

Crash Tests of Work Zone Traffic Control Devices

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Full-scale vehicle crash tests were used to evaluate performance of typical work zone traffic control devices. Modified test procedures and evaluation criteria from National Cooperative Highway Research Program Report 230 were used in 108 tests, providing significant insight into impact performance. Plastic drums used as channelizing devices, cones, tubes, and vertical panels performed well in most tests, presenting no hazards in terms of passenger compartment intrusion, interference with vehicle control, or threat to workers and other traffic from impact debris. Various nonstandard forms of ballast placed on top of or inside channelizing devices detracted from performance, and sometimes posed a severe threat to test vehicle occupants, workers, and other traffic. Similarly, impact debris formed in several tests on Type I and III barricades and portable signs and supports posed a threat, and was often thrown long distances through work zones. Warning lights attached to traffic control devices were also thrown free in a number of tests, and appeared to threaten workers and other traffic.

With increased emphasis on repairing and rehabilitating the existing infrastructure, work zones have become commonplace on the nation's highways. A variety of signs, channelizing devices, and other traffic control devices (TCDs) guide and control traffic in these zones. Primarily, TCDs convey information to the motorist (1), and a number of recent studies have developed a wide array of work zone TCDs that effectively accomplish this purpose (2, 3). However, work zone TCDs must also fulfill an important secondary function. Work zone traffic accidents are common occurrences, and TCDs are often involved because of their close proximity to the traveled lanes. Thus, in addition to transferring information, they must perform safely when impacted by errant vehicles.

Performance criteria for permanent highway safety appurtenances such as traffic barriers and sign supports have existed for some time (4), and also apply to temporary work zone safety devices such as portable traffic barriers. Considerable research (5, 6) on traffic barriers and related features for highway work zones has provided information on their performance. However, only limited published data describe impact performance of work zone TCDs (7), and no performance criteria have been proposed or accepted for widespread use.

This paper describes a 1988 study by the New York State Department of Transportation (NYSDOT) that evaluates impact performance of TCDs commonly encountered in New York work zones. Test procedures were modified to deal

specifically with the TCD types tested, and performance criteria were developed to evaluate the results. In all, 108 full-scale tests were conducted on 62 different combinations of TCDs and installation conditions.

TEST PROCEDURES AND EVALUATION CRITERIA

The tests were performed during the summer of 1988 at the Department's Highway Safety Test Center in Scotia, New York, near Albany. All tests were recorded by two electronic video camera-recorders and one 35-mm movie camera. In addition, still photographs documented the devices tested and the results. Because the size and weight of the devices were small, significant vehicle deceleration on impact was not expected. To simplify procedures and permit completion of a greater number of tests within the time available, accelerometers were not installed in the vehicles. After each test, damage to the vehicle and test device was noted. Particular attention was given to any tendency of the devices to penetrate the passenger compartment or to cause windshield damage. Postimpact location of the test device was noted, as was all debris formed by the impact.

Two categories of test vehicles were used—1,800-lb Honda front-wheel-drive sedans and full-size rear-wheel-drive sedans of various makes and models, each weighing about 4,500 lb. Windshield conditions were recorded in detail before and after impact to assess actual damage from each test. Test speeds varied from 20 to 60 mph, representing the range of speeds typically encountered in work zones.

NCHRP Report 230 (4) presents safety evaluation guidelines for crash tests involving highway safety appurtenances. Those evaluation factors include structural adequacy of the device tested, risk of injury to vehicle occupants, and postimpact trajectory of the test vehicle. Traffic control devices evaluated in this study, however, serve a different function. In addition to differences in structural capacity and intended function, the environment in which work zone TCDs are used varies considerably from that of typical permanent safety appurtenances. Considering the evaluation factors in NCHRP Report 230 (4), as well as the intended function of work zone TCDs and the environment in which they must function, three specific criteria were developed for evaluating these tests:

1. Passenger Compartment Intrusion—Intrusion into the vehicle by any debris from the test device caused by the impact was considered unacceptable because it greatly increases risk of injury to its occupants.

