Best Practices

Improving Work Zone Safety

Recommendations Based on a NIOSH Fatality Investigation

More than half of the work-related fatalities in the U.S. highway construction industry involve vehicle- or equipment-related incidents in a work zone—and many of these fatalities involve a worker on foot being struck by a vehicle.

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 Bureau of Labor Statistics (BLS) indicate that of more than half of the work-related fatalities in the U.S. highway construction industry involve vehicle- or equipment-related incidents in a work zone—and many of these fatalities involve a worker on foot being struck by a vehicle. According to Pratt, Fosbroke and Marsh (2001), "victims of these events were as likely to be struck by a construction vehicle as by a passing traffic vehicle." These authors also note that many worker-on-foot incidents involve backing vehicles.

A recent report from NIOSH's Fatality Assessment and Control Evaluation (FACE) program recounts the events leading to the death of a laborer working in a residential roadway construction work zone in North Carolina (NIOSH, 2007). The incident (summarized here) and the resulting recommendations offer insight into ways to improve overall safety in work zones.

This article is adapted from a report from NIOSH's Fatality Assessment and Control Evaluation (FACE) Program. FACE's goal is to prevent fatal work injuries by studying the work environment, the worker, the task and tools the worker was using, the energy exchange resulting in fatal injury and the role of management in controlling how these factors interact. FACE gathers information from multiple sources, such as personal interviews, examination of the fatality site and equipment involved, police and medical examiner reports, and employer safety procedures and training. The program does not seek to determine fault or place blame on workers or employers. Findings are then summarized in reports that include recommendations for prevent similar events. Learn more about the program at www.cdc.gov/niosh/FACE.

Background: The Employees & Employer

A 28-year-old laborer was working full-time for an employer that provides construction services ranging from site preparation to final building completion. He had been employed by the company for about 2 months and was primarily assigned to work on the maintenance crew. His duties included replacing curbs, gutters and sidewalks, patching asphalt, and raising and lowering water valves and manhole covers. When the paving crews were shorthanded, he also worked as a flagger, which involved directing, stopping and slowing public traffic entering and exiting roadway work zones.

The company's written safety program required new employees to attend a 1-hour safety and health orientation. They also received a 93-page employee handbook that covered many safety topics, including the company's safety policy, fall protection, electrical safety, worker clothing and PPE. The employer considered it the employee's responsibility to read and understand the handbook.

The safety manager provided specialty training (e.g., trenching, forklift, flagging) on an as-needed basis. Employees designated as flaggers had to attend formal flagging training, which consisted of 4 hours of instruction using a handbook, video and a written test. Course topics included working around work zone hazards, flagging procedures, responsibilities and coordination in the work zone. The laborer had not attended this course, although he had reportedly received informal instruction on flagging from the foreman on a previous project.

The driver of the TAC truck on this project maintained a current commercial driver's license and had worked with this employer for 5 years. He had operated a TAC truck for 1.5 years. At the time of hire, the company's drivers completed a 4-hour training class that consisted of classroom instruction and hands-on operation. This training is updated each year, and the driver had completed the required refresher training.

The Incident Scene

Work crews were resurfacing the asphalt on several residential city streets located in neighborhoods consisting of single-family dwellings. On the day of the incident, crews were resurfacing several connecting city streets. Traffic was light—it was estimated that only one or two cars per hour traveled through the work zone on the day of the incident.

The asphalt resurfacing required the application of a cationic rapid-set asphalt emulsion commonly referred to as "TAC," which acts as a glue to bond the old and new asphalt together. As part of the work process, workers elevated manhole covers in the roadway areas that needed to be resurfaced. Road work signage was set up according to the specifications in the written work contract with the city. The day of the incident was the victim's second day at this location.

The TAC truck had a gross vehicle weight rating of 50,000 lb. It had a 2,000 gallon tank and a spray assembly with 30 nozzles attached to distribute the TAC solution. Large mirrors (7 in. wide by 16 in. high) were mounted on each door of the truck, and a round spot (convex) mirror was mounted on the large mirror on the passenger side. The truck was 24 ft long and the rear tailgate was approximately 8 in. above the ground. The spray assembly was in the activated (down) position at the time of this incident, making the width at the rear of the truck approximately 10 ft.

According to employer policy, the driver was to inspect the truck each day using an equipment checklist (e.g., brakes, horn, lights, wipers, reverse alarm and safety equipment). The checklist was completed by the driver on the morning of this incident. Investigation also revealed that the truck had a working audible reverse alarm that could be heard from about 30 ft away.

