



Research note

Heavy equipment and truck-related deaths on excavation work sites

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Abstract

Problem: Contact with objects and equipment is the third leading cause of death in construction. This study examines heavy equipment- and truck-related deaths in the excavation work industry in construction. **Methods:** The Bureau of Labor Statistics Census of Fatal Occupational Injuries identified 253 heavy equipment related deaths on construction sites in the Excavation Work industry for the years 1992–2002. **Results:** Heavy equipment operators and construction laborers made up 63% of the heavy equipment- and truck-related deaths. Backhoes and trucks were involved in half the deaths. Rollovers were the main cause of death of heavy equipment operators. For workers on foot and maintenance workers, being struck by heavy equipment or trucks (especially while backing up for workers on foot), and being struck by equipment loads or parts were the major causes of death. **Discussion:** Ensuring adequate rollover protective structures for heavy equipment, requiring fastening of seat belts, adoption of a lock-out/tagout standard, establishing restricted access zones around heavy equipment, and requiring spotters for workers who must be near heavy equipment or trucks would reduce the risk of heavy equipment- and truck-related deaths in construction. **Impact on industry:** Safety of heavy equipment operators in particular is a major concern in excavation that needs to be addressed.

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Keywords: Construction; Heavy equipment; Trucks; Struck by; Caught in/between; ROPS; Seat belts; Surveillance

1. Problem

There has been extensive research on deaths due to trenching, especially cave-ins (National Institute for Occupational Safety and Health, 1985; Rees, 1977; Suruda, Castillo, Helmkamp, & Pettit, 1994; Suruda, Smith, & Baker, 1988; Suruda, Whitaker, Bloswick, Philips, & Sese, 2002; Twardowski, 1997). Estimates vary, but data based on the Census of Fatal Occupational Injuries (CFOI), a United States Bureau of Labor Statistics database, for 1992–1999 identified 54 deaths per year from trenching for all industries except mining and shipbuilding (The Center to Protect Workers' Rights, 2002). Eighty percent of these were in construction. Excavation-related heavy equipment, such as backhoes, and vehicles accounted for 11% of trench-related deaths, about 6 deaths per year.

Heavy equipment- and vehicle-related deaths have been extensively studied in highway work zones (U.S. 1987 Standardized Industrial Classification (SIC) code 1611 — Highway and Street Construction), especially by the U.S. National Institute for Occupational Safety and Health (NIOSH). One study found an average of 70 work zone deaths per year, 66 of them related to vehicles or heavy equipment in work zones (Pratt, Fosbroke, & Marsh, 2001). Just over two-thirds of these heavy equipment and vehicle-related work zone deaths involved workers on foot, equally split between traffic vehicles intruding into the work zone and construction vehicles or heavy equipment (especially while backing up). The latter mainly comprised trucks (61%). One quarter of the deaths involved vehicle or equipment operators, with the primary injury source being construction heavy equipment (53%) and trucks (26%). One third of the workers operating heavy equipment were not classified in heavy equipment operating professions.

Agricultural tractors accounted for about 30% of machinery-related occupational deaths from 1980–1989, according to data from the NIOSH National Traumatic

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Occupational Fatalities (NTOF) surveillance system (Pratt, Kisner, & Helmkamp, 1996). Forklifts, cranes, excavation machinery, and loaders each accounted for over 5% of deaths, according to the NTOF study. The large number of agricultural tractor rollovers led to the development of

rollover protective structures (ROPS) in the 1950's as a preventive measure (Myers, 2000).

In the United States, according to CFOI data, at least 90 workers have been killed because of compactor (steam rollers, road pavers) rollovers and collisions since 1993

