are compared with those from the case 1 simulation (Table 1), which excluded cargo displacement for the 0.89-m (35-in) barrier. Further, proper delineation of the cargo center of gravity (cases 13, 14, and 15) in the computer program in comparison with the assumption that it corresponded with vehicle center of gravity (cases 10, 11, and 12) also demonstrated a greater rollover potential.

A final series of simulations was performed to determine the barrier height that would have resulted in a safe redirecting of the school bus (see Table 3). For these simulations, an assumed cargo displacement (Figure 4), defined in case 15 (Table 2), was used. As the data show, even with the barrier raised to a 0.97-m (38-in) height, the resultant roll angular velocity was extremely high (99 percent of the critical roll rate). Note that this series assumed an extreme lateral and vertical cargo displacement. However, these displacement extremes cannot be overly conservative because of the many vehicle and barrier variables involved in an actual crash that are not addressed in this simple program (e.g., vehicle and barrier deformation).

CONCLUSIONS

The problem of cargo displacement is integral to studies of the postimpact behavior of heavy vehicles in collision with barrier systems. This investigation substantiates the relationship. Moreover, the modified rollover vaulting algorithm (RVA 2) is an efficient tool with which to consider this complex phenomenon. Although the sample cases in this study were limited to those involving a school bus, RVA 2 can be used to simulate a wide range of single-unit vehicles where a potential cargo shift could contribute to hazardous vehicle behavior.

ACKNOWLEDGMENT

I gratefully acknowledge the assistance of G.A. Walker and L. Mesa in the writing and preparation of this paper.

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The Rural Mailbox: A Little-Known Roadside Hazard

HAYES E. ROSS, JR., KENNETH C. WALKER, AND W. J. LINDSAY

The results of seven full-scale crash tests conducted at the Texas Transportation Institute to evaluate the impact behavior of rural mailbox installations are reported. Three of the seven tests—two of single-box installations and one of a four-box installation—involved commonly used wood-post supports. Two tests of single-box installations involved promising new support concepts that use standard steel pipe with a breakaway mechanism. The final two tests involved a steel-pipe, multiple-box support in the shape of an inverted U. The results showed that installations with multiple boxes mounted on boards pose a serious hazard to motorists because the board can easily penetrate the windshield. The inverted-U design eliminated the penetration problem, but the change in vehicle momentum on impact exceeded the recommended limit. The results also showed that, for a single-box installation, a pipe post performs better than a wood post. Careful attention must be given to the box-to-post attachment to prevent separation during impact and thus minimize the potential for windshield penetration by the mailbox.

Little attention has been given to rural mailbox structures as potential hazards to motorists. Although the incidence of vehicle collisions with mailboxes may be small in comparison with collisions with more formidable hazards, mailbox accidents are not statistically insignificant. Table 1 gives a summary of 1972 data from four states on road accidents involving mailboxes (1). By using available accident data, the Federal Highway Administration (FHWA) has estimated that approximately 200 or more fatalities occur each year as a result of mailbox accidents.

The U.S. Postal Service issues design specifications for the rural mailbox itself and its vertical position (2), but it has no specifications for mailbox supports. In 1969, the American Association of State Highway Officials (AASHO) published guidelines for erecting mailboxes on highways, including suggested structural supports (3). Some of these recommended supports, however, were found to be undesirable in the testing reported in this paper. A cursory review of several state and county agencies reveals an almost total absence of any standards for mailbox supports. Only one state is known to have such standards.

Figure 1 shows some of the "ingenious" devices used to support mailboxes. These include steel tractor wheels, old-time stoves, water pumps, plowshares, milk cans filled with concrete, massive I-beams, and pipes. Such supports may be artistic to some, but most are serious roadside hazards.

Mailboxes are hazardous primarily because of the mounting height of the box. Most boxes are mounted approximately 42 in (106.7 cm) above ground to make it easier for the mail carrier to place mail in the box. As Figure 2 shows, this height places the box in direct line with the windshield of many vehicles. The support systems shown in Figure 2 were used for illustrative purposes only and are not considered crashworthy systems. The base of each of the three different-sized boxes is approximately 42 in above the ground.

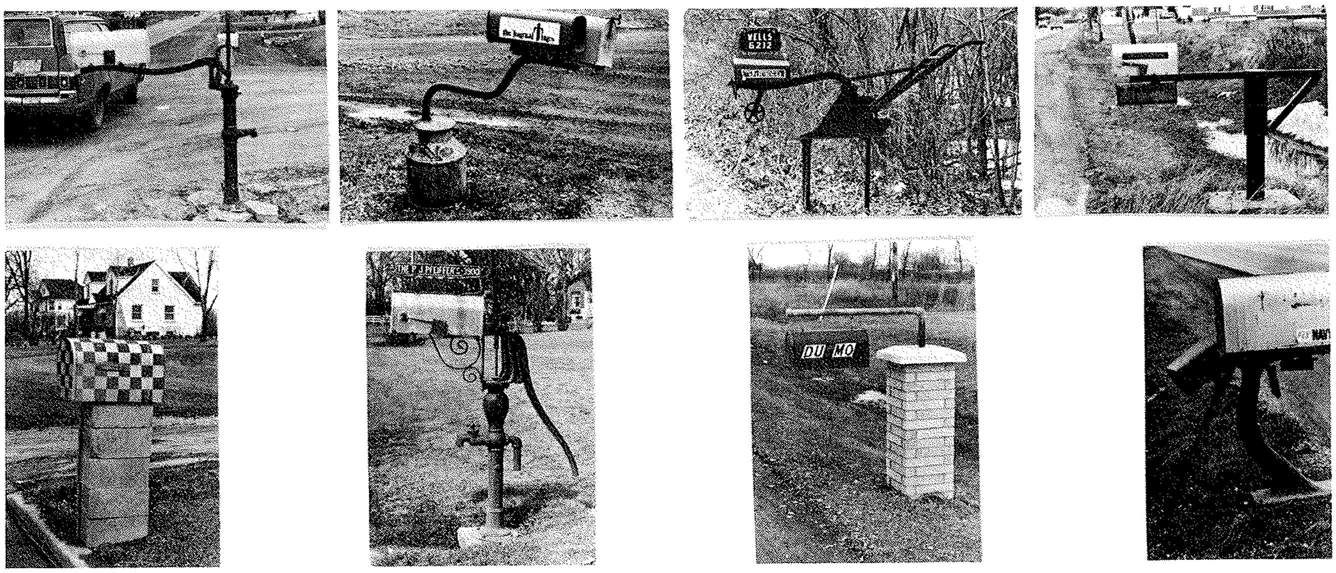
Mounting several boxes on a wood board compounds the problem, since the board can spear through the windshield. Field installations of multiple boxes are shown in Figure 3. Figure 4 shows what may be a record for the number of boxes mounted on one continuous support (more than 200).

