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DEVELOPMENT OF A STRONG BEAM GUARDRAIL TO BRIDGE RAIL TRANSITION

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Guardrail to Bridge Rail Transition

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Abstract

The development and testing of a strong beam guardrail to bridge rail transition is described. Barrier VII was validated and used to simulate impacts with flexible barriers attached to a rigid barrier. Design curves for selecting transition design parameters of beam strength, post size, and post spacing are presented. The selected design incorporated a tubular W-beam rail element mounted on 7 in. diameter round posts spaced on 3 ft.- 1.5 in. centers. The transition was designed to simplify retrofit operations and can be used on bridges which require bridge end drains. Three full scale crash tests were conducted to verify the acceptable performance of the transition when attached to either a vertical concrete parapet or a concrete safety shaped barrier.

Introduction

A bridge rail is a longitudinal barrier whose primary function is to prevent errant vehicles from going over the side of the bridge. Because of its critical nature, most bridge rails are either rigid or semi-rigid in order to limit dynamic deflections and safely contain the vehicle without allowing it to extend beyond the edge of the bridge deck. Two common types of bridge rails are reinforced concrete safety shaped barriers and vertical concrete parapets. The exposed ends of these rigid concrete barriers can pose a serious safety hazard. Approach roadside barriers are warranted, not only to shield the exposed bridgerail end, but also to prevent errant vehicles from getting behind the railing and falling off the bridge. These approach barriers are typically much more flexible than the bridge rails or wingwalls to which they are attached. Flexible barriers can deflect sufficiently to allow an errant vehicle to impact or "snag" on the end of the rigid barrier, even when the two barriers are securely attached. Therefore a transition section is required whenever there is a significant change in lateral strength from the approach barrier to the bridge rail. The transition section should provide a smooth change in lateral barrier stiffness in order to prevent impacting vehicles from snagging on the end of the rigid barrier.

Strong post W-beam guardrail is the most common bridge approach railing in use today. Most existing transitions involve reducing guardrail post spacing to 3 ft.- 1.5 in. near the end of the bridge rail. This transition design has been shown to be unable to prevent severe snagging on the end of rigid concrete barriers (1). Several acceptable guardrail-to-bridge rail transition designs utilizing 1 ft.- 6.75 in. post spacings and rub rails near the bridge end were recently developed by Bronstad (1). Although these designs have exhibited good impact performance, the tight post spacing does present a problem when used on bridges designed to drain water around the end of the railing. The maximum clear distance between posts in these designs is only 12 in. and is inadequate for most bridge end drain designs. These problems are especially acute when the new transitions are used to retrofit existing bridge sites. Other acceptable transition designs were recently developed by Post (2). These systems are characterized by oversized posts, reduced post spacing near the bridge end, nested W-beam or Thrie-beam rails, and flared bridge rail ends. Problems associated with the implementation of these designs include inventory and repair problems arising from the use of a non-standard guardrail post and high costs of flaring bridge rail ends during retrofit operations.

In view of the general lack of acceptable guardrail-to-bridge rail transitions that can be economically implemented in retrofit situations the study described herein was undertaken to develop a new transition design with the following characteristics:

(1) Provide for easy retrofit of existing installations

(2) Provide sufficient post spacing to allow implementation where bridge end drains are required

(3) Designed for use with either vertical concrete parapets or concrete safety shaped barriers

(4) Meet nationally recognized safety standards.

Research Approach

As mentioned previously, a guardrail-to-bridge rail transition must be designed to prevent impacting vehicles from deflecting the guardrail sufficiently to allow vehicle snagging on the end of the rigid barrier. Standards for testing barrier transitions are presented in NCHRP Report 230 (3). This report requires that transitions be evaluated with a single test that invloves a vehicle impacting the more flexible barrier upstream from its transition to the stiffer barrier. This test condition examines the propensity for the flexible barrier to deflect and allow the test vehicle to snag on the end of the stiffer barrier. The size of the test vehicle and impact speed and angle vary with the level of service of the barrier system (3). Most concrete bridge rails and strong post guardrail systems have been tested to service level 2 as described in NCHRP Report 230. For service level 2, NCHRP Report 230 requires that transitions be tested with a 4500 lb. automobile, impacting at 60 mph and 25 deg. Note that in most practical guardrail/bridge rail transition designs the guardrail is first transitioned into an intermediate strength barrier which is then transitioned into the rigid bridgerail. Therefore safety performance of the design must be evaluated at both transition points.

The Barrier VII simulation model (4) has been shown to be capable of accurately predicting barrier deflections for impacts involving full size vehicles impacting at speeds up to 60 mph and angle up to 25 degrees (5,6). Further, for impacts into barriers placed on flat terrain, such as that found on the approach to a bridge, vehicle vaulting, override, and underide is of little concern. Thus the 2-D nature of the Barrier VII program was not considered to be a severe limitation and this model was chosen for use in developing the new transition design.

Although Barrier VII has been successfully used to simulate impacts with a variety of flexible barriers, its use in studying impacts near the transition from a flexible to a rigid barrier has been somewhat limited. Therefore the first step in transiton development was to conduct a limited validation of Barrier VII for analysis of impacts in the region of a transition. Two full scale crash tests of guardrail-to-bridge rail transitions from reference 1 were selected for the validation effort. Simulated guardrail beam elements were assumed to be of uniform cross section and to have bilinear elastic/perfectly plastic properties both flexurally and extensionally. Simulated beam stiffness characteristics were estimated to be approximately 1.5 times calculated static values. Table 1 shows simulated post properties collected from references 1, 7, and 8.

Since barrier deflection is the primary indicator of the propensity for a vehicle to snag on the concrete barrier, this parameter was selected as the primary measure of correlation between simulation and crash testing. As shown in Table 2, Barrier VII was found to give very good predicitons of maximum barrier deflections for the two tests simulated. Other measures of simulation validity, including vehicle trajectory and crush, also showed excellent correlation between Barrier VII and the two crash tests.

The critical impact point for testing guardrail/bridge rail transitions is the point at which the potential for snagging on the end of the rigid barrier is maximized. Note that this critical impact point changes with the stiffness of the approach barrier. Stiff approach barriers redirect impacting vehicles more quickly and therefore have a critical impact point nearer to the rigid barrier than more flexible approach rails. Bronstad (1) detemined that for double W-beam rails mounted on posts spaced 1 ft.- 6.75 in. the critical impact point is approximately 112 in. upstream of the rigid barrier. Barrier VII simulations indicated that the critical impact location is the same for approach barriers that deflect approximately the same as those used in the study by Bronstad (1). Therefore this impact location was used for all simulation and testing of transitions to rigid barriers. Further, Barrier VII analysis indicated that the critical impact location on standard strong post guardrails is approximately 125 in. from the end of the intermediate barrier. Therefore analysis and testing of impacts on standard guardrails was conducted using an impact point 125 in. upstream from the start of the transition.

Barrier VII was used to conduct a parameter study of designs for

TABLE 1. POST PARAMETERS FOR BARRIER VII INPUT

(EFFECTIVE RAIL HEIGHT = 21")

MATERIAL	WOOD	WOOD	STEEL
SIZE	6" X 8" (1)	7" DIAM. (7)	W6 X 8.5 (1)
k_A (k/in.)	1.95	2.9	1.15
k_B (k/in.)	1.56	2.9	2.46
M_A (in–k)	191.1	256.	256.2
M_B (in–k)	214.2	256.	107.1
F_A (k)	10.2	12.2	5.1
F_B (k)	9.1	12.2	12.2
Δ_A (in.)	4.7	20.	13.6
Δ_B (in.)	15.5	20.	13.2

A – Denotes Longitudinal or Major Axis

B – Denotes Transverse or Minor Axis

k – Stiffness of Post For Elastic Horizontal Deflections

M – Base Moment At Which Post Yields

F – Shear Force Causing Failure of Post

Δ – Deflection Causing Failure of Post

COMPARISON OF MAXIMUM BARRIER DEFLECTIONS

CRASH TESTS (1) VS. BARRIER VII SIMULATIONS

TEST (NO.)	DESCRIPTION	CONCRETE WINGWALL	RAILTYPE	POST DATA		VEHICLE DATA	IMPACT POINT FROM WINGWALL	MAXIMUM LATERAL DEFLECTION		
				TYPE	SPACING	LB/MPH /DEG		ACTUAL	SIMULATED	% DIFF
T-2 (1)	THRIE BEAM BRIDGE TRANSITION	STRAIGHT	THRIE BEAM	WOOD (6"X8")	4@1'6-3/4" 4@3'1-1/2"	4658/61.5 /25.2	96.5"	9.4"	9.92"	5.5
T-2 (1)	THRIE BEAM BRIDGE TRANSITION	TAPERED WOOD BLOCK OUT	THRIE BEAM	WOOD (6"X8")	4@1'6-3/4" 4@3'1-1/2"	4650/64.0 /25.6	112.5"	14.4"	14.74"	2.4

TABLE 2. BARRIER VII CRASH TEST SIMULATIONS

transtions to rigid barriers. All simulations involved impacts with a 4500 lb vehicle traveling 60 mph and contacting the rail 112 in. upstream of the rigid barrier end at an angle of 25 deg. The basic transition design consisted of a standard strong post W-beam approach rail with modified post spacing and beam strength over the last 25 ft. before the bridge rail. The bridge rail was modeled as a straight vertical concrete parapet. Design parameters investigated include beam strength, post spacing, and post size. The two post sizes investigated were a standard 7 in. diameter wood post and a "double strength" post. A double strength post was defined as a post that would develop twice the dynamic lateral resistance of the standard post. This can be achieved by increasing post section modulus and either embedment depth or post width. Examples of double strength posts are an 8 in. X 8 in. wood post embedded approximately 48 in. and a 10 in. X 10 in. wood post with an embedment of 40 in. Figures 1 and 2 show predicted deflections for the two different post sizes studied. These figures were used to determine the barrier deflection that could be expected for a wide range of beam strengths and post spacings. Note that 6 in. X 8 in. wood posts and W 6X9 steel posts have been shown to have dynamic lateral capacity approximately the same as a 7 in. diameter round wood post. Thus, although Figure 1 was developed for a 7 in. round post, either of these other posts could be substituted as the "standard post" for transition design.

