Building Safer Highway Work Zones:

Measures to Prevent Worker Injuries From Vehicles and Equipment

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Foreword

Highway and street construction workers are at risk of fatal and serious nonfatal injury when working in the vicinity of passing motorists, construction vehicles, and equipment. Each year, more than 100 workers are killed and over 20,000 are injured in the highway and street construction industry. Vehicles and equipment operating in and around the work zone are involved in over half of the worker fatalities in this industry.

Historically, efforts to reduce vehicle-related worker injuries in this industry have focused on improving traffic control devices and work zone configurations to minimize confusion of motorists passing through the work zone and to limit collisions involving motorists. The premise has been that by minimizing traffic collisions in work zones, worker injuries are minimized. However, fatality data indicate that workers being struck by a motorist passing through the work zone account for only half the vehicle-related fatalities among highway workers.

To better understand these injury risks, NIOSH reviewed the current literature on highway safety, analyzed data on worker fatalities in the highway and street construction industry, and held a workshop with individuals from government, labor, industry, academia, and state departments of transportation. During the workshop, participants were asked to discuss measures that could be taken by employers, manufacturers, and government and research agencies that would reduce or eliminate these hazards. This document draws on the collective knowledge, experience, and expertise of numerous individuals and organizations who are intimately involved with highway construction. By bringing together partners from all parts of the industry to discuss prevention of these injuries, NIOSH hoped to improve our understanding of the hazards faced by highway workers, raise the industry's awareness of these hazards, and initiate discussion among all concerned about measures that can reduce these hazards. The material presented in this document does not constitute an all-inclusive checklist. Rather, it is a listing of interventions from which contractors, contracting agencies, and other entities may choose those most appropriate to their situations and needs. More than 50 individuals participated in the workshop, and more than 30 individuals and organizations reviewed prior drafts of this document. Each of their contributions is sincerely appreciated.

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Public Health Summary

What are the hazards?
Workers in highway work zones are exposed to risk of injury from the movement of construction vehicles and equipment within the work zones, as well as from passing motor vehicle traffic. Data from the Census of Fatal Occupational Injuries (CFOI) indicate that of the 841 work-related fatalities in the U.S. highway construction industry between 1992 and 1998, 465 (55%) were vehicle- or equipment-related incidents that occurred in a work zone.

How are workers exposed or put at risk?
Highway workers routinely work in proximity to construction vehicles and motor vehicle traffic. Flaggers and other workers on foot are exposed to the risk of being struck by traffic vehicles or construction equipment if they are not visible to motorists or equipment operators. Workers who operate construction vehicles or equipment risk injury due to overturn, collision, or being caught in running equipment. Highway workers, regardless of their assigned task, work in conditions of low lighting, low visibility, and inclement weather, and may work in congested areas with exposure to high traffic volume and speeds.

What recommendations has the federal government made to protect workers' safety?
The Federal Highway Administration has developed and maintained the Manual on Uniform Traffic Control Devices (MUTCD), which provides for uniform design and setup of highway work zones. The primary focus of Part 6 of the MUTCD is the interaction between the road user and the work zone. The MUTCD contains exhaustive specifications for signage, pavement and curb markings, traffic signals, and marking of school zones, bicycle facilities, and highway-rail crossings. It also prescribes temporary traffic control measures for numerous scenarios involving lane closures, lane shifts, detours, shoulder work, median crossovers, mobile operations, and blasting. The MUTCD addresses topics such as training, personal protective equipment, speed reduction, barriers, and lighting, as they apply to highway construction.

OSHA construction industry regulations (29 CFR* 1926, Subpart O) address operation of vehicles and equipment within an off-highway job site not open to public traffic. However, Subpart O is not exhaustive in its coverage of machinery types or safety equipment, nor does it address work practices, traffic control plans, or shift work. Flagging and signaling practices are discussed in general terms in Subpart G, which covers signs, signals, and barricades. Subpart G defers to the 1971 MUTCD on matters relating to hand signals, barricades, and traffic control devices.

Where can more information be found?
The references, additional readings, and on-line resources cited at the end of this document identify sources that provide more information on highway work zone safety. Additional information from NIOSH may be obtained through:

1-800-35-NIOSH
(800-356-4674)
http://www.cdc.gov/niosh/homepage.html

*Code of Federal Regulations. See CFR in references.

Building Safer Highway Work Zones:

Measures to Prevent Worker Injuries
From Vehicles and Equipment

Introduction

Construction contractors, contracting agencies, and others responsible for work zone safety face the challenge of providing a safe workplace while ensuring the safe movement of the public through the work zone. Highway and street construction presents a complex work situation in which workers face multiple injury risks under conditions that may change without warning.

Highway workers are at risk of injury from passing traffic vehicles:

An 18-year-old flagger, outfitted in full reflective vest, pants, and hard hat, was directing traffic at one end of a bridge approach during a night milling operation. The work zone was correctly marked with cones and signs, and the entire bridge was illuminated with street lights. The flagger was standing under portable flood lights in the opposing traffic lane close to the center line, facing oncoming traffic. A pickup truck traveling in the wrong lane at an estimated 55 to 60 miles per hour struck the flagger head on and carried him approximately 200 feet. He died at the scene of multiple traumatic injuries [Minnesota Department of Health 1992].

Highway workers are at risk of injury from construction equipment operating inside the work zone and in ancillary areas that support the work zone (e.g., temporary batch plants):

A 33-year-old construction laborer was working at a gravel-unloading operation at a highway construction site. His usual work assignment was to operate the generator for the conveyor system that moved gravel unloaded from belly dump trailers. A dump truck driver on the site was having difficulty opening the gates of his belly dump trailer. Attempting to assist the driver, the laborer went under the trailer to manually open the gates. The driver, not realizing the laborer was under the trailer, pulled away from the unloading platform and ran over him with the rear dual tires of the trailer. The laborer was pronounced dead at the scene [Minnesota Department of Health 1997].

Highway workers are at risk of injury from construction vehicles operating inside work zones, as well as construction vehicles entering and leaving the work zone:

An 11-person construction crew was paving the northbound side of a 6-lane interstate highway. The far left and middle lanes of the highway were closed to traffic, with two pavers operating simultaneously in staggered positions. Hot asphalt was delivered to the site in tractor-trailers which queued on the left shoulder while waiting to back up to the pavers. A 34-year-old construction laborer was positioned adjacent to the far left lane, approximately 12 feet behind the paver's work area, shoveling old asphalt from around a catch basin. A tractor-trailer pulled away from the paver in the middle lane and began backing. The driver stopped when he heard other workers yelling. Exiting the vehicle, he found the laborer run over by the four left rear wheels. The laborer was pronounced dead at the scene [Massachusetts Department of Public Health 1996].

The Manual on Uniform Traffic Control Devices (MUTCD) provides for uniform design and setup of highway work zones, and includes guidance for the development of temporary traffic control plans (TCPs) that determine the flow of traffic through work zones [FHWA 2000]. The Millennium Edition of the MUTCD, which went into effect on January 17, 2001, includes new signs and pavement markings, changes in both standards and guidance, new sections, and changes in Part 6, which covers work zones. The last full-scale revision of the MUTCD was in 1978; however, frequent updates have been made to specific sections of the MUTCD since that time. States have until January 17, 2003 to reach substantial conformance with the Millennium Edition of the MUTCD; therefore, both the Millennium Edition and the previous edition [FHWA 1998a] are listed in the reference section.

OSHA construction industry regulations (29 CFR* 1926, Subpart O) address operation of vehicles and equipment within an off-highway job site not open to public traffic. However, Subpart O is not exhaustive in its coverage of machinery types or safety equipment, nor does it address work practices, traffic control plans, or shift work. Flagging and signaling practices are discussed in general terms in Subpart G, which covers signs, signals, and barricades. Subpart G defers to the 1971 MUTCD on matters relating to hand signals, barricades, and traffic control devices.

Compliance with the MUTCD and OSHA regulations is a necessary first step in providing a safe work environment. However, these sources, taken together, do not provide comprehensive guidance to ensure worker safety in highway work zones. To identify gaps in standards and regulations and to compile additional prevention measures to enhance worker safety, NIOSH undertook a comprehensive review of scientific literature, fatality and injury data, and current safety research. NIOSH also convened a workshop attended by a broad range of stakeholders in work zone safety. The NIOSH workshop, "Preventing Vehicle- and Equipment-Related Occupational Injuries in Highway and Street Construction Work Zones," held in Washington, D.C., December 2 through December 4, 1998, investigated the following areas of concern:

*Code of Federal Regulations. See CFR in references.

- Safety of all workers on foot around traffic vehicles
- Safe operation of construction vehicles and equipment in highway work zones
- Planning for safe operations within work zones
- Special safety issues associated with night work in highway construction.

The workshop was attended by over 50 individuals from government, labor, industry, academia, and state departments of transportation. In breakout sessions addressing the four topic areas, participants were presented with questions to stimulate discussion about preventing occupational injuries in highway work zones. Their shared information, experiences, research results, resources, opinions, and recommendations were the starting point for this document.

Through synthesis of current research on highway work zone safety with input provided by participants in the December, 1998 workshop, this document offers additional measures that contractors, contracting agencies, policy makers, manufacturers, law enforcement, and the research community can take to reduce occupational injuries in highway work zones. This document also includes an Appendix with descriptions of highway construction fatalities investigated through the NIOSH Fatality Assessment and Control Evaluation (FACE) program. Each fatality description includes case-specific prevention recommendations.

The measures described in this document reflect ideas for reducing highway work zone injuries generated by a broad cross-section of key stakeholders. Some prevention measures are ready to be used; others deserve additional consideration and research. The material presented here does not constitute an all-inclusive checklist. Rather, the document provides a listing of interventions from which contractors, contracting agencies, and other entities may choose those most appropriate to their situations and needs. Readers should not view these prevention measures as official NIOSH recommendations.

Worker Fatalities and Injuries in Highway Work Zones

Between 1992 and 1998, the Census of Fatal Occupational Injuries (CFOI) reported 841 worker fatalities in SIC 1611 (Highway and Street Construction) [Bureau of Labor Statistics, unpublished data]. As Table 1 shows, the majority of fatalities in this industry occurred in work zones, with vehicle and equipment-related incidents similar to those described above the predominant type of fatal event.

Table 1. Fatalities in the highway and street construction industry (SIC 1611), CFOI, 1992-1998

	Number	Percent
Occurred in a highway or street construction work zone:	**492**	**58.5**
Vehicle or equipment-related	465	55.3
Other event	27	3.2
Occurred outside a work zone:	**349**	**41.5**
Vehicle or equipment-related	198	23.5
Other event	151	18
Total	**841**	**100**

Among the 492 work zone fatalities, the leading occupations were construction laborer (42%), truck driver (9%), construction trades supervisor (8%), and operating engineer (8%). The most common primary sources of injury were trucks (45%), road grading and surfacing machinery (15%), and cars (15%). Seventy-four percent of the work zone fatality victims were employed privately, the remainder by state or local governments (13% each).

In 318 of the 465 vehicle and equipment-related fatalities within work zones, a worker on foot was struck by a vehicle. Victims of these events were as likely to be struck by a construction vehicle (154 fatalities) as by a passing traffic vehicle (152 fatalities). Incidents involving backing vehicles were prominent among the 154 worker-on-foot fatalities that occurred within the confines of the work zone (51%).

The primary injury sources for fatalities of workers on foot struck by a construction vehicle within the work zone were trucks (61%) and construction machines (30%). For fatalities involving a traffic vehicle, the major injury sources were more evenly divided among cars (43%) and trucks (47%). In all but 13 of the incidents involving a traffic vehicle, the motorist left the traffic space and intruded into the work space, striking the worker. For 108 (71%) of these intrusion fatalities, the CFOI narrative denoted the worker's activity at the time of the incident. The most prominent work tasks were repairing the road (41), flagging (27), and setting or moving traffic control devices (24).

In 110 fatalities, the victim was operating a vehicle or mobile construction equipment. For vehicle and equipment operators, the primary injury sources were construction machines (53%) and trucks (26%). Thirty-eight of the 110 workers operating equipment at the time of injury (35%) were not classified in equipment operating professions. An additional 26 victims were passengers, and location could not be determined for 11 workers [Bureau of Labor Statistics, unpublished data].

In addition to vehicle- and equipment-related hazards, CFOI and other sources report that highway workers are at risk of injury or death from contact with overhead power lines, falls from machinery or structures, gas line explosions, or being struck by falling objects or materials [Blacklow and Hoffner 1996; Bryden and Andrew 1999; Ore and Fosbroke 1997; Pigman and Agent 1990; Bureau of Labor Statistics, unpublished data].

Data collection systems for nonfatal occupational injuries do not provide sufficient detail to estimate the number of workers injured in work zones nationally. Data from the Bureau of Labor Statistics (BLS) Survey of Occupational Injuries and Illnesses are reported for all of SIC 1611, with no separate tabulations for work zone incidents provided. Further, these data cover private construction firms only (public entities engaged in highway construction and maintenance are excluded). BLS Survey data for 1997 indicate that there were an estimated 22,200 injuries to employees of private highway and street construction contractors; 8,767 of these resulted in days away from work. Injuries to workers in SIC 1611 resulted in a median 7 days away from work, compared with 8 days for all construction industry injuries. In SIC 1611, 23.5% of the days-away-from-work injuries resulted in 31 or more days away from work [Bureau of Labor Statistics 1999].

An analysis of 240 incidents involving serious injuries to workers on highway and bridge construction projects in New York State confirms that highway workers are at risk of severe nonfatal injuries from being struck by or run over by traffic vehicles or by construction vehicles and equipment [Bryden and Andrew 1999]. This analysis, which covered incidents occurring between 1993 and 1997, revealed that although traffic accounted for 22% of worker injuries and 43% of worker deaths in New York, the remaining cases resulted from construction incidents not involving traffic. The most frequently occurring type of serious injury incident involved workers struck by construction vehicles or large equipment, which included 44 hospitalized injuries and 3 fatalities.

Fatal and nonfatal injury data suggest a need to focus work zone safety efforts beyond issues of motorist safety. Clearly, safety efforts must address eliminating vehicle crashes of the motoring public traveling through work zones while ensuring the safety of workers who work adjacent to traffic. However, safety efforts must also protect construction workers within work zones who are working on foot around moving vehicles and equipment, as well as those who are operating dump trucks, rollers, pavers, and other pieces of construction equipment.

The Transportation Equity Act for the 21st Century (TEA-21) authorized approximately $80 billion for highway and bridge construction between FY 1998 and FY 2003, the majority of which provides for rehabilitation of existing highways [Federal Highway Administration 1999]. Because of increased spending under TEA-21, the number of workers employed in highway and street construction is likely to increase. Further, the emphasis on rehabilitation rather than construction of new highways means that more highway workers will continue to confront the dual injury risks posed by passing traffic vehicles and by construction equipment moving within the work zone [National Transportation Safety Board 1992].

Injury Prevention Measures

Work zone layout

Road builders and maintainers can:

- Assign a traffic control supervisor who is knowledgable in traffic control principles overall responsibility for the safety of the work zone setup.
- Carefully review the TCP and, during contract negotiations, negotiate with the contracting agency as to revisions to the TCP that are needed to ensure worker safety.
  - Ensure that the work zone is set up in accordance with the Millennium Edition of the MUTCD.
  - Evaluate the effectiveness of the temporary traffic control setup by having the project supervisor walk or ride the job looking for evidence of near misses (e.g., skid marks, damaged barricades).
  - Include employees in the walk- or drive-through as a training tool, and to emphasize that safety is a continuous priority.
  - Authorize the traffic control supervisor to temporarily halt work until unsafe conditions related to temporary traffic control have been eliminated.
- Document work zone setup and changes throughout the course of the project. Retain these records in a "job file" as a reference for future jobs.
- Where provided for in contract documents, increase the size of the lateral buffer zone to reduce worker exposure to passing motorists.
- To the extent practical, keep the length of the work zone appropriate to the work in progress so that motorists do not increase speed after passing through a long stretch with no sign of work activity.

