



Log H-565B

National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: June 3, 1992

In reply refer to: H-92-46 through -49

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The number of fatalities that occurred in highway work zones increased from 489 in 1982 to 780 in 1988. Concurrently, total spending on highway construction increased from about \$32 billion to about \$52 billion. The Nation's interstate system, for the most part, has been completed. As the infrastructure ages, the number of maintenance and construction zones to repair and to replace sections of the network can be expected to increase. Further, growth in traffic volume has required that roadway capacities be increased to provide a more desirable level of service to motorists; thus construction for this reason can also be expected to increase. The available data indicated that unless additional efforts were made to reduce work zone accidents, the number of fatalities would continue to increase. Because of these factors, the National Transportation Safety Board became increasingly concerned about the adequacy of traffic safety in work zones and initiated a study in 1988 concerning work zone related accidents. More than 40 accidents were investigated during the next 2 years, and previous work zone accidents investigated by the Safety Board were reviewed.

In July 1990, as the review of the accident cases neared completion, the Safety Board conducted a major investigation of a work zone accident near Sutton, West Virginia. Eight persons were killed in the accident, and five vehicles were either destroyed or severely damaged. In its statement of probable cause, the Safety Board determined that contributing to the cause of the accident was the less than optimal work zone control devices and procedures used at the site. The accident underscored the Safety Board's concern regarding safety in work zones, and several safety recommendations were issued to the West Virginia Department of Transportation and the Federal Highway Administration to improve work zone safety.

Additional investigations of work zone accidents were conducted in 1990 and 1991, as they occurred. A review of these accidents and the Sutton, West Virginia, accident raised additional work zone safety issues that are discussed in the Board's study.¹

¹ National Transportation Safety Board. 1992. Highway Work Zone Safety. Safety Study NTSB/SS-92/02. Washington, D.C.

About 9 a.m. on September 26, 1989, four State of Illinois Department of Transportation maintenance trucks began a pavement striping operation, traveling north in the right northbound lane of I-39 near Ogle County, Illinois, at a speed estimated by one of the truckdrivers to be 20 mph. The operation included the painting of the right edgeline and the dashed white line separating the two northbound lanes. The paint striping machine was being pulled by the lead truck. The last truck, a 1987 Ford 8000, was equipped with a truck-mounted attenuator (TMA), which is a type of crash cushion mounted typically on the rear of a State transportation vehicle. No advance signs warning of the painting operation ahead were posted on the 10-foot-wide shoulder, nor were they required to be.

About 10:50 a.m., a 1986 Mack tractor, traveling in the right northbound lane and pulling a 1970 Heil dry bulk trailer loaded with dry concrete (78,000 pounds), overtook the painting operation on a straight section of roadway and struck the rear of the TMA-equipped Ford 8000 truck at a speed estimated by the driver of the Mack truck to be 55 to 60 mph. Another truckdriver following the Mack truck indicated that the driver of the Mack truck may have been traveling at 65 mph. The Mack truck crushed and overrode the TMA on the rear of the Ford truck and pushed the Ford truck across the left northbound lane and into the median of I-39. From the point of impact, the vehicles traveled a distance of about 700 feet to their final resting positions.

Most likely because the TMA absorbed a substantial amount of the impact forces, the driver of the Mack combination vehicle was not injured. The driver of the Ford truck received minor injuries (cervical neck strain, scalp abrasion, abrasion/contusion on his right calf) and was treated and released from a local hospital.

On the morning of March 19, 1989, the California Department of Transportation was conducting a trash removal/sweeping operation on I-5, in Downey, California. The highway in this area was four lanes in each direction separated by a W-beam guardrail. The vehicles involved in the trash removal/sweeping operation included (from front to rear) a trash truck, two dump trucks, two sweepers, and two shadow trucks. Both shadow trucks were equipped with TMAs on the rear, flashing arrow board signs, and a white and black warning sign that read "Sweeper Ahead."