To gain insight into the hazard of mailbox installations, FHWA and the Texas State Department of Highways and Public Transportation (TSDHPT) elected to conduct limited full-scale crash-test

Table 1. Mailbox accident data from four states for the year 1972.

State	Total Mailbox Accidents	Percentage of Total Fixed-Object Accidents	Fatal Mailbox Accidents	Percentage of Total Fatal Fixed-Object Accidents	Personal-Injury Accidents	Percentage of Total Fixed-Object, Personal Injury Accidents	Property-Damage Accidents	Percentage of Total Fixed-Object, Property-Damage Accidents
Michigan	3326	5.2	15	2.3	726	3.0	2585	6.6
Missouri	272	3.0	7	3.0	93	2.7	172	3.2
Texas	1053	1.9	12	1.4	225	1.3	816	2.1
Washington	254	3.5	0	0.0	77	2.5	177	4.4

Figure 1. Single-box installations.



programs. Tests were conducted on widely used wood-post supports, two promising new support concepts that make use of standard steel pipe and a breakaway mechanism, and a steel-pipe, multiple-box support in the shape of an inverted U. The third design was developed by TSDHPT to reduce the hazard of wood-post and wood-beam multiple-box designs.

This paper summarizes the tests conducted and their results. Complete details of the tests can be found elsewhere (4,5).

TEST CONDITIONS

Table 2 gives a summary of the seven test conditions. Further design details are given in subsequent sections.

It was clear from previous tests of sign posts (4) that high-speed impacts would be more hazardous than low-speed impacts for the mailbox installations to be evaluated. Therefore, the impact speed in each test was approximately 60 miles/h (26.8 m/s). Test data were recorded and analyzed in accordance with recommended guidelines for testing roadside appurtenances (6). Soil at the test site conformed to recommended standards (6).

Test Mailboxes and Supports

Wood-Post Support

Tests 22, 23, and 24 involved a single 4x4-in (10.2x10.2-cm) wood-post support. In each of these three tests, the post was set 2 ft (0.61 m) into a drilled hole 18 in (45.7 cm) in diameter, the hole was backfilled, and then the post was tamped into position. The base of the mailbox was 42 in (106.7 cm) above ground level for all tests.

Figure 5 shows the installation details. Although the post was similar in these tests, the arrangement, size, and attachment of the mailbox differed.

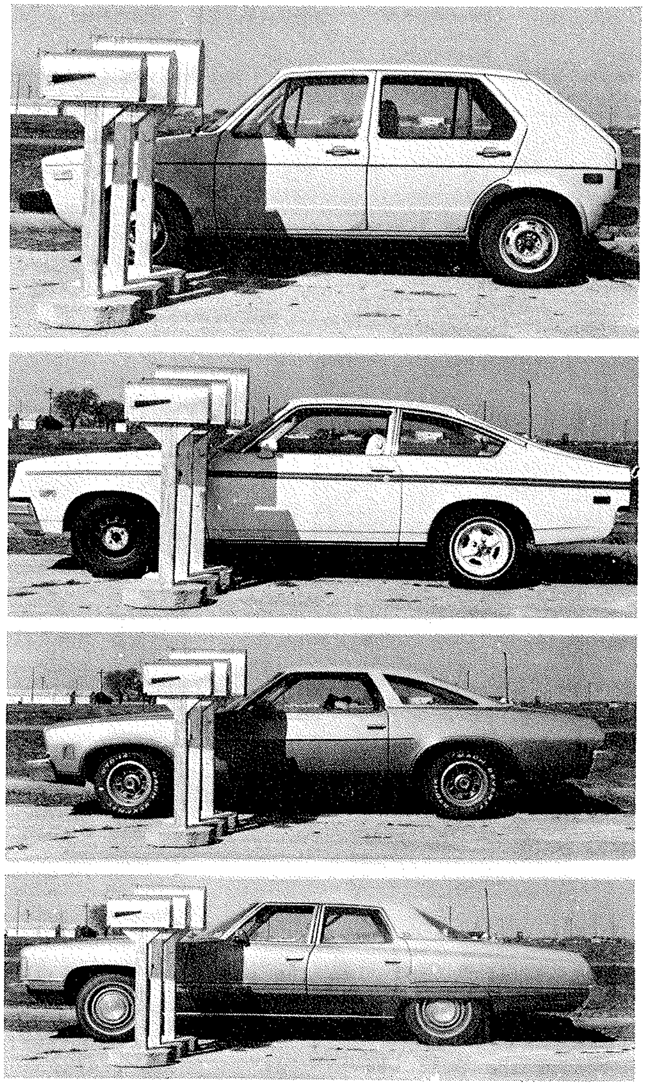
Single Mailbox

Test 22 used a single No. 1-A mailbox (2) mounted on a 1.625x8x19.5-in (4.13x20.3x49.5-cm) yellow-pine timber cap. The mailbox was attached to the cap by six 1.5-in (3.81-cm) long composition roofing nails. Three sixteenpenny nails were used to attach the cap to the post. Two triangular braces, each with four eightpenny nails, secured the timber cap to the post. Figure 6 shows the installation from the direction of impact and the mailbox height with respect to the test vehicle.

