34.8)	5.2 (13.1)	21.6 (54.9)
Maximum Vehicle Crush, in (cm)	16.0 (40.6)	8.0 (20.3)	16.0 (40.6)

Notes. 1 The velocity change was higher than the recommended value of 15 mi/h (24.1 km/h) in all three tests, but the vehicle was judged not to be a hazard to adjacent traffic lanes.

2 According to NCHRP Report 230 guidelines, the occupant risk criteria are applicable only for the 1,800-lb passenger car crash test (test 2) and not applicable for the 4,500-lb passenger car crash test (tests 1 and 3).

vehicle tire marks were observed on Posts 2–5 and on the first 4.0 ft (1.22 m) of the concrete bridge parapet. However, there was no apparent structural damage to the concrete bridge parapet. Also, there was no debris or detached elements to show potential for penetration of the occupant compartment or to present undue hazard to other vehicles.

The vehicle received considerable damage to the right front quarter. The right front wheel and control arm were severely bent and pushed rearward 10.0 in. (25.4 cm). The entire front end of the vehicle was shifted 7.0 in. (17.8 cm) to the left. The roof, floor pan in the rear passenger area, hood, and bumper were also damaged. However, there was minimal deformation and intrusion into the occupant compartment.

Test 2

A 1987 Chevrolet Sprint impacted the transition just downstream from guardrail Post 5, 8 ft 6¼ in. (2.6 m) from the end of the bridge parapet, at 61.5 mph (99.0 km/hr) and an angle of 20.5 degrees. The empty weight of the vehicle was 1,800 lb (817 kg); the test weight was 1,969 lb (894 kg). The additional weight was the weight of an unrestrained, uninstrumented, 50th percentile male anthropometric dummy in the driver's seat.

The transition successfully contained and redirected the vehicle. The vehicle remained upright and stable during the initial test period and after leaving the installation. The lateral occupant impact velocity of −26.5 ft/sec (8.1 m/sec) was higher than the design value of 20 ft/sec (6.1 m/sec), but below the limit of 30 ft/sec (9.1 m/sec). The longitudinal occupant impact velocity and the ridedown accelerations were all below the design values outlined in NCHRP Report 230.

The installation received minor damage, as shown in Figure 3. There was residual deformation to the rail in the area of the first six posts, but no apparent structural damage to the concrete bridge parapet. It appeared that the right front tire of the vehicle was momentarily wedged between the W-beam and the top of the curb transition, resulting in the bottom of the W-beam being pushed and deformed slightly upward. However, there is no evidence to indicate that this action had any adverse effect on the vehicle kinematics or trajectory. Also, there was no debris or detached elements.

The vehicle received considerable damage to the right front quarter. The right front wheel and strut assembly/control arm were severely bent and pushed rearward 10.0 in. (25.4 cm). The floor pan, hood, and bumper were also damaged. The passenger door was ajar and the window was broken from the impact by the dummy. However, there was minimal deformation and intrusion into the occupant compartment.

Test 3

A 1981 Pontiac Bonneville impacted the transition 1.0 ft (0.3 m) downstream from Post 9, 23 ft 4¾ in. (7.1 m) from the end of the bridge parapet at 61.8 mph (99.4 km/hr) and an angle of 25.2 degrees. The test weight of the vehicle was 4,500 lb (2,041 kg). The transition successfully contained and redirected the vehicle. The vehicle remained upright and stable during the initial test period and after leaving the installation.

The installation received moderate damage, as shown in Figure 4. There was residual deformation to the rail from Posts 2 through 10, but no apparent structural damage to the concrete bridge parapet. Also, there was no debris or detached elements. The vehicle received severe damage, the majority of which occurred to the right front quarter of the vehicle. The right front wheel and control arm were severely bent and pushed 7.0 in. (17.8 cm) rearward. In addition, the entire front end was shifted 4.0 in. (10.2 cm) to the left. The floor pan and drive shaft were also damaged.