About 6:30 a.m., while the sweeping operation was being conducted in the lane adjacent to the median, traveling at a speed estimated by the driver of the last truck in the operation to be 3 mph, a Dodge Omni traveling north on I-5 ran into the TMA on the rear of the last truck in the sweeping operation. According to the driver of the Omni, he had been traveling about 55 mph before applying his brakes, but was unable to stop before impacting the TMA.

The Dodge Omni sustained crush damage across the front to a maximum depth of 2 feet. The TMA sustained severe crush damage; there was no damage to the shadow truck. Based on the damage to the TMA, the estimated speed of the car at the time it struck the TMA was between 30 and 40 mph.

Neither the driver of the Dodge Omni nor the driver of the shadow truck was injured as a result of the accident. Both drivers were restrained with lap/shoulder belts. Although the Safety Board has some concerns that advance warning signs were not being used in the above two examples of slow moving maintenance operations and believes that the lack of severe injuries can be attributed, in part, to the fact that occupant restraints were used in one case, the benefits of using truck mounted attenuators in slow moving, maintenance operations are apparent.

On May 17, 1989, the Texas Department of Highways and Public Transportation was painting pavement stripes on I-20 eastbound near Sweetwater, Texas. About 3:05 p.m., maintenance personnel positioned a 1985 GMC 7000 truck astraddle the right edgeline about 1/2 mile west of the area being painted. The truck was equipped with a Hex-Foam TMA on the rear and a flashing arrow board mounted about 6 feet above the ground. Shortly after the truck equipped with the TMA was positioned astraddle the right edgeline, a 1989 Ford F250 pickup truck, traveling about 65-67 mph in the right eastbound lane, skidded 10 feet and then impacted the left side of the TMA. The pickup truck then struck the left side of the GMC truck. The TMA was crushed about 12 to 18 inches along the entire 7-foot-long left side, and the metal backup plate was pushed inward about 2 feet. There was about 12 inches of contact damage along the right side of the pickup truck, and the hood, door, and roof were crushed into the passenger's seating area.

The passenger of the pickup truck, who was restrained with a lap/shoulder belt, was killed. The driver of the pickup truck, who was also restrained, received moderate injuries. Most likely because of the angle at which the TMA was impacted, the effectiveness of the TMA to mitigate injuries was substantially reduced.

The statement by the manufacturer of the Hex-Foam TMA--that it warns users of TMAs not to position a truck with a TMA astraddle or partially in a lane--raises concerns regarding the adequacy of guidance currently available on the applicable uses of TMAs. Although the manufacturer's statement may be sound advice, there appears to be little additional information to support or refute such a position, despite the ever increasing use of these devices by State departments of transportation in the last few years.

Because of the limited guidance available on the use of TMAs, researchers at the University of Tennessee Transportation Center in 1989 conducted extensive interviews with highway agency personnel from five States involved in maintenance and construction work zone activity. The interviews were to be the basis for developing a set of guidelines on the use of TMAs. The results of the interviews indicated that the most common application of TMAs was for protection of workers and motorists in moving work zones. Those interviewed, however, voiced strong support for more frequent use of TMAs on barrier vehicles in stationary operations. Based on the information gathered, the researchers developed suggested priorities for the application of TMAs.

In their conclusions, however, the researchers cautioned:

Two limitations on the significance and suggested use of the guidelines are acknowledged by the research team. First, the project was not a research project spelled with a capital "R." Such an effort would have involved the collection and analysis of data which are not readily available, at a cost measured in \$100,000s (well beyond the budget of this project) over a period of time measured in years. Second, the guidelines in the present format are most appropriately used as a policy formulation and budgeting tool. Further refinement and simplification will be required.

The Safety Board's investigations of work zone accidents over the last several years revealed that the severity of several accidents could have been substantially reduced had TMAs been used on barrier vehicles at stationary work zone sites.