Table 1
FACE program reports on excavation deaths in construction

FACE # (1)	Title
<i>Equipment Operator Deaths</i>	
92AK01301	Bulldozer operator crushed by bulldozer during construction of oil exploration island — Alaska
MN9218	Excavation company owner dies after bulldozer slips over the side of a flat bed trailer
95CA02001	Truck driver run over by heavy equipment in California
FACE 9616	Equipment operator dies after scraper overturns — Virginia
96CA01001	Operator dies when his front-end loader falls into an excavation and crushes him in California
96CA012	Truck driver run over by heavy equipment in California
96MN08401	Construction worker dies after being run over by bulldozer he had been operating
97AK01901	A low bed trailer operator was crushed during a surface compactor tipover — Alaska
97CA008	Operating engineer is crushed by a backhoe attachment when it disconnects from its tractor in California
97KY032	Bulldozer operator killed in rollover
FACE 9801	Truck driver dies after crane boom strikes truck cab at construction site — Virginia
98NJ09401	Equipment operator killed after backing a forklift into an excavation
99WI041	Heavy equipment operator pinned after bulldozer slides off flatbed trailer
01MI001	Operator pinned between the hydraulic tilt cylinder housing and the frame of a skid-steer loader
01MI056	Grader operator run over by rear tire while jumpstarting grader
FACE 2002–08	Hispanic dump-truck driver dies after being caught between frame and dump body of off-road truck while performing routine lubrication — Tennessee
02CA001	A heavy equipment operator died when the dump truck he was backing slide down an embankment and then tumbled over
02KY025	Backhoe operator dies after backhoe tips over
<i>Worker on Foot Deaths</i>	
FACE 9403	Pipefitter crushed by 5,000-pound shoring plate — South Carolina
93MN008	Worker dies after being run over by a digger derrick truck
94MA06701	New Hampshire construction project manager dies when crushed by five ton concrete slab on Massachusetts construction site
94MD063	Construction foreman crushed by excavator — Maryland
97CA009	Laborer is crushed by a clam shell bucket when it disconnects from its crane in California
97MN01901	Excavation laborer dies after being run over by a caterpillar
97MN047	Worker dies after being run over by a caterpillar
97NE041	Backhoe bucket crushes workers in trench
98AK01801	Ironworker crushed between crane outrigger and back of stretch deck trailer
98AK023	Apprentice lineman killed when caught in trencher
99MN032	Laborer run over by dump truck while paving lot
99TX390	A plumber repairing a water line in a trench died when he was struck by the bucket of a backhoe
FACE 2000–26	Construction laborer dies after being struck in the head by backhoe bucket — North Carolina
00KY09601	Construction worker dies after being struck by a falling excavator bucket
00MA5501	Construction laborer killed after a backhoe slid into an excavation — Massachusetts
01AK00801	Mechanic struck by backhoe while assisting with excavator disassembly
01AK01501	Construction laborer/equipment operator crushed by skid-steer loader
02MI157	Hispanic laborer dies when dump mechanism of lift truck activates and crushes him between truck bed bulkhead and bridge beam
FACE 2003–06	Hispanic carpenter dies after being crushed between the loader bucket of a backhoe/loader and a concrete building — North Carolina
FACE 2003–12	Hispanic pipe layer dies after being struck by excavator (track hoe) bucket on construction site — South Carolina

(1) NIOSH Fatality Assessment and Control Evaluation (FACE) Programs.

FACE: NIOSH Division of Safety Research, Morgantown, WV.

AK: Alaska Department of Health and Social Services, Anchorage, AK.

CA: California Department of Health Services, Oakland, CA.

KY: Kentucky Injury Prevention and Research Center, Lexington, KY.

MA: Massachusetts Department of Public Health, Boston, MA.

MD: Maryland Division of Labor and Industry, Baltimore, MD.

MI: Michigan State University Occupational and Environmental Medicine, East Lansing, MI.

MN: Minnesota Department of Health, Minneapolis, MN.

NE: Nebraska Department of Labor, Lincoln, NE.

NJ: New Jersey Department of Health and Senior Services, Trenton, NJ.

TX: Texas Department of Health, Austin, TX.

WI: Wisconsin Division of Health, Madison, WI.

National Institute for Occupational Safety and Health. NIOSH Fatality Assessment and Control Evaluation Website. <http://www.cdc.gov/niosh/face/faceweb.html>.

(Myers, 2003a,b). A NIOSH study of skid-steer loader-related fatalities in several industries (Parker et al., 1996) implicated bypassing or ignoring safety precautions as major contributors to the cause of death, especially in rollovers. Examples included deactivation of the seat belt interlock control system and operation of the loader without the ROPS. Another NIOSH study found that workers near excavators and backhoes are at risk of being struck by the heavy equipment or equipment parts such as buckets (NIOSH, 2004).