Deflection Limit Design Criteria

As discussed above, barrier deflection is believed to be a good indicator of the probability of a vehicle snagging on the end of a rigid barrier. Twelve full scale crash tests from reference 1 were reviewed in an effort to determine the maximum allowable barrier deflection. Figure 3 shows a plot of barrier deflection for each of the tests conducted in the referenced study.

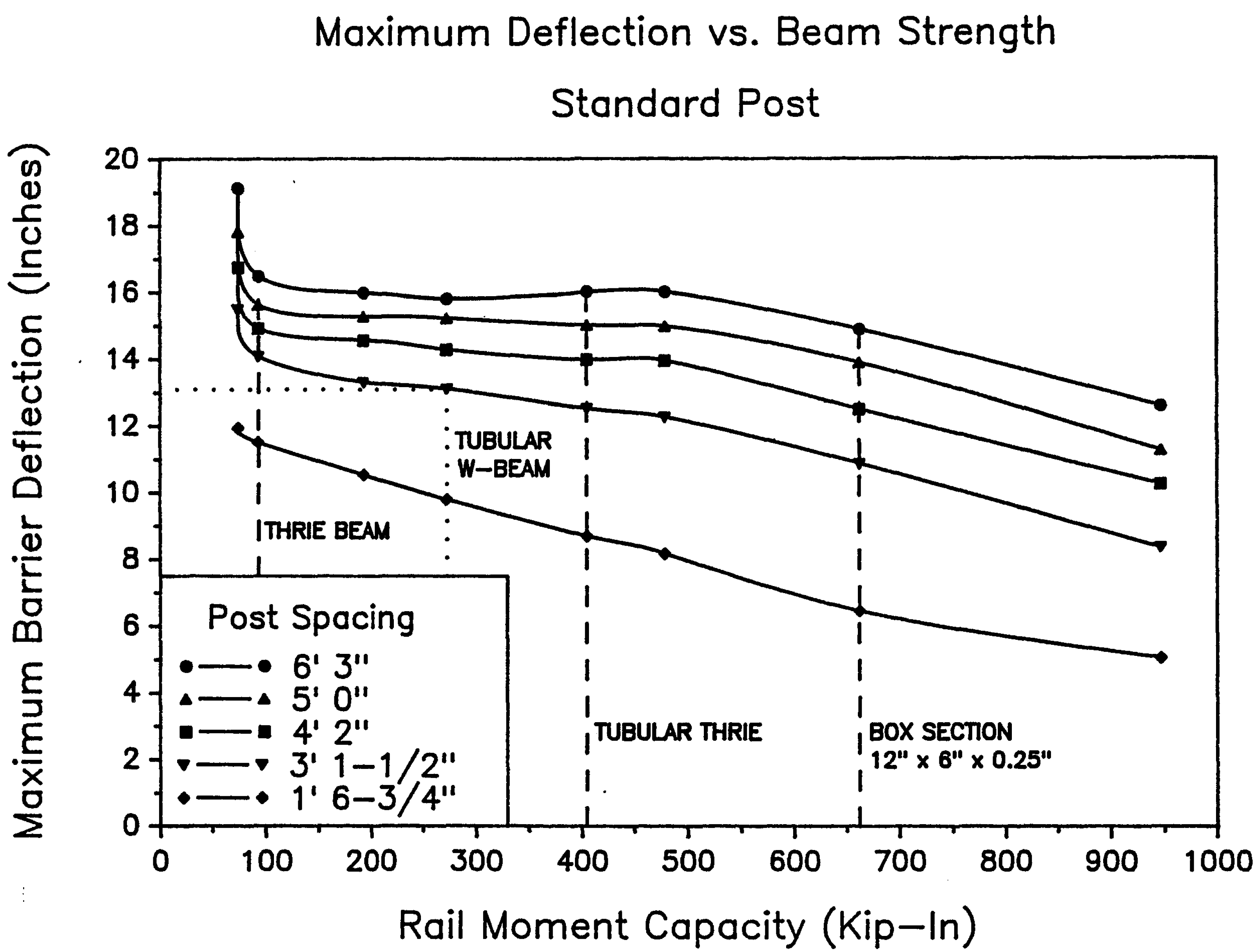


FIGURE 1. DESIGN CURVES FOR STANDARD POST TRANSITIONS

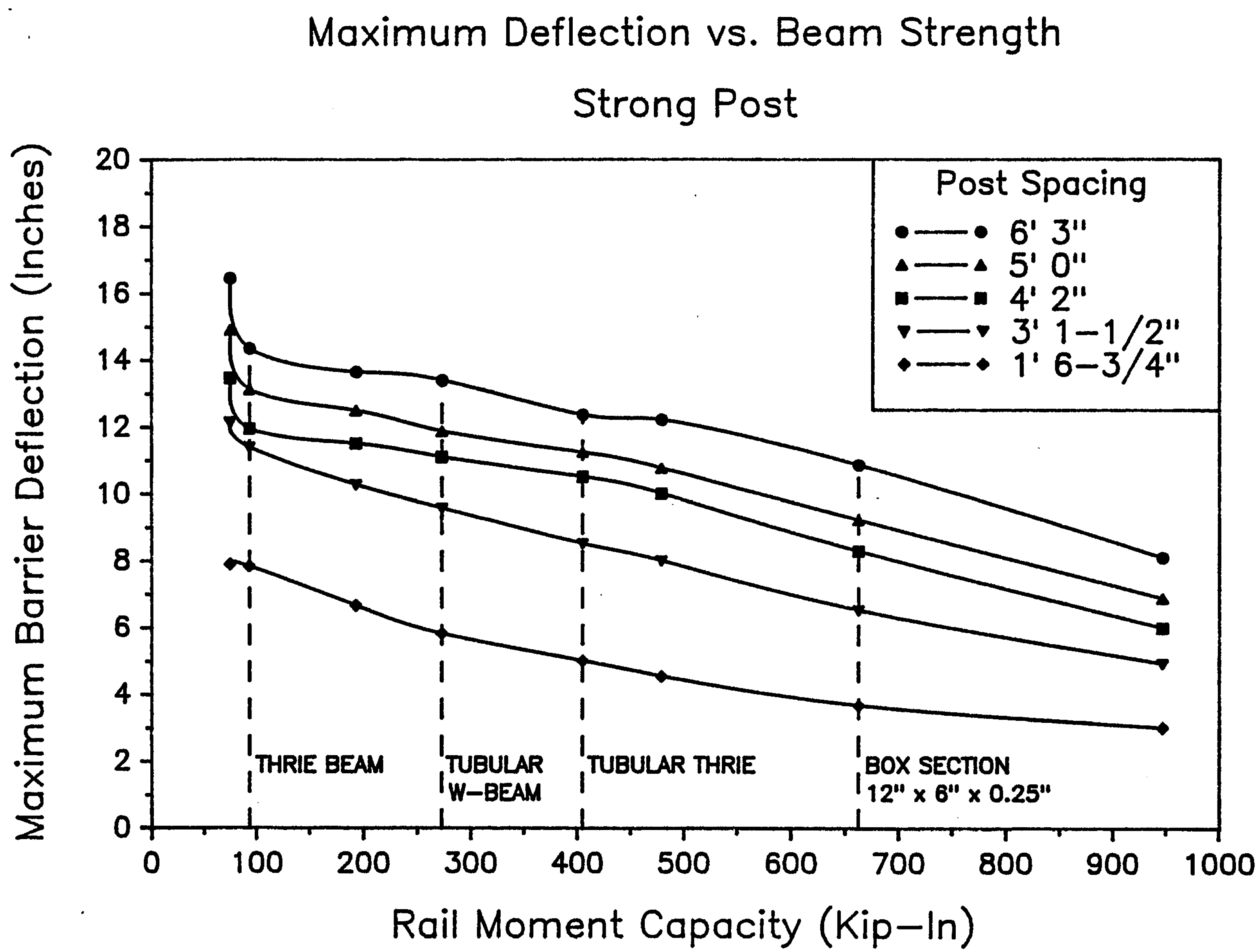


FIGURE 2. DESIGN CURVES FOR STRONG POST TRANSITIONS

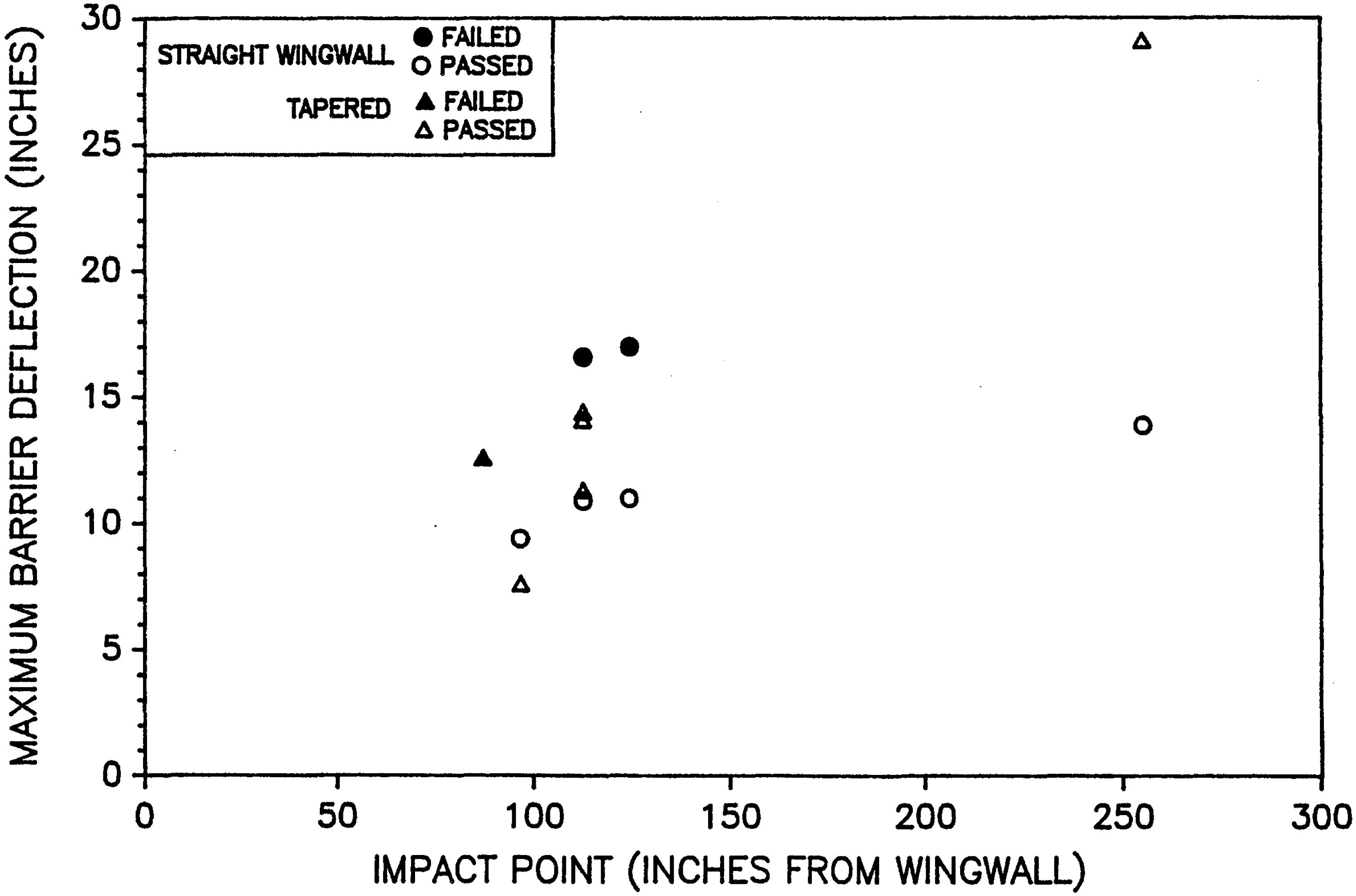


FIGURE 3. MAXIMUM DEFLECTION FROM TRANSITION CRASH TESTS (1)

As shown in Figure 3, for unflared bridge rail ends, the approach guardrail can be allowed to deflect no more than 12 in. before significant vehicle snagging becomes a potential problem. In support of the crash test data, a series of simulation runs were made for the purpose of tracking wheel position past the end of the rigid barrier end. It was observed that for deflections in excess of 12 in., the wheel followed a trajectory through the end of the concrete barrier, indicative of severe vehicle snagging and poor safety performance for the transition. However, for barrier deflections less than 12 in. the wheel followed a path safely outside of the bridge rail end. These results supported a deflection limit of 12 in. as the initial evaluation criteria in the transition design. Therefore, it was concluded that all transition designs limiting maximum lateral deflections to less than 12 in. should provide acceptable performance.

Selection of Transition System

Using Figures 1 and 2, a basic design is selected by choosing the type of post to be used (i.e. standard or strong) and either the post spacing or beam type desired. The remaining parameter is then found using the 12 in. deflection limit discussed above. For example, if it is desirable to maintain a 6 ft.- 3 in. post spacing, a transition design would involve a beam with a yeild moment of 660 kip-in (such as a 12 in. X 6 in. X 0.25 in. stuctural steel tube) mounted on strong posts. This system has a predicted maximum barrier deflection of approximately 11 in. (see Figure 2). Similarly, if it is desirable to use a nested thrie beam (My = 190 kip-in) in the transition zone, one alternative would be to mount it on "strong" posts spaced at 3 ft.- 1.5 in. This transition configuration has a predicted dynamic deflection of approximately 10.5 in. (see Figure 2).