2. Loss of Vehicle Control—Because work zones often provide restricted operating space for vehicles, and numerous hazards are frequently located close to the designated travel lanes, interference with driver control of the vehicle resulting from a TCD impact is considered unacceptable. Loss of control may occur in four ways: (a) physical interference by the test device with vehicle steering and braking; (b) windshield damage restricting driver visibility or startling the driver so that vehicle control is lost; (c) debris thrown into opposing traffic lanes appearing hazardous to an oncoming driver, causing emergency evasive action, leading to loss of control and a secondary collision; (d) sand or other debris scattered on the pavement leading to loss of control of other vehicles, especially motorcycles.

3. Physical Threat to Workers or Other Vehicles—Because of close proximity of construction workers and other traffic to the TCDs, devices or fragments thrown by an impact may present a hazard. Size, shape, weight, composition, and dis-

tribution of debris were recorded for each test and evaluated to determine whether the debris constituted a hazard.

Following completion of the test program, each test was rated according to these three criteria. In addition, cosmetic damage to the vehicle and TCD damage were noted because each represents a cost factor. Rating factors for each criterion are presented in Table 1.

TRAFFIC CONTROL DEVICES AND TEST PARAMETERS

Six types of traffic control device were tested—steel channelizing drums, plastic channelizing drums, temporary traffic signs and supports, Type I and III barricades, and miscellaneous small channelizing devices. In addition, a variety of ballast procedures, warning lights, and other parameters were

TABLE 1 SUMMARY OF EVALUATION FACTORS

PASSENGER COMPARTMENT INTRUSION

1. Windshield Intrusion
 - a. No windshield contact
 - b. Windshield contact, no damage
 - c. Windshield contact, no intrusion
 - d. Device embedded in windshield, no significant intrusion
 - e. Partial intrusion into passenger compartment
 - f. Complete intrusion into passenger compartment
2. Body Panel Intrusion (yes or no)

LOSS OF VEHICLE CONTROL

1. Physical Loss of Control
2. Loss of Windshield Visibility
3. Perceived Threat to Other Vehicles From Debris
4. Debris on Pavement

PHYSICAL THREAT TO WORKERS OR OTHER VEHICLES

Harmful Debris (yes or no)

VEHICLE AND DEVICE CONDITION

1. Vehicle Damage
 - a. None
 - b. Minor scrapes, scratches, or dents
 - c. Significant cosmetic dents
 - d. Major dents to grill and body panels
 - e. Major structural damage
 2. Windshield Damage
 - a. None
 - b. Minor chip or crack
 - c. Broken, no interference with visibility
 - d. Broken and shattered, visibility restricted but remained intact
 - e. Shattered, remained intact but partially dislodged
 - f. Large portion removed
 - g. Completely removed
 3. Device Damage
 - a. None
 - b. Superficial
 - c. Substantial, but can be straightened
 - d. Substantial, replacement parts needed for repair
 - e. Cannot be repaired
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tested. The TCDs and other parameters discussed in the following sections are presented in Table 2.

Steel Channelizing Drums

Steel 55-gal drums, once widely used as channelizing devices in highway work zones, are no longer permitted on New York projects. Five empty drums weighing 50 to 55 lb were tested, all with closed tops.

Plastic Channelizing Drums

Twelve different models from six manufacturers or suppliers were tested, including five specific types. Two-piece drums with detachable bases had a closed top and open bottom, and snap over a low base unit. Ballast may be placed inside on the base. On impact, the two pieces separate, with the ballast and base intended to stay near the impact point. One type of one-piece drum used had a closed top and open bottom, with external tabs provided at the bottom for ballast. Another had a closed top and bottom, but the base was slotted to form radial fingers. The drum is inverted, ballast is inserted through the slotted fingers, and the drum is then placed with the slots down. Drums were also tested with an open top, with the ballast simply placed inside on the base. They may be specifically designed for use in this manner, or two-piece units may be purchased without a base and inverted for use. The final drum consisted of upper and lower pieces separated at about midheight. Ballast may be placed inside, and the top is fitted over the bottom to form a closed unit.