Single Mailbox with Strap Attachment

Installation details in test 23 were identical to those in the previous test with the exception of the two straps that were added to increase the mailbox-to-post connection strength. Commercially available hanger straps were used. Static load tests of the strap showed it had a tensile strength of approximately 500 lbf (2224 N). The width of the 24-gauge strap was 0.75 in (1.91 cm); the holes were 0.25 in (0.64 cm) in diameter on 1-in (2.54-cm) centers. Each strap was attached to the post with ten 1.5-in (3.81-cm) long composition roofing nails,

Figure 2. Mailbox height in relation to vehicle windshield.



five on each side, beginning 6 in (15.24 cm) from the bottom of the timber cap and continuing on 1-in (2.54-cm) centers. Connection to the timber cap was made with one 1.5-in (3.81-cm) long roofing nail on each side of the mailbox. Details of the installed strap and the direction of impact are shown in Figure 7.

Multiple Mailboxes on Wood Support

Test 24 involved four mailboxes: one No. 1, two No. 1-A, and one No. 2 (2). Each mailbox was attached to a yellow-pine timber cap with six 1.5-in (3.81-cm) long composition roofing nails. A 1.625x5.625x57-in (4.13x14.3x144.8-cm) support arm held the timber caps, each with three sixteenpenny nails. The support arm was connected to the 4x4-in (10.2x10.2-cm) post with four sixteenpenny nails and two triangular braces, each held by four eightpenny nails. The installation is shown in Figure 8.

Standard Steel Pipe Posts

In tests 25 and 26, 1.5-in (3.81-cm) inside-diameter (ID) standard steel pipe with two post-to-base combinations was evaluated. Both are commercially available support systems. Installation details are shown in Figure 9. The base in both cases was a 1.5-in-ID standard steel pipe 30 in (76.2 cm) long with a 5-in (12.7-cm) auger on one end to facilitate installment. The base was installed by simply digging a small hole and then turning the augered pipe with a pipe wrench.

In test 25, a lap-spliced steel pipe with bolted shear connection, shown in Figure 9, was evaluated. The lower bolt was a 0.375x4.5-in (0.95x11.4-cm) retainer bolt, and the other was a 0.3125x4.5-in (0.79x11.4-cm) shear bolt with a short section machined down to the minor thread diameter of 0.2524 in (0.64 cm).

In test 26, the post-to-base assembly consisted of a frangible coupling. It incorporated two retainer straps attached with two 0.375x2.5-in (0.95x6.35-cm) bolts. Four 0.3125x1.5-in (0.79x3.81-cm) bolts connected the coupling to the base and post. All bolts were grade 2.

The mailbox bracket was attached to the threaded support post with lock nuts. One lock nut was set below the mailbox bracket. In test 25, one lock nut was used to hold the bracket down; in test 26, two

Figure 3. Multiple-box installation.

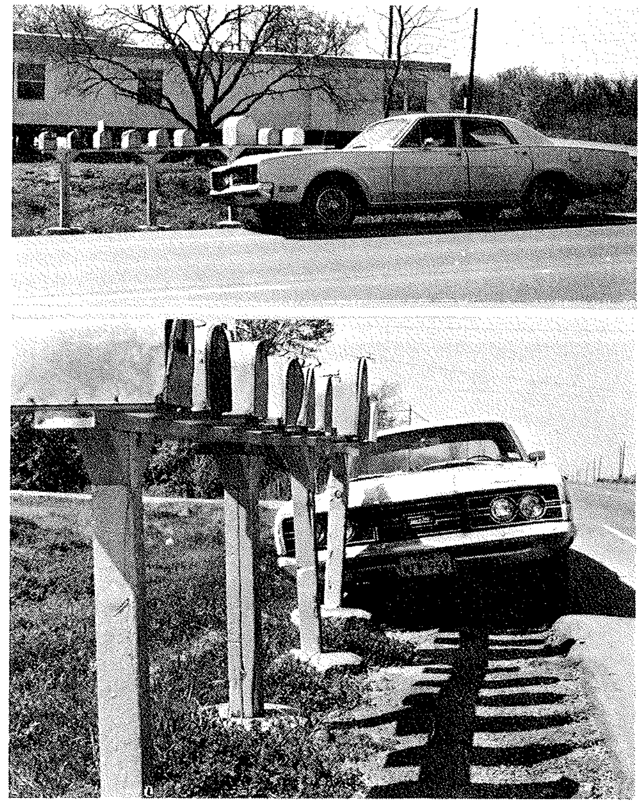


Figure 4. Field installation with numerous boxes.