As can be seen from Figures 1 and 2, numerous transition configurations were acceptable based on the 12 in. deflection limit criteria. Additional selection guidelines were therefore established to aid in the determination of a final design. It was desirable that the transition: (1) be able to retrofit existing bridge rails, (2) provide sufficient post spacing to allow for adequate bridge end drainage, (3) allow for ease of transition at both approach rail and bridge rail, and (4) use standard hardware items.

Consultations with officials from the Texas State Department of Highways and Public Transportation indicated that, due to inventory and maintenance problems associated with non-standard guardrail posts, the new transition should be constructed with standard guardrail posts. Further, SDHPT engineers expressed an interest in developing a transition that utilized a 12 ga. tubular W-beam rail. This beam has an approximate moment capacity of 280 kip-in. As shown in Figure 1, Barrier VII predicts a maximum deflection of 13 in. for the tubular W-beam mounted on standard posts spaced 3 ft.- 1.5 in. Although the predicted deflection for this design is slightly above the deflection limit criteria, it was believed that the added depth of tubular W-beam would act as an effective blockout. Thereby, effective deflection of the beam would be reduced to 10 inches, which is well below the deflection limit of 12 in.

Transition Design

The final transition design consisted of a 25 ft. segment of 12 ga. tubular W-beam mounted on 7 in. diameter round wood posts spaced 3 ft.- 1.5 in. with a 38 in. embedment as shown in Figure 4. Barrier VII was then used to simulate impacts with the selected design at a number of locations in an effort to identify any other potential snagging problems and to determine the necessary connection design loadings. Barrier VII predicted that for impacts on the upstream transition from the single W-beam to the tubular W-beam, the

GUARDRAIL / BRIDGE RAIL TRANSITION

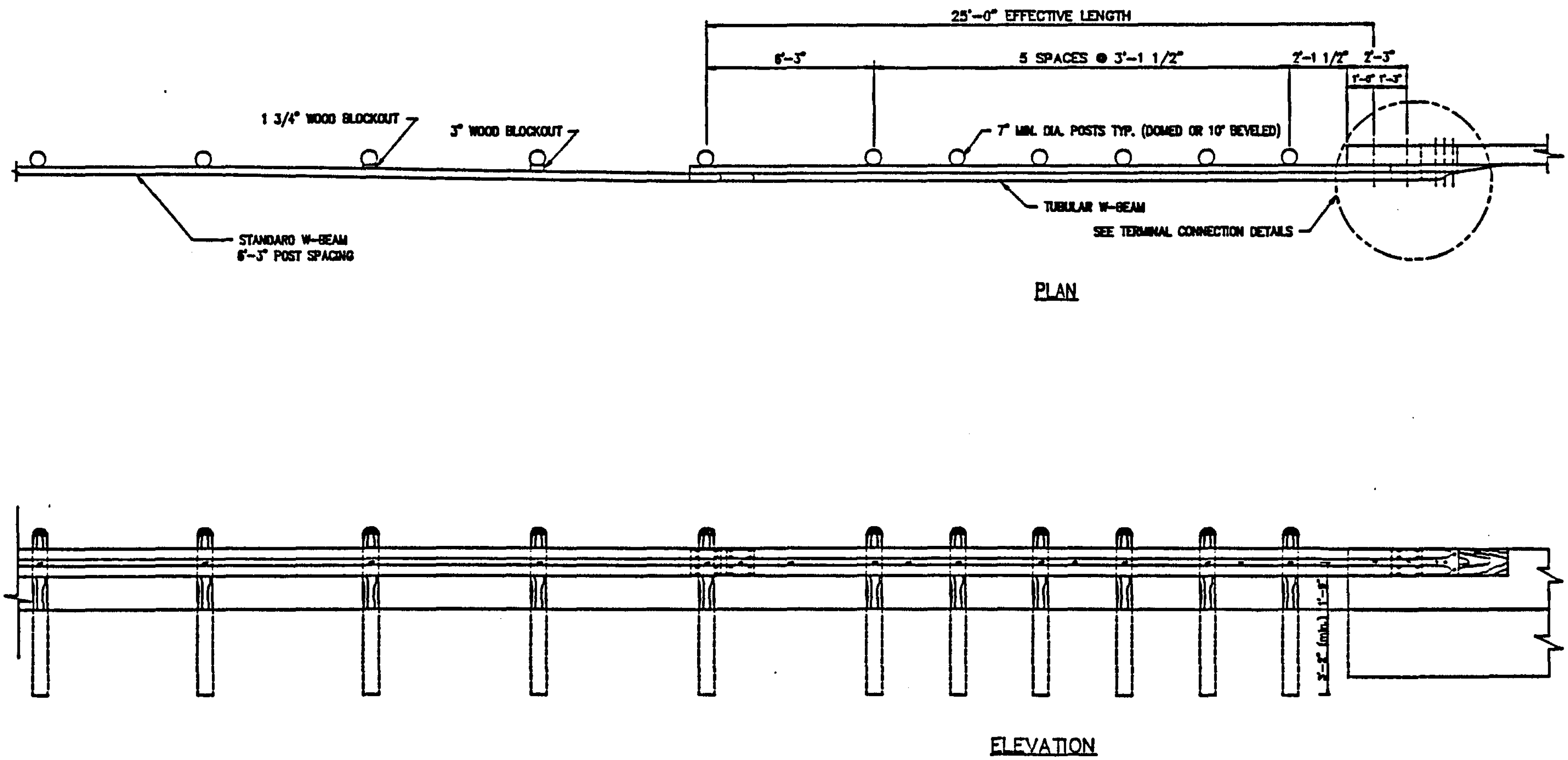


FIGURE 4. GUARDRAIL TO BRIDGE RAIL TRANSITION, RETROFIT DESIGN

possibility of wheel snagging would be reduced if the first post spacing on the tubular segment was maintained at 6 ft.- 3 in. Design loading conditions from Barrier VII for the connection between the tubular W-beam and the concrete barrier end included a 140 kip tensile force, a 60 kip shear force, and a 280 kip-in bending moment. This connection was accomplished with six 7/8 in. diameter high strength bolts (A325 or equivalent grade threaded rod), a steel end shoe, and a tapered wood blockout as shown in Figure 5. The connection was designed to be used with either vertical parapets or concrete safety shaped barriers.