Contracting agencies can:

- Establish a streamlined process for reviewing and approving changes in the work zone setup that are necessitated by safety concerns.
- Close the road completely and reroute traffic where feasible.
- Provide alternative transportation modes and alternative routes for road users.
- On interstate and similar roadway systems, minimize worker exposure to traffic hazards by forcing traffic moving in both directions onto one side of the road and completely closing off the work space.
- Specify the use of temporary pavement markings to laterally move the traffic lane away from the work space on projects lasting less than 2 weeks.
- For night work, specify:
  - Increased taper length
  - Installation of low-level transitional lighting in advance warning areas and termination areas to ease motorists' adjustment to changing lighting conditions.

Road builders and maintainers and contracting agencies can:

- Cooperate to design and implement TCPs in accordance with safety management principles that call for a hierarchical approach to prevention of worker injuries:
  - Reduce worker exposure to injury to the extent possible. For highway construction, possible strategies to reduce exposure to injury from traffic vehicles include rerouting all traffic to one side of a multi-lane highway, or complete road closure.
  - Where worker exposure to traffic cannot be completely eliminated, use positive protective barriers to shield workers from intrusions by traffic vehicles. Examples applicable to highway work zones are truck-mounted attenuators (TMAs) and temporary traffic barriers.
  - Where installation of temporary traffic barriers is impractical or creates a greater hazard, install channelizing devices such as traffic cones and barrels to delineate the work zone. Keep in mind that channelizing devices supplement the use of temporary traffic barriers, but are a less effective physical barrier to prevent vehicles intruding into the work zone.
  - Consider additional measures such as sensors, handheld radios, and intrusion alarms, but do not rely on them as a primary protection against injury.

Policy makers (Federal, state, and local) can:

- Revise OSHA regulations for the construction industry (29 CFR 1926, Subpart G – Signs, Signals, and Barricades) to require adherence to the Millennium Edition of the MUTCD in place of the 1971 version that is currently specified [FHWA 2000; CFR]. This change would make OSHA regulations consistent with Federal Department of Transportation policy, which will require state departments of transportation to adhere to the more protective version of the MUTCD by January 17, 2003.
- Where Federal agencies have overlapping responsibilities for work zone safety, collaborate to ensure that regulations are consistent and comprehensive enough to ensure worker safety.
- Collaborate with contractors, labor, and the research community to develop tables of recommended widths for lateral buffer spaces under varying traffic speeds and volumes.

Use of temporary traffic control devices

Road builders and maintainers can:

- Use temporary traffic control devices, such as signage, warning devices, paddles, and concrete barriers, in a consistent manner throughout the work zone.
- Set up temporary traffic control within a reasonable time prior to construction so that motorists do not become complacent and ignore warning signs and devices when work begins.

- Provide flaggers with devices that increase their visibility to passing motorists and construction vehicles. One example that has been field-tested and shown to be effective is the flashing slow/stop paddle, which consists of a standard paddle with a strobe light mounted on its face [Stout et al. 1993].
- Keep channelizing devices clean and properly maintained to preserve their reflective intensity and visibility.
- Ensure that all traffic control devices are operating properly and in place at all times. Missing traffic control devices create the potential for motorists to inadvertently enter the work space or exit the highway in the wrong place.
- For night work:
  - Reduce spacing between channelizing devices to compensate for reduced driver visibility.
  - Ensure arrow panels are set at nighttime levels; daytime settings used at night produce blinding light.
- Increase the size of traffic control devices, reflective material, and lettering to improve driver recognition.

Contracting agencies can:

- To better delineate highway exits in work zones, consider specifying a different color for channelizing devices and signs intended to guide motorists off the exit ramp.
- Create positive separation between the traveling public and workers by specifying:
  - Use of temporary traffic barriers whenever possible. Paint barriers a color that contrasts with the background. Reflectors, lights, or light tubes can be installed on barriers to further enhance delineation.
  - Use of truck-mounted attenuators (TMAs) for a wider range of work zone safety applications. TMAs can be placed on the upstream, lateral, or downstream sides of traffic flow to physically isolate the work space. They may be particularly useful in moving work zones, where they can move forward as work progresses to protect workers from being struck from behind by traffic vehicles.

Policy makers (Federal, state, and local) can:

- In cooperation with contractors, labor, and manufacturers, develop a consensus standard for the use of temporary traffic barriers and TMAs as positive separators.
- Require consistency in traffic control devices within a single work zone area. Move toward uniformity in the type and placement of traffic control devices within local jurisdictions, at the state level, and nationally.

Motorist education and speed enforcement

Road builders and maintainers and contracting agencies can:

- Give motorists plenty of advance warning of upcoming work zones.
- Ensure that motorists have real-time information in signage and in traveler's advisory radio broadcasts.

- Install warning signs that provide estimated time of delay and other road closure information so that drivers have sufficient opportunity to exit and take a different route.
- Use a combination of traffic queue detection equipment and dynamic message signs to vary messages as traffic conditions change.
- Keep warning sign messages simple and brief.
- Cover or take down warning signs when workers are not present.
- Remove channelizing devices when they are no longer needed.

Contracting agencies can:

- Follow the MUTCD recommendation that reduced speed zoning should be avoided as much as practical. However, in highly vulnerable situations which threaten worker safety, consider reducing speed through regulatory speed zoning, use of police, funneling, lane reduction, flashing lights, or flaggers. Speed reductions should be applied incrementally to maintain uniform traffic flow. Normal speed limits should be restored when work is no longer in progress, when workers are no longer at the job site, or when hazards have been removed or protected.
- Use an advance media campaign to advise the public of upcoming road work.

Policy makers (Federal, state, and local) can:

- Educate the public about work zone safety issues (e.g., standard signage, apparel colors, and importance of obeying reduced postings) through public service announcements, driver education courses, and driver training manuals.
- Educate the public about human factors related to safe navigation of work zones (e.g., decision sight distance, reaction time, and stopping distance) through public service announcements, driver education courses, and driver training manuals.

Policy makers (Federal, state, and local), law enforcement, and others can work together to:

- Implement and evaluate alternative speed control measures in the work zone:
  - Videotape speeding motorists to provide an incentive to slow down through the work zone.
  - Use radar-gun technology to advise motorists when they are exceeding work zone speed limits. Explore the extension of this technology to automatic issuance of speeding tickets.
  - Increase fines for motorists exceeding work zone speed limits, and increase penalties for motorists convicted of driving through the work zone under the influence of drugs or alcohol.
  - Use pace vehicles to pull into lanes and slow traffic.
  - Increase presence of law enforcement at the beginning of the work zone.

- Use a variety of speed control methods throughout the course of a project so that motorists do not learn how to anticipate and avoid speed controls.
- Follow through on speed control measures through ticketing and fining violators.

- Use a law enforcement officer who is trained in work zone traffic control as a flagger in work zones where speed control is needed.
- Ensure that officers are trained in work-zone traffic control procedures and know the MUTCD.
- Ensure that officers working temporary traffic control are adequately protected from work zone hazards.

A New Jersey cooperative program enlists law enforcement personnel to improve worker safety:

Parsippany, New Jersey is a model of collaborative efforts to improve highway work zone safety. This program has not only reduced work-site accidents and injuries, but has also reduced motorist collisions and fatalities in work zones. Police officers receive three to four days of OSHA training on the job risks associated with roadway construction, and are then authorized to warn employers of safety hazards on the job site. If hazards are not corrected after the second warning, police notify OSHA. Cooperators in this effort are the New Jersey State Police, international and local Laborers' Union, the Utilities and Transportation Contractors' Association, Rutgers University, local and county police, and the New Jersey Department of Labor.

A Wisconsin program places law enforcement personnel among highway workers as a speed control measure:

Beginning in the spring of 1999, a new program in Racine County, Wisconsin, placed deputy sheriffs in plainclothes among highway construction workers in an effort to control speeding through work zones. Deputies, wearing orange work vests and equipped with handheld laser speed detectors and portable radios, identify speeding or erratic vehicles and notify law enforcement personnel positioned after the work zone if a stop or arrest is warranted. Racine County Sheriff Bill McReynolds stated that while the presence of law enforcement vehicles is a partial deterrent, the possible presence of officers among construction workers might cause motorists to exercise greater caution driving through the work zone [National Public Radio 1999].

Flaggers

Road builders and maintainers can:

- Train all flaggers consistent with their level of responsibility and work zone conditions. Flaggers should know the traffic flow, the work zone setup, and proper placement of channelizing devices.
- Assign each flagger responsibility for monitoring operations in his or her immediate work area. Authorize flaggers to recommend to the traffic control supervisor that operations be temporarily halted and the hazard corrected when they see a hazard threatening the safe movement of traffic through the work zone. Authorize flaggers to halt operations in the event a hazard arises and the traffic control supervisor is not in the immediate area.
- Train flaggers to maintain sufficient distance from other highway workers, so that they can be identified by passing motorists.
- In the event multiple flaggers are required, ensure they have the appropriate sight distance or two-way radios to communicate effectively.
- Avoid using flaggers whenever possible. Use alternative traffic management systems such as lane shifts, portable traffic signals, or remote signaling devices operated by workers away from the flow of traffic.
  - Use alternatives to flaggers when traffic control is required under hazardous conditions such as high traffic speeds, inclement weather, night work, and other conditions which limit visibility.

Policy makers can:

- Develop flagger training program(s) that provide core competencies and are flexible enough to address varying work situations. The current OSHA 500 course in construction can serve as a model. Flaggers who successfully complete the program(s) could be issued documentation that could be carried from employer to employer and state to state.
- Add requirements for protection of flaggers to the OSHA construction standard.

High-visibility apparel

Road builders and maintainers can:

- Require all workers on foot to wear high-visibility safety apparel.
- Inspect high-visibility clothing regularly to ensure that color has not faded and that retroreflective properties have not been lost.
- So that workers do not blend into the background, consider seasonal variations in landscape and foliage when choosing colors for worker apparel.

- Consider using fluorescent garments with retroreflective material when working under poor lighting conditions.
- Consider increasing visibility by using high-visibility arm bands and hats, and vests with strobes.

Contracting agencies can:

- Require fluorescent and retroreflective materials on head gear and on flaggers' gloves.

Policy makers (Federal, state, and local) can:

- Change the MUTCD to require that all workers wear high-visibility safety apparel.
- Periodically evaluate visibility requirements in the MUTCD and OSHA regulations in light of changes in technology and consensus standards.
- Because visibility will be affected by background colors and available light, develop guidelines and mandates that specify retroreflective or fluorescent material, rather than prescribe a specific color. {Note: research suggests that the most effective choices for fluorescent colors are red-orange, fluorescent yellow-green, or a combination of these [Turner et al. 1997].}
- Incorporate criteria for selection and use of high-visibility clothing into 29 CFR 1926 Subpart E– Personal Protective and Life Saving Equipment, or incorporate them into the MUTCD for reference in Subpart E.

Manufacturers can:

- Design high-visibility apparel that is effective 24 hours a day and during any weather condition.
- Create high-visibility apparel with one design on the front and a different design on the back. If a worker's back is to the driver, the driver knows that the worker cannot see him.
- Manufacture apparel to ensure visibility of the wearer from 360 degrees.

A new consensus standard provides guidance on high-visibility safety apparel:

A new voluntary consensus standard, ANSI/ISEA 107-1999, American National Standard for High-Visibility Safety Apparel, provides guidance for use of high-visibility safety apparel to protect workers exposed to hazards of low visibility, including highway construction workers. The standard specifies minimum amounts of retroreflective materials, colors, and placement of materials for high-visibility worker apparel. It also defines three garment classes based on the surface area of background and retroreflective material used to make the garment. Specifications in the standard are intended to make the wearer of the apparel conspicuous under any light conditions by day, and under illumination of vehicle headlights in the dark.

Though not considered a part of ANSI/ISEA 107-1999, Appendix B provides the following conspicuity criteria for selection of apparel:

Class 1 – For use in situations which permit the worker's full attention to approaching traffic, with ample separation of workers and vehicles, and traffic speeds not exceeding 25 mph.

Specifies a minimum of 0.14 m^2 fluorescent background material and 0.10 m^2 retroreflective material.

Class 2 – For use in inclement weather conditions, for work on or near roadways with higher traffic levels, or for traffic speeds above 25 mph. Class 2 apparel is appropriate for use in situations where worker attention is diverted from approaching traffic, or where separation of workers and traffic is less than ample.

Specifies a minimum of 0.50 m^2 fluorescent background material and 0.13 m^2 retroreflective material.

Class 3 – For use in settings where workers and vehicle operators have high task loads, where workers are exposed to traffic speeds above 50 mph, and where workers are exposed to a wide range of weather conditions. Class 3 apparel is recommended for all highway construction personnel.

Specifies a minimum of 0.8 m^2 fluorescent background material and 0.2 m^2 retroreflective material.

Note: Performance of Class 3 apparel, suggested for use by all highway construction personnel, exceeds the 1,000-foot distance visibility recommendation in the MUTCD. The new ANSI/ISEA standard states that the worker should be conspicuous through the full range of body motions and be identifiable as a person. Appendix B further suggests that workers needing Class 3 apparel should be conspicuous from a minimum distance of 1,280 feet [ANSI/ISEA 1999].

Illumination of the work zone

Road builders and maintainers can:

- When installing lighting within a work zone, ensure proper illumination for the work space, while controlling glare so as not to blind workers and passing motorists:
  - Lower the height of lighting equipment to reduce glare for motorists.
  - Consider using glare-free light balloons and glare screens.

Policy makers (Federal, state and local) can:

- Develop a comprehensive consensus standard for illumination of work zones. The standard could include:
  - Minimum lighting levels needed for each work task
  - Types of light sources recommended for both portable lighting and equipment-mounted lighting
  - Minimum area to be illuminated around each type of equipment
  - Recommendations for placement of both portable lighting and equipment-mounted lighting.

Manufacturers can:

- Work with policy makers, contracting agencies, contractors, and labor to develop standards for illuminating highway work zones.

Research into work zone illumination needs:

Illumination guidelines for nighttime highway work are now being developed by researchers at the University of Florida. Preliminary recommendations from this research defined three categories of highway construction and specified lighting levels needed for each:

Category I: General illumination requirement for the work space (5 foot-candles)
Recommended for large-scale visual tasks with comparatively low need for accuracy

Category II: Provides for general illumination of tasks and around equipment (10 foot-candles)
Recommended for work done on and around construction equipment such as paving and milling which require somewhat greater accuracy and where workers are located near machinery

Category III: Specified for small scale visual tasks requiring high accuracy, such as repairing cracks or pot holes (20 foot-candles)
Also recommended for situations requiring extreme caution and attention, such as flagging and signaling

The preliminary illumination recommendations also cover light sources, lighting system configurations (temporary, portable, and equipment-mounted), steps for designing a lighting system, and the importance of maintenance and backup of the system. The final product of the research will be illumination guidelines for nighttime highway work that specify design requirements for work zone lighting, taking into account visibility requirements of motorists passing through the work zone. The research is funded through the National Cooperative Highway Research Program [Transportation Research Board 1996].

Developing internal traffic control plans

A temporary traffic control plan (TCP) describes how a specific work zone is to be set up to ensure the safety of the motoring public traveling through the work zone; however, construction equipment and vehicles within the work space are not addressed by TCPs [Graham and Migletz 1994] . In contrast to a TCP, an internal traffic control plan (ITCP) is a tool that project managers can use to coordinate the flow of construction vehicles, equipment, and workers operating in close proximity within the activity area, so that the safety of workers can be ensured.