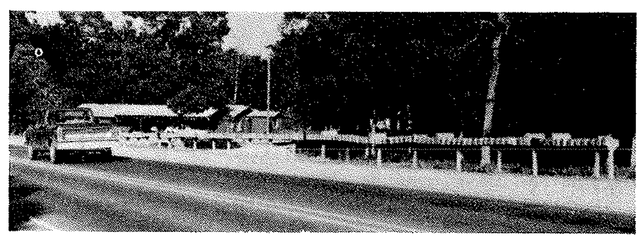


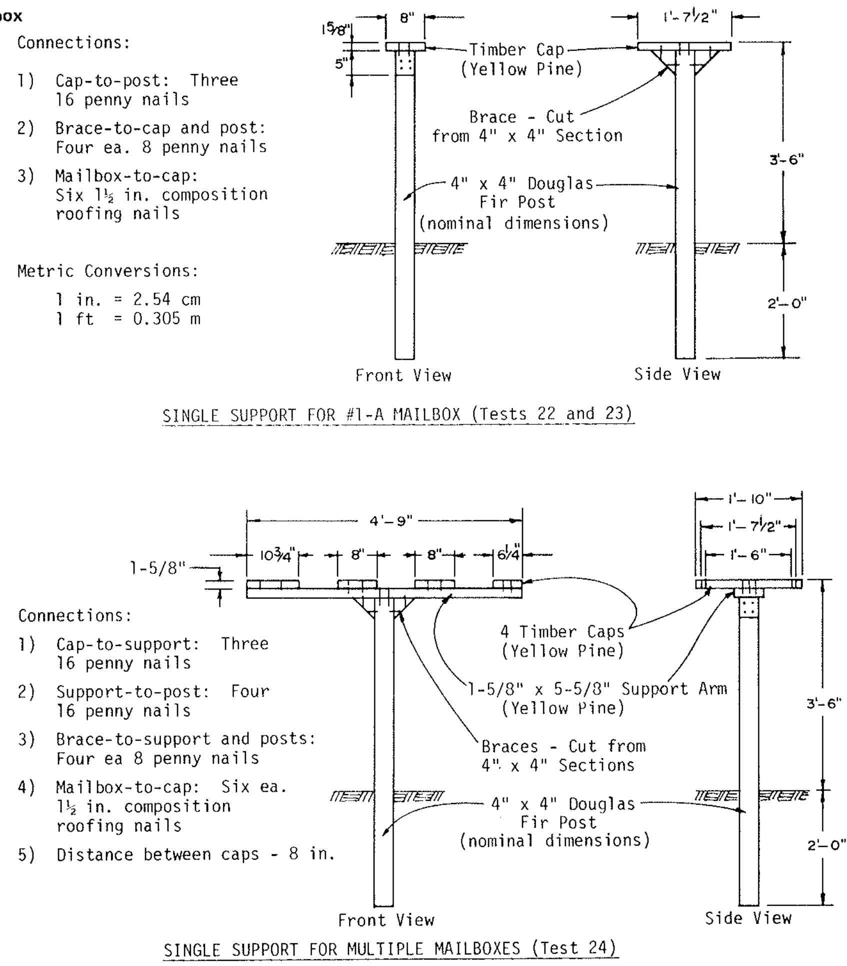
Table 2. Summary of test conditions.

Test No.	Vehicle Weight (lb)	Impact Speed (miles/h)	Type and Size of Support Post	Cap and Support Arm Details	Post Embedment Depth (ft)	Number of Mailboxes on Post	Type of Mailbox[a]
22 (4)	2270	58.2	Wood, 4 x 4 in (nominal)	Figures 5 and 6	2.0	1	No. 1-A
23 (4)	2270	62.6	Wood, 4 x 4 in (nominal)	Figures 5 and 7	2.0	1	No. 1-A
24 (4)	2440	58.8	Wood, 4 x 4 in (nominal)	Figures 5 and 8	2.0	4	One No. 1, two No. 1-A, one No. 2
25 (4)	2260	58.8	Standard steel pipe[b], 1.5-in ID	Figures 9 and 10	2.3	1	No. 1-A
26 (4)	2260	60.9	Standard steel pipe[c], 1.5-in ID	Figures 9 and 10	2.3	1	No. 1
5 (5)	2470	61.3	Standard steel pipe, 1.25-in ID	Figures 11 and 12	2.0	7	Three No. 1, three No. 1-A, one No. 2
6 (5)	2500	60.4	Standard steel pipe, 1-in ID	Figures 11 and 13	2.0	5	Two No. 1, two No. 1-A, one No. 2

Note: 1 lb = 0.45 kg; 1 mile = 1.6 km; 1 ft = 0.3 m; 1 in = 2.54 cm.

[a]U.S. Postal Service type 1 standard rural mailboxes. [b]Lap-splice design with bolted shear connection. [c]Frangible cast-iron coupling with retainer straps.

Figure 5. Installation details for wood-post mailbox supports.



nuts were used. In addition, an ornamental S-brace was used in test 25 to connect the bracket and support post. For both pipe tests, six 0.1875x0.75-in (0.48x1.91-cm) bolts with lock washers were used to attach the mailbox to the bracket. A No. 1-A mailbox was used in test 25, and a No. 1 mailbox was used in test 26. The completed installations can be seen in Figure 10.

Multiple Mailboxes on Steel-Pipe Support

Details of the mailbox installations for tests 5 and 6 are shown in Figure 11. Details of the mailbox-to-support attachment are shown in Figures 12 and 13. The smaller boxes were attached to the brackets by four 0.1875x0.75-in (0.48x1.91-cm) bolts with lock washers. The middle-sized boxes and larger boxes were attached to the brackets by six 0.1875x0.75-in bolts with lock washers. The completed installations are shown in Figure 14.

Test Vehicles

The vehicles for tests 22-26 were 1972 and 1973 Chevrolet Vegas that weighed approximately 2250 lb (1022 kg). The vehicles used in tests 5 and 6 were 1974 Chevrolet Vegas that weighed approximately 2500 lb (1135 kg). Data acquisition systems consisting of high-speed motion pictures and on-board instrumentation (4) were used.

PERFORMANCE SPECIFICATIONS

Although there are no formal performance specifications for mailbox supports, it seems logical that such appurtenances should comply with recognized safety standards for sign posts, light poles, and traffic signals as published by the American Association of State Highway and Transportation Officials (AASHTO). According to AASHTO specifications (7), "Satisfactory dynamic performance is indicated when the maximum change in momentum for a standard 2250 lb (1020 kg) vehicle, or its equivalent, striking a breakaway support at speeds from 20 mph to 60 mph (32 km/h to 97 km/h), does not exceed 1100 pound-seconds (4893 N-sec), but

Figure 6. Completed installation, test 22.

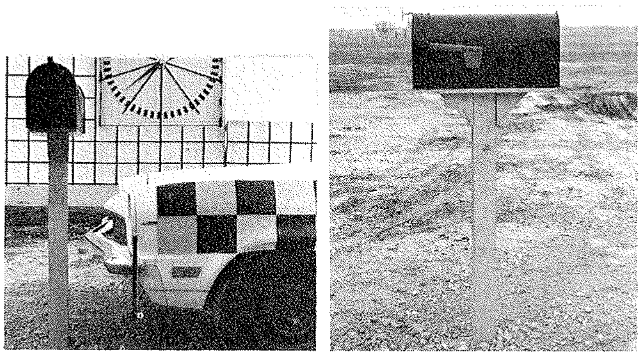


Figure 7. Completed installation, test 23.