The Incident Itself

On the morning of the incident, a work crew consisting of an asphalt supervisor, four operators, two skilled operators, four skilled laborers, three laborers (including the victim), five flaggers and four drivers were present in a work zone. Resurfacing activities were delayed because the streets were wet from an earlier rain.

The asphalt supervisor told the laborer he would be flagging for the paving crew. While waiting for the streets to dry, he helped with street-cleaning activities and raising manhole covers. Around 11:00 a.m., resurfacing began and the laborer was designated to flag public traffic on street A. About 1 hour later, he moved to flag public traffic at the intersection of streets B and A. At the time of the incident, he was wearing a Class II high-visibility orange vest and work boots.

Around 1:00 p.m., the asphalt supervisor left the jobsite to attend a meeting. Before leaving, he assigned a flagger and an operator to oversee the resurfacing operations. The driver of the TAC truck drove west on street B while applying TAC to the roadway surface. Following the application, he parked the truck on street B and walked west on the street where he met up with the laborer.

Another laborer came over from street A to talk to the victim and the driver. Several minutes later, the operator overseeing operations made a radio call to tell the TAC truck driver to spray another 2-ft-wide strip of TAC on the entire length of street B. The laborer from street A relayed the instructions, then returned to street A. The driver then warned the laborer/flagger to move out of the way because the driver was going to back the TAC truck (west) along street B. The total distance of the reverse travel would have been about 1,072 ft.

As this was happening, a dump truck driver drove east along street B, then parked and got out to wait until he was needed. He saw the victim standing approximately 200 ft in front of him at the intersection, with his back to the TAC truck. The dump truck driver noticed the TAC truck moving in reverse, heard the audible reverse alarm and realized the victim was standing in the truck's direct path. The dump truck driver began waving his arms in an effort to get the victim's attention.

After backing nearly 427 ft, the TAC truck struck the laborer. Thinking he had run over a manhole cover, the driver continued driving in reverse for another 25 ft. It was estimated that the truck was traveling 5 mph at the time of impact.

While waving his arms, the dump truck driver ran toward the TAC truck. Seeing the dump truck driver in his mirror, the driver stopped and exited his truck. Together they found the victim lying in front of the truck facedown on the ground on a manhole cover.

Recommendations & Discussion

• **Recommendation #1:** Employers should ensure that backing procedures are in place for mobile construction vehicles, that a spotter is designated to direct backing and that drivers are in communication with workers on foot.

Discussion: Backing procedures for trucks and construction equipment should be developed and implemented for each roadway construction job. In this case, there were only two established backing protocols and no requirement to use designated backing spotters. The employer's employee handbook states that before backing on the worksite a driver is to exit the vehicle and determine whether it is safe to back up. Additionally, the handbook advises a driver to check the vehicle's mirrors before backing.

Backing protocols should include an assigned backing spotter as well as policies which state that backing will not begin without an understandable signal from the spotter that it is safe to start backing (Pratt, et al., 2001). In addition, all operators of construction vehicles and equipment must come to a complete stop if they lose contact with a spotter and backing should not resume until contact is reestablished. Upon entering the roadway work zone, all equipment operators and truck drivers should know who the spotters are and the established backing protocol. To ensure that they are visible to the operators, all workers on foot (e.g., spotters, flaggers) should be required to wear a high-visibility safety garment (Pratt, et al.).

Employers must ensure adequate communication among all workers in a roadway work zone. Communication of any changes to scheduled tasks is critical, especially between mobile vehicle and equipment operators and workers on foot. This can be accomplished by personal one-on-one communication or hand signals, or via two-way radios. In this incident, none of the flaggers had mobile radios so they could not easily communicate with each other or their coworkers. When communication was necessary, they had to leave their designated work area to find the required person.

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• **Recommendation #2:** Provide safety training for the duties that workers are assigned to perform, and develop/implement specific training on equipment blind areas for roadway construction workers.

Discussion: OSHA regulations [specifically 29 CFR 1926.21(b)(2)] require employers to train workers to recognize and avoid unsafe conditions that may be present in their work environments, and to provide training on the regulations applicable to their work. Training should be an essential part of a roadway construction company's safety program and should address all known and anticipated hazards. To ensure the utility of the safety training, an employer might consider ways to ensure that the worker comprehends the important information (e.g., written testing, verbal questions, role-playing).

Roadway construction workers, flaggers, mobile vehicle and equipment operators should be made aware that blind areas exist around vehicles and they should be trained to identify such areas. A blind area (or blind spot) is the area around a vehicle or piece of construction equipment that is not visible to the operator, either by direct line-of-sight or indirectly by the use of internal and external mirrors.