An Australian study of work-related fatalities from 1989–1992 involving earthmoving equipment involved 26 deaths (National Occupational Health and Safety Commission, 1999). Of these, 14 were due to being struck by the machine or machine part, and 9 were due to rollovers.

Thirty-eight NIOSH Fatality Assessment and Control Evaluation (FACE) Reports investigated excavation deaths in construction involving heavy equipment and trucks (see Table 1). Of these, 20 involved deaths of workers on foot, and 18 involved deaths of equipment operators. Of the 20 worker-on-foot deaths, 5 of 7 struck by vehicle deaths involved vehicles backing up, and 9 deaths involved workers struck by vehicle parts (e.g., backhoe buckets) or vehicle loads. Of the nine operator deaths due to vehicle rollovers, three involved seat belts not fastened, one had the seat belt removed, and one seat belt malfunctioned. Of six operator deaths while maintaining their vehicle, five involved failure to set brakes or otherwise lockout the vehicle while working on it. Since NIOSH FACE reports investigate only selected deaths, the results are not indicative of the actual breakdown of causes of death.

Heavy equipment such as bulldozers, backhoes, loaders, and trucks such as dump trucks are commonly used in excavation work. SIC code 1794 — Excavation Work — involves special trade contractors primarily involved in excavation work, digging foundations for buildings, and grading (except for highways, streets, and airport runways).

This paper examines heavy equipment- and truck-related deaths in the excavation work industry in construction.

2. Methods

Construction industry fatality data for the 2-digit BLS Standardized Industrial Classification (SIC) Codes 15, 16, and 17 for the 11 years 1992 through 2002 were identified in the CFOI database. The resulting data were entered into a Microsoft Access 2000 database.

Deaths related to SIC code 1794 (Excavation Work) were identified by selecting all records with this industry code. A total of 481 records were identified. Relying primarily on the narratives and source codes for each case, a total of 253 heavy equipment- and truck-related deaths on construction sites were identified. Deaths occurring during transportation to or from a construction site were excluded ($n=90$). Heavy equipment in this study includes bulldozers, backhoes, and other excavating equipment, and other mobile construction

equipment; trucks include dump trucks, semi-trailers, tractor trailers, and so forth. The term vehicle is used in this paper to mean either trucks or heavy equipment.

Based on the CFOI narratives, workers killed were classified into the following categories based on where they were killed: vehicle operator, worker on foot, worker maintaining vehicle, and other. Based on narratives and event code, the causes of death were classified into the following categories: rollovers, struck by vehicle, struck by object, caught in/between, and other.

Analyses are primarily descriptive. Comparative analyses (e.g., between categories of workers) are based on *proportions*, not rates, because denominator data are not known for the number of workers performing particular activities. Comparative rates between the excavation work industry and other construction industries such as street and highway construction could not be made since denominator data are not available for SIC 1794.

3. Results

CFOI data identified a total of 481 deaths in the excavation work industry from 1992 to 2002. Vehicles caused 253 of these deaths. Table 2 shows the distribution of these deaths. Moving vehicle incidents (includes 200 transportation accidents — BLS Event code 4*, and 26 Event code 0240 incidents involving a worker struck by a rolling, sliding vehicle) included 90 highway deaths and 134 deaths on excavation construction sites. The highway deaths were excluded from this analysis.

3.1. Causes of death

Table 3 shows the causes of vehicle-related deaths on excavation construction sites in greater detail, according to worker activity.

Table 2
Causes of death in the excavation industry, 1992–2002

Cause of death	Total deaths		Vehicle-related deaths on construction site	
	No.	%	No.	%
Moving vehicle incidents ¹	224	46%	134	53%
Struck by objects	76	16%	60	24%
Excavation or trenching cave-in	76	16%	—	—
Caught in/between	35	7%	31	12%
Other ²	70	15%	26	10%
Total	481	100%	253	³

1) Includes 200 BLS Event Codes 4* (transportation accidents) and 26 Event code 0240 (involving struck by rolling, sliding vehicle) where workers was struck by vehicle.

2) Other includes contact with electric current, falls, fires, explosions, caught in collapsing structures or materials.

3) Does not add to 100% due to rounding.