Road builders and maintainers can:

- Develop an internal traffic control plan (ITCP) once the temporary traffic control plan has been established. As the ITCP is developed, consider how the work space fits within the overall work zone and make sure that the ITCP is placed in the context of a temporary traffic control plan.
- Develop internal traffic control plans for all medium, large, and multi-contractor jobs. For small recurrent operations such as filling potholes, routine maintenance, and mowing, a checklist could be used in place of a complete ITCP.
- Develop schematic diagrams depicting the movement of construction workers and vehicles within the work space. Sample diagrams have been developed for paving, trenching, and dirt-spread operations [Graham and Migletz 1997]. These diagrams provide an idea of how a typical ITCP diagram might look, but must be modified to assure compatibility with the overall TCP and to address site-specific conditions.

Management elements that may be addressed in an ITCP:

- Chain of command
- On-site equipment and personnel
- Contact information, including company personnel, other on-site contractors, the contracting agency, and emergency response services
- The location, time table, and scope of the project
- An operations communication plan that includes the following:
  - A plan for orienting independent truck drivers and subcontractors to the work space and the ITCP
  - Methods of communication regarding changes in the ITCP
  - A means for workers on foot to talk with equipment operators, truck drivers, and the people in charge of controlling or coordinating the flow of vehicles and equipment entering and leaving the work space and the movement of heavy equipment within the work space
  - A means for grader operators, dozer operators, truck drivers and scraper operators to communicate with each other and with the prime and sub-contractors

Safety elements that may be addressed in an ITCP:

- Identification of ITCP coordinator assigned to the project
- A description of the role and authority of the ITCP coordinator
- A description of the role employees have in implementing the ITCP, and in recognizing, reporting and eliminating safety hazards
- A continuous process for reviewing incidents, close calls, and potential hazards involving workers and equipment within the work space and for elimination of reported hazards
- A description of how the ITCP fits within the temporary traffic control plan

Hazard assessment and control elements that may be addressed in an ITCP:

- Schematic diagrams depicting the movement of construction workers and vehicles within the work space (see ITCP diagram elements)
- A checklist of site-specific hazards with a description of how these hazards will be minimized: what procedures, safety equipment, and control strategies will be used?
- A reporting system for all close-calls and incidents related to the internal traffic control plan (to encourage reporting, consider using an anonymous reporting system)
- A plan for safely handling intermittent traffic stoppages; e.g., for equipment turn-around
- Anticipated traffic volume and speed, as well as speed limit for operation within the work space
- Specifications for lighting in the work space

Elements of an ITCP diagram:

- Standard symbols for pieces of equipment and project personnel that will be on site
- Overview of how the activity area fits within the temporary traffic control plan
- Location of proximate traffic control devices
- Delineated areas around specific pieces of equipment and operations where workers on foot are prohibited (e.g., swing radius of an excavator, blind areas of a dump truck)
- Locations for storing and servicing materials and equipment
- Location of parking for visitors and workers
- Size and location of lateral buffer zones
- Description of internal signage and all internal traffic control devices

Contracting agencies can:

- Assist contractors in the development of ITCPs and in reviewing compatibility of ITCPs with the project TCP.

Policy makers (Federal, state, and local) can:

- Establish guidelines for developing ITCPs.
- Develop sample ITCPs for selected road construction operations.

Implementing internal traffic control plans

Road builders and maintainers can:

- Train workers in the implementation of the ITCP for each project.
- Place a trained ITCP coordinator at each job site. By being at the job site, the coordinator is able to respond immediately to hazardous situations. The employer should authorize the coordinator to make adaptive changes and/or halt operations as needed to ensure worker safety.
- Evaluate the effectiveness of the ITCP throughout the project, noting changes required as the project evolves. Retain schematic drawings and other documents in the "job file" for use in developing future ITCPs.
- At entrances to the activity area, distribute site-specific safety materials, including a copy of the ITCP and safety guidelines for workers on foot, to all drivers and visitors coming into the activity area. Other means of communicating this information include toolbox safety meetings, faxing the ITCP to other employers who will be on site, and distributing the ITCP to truck drivers at the loading facility.

Contracting agencies can:

- Ensure agency staff understand the ITCP for each project so that they can comply with the ITCP when they travel to a work site during inspections.

Accountability and coordination at the work site

Road builders and maintainers can:

- Avoid assigning collateral duties that distract safety personnel from focusing on their safety responsibilities.
- Make supervisors accountable for daily documentation of hazards and how hazards were mitigated.
- Maintain lines of communication between the individuals responsible for different aspects of work zone safety.

Contracting agencies can:

- Require contractors and subcontractors to prepare site-specific hazard assessments that include identification of hazards and description of how hazards will be eliminated or controlled.
  - For each project, use hazard assessments to guide identification of immediate worker training needs.
- Adopt a project-wide communication program in which each contractor informs all other contractors of hazards related to their work. This allows each contractor the opportunity to ensure that employees are aware of hazards resulting from work being done by others at the site.
- Require an on-site senior project supervisor with final authority and overall responsibility for safety on the project.
- Conduct a pre-construction meeting among contractors to coordinate project activities, discuss potential hazards and how hazards will be eliminated, or minimized.

Equipment operation and maintenance

Road builders and maintainers can:

- Make sure that each equipment and vehicle operator has a valid driver's license.
- Allow equipment to be operated or repaired only by persons who have been trained and authorized to work with that piece of equipment. Assign responsibility for each piece of equipment to an individual worker.
- Designate a supervisor to be responsible for daily pre-shift equipment checks and for verifying that any problems are corrected. Although equipment may be inspected by various people, the supervisor must be responsible for ensuring that inspections are performed daily, that necessary repairs are made, that scheduled maintenance is performed, and that records of all inspections and repairs are maintained.

- Ensure that workers are paid for the time they spend performing equipment safety checks.
- When repairs are made on site, require that the operator's controls are made inoperable so that the equipment cannot be moved by another worker while repairs are being made.
- Require equipment operators to set parking brakes when leaving equipment unattended. When equipment is parked on an incline, chock wheels in addition to setting parking brakes. Chocks should be of sufficient size and configuration to immobilize the equipment.
- Require employees to report equipment problems to the designated competent person and give employees the authority to shut down unsafe equipment without repercussion.
- Develop pictorial checklists to make equipment inspections easier.
- Keep operator manuals in the equipment cab.
- Ensure ready access to repair manuals by maintenance personnel at all work locations.
- Contact the equipment manufacturer to obtain operator and repair manuals when purchasing used equipment.
- For night work, install light strips on trucks to better delineate vehicles and equipment. Drivers must turn off this additional lighting before leaving the work area.
- Use equipment with rollover protective structures (ROPS). Purchase and have installed retrofit ROPS and seat belts for older equipment.
- Train equipment operators in safe work practices to prevent equipment rollovers:
  - Maintain proper tire pressure
  - Know material density and surface stability
  - Use spotters with two-way radio communication
  - Train operators to use seat belts and to remain belted in the event of a rollover
  - Use edge guards on trailers to prevent rollovers
  - Use spotters during loading and unloading of equipment from transport trailers
  - Install full-width loading ramps on transport trailers.

Contracting agencies can:

- Specify use of high conspicuity tape to delineate height and width of construction vehicles and equipment. Existing Federal standards that apply to tractor-trailers provide a model for placement, pattern, color, and reflectivity of tape at the sides and rear of the trailer [49 CFR 393.13].
- For night work, specify installation of low-level lighting on trucks and equipment so that operators can see workers on foot in the vicinity.

Policy makers (Federal, state, and local) can:

- Require the highway construction industry to comply with a standard similar in purpose to the general industry lockout/tagout standard (29 CFR 1910.147).

Manufacturers can:

- Make operator and repair manuals for equipment available on manufacturers' Websites or through an on-line clearinghouse.

Safe equipment operation around workers on foot

Road builders and maintainers can:

- Separate workers on foot from equipment as much as possible:
  - Schedule work tasks to keep workers on foot out of areas where heavy equipment is in use.
  - Channelize dump trucks leaving the work space and keep workers on foot out of that channel. Use flexible, colored poles (as used for snowplow markers) or temporary pavement marking inside the work space to mark pedestrian-free areas or flow-of-traffic lines. These delineators should be installed so that the public will not notice or respond to them, but the workers will recognize them as guideposts.
  - Train subcontractors, crews, operators, and truck drivers to understand any symbols, markers, and colors used to separate workers on foot from equipment within the work space.
  - Design the work space to eliminate or decrease backing and blind spots; when feasible pull trucks in and let the operation catch up to them.
- Train workers on foot and equipment operators in appropriate communication methods (e.g., using hand signals and maintaining visual contact) to be used when workers on foot are required to be in the same area as equipment.
- Train equipment operators never to move equipment without making positive visual contact with any workers on foot near the equipment.

Training and certification

Road builders and maintainers can:

- Implement performance-based training that evaluates trainees' core and specialized knowledge and demonstrated ability to perform the tasks for which they were trained.
- Create an industry-wide campaign to promote training and to publicize available training programs.
- Since all workers, including equipment operators and supervisors, are likely to be on foot around operating vehicles and equipment, train all workers to recognize and avoid the hazards of working on foot around equipment.
- Train all workers in hazards and adaptations for work at night and in other low-visibility conditions.

- Hold daily toolbox meetings at the job site to discuss and report hazards and close-calls, and to discuss safety considerations for performing the day's tasks.
- Train workers on the specifics of the ITCP for each new construction project. Review ITCP with workers whenever it is modified.

Policy makers (Federal, state, and local) can:

- Promulgate an OSHA regulation mandating training of all construction workers whose actions affect work zone safety. The current MUTCD recommends but does not require that all such persons, from upper level management through field personnel, receive training appropriate for the job decisions each is required to make.
- Develop training programs that provide workers with an understanding of safety hazards and methods of hazard reduction in highway and street construction.
- Begin to develop a national certification process for equipment operators.
  - Preparation for certification could involve a 2- to 4-year qualification period that includes classroom and on-the-job training and experience.
  - Certification would be a function of the operator's qualifications, demonstrated knowledge, and proficiency.
  - The certification process should provide for maintaining and renewing certification on a periodic basis.

A national third-party crane certification program:

The National Commission for the Certification of Crane Operators (NCCCO) is a nonprofit corporation that was founded in 1995 to develop effective performance standards for safe crane operation to assist all segments of general industry and construction. The NCCCO is strictly a credentialing organization—the Commission does not offer training programs, since that would compromise its objective measurement of a candidate's knowledge and skills. What the NCCCO does provide is a comprehensive and independent means of assessing crane operator knowledge and skills through administration of a core and several specialty written examinations. On February 26, 1999, the OSHA and the NCCCO signed an agreement officially recognizing the NCCCO national crane operator certification program as meeting OSHA requirements for crane operator proficiency. As a result, when compliance safety and health officers perform inspections or make accident investigations, they will recognize NCCCO certification as verification that crane operators have met the training requirements of the OSHA standards.

An OSHA standard with specifications for performance-based training:

The OSHA standard for powered industrial truck training provides a model for performance-based training. The standard stipulates that training shall consist of a combination of formal instruction, demonstrations by the trainer, practical exercises performed by the trainee, and evaluation of the operator's performance in the workplace. Also specified in the standard are situations in which refresher training must be conducted, including the following: unsafe operation has been observed; the operator has been involved in an accident or "near-miss" incident; the operator is being assigned to drive a different type of truck; or workplace conditions have changed such that the safe operation of the vehicle may be affected. At a minimum, the standard requires that operator competence be re-evaluated at least once every 3 years. In contrast with the crane operator certification program discussed above, the OSHA standard requires the operator to be certified by the employer; certification through a third party is not allowed [29 CFR 1910.178(l)]. Note: The requirements applicable to construction work under 29 CFR 1926.602(d) reference those set forth in 29 CFR 1910.178(l).

Changes in the contracting process

Contracting agencies can:

- Level the playing field among all potential contractors by requiring a written safety program in bid specifications. Contractors may risk losing jobs when they bid higher to account for costs of training, maintenance, and other safety program elements.
- Level the playing field among all potential contractors by specifying appropriate protective technologies (e.g., TMA, concrete barricades) as individual bid line items when preparing bid specifications, instead of using generic contract language that simply specifies contractors must comply with Federal and state safety regulations.
- In bid specifications, stipulate that all workers on foot be equipped with high-visibility safety apparel.
- In planning new construction and rehabilitation, specify durable surfacing materials that will need to be replaced less frequently.
- Pre-qualify all contractors and subcontractors to ensure that they have good safety records. Periodically re-evaluate the pre-qualified list of contractors.
- Through contract language, specify that the traffic control supervisor must have overall responsibility for temporary traffic control.
- In bid specifications, include provisions for the contractor to set up an adequate work space for safe operations (e.g., sufficient lateral buffer space and room for equipment to maneuver).

- Require demonstrated understanding and ability to implement the TCP as an acceptance criterion for awarding contracts. Do not award contracts based solely on a low bid criterion.
- Use the quality and completeness of the TCP and the ITCP as acceptance criteria for awarding contracts.

Policy makers (Federal, state, and local) can:

- Develop model safety specifications for contracting agencies to use when developing contract documents. During the bidding process, contractors would then be able to assign costs for implementing better safety practices.
- Create forums for dialogue among all entities involved in highway construction.

Laboratory and field research needs

Policy makers (Federal, state, and local), contracting agencies, road builders and maintainers, labor, and the research community can work together to:

- Develop prototype internal traffic control plans for a broad range of highway construction tasks and evaluate their effectiveness through field studies.
- Determine the optimum dimensions and spacing for channelizing devices.
- Determine the optimum lateral buffer zone distance and re-calculate the maximum travel speed outside the work space based on this distance.
- Determine optimum spacing between the truck-mounted attenuator (TMA) and the vehicle in front of it; develop interventions to deter motorists from driving in front of the TMA in order to get around it.
- Evaluate driver recognition and comprehension of different channelizing devices under various lighting and weather conditions.
- Evaluate the reliability of intrusion alarms for alerting workers of traffic vehicles that have penetrated the work space.
- Evaluate the effectiveness of law enforcement officers or vehicles stationed in the advance warning area as a means of reducing crashes and worker injuries. Evaluate risk to law enforcement personnel who are used in work zone advance warning areas.
- Evaluate effectiveness and applicability of phosphorescent, fluorescent and retroreflective materials, including the patterns used when they are applied to a garment.
- Evaluate the effectiveness and applicability to work zones of:
  - Sensing devices that sound an alarm when an object is near the vehicle
  - Parabolic mirrors on construction equipment—similar mirrors are now in use on school buses
  - Individual vibrating alarms that can be triggered from any place on the site, giving a worker 8-10 seconds notice of approaching vehicles

- Transmitters worn by workers which will send a signal/alarm to approaching construction equipment [Hoffner 1997]
- Tapes that sound an alarm when a person or vehicle crosses them
- Closed-circuit television cameras, mirrors, and devices that stop a vehicle nearing a collision.

- Evaluate ways of reducing glare caused by work zone illumination:
  - Evaluate polarized windshield glass or polarized material over windows as a means of limiting glare.
  - Assess warning lights and strobe lights used on emergency vehicles and traffic control devices to determine need for glare reduction.
- Conduct research to better understand physiological and psychosocial effects of night work, extended shifts, rotating shifts, and irregular work schedules on worker safety.
- Conduct research to determine the most effective means of delivering training to highway construction workers.
- Measure light levels and test the effectiveness of mirrors and video cameras under nighttime construction conditions.
- Conduct hazard surveillance research to determine levels of worker exposure to specific types of machinery in highway construction zones.

Data and record keeping

Policy makers (Federal, state, and local) can:

- Modify existing injury and fatality data systems to allow more detailed analysis of exposure to injury risk for highway construction workers in work zones:
  - In highway crash data systems, distinguish between injuries to workers and injuries to motorists.
  - Continually analyze work zone crash data so that high-risk work zones can be quickly identified and hazards eliminated.
  - Accurately identify work zones where crashes are occurring by recording a unique identifier (e.g., DOT project code) on documents such as police crash reports.
  - Consider adding time of injury and type of equipment information to the OSHA 200 logs or other data collection forms.
  - Collect information on type of road construction: new, rehabilitation, or maintenance, as well as information on type of work schedule (i.e., regular or compressed work schedules, overtime work, or night work).
  - To produce better state-level data on highway work zone injuries and better estimates of worker exposure, coordinate data collection and analysis between state departments of health and transportation. Consider developing injury rates per mile of highway built or maintained.
  - Assess work zone-related worker injuries and fatalities on an annual basis and report results through Web and print media.