Training is important for both construction vehicle operators and workers operating near mobile

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vehicles and equipment. As part of a research project to evaluate different strategies to prevent worker injuries in construction work zones, NIOSH contracted with Caterpillar Inc. (2003, 2004) to provide blind area diagrams for 38 different vehicles or machines used in roadway construction. These diagrams may be useful in worker training.

• Recommendation #3: Employers should develop, implement and enforce procedures that minimize exposure of workers on foot to moving construction vehicles and equipment.

Discussion: According to a December 2004 article in *BLS Monthly Labor Review*, of the 844 fatal workplace injuries on road construction sites identified by the Census of Fatal Occupational Injuries from 1995 to 2002, about 60% were the result of a worker being struck by a vehicle or some kind of mobile equipment—274 workers were struck by trucks (including 100 dump trucks), 172 were struck by automobiles or other vehicles and 63 were struck by machinery. Employers must develop procedures to minimize exposure of workers on foot to moving vehicles and equipment in the tight confines of roadway construction work zones. Construction vehicle and equipment operators and workers on foot must be made aware of the potential for exposure to construction vehicles and steps to minimize hazards for workers on foot.

Internal traffic control plans (ITCPs) are promising tools for protecting workers on foot from moving vehicles and equipment (RWZSHCA, 2005). ITCPs are site-specific plans that coordinate the flow of construction vehicles, equipment and workers on foot. These plans identify directions and pathways for moving vehicles and equipment, and should be developed by employers to minimize the backing of vehicles and equipment. ITCPs may also include designated walkways for workers on foot that are clear of operating construction vehicles and equipment, and should be developed to minimize the backing distance of vehicles and equipment and to designate areas of a work zone that are prohibited to workers on foot.

For small recurrent operations, such as filling potholes, routine maintenance and mowing work zones, a checklist could be used in place of a complete ITCP (Pratt, et al., 2001; RWZSHCA, 2005). An ITCP used with communication and a site-specific backing protocol could reduce the likelihood of workers on foot being struck by backing vehicles. Roadway construction supervisors need to continually evaluate and ensure that the work is in compliance with the prescribed procedures for the work.

Recommendation #4: Employers should consider installing aftermarket devices (e.g., camera, radar, sonar) on construction vehicles and equipment to help monitor the presence of workers on foot in blind areas.

Discussion: Rearview cameras and sensors based on radar, sonar and infrared technology are available to help monitor equipment blind spots (Ruff, 2001, 2003). Although improvements may be needed to make this technology more durable in the rough physical environment of a construction site, this equipment shows promise as a tool for worker safety. A camera mounted on the rear of the equipment provides a view of the obstructed area on a video monitor in the cab. Sensor systems provide an alarm in the cab when a person or other obstacle is detected at the rear of the equipment. A combination of a camera and a sensor system may offer the best protection, especially in congested work areas.

Recommendation #5: Manufacturers of heavy construction equipment, such as TAC trucks, should explore the possibility of incorporating new monitoring technology [e.g., tag-based warning systems that use radio frequency (RFID) or magnetic field generators on equipment to detect electronic tags worn by workers] to help monitor the presence of workers on foot in blind areas.

Discussion: In this incident, the police reported that the driver stated that he did not see the victim behind the truck. Emerging technology, such as sensor-based systems, rearview cameras and tag-based warning systems that use RFID or magnetic field generators are becoming available for construction equipment, although testing and demonstration at construction projects are still needed (Pratt, et al., 2001; Ruff, 2001, 2003). Collisions between construction vehicles, equipment and workers have been attributed, in part, to limited visibility around the equipment. As new or existing monitoring technologies are proven to be effective on worksites, equipment manufacturers should offer these systems on new equipment.

Key Recommendations

After investigating this fatality, NIOSH staff developed the following recommendations for improving work zone safety:

- Ensure that backing procedures are in place for mobile construction vehicles, a spotter is designated to direct backing and drivers are in communication with workers on foot
- Provide workers with safety training for the duties they are assigned to perform, and develop/implement specific training on equipment blind areas for roadway construction workers
- Develop, implement and enforce procedures that minimize exposure of workers on foot to moving construction vehicles and equipment
- Consider installing aftermarket devices on construction vehicles and equipment to help monitor the presence of workers on foot in blind areas
- Manufacturers of heavy construction equipment should explore the possibility of incorporating new monitoring technology to help monitor the presence of workers on foot in blind areas.

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