Temporary Sign Support

Six different types of supports were tested. A 12-lb steel tripod support can accommodate sign panels up to 48 in. square, either rectangular or diamond shaped. A fixed wood support included a nominal 4- by 4-in. by 16-ft wood post imbedded 4 ft in the ground, and stiffened by 2- by 4-in. by 8-ft diagonal braces. These braces were attached to stakes driven into the ground and to the post 6 ft above the ground. The support was tested with the longitudinal brace facing both toward and away from the impact vehicle. Height from the ground to the bottom of the 4- by 4-ft by $\frac{5}{8}$ -in. plywood diamond sign panel was 7 ft. Tall portable wood supports were constructed from 2- by 4-in. and 2- by 6-in. wood elements. Base dimensions were 3- by 4-ft for one support and 27 in. by 5 ft for the other. Two 2- by 4-in. vertical supports were stiffened by one lateral and two longitudinal 2- by 4-in. diagonal braces. Tests were conducted with these braces facing both toward and away from traffic. A 4- by 4-ft rectangular plywood panel 52 in. above ground was included. Both were ballasted using two 50-lb sandbags. A low portable wood support constructed from 2- by 4-in. wood elements was tested with diagonal braces facing both toward and away from the impacting vehicle. Base dimensions were 3 by 4 ft. A 4-ft-wide by 3-ft-high plywood sign panel was mounted 12 in. above the pavement. Ballast was provided by two 50-lb sandbags. A proprietary steel support had four horizontal legs in an X pattern and an adjustable steel vertical support attached to the legs through a spring mechanism. A 4-ft diamond aluminum sign panel was mounted about 4 ft above ground. Ballast was provided by four 50-lb sandbags, one on each leg. A generic design developed by the New York State Thruway Authority was constructed using

TABLE 2 SUMMARY OF TRAFFIC CONTROL DEVICES AND TEST PARAMETERS

Device and Description	Device and Description
STEEL DRUM (55 gal)	BALLAST
PLASTIC DRUM	Sandbag internal
Two-piece, detachable base	Sandbag external
One-piece, base tab	Sandbag on top
One-piece, base fingers	Sandbag suspended
Open top	Water
Two-piece, split middle	Gravel
SIGN SUPPORTS	Concrete block on top
Steel tripod	Miscellaneous material
Low wood, portable	Does not apply, none
Tall wood, portable	WARNING LIGHTS
Tall wood, fixed	Light not attached
Metal, miscellaneous	Light attached with bolt
BARRICADES, TYPE I	Light attached with bolt and washer
8-ft wood, plastic legs	Light attached with bolt and cable
2-ft plywood, metal legs	No light
3-ft metal, metal legs	
5-ft metal, metal legs	
BARRICADES, TYPE III	
Wood	
PVC	
Metal	
MISCELLANEOUS CHANNELIZING DEVICES	
Cones	
Tube	
Vertical panels	

1½ in. and 1¾ in. square perforated steel tube. Two 1¾ in. square, 5-ft-long legs with vertical stubs supported two 1½ in. square, vertical supports that slipped into the base stubs. Two transverse braces connected the vertical supports. A 4-by 5-ft plywood panel was mounted 6 ft above the pavement. Four 50-lb sandbags (one on the end of each leg) provided ballast.

Type I Barricades

Four different models of Type I barricades were tested. The smallest was a 2-ft plywood and metal barricade fabricated from steel angle legs and 2-ft by 6-in. plywood panels and lateral braces, weighing 19.3 lb. A 3-ft metal barricade included round tubular-steel legs and a 3-ft by 6-in. sheet metal panel weighing 18.2 lb. A 5-ft metal barricade consisted of square tubular steel legs and a 5-ft by 8-in. sheet metal panel. Its weight was 31.8 lb. The largest Type I barricade included a 2- by 8-in. by 8-ft wood panel and molded plastic legs, weighing 29.9 lb.