List of Acronyms

ANSI	American National Standards Institute
BLS	Bureau of Labor Statistics
CFOI	Census of Fatal Occupational Injuries
CFR	Code of Federal Regulations
FACE	Fatality Assessment and Control Evaluation
FHWA	Federal Highway Administration
ISEA	International Safety Equipment Association
ITCP	Internal traffic control plan
LHSFNA	Laborers' Health and Safety Fund of North America
MUTCD	Manual on Uniform Traffic Control Devices
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
ROPS	Rollover protective structure
SIC	Standard Industrial Classification
TCP	Traffic control plan
TEA-21	Transportation Equity Act for the 21st Century
TMA	Truck-mounted attenuator

Glossary

Activity area	The portion of "the highway where the work takes place. It is comprised of the work space and the traffic space, and the buffer space" [FHWA 2000 (MUTCD, Section 6C.06)].
Advance warning area	The area in advance of the work zone where drivers are informed of what to expect. "The advance warning may vary from a single sign or rotating/strobe lights on a vehicle to a series of signs in advance of the temporary traffic control zone activity area" [FHWA 2000 (MUTCD, Section 6C.04)].
Certification	A process which assesses an individual's knowledge and skills to determine if the individual meets a minimum standard of qualification.
Channelizing devices	"The function of channelizing devices is to warn road users of conditions created by work activities in or near the roadway and to guide road users. . . . They are also used to separate motor vehicle traffic from the work space, pavement drop-offs, pedestrian or bicycle paths, or opposing directions of motor vehicle traffic. . . . Channelizing devices include cones, tubular markers, vertical panels, drums, barricades, and temporary raised islands" [FHWA 2000 (MUTCD, Section 6F.55)].
Chock	A wedge or block for blocking the movement of a wheel.
Competent person	"One who is capable of identifying existing and predictable hazards in the surroundings or working environments which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them" (29 CFR 1926 Subpart C).
Consensus standard	"Any occupational safety and health standard, or modification thereof, which has been adopted and promulgated by a nationally recognized standards-producing organization under procedures whereby it can be determined by the Secretary [of Labor] that persons interested and affected by the scope or provisions of the standard have reached substantial agreement on its adoption [and] was formulated in a manner which afforded opportunity for diverse views to be considered . . ." (OSH Act, Sec-3).
Foot-candle	One lumen per square foot.
High conspicuity tape	Retroreflective marking material, usually white or an alternating red-white pattern, that is applied to the rear and sides of vehicles to create visual contrast and clearly delineate vehicle size.
High-visibility vest/apparel	"Personal protective safety clothing intended to provide conspicuity during both daytime and nighttime usage" [ANSI/ISEA 1999].

Internal traffic control plan	A traffic control plan developed to control the flow of construction workers, vehicles, and equipment within the work space.
Internal traffic control plan coordinator	A person designated by the contractor as a competent person who has the ability to recognize hazards associated with the movement of construction vehicles, equipment, and personnel within the work space and has the authority to modify conditions to eliminate those hazards.
Lateral buffer space	A "lateral buffer space may be used to separate the traffic space from the work space . . . [or a hazardous area], such as excavations or pavement drop-offs. A lateral buffer space also may be used between two travel lanes, especially [those carrying traffic in opposite directions]. The width of the lateral buffer space should be determined by engineering judgement" [FHWA 2000 (MUTCD, Section 6C.06)].
Light balloon	A self-inflating elliptical lighting fixture designed to produce uniform non-glare illumination.
Milling	Process in which a rotating drum, equipped with special working tools, cuts the pavement to a predetermined depth and reduces the cuttings to a minimum size in the process. Also called cold planing [Webster 1995, p. 125].
Pedestrian	A person traveling on foot, who may be a construction worker or a member of the public.
Pre-construction meeting	A meeting between the owner's representatives and representatives for the contractor(s) to discuss their respective safety requirements and implementation of health and safety provisions pertinent to the work under contract [Hinze 1997, p. 102].
Pre-qualification	A process by which only selected contractors that meet predetermined performance criteria are entitled to bid on a construction project. The contractor's safety performance is often one of the qualifying criteria [MacCollum 1995, p. 53-54].
Project supervisor	Manages the activities at the construction site, schedules work crews and materials, and is responsible for keeping project on schedule and on budget.
Retroreflective material	Retroreflective material reflects light back towards the source. For example, retroreflective material reflects vehicle headlights so that signs, safety clothing, and other safety devices appear more visible to drivers at night.
Senior project supervisor	The senior project supervisor has final authority and responsibility for safety and health on the project, ensuring correction or abatement of hazards, monitoring for potentially hazardous conditions, determining that competent persons are

	designated by contractors, notifying responsible contractor of conditions that may cause injury or illness, and maintaining project safety and health records [ANSI A10.33-1992 (R1998)].
Site-specific hazard assessment	"Review of plans and specifications to identify the location and nature of potential hazards..." [MacCollum 1995, p. 60].
Skilled construction trades	A grouping of occupations that includes the traditional building trades, such as carpenters, painters, electricians, and cement finishers.
Taper	"Tapers may be used in both the transition and termination areas. . . . Tapers are created using a series of channelizing devices and/or pavement markings to move traffic out of or into the normal path" [FHWA 2000 (MUTCD, Section 6C.08)].
Temporary pavement markings	Markings used until "the earliest date when it is practical and possible to install pavement markings that meet [the full MUTCD standards] for pavement markings." Normally, it should not be necessary to leave temporary markings in place for more than 2 weeks [FHWA 2000 (MUTCD, Section 6F.66)].
Temporary traffic control plan	"A temporary traffic control plan (TCP) describes temporary traffic control measures to be used for facilitating road users through a work zone. . . . [The plan] may range in scope from being very detailed, to simply referencing typical drawings contained in [the MUTCD], standard approved highway drawings and manuals, or specific drawings contained in contract documents" [FHWA 2000 (MUTCD, Section 6C.01)].
Termination area	"The termination area is used to return road users to their normal path. The termination area extends from the downstream end of the work area to the END ROAD WORK signs, if posted" [FHWA 2000 (MUTCD, Section 6C.07)].
Toolbox meeting	Toolbox meetings are typically short (10 to 30 minutes), and are held on a regular basis (weekly, or daily) to discuss safety rules, procedures, hazards, corrective actions, mishaps, and injury and illness prevention [Hinze 1997, p. 106].
Traffic control device	"A traffic control device is a sign, signal, marking or other device placed on, over, or adjacent to a street or highway, pedestrian facility, or bike way (by authority of a public agency having jurisdiction) to regulate, warn, or guide traffic" [FHWA 2000 (MUTCD, p. I-1)].
Traffic control supervisor	A person designated by the contractor to assume overall responsibility for the safety of the work zone setup and conformance of the temporary traffic control devices with the TCP.

Traffic space	The traffic space is the portion of the highway in which road users are routed through the activity area [FHWA 2000 (MUTCD, Section 6C.06)].
Transition area	"The transition area is that section of highway where road users are redirected out of their normal path" [FHWA 2000 (MUTCD, Section 6C.05)].
Truck-mounted attenuator (TMA)	A safety appliance mounted on the rear of a truck that dissipates the energy of a rear-end collision.
Worker on foot	A worker on foot is any worker, regardless of task assignment, who is on the ground (standing, walking, or sitting) rather than inside a vehicle or piece of equipment.
Work space	"The work space is that portion of the highway closed to road users and set aside for workers, equipment, material, and a shadow vehicle if one is used upstream. Work spaces are usually delineated for road users by channelizing devices, or to exclude vehicles and pedestrians, by temporary barriers. The work space may be stationary or move as the work progresses" [FHWA 2000 (MUTCD, Section 6C.06)].
Work zone	The area between the first warning sign and the last traffic control device, as well as non-roadway areas (e.g., shoulders and drainages), and ancillary areas that serve as staging areas, or support areas for the work zone (e.g., temporary batch plants). This definition is broader than the work zone described in the MUTCD, which does not include ancillary areas that serve as staging areas, or support areas (e.g., temporary batch plants) for the work zone.

References

ANSI/ISEA [1999]. American National Standard for high-visibility safety apparel. New York, NY: American National Standards Institute, ANSI/ISEA 107-1999.

ANSI/NSC [1992 (R1998)]. American National Standard for construction and demolition operations– safety and health program requirements for multi-employer projects. New York, NY: American National Standards Institute, ANSI/NSC A10.33 (1992 (R1998)).

Blacklow B, Hoffner K [1996]. Fatalities and serious injuries among highway construction workers. Laborers' Health and Safety Fund of North America, unpublished report for FHWA Grant DTFH-93-X-00024.

Bryden JE, Andrew LB [1999]. Serious and fatal injuries to workers on highway construction projects. Paper presented at the Annual Meeting of the Transportation Research Board, Washington, DC, January 10-14, 1999.

Bureau of Labor Statistics [1992-1998]. Census of Fatal Occupational Injuries (CFOI). Unpublished data (analysis by the NIOSH Division of Safety Research).

Bureau of Labor Statistics [1999]. Occupational injuries and illnesses: counts, rates, and characteristics, 1997 (U.S. Department of Labor Bulletin 2518). Washington, DC: U.S. Government Printing Office.

CFR. Code of federal regulations. Safety and health regulations for construction (29 CFR 1926), Safety and health regulations for general industry (29 CFR 1910), and Parts and accessories necessary for safe operation (49 CFR 393). Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

FHWA [2000]. Manual on uniform traffic control devices millennium edition. U.S. Department of Transportation, Federal Highway Administration (FHWA).

FHWA [1998a]. Part VI of the manual on uniform traffic control devices – 1988 edition of MUTCD, Revision 3 – September 3, 1993, Includes Revision No. 4A Issued February 19, 1998. U.S. Department of Transportation, Federal Highway Administration (FHWA).

FHWA [1999]. TEA-21: Moving Americans into the 21st Century (web site). http://www.fhwa.dot.gov/tea21/index.htm. Last accessed November 29, 1999.

Graham JL, Migletz J [1994]. Development and implementation of traffic control plans for highway work zones. Transportation Research Board, NCHRP Synthesis of Highway Practice 208.

Graham J, Migletz J [1997]. Internal traffic control plans. Laborers' Health and Safety Fund of North America, unpublished report for FHWA Grant DTFH-93-X-00024.

Hinze JW [1997]. Construction safety. Columbus, OH: Prentice Hall, pp. 102, 106.

Hoffner K [1997]. A training program for the spotter to operator alarm system – the spot alarm. Laborers' Health and Safety Fund of North America, unpublished report for FHWA Grant DTFH-93-X-00024.

MacCollum DV [1995]. Construction safety planning. New York: Van Nostrand Reinhold, pp.53-54, 60.

Massachusetts Department of Public Health [1996]. Construction laborer crushed by asphalt truck while paving interstate highway. Boston, MA: Fatality Assessment and Control Evaluation (FACE) Report No. 95-MA-039-01.

Minnesota Department of Health [1992]. Highway construction flagman dies after being struck by a pickup truck. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. MN9214.

Minnesota Department of Health [1997]. Conveyor operator dies after being run over by belly dump trailer. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. MN 96-92.

National Public Radio [1999]. All Things Considered [transcript], February 24, 1999.

National Transportation Safety Board [1992]. Safety study: highway work zone safety (PB92-917005 NTSB/SS-92/02). Washington, DC: National Transportation Safety Board.

Ore T, Fosbroke DE [1997]. Motor vehicle fatalities in the United States construction industry. Accid Anal Prev *29*(5):613-626.

Pigman JG, Agent KR [1990]. Highway accidents in construction and maintenance work zones. Transportation Research Record *1270*:12-21.

Stout D, Graham J, Bryant-Fields B, Migletz J, Fish J [1993]. Maintenance work zone safety devices development and evaluation (final report). Strategic Highway Research Program, Report SHRP-H-371.

Transportation Research Board [1996]. Illumination guidelines for nighttime highway work. NCHRP Research Results Digest 216.

Turner JD, Simmons CJ, Graham JR [1997]. High-visibility clothing for daytime use in work zones. Transportation Research Record *1585*:1-8.

Webster LF [1995]. The contractor's dictionary of equipment, tools, and techniques. New York: John Wiley & Sons, Inc., p. 125.

Additional Readings

Agent K, Hibbs JO [1996]. Evaluation of SHRP work zone safety devices. Kentucky Transportation Center, Report KTC-96-80.

American Road and Transportation Builders Association [1996]. Construction safety management manual. Washington DC: ARTBA.

Anderson RW [1990]. Part I: worker safety in street and highway work zones. TransSafety Reporter *8*(5):4-7.

Andrew LB, Bryden JE [1997]. Managing construction safety and health: experience of New York State Department of Transportation. Transportation Research Record *1585*:9-18.

Booker SC, Ullman GL, Levine SZ [1987]. Supplemental devices to enhance flagger safety. Transportation Research Record *1148*:34-37.

California Department of Transportation [1988]. Highway maintenance activities during low volume traffic hours. Report to the Legislature, March 1988.

Chappell DW [1992]. Backing accident prevention. Professional Safety *37* (May):40-41.

Construction Safety Association of Ontario [1991]. Backing up. Construction Safety (Mar/Apr): 4-9.

Dalere EF, ed. [1993]. The traffic safety toolbox: a primer on traffic safety. Institute of Transportation Engineers, ITE Publication No. LP-279.

Daly JB [1997]. Working on safety. ENR *238* (Feb. 24):3.

Ellis RD, Herbsman ZJ, Chheda PN, Epstein WC, Kumar A [1993]. Developing procedures for night operations. University of Florida Transportation Research Center, Report No. UTC-UF-326-93-1. Submitted to the University of North Carolina Institute for Transportation Research and Education, Raleigh, NC.

Elrahman OA, Perry RJ [1994]. Night-time construction operations. New York State Department of Transportation, Engineering Research & Development Report No. FHWA/NY/SR-94/116.

FHWA [1992]. Proceedings of the Symposium on Work Zone Traffic Control, 1991, Orlando, FL. U.S. Department of Transportation, Federal Highway Administration, Office of Research and Development. Publication No. FHWA-TS-91-003.

FHWA [1995]. Innovative devices for safer work zones. U.S. Department of Transportation, Federal Highway Administration, Office of Technology Applications, Report No. FHWA-SA-95-029.

FHWA [1998b]. Meeting the customer's needs for mobility and safety during construction and maintenance operations (Pub. No. FHWA-PR-98-01-A). U.S. Department of Transportation, Federal Highway Administration, Office of Program Quality Coordination.

FHWA [1998c]. Meeting the customer's needs for mobility and safety during construction and maintenance operations: Model Work Zone Traffic Management Program and Self Evaluation Guide (Pub. No. FHWA-PR-98-01-C). U.S. Department of Transportation, Federal Highway Administration, Office of Program Quality Coordination.

Graham JL, Paulson RJ, Glennon JC [1977]. Accidents and speed studies in construction zones. Report FHWA-RD-77-80. Kansas City, MO: Midwest Research Institute.

Harris-Stewart C [1987]. Work zone safety arouses concern. Engineering News Record *218*:30-31.

Hinze J, Carlisle DL [1990]. Variables affected by nighttime construction projects. Transportation Research Record *1282*: 95-103.

Hoffner K [1997]. A training program for the ribbon switch/radio control truck stopping system: the truck stop. Laborers' Health and Safety Fund of North America, unpublished report for FHWA Grant DTFH-93-X-00024.

Keeping motorists and workers safe in the work zone: North Carolina's training program [1993]. Road Work Safety Report *3*(3):3-6.