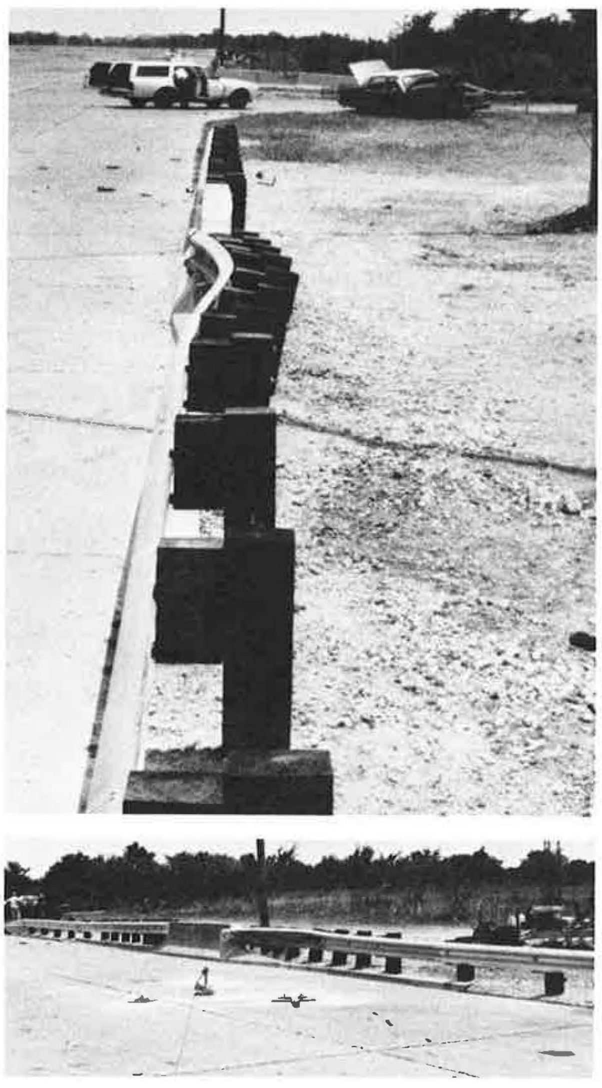

FIGURE 2 Integral end-post transition after Test 1.

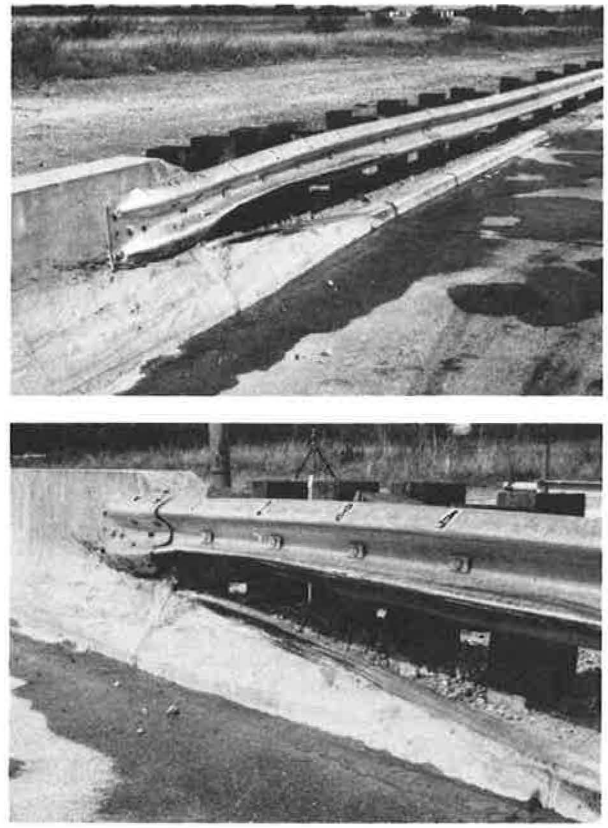

FIGURE 3 Integral end-post transition after Test 2.

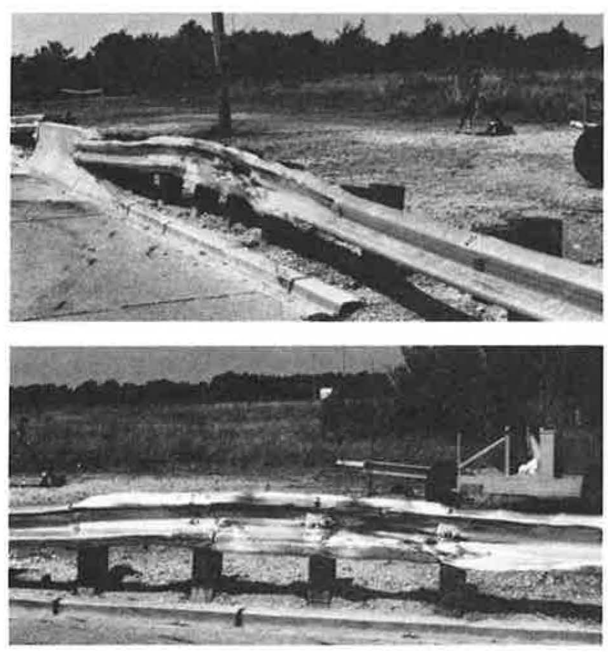

FIGURE 4 Integral end-post transition after Test 3.