Note that the design shown in Figure 4 is a retrofit of the existing Texas standard transition and uses two small wood blockouts on the standard W-beam approach in order to move the rail to the outside of the tubular beam. No blocks were used in the rest of the transition to maintain compatibility with the Texas standard guardrail. Further, due to retrofit considerations, the attachment between the single W-beam barrier and the tubular W-beam rail required a small splice plate. Retrofitting an existing installation thus involves replacing a 25 ft. length of W-beam railing, drilling six holes in the concrete barrier, and placing two small blockouts in the approach rail.

Full-Scale Crash Tests

The tubular W-beam transition was evaluated for impact performance in accordance with Test Number 30 of NCHRP Report 230 (3). Test 30 involves a 4500 lb vehicle impacting the transition section at 60 mph at an angle of 25 deg. The testing program consisted of three full scale crash tests, each of which evaluated a different aspect of the transition design. The tests conducted were as follows:

1. Evaluation of tubular W-beam transitioning into a vertical concrete parapet.

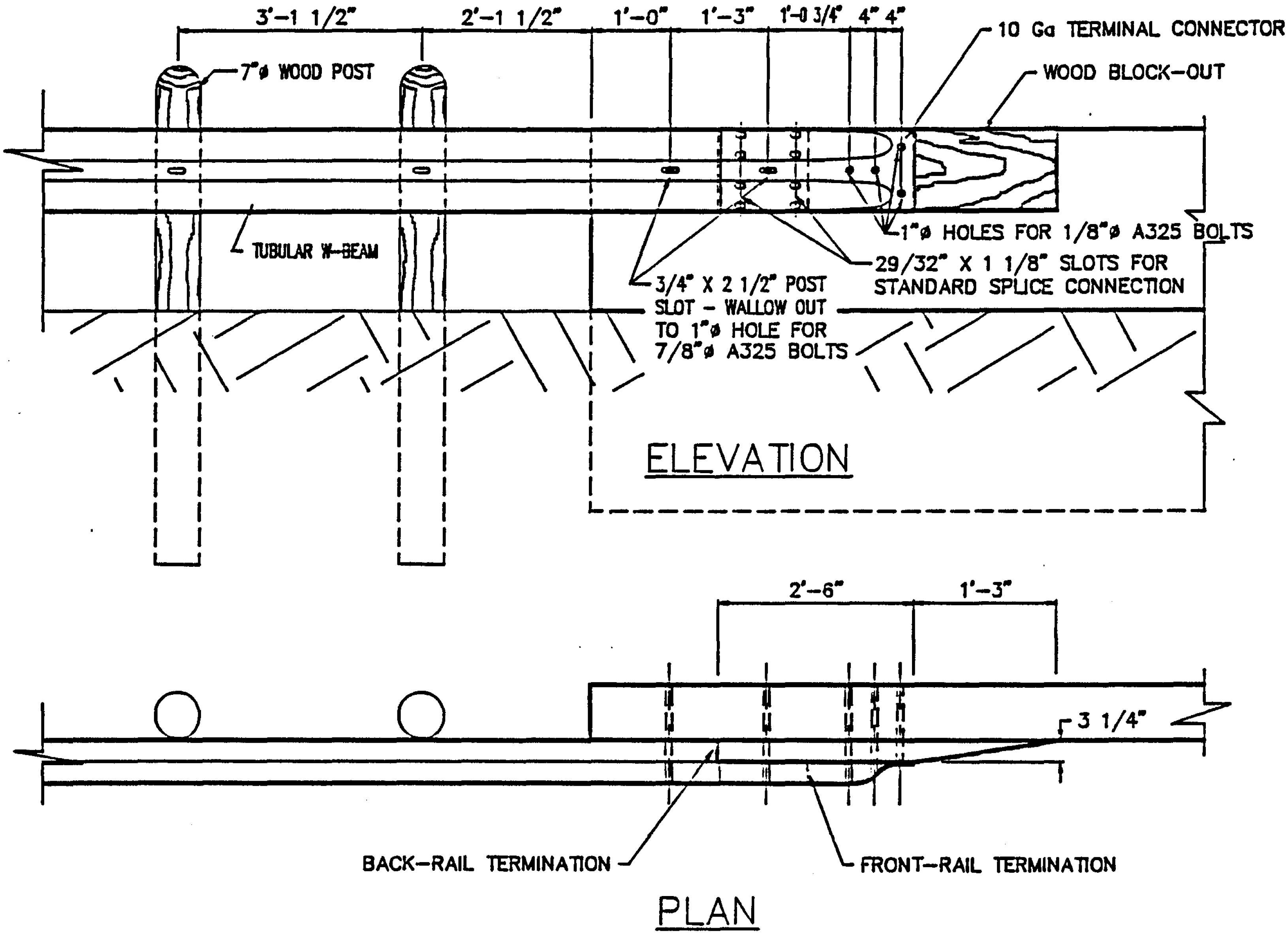


FIGURE 5. TRANSITION CONNECTION DETAILS

2. Evaluation of tubular W-beam transitioning into a concrete safety shaped barrier.

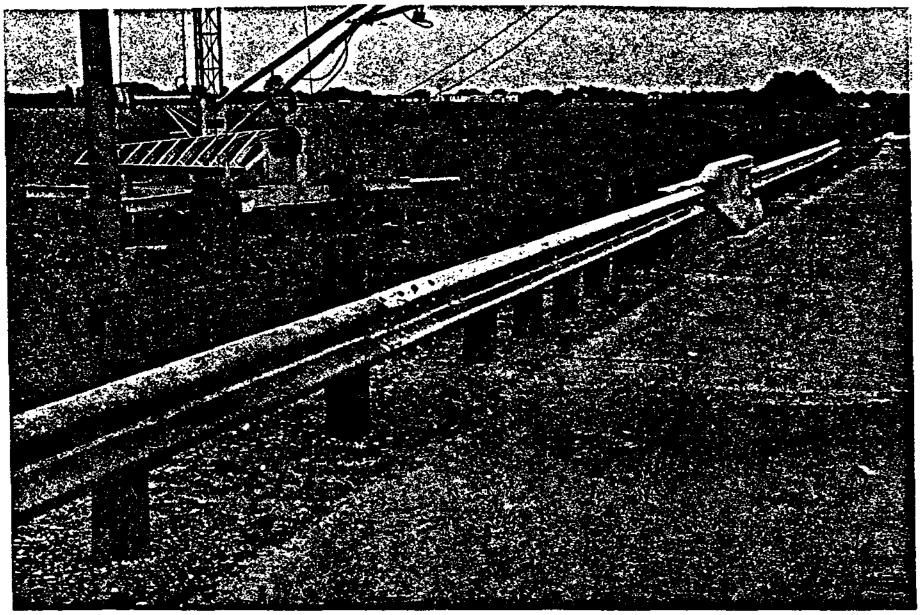
3. Evaluation of the standard w-beam guardrail transitioning to the tubular W-beam.

Test 1

The purpose of this test was to evaluate the tubular W-beam transition to a vertical concrete wall. The barrier transition was constructed as shown in Figure 4 above. Figure 6 shows the completed installation before Test 1.

A 4570 lb Cadillac impacted the transition at 55.0 mph and 26.4 deg. at a point 112 in. upstream from the bridge rail end. The vehicle was successfully redirected although significant wheel snagging on the bridge rail end was observed. Some sheet metal snagging occurred at the tops of the posts and minor wheel snagging at the base of the posts was also evident. While the top of the tubular rail was only partially flattened, the bottom half of the rail was completely collapsed. This collapse effectively increased the maximum deflection of the rail and thus the degree of snagging. The test vehicle was only moderately damaged for a test of this severity. Damage to both the vehicle and barrier after test 1 are shown in Figure 7. Note that hood snagging on the top of the wood posts and the concrete barrier was not considered to be a significant hazard since the hood rides up the post or barrier until it slips off of the top. There was no tendency of the hood to become detached from its hinges and penetrate the occupant compartment. Note that this performance is similar to observations made during testing of luminaire supports mounted on concrete safety shaped barriers (9).

NCHRP report 230 (3) does not require that a strength test, such as that used for evaluation of transition designs, meet occupant severity limits. However, the occupant severity measures from Test 1 were all within maximum acceptable limits. A summary of the test results is given in Figure 8.



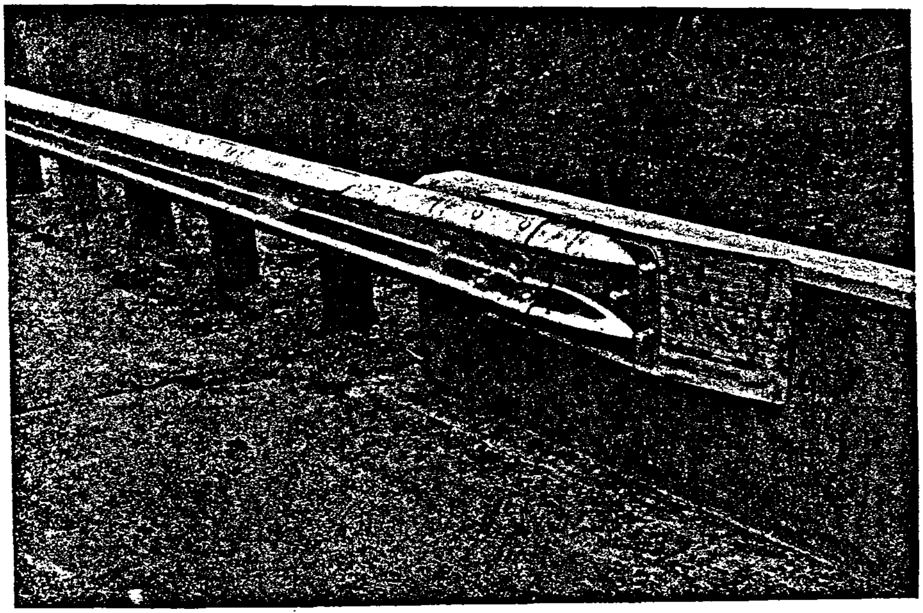


FIGURE 6. TUBULAR W-BEAM TRANSITION TO VERTICAL WALL,
TEST 1 INSTALLATION.