In June 1988, pavement work was being performed in the left lane of southbound I-57 near Effingham, Illinois. A flagger was located about 1,286 feet into the zone about 100 feet ahead of a pavement grinding machine that was working in the left lane near the center line and extending across the center line about 14 inches.

About 8:35 a.m., on June 15, 1988, a 1984 Freightliner truck tractor pulling a van semitrailer was traveling at an estimated speed of 55 to 70 mph in the right lane approaching the construction zone. According to witness statements, about 1,076 feet into the work zone, the driver applied the brakes in emergency and the unit veered to the left straddling the center line with its left side tires. The truck then skidded about 330 feet before colliding with the left front of the pavement grinder. The combination unit veered to the right, traveled about 134 feet in a jackknifed configuration, and then came to rest on the west side of I-57 engulfed in flames. The pavement grinder was rotated 228^o counterclockwise and pushed rearward about 28 feet. The truck driver and codriver were fatally injured as a result of the collision and postcollision fire. The operator of the pavement grinder was fatally injured as a result of the collision. The semi-combination was destroyed by the collision and fire, and the pavement grinder was substantially damaged.

In June 1989, a contractor hired by the Illinois Department of Transportation was installing raised reflective pavement markers on I-94, a six-lane divided highway, in Chicago, Illinois. A 4.8-mile section of the right northbound lane was closed for installation of these markers. Four crewmembers, working as two-member teams, were installing markers near the 111 Street exit ramp on the morning of June 24, 1989. One member of the team would install the markers while the other member monitored traffic.

About 8:24 a.m., a 1979 Cadillac traveling north on I-94 entered the construction zone. The vehicle had traveled about 3 miles into the construction zone when it suddenly veered to the right and entered the closed lane. The Cadillac struck three reflectorized drums and one barricade

before striking three of the construction workers. Two workers were killed and one was injured. The driver of the Cadillac stated that he had fallen asleep.

The Safety Board believes that had TMAs been in use on barrier vehicles immediately behind the workers in both of the above accidents, far more protection would have been provided to the workers, and the accidents might not have resulted in fatalities. A vehicle equipped with a TMA could easily have been positioned in front of the grinding machine in the Effingham accident, and in front of the workers in the Chicago accident.

Notwithstanding the work by the University of Tennessee Transportation System Center, the Safety Board is concerned that the use of TMAs in various work zone environments has not been sufficiently addressed in the guidance and reference materials routinely used by State and local transportation officials. According to the FHWA, because a TMA is not a traffic control device, the MUTCD and the Traffic Control Devices Handbook are not the appropriate manuals in which to discuss the applicable uses of TMAs. According to FHWA and AASHTO officials, the Roadside Design Guide would be the appropriate document in which to incorporate guidance on the applicable uses of TMAs in short-term moving/maintenance operations and long-term stationary construction sites. Although the Safety Board recognizes that additional tests and research are needed to determine the effectiveness of TMAs when impacted at an angle or offset and when used in situations where the speed differential exceeds 45 mph, the Board believes that sufficient information is currently available to provide some guidance on the various applications of TMAs. Accordingly, the Safety Board urges AASHTO to incorporate such guidance into the Roadside Design Guide. The Safety Board also believes that even though the TMA is not considered a traffic control device and, consequently, the applicable uses of TMAs would not be appropriate in the MUTCD, a reference to the Roadside Design Guide concerning the uses of TMAs would be appropriate in the MUTCD and the Traffic Control Devices Handbook.

Also of concern to the Safety Board is that drivers of vehicles equipped with TMAs may not be provided adequate protection in terms of restraints and headrests. In the moving maintenance operation of the State of Illinois Department of Transportation during September 1989, the driver of the vehicle that struck the TMA was not injured. However, the driver of the State department of transportation vehicle that was equipped with a TMA did receive minor injuries, including cervical neck strain, scalp abrasion, and abrasion/contusion on his right calf. The investigation of the accident revealed that the State vehicle was not equipped with a headrest and that the seatbelt was being worn loosely at the time of the accident. The Safety Board believes that because of the likelihood of rear-end collisions, vehicles equipped with truck-mounted attenuators need to be equipped with lap/shoulder restraints and headrests to provide drivers the maximum protection possible.