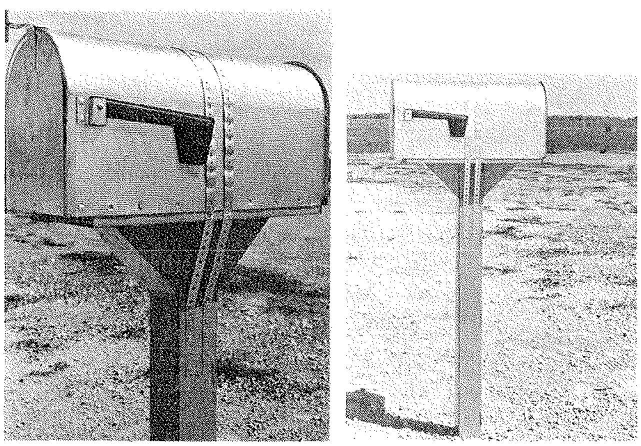


Figure 8. Completed installation, test 24.

desirably does not exceed 750 pound-seconds (3336 N-sec)."

"Breakaway supports", as used in the AASHTO specification, is a generic term meant to include all types of sign supports whether the release mechanism is a slip plane, plastic hinges, fracture elements, or a combination of these. The specification states that "Breakaway structures should also be designed to prevent the structure or its parts from penetrating the vehicle occupant compartment." The specification also alludes to the unacceptability of vehicle rollover after impact with the sign post.

TEST RESULTS

Data derived from accelerometer readings include change in momentum, peak acceleration, highest 50-ms average acceleration, and duration of event. Peak acceleration is found directly from the accelerometer readings, and the highest 50-ms acceleration is derived by averaging the readings over all 50-ms intervals. Change in momentum is found by first integrating the acceleration-versus-time plot given by the accelerometer signals. This is the change in vehicle velocity, which, when multiplied by the vehicle mass, gives the momentum change. Since change in momentum is time dependent, the length of time over which the integration is performed must be specified. Because of this time dependency, guidelines have been established to determine "duration of event" (6) for computation.

Table 3 gives a summary of the five tests (impact conditions are given in Table 2). A discussion of each test follows.

Test 22

In test 22, almost immediately after impact, the mailbox, mailbox base, and base braces separated from the post. Shortly thereafter, the post broke away at ground level. Because of inertia, the mailbox and timber cap remained almost stationary as the post broke away. Then the box struck the top of the hood and rolled into the windshield, breaking and dishing the windshield and bending the molding above it. It did not, however, penetrate into the passenger compartment. Other than a broken windshield, the vehicle sustained only minor damage.

Test 23

Analysis of mailbox and support response in test 22 indicated that a stronger connection was needed to keep the mailbox attached to the post. The design was modified to include two galvanized hanger straps to secure the mailbox to the support. This design was developed to keep the breakaway features of the wood post and at the same time keep the post and mailbox from separating on impact.

In test 23, the post split on impact at the top where the connecting straps were attached to the post and then broke on the side away from impact. The mailbox and timber cap gained little velocity during the initial impact. After the support broke at ground level, the vehicle continued moving forward and the mailbox struck and broke the windshield. However, the box did not penetrate into the passenger compartment.

Test 24

In test 24, the support post broke on impact at ground level and at bumper height [20 in (50.8 cm)]. The support arm also separated from the post soon

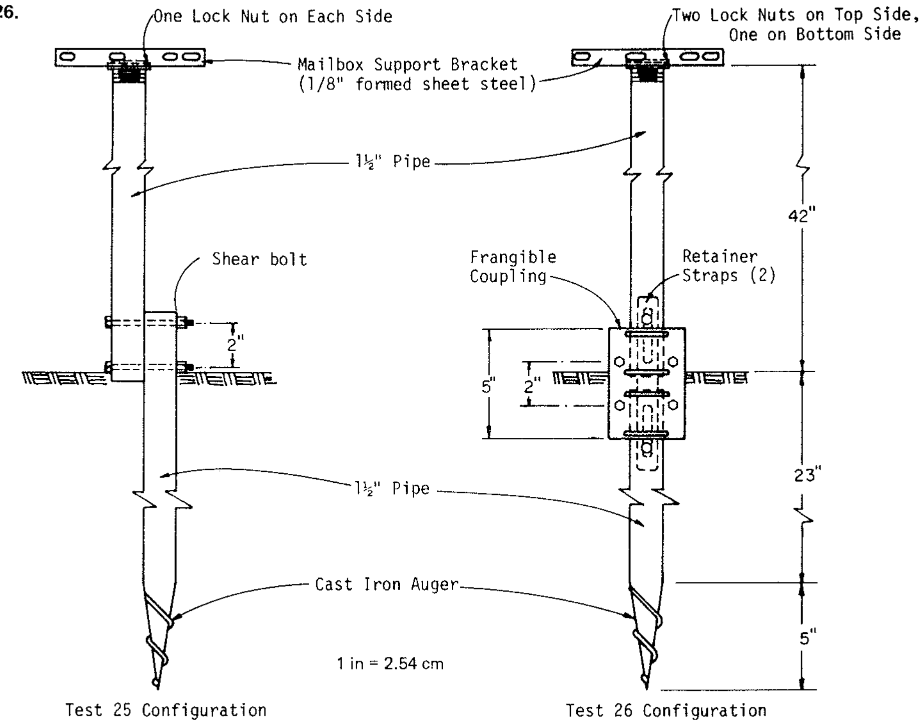


Figure 9. Installation details, tests 25 and 26.