Type III Barricades

Four models were tested. The first was constructed from 2-by 6-in. wood elements, and was 4 ft wide by 5 ft high. It had three panels and weighed 60 lb. Because of its weight, no extra ballast was used. Two variations of polyvinylchloride (PVC) plastic were tested, each 4 ft wide by 5 ft high. These are shown on NYSDOT Standard Sheet 619-4R1 as Alternates A and B. Alternate A had glued joints, while Alternate B was not glued but included an external tie wire to provide stability, plus an internal rope to retain debris on impact. Both were constructed using 3-in.-diameter pipe meeting ASTM D 2665 standards. A metal unit was constructed from 1½ in. square 12-gauge perforated steel tube, and was also 4 ft wide by 5 ft high. The panels were lightweight aluminum, of total weight 57 lb. This device included hinges attaching the vertical members to the base, and was intended to fold down on impact. No ballast was used.

Miscellaneous Channelizing Devices

These devices included cones, a tubular marker, and vertical panels. Three cone types were tested. Two were one-piece cones fabricated from flexible plastic 34.5 and 36 in. high. The third was a rigid plastic two-piece cone, 36.5 in. high. The detachable base can be filled with sand or water for ballast and slipped over the cone body. All three cones weighed about 11 lb each. A 42-in.-high, plastic, two-piece tubular marker weighed 13 lb and included a heavy plastic base for stability. Two vertical panels were tested; one was a 6- by 36-in. plastic panel mounted on a fiberglass vertical support. It was attached to a 16-in.-square steel base plate to provide ballast, and weighed 33 lb. The other was an 8- by 24-in. plastic panel mounted on a nylon support, and attached to a 13- by 18-in. PVC plastic base. Its total weight was 22.5 lb.

Ballast

Eight different methods of ballast, plus unballasted TCDs, were included in these tests. A single sandbag weighing 50 lb was the standard ballast device for these tests. This sandbag consisted of dry gravel inside a reinforced polypropylene sample bag closed with packing twine. For the channelizing drums, a single sandbag was placed inside on the base, externally on the ballast tab at ground level, or on top of the drum. For sign supports and barricades, up to four sandbags were placed on the base supports, depending on the number required to provide stability against overturning from wind loads. For one drum test, a 30-lb sandbag was suspended inside the drum, hung from the top by a cable. Two traffic cones were tested with suspended 8-lb sandbags. One inverted drum was filled halfway with water weighing about 150 lb. One open-top drum was ballasted with 180 lb of loose gravel inside. A concrete block weighing 42 lb was placed on top of plastic drums in two tests. This ballast is similar in size and weight to heavy-duty batteries sometimes placed on top of drums to power warning lights. Pieces of rock or broken concrete pavement provide similar ballast. Construction debris consisting of a broken 42-lb concrete block and 13 lb of wood scraps was placed inside one open-top plastic drum.

Warning Lights

Type A warning lights were attached to a number of devices by various means (see Table 2).

RESULTS

Table 3 presents full-scale tests in this investigation.

Steel Drums

None of the five tests on steel drums provided satisfactory results in terms of all evaluation criteria. None resulted in passenger compartment intrusion, but all five interfered in some measure with vehicle control. Two 1,800-lb cars and one 4,500-lb car rode up onto the collapsed drum, with partial or full loss of steering control in 45- and 60-mph tests. In addition, the small car nearly rolled over in the 45-mph test before coming to rest partially on the drum. In the other two tests, at 30 and 45 mph with 1,800-lb cars, the drum bounded ahead of the car, threatening injury to workers as well as loss of control by other drivers resulting from severe evasive maneuvers. Figure 1 shows an 1,800-lb vehicle riding up on a 55-gal drum in a 60-mph impact.