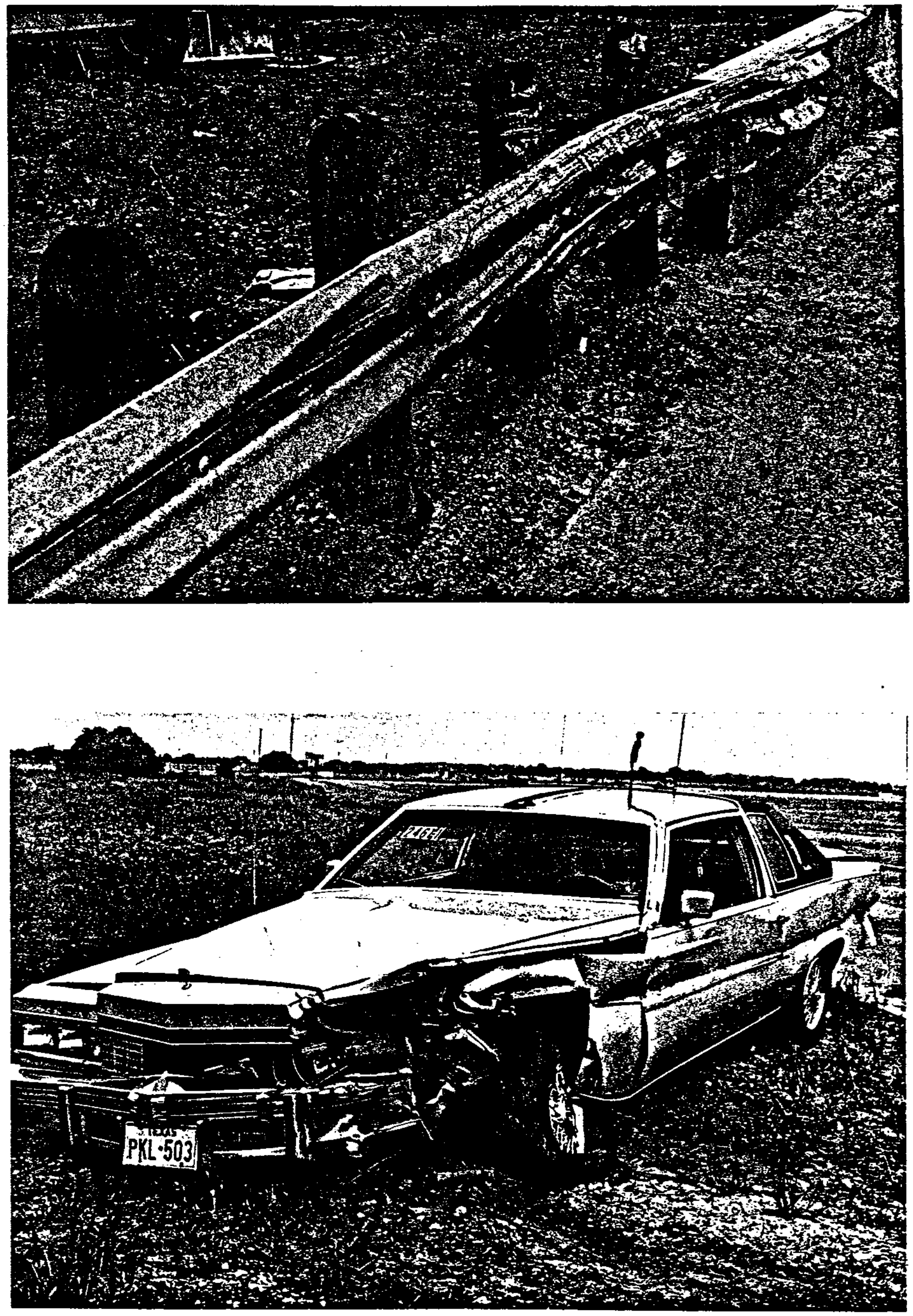


FIGURE 7. VEHICLE AND BARRIER DAMAGE AFTER TEST 1

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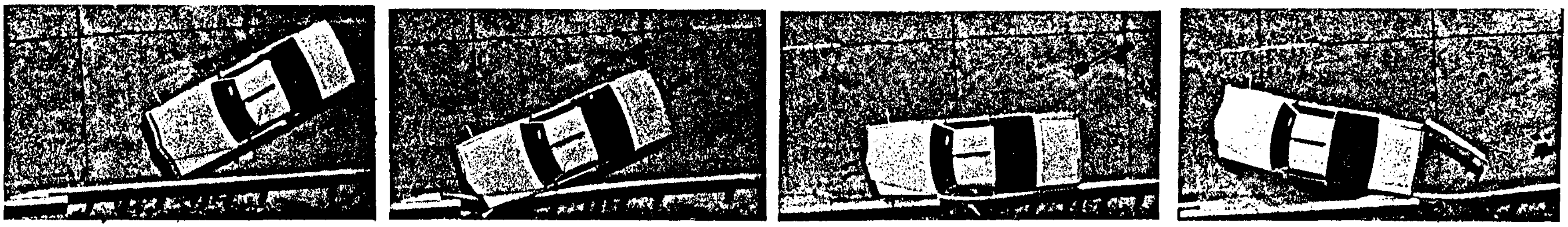


Test No	2461-1
Date.	5/14/87
Test Installation	Tubular W-Beam Transition to T201
Length of Transition.	25 ft (7.6 m)
Vehicle	1977 Cadillac
Vehicle Weight	
Test Inertia.	4400 lb (1998 kg)
Gross Static.	4570 lb (2075 kg)
Vehicle Damage Classification	
TAD	11LFQ6
CDC	11LFES4
Maximum Vehicle Crush	13.0 in (33.0 cm)
Max. Dyn. Rail Deflection . .	9.6 in (24.4 cm)
Max. Perm. Rail Deformation .	4.8 in (12.2 cm)

Impact Speed	55.0 mi/h (88.5 km/h)
Impact Angle	26.4 deg
Exit Speed	33.1 mi/h (53.3 km/h)
Exit Angle	13.4 deg
Vehicle Accelerations (Max. 0.050-sec Avg)	
Longitudinal	-8.0 g
Lateral.	-9.4 g
Occupant Impact Velocity	
Longitudinal	26.7 ft/s (8.1 m/s)
Lateral.	22.0 ft/s (10.0 m/s)
Occupant Ridedown Accelerations	
Longitudinal	-3.1 g
Lateral.	-11.5 g

FIGURE 8. SUMMARY OF RESULTS FOR TEST 1

Although the change in vehicle velocity was above the recommended value set forth in NCHRP 230 Evaluation Criteria I (3) this test was considered to be a success as presented in discussion of results.

Test 2

The purpose of this test was to evaluate the tubular W-beam transtion to the concrete safety shaped barrier. The geometry of the safety shaped rail increases the potential for vehicle snagging. The lower curb face of the barrier projects beyond the face of the tubular W-beam and the 32 in. wall height extends above the approaching guardrail. In order to reduce the severity of snagging observed in Test 1, some modifications were made to improve the impact performance of the transition. Wood inserts were added in both the top and bottom of the tubular W-beam to prevent the rail from collapsing (see Figure 9). Also, the tops of the posts were cut with a 10 deg. bevel at rail height in order to minimize sheet metal snagging. Figure 10 shows the modified transition before Test 2.

A 4637 lb Cadillac impacted the transtion at 60.8 mph and 25.8 deg. at a point 112 in. upstream from the bridge rail end. The vehicle was smoothly redirected with greatly improved performance over Test 1. The wood inserts prevented the tubular rail from collapsing and greatly reduced the degree of snagging. Minor wheel snagging was observed at the base of posts 1 and 2 and at the bridge rail end. Although some sheet metal snagging occurred on the top of the concrete rail, the forces involved appeared to be significantly lower than in the previous test. Evidence of the post and wingwall snagging is shown in Figure 11.

The vehicle damage sustained in Test 2 was moderate for the severity of the impact. Damage to the vehicle and barrier after Test 2 is shown in Figure 12. Although not a requirement for the transition test, the occupant impact