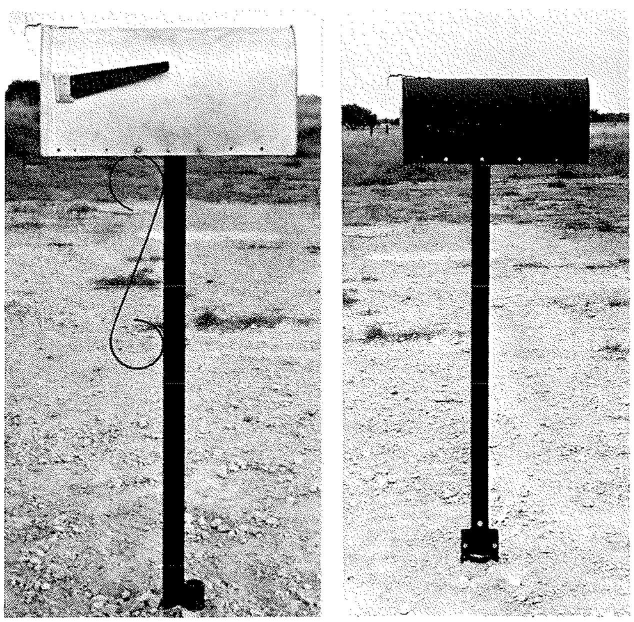


Figure 10. Test installations with standard steel pipe supports.

after impact without gaining any significant velocity. As a result, the support arm and four mailboxes hung in midair as the vehicle drove into it. When the support arm hit the windshield, three mailboxes entered the passenger compartment along with 75 percent of the support arm (see Figure 15). The dummy was struck on the chin by the support arm and was almost decapitated. The impact also forced the seat back. There is little doubt that a driver would have been killed under these circumstances.

<u>Test 25</u>

Test 25 was the first test in which the windshield

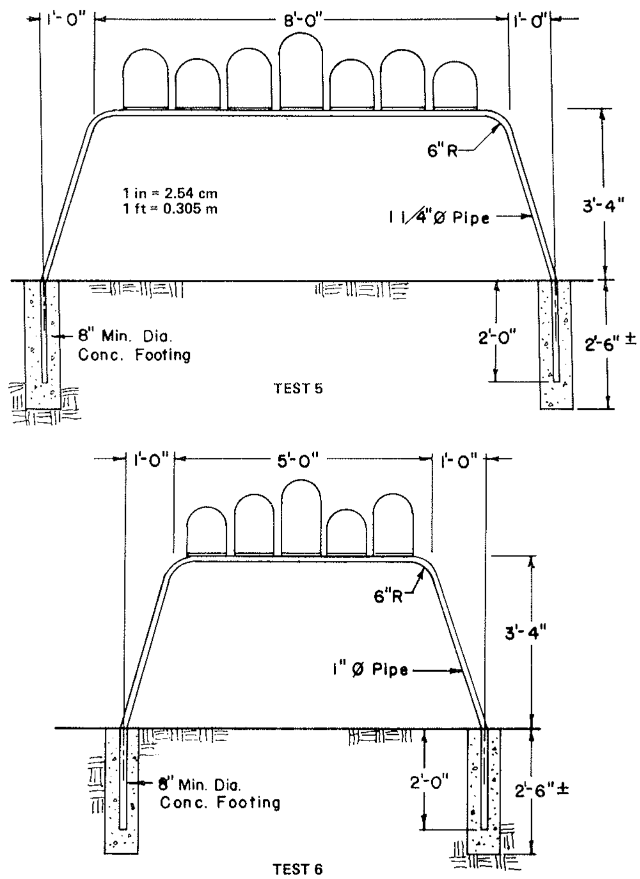
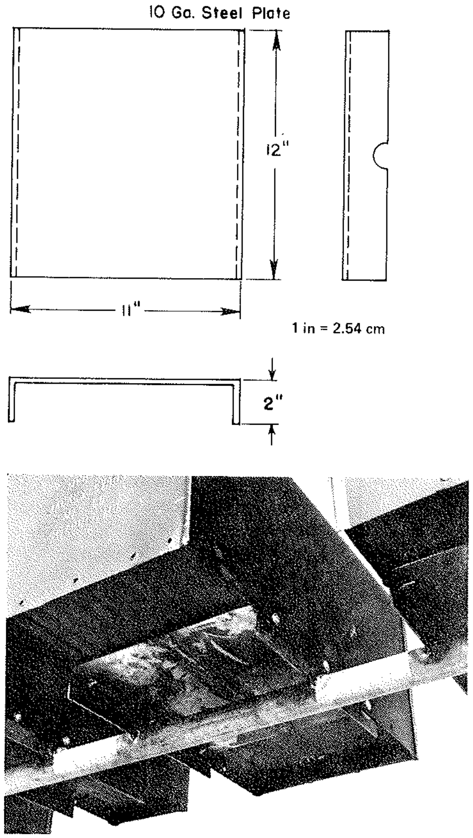


Figure 11. Mailbox support configurations, tests 5 and 6.

was not struck by some part of the mailbox or its support. Although the mailbox broke free of the support, it remained intact long enough to attain a

Figure 12. Mailbox-to-support attachment details, test 5.



velocity approximately equal to that of the vehicle. As a result, the mailbox rode along on the hood and harmlessly fell away. Investigation of the bracket-to-post connection showed that the lock-nut threads stripped, allowing the box to separate from the post. Two lock nuts on the top of the bracket would probably have prevented this separation (see the description of test 26). The support and the mailbox were too badly damaged to be reused. The anchor post, however, was not damaged and could be reused. The shear bolt fractured as it was designed to do, retaining the post but allowing it to rotate downward. Vehicle damage was minimal.

Test 26

In test 26, the frangible coupling broke, and the retainer straps held the post after fracture as desired. The mailbox remained with the support until the vehicle rode over the box and the support. Note that two lock nuts were used on the top side of the bracket to attach the bracket to the post (Figure 9). The retainer straps functioned as designed, preventing translational movement of the support post.

As in test 25, the support and the mailbox were damaged beyond repair and reuse. The anchor post was also damaged and would probably have to be replaced. Vehicle damage was minimal.