Plastic Drums with Sandbag Ballast

Drums ballasted with 50-lb sandbags at ground level (see Figure 2) underwent 24 tests, with satisfactory results in 18 tests. Five of the six unsatisfactory tests had drum parts flying into traffic areas with potential for causing severe evasive maneuvers. The sixth unacceptable test resulted from sandbag

TABLE 3 SUMMARY OF FULL-SCALE TEST RESULTS

Device	Total Tested	Satisfactory	Failed Evaluation Factor*		
			Passenger Compartment Intrusion	Loss of Control	Threat of Debris
Steel Drums	5	0	0	5	2
Plastic Drums					
50-lb Sandbags	24	18	0	6	0
Unballasted	15	11**	0	4	0
Nonstandard Ballast	7	2***	2	3	3
Warning Lights	19	5	1	3	14
Temporary Signs and Supports	10	1	0	9	9
Types I and III Barricades	9	1	2	8	7
Small Channelizing Devices	19	16	0	1	2
Total	108	54	5	39	37

*Some devices failed more than one factor, thus total failures may exceed total devices tested.

**Four tests included drums thrown to one side, but not judged to threaten other traffic.

***One test rated satisfactory for primary criteria resulted in extensive vehicle damage.



FIGURE 1 An 1,800-lb car impacting a 55-gal steel drum at 60 mph resulted in loss of vehicle control.

ballast in an open-top drum scattering across the pavement, and causing a skidding hazard. Typical impact performance by plastic drums ballasted with sandbags at ground level consisted of the sandbag and base (if used) remaining near the point of impact, with the drum staying against the front of the car or under it. Even in several impacts with the front corner of the vehicle, drums wrapped around the car's front and stayed there or came to rest under it. Drums with detachable bases, external base tabs, or slotted base fingers all displayed similar behavior. Damage to plastic drums was variable, 11 tests resulting in only superficial damage. Seven drums were completely destroyed, and the other six experienced intermediate damage. Both open-top drums and one two-piece drum split at midheight were totally destroyed, as was one with slotted base fingers. This severe damage related to ballast being trapped inside the drum, thus offering increased resistance to movement by the drum on impact. It was also apparent that some brands of drums were more resilient than

others, experiencing less tearing and breakage in similar impacts. Some drums were used in several tests—although some were completely destroyed after only one impact, others were still serviceable after several impacts. Plastic drums with sandbag ballast placed at ground level generally provided excellent performance. However, open-top drums with internal ballast and two-piece drums split at midheight both resulted in debris that could threaten other traffic.

Unballasted Plastic Drums

Performance was similar to that of the drums ballasted with 50-lb sandbags. Test results were completely satisfactory in 7 of the 15 tests, with the drum staying with the car. In four other tests, drums were pushed to the right by brushing impacts. Although drum trajectories were not sufficient to threaten other traffic significantly, they did include thrown debris. Because of their light weight and soft material construction, this debris did not threaten workers. Four out of 15 tests, all involving two-piece drums split at midheight, resulted in the top half being thrown high into the air and a long distance into the work zone, even for 30-mph impacts by only 1,800-lb cars. This behavior was considered a possible threat to other traffic, and these four tests were classified as unsatisfactory. Damage was similar to ballasted drums, with 11 out of 15 drums suffering only superficial damage. Four drums were destroyed—two from corner impacts with front tires rolling over the drum, and the other two from shattering and tearing on impact. Other than reducing the drum damage caused by added resistance of the sandbag ballast, performance of unballasted drums was similar to those with ballast. On the basis of these tests, bagged sand ballast at ground level, up to 50 lb per drum, does not appear to affect drum performance adversely.



FIGURE 2 Typical impacts with plastic drums ballasted with 50-lb sandbags resulted in drums staying with the front of the car (top), being pushed aside in a brushing impact (center), and two-piece drum being thrown high into the air (bottom).