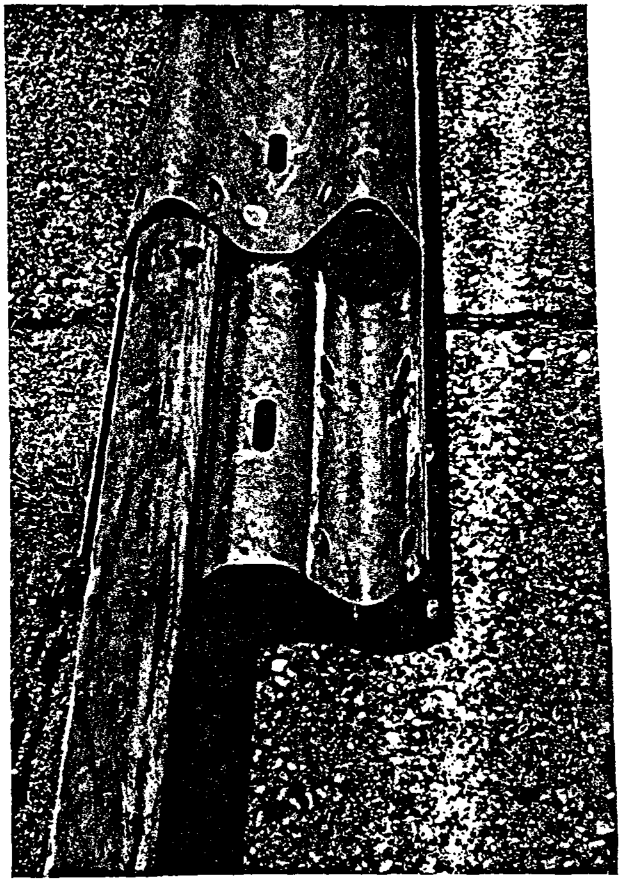


FIGURE 9. WOOD INSERTS FOR TUBULAR W-BEAM

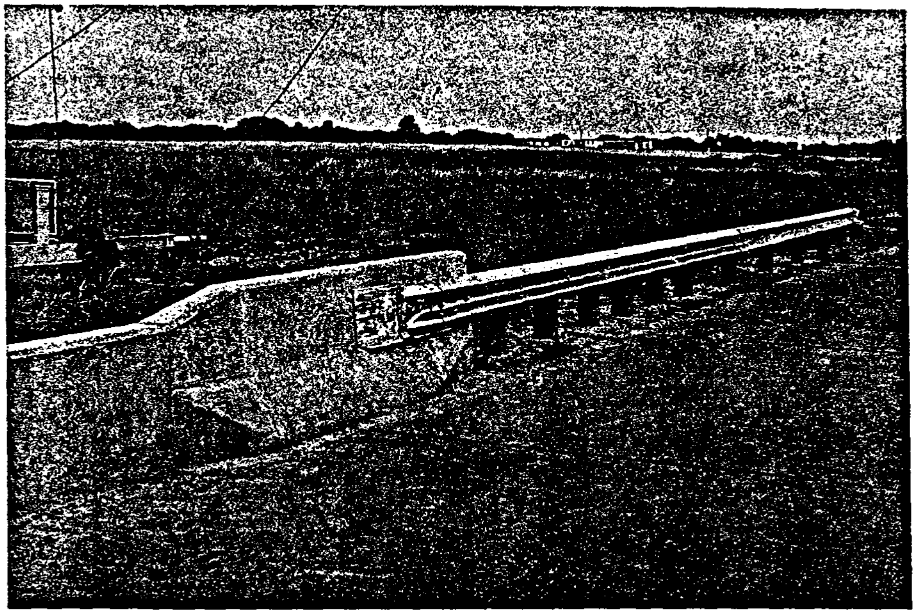
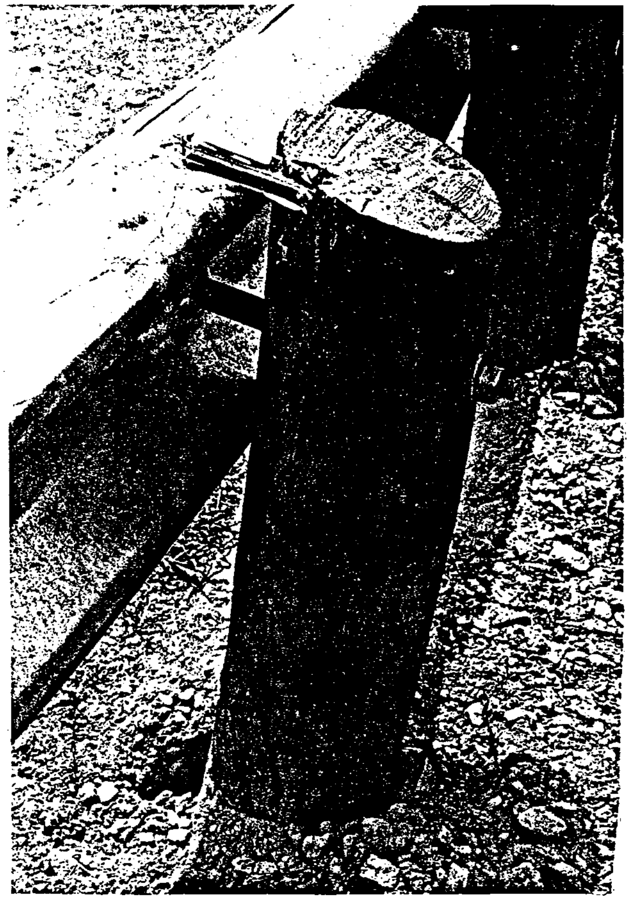


FIGURE 10. TUBULAR W-BEAM TRANSITION TO CSSB, TEST 2 INSTALLATION



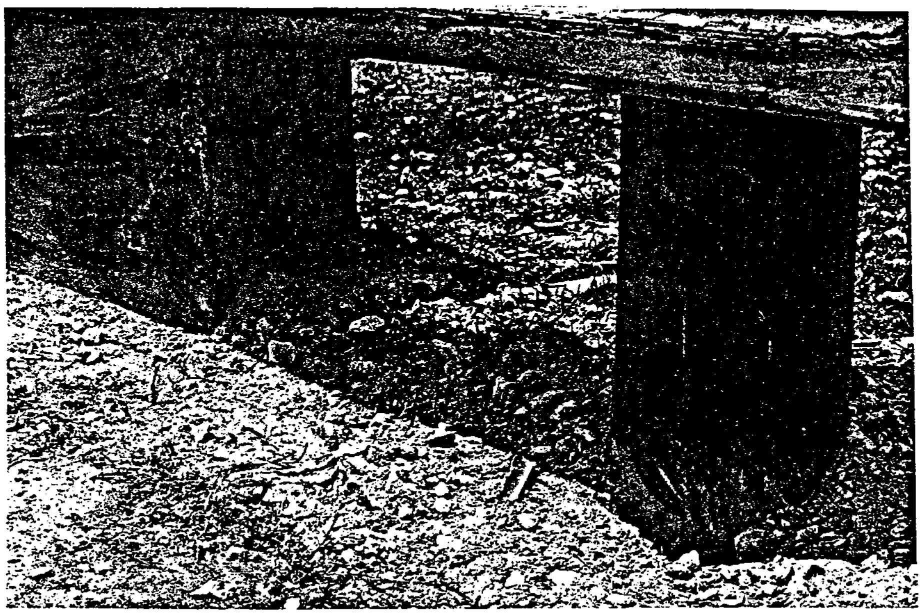
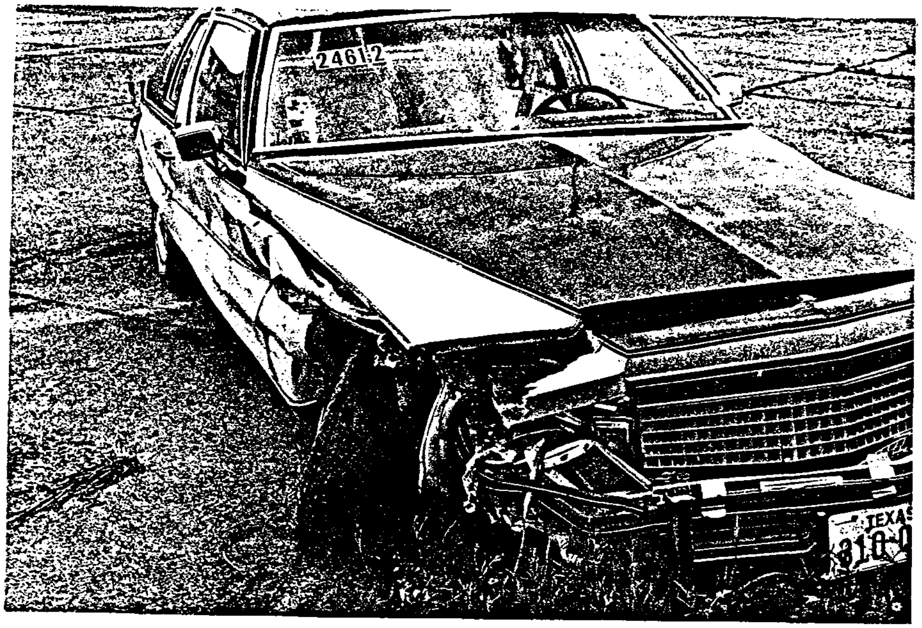


FIGURE 11. EVIDENCE OF SNAGGING ON POSTS AND CONCRETE WALL



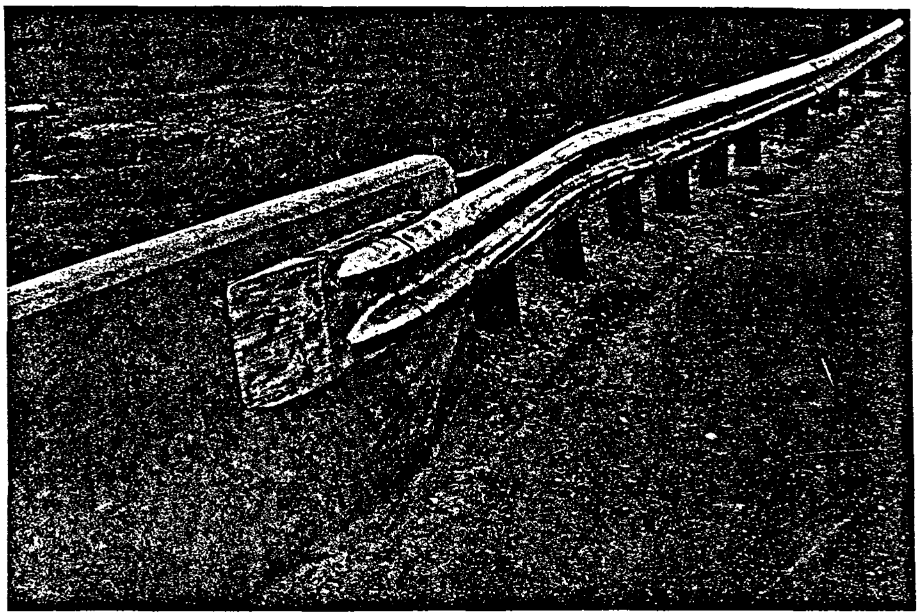


FIGURE 12. VEHICLE AND BARRIER DAMAGE AFTER TEST 2

indices of NCHRP report 230 (3) were all within maximum acceptable limits. A summary of Test 2 results is given in Figure 13.

Test 3

The purpose of this test was to evaluate the performance of the W-beam transition to the tubular W-beam. The guardrail was not blocked out for this test except for the use of two small blockouts as spacers to back up the W-beam after the tubular W-beam terminated. Figure 14 shows the installation before Test 3.