Test 5

In test 5, at impact the support formed a hook and the pipe wrapped around the hood of the vehicle. Continued forward vehicle movement broke the lead support post. The boxes and the remaining portion of the support were then ridden down, and the boxes

Figure 13. Mailbox-to-support attachment details, test 6.

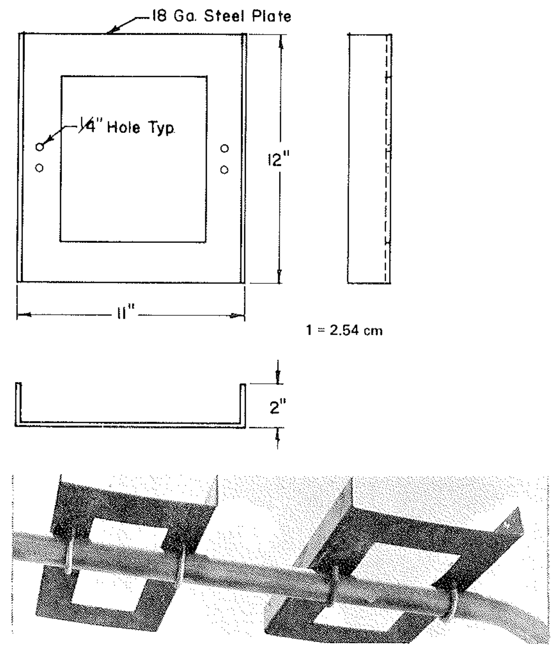
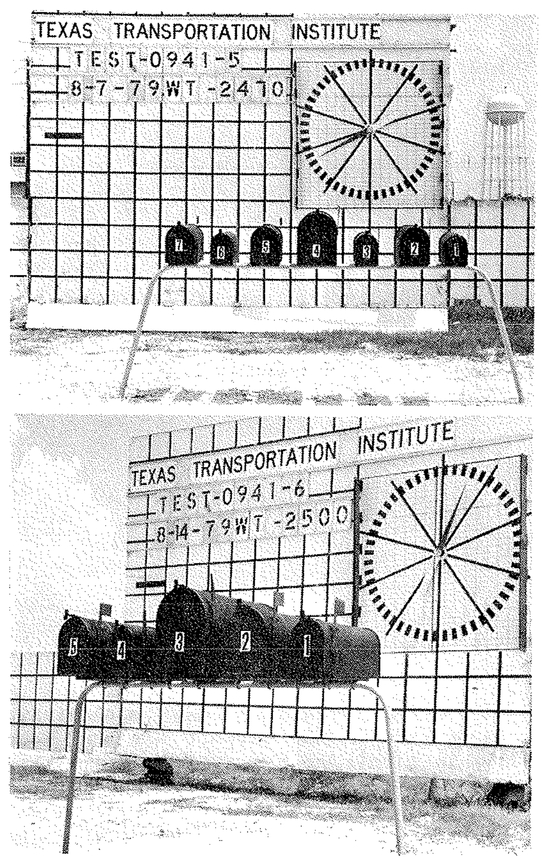


Figure 14. Completed installation, tests 5 and 6.



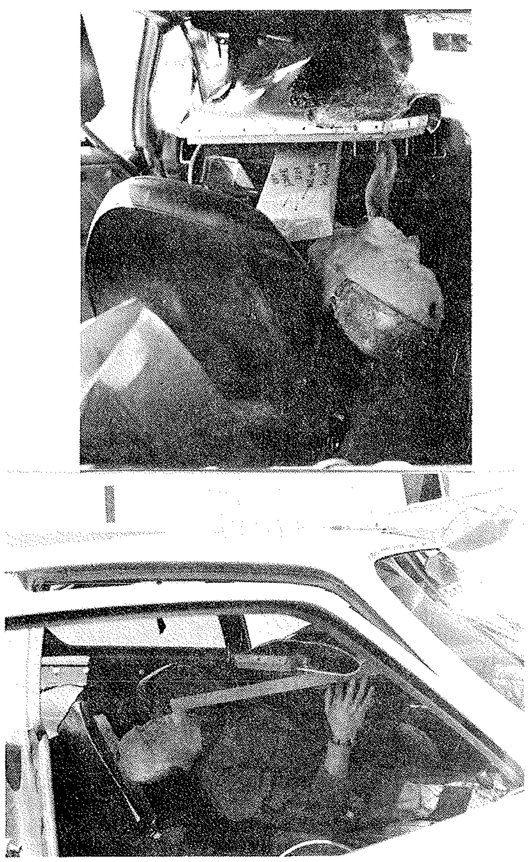
were stripped from the pipe. Impact occurred at the left quarter point of the front bumper. After impact, the vehicle spun or yawed approximately 120°. The vehicle sustained considerable front-end damage. There was no windshield contact by any part

Table 3. Summary of test results.

Test No.	Change in Momentum (lbf·s)	Comments
22	65	Box and cap separated from post and hit windshield
23	49	Box and cap separated from post and hit windshield
24	151	Support arm separated from post and penetrated windshield
25	217	Box and cap separated from post but did not hit windshield
26	114	Box and cap remained with post until box hit ground; no windshield contact
5	1925	Change in momentum exceeded recommended limit of 1100 lbf·s; boxes remained on support
6	1267	Change in momentum exceeded recommended limit of 1100 lbf·s; boxes remained on support

Note: 1 lbf·s = 4.45 N·s.

Figure 15. Interior vehicle damage, test 24.



of the installation. Change in vehicle momentum considerably exceeded the recommended limit.

Test 6

The impact behavior of the vehicle and the support in test 6 was similar to that in test 5. In this case, the lead support did not fracture and the boxes were not stripped from the pipe as the vehicle rode over the support. The vehicle yawed about 180° before coming to a stop. Although the change in vehicle momentum exceeded the recommended limit, this design represents a step in the right direction and is a vast improvement over the design evaluated in test 24.