— Doesn't meet BLS publication criteria.

Source: U.S. Bureau of Labor Statistics CFI Research File.

Table 3

Causes of construction site heavy equipment and truck-related deaths in excavation work, by worker activity, 1992–2002

Cause of death	Vehicle operator	Worker on foot	Maintaining vehicle	Other	Total # deaths	%
Struck by vehicle	24	42	10	–	77	30%
Struck by objects	17	34	9	–	60	24%
Rollovers	57	–	–	–	57	23%
Caught in/ between	19	–	7	–	31	12%
Other*	15	–	8	–	28	11%
Total	132	82	34	5	253	100%

* Other includes non-collision accidents, falls, explosions, contact with electric current, collapsing materials, and cave-ins.

– Doesn't meet BLS publication criteria.

Source: U.S. Bureau of Labor Statistics CFOI Research File.

3.1.1. Vehicle operator deaths

Vehicle operators make up 52% of the heavy equipment- and truck-related deaths on excavation industry sites. Of the 132 vehicle operators killed, 20 (15%) were working on foot around their vehicle.

Fifteen of the 24 deaths of vehicle operators who were struck by vehicles (63%) involved the operator falling or jumping from the vehicle and then being run over by it. All nine operators on foot who were struck by vehicles were run over by their own vehicle, mostly due to it being left in gear, or a failure to set brakes.

Twenty-one of the 57 rollovers involving vehicle operators (37%) occurred when the vehicle went over an embankment or slope, deliberately or by accident. Another 16 of the 57 vehicle operator rollovers (28%) occurred while loading or unloading construction heavy equipment off trailer trucks or similar vehicles.

In 13 of the rollover instances (23%), the operator didn't fasten seat belts, including 6 cases where the operator was ejected from the overturning vehicle and crushed by it. Another five of these deaths were attributed to striking or being crushed by the ROPS.

Eleven of the 17 vehicle operators who were struck by objects (65%) were clearing trees when a falling tree struck the cab of the heavy equipment.

3.1.2. Worker on foot deaths

This group comprised 82 of the vehicle-related deaths (34%) on excavation industry site, 15 of which involved workers in trenches. Vehicles that were backing up caused the deaths of 18 of the 42 workers on foot (43%) who were struck by vehicles. Five deaths involved traffic vehicles intruding into the work area (12%).

Of the 34 workers on foot struck by objects, 14 (41%) were struck by vehicle parts such as backhoe buckets, 13 (38%) were struck by falling vehicle loads, and 6 (18%) by vehicles falling onto workers in trenches. Seven of the 34 (20%) involved crane loads or crane booms.

Thirteen of these 34 deaths involved workers in trenches (41%). Eleven of these trench-related deaths involved

falling backhoes or being struck by backhoe buckets or their loads.

3.1.3. Worker maintaining vehicle deaths

A contributing cause in 21 of the 26 deaths (81%) of maintenance workers due to being struck by vehicles/objects or caught in/between was a failure to set brakes or otherwise lock out the vehicle or vehicle parts while working on it. In five of these deaths, a driver or other person moved the vehicle while it was being worked on. Five of the eight other causes of death of these workers involved repairing vehicle tires, which exploded, and they were struck by the tire rim.

3.1.4. Other deaths

This category involved five workers who were killed while working on or in a vehicle, but were not operating it.

3.2. Vehicle types

Table 4 lists the types of vehicles involved in the heavy equipment- and truck-related deaths. Trucks (half dump trucks), backhoes and other excavating machinery, and bulldozers account for 68% of the deaths. Vehicle rollovers were involved in 18 of 45 bulldozer-related deaths (40%), 10 of 28 loader-related deaths (36% — almost all front-end loaders), 7 of 21 road grading and surfacing machinery-related deaths (33%), and 6 of 14 tractor-related deaths (43%). Twenty-six of the 63 backhoe/other excavation

Table 4

Types of vehicles involved in heavy equipment and truck-related deaths in excavation work, 1992–2002

Vehicle type	Rollover	Struck by vehicle	Struck by objects	Caught in/ between	Other	Total	%
Trucks ¹	5	34	8	11	6	64	25%
Backhoes/ other excavating machinery ²	9	13	26	6	9	63	25%
Bulldozers	18	11	7	–	8	45	18%
Loaders ³	10	–	8	6	–	28	11%
Road grading and surfacing machinery ⁴	7	10	–	–	–	21	8%
Tractors	6	–	–	–	–	14	6%
Other ⁵	–	–	10	–	–	18	7%
Total	57	76	61	31	28	253	100%

1) Includes 33 dump trucks, 15 semi-trailers/tractor trailers/tractor trucks, 16 miscellaneous trucks.