In a manual developed by one manufacturer of TMAs, safety instructions address the use of seatbelts and headrests for the occupants of trucks equipped with a TMA. The Safety Board is aware that some State highway

departments recognize the need to provide protection to the drivers of trucks with TMAs. California, for example, installs headrests and lap/shoulder restraints on vehicles equipped with TMAs. The Safety Board is concerned, however, that recognition of the need to provide the driver with adequate protection to mitigate injuries may not be widespread, as the above accident suggests. The FHWA and AASHTO should encourage State highway departments to incorporate these safety features into the specifications for the purchase of new vehicles and to retrofit existing vehicles.

Accidents investigated in conjunction with this safety study revealed several instances in which the traffic control techniques and devices were clearly not in compliance with existing guidelines. The lack of compliance raises concern about the adequacy of monitoring and reviewing traffic control plans by State department of transportation officials and the adequacy of the FHWA's emphasis on recurring problems. In addition to the lack of compliance with flagging guidelines, as evidenced in the Effingham, Illinois accident on June 15, 1988, two specific problems--pavement edge dropoffs and the obliteration of conflicting pavement markings--highlight this concern.

The MUTCD addresses the issue of conflicting pavement markings. "Conflicting pavement markings shall be obliterated to prevent confusion to vehicle operators....The intended vehicle path should be clearly defined during day, night, and twilight periods under both wet and dry pavement conditions." The Traffic Control Devices Handbook provides similar guidance, stating: "Inappropriate markings should be removed to eliminate any misleading cues to drivers under all conditions of light and weather."

Despite this guidance, the Board's investigation of an accident in South Nyack, New York, on April 26, 1989, in which the 77-year-old driver suddenly veered into the closed left lane and crashed into the rear of a dump truck, revealed that all preconstruction pavement markings had not been obliterated. Although the reason for the driver's sudden maneuver to the left lane is unknown (all occupants of the vehicle were fatally injured), it is possible that the old pavement markings caused the driver to become confused and the driver followed the old pavement markings when he veered to the left.

The investigation of an accident in Sterling, Pennsylvania, on August 14, 1989, in which the driver of the combination unit was killed, revealed that old pavement markings had not been obliterated. The preconstruction yellow edgeline was not obliterated and may have confused the already fatigued driver about the exact location of lanes.

The FHWA has addressed this issue in the past. In a memorandum dated January 7, 1988, FHWA headquarters encouraged regional administrators to "Monitor projects to assure that both temporary and permanent pavement markings and signing are properly applied and removed in work zones. Inappropriate traffic control devices are still being left in place. Division offices should review the States' policies, procedures, and projects."

The previously mentioned Roadside Design Guide developed by the AASHTO Task Force for Roadside Safety provides guidance on the need to protect

uncompacted shoulders and pavement edge dropoffs. In addition, the FHWA has recognized this problem over the years. In December 1986, the FHWA addressed the issue in a memorandum to regional administrators based on observations during field reviews. This "information was to provide guidelines to States in the development of their own dropoff policy. Any dropoff is considered hazardous, but those greater than 2 inches, left overnight, and immediately adjacent to traffic have a high accident potential." Again in 1987, the FHWA encouraged its regional and division offices to work with States in the development and implementation of policies for pavement edge dropoffs.

Despite this guidance, accidents investigated by the Safety Board in conjunction with this study indicate that the problem continues to exist.