LHSFNA (Laborers' Health and Safety Fund of North America) [1996]. Heavy equipment expert task team teleconference notes, unpublished report for FHWA Grant DTFH-93-X-00024.

LHSFNA [1997]. Highway work zone safety. Unpublished training course manual for FHWA Grant DTFH-93-X-00024.

Melia MK [1994]. How to improve work-zone safety. Traffic Safety *94*(3):6-9.

Melia MK [1995]. Warning: work still ahead on work-zone safety. Traffic Safety *95*(2):16-19.

National Association of County Engineers [1995]. Traffic operations. 1995 ed. NACE Action Guide Volume III-2.

Pietrucha MT [1995]. Human factors issues related to work zone safety. Transportation Builder (May):40-42.

Pratt SG, Kisner SM, Moore PH [1997]. Machinery-related fatalities in the construction industry. Am J Ind Med *32*:42-50.

Safety after MUTCD: is it enough? [1997]. Better Roads *67*(2):17-20.

Sorock GS, Rainey TA, Lehto MR [1996]. Motor vehicle crashes in roadway construction workzones: an analysis using narrative text from insurance claims. Accid Anal Prev *28*(1):131-138.

Trout ND, Ullman GL [1997]. Devices and technology to improve flagger/worker safety. Texas Department of Transportation, Office of Research and Technology Transfer, Report TX-97/2963-1F.

Washington State Department of Transportation [1996]. Safety in the work zone (videocassette).

Work zone safety: dangers and some solutions [1988]. Highway and Heavy Construction *131* (Nov):94-97.

On-line Resources

NOTE: *The addresses below were correct as of January, 2001. Since Internet addresses for Websites change frequently, readers are cautioned that slight changes may have taken place since that time.*

American Association of State Highway Transportation Officials
http://www.aashto.org/

American Concrete Pavement Association
http://www.pavement.com

American Road and Transportation Builders Association
http://www.artba.org

American Traffic Safety Services Association
http://www.atssa.com

Associated General Contractors of America
http://www.agc.org

Federal Highway Administration home page
http://www.fhwa.dot.gov

Federal Highway Administration
Safety
http://safety.fhwa.dot.gov/

Federal Highway Administration
Manual on Uniform Traffic Control Devices
http://mutcd.fhwa.dot.gov/

Federal Highway Administration
Turner-Fairbank Highway Research Center
http://tfhrc.gov

International Safety Equipment Association (ISEA)
http://www.safetyequipment.org/

National Asphalt Pavement Association
http://www.hotmix.org/

National Institute for Occupational Safety and Health
http://www.cdc.gov/niosh/

National Highway Traffic Safety Administration
http://www.nhtsa.dot.gov/

National Safety Council
Highway Traffic Safety Division
http://www.nsc.org/mem/htsd.htm

National Transportation Safety Board
http://www.ntsb.gov/

National Work Zone Safety Information Clearinghouse
http://wzsafety.tamu.edu/

Occupational Safety and Health Administration
http://www.osha.gov/

Transportation Research Board
http://www.national-academies.org/trb

Appendix

Case Examples of Highway Construction Fatalities

Since 1982, NIOSH has conducted site investigations of workplace fatalities through the Fatality Assessment and Control Evaluation (FACE) program, a research program for the identification and investigation of fatal occupational injuries. The goal of the FACE program is to collect information on factors that may have contributed to occupational fatalities, using an epidemiologic approach, and to develop and disseminate recommendations for prevention of similar incidents in the future. The FACE program has conducted investigations of machinery-related fatalities since 1994, and in the fall of 1999, began to target highway work zone fatalities. FACE investigations are conducted by staff from the NIOSH Division of Safety Research, and by FACE programs housed in state departments of health or departments of labor, with technical assistance provided by NIOSH.

The product of each FACE investigation is a narrative report describing the incident and providing recommendations for prevention. FACE investigators draw upon multiple sources to gather information needed to develop a report: employer and witness interviews; coroner, medical examiner, police, or OSHA reports; death certificates; equipment operator's manuals; and manufacturers' representatives. The role of FACE is not to place blame for the fatality or to assess compliance with safety and health regulations. Rather, as a research program, it seeks to provide concrete, practical recommendations that can be applied to prevent similar types of fatalities.

The following case examples underscore the fatality risks faced by those who work near vehicles and machinery in work zones and in ancillary areas that serve as staging, or support areas for the work zone (e.g., temporary batch plants). Although most of the examples involve highway construction, a few cases that occurred in maintenance and utility work zones are also included. Each case example consists of a summary of the incident and the prevention recommendations put forth by the investigator. The full text of the narrative reports on which these case examples are based may be found at http://www.cdc.gov/niosh/face/faceweb.html. It is hoped that these examples will be of use to construction contractors, contracting agencies, and safety professionals in assessing hazards in their own workplaces and communicating those hazards to workers.

Sources for Case Examples

Case #1. Minnesota Department of Health [1992]. Highway paving crew member dies after being run over by a rear end dump truck. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. MN9207.

Case #2. Minnesota Department of Health [1992]. Highway construction flagman dies after being struck by a pickup truck. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. MN9214.

Case #3. Minnesota Department of Health [1993]. Worker dies after being run over by a dump truck. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. MN9219.

Case #4. Minnesota Department of Health [1993]. Road paving crew member dies after being run over by a digger derrick truck. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. MN9300801.

Case #5. New Jersey Department of Health [1994]. Road construction laborer dies after falling underneath the wheel of a front end loader. Trenton, NJ: Fatality Assessment and Control Evaluation (FACE) Report No. 93-NJ-090-01.

Case #6. Maryland Division of Labor & Industry [1994]. Construction foreman crushed by excavator–Maryland. Baltimore, MD: Fatality Assessment and Control Evaluation (FACE) Report No. 94MD063.

Case #7. Minnesota Department of Health [1995]. Highway construction worker dies after being struck while crossing roadway. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. 94MN03101.

Case #8. Nebraska Department of Labor [1995]. Asphalt roller crushes flagman. Omaha, NE: Fatality Assessment and Control Evaluation (FACE) Report No. 94NE059.

Case #9. NIOSH [1994]. Tree trimmer foreman dies after being struck by a pickup truck—South Carolina. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Safety Research. Fatality Assessment and Control Evaluation (FACE) Report No. 94-07.

Case #10. NIOSH [1994]. Asphalt milling superintendent crushed under asphalt milling machine—Virginia. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Safety Research. Fatality Assessment and Control Evaluation (FACE) Report No. 94-18.

Case #11. Minnesota Department of Health [1997]. Conveyor operator dies after being run over by belly dump trailer. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. MN 96-92.

Case #12. NIOSH [1994]. Laborer dies after being struck by overturning crane—Virginia. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Safety Research. Fatality Assessment and Control Evaluation (FACE) Report No. 94-19.

Case #13. Massachusetts Department of Public Health [1996]. Construction laborer crushed by asphalt truck while paving interstate highway. Boston, MA: Fatality Assessment and Control Evaluation (FACE) Report No. 95-MA-039-01.

Case #14. California Department of Health Services [1996]. Crane operator falls 30 feet while working from a freeway overpass in California. Los Angeles, CA: Fatality Assessment and Control Evaluation (FACE) Report No. 95CA01101.

Case #15. NIOSH [1998]. Construction laborer dies after being run over by asphalt roller at highway construction site—Virginia. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Safety Research. Fatality Assessment and Control Evaluation (FACE) Report No. 98-06.

Case #16. Minnesota Department of Health [1995]. Construction worker dies after 9-wheel pneumatic roller rolls over on her. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. 95MN04701.

Case #17. Missouri Department of Health [1995]. County highway department worker crushed when dump truck and trailer tipped over. Springfield, MO: Fatality Assessment and Control Evaluation (FACE) Report No. 95MO057.

Case #18. University of Iowa [1996]. Asphalt machine runs over and kills worker–Iowa. Iowa City, IA: Fatality Assessment and Control Evaluation (FACE) Report No. 96IA55.

Case #19. Missouri Department of Health [1996]. Highway department supervisor struck by reversing dump truck. Springfield, MO: Fatality Assessment and Control Evaluation (FACE) Report No. 96MO012.

Case #20. NIOSH [1996]. Equipment operator dies after scraper overturns—Virginia. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Safety Research. Fatality Assessment and Control Evaluation (FACE) Report No. 96-16.

Case #21. Missouri Department of Health [1997]. Asphalt roller operator dies following rollover incident. Springfield, MO: Fatality Assessment and Control Evaluation (FACE) Report No. 97MO037.

Case #22. NIOSH [1997]. Construction laborer dies after being struck by a front end loader at a construction site — Pennsylvania. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Safety Research. Fatality Assessment and Control Evaluation (FACE) Report No. 97-11.

Case #23. Minnesota Department of Health [1998]. Worker dies after being run over by a front end loader. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. 98MN030.

Case #24. Minnesota Department of Health [2000]. Laborer run over by dump truck while paving parking lot. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. 99MN03201.

Case #25. Minnesota Department of Health [1999]. Electrician dies after falling from cherry picker basket. Minneapolis, MN: Fatality Assessment and Control Evaluation (FACE) Report No. 99MN01801.

Case #26. Wisconsin Division of Public Health [1999]. Heavy equipment operator pinned after bulldozer slides off flatbed trailer. Madison, WI: Fatality Assessment and Control Evaluation (FACE) Report No. 99WI04101.

Case #27. Nebraska Department of Labor [1999]. Member of road crew struck by semi. Omaha, NE: Fatality Assessment and Control Evaluation (FACE) Report No. 99NE021.

Case #28. NIOSH [2000]. Female construction worker dies in a compactor tip over at a highway construction site—South Carolina. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Safety Research. Fatality Assessment and Control Evaluation (FACE) Report No. 99-03.

Case #29. NIOSH [1998]. Laborer run over by dump truck at roadway resurfacing operation—Virginia. Morgantown, WV: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Division of Safety Research. Fatality Assessment and Control Evaluation (FACE) Report No. 98-19.

Case #1: Highway Paving Crew Member Dies After Being Run Over by a Rear End Dump Truck

A 45-year-old member of a highway paving crew died as a result of being run over by a rear end dump truck that was backing up on a section of highway under construction. The incident occurred on a blacktop mat which was the underlayment for concrete paving the crew was laying that day. The victim and two helpers were setting reinforcing rods on the mat, over which concrete would be spread.

The victim had completed his work and was watching the paving operation. He was asked to instruct the drivers of a line of seven or eight batch trucks waiting to drive towards the paver to back up approximately 1000 feet. The paver had advanced to a position where using the blacktopped area in the median as a turnaround was not possible, and this maneuver was necessary in order to use another section of the highway.

The victim walked to the rear truck (Truck 1) and gave the driver instructions to back up. At the same time, another truck (Truck 2) was coming forward towards the rear of the truck line. As the victim was signaling Truck 2 to stop, he positioned himself in the path of Truck 1 which was backing up, in that driver's blind spot. Truck 1's driver was backing and turning into the opposite lane, the lane used to drive away from the paver, to make right-of-way for Truck 2. Despite Truck 1's having an operational back-up alarm and attempts by Truck 2's driver to warn him of the danger, the victim was hit by the right rear dual wheels of Truck 1 and pushed approximately 14 feet on the blacktop. He stated to rescue personnel before transport that he "thought (he) could make it." He died later in surgery from loss of blood.

To prevent similar fatalities, investigators recommended the following measures:

- Workers should direct only traffic moving in one direction at busy, noisy construction sites.
- Include in employee safety training information about human inaccuracy in estimating the arrival time of a moving vehicle.
- Equip trucks used on construction sites with rearview sonar which alarms drivers of close proximity to objects behind them.

Case #2: Highway Construction Flagman Dies After Being Struck by a Pickup Truck

An 18-year-old highway construction flagger died as a result of traumatic injuries received after he was struck by a pickup truck. A highway crew was milling the surface of a bridge approach in preparation for resurfacing. This job was being performed at night during minimum traffic hours; the incident occurred at approximately 3:00 a.m. The milling machine had advanced from the north towards the bridge approach and the job was near completion. The posted speed limit for the stretch of highway involved was 55 mph.

The flagger was positioned just at the north end of the bridge, approximately 75 feet in front of the milling machine. He stood just west of the center line in the southbound lane with the milling machine at his back, facing oncoming (northbound) traffic. He was responsible for stopping and directing this northbound traffic. A portable generator with 7-foot-tall floodlights was positioned 15 to 20 feet from the flagger, and the bridge was well lit by street lights. Traffic signs, cones, and beacon lights were appropriately in place throughout the construction zone. The victim was outfitted with a full reflective vest, reflective pants, and hard hat. It was a clear night and visibility was good.

A pickup truck traveling north at approximately 55 to 60 mph approached the bridge. It advanced across the bridge in the wrong (southbound) lane, directly towards the flagger, who was standing in that lane. The truck struck the flagger, then moved into the correct (northbound) lane before striking the milling machine and other workers, and carried the victim approximately 200 feet before coming to rest in the road at the north end of the bridge. There was no indication of the truck slowing or stopping before impact. The flagger was pronounced dead at the scene of multiple severe traumatic injuries.

To prevent similar fatalities, investigators recommended the following measures:

- Reduce the posted traffic speed limit through highway construction and work zones.
- Post law enforcement vehicles and/or personnel near and before highway construction zones to capture drivers' attention and ensure that traffic slows before entering the work area.

Case #3: Road Paving Crew Member Dies After Being Run Over by a Dump Truck

A 27-year-old member of a road paving crew (victim) died of injuries he received as a result of being run over by a dump truck. The fatality occurred as the crew was laying blacktop in two lanes of a four-lane residential city roadway. Dump trucks were being used to haul blacktop to a paver, which was situated on a north-southbound road. Trucks waiting to dump their load of blacktop were parked around the corner from the paver. The victim's dump truck was parked in the inner lane of this road, facing west. Tack, a sticky liquid spray used between two layers of blacktop for better adhesion, had been sprayed in the outer lane of the work area. Trucks were able to drive on the tacked area of the road if necessary, but the surface was too sticky for other equipment, such as rollers.

While the victim's truck remained idling, he left the cab, apparently to check something underneath it or to adjust its brakes. A hammer and the wrench used for brake adjustment were found near him after the incident. He was positioned between the cab and the rear tandem wheels of the truck on the passenger side. A roller approaching from the west was unable to pass the truck because it could not proceed in the tacked lane. The operator approached the idling truck on the driver's side, entered the cab, and released the parking brake. He did not see the victim, who was located on the passenger side of the truck. He put the truck into gear and drove it forward approximately 15 feet to make enough clearance in the inner lane for the roller to pass. The truck driver was run over and killed in the process.

Another nearby truck driver, observing that the victim had been run over, immediately dialed 911 from his cellular radio. First responders attempted to resuscitate the victim, but he died en route to the emergency room of multiple traumatic injuries.

To prevent similar fatalities, investigators recommended the following measures:

- Use of a lockout-tagout system should be required when vehicles are left unattended or undergoing repair/adjustment.
- Wheels of vehicles undergoing repair or adjustment should be chocked to help prevent unintentional movement of the vehicle.

Case #4: Worker Dies After Being Run Over by a Digger Derrick Truck

A 23-year-old apprentice lineman died of injuries he received after being run over by the tandem dual rear tires of a digger derrick truck. The construction company the victim worked for had been subcontracted to frame and set new electrical poles along a 2-mile stretch of paved county road. The digger derrick truck with an attached boom was used for hole digging and pole stabilization during the setting operation. The crew had been on site for 3 days, and several poles had already been framed and set.

The crew had returned to work after the lunch break, forgetting to don their high-visibility vests. At this time, two company vehicles were parked on the shoulder of the road about midway between two poles in the northbound lane. The crew began work by setting and backfilling pole #1 with the digger derrick, then walked south in the northbound lane to pole #2. They were about 30 feet in front of the digger derrick truck, which was proceeding in reverse to the same pole at about 2 miles per hour. Approximately halfway between pole #1 and pole #2, the victim knelt with his back to the truck to apparently inscribe a word or initials into some soft seal coating. The truck driver, not seeing the victim in his blind spot, continued backing. The victim was hit and run over by both sets of tandem dual rear tires on the passenger side of the truck before it could be stopped. The victim was pulled from beneath the truck and CPR was immediately initiated by co-workers. First responders arrived on the scene within 5 minutes, but the victim was pronounced dead at the scene of multiple traumatic injuries.