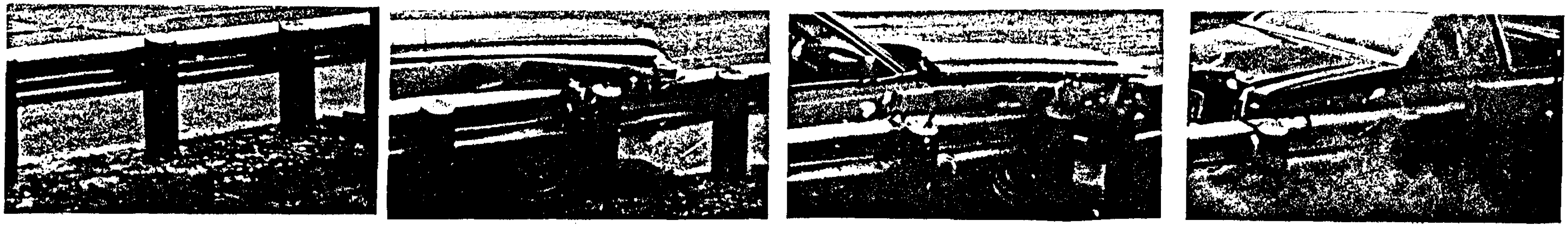
A 4595 lb Cadillac impacted the rail at 61.8 mph and 24.2 deg, 125 in. upstream from the end of the tubular W-beam. The vehicle was safely redirected although significant wheel snagging was observed at several posts. The wheel snagging caused the post at the splice connection to seperate from the rail and the next post downstream to splinter. This wheel snagging can be virtually eliminated through the use of rail-to-post blockouts in the transition region.

Vehicle damage was primarily concentrated in the area of the right front wheel which snagged on a number of posts. Figure 15 shows vehicle damage after Test 3. Barrier damage after Test 3 is shown in Figure 16.

The exit angle and change in velocity of the test vehicle were above the recommended values of NCHRP 230 Evaluation Criteria I (3). Blockouts throughout the length of the transition should greatly improve overall performance and correct the deficiencies mentioned above. Although not required for evaluation of a transition, all of the occupant severity measures from Test 3 were within recommended limits set forth in NCHRP report 230 (3). A summary of the test results is given in Figure 17.

Discussion of Results

The tubular W-beam transition was judged to have met the intent of the



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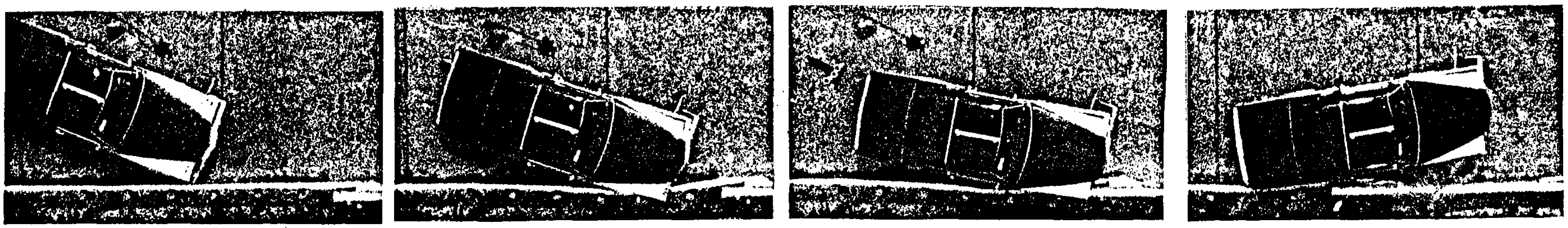


Test No	2461-2
Date	5/28/87
Test Installation	Tubular W-Beam Transition to T501
Length of Transition	25 ft (7.6 m)
Vehicle	1979 Cadillac
Vehicle Weight	
Test Inertia	4470 lb (2029 kg)
Gross Static	4637 lb (2105 kg)
Vehicle Damage Classification	
TAD	01RFQ5
CDC	01RYES3
Maximum Vehicle Crush	7.0 in (17.8 cm)
Max. Dyn. Rail Deflection	9.6 in (24.4 cm)
Max. Perm. Rail Deformation	6.0 in (15.2 cm)

Impact Speed	60.8 mi/h (97.8 km/h)
Impact Angle	25.8 deg
Exit Speed	41.4 mi/h (66.6 km/h)
Exit Angle	15.0 deg
Vehicle Accelerations (Max. 0.050-sec Avg)	
Longitudinal	-7.8 g
Lateral	10.6 g
Occupant Impact Velocity	
Longitudinal	24.6 ft/s (7.5 m/s)
Lateral	24.1 ft/s (7.3 m/s)
Occupant Ridedown Accelerations	
Longitudinal	-2.9 g
Lateral	13.8 g

FIGURE 13. SUMMARY OF RESULTS FOR TEST 2

FIGURE 14. W-BEAM TO TUBULAR W-BEAM TRANSITION, TEST 3 INSTALLATION

FIGURE 15. VEHICLE DAMAGE AFTER TEST 3

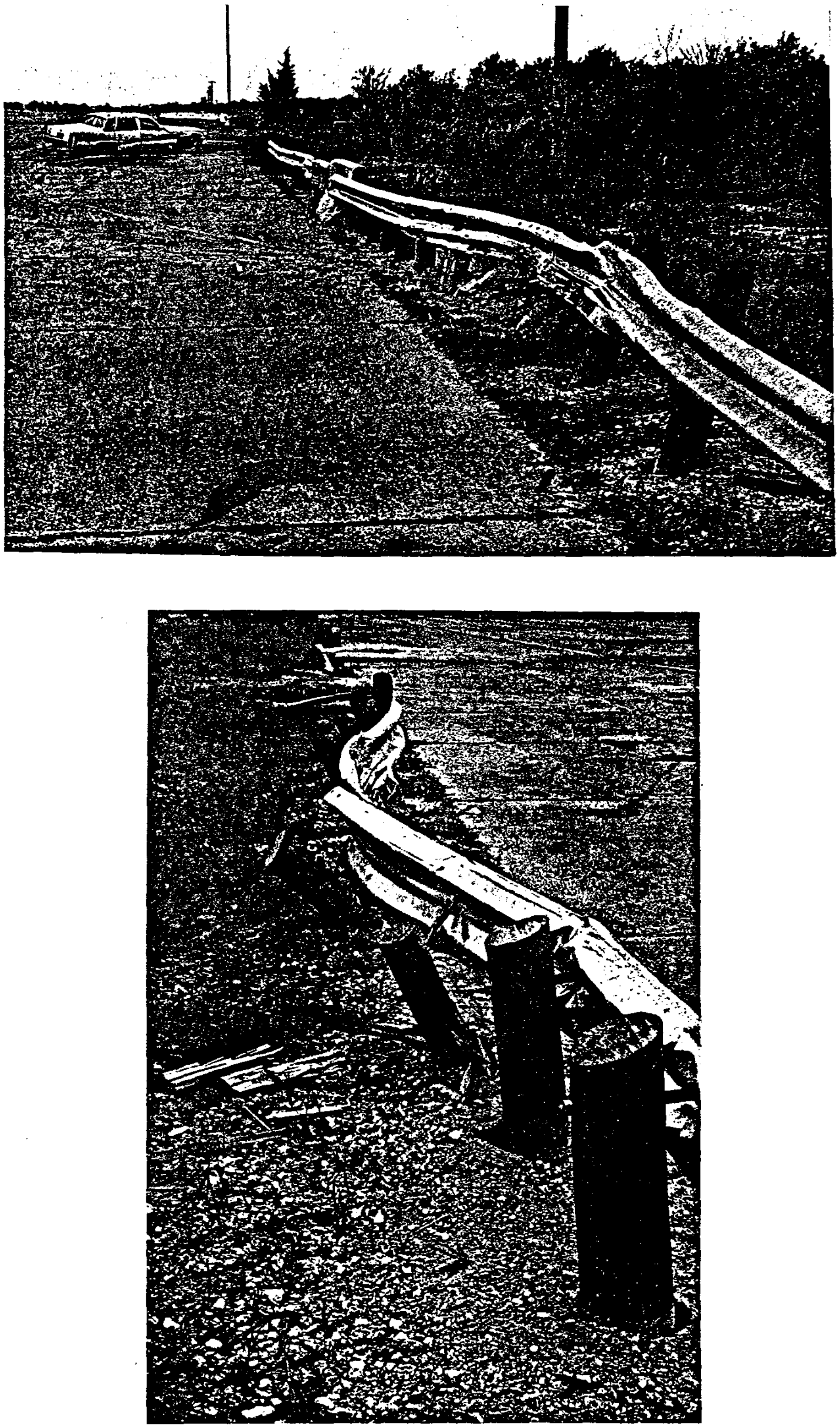
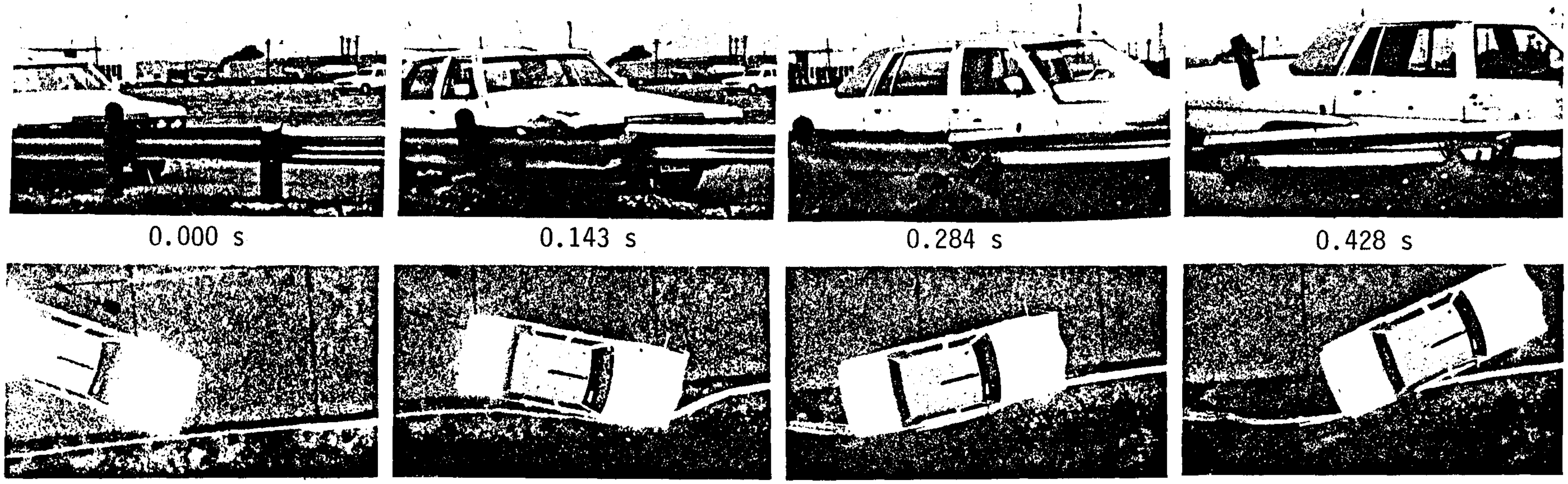