Plastic Drums with Nonstandard Ballast

Ballast, other than bagged sand at pavement level, provided satisfactory results in only two of seven tests. A suspended 30-lb sandbag hanging from the top of the drum provided acceptable results. Another drum containing about 20 gal of water met the three primary criteria, although the drum was destroyed and the front of the car sustained substantial dam-



FIGURE 3 A 42-lb concrete-block ballast placed on a drum resulted in unacceptable intrusion into the passenger compartment.

age in a 60-mph test. The five other tests were considered unsatisfactory. Two tests used 42-lb concrete blocks on top of the drum as ballast. In the 30-mph test, the block entered the passenger compartment through the windshield, and nearly exited the rear window (Figure 3). In a similar test at 45 mph, the block impacted and severely crushed the leading edge of the roof, but did not enter the passenger compartment. Both of these tests represented potentially fatal injuries to vehicle occupants. A sandbag on top of a drum resulted in sand scattered over a wide area of pavement, considered unacceptable debris. An open-top drum, ballasted inside with 180 lb of gravel, was torn apart on impact, and the drum's top portion was thrown and could have threatened other traffic.

Finally, an open-top drum ballasted with construction debris—broken concrete and 2- by 4-in. lumber—resulted in debris thrown throughout the work zone, an unacceptable risk to workers and other traffic. In addition to unacceptable behavior in terms of the primary evaluation criteria, all three open-top drums and the drum with a sandbag on top were destroyed by the impacts (this last drum had been impacted in four previous tests). Added resistance of the heavier ballast and the inability of internal ballast to separate from the drum resulted in severe impact forces. In previous tests with standard ballasts, most drums withstood similar impacts with only minor damage.

Plastic Drums with Warning Lights

Of 19 tests of plastic drums with Type A warning lights attached (Figure 4), only five met the primary evaluation criteria. Lights were attached to the drums by various methods. The primary problem was that the lights, weighing about 6 lb including lantern batteries, separated on impact and flew through the work zone, creating hazards to workers or other vehicles' windshields. In two 60-mph tests, batteries traveled about 250 ft from impact, and over 150 ft in several others. Several attachment methods were examined. In one test with an unbolted warning light set into a retainer pocket molded into the top of the drum, the light detached on impact as expected. In 11 tests, the light was attached using a 1/2-in. bolt without a washer. Attachment points to the drums included various retainer tabs and pockets, and on open-top drums the light was bolted to the side. In all but 2 of these 11 tests—both at 30 mph—the bolts pulled through the plastic and the lights detached on impact. In eight of the nine tests in which lights broke free, they were considered a hazard to workers, and in the ninth the light embedded in a windshield. In three other tests, lights impacted and damaged windshields, although there was no penetration, and then were thrown into the work zone.

In an attempt to avoid light detachment, seven additional tests were conducted with 1-in.-OD washers installed behind the bolt heads to prevent their pulling through the plastic. In three tests with 4,500-lb cars, two at 60 mph and one at 30 mph, the lights remained attached to the drums, and the drums stayed with the front of the car on impact, thus providing acceptable results.

None of the four tests with 1,800-lb cars at 60 mph were acceptable. In one, the bolt and washer pulled through the plastic and the light impacted the windshield. In the second, the top of the drum broke apart, throwing the light into the work zone. In the third, the light unit remained attached but the battery compartment ruptured, throwing the batteries into the work zone. In the fourth, the light remained attached but the increased weight of the light on the top of the drum, combined with the low frontal profile of the small car, resulted in the drum's flying over the car rather than staying in front, presenting a potential threat to other traffic and workers.