CONCLUSIONS AND RECOMMENDATIONS

This study has delineated several noteworthy points:

1. Although the incidence of vehicle impacts with mailbox installations may be small in comparison with collisions with more formidable roadside hazards, mailbox accidents occur and the consequences are not always insignificant.
2. Although the U.S. Postal Service has design specifications for the mailbox itself, it has no such specifications for the mailbox support.
3. Only one state is known to have and to enforce a standard design for mailbox supports.
4. There is a bewildering variety of support designs, many of which are unnecessarily hazardous to the traveling public.

To gain insight into the hazard of mailbox installation, FHWA and TSDHPT elected to conduct limited full-scale crash-test programs. Tests were conducted on widely used wood-post supports, two promising new support concepts that use standard steel pipe, and a multiple-box support that uses an inverted-U steel pipe. All tests were conducted at approximately 60 miles/h (26.8 m/s).

The conclusions drawn as a result of the tests are as follows:

1. Most mailboxes are mounted approximately 42 in (106.7 cm) above the ground, which places them in direct line with the windshield of most automobiles. It is therefore of primary importance that the strength of the box-to-post attachment be sufficient to prevent separation during impact. This will reduce the potential for the box to impact the windshield.
2. Multiple-mailbox installations usually have a beam or support member running parallel to the roadway. At impact, the beam can easily spear through the windshield, which obviously can cause and has caused serious injuries and fatalities. The inverted-U steel-pipe, multiple-box support eliminated the spearing problem, but change in vehicle momentum exceeded recommended limits. At the present time, there are no multiple-box support systems known to be acceptable.
3. Standard steel pipe that has a post-to-base design and incorporates some type of breakaway feature offers considerable promise as a single-mailbox support. Tests of a lap-spliced bolted-base design and a frangible coupling design proved to be satisfactory. The cost of such systems is nominal.
4. Wood posts may present special problems as mailbox supports when they are used on roadways where vehicle operating speeds exceed approximately 40 miles/h (64.4 km/h). The major difficulty concerns the box-to-post attachment and the brittle nature of wood under impact conditions. A wood post will typically fracture at bumper height and ground level. Depending on the size of the mailbox, the geometry of the vehicle, and the impact speed, the upper part of the fractured post and mailbox may remain together and impact the windshield. If the mailbox separates from the post, the probability of windshield impact increases significantly. In tests of two single-mailbox installations with wood posts, mailbox separation occurred and the windshield was impacted. Attempts to prevent separation by using hanger straps were unsuccessful.

As a result of the tests described in this paper, the following recommendations are made:

1. An effort should be undertaken on the national

level to provide standards and/or performance specifications for mailbox supports. Tests have shown that simple, safe, and economical support systems are attainable. The U.S. Postal Service, with assistance from FHWA, appears to be the logical agency to promulgate standards and specifications for mailbox supports. It seems reasonable to require that mailbox installations meet the same performance specifications now applied to structures such as signs and lightpoles.

2. Where possible, mailbox owners should be encouraged to place their installations on a side road, along a driveway, or a safe distance from the main roadway.

3. Multiple-box installations that include a beam or support member running parallel to the roadway are extremely hazardous and should be avoided. In our opinion, an acceptable alternative to multiple supports would be an individual, crashworthy support for each box. Impact should then cause a "domino effect". Tests are needed, however, to substantiate this hypothesis.

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The contents of this paper reflect our views, and we are responsible for the facts and the accuracy of the data presented. The contents do not necessarily reflect the official views or policies of the U.S. Department of Transportation. This paper does not constitute a standard, specification, or regulation.

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Crash Tests of Construction-Zone Traffic Barriers

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Tests conducted by the New York State Department of Transportation to determine the performance of various types of traffic barriers for construction zones are described. A 30.5-cm (12-in) timber curb with steel splice plates between sections and steel pins driven into the subbase was unable to redirect vehicles in minor impacts. A 40.6-cm (16-in) high timber curb with a W-beam steel rail bolted to the face was successfully tested at 76 km/h (47 miles/h) and 17° and at 61 km/h (38 miles/h) and 14°. Steel washers welded atop the anchor pins reduced barrier movement at impact. This barrier is suitable for use where moderate impacts may occur [64 km/h (40 miles/h) and 15°] and requires only a few inches of deflection distance. New York's standard portable concrete median barrier with pin-connected joints, which contained an impacting vehicle at 89 km/h (55 miles/h) and 25° without any connection to the pavement except the two terminal sections, appears to be suitable for use in high-speed work zones. Pulling the joints tight when it was installed and grouting the bottom corners reduced barrier deflection and damage. Deflection of as much as 38.1 cm (15 in) may be produced by 97-km/h (60-mile/h) impacts where anchorage to the pavement is not provided, but it would be less where conditions do not permit such severe impacts.

Timber curbs have been widely used as construction-zone barriers to provide delineation to guide traffic through work areas and redirect errant vehicles that leave the travel lanes. Several design variations have been used; most include timber sections from 25.4 to 30.5 cm (10-12 in) square and about 3.66 m (12 ft) long. In some states, vertical posts with horizontal rail elements are attached to the curb. Anchorage is generally minimal--often only a metal clip to join adjacent sections but no anchorage to the pavement.

These barriers, which are relatively inexpensive and easy to install, are so narrow as to detract little from the narrow pavement widths frequently encountered in work zones, and they generally provide good delineation. Unfortunately, they provide little redirection to impacting vehicles. A recent Virginia study (1) reported that 73.5 percent of vehicles impacting a 25.4-cm (10-in) square timber curb with timber railing penetrated or straddled the barrier. What is possibly even more serious is that barrier sections were frequently dislodged on impact and became additional hazards to oncoming traffic and workers in the area. Tests conducted by Southwest Research Institute (2) confirmed these problems.

When the hazards associated with timber curbs were recognized, their use on federal-aid projects was restricted by Federal Highway Administration (FHWA) Notice N5160.27. Because this federal action left no simple, inexpensive barrier available for construction-zone use, several research efforts were initiated to develop suitable barriers. These efforts can be grouped in three categories:

1. Modifications of timber curbs,