To prevent similar fatalities, investigators recommended the following measures:

- Consider equipping vehicles with additional mirrors to help eliminate the blind spot behind vehicles, or utilize infrared or ultrasonic devices to detect the presence of objects behind the vehicle.
- Consider equipping vehicles with audible back-up alarms.
- Consider implementing a safety policy which assigns one person per site the responsibility for directing vehicles, and specifies site locations for other pedestrian personnel.

Case #5: Road Construction Laborer Dies After Falling Underneath the Wheel of a Front End Loader

A 39-year-old road construction laborer was killed after falling beneath the wheel of a moving front end loader. The incident occurred during a paving operation in a large suburban housing development. The victim was in one of three crews working in different parts of the development under the supervision of a roving foreman. He had been assigned to work with a front-end-loader operator to chip and fill in the asphalt around manhole covers in preparation for paving. At about 12:15 p.m., the crew completed work on a manhole near a T-intersection of two roads. The driver then started moving the front end loader to the next manhole, located about 50 yards away. Hitching a ride, the victim jumped onto the loader's battery box, which was part of a side step leading up to the driver. The site foreman and a neighbor saw the loader move slowly up the road and turn onto the next street. As the loader climbed a slight incline, the driver stated that the victim (who was apparently engaging in horseplay) grabbed at the forward/reverse control lever on the loader. The driver told him to stop, but he again grabbed at the lever and moved it. This caused the machine to go into reverse, jarring the victim off the loader. He fell three feet to the ground, and the front wheel of the loader ran onto his chest. The driver immediately stopped the machine and went for the supervisor. The neighbor called for an ambulance. The police and EMS arrived and transported the victim to the local trauma center where he underwent emergency surgery. He died of his injuries 7 hours after the incident. The medical examiner determined the cause of death to be hemorrhagic shock due to multiple devastating injuries.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should develop, implement, and enforce a comprehensive safety program with the assistance of a joint labor/management safety committee.
- Employers should conduct periodic job safety meetings and refresher training.
- Manufacturers of construction equipment should consider installing an interlock system that prevents heavy equipment from suddenly reversing direction.

Case #6: Construction Foreman Crushed by Excavator

A 47-year-old construction foreman was crushed by the crawler treads of an excavator. The company had been contracted to modify existing sewer lines for new home construction. The excavator was being used to dig a trench across a two-lane road, with traffic to be routed around the work zone under flagger control. The victim had given directions to the operator regarding placement of the excavator. After speaking with the operator, he walked around to the opposite corner of the excavator. With his back to the excavator, he leaned over to move an orange safety cone. The west track of the excavator caught the victim's leg, and he fell to the ground face first into the path of the excavator. A witness ran toward the operator shouting to him to stop the machine and move backward off the victim. Another member of the crew radioed the company to notify 911. Paramedics arrived within minutes of the call. The victim was flown by helicopter to a university trauma center where he died approximately 45 minutes after the incident. The medical examiner attributed death to multiple injuries.

According to the witnesses, the excavator was equipped with an omni-directional alarm that was audible when the incident occurred. The machine was new, having logged fewer than 100 hours of operation. All of the controls were reportedly functional and the windows of the operator's station were free of cracks or other impediments to the operator's vision. The upper structure was equipped with parabolic mirrors on the cab (right) and the frame (left). The position and configuration of the upper structure and the position of the boom may have obstructed the operator's view of the track that struck the victim.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that employees are instructed to stand clear of heavy equipment that is maneuvering in a work zone.
- Employers should ensure that heavy equipment operators who must maneuver equipment with limited visibility in the direction of travel utilize an employee to signal the operator from a safe distance.
- Employers should ensure that heavy equipment operators make every effort to establish a clear view in the direction of travel before maneuvering a piece of equipment.
- Heavy equipment and other vehicles should be, when feasible, equipped with devices for visualizing or sensing the presence of humans or obstacles that are in the path of travel.

Case #7: Highway Construction Worker Dies After Being Struck While Crossing Roadway

A 55-year-old construction worker died of injuries sustained after being struck by a vehicle on an interstate highway near a major metropolitan area. The victim and a co-worker were assigned to drill holes for installation of steel pipes beneath the highway, using a boring machine. The machine was located in the ditch on the east side of the northbound lanes. Construction warning signs were set up 2,000 feet ahead of the work area. At the time of the incident, the victim's task was to cross the highway lanes to mark the exit location of the hole currently being drilled, as his co-worker monitored the gauges on the boring machine. According to witnesses, the victim was not wearing a high-visibility safety vest.

At about 8:30 a.m., when the victim crossed the highway and was near the middle of the left lane, two vehicles traveling in that lane approached him. The driver of the second vehicle momentarily looked to the right, toward the boring machine. When he looked forward again, the vehicle ahead of him had moved one lane to the right, and he saw the victim standing directly in front of him. The driver of the second vehicle turned his vehicle to the right and applied his brakes. The victim was struck by the skidding vehicle and thrown 40 feet, landing in the ditch along the left shoulder of the highway. Emergency medical personnel arrived at the scene within a few minutes. The victim was transported to a local hospital where he died approximately 2 hours later. Death was attributed to multiple blunt force injuries.

The total skid distance of the vehicle that struck the victim was 193 feet. Based on the length of the skid and the dry conditions of the road surface, the state patrol estimated the minimum speed of the vehicle as 61 miles per hour at the time the driver started braking. According to the state patrol officer's report, several drivers who witnessed the incident said that the victim was not watching the traffic as he began to cross the highway.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that employees wear high visibility vests or garments while walking and working on roadways.
- Roadway construction work should be scheduled during non-peak traffic periods.

Case #8: Asphalt Roller Crushes Flagman

A 20-year-old road construction company flagger was crushed to death when he fell from and was run over by an asphalt roller during a highway resurfacing operation. The victim had been employed by the company for 3 days. The roller operator was driving the roller up an approximate 10-degree incline, with the flagger riding on the roller. He attempted to shift into a higher gear as he was moving forward, but the roller did not shift and became stuck in neutral. The roller then began moving backwards down the incline. The operator was unable to stop the roller with the foot brake; he did not attempt to apply the emergency brake. As the roller was going downhill and gaining speed, the operator saw cars approaching on the road. To avoid a collision, he decided to turn the roller into the ditch. He told the flagger to jump clear of the roller when he drove off the pavement. As the roller left the pavement, it appeared the victim was thrown from it. The roller rolled backward into a culvert at an opposite incline, then forward. At this time, the roller drum rolled over and came to rest on the victim's head. A witness immediately directed the roller operator to reverse the roller off the victim. His injuries were too severe for any first aid to be rendered, and he died at the scene of massive head trauma.

Several risk factors may have contributed to the fatality. The flagger was riding on the roller in violation of written company policy prohibiting nonoperators from riding on equipment. Secondly, the operator attempted to shift gears while the roller was in motion, although a placard on the machine stated that doing so could result in loss of control, leading to serious injury or death. The roller operator said this prohibition was not explained to him during the 10 to 15 minutes of verbal training he had received. Finally, inspection of the roller after the incident revealed an aerosol can of starting fluid in the area of the brake pedal. This can may have been lodged under the brake pedal when the operator depressed the pedal, thus preventing the brakes from engaging. Subsequent tests on the roller showed the foot brake to be operational.

To prevent similar fatalities, investigators recommended the following measures:

- Establish a comprehensive training program for all personnel operating specialized machinery to include "hands-on" training and documentation.
- Establish a thorough vehicle maintenance and inspection program.
- Develop, implement and enforce a comprehensive safety program that includes, but is not limited to, training in all hazard recognition.

Case #9: Tree Trimmer Foreman Dies After Being Struck by a Pickup Truck

A 21-year-old tree trimmer foreman died after being struck by a pickup truck as he fed brush into a wood chipper along a two-way, two-lane state highway. The victim and a co-worker (a climber) were cutting brush for a utility company along a power line right-of-way. The wood chipper and truck used by the crew were located approximately 4 feet from the edge of the highway. Orange safety cones were placed in front of the truck, at the truck door, at the rear of the truck, and at the wheels of the chipper. Four cones were also set behind the chipper at 15-foot intervals. A 48-inch-square "Utility Work Ahead" sign was placed on the same side of the highway, behind the chipper. The posted speed limit was 55 mph. The workers were wearing green work uniforms without orange vests. Company policy required them to wear safety vests in the woods during the hunting season and at intersections; at other times vests were worn at the foreman's discretion.

At 4:30 p.m. on the second day of work at the site, the two men were feeding brush into the wood chipper attached to their truck. The victim emerged from the woods with an armload of brush as his co-worker entered the woods to gather another load. The victim began to feed the brush into the chipper. The co-worker heard a loud crash and turned to see that a small pickup truck had struck the victim, then the chipper. EMS personnel who responded could not detect any vital signs. The victim was pronounced dead at the scene by the county coroner, who listed the cause of death as closed head trauma and multiple fractures. The investigating officer estimated the speed of the pickup truck at the time of impact was 50 to 55 mph. The pickup truck driver, who was critically injured, told hospital personnel he had no memory of the incident.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that a flagger or lookout is present while work is being performed on the sides of roadways normally open to the public.
- Employers should ensure that employees wear high-visibility clothing while performing operations on the sides of roadways normally open to the public.

Case #10: Asphalt Milling Superintendent Crushed Under Asphalt Milling Machine

A 40-year-old asphalt milling superintendent was crushed when the milling machine he was operating overturned off a transporter trailer. The victim had arrived about 1:30 a.m. to complete a milling job after the regular machine operator had quit and left the site. At about 2:45 a.m., the crew began loading the milling machine for transport from the job site. Because of the length of the milling machine, the rear tracks are normally positioned over the axles of the transporter for transport, while the discharge conveyor is over the cab of the transporter's tractor. Positioning the milling machine in this manner requires that ramps be used to enable the machine to negotiate the transition from the transporter's deck in front of its wheels to the deck over the transporter wheels. To accomplish this, the crew placed two wedge-shaped wooden blocks (12- by 12- by 52-inch) in front of the deck transition. The victim began to tram the machine in reverse onto the transporter with the assistance of his co-workers, one positioned on the ground between the transporter and the edge of the roadway and the other positioned behind and to the culvert side of the trailer. As the victim trammed the machine up onto the transporter, the wooden blocks used to elevate the rear end of the machine over the transporter wheels dislodged, and the machine overturned off the transporter into a roadside culvert. The victim was trapped in the operator's station and crushed as the machine rolled on top of him. EMS responded within 15 minutes, followed by the medical examiner. The victim was pronounced dead at the scene of crush injuries to the chest.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that equipment used for loading mobile machines on transporters is configured so that precise alignment of the machine is not critical to the safety of the operation.

In addition, equipment designers, manufacturers, and employers should:

- Consider providing control station layouts that use dissimilar-shaped control levers for differing functions, or which include lockout devices to prevent hazards from inadvertent activation of controls.
- Consider machine operator visibility when developing machine designs and operational procedures.

Case #11: Conveyor Operator Dies After Being Run Over by a Belly Dump Trailer

A 33-year-old conveyor operator died of injuries he sustained when a belly dump trailer that was preparing to unload gravel ran over him. The victim was working at a job site where gravel for a highway construction project was being dumped by belly dump truck trailers. The trucks drove up a ramp composed of sand and gravel to an unloading platform, where the gates of the trailers were opened and the loads emptied into a grating system on a conveyor belt. The victim had been assigned to operate the generator of the conveyor system. As the first truck of the day approached, the driver informed the victim he was going to pour alcohol in the lines that operated the gates of the belly dump trailer to prevent the lines from freezing. The driver then pulled onto the ramp and made two unsuccessful attempts to open the gates from inside the truck cab. The victim, seeing that the gates were not opening, ran up the side of the ramp, which was outside the truck driver's field of vision. He went to an area under the trailer, where there was a lever that could be used to manually open the gates. The truck driver, noticing that other trucks were queuing up behind him, began to drive down the ramp to clear the way for other trucks to dump their loads and to make room for a mechanic to repair his trailer. The driver of the truck immediately behind him, who had observed the victim go under the trailer, attempted to contact the truck driver by radio. However, the truck was already in motion, and the victim was run over by the dual rear wheels on the passenger side of the trailer. Emergency personnel were contacted, but the victim was pronounced dead at the scene. The cause of death was transected thoracic aorta as a result of a pedestrian-dump truck accident.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that belly dump trailers are equipped with a manual gate- release lever located on the side of the trailer rather than underneath the trailer.
- Employers should ensure that employees only perform tasks which they have been trained to do.
- Employers should develop and implement a comprehensive safety program.

Case #12: Laborer Dies After Being Struck by Overturning Crane

A 24-year-old construction laborer was fatally injured when a crane being used to lower a bucket of gravel from the shoulder of an interstate highway into a drainage ditch tipped over. The six-person crew began work at 7 a.m. They positioned a 22-ton capacity, rough terrain, hydraulic crane along the highway shoulder to lower buckets of gravel and concrete down to the ditch line, about 20 feet below the shoulder's edge. The crane was set up on fully extended outriggers, with the left side outrigger floats placed on stacked wooden blocks, which provided additional bearing surface on the shoulder's newly placed fill material. The blocks also tipped the crane slightly toward the highway for additional resistance to the load. This procedure had been followed by the crew in response to a tipping incident that had occurred 3 weeks earlier. A ½-cubic-yard capacity bucket attached to the crane's load line was used to lower concrete or gravel into the ditch. The victim's task was to trip the bucket's discharge mechanism and pour out the contents.

At about 10:30 a.m., after a break, the crew repositioned the crane along the shoulder to access the unfinished area of the ditch. While part of the crew set forms in the ditch, the victim, one laborer, and the crane operator began depositing and spreading gravel. At approximately 10:45 a.m., the crane operator was lowering a load of gravel (approximately ¼ cubic yard) to the victim when the ditch side outrigger floats slipped off the timbers, allowing the crane to slide and tip over toward the ditch. As the crane tipped, the head sheave of the boom struck the victim, fracturing his skull and amputating his right arm above the elbow. One of the crew immediately called the emergency medical service (EMS), which responded within 10 minutes and pronounced the victim dead at the scene. The medical examiner determined the cause of death to be skull fracture.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that each time a crane is set up, it is level and the outrigger floats are supported by firm stable footing.
- Employers should ensure that equipment manufacturer's recommended safe operating procedures for crane set-up and lift configurations are followed.
- Employers should ensure that all crane components are properly rigged while lifting operations are being conducted.

Case #13: Construction Laborer Crushed by Asphalt Truck While Paving Interstate Highway

A 34-year-old construction laborer was fatally injured when he was crushed beneath an asphalt-carrying tractor trailer while paving a six-lane interstate highway. The 11-person crew was paving the northbound side of the highway. The high-speed lane and the middle lane had been closed to traffic. Tractor trailers delivering asphalt paving material were queued on the shoulder and partially in the high-speed lane. Two pavers were operating simultaneously in staggered positions in adjacent lanes. Paver #1 was in the far left (high-speed) lane. Paver #2 was in the middle lane staggered some distance behind paver #1, allowing trucks leaving paver #1 to pull into the middle lane to leave. Usually, trucks waited to be signaled to approach the paver, but sometimes drivers backed up as soon as they saw the previous truck leave the paver.

At the time of the incident, the driver of the truck next in line for paver #1 had just re-entered the cab of his truck. About a minute later, the victim went over to shovel old asphalt from around the catch basin located approximately 12 feet behind the waiting tractor trailer filled with asphalt. The driver saw a truck pull away from paver #1 into the adjacent middle lane, started backing up, and then heard people yelling and the truck driver working at paver #2 blowing his air horn. He stopped and found that the four left rear wheels had completely passed over the victim. The county medical examiner pronounced the victim dead at the scene. The cause of death was crushing injuries of the head and torso.