Summary

Three crash tests were used to evaluate the integral end-post transition design. Results of the crash tests indicated that the design met all impact performance evaluation criteria according to the guidelines outlined in NCHRP Report 230.

In all three crash tests, the transition successfully contained and redirected the vehicle. There was severe damage to the vehicle, but only moderate damage to the guardrail and no apparent structural damage to the concrete bridge parapet. There was minimal deformation and intrusion into the occupant compartment. The vehicle remained upright and stable during the initial test period and after leaving the installation. The velocity change was higher than the recommended velocity change of 15 mph (24.1 km/hr), but the vehicle was judged to not be a hazard to vehicles in adjacent traffic lanes. It should be noted that this velocity change criterion is seldom met in crash tests involving transition designs.

SEPARATE END-POST TRANSITION DESIGN

The separate end-post transition design, as implied by its name, incorporates an end post 2 ft (0.61 m) in length, separate from the existing bridge railing, for attachment of the W-beam guardrail transition. Two versions of the transition designs were evaluated. The initial design did not perform satisfactorily in the crash testing and was subsequently modified to improve its impact performance. The improved design was then crash tested and found to perform satisfactorily.

One crash test (Test Designation 30 in NCHRP Report 230) was conducted for each of the two versions of the separate end-post transition design, which involved a 4,500-lb (2,041-kg) passenger car impacting the transition at a speed of 60 mph (96.5 km/hr) and an angle of 25 degrees. The point of impact was the midspan of guardrail Posts 7 and 8, 14 ft 8½ in. (4.5 m) from the end of the bridge-rail end post. The crash test procedures and evaluation of the impact performance were in accordance with guidelines presented in NCHRP Report 230. A summary of the test results is presented in Table 2. Following are brief descriptions of the tests and discussions of the results.

Initial Design

The basic design of the initial separate end-post transition design is similar to that of the integral end-post design with the following exceptions.

TABLE 2 Summary of Test Results, Separate End-Post Transition Design

Description	Initial Design (7163-2)	Improved Design (7182-1)
Test Vehicle	1981 Buick Electra	1980 Cadillac Coupe deVille
Test Weight, lb (kg)	4500 (2041)	4500 (2041)
Impact Speed, mi/h (km/h)	57.6 (92.7)	62.2 (100.1)
Impact Angle, deg.	27.3	26.2
Exit Speed, mi/h (km/h)	N/A	44.0 (70.8)
Exit Angle, deg.	N/A	14.4
Velocity Change[1], mi/h (km/h)	57.6 (92.7)	18.2 (29.3)
Occupant Impact Velocity[2]		
Longitudinal, ft/s (m/s)	29.8 (9.1)	24.3 (7.4)
Lateral, ft/s (m/s)	20.8 (6.4)	22.5 (6.9)
Occupant Ridedown Acceleration[2]		
Longitudinal, g	-24.1	- 4.0
Lateral, g	- 9.7	-11.1
Length of Rail Contact, ft (m)	16.9 (5.2)	17.3 (5.3)
Maximum Dynamic Rail Deflection, in (cm)	15.2 (38.7)	20.4 (51.8)
Maximum Vehicle Crush, in (cm)	32.0 (81.3)	10.0 (25.4)

Notes. [1] For the initial design, the vehicle was practically stopped when it exited from the transition and the velocity change was thus the same as the impact speed of 57.6 mi/h (92.7 km/h). For the improved design, the velocity change was higher than the recommended value of 15 mi/h (24.1 km/h), but the vehicle was judged not to be a hazard to adjacent traffic lanes.

[2] According to NCHRP Report 230 guidelines, the occupant risk criteria are not applicable for 4,500-lb passenger car crash tests.