Temporary Sign Supports

Of 10 supports tested, only one met the three primary evaluation criteria. Nine tests resulted in interference with control



FIGURE 4 Attaching warning light to channelizing drums resulted in lights being thrown on impact and drums flying over the vehicle (top), with varying degrees of windshield damage (bottom).

of the vehicle from windshield impacts or threatening debris, as well as debris considered a threat to workers or to the windshields of other vehicles (Figure 5). In four tests on low-mounted signs, with the bottom of the panel at bumper height, rigid wood or metal panels were flipped back into the car windshield, three of the four resulting in windshield damage. In addition, the steel tripod and wood supports were all thrown on impact, threatening other workers and traffic.

In four 60-mph tests on high-mounted signs on timber supports (panels were above the car roof) the panels presented no hazard. In every case the test vehicle passed under the panel, which dropped to the pavement near its original location. However, the 2- by 4-in. lumber braces were thrown on impact and presented a hazard to other vehicles and workers. In three out of four tests, debris from the support also impacted and damaged the test vehicle's windshield.

Use of a commercial metal tripod with a 4-ft diamond sign panel mounted 4 ft above the pavement, tested at 55 mph, resulted in the panel's being pulled down into the windshield on impact. The vertical support did not fracture or release on impact, but instead deformed against the front of the car. The panel broke free after striking the hood and windshield and was thrown over the car, presenting a hazard to workers and other traffic. Except for one leg that broke free but remained on the pavement, no harmful debris resulted from the support.



FIGURE 5 A portable low-mounted sign resulted in windshield penetration and debris (top). A tall portable sign resulted in unacceptable debris, although the panel cleared the car (bottom).

If equipped with a flexible rather than rigid panel, this support might perform acceptably.

The metal support constructed by the Thruway Authority was the only one to perform acceptably. The vehicle impacted one leg and passed under the panel. One base support broke free and slid along the pavement, and the panel and remaining support fell at the impact point.

Type I and III Barricades

Four tests on Type I barricades resulted in debris being thrown into the work zone, threatening workers and other traffic (see Figure 6). In three 60-mph tests, debris was thrown from 102 to 172 ft, and in the single 30-mph test, 70 ft. Considering that these barricades weighed 18 to 32 lb and included various steel and wood members, this debris appears to present a significant hazard if it were to strike a worker or the windshield of another vehicle. In each case, debris was thrown high in the air, presenting a substantial risk that such contact would occur.

A 45-mph impact on a wooden Type III barricade resulted in unacceptable debris—pieces of 2 by 6 in. were thrown 150 ft from impact. This was expected, and wooden Type III barricades have not been permitted on New York State projects for the last decade.

Three tests of PVC-plastic Type III barricades resulted in their shattering, with debris thrown up to 207 ft from impact at 60 mph. Resulting debris was light in weight, and did not appear to represent a significant hazard to workers or other traffic. All three tests resulted in broken windshields on the test vehicles. In two of the three tests, a warning light was attached to the top barricade rail that contributed to windshield damage. In the third (at 60 mph) the windshield of the large sedan was shattered by impact with the top barricade rail (Figure 7). All three tests with PVC barricades were thus considered unsatisfactory because of windshield damage. These barricades were all constructed using heavy grade pipe (ASTM D 2655) and a lighter grade might prevent this damage.

Results of a single 60-mph test on a metal Type III barricade were considered acceptable. It deformed around the front of the 1,800-lb vehicle and produced no debris or impact with the windshield. The barricade was extensively damaged, with some cosmetic damage to the front of the impact vehicle, but no threat to workers, other traffic, or occupants of the test vehicle.



FIGURE 6 Collision with a Type I barricade resulted in unacceptable debris.



FIGURE 7 A 60-mph impact with a PVC Type III barricade resulted in a shattered windshield.

Small Channelizing Devices

In 19 tests on cones, tubes, and panels, 16 provided acceptable results. Two of the three unacceptable tests resulted in warning lights attached to the devices being thrown on impact. In addition, one vertical panel provided unacceptable results when its base plate was tipped over before impact. A front tire impacted the leading edge of this steel plate, resulting in a blowout and partial loss of steering control. In addition, the plate was thrown into the work zone by the impact, although it remained near pavement level. In seven out of nine tests, at speeds ranging from 20 to 60 mph, the panels, vertical supports, and base plate connections were damaged to the extent that replacement parts were required to place the device back in service, and one was damaged beyond repair. In this regard, vertical panels were inferior to cones and tubes, with only 2 of 10 devices tested requiring repair after impact. Except for warning lights added to these devices and an improperly deployed vertical panel, these small channelizing devices appear to perform very well in full-scale impacts, presenting no significant hazard to workers or traffic.