About 10:14 p.m. on September 14, 1989, a 1988 Ford truck tractor in combination with two trailers was northbound on two-lane, two-way U.S. Highway 63 near the northern limits of Portia, Arkansas. The driver stated that as he was approaching oncoming traffic, his right tires went off the pavement. The combination vehicle traveled off the right edge of the asphalt onto a soft shoulder that was under construction. After the combination vehicle traveled about 300 feet along the shoulder, the rear trailer broke loose and rolled onto its right side. The trailer received moderate damage. The driver was not injured.

The contractor had been doing shoulder work on both sides of the travelway on the 1.4-mile project, even though Arkansas highway construction specifications stated that "shoulder material shall not be cut from the edge of the pavement on both sides of any section open to traffic." The shoulder material was a soft clay material, and in some areas of the project, the shoulder was 12 inches below grade. Because of rain on the day of the accident, the shoulders in the accident area were soft and muddy.

About 1 hour after the above accident, a second truck tractor in combination with one semitrailer, also traveling northbound, was being directed around the accident scene. As the combination vehicle was being directed to the left side of the travelway, the truck went off the edge of the asphalt onto the muddy shoulder. As the driver attempted to turn back to the right, the combination unit rolled onto its left side.

On August 3, 1989, construction work was being performed on 2.5 miles of State Highway 28, a two-lane highway, near Distant, Pennsylvania. The construction work involved building up the roadway and adding a passing lane. Approaching the construction zone southbound, the southbound lane and northbound lane were 10.25 feet wide and 12 feet wide, respectively. Within the construction zone, the southbound and northbound lane widths were 7.67 feet and 13 feet, respectively. Within the first 20 feet of the construction zone, there was a 5-inch dropoff on the outside edge of the southbound lane. Over a distance of 20 feet, the 5-inch dropoff increased to 6.5 inches onto an 8-inch-wide ledge. There was another dropoff of 6.5 inches at the outside of the ledge for a total dropoff of 13 inches from the pavement surface. No signs were posted to warn of the dropoffs or reduced lane width for the southbound lane, and pavement markings were not added to delineate the reduced southbound lane width.

About 5:15 a.m., on August 3, 1989, a southbound truck, with its lights on, loaded with 2,000 pounds of liquid nitrogen, was approaching the construction zone. Upon entering the construction zone, the southbound truck went off the pavement. The right front tire rode on the 8-inch-wide ledge (a 6.5-inch dropoff) while the right rear tires rode outside of the ledge (a 13-inch dropoff). After travelling a short distance, the truck came back onto the pavement, crossed the southbound and northbound lanes and hit a drainage culvert on the east side of the roadway. The truck then rolled over 360 degrees and came to rest in the ditch. The truckdriver sustained a broken leg.

The above accidents suggests that States are not adequately monitoring work zone projects to determine if contractors are complying with existing guidelines. The problem may well be a financial one, in that adequate funding is not available for the review and monitoring process. However, more emphasis needs to be placed on these problem areas by FHWA division offices and State transportation officials. The FHWA reviews annually each State's work zone traffic safety program and conducts on-site reviews of work zone projects. The States, however, are ultimately responsible for their or their contractors' compliance with existing guidelines. The Safety Board believes that AASHTO, in cooperation with the FHWA, should develop a program to enhance compliance with existing guidelines regarding work zone safety features. The States may need to allocate a percentage of the funding for projects for monitoring and compliance purposes.

From 1972 to 1982, 20 California Department of Transportation (Caltrans) workers were killed in construction work zones. As a result, in 1982, Caltrans initiated an educational program entitled "Give 'Em a Brake" that provided information on work zone safety through the use of billboard space, public service advertisements on radio and television, presentations to driving classes, bumper stickers, and posters. From 1982 to 1987, five Caltrans employees were killed, and according to Caltrans, California experienced a major reduction in the number of employee fatalities, injuries, and lost work days by 1989.