- The height from the top of the W-beam guardrail at its anchor to the concrete parapet is 32 in. (81.3 cm) instead of the standard 27 in. (68.6 cm) height. The height of the top of the W-beam is then gradually reduced to the standard 27 in. (68.6 cm) over the transition length of 25 ft (7.6 m).
- The first post is located 7¾ in. (19.7 cm) from the end of the concrete parapet. The post spacings are 1 ft 6¾ in. (0.48 m) center to center (4 spaces) for Posts 1 through 5, 3 ft 1½ in. (0.95 m) center to center (3 spaces) for Posts 6 through 9, and 6 ft 3 in. (1.91 m) for Post 10 and beyond.
- The curb transition section is only 3 ft (0.91 m) long. Its height changes from 9 in. (22.9 cm) at the concrete parapet to a 6-in. (15.2-cm) curb. The face of the curb is about 4 in. (10.2 cm) in front of the face of the W-beam. In comparison, the curb transition for the integral end-post design is 7 ft (2.1 m) long. Its height changes from 13 in. (33.0 cm) at the concrete parapet (the same height as the breakpoint between the lower and upper slopes of the safety shape) to a 4-in. (10.2-cm) curb. The face of the curb aligns with the face of the W-beam for the integral end-post design.

These differences in the designs of the curb transition sections are reflective of the different applications of the two transition designs. The separate end-post design is intended for retrofit of existing bridge railings where curbs are already in place. The curb height and location of the curb face reflect what is already in the field. The integral end-post design is intended for new construction and reconstruction in which there are no existing restrictions on the curb height and the location of the curb face.

The test installation for the initial separate end-post transition design is shown in Figure 5.

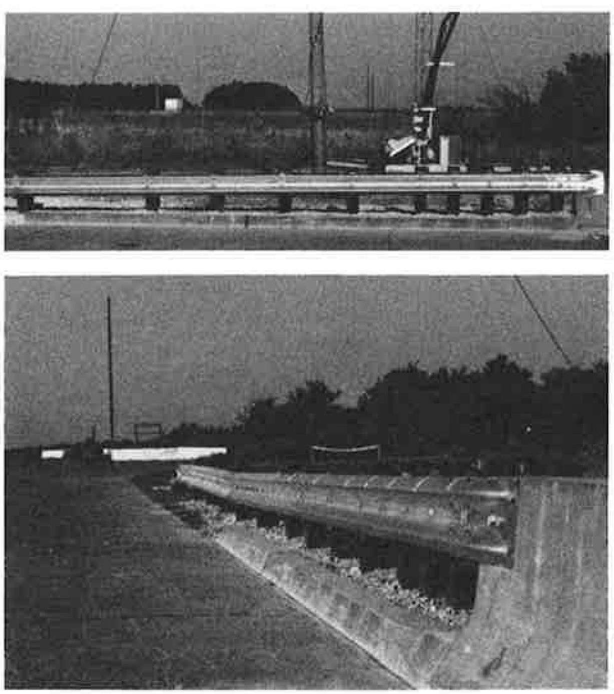

FIGURE 5 Photographs of initial separate end-post transition design test installation.

A 1981 Buick Electra impacted the midspan of Posts 7 and 8, 14 ft 8½ in. (4.5 m) from the end of the concrete end post, at 57.6 mph (92.7 km/hr) and an angle of 27.3 degrees. The test weight of the vehicle was 4,500 lb (2,041 kg). The front bumper of the vehicle slid below the W-beam shortly after impact. The left front wheel contacted Post 7, and the bumper contacted Post 6. As the vehicle proceeded along the transition, the bumper remained below the W-beam and hit the remaining posts (1 through 5) directly, splintering or breaking Posts 2–5. This resulted in excessive deflection to the rail, but the vehicle was not significantly redirected. The vehicle pocketed at the end of the bridge parapet, traveling at 35.1 mph (56.5 km/hr). The vehicle snagged on the end of the bridge rail and was displaced almost perpendicularly away from the end of the bridge parapet. The vehicle was practically stopped as it exited from the bridge parapet, and the exit angle was unobtainable.

The installation received severe damage, as shown in Figure 6. There was residual deformation to the rail in the area of the first eight posts. Posts 2–5 were splintered and broken, and the W-beam was pushed upward. There was no apparent structural damage to the concrete end post. Also, there was minimal debris or detached elements.