To prevent similar fatalities, investigators recommended the following measures:

- Construction employers should ensure that one person be designated as a spotter to direct trucks backing up within highway construction sites.
- Trucking company employers should design, develop and implement a comprehensive safety program that includes, but is not limited to, training for truck drivers in hazard recognition on construction sites and providing back-up alarms on trucks.
- Highway paving contractors should design, develop and implement a comprehensive safety program that includes, but is not limited to, training for highway workers in controlling traffic hazards on highway construction sites.
- Tractor-trailer manufacturers should consider providing back-up alarms and back-up lights as standard equipment on new vehicles.

Case #14: Crane Operator Falls 30 Feet from a Crane While Working from a Freeway Overpass

A 60-year-old equipment operator died after falling 30 feet from the crane he was operating on an elevated freeway. The freeway was approximately 25 feet wide from concrete guardrail to concrete guardrail. The crane was being used to set 12-inch x 12-inch timber stringers on top of the falsework on the west side of the elevated freeway. Witnesses stated that he had pulled in the outriggers on the east side to let a truck go by and had not extended them afterward. Co-workers stated that it was common practice for the crane operator to pull in the outriggers in order to allow trucks to go by. The victim continued to lift three more timbers and place them on the falsework. He then climbed down from the crane for a brief discussion with the foreman. Returning to the crane, he began to rotate the boom to the east side and over the rear of the crane. The boom was rotated at approximately an 80 degree angle from the horizontal position and was extended approximately 60 feet. Co-workers stated that they heard the crane making creaking sounds at the time. One witness stated that the victim came out of the cab and shouted "get out of the way." The crane fell over quickly and the victim was thrown to the east side, struck the boom several times, then fell approximately 30 feet to the ground. The end of the boom landed on the freeway without incident. The victim was not wearing a seat belt or hard hat. When city fire paramedics arrived 20 minutes later, they found the victim without a pulse or spontaneous respiration. The coroner listed the cause of death as craniocerebral trauma.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that operators extend and set crane outriggers when the load handled exceeds the rated load without the outriggers.
- Employers should require that there be a qualified signal person or oiler working with the crane operator to provide assistance to the operator.
- Employers should establish, as part of their site planning, a specification which does not require crane operators to retract outriggers for any type of vehicular traffic.
- Employers should require that crane operators wear seat belts at all times during operation.
- In addition, manufacturers and product designers should consider designing cranes with control systems that prohibit or limit certain maneuvers for specific load, boom, and outrigger configurations.

Case #15: Construction Laborer Dies After Being Run Over by Asphalt Roller at Highway Construction Site

A 37-year-old construction laborer died after being run over by an asphalt roller during a highway paving operation. A seven-person crew was engaged in paving the westbound lanes of a four-lane U.S. highway. At the time of the incident, the crew was paving the right lane and traffic was moving in the left lane. The victim was assigned to walk back and forth along the highway, checking the traffic cones positioned along the dotted lines at the center of the highway to ensure they were standing upright, and ensuring that the construction-zone warning signs remained standing. As the foreman of the crew operated the paving machine, the asphalt roller followed behind to smooth the newly laid asphalt. The roller operator was transporting another employee, who was standing at the front of the machine, leaning against the roll bar and looking backward. The operator made a forward pass with the roller, stopped the machine, then put it in reverse gear. The machine had traveled approximately 10 feet when the operator sensed that something was wrong; at the same time, the rider alerted the operator to stop the roller. The victim was discovered lying face down with his arms at his sides, his head crushed by the roller. The foreman radioed emergency personnel. A local fire department responded within 15 minutes, followed by a rescue squad and the state police. The victim was pronounced dead at the scene. The autopsy report indicated that the cause of death was a crushed skull.

A passing motorist who witnessed a portion of the incident told state police she saw the victim's right shoe get caught by the left side of the metal plate that ran across the back of the machine. She stated that he was on his back, then raised himself to a sitting position. She last observed him pushing against the metal plate.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that equipment operators are trained to check work areas for the presence of pedestrians in the machine's path before changing the direction of travel.
- Employers should ensure that passengers are not permitted to ride on rollers or similar mobile equipment.
- Manufacturers should consider equipping machines that must change direction frequently (such as rollers) with sensors to detect the presence of persons in the machine's path.

Case #16: Construction Worker Dies After 9-Wheel Pneumatic Roller Rolls Over on Her

A 39-year-old construction worker died of injuries sustained when the 20,000-pound 9-wheel pneumatic roller she was driving rolled over on her. She had worked for the employer for 3 months (2 days at the incident site) and had previous operating experience. The roller's drive system consisted of a four-speed manual transmission coupled with a variable-speed hydrostatic drive. This configuration required the operator to manually place the transmission in one of four gears while the roller was stationary. The drive system enabled the operator to change the direction of travel without shifting the manual transmission between gears. The normal operating speed of the roller was 3 to 5 mph. When the roller was being driven from job to job, speeds of up to 15 mph were possible. The roller was not equipped with a rollover protective structure.

Prior to the incident, the victim was operating the roller near the top of a one-half mile hill. After compacting the asphalt near the crest of the hill, she drove the roller downhill around a curve in the road. She may have shifted the roller into neutral while attempting to shift into a lower gear. However, once the machine was in neutral, it was not possible to shift into a lower gear, and the roller began to accelerate down the hill. As the roller continued downhill, the victim was able to steer it around a paver and three other paving company employees. She then left the paved road and drove on the gravel portion of the road for another quarter of a mile. The roller, traveling between 40 and 50 mph, entered a ditch and traveled approximately 100 feet before striking a rock embankment. The roller traveled across the rock embankment another 41 feet before it rolled upside down. The victim was pronounced dead at the scene. The cause of death listed on the death certificate was severe head trauma.

To prevent similar fatalities, investigators recommended the following measures:

- Pneumatic rollers should be equipped with a rollover protective structure and a seat belt; older pneumatic rollers should be retrofitted with a properly designed, manufactured, and installed rollover protective structure and seat belt.
- Employers should design, develop, and implement a comprehensive safety program.

Case #17: County Highway Department Worker Crushed When Dump Trailer and Truck Tipped Over

A 47-year-old county highway department worker was crushed when the dump trailer and truck he was directing tipped over onto him. The victim was part of a five-person crew installing a culvert drain across a county road. He began guiding a truck driver to the edge of the culvert. As the driver started to raise the dump bed, the victim was standing on the right side toward the rear of the trailer. As the trailer began to dump the load of fill around the culvert drain pipe, the fill dirt on the right side remained in the bed while the fill on the left side began sliding out. The uneven weight distribution caused the trailer to tip. The victim began running parallel with the trailer as it was beginning to tip. As the trailer tipped, it brought the truck along with it. The victim reached the area around the passenger side door of the truck when the truck tipped over onto him. Emergency personnel were called to the scene. Extrication was initiated by cutting off the top of the cab and lifting the truck with a track hoe. The victim was conscious during the extrication process. When the weight of the truck was released, the victim began hemorrhaging internally and died at the scene. The cause of death listed on the death certificate was traumatic shock and massive hemorrhaging. The truck driver sustained minor injuries.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should establish and enforce standard procedures to immediately alert the operator when loaded material in a dump trailer or truck becomes lodged within the dump bed during dumping operations. All employees on site should be trained to follow these procedures, and to identify hazards associated with instability of loaded materials.
- Employers should develop, implement, and enforce a comprehensive safety and health plan that addresses the hazards associated with heavy equipment and takes into consideration the manufacturer's safety recommendations for operation of the equipment.
- Employees working with heavy equipment operators may use signaling devices such as a whistle or radio contact in order to alert the operator when a problem arises. This allows the employee to notify the operator immediately from a safe distance.
- Employees should be trained to maintain safe working distances and work within the line of sight of the operator.

Case #18: Asphalt Machine Runs Over and Kills Worker

A 35-year-old road construction worker died after being run over by a 40-ton asphalt road-widening machine. The victim, who had been on the job only 4 days, was part of a nine-person crew that was widening a state highway in preparation for resurfacing. The victim (the ground man) and the machine operator were working alone, laying down a strip of asphalt on the right shoulder of the road. The crew normally laid two layers of asphalt: the machine moved slowly forward applying the first layer, then backed up to lay the second layer. The victim's job was to walk to the side and rear of the road widener, adjusting the width and height of the asphalt strip according to changing road conditions by adjusting the machine's side-mounted spreader arm.

The machine operator was seated on the top right side of the machine and had just finished applying the first layer of asphalt. He yelled to the victim, who was to the right and rear of the machine at a safe distance. The operator then began to back up the machine, avoiding cones and other barriers on the road. Unknown to the operator, the victim apparently jumped onto the machine as it was backing up, slipped off, and was run over by the right front tire. Although the machine was traveling only a few miles per hour, by the time the operator heard the victim's shouts and stopped the machine, it had already run over the victim. The operator moved the machine off the victim and rushed to his aid. The victim's left leg was amputated below the knee. He was transported to a county hospital, then transferred to a regional hospital, where he suffered multiple complications and died 9 days later. The medical examiner's report listed the cause of death as complications of crush injury to left hemipelvis and left leg.

The victim had frequently been observed walking inside the right arm of the machine, making adjustments using an auxiliary control panel mounted on the side of the machine. Normally these adjustments were made by the machine operator, taking verbal directions from the ground man. It is possible the victim was attempting to make some adjustments while the machine was backing up. At the time of the incident, the machine had an operating backup alarm. Crew members reported that the victim appeared fatigued that day and was perhaps not fit for duty.

To prevent similar fatalities, investigators recommended the following measures:

- Heavy equipment operators must always remain aware of the location of workers around their machines.
- Employers should enforce policies which prohibit riders on industrial equipment or vehicles that are not designed for passengers.
- Workers who are not fit for duty due to illness or fatigue should not be assigned to hazardous tasks.
- To eliminate injury risk from walking inside the wing trying to make adjustments while the machine is in operation, modify the side-mounted auxiliary control panel with a remote control which can be safely actuated by the ground man walking at a safe distance behind the machine.

Case #19: Highway Department Supervisor Struck by Reversing Dump Truck

A 55-year-old highway department supervisor died from injuries sustained after being struck by a reversing dump truck at a multi-lane highway repair project. He had been employed by the company for 30 years, and had worked at the incident site for the previous 2 weeks. The incident occurred on a heavily traveled metropolitan six-lane highway with a center divider. Counting the highway entrance acceleration lane, the incident area was four lanes wide. The crew was to patch potholes and lay down a new layer of asphalt. On the day of the incident, they had set cones and closed down all three travel lanes and the acceleration lane to traffic.

The driver of the dump truck involved in the incident was directed to the start of the patch area. The spotter then set the chains on the dump gate. The driver was then instructed to raise his bed and begin spreading the load of asphalt. At the end of the patch, the driver was instructed to lower the bed and stop the mix. He then pulled forward a short distance and parked next to the oil distributor truck. The victim, in his role as the job-site superintendent, instructed the spotter, the dump truck driver, and the distributor truck driver to lay down another patch beside the first one. He turned and walked along the shoulder. The dump truck driver and the distributor truck driver decided that the dump truck, then the oil distributor truck, would back up to the starting point of the patch. The dump truck then pulled into the rightmost traffic lane and started backing. At some point the supervisor crossed from the shoulder into the lane used by the reversing truck. The truck driver did not see the victim and backed over him. Witnesses tried to warn the victim and the driver, rushing to the site to halt the truck. Local emergency medical services (EMS) responded within minutes; however, the victim was pronounced dead at the scene. The autopsy report listed the cause of death as blunt head and chest trauma.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that mobile equipment is equipped with well-maintained audible backup alarms to warn pedestrians of impending equipment movement.
- Employers should ensure that work procedures minimize or eliminate pedestrians' exposure to hazards from moving vehicles and mobile equipment, and should enforce existing policies that establish pedestrian-free zones.
- Employers should consider providing personal audible alarms to pedestrian workers who are exposed to hazards of vehicle movement.

Case #20: Equipment Operator Dies After Scraper Overturns

A 47-year-old male equipment operator died when the scraper he was operating overturned while negotiating a turn. The victim worked for a company that had been contracted to widen a stretch of road as part of a parkway construction project. The crew consisted of two scraper operators, a bulldozer operator, a roller operator, and a site foreman. The crew was removing material from a 40-foot-wide cut area along the east edge of the existing two-lane road and transporting the material to a fill area located along the west edge of the road. The length of haul varied from 200 to 300 yards as work progressed northward. The scrapers normally cut a 6-inch-deep lift, aided by the bulldozer which pushed them through the cut area. Once the scraper was loaded, the bulldozer returned to the mouth of the cut and waited to assist in loading the next scraper. The victim had been moving earth from a cut area to a fill area. Since the lunch break, he had made four or five passes through the cut area. He had been turning in approximately the same area for about 45 minutes. As he was completing a U-turn into the cut area, the right side tire of the scraper's tractor ran up on an elevated berm, causing the machine to slowly tip over to the left. As the machine tipped, the victim apparently abandoned the operator's cab, jumping to the ground where he slipped and fell. As he was attempting to get up and retreat to safety, he was crushed by the top bar of the machine's rollover protective structure (ROPS). A co-worker who had been operating a bulldozer behind the scraper immediately notified the job foreman who called for emergency assistance. A local emergency medical service (EMS) responded in 15 minutes; however, because of the extent of the victim's injuries no first aid was rendered, and the victim was pronounced dead at the scene. Autopsy revealed the cause of death to be multiple crush injuries of the thorax, abdomen, and lower extremities.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that earthmoving equipment operators are aware of the hazards of attempting escape from the equipment during overturns and emphasize that operators remain inside the protection of the ROPS with seat belt fastened.
- Employers should ensure that operators of earthmoving equipment are aware of the importance of maintaining the lowest possible machine center of gravity at all times.
- Employers should ensure that haul-road routes are free from overturn hazards of sharply contrasting gradients and curves.

Case #21: Asphalt Roller Operator Dies Following Rollover Incident

A 24-year-old asphalt roller operator was fatally injured when a 10-ton asphalt roller rolled over her. The victim was working with a small crew on a highway outer-road resurfacing project. She had a total of 30 hours experience operating the roller on street repairs. This was her first resurfacing project. Her task was to compress the overflow of freshly poured asphalt at an established driveway to create a smooth transition. The street had an upward slope of 5 to 10 degrees and was 23 feet wide. The road curved slightly to the left with no banking. The depth of fresh asphalt on the street was about 3 inches with overflow asphalt on the sides of the road about 10 inches. The entire project covered approximately one-half mile. There was a ditch on the left side of the roller with an approximate 45-degree downward slope from the road surface, with no shoulder present.

At the time of the incident the victim, who was not wearing a seat belt, was driving forward and approaching the edge of the driveway. She did not stop at the edge of the driveway but proceeded toward the road. At this time, only a portion of the front steering roller was on the asphalt road bed. The roller began pushing up a small mound of fresh asphalt instead of rolling over and compressing it. When the back drive roller left the established driveway surface the back end slid toward the ditch. The operator attempted to pull the roller back onto the asphalt by turning the front steering roller to the right and revving the engine. As the unit began to roll over the operator slipped out of her seat, falling in the direction of the rollover and into the path of the rollover protective structure (ROPS). Co-workers were able to pull the victim clear of the roller and called EMS. The cause of death was determined to be traumatic asphyxia.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that all employees wear seatbelts during operation of any heavy equipment equipped with ROPS.
- Employers should provide workers training on how to react in the event of an equipment rollover.
- Employers should implement a training program specifically tailored to operators and their assigned equipment.
- Employers should provide worker training for hazard recognition and avoidance, along with safe work practices.