All but nines States have initiated work zone safety programs similar to the "Give 'Em a Brake" program since 1982 when California implemented its program. The programs initiated by the States vary from limited efforts, such as occasional news releases and public service announcements, to full year-round campaigns that involve the development of videos and educational programs for high schools, incorporation of work zone safety in driver education programs, improved traffic control devices and advisories, and onsite use of police officers for enforcement purposes. The emphasis with most of the States' programs when first implemented was to educate motorists about the dangers in work zones in order to protect the workers. Some State programs now focus on the need for drivers to recognize the dangers work zones create for motorists and have incorporated engineering, enforcement, and educational activities into their programs. The underlying issue with each of these activities is excessive speed in work zones and the need for motorists to adhere to speed limits and warnings.

Although various agencies and associations, including the FHWA and AASHTO, have encouraged the development of work zone safety programs, no agency or association has taken the lead to direct a nationwide work zone safety program. The variation and range of work zone safety programs at the State level and the expected increase in construction and maintenance work zone activity in the coming years suggests that a uniform program at the national level, analogous to Operation Lifesaver, the rail/highway grade crossing program, is needed. The FHWA and AASHTO are the appropriate agencies to take the lead in developing a national program that should address engineering, enforcement, and education. To adequately address these three areas of the program, the participation of other organizations should be enlisted, including the National Highway Traffic Safety Administration, the National Safety Council, the American Automobile Association, the American Trucking Associations, Inc., the International Association of Chiefs of Police, the American Road and Transportation Builders Association, the Associated Builders and Contractors, Inc., the American Traffic Safety Services Association, the American Association of Motor Vehicle Administrators, the International Bridge, Tunnel, and Turnpike Association, the National Association of Governor's Highway Safety Representatives, the Highway Users Federation for Safety and Mobility, and the Professional Truck Driver Institute of America. Funding for enforcement and education programs could be provided by a percentage of FHWA's apportionments to States for highway construction.

Therefore, as a result of the safety study, the National Transportation Safety Board recommends that the American Association of State Highway and Transportation Officials:

Incorporate, into the Roadside Design Guide, guidance on the applicable uses of truck-mounted attenuators in short-term moving/maintenance operations and at long-term stationary construction sites. (Class II, Priority Action) (H-92-46)

Encourage, in cooperation with the Federal Highway Administration, State highway departments to (1) incorporate headrests and lap/shoulder restraints into the specifications for the purchase of new vehicles given that the vehicles may at times be equipped with truck-mounted attenuators and (2) retrofit existing vehicles used for that purpose. (Class II, Priority Action) (H-92-47)

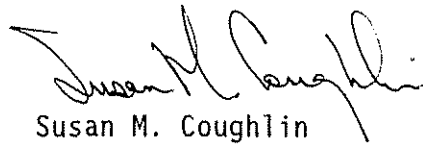
Develop, in cooperation with the Federal Highway Administration, a program to enhance compliance with existing guidelines regarding work zone safety features. (Class II, Priority Action) (H-92-48)

Develop, in cooperation with the Federal Highway Administration, a national work zone safety program that integrates substantive enforcement and public information and education efforts. Enlist the support of those organizations and associations that can provide expertise in the areas of engineering, enforcement, and education. (Class III, Longer Term Action) (H-92-49)

Also, as a result of the safety study, the Safety Board issued safety recommendations to the National Highway Traffic Safety Administration and the Federal Highway Administration.

The National Transportation Safety Board is an independent Federal agency with the statutory responsibility "...to promote transportation safety by conducting independent accident investigations and by formulating safety improvement recommendations" (Public Law 93-633). The Safety Board is vitally interested in any actions taken as a result of its safety recommendations and would appreciate a response from you regarding action taken or contemplated with respect to the recommendations in this letter. Please refer to Safety Recommendations H-92-46 through -49 in your reply.

Acting Chairman COUGHLIN, and Members LAUBER, HART, HAMMERSCHMIDT, and KOLSTAD concurred in these recommendations.



By: Susan M. Coughlin
Acting Chairman