2) Includes 46 backhoes.

3) Includes 16 front end loaders, 6 bucket loaders.

4) Includes 12 graders/levelers/planers/scrapers, 8 steam rollers/road pavers.

5) Includes 10 cranes.

– Doesn't meet BLS publication criteria.

Source: U.S. Bureau of Labor Statistics CFOI Research File.

Table 5
Occupations of workers involved in heavy equipment- and truck-related deaths in excavation work, 1992–2002

Occupation	Vehicle operator	Worker on foot	Maintaining vehicle	Other	Total # deaths	%
Heavy equipment operators ¹	87	11	11	–	109	43%
Construction laborers	6	36	–	5	51	20%
Supervisors	10	13	–	–	25	10%
Managers/administrators	13	7	–	–	24	9%
Truck drivers	12	6	–	–	20	8%
Mechanics	–	–	8	–	10	4%
Other trades	–	7	–	–	14	6%
Total	132	82	34	5	253	100%

1) Includes 48 operating engineers, 28 excavating and loading machine operators, and 28 grader, dozer and scraper operators.

** Does not add to 100% due to rounding.

Source: U.S. Bureau of Labor Statistics CFOI Research File.

equipment deaths (41%) involved workers who were struck by objects, including backhoe booms and buckets, backhoe loads, and falling backhoes.

Overall, 34 of 64 truck-related deaths (53%) involved workers struck by trucks. Ten of 21 deaths related to road grading and surfacing machinery (48%) involved workers struck by vehicles. Seventeen of the total of 34 deaths of workers maintaining vehicles (50%) involved trucks. Trucks caused 21 of the 132 vehicle operator deaths (16%), and 23 of the 82 worker on foot deaths (28%).

3.3. Occupation

Table 5 lists the occupations of the workers killed in vehicle-related deaths on excavation industry sites. Heavy equipment operators (44% operating engineers) and construction laborers predominate. Eighteen of 24 managers/administrators who died (75%) were self-employed, as were 27 of 109 heavy equipment operators (25%), and 6 of 24 supervisors (24%). Note that workers maintaining vehicles were not just mechanics, but also included vehicle operators and other trades.

4. Discussion

About 44 workers are killed each year in the excavation work industry (SIC code 1794), 23 of them in heavy equipment- and truck-related incidents on excavation industry sites.

Almost half of the workers killed in these vehicle-related incidents on excavation industry sites were vehicle operators. By contrast, in highway and street construction (SIC code 1611), there were about 66 deaths per year, with one quarter of them being vehicle operators (Pratt et al., 2001). Most of the difference can be attributed to traffic intrusions killing workers on foot.

Vehicle rollovers accounted for almost one-quarter of the vehicle-related deaths on excavation industry sites. Rollovers of bulldozers and loaders caused 49% of the rollover deaths, but only 28% of all vehicle-related deaths. Going over embankments and loading and unloading heavy equipment off flatbed trucks used to transport them were the two main causes of rollovers. It was apparent from the CFOI narratives that fastening seat belts might have prevented at least one-quarter of these deaths. The fact that several operators were crushed by overturned vehicles suggests that a ROPS was not present.

OSHA regulations require ROPS for rubber-tired scrapers, rubber-tired front-end loaders, rubber-tired bulldozers, wheel-type tractors, crawler tractors and loaders and motor graders, but not compactors (29 CFR 1926.1000). ROPS help prevent injuries by preventing the vehicle from rolling more than 90 degrees and by preventing the operator from being crushed against the ground. However, seat belts must be fastened to prevent operators from being crushed against the ROPS in rollovers or from being ejected. Further research is needed on the proper design of ROPS since this study and others (Brickman & Barnett, 1998; Myers, 2003a,b) identified deaths due to equipment operators striking the ROPS. Not all of these cases involved failure to fasten seat belts.