SUMMARY AND FINDINGS

Test procedures and evaluation criteria based on modifications to those in NCHRP Report 230 (4) provided considerable insight into the performance of typical work zone traffic control devices. Results of 108 full-scale tests show that some devices create hazards when impacted. Performance deficiencies noted included penetration of the passenger compartment through the windshield, loss of or interference with vehicle control, and debris thrown through the work zone that was considered potentially hazardous to workers or passengers of other vehicles.

Although some test results were not considered acceptable, many devices performed well in a number of tests. Plastic channelizing drums, both unballasted and ballasted with 50-lb sandbags, typically performed well, in most cases staying with the car's front after impact. However, open-top drums

with ballast inside and two-piece drums split at midheight generally did not perform as well. Small channelizing devices—cones, tubes, and vertical panels—also performed well in most tests. On the other hand, 55-gal steel drums performed poorly, resulting in loss of vehicle control or threatening workers and other traffic when the drums were thrown through the work zone.

Nonstandard ballast, especially heavy ballast on top of drums, caused potentially severe results from penetration of the windshield and debris thrown through the work zone. Warning lights attached to channelizing devices also detracted from performance. In some cases, lights were thrown free on impact and damaged the windshield or were thrown through the work zone, causing a hazard to workers and other traffic. In other cases, lights caused drums to fly over the impacting vehicle rather than remain in front of it, but no lights completely penetrated a windshield.

Most portable sign supports tested did not perform acceptably. Rigid panels mounted at bumper height impacted windshields, threatening intrusion into the passenger compartment. Panels mounted above roof level cleared the car and remained near the impact point. However, debris from temporary timber and steel supports was thrown through the work zone in most tests, causing severe hazard to workers and other vehicles.

Type I and III barricades also provided mixed results. All four Type I barricades tested, even in 30-mph tests, were thrown on impact and appeared to represent a risk to workers and other traffic. PVC-plastic Type III barricades resulted in considerable debris, although this was not considered a significant threat. However, all PVC Type III barricade tests resulted in windshield damage. A steel Type III barricade performed well, with no debris and no windshield damage.

Based on 108 full-scale crash tests on 62 combinations of work zone traffic control devices and installation conditions, the following findings can be stated:

- Full-scale vehicle tests based on modified NCHRP Report 230 procedures and evaluation criteria provided significant insight into impact performance of work zone traffic control devices.
- Many typical work zone traffic control devices performed well, but some devices and deployment conditions resulted in potentially hazardous performance in a number of tests.
- Plastic drums, cones, tubes, and vertical panels performed well in most tests when properly deployed and ballasted.
- Improperly ballasted channelizing devices, especially ballast placed above ground level, may present a significant hazard to motorists and workers.
- Warning lights attached to channelizing devices became flying objects in a number of tests, which resulted in windshield damage in some tests, although none completely penetrated a windshield. They may also threaten workers when the lights are thrown into a work zone.
- Most temporary sign supports tested did not perform well. Rigid sign panels mounted at bumper height were thrown onto windshields. In addition, debris from several supports threatened workers and other traffic.
- Type I and III barricades had mixed results. Some performed well, but others resulted in windshield damage, unacceptable debris, or both.

This research is also described in Research Report 147 (8), available from the Engineering Research and Development Bureau, New York State Department of Transportation, Albany, N.Y. 12232. That report provided detailed data on each of the 108 tests conducted, as well as an expanded description of the test procedures and evaluation criteria used.

REFERENCES

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