Case #22: Construction Laborer Dies After Being Struck by a Front End Loader at a Construction Site

A 20-year-old construction worker was struck by a front end loader at a construction site and died 13 hours later. The incident occurred at a concrete batch plant operated by a private contractor which accepted shipments by truck of sand and stone used to produce concrete. The facility included separate sand and stone bays, and a hopper to mix the raw materials and transport them via conveyor belt to a large mixing tank where concrete was produced. The concrete was then transported by truck to an interstate highway construction site nearby.

The area of the facility used for incoming shipments consisted of a 100-foot by 110-foot sand bay and a 130-foot by 130-foot stone bay, separated by a 25-foot-wide mixing hopper. The maneuvering area in front of the hopper and raw material bays was approximately 240 feet wide by 130 feet deep. A front end loader was used to move the raw material from the bays to the mixing hopper. A 40-foot-wide by 48-foot-deep earthen ramp was constructed in front of the hopper for use by the front end loader. The remaining area in which incoming trucks could maneuver was approximately 240 feet wide by 60 feet deep.

The victim had worked on site for approximately 15 days. On the day of the incident, he started work at approximately 7:00 a.m. and was assigned to collect shipping manifests at the entrance to the facility and direct incoming trucks to dump their loads in the sand and stone bays. He had performed these duties for 8 of the 15 days he had been at the site. He was wearing an orange reflective safety vest. At approximately 11:30 a.m., the victim directed a truck into the sand bay located to the left of the mixing hopper. The truck was dumping its load of sand when the victim walked behind the toe (bottom) of the earthen ramp located in front of the mixing hopper. A front end loader backing down the earthen ramp struck the victim approximately 24 feet from the toe of the ramp with the left rear tire, backing over him. At the time of the incident, the backup alarm and front horn on the front end loader were not operational. A state Department of Transportation official who witnessed the incident alerted the loader operator to stop. Emergency personnel arrived within minutes and administered first aid. The victim died 13 hours later at an area hospital. The autopsy report listed the cause of death as multiple blunt force trauma.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that backup alarms, horns, and other safety equipment on construction machinery are functional and tested daily. Equipment that has nonfunctioning backup alarms, horns, or other safety equipment should be removed from service until it is repaired.
- Employers should ensure that construction workers who are directing traffic flow are placed in a location where they are visible to equipment and vehicle operators. The site layout should be designed for efficient and orderly traffic flow and with personnel safety in mind. Site-specific traffic control procedures should be designed and implemented to allow for construction-site traffic and safe personnel mobility.

Case #23: Worker Dies After Being Run Over by a Front End Loader

A 31-year-old worker died of injuries he sustained after being run over by a front end loader at a construction site. On the day of the incident, the crew was working at a site where asphalt and concrete were pulverized by a crusher into material to be used for new road bases. One of the workers was operating a large front end loader equipped with a bucket to transport the asphalt and concrete to the crusher. His task was to pick up uncrushed material, drive up an earthen ramp, and dump it into the crusher. He then backed down the ramp and went to pick up additional material.

Shortly before the incident, the loader operator dumped material into the crusher and backed down the earthen ramp. After reaching the bottom of the ramp he turned the loader and continued to back across the work site. Although he knew that the victim was in the general work area, he was not aware the victim was walking in the immediate vicinity of the loader. As the operator turned the loader and continued to back across the work site, he felt the right front wheel of the loader strike something. He continued to back a short distance and then observed the victim lying on the ground in front of the loader. A co-worker contacted emergency personnel, who arrived shortly thereafter and pronounced the victim dead at the scene. The cause of death listed on the death certificate was multiple blunt force injuries.

The loader was equipped with an enclosed cab. The distance from the roof of the cab to the ground was 13 feet, 7 inches. The operator's view was obstructed only in the areas directly beyond the cab's corner support columns. However, the size of the loader made it difficult for the operator to see workers or objects in close proximity to the loader. The loader was equipped with an audible back-up alarm, but it was not working at the time of the incident. The loader had three reverse gears that allowed speeds from 4.9 mph to 14.6 mph.

To prevent similar fatalities, investigators recommended the following measures:

- Mobile equipment should be equipped with an audible back-up alarm as well as sensing units to detect pedestrian workers in the blind spots of equipment operators.
- Employers should ensure that equipment is always maintained in the proper working condition.
- Employers should ensure that heavy equipment is driven in a forward direction as much as possible.
- Employers should design, develop, and implement a comprehensive safety program.

Case #24: Laborer Run Over by Dump Truck While Paving Parking Lot

A 19-year-old laborer (victim) died after being run over by a dump truck filled with asphalt. The victim worked for a paving company that was contracted to pave the parking lot of a small office complex. At the time of the incident, the victim was leveling and smoothing freshly laid asphalt with a lute. He was in the "danger zone" area between the dump truck and the paver, smoothing a section of asphalt near the edge of a previously laid strip of asphalt. He had received training that specifically addressed the hazards associated with the fatality and he had been warned twice about not entering the area between the front of the paver and a loaded dump truck backing toward the paver. The dump truck driver did not see the victim as he backed toward the paver with a load of asphalt. Although the truck's back-up alarm was sounding, the victim did not move as the truck approached. The truck driver noticed a nearby skid-steer loader operator and the paver operator signaling him to stop. He stopped the truck and then drove forward over the victim again with the truck's rear passenger-side dual wheels. Co-workers immediately placed a call to emergency medical personnel who arrived at the scene shortly after being called. The victim was transported to a local hospital where he was pronounced dead.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should designate a single on-site worker who has responsibility for authorizing and directing the movement of certain vehicles, such as trucks traveling in reverse.
- Mobile equipment should be equipped with sensing units to detect pedestrian workers in the blind spots of the equipment operator.
- Employers should design, develop, and implement a comprehensive safety program.

Case #25: Electrician Dies After Falling From Cherry Picker Basket

A 41-year-old male electrician (victim) died after he fell from the basket of an aerial lift truck. The victim and two co-workers were installing electrical wiring for a changeable message sign on the side of a highway bridge. The two leftmost traffic lanes were closed to traffic. The workers arrived at the scene with a pickup truck and a truck equipped with a basket-type work platform attached to a hydraulic boom. After arriving at the site the victim entered the basket, swung it beneath the bridge and raised it up between two of the bridge beams. The victim determined the length of steel pipe needed for the electrical wires and verbally told his co-workers the required length of pipe. At this time the basket was positioned above the closed traffic lanes. While the co-workers cut the pipe, the victim apparently moved the basket to a location above the nearest open traffic lane.

A semi-truck approached the site and observed warning cones and signs directing traffic to merge to the right. The driver proceeded toward the work site in the open traffic lane nearest the closed lanes at approximately 60 mph. When the truck was about 50 feet from the workers' vehicles, the truck driver noticed the basket over the traffic lane in which he was driving. Before the driver could slow the truck or safely move to the next lane, the semi-truck struck the cherry picker basket. The collision caused the victim to be thrown from the basket to the surface of the roadway. Co-workers who heard the collision and saw the victim fall used a cell phone to place a call to emergency personnel. Emergency personnel arrived shortly after being notified and pronounced the victim dead at the scene.

To prevent similar fatalities, investigators recommended the following measure:

- All workers and equipment should remain or be kept within the boundaries of established work zones.

Case # 26: Heavy Equipment Operator Pinned After Bulldozer Slides off Flatbed Trailer

A 45-year-old supervisor for an excavation construction company died when the bulldozer he was driving onto a flatbed trailer overturned, pinning him underneath. The victim had returned to a residential construction site accompanied by his wife, to load the bulldozer and transport it back to the company shop. He parked the truck and trailer across the two-lane road from the driveway of the residence, with the left wheels on the road and the right wheels on the shoulder. There was a slight downhill grade on the shoulder to the ditch. Light rain was falling at the time of the incident, and the trailer was wet. The trailer was equipped with two metal and wood ramps that led from the ground to a wooden "beavertail" platform. After one unsuccessful attempt to drive the bulldozer onto the platform, the victim drove up the ramps and partway onto the platform. The tracks of the machine began to slide sideways towards the ditch, and off the trailer. He tried to jump out of the cab, but was pinned beneath the cab structure when it landed on top of him. The victim's wife, who had witnessed the incident from the passenger seat of the truck cab, flagged down a passing car to call for help. EMS responders elevated the bulldozer with air bags and blocks to remove the victim's body. They noted the unfastened seatbelt dangling from the seat. The victim was pronounced dead at the scene by the medical examiner. The cause of death was crushing chest injuries.

To prevent similar fatalities, investigators recommended the following measures:

- Workers should always use an operator restraint system while operating equipment equipped with rollover protective structures (ROPS).
- Employers should implement work procedures requiring that work crews (including bulldozer operators) evaluate the terrain prior to loading track equipment onto a trailer, and plan safe strategies for addressing the hazards.
- Employers should designate a qualified observer to provide verbal or signal directions when track equipment is being loaded onto a trailer.

Case #27: Member of Road Crew Struck by Semi

A 56-year-old senior highway maintenance worker was killed when the vehicle he was operating was struck from the rear by a semi on an interstate highway. The victim was driving the trail vehicle of a three-vehicle highway striping crew. On the day of the incident the victim started his shift at 7:00 a.m. He worked in the maintenance yard in the morning. The incident happened in the afternoon at approximately 3:30 p.m., only 6 or 7 minutes after the striping operation had begun.

The striping operation consisted of three vehicles. The lead vehicle was the striping machine and it was followed by a trailing vehicle with beacons and a "WET PAINT" sign. The incident vehicle was in the rear and was equipped with beacons, a "WET PAINT" sign and a roof-mounted flashing arrow board with the arrow flashing to the right. Separation distance between each of the vehicles was approximately ¼ mile to allow for the paint to dry. All three vehicles were in the left lane of the eastbound lanes of the interstate.

All three vehicles in the striping operation were moving east at approximately 18 miles per hour. A semi and trailer was passing two other semis going east. Weather conditions were optimal and the semi driver had a clear, unobstructed view of the road for approximately 15 seconds prior to the crash. The driver of the front semi that was passed also stated the driver of the incident semi appeared to have sufficient room to pull back into the right lane before impact. From the skid marks at the incident site it appears the driver of the incident semi applied the brakes approximately 1.7 seconds prior to impact. His estimated speed prior to applying the brakes was 75 to 80 mph. He struck the rear vehicle, which was a 1989 Chevrolet Suburban, and it flipped over one time and came to rest upright in the median, 195 feet from the point of impact. The driver of the vehicle that was struck was not wearing a seat belt. The impact caused him to slide up and back and he struck his head, and broke his neck. He was killed instantly.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that for mobile striping operations on a multilane road, the rear vehicle is equipped with a truck-mounted attenuator (TMA) and that it travels on the shoulder if possible.
- Employers should ensure that vehicle operators and occupants always use vehicle restraint systems.
- Employers should consider using a combination of white, orange, or blue strobe lights mounted on all vehicles in the striping operation.
- Consideration should be given to using a more durable method of striping than painting, such as heat inlaid tape, thermo-plastic striping, or tape laid in grooves in the pavement, that would decrease worker exposure to hazards.
- Training for mobile operations should address the need to constantly scan rear-view mirrors for quickly approaching traffic as well as procedures to avoid collision.

Case #28: Female Construction Worker Dies in a Compactor Tip Over at a Highway Construction Site

A 38-year-old female equipment operator (the victim) died when she was partially thrown from the compactor she was operating when it tipped over an embankment and pinned her beneath the ROPS. The employer had been subcontracted to construct a highway off ramp that would eventually lead to an overpass bridge. The employer had been involved for over 16 months with other construction activities on this particular highway expansion project, but had only been on the exit ramp project for 3 days. On the first day of the exit ramp job, the company had delivered to the site a new compactor equipped with an enclosed cab that incorporated the rollover protective structure (ROPS). Although the new compactor had ROPS, no seatbelts were installed. Unlike the old compactor, with front and rear rollers, which the victim had operated for over a year, the new compactor had a single roller in the front and pneumatic tires in the rear. The victim's job at this site was to compact the dirt ramp in preparation for hard surfacing. The victim was operating the compactor, with the enclosed cab door open, back and forth over a built-up road bed. At approximately 1:15 p.m., as she backed the compactor to the road edge, the dirt underneath the rear tire gave way and the compactor tipped over on its side and slid down the embankment. The embankment had an approximate 45-degree slope, and after the compactor slid down the hill on its side it came to rest some 25 feet from the top. When the compactor tipped, the unrestrained victim was partially thrown through the open door, and was pinned underneath the ROPS. Emergency rescue personnel were immediately called and arrived at the site within 15 minutes. The victim was pronounced dead at the site.

To prevent similar fatalities, investigators recommended the following measures:

- Equipment manufacturers, equipment dealers, and employers should ensure that all ROPS-equipped vehicles are also equipped with functioning seatbelts.
- Employers should inspect newly delivered equipment to ensure that all safety devices are available and working properly before accepting equipment and placing it in operation.
- Employers should ensure that all operators receive training on the importance of wearing seatbelts when operating machinery equipped with ROPS.
- Employees should comply with company policies that require use of safety devices.
- Employers should comply with state and federal rules and regulations pertaining to occupational safety and health.

Case #29: Laborer Run Over by Dump Truck at Roadway Resurfacing Operation

A 35-year-old male laborer was run over by a dump truck during resurfacing operations on a two-lane municipal road. The eight-person crew began resurfacing where the two-lane and four-lane road intersected. The crew began by placing a new apron of asphalt across the mouth of the intersection. The apron was then rolled while the paving machine proceeded to lay down new asphalt in the northbound lane of the two-lane road. The laborer had been assigned to rake and finish the edge of the pavement where it abutted and joined with the existing concrete curb. As paving operations proceeded northward, he finished the pavement edge up to the back of the paver, which had stopped to await reloading of asphalt mix. The laborer went around the front of the paver and continued walking south in the unpaved lane toward the intersection along the center-line edge of the new mat. At about the same time, a tandem-axle dump truck, leaving the work zone at about 5 mph, was also traveling south in the unpaved lane behind him. As the laborer walked along the center line, the truck passed the paver and the driver glanced in the right-side rear-view mirror to make sure that he had cleared the paver. At this time, the laborer was slightly ahead of and adjacent to the truck's right front bumper. The roller operator working behind the paver near the intersection saw him walk in front of the truck. The truck struck and ran over him. The roller operator and the superintendent shouted to the truck driver to stop; however, the driver did not hear the warnings until the truck's right front wheel had passed over the laborer and the lead wheel of the truck's rear tandem axles had started to run over his foot. The driver stopped the truck and reversed it a short distance to free the laborer's foot. Co-workers notified 911, and emergency medical personnel responded within 12 minutes. CPR and first aid procedures were started at the scene and continued while the laborer was transported to a local hospital, about 4 miles from the site. He died at the hospital approximately ½ hour after the incident. The medical examiner attributed death to multiple body injuries.

Investigators identified several factors that may have affected the truck driver's ability to see the laborer. The laborer was wearing a white fishing hat which may have been difficult to distinguish from the white hood of the truck. Additionally, the level of the rear-view mirrors was significantly higher than the right front edge of the hood, requiring a person behind the wheel to consciously look down to see a pedestrian. Finally, several objects in the front of the truck may have been visually distracting to the driver: the top of the air cleaner (white in color) and the windshield/door post frame; a fan mounted on the dashboard; regulatory stickers affixed to the inside of the windshield directly in line with the corner of the truck hood and the driver; and a red translucent bug shield mounted across the front of the hood.

To prevent similar fatalities, investigators recommended the following measures:

- Employers should ensure that workers remain clear of moving equipment and that only those workers necessary to the job at hand be in the area.
- Employers should consider the use of electronic signaling devices or sensors to warn equipment operators of the presence of pedestrians in the blind spots of mobile equipment.
- Employers should consider providing and requiring pedestrian workers to wear high-visibility headgear of standardized color.
- Employers, manufacturers, and regulators should carefully evaluate the placement of auxiliary equipment in vehicle cabs.