The preponderance of falling trees in operator-struck-by-object deaths in excavation work suggests that the heavy equipment used does not have adequate falling object protection. In addition, heavy equipment operators need specific training in tree clearing operations. Procedures are needed to ensure that the trees fall away from the vehicle.

One of the main causes of deaths of operators on foot and of workers maintaining vehicles was failure to set brakes, leaving vehicles in gear, or other failures to lock out vehicles when getting off them or working around them. Promulgating an OSHA lockout/tagout standard for construction, such as is found in the OSHA General Industry Standards, would be a big step forward to decreasing these deaths. Over half of maintaining vehicle deaths involved trucks, although trucks were involved in only one-quarter of all vehicle-related deaths on excavation industry sites. More research is needed to determine why trucks are a greater maintenance hazard.

One quarter of the workers killed on excavation industry sites were workers on foot, compared to two-thirds for workers on foot in highway work zones. Much of this difference is due to fewer deaths due to traffic vehicles intruding onto the construction site, 12% of struck-by-vehicle deaths on excavation industry sites compared to 48% for highway work zones (Pratt et al., 2001). Worker-on-foot deaths due to backing vehicles on the construction site were similar in both industries, about half of struck-by-vehicle deaths. Standard backup alarms do not seem to be a solution due to other competing noises in the construction environment. Research into warning systems that alert the backing vehicle operator of nearby workers on foot or even stop the vehicle was pioneered in the mining industry but is just

starting in construction. More research is definitely needed in construction on backup warnings systems.

Being struck by vehicle parts, vehicle loads, or falling vehicles comprised over three-quarters of the struck-by-object deaths. Workers on foot accounted for almost three-quarters of these deaths. Backhoes were involved in 18 of these deaths and cranes were involved in 7 of the deaths. Vehicle parts striking workers included crane and backhoe booms, and backhoe buckets. The possibility of falling loads striking workers is the main reason for OSHA prohibiting workers from being under loads being handled by digging or lifting equipment, and requires workers to stand away from vehicles being loaded or unloaded (29 CFR 1926.651(e)). These regulations need enforcement. In addition, more attention needs to be paid to keeping workers out of the swing range of heavy equipment, especially while in trenches. Possible recommendations include establishing restricted access zones and requiring spotters for workers who have to be near heavy equipment.

This study has limitations. Rates cannot be determined since denominator data is not available for SIC 1794 from the Current Population Survey. The County Business Patterns data from the U.S. Census Bureau, which does include denominator data for the excavation work industry in the 1997 North American Industry Classification System (NAICS 23593, which is comparable to SIC 1794), does not include self-employed workers, which account for 21% of the deaths in this study. As a result, the data cannot be effectively statistically analyzed, and the comparisons of the different proportions are only qualitatively based. However, despite this, the study does show the need for interventions to address particular causes of death found in this study.

5. Summary

About 45 workers are killed each year in the excavation work industry (SIC code 1794), 23 of them in heavy equipment-related incidents on construction sites. Heavy equipment operators — especially operating engineers — and construction laborers make up almost two-thirds of the workers killed. Bulldozers, backhoes, and dump trucks were involved in over half the deaths. Just over half of the deaths involved vehicle operators, with rollovers of vehicles being the main cause of death. Failure to fasten seat belts was a contributing cause in at least one-fifth of the rollovers. Ensuring adequate ROPS and enforcement of fastening of seat belts is a crucial recommendation.

For vehicle operators on foot around their vehicles and for workers maintaining vehicles, being run over by that vehicle or being caught in/between vehicle parts were the main causes of death. Failure to set brakes or otherwise lock out the vehicle while working on or around the vehicle was a major contributing cause of death. One recommendation is promulgation of an OSHA lockout/tagout standard for construction.

For workers on foot, being struck by vehicles, especially backing vehicles, and being struck by vehicle loads and vehicle parts were the major causes of death. For workers in trenches, being struck by backhoe loads and backhoe parts or falling backhoes caused three-quarters of the deaths. Recommendations include establishing restricted access zones, requiring spotters for workers who have to be near heavy equipment, and the development of effective warnings systems for operators of backing vehicles.

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