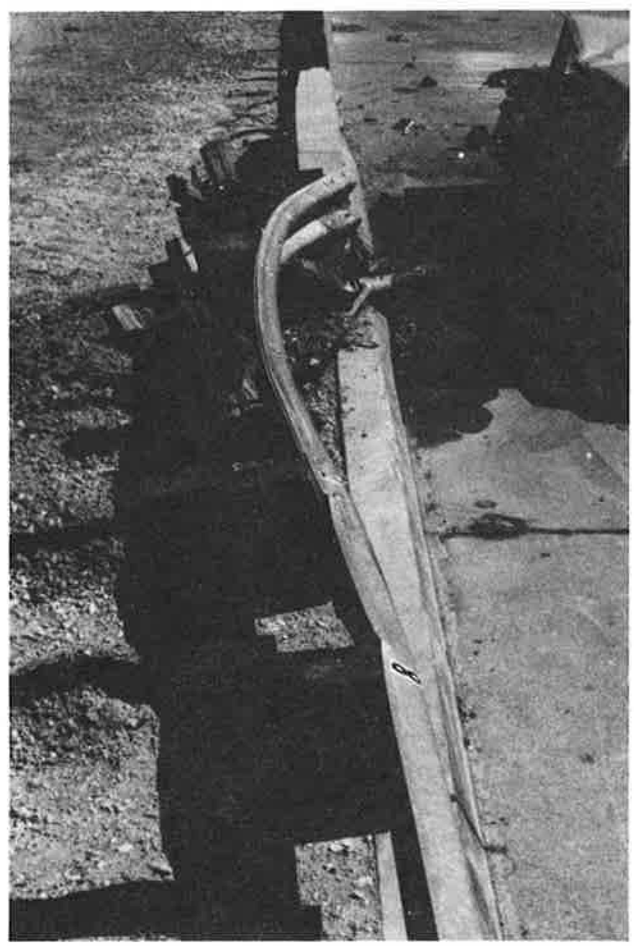

FIGURE 6 Initial separate end-post transition after initial design test.

The vehicle was severely damaged. The maximum crush was 32.0 in. (81.3 cm) at the left front corner of the vehicle. The left front wheel and control arm were severely bent and pushed rearward 22.0 in. (55.9 cm). The entire front end of the vehicle was shifted to the left 6.5 in. (16.5 cm). The subframe, roof, floor pan, hood, and bumper were among the many damaged components. In addition, the drive shaft and the steering column were bent. There was substantial deformation and intrusion into the occupant compartment. Although the occupant risk criteria are not applicable to this test, a review of the longitudinal accelerometer trace and the resulting occupant impact velocity and occupant ridedown acceleration is revealing. The deceleration levels during impact with the transition guardrail was acceptable, as reflected in a longitudinal occupant impact velocity of 29.8 ft/sec (9.1 m/sec), which was below the design value of 30.0 ft/sec (9.1 m/sec). However, as the vehicle pocketed and impacted the end of the concrete end post, high deceleration levels were experienced by the vehicle and reflected in a ridedown acceleration of $-24.1\ g$, which was above the limit of $20\ g$.

In summary, the installation contained and redirected the vehicle. The damage to the vehicle was severe, and there was deformation and intrusion into the occupant compartment. The guardrail transition sustained severe damage, but the concrete end post sustained no apparent structural damage. The amount of debris and detached elements was minimal. The vehicle pocketed and impacted the end of the concrete bridge parapet and was practically stopped as it exited from the test installation. The velocity change for the vehicle was thus the same as the impact speed of 57.6 mph (92.7 km/hr).

The poor impact performance of the separate end-post design was partially attributed to the mounting height of the guardrail. The height of the top of the W-beam at the point of impact was approximately 30 in. (76.2 cm), 3 in. (7.6 cm) higher than the standard 27 in. (68.6 cm). This resulted in the front bumper of the vehicle underriding the W-beam, thus allowing the bumper to come into direct contact with the posts. The posts were splintered or broken, resulting in excessive deflection of the W-beam. The vehicle was not significantly redirected.

Improved Design

To eliminate the potential for the vehicle to underride the W-beam, the separate end-post design was improved by incorporating a C6x8.2 rub rail into the transition design. The rub rail was mounted directly beneath and parallel to the W-beam.

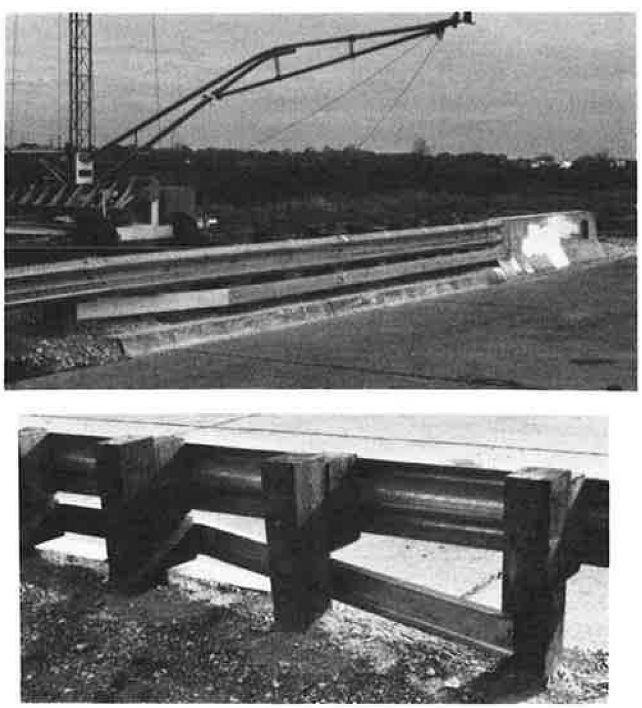

FIGURE 7 Photographs of improved separate end-post transition design test installation.