FIGURE 16. BARRIER DAMAGE AFTER TEST 3



Test No	2461-3
Date	6/08/87
Test Installation	W-Beam Transition to Tubular W-Beam
Length of Transition	25 ft (7.6 m)
Vehicle	1979 Cadillac
Vehicle Weight	
Test Inertia	4430 lb (2011 kg)
Gross Static	4595 lb (2086 kg)
Vehicle Damage Classification	
TAD	01RFQ5
CDC	01RYES3
Maximum Vehicle Crush	12.0 in (30.5 cm)
Max. Dyn. Rail Deflection	2.6 ft (0.8 m)
Max. Perm. Rail Deformation	2.0 ft (0.6 m)

Impact Speed	61.8 mi/h (99.4 km/h)
Impact Angle	24.2 deg
Exit Speed	33.6 mi/h (54.1 km/h)
Exit Angle	18.1 deg
Vehicle Accelerations (Max. 0.050-sec Avg)	
Longitudinal	-6.2 g
Lateral	7.9 g
Occupant Impact Velocity	
Longitudinal	25.7 ft/s (7.8 m/s)
Lateral	17.5 ft/s (5.3 m/s)
Occupant Ridedown Accelerations	
Longitudinal	-10.1 g
Lateral	10.3 g

FIGURE 17. SUMMARY OF RESULTS FOR TEST 3

performance criteria set forth in NCHRP 230 (3). The transition test is, first and foremost, a strength test. In this regard, the tubular W-beam transition has been shown to be able to contain and redirect a 4500 lb vehicle impacting at a high speed and angle.

It is noted that for all three tests, the change in vehicle velocity exceeded the 15 mph value recommended in NCHRP 230 Evaluation Criteria I (3). Although meeting this criteria is desirable, it is believed that strict compliance to this factor is not critical. This criteria is a subjective evaluation based on whether or not the vehicle is judged to have been redirected into or stopped while in adjacent traffic lanes. In all three crash tests described herein, the test vehicle returned to the side of the road after a short time interval and was not projected across traffic lanes. Depending on the existence and width of a shoulder, the test vehicles may or may not be judged to have briefly encroached on adjacent traffic lanes.

The primary intent of Evaluation Criteria I is to prevent the redirected vehicle from becoming a potential hazard to other traffic. It should be noted that, at this time, there is no definitive evidence that post impact trajectory is a serious problem. Furthermore, impacting the transition at such a severe speed and angle is a low probability event. Although, as stated above, the change in vehicle velocity exceeded the recommended value of 15 mph, the occupant impact velocities and ridedown accelerations were all within maximum acceptable limits (3) for all three tests. This fact suggests that the severity of impact was well within tolerance limits.

New Construction Transition Design

It should be emphasized that the design which was crash tested is a retrofit of the existing Texas standard transition. The basic tubular W-beam design can be adapted for new construction applications by simply moving the entire single W-beam approach barrier 15 in. closer to the end of the concrete barrier. This adjustment will eliminate the need for a splice plate and will allow the single W-beam to be spliced directly onto the front rail of the tubular W-beam. Furthermore, the posts upstream from the tubular W-beam (i.e. the posts to which the single W-beam approach rail is attached) can be offset 3 in. closer to the roadway. This will eliminate the need for the spacer blocks at the end of the single W-beam.

The modifications described above are intended to reduce the number of details in the transition design and, thereby, aid in the ease of field installation. Further changes can be implemented to improve the impact performance of the design. The exposed end of the concrete bridge rail may be beveled or flared. This should further reduce the possibility of wheel snag and could eliminate the need for the wood inserts used in Test 2. Finally, block-outs can be provided in the transition region. This would effectively eliminate wheel snagging on guardrail posts and should improve the overall impact performance of the barrier. A conceptual transition design which utilizes all of the above modifications is shown in Figure 18. Any or all of these variations may be employed to improve upon the retrofit transition.

Conclusions and Recommendations

A guardrail/bridge rail transition from a W-beam to a rigid concrete barrier has been successfully designed and crash tested. A number of favorable characteristics have been incorporated into the design to help insure its acceptance and implementation in both retrofit and new construction applications. The tubular W-beam transition (1) can easily retrofit existing installations, (2) provides sufficient post spacing to allow implementation where bridge end drains are required, and (3) is designed for use with either

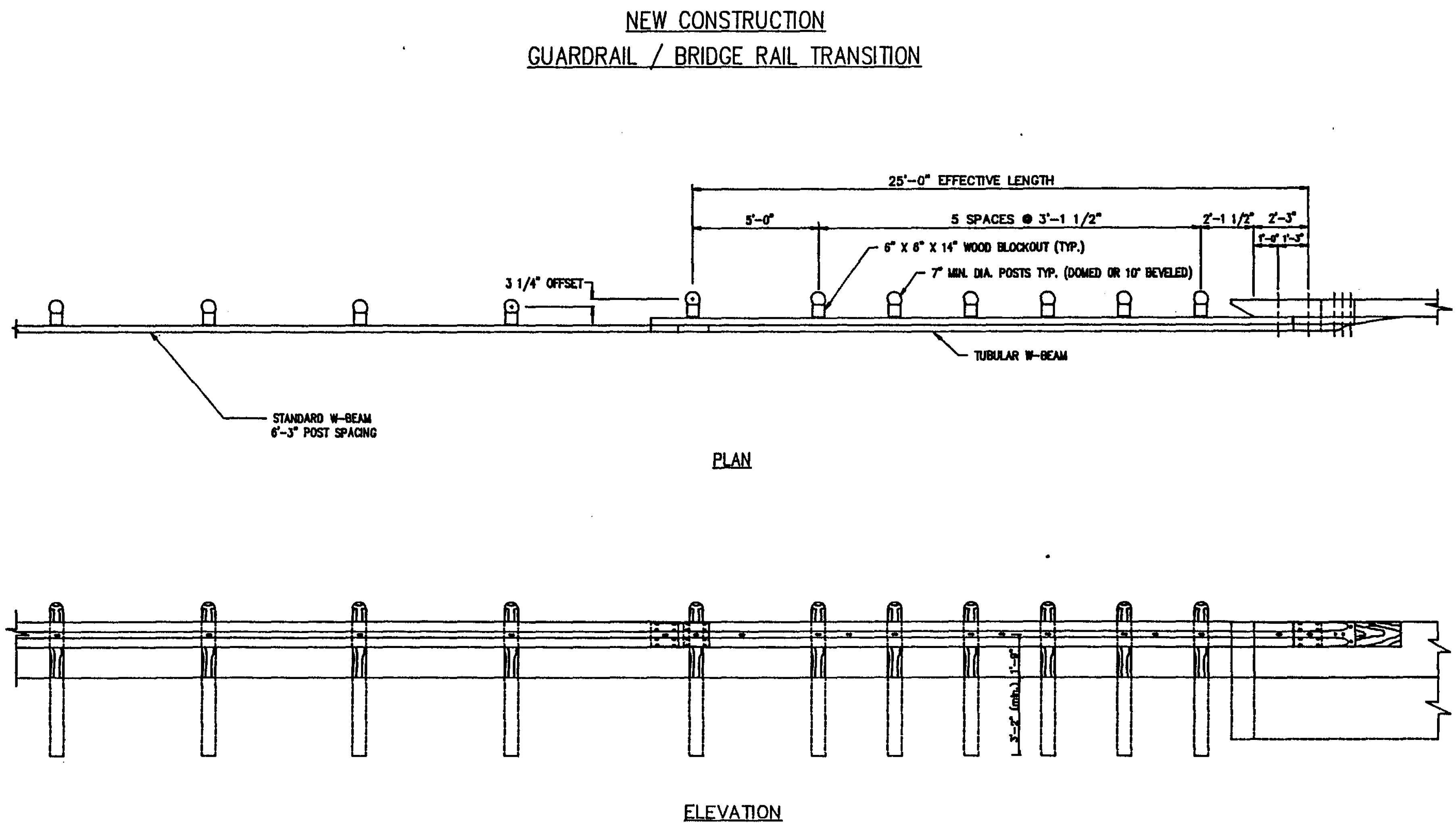


FIGURE 18. NEW CONSTRUCTION TRANSITION

a vertical concrete parapet or concrete safety shaped barrier.

Although the change in vehicle velocity for these tests exceeded the recommended value of Evaluation Criteria I (3), it should be noted that the system which was tested is a retrofit design. In order to maintain compatibility with the standard Texas system, no blockouts were used. It is believed that the use of blockouts throughout the length of guardrail would eliminate post snagging and reduce these numbers to recommended levels.

Because of its improved impact performance, it is recommended that the modified transition with wood inserts be used in conjunction with both the vertical parapet and safety shaped barriers. The wood inserts are necessary to eliminate the propensity for the tubular beam to collapse.

For new construction applications it is recommended that the end of the concrete bridge rail be beveled or flared thereby reducing the potential for wheel snag. Through use of these modifications the need for wood reinforcement of the tubular W-beam may be eliminated. Although this system was developed for a 7 in. diameter round wood post, it is believed that it will perform equally well with 6 in. X 8 in. wood or W 6X9 steel posts since they have equivalent lateral strength characteristics.

The transition developed in this study greatly simplifies retrofit operations and offers designers another alternative for new construction projects. Based on the results of the full-scale testing, the tubular w-beam transition is suitable for immediate implementation for field evaluation.

DISCLAIMER

The contents of this paper reflect the views of the authors, who are responsible for the opinions, findings, and conclusions presented herein. This paper does not necessarily reflect the official views or policies of the Texas State Department of Highways and Public Transportation or the Federal Highway Administration.

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