FIGURE 8 Improved separate end-post transition after improved design test.

The center of the rub rail was 11 in. (27.9 cm) below that of the W-beam. The rub rail was blocked out with 6- × 8- × 8-in. (15.2- × 20.3- × 20.3-cm) wooden blockouts so that the face of the rub rail aligned with that of the W-beam. The total length of the rub rail was 25 ft (7.62 m), spanning from the concrete end post to Post 9, after which the rub rail was bent slightly backward for termination at the back of Post 11. At its connection with the concrete end post, the lower flange of the channel rub rail was cut to accommodate the lower sloped surface of the concrete safety shape so that the face of the rub rail would remain vertical. A special end shoe was fabricated to cover the exposed end of the rub rail. Photographs of the completed installation are shown in Figure 7.

A 1980 Cadillac Coupe de Ville hit the transition midspan of Posts 7 and 8, 14 ft 8½ in. (4.5 m) from the end of the concrete end post at a speed of 62.2 mi/hr (100.1 km/hr) and an angle of 26.2 degrees. The test weight of the vehicle was 4,500 lb (2,041 kg). The vehicle was successfully redirected and did not penetrate or go over the transition system. The vehicle remained upright and stable during the impact with the transition and after exiting the test installation.

The transition system received moderate damage, as shown in Figure 8. There were tire marks all along the rub rail, and some of the bolts were damaged from contact with the vehicle wheel rims. The maximum permanent deformation of the W-beam rail element was 1.3 ft (0.4 m) between Posts 5 and 6. Maximum permanent deformation of the rub rail was 1.25 ft (0.38 m), also between Posts 5 and 6. There were no detached elements or debris.

The vehicle sustained extensive damage to the left side. There was damage to the front and rear bumpers, hood, grill, right and left front quarter panels, left front and rear doors, and left rear quarter panel. The tie-rods, left upper and lower control arms, and left front and rear rims and tires were damaged. A small strip of sheet metal was torn from the left side of the vehicle, evidently by the exposed end of the terminal connector (end shoe) lapped in the direction of impact (the end shoe had to be lapped in this manner in order for the bolt holes to fit). There was no deformation or intrusion into the occupant compartment.

The velocity change of 18.2 mi/hr (29.3 km/hr) was slightly higher than the recommended limit of 15 mi/hr (24.1 km/hr) according to NCHRP Report 230 guidelines, but the vehicle was judged to not be a hazard to adjacent traffic lanes. This higher-than-recommended velocity change could partially be attributed to the interaction between the blocked-out rub rail and the tires of the vehicle.

FINDINGS

Two Minnesota W-beam guardrail-to-concrete safety-shaped bridge-rail transition designs were crash tested and evaluated. The integral end-post design was evaluated by means of three crash tests. Results of the crash tests indicated that the integral end-post design met all impact performance evaluation criteria according to NCHRP Report 230 guidelines.

Two versions of the separate end-post transition design were evaluated, each with one crash test. Results of the crash tests indicated that the initial separate end-post design did not meet the impact performance evaluation criteria outlined in NCHRP Report 230. The vehicle pocketed and impacted the end of the concrete bridge end post, resulting in substantial deformation and intrusion into the passenger compartment and an unacceptable level of longitudinal occupant ride-down acceleration. The vehicle was practically stopped by the impact with the concrete bridge end post and was not significantly redirected. The design was then modified by MnDOT, and the improved separate end-post transition design was crash tested. The improved design successfully met the impact performance evaluation criteria outlined in NCHRP Report 230.

These two transition designs have since been approved by FHWA and adopted as standard designs by MnDOT for field implementation. As mentioned previously, the integral end-post transition design is used with new construction and reconstruction in which existing bridge railings are to be replaced. The separate end-post transition design is used for retrofit of existing bridge railings in 3R and 4R projects where speed limits are greater than 40 mph and the traffic volume is greater than 1,500 ADT.

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