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Crane-Related Deaths in the U.S. Construction Industry, 1984-94

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Contents

Construction work is hazardous and can lead to occupational injury and disease (Burkhart and others 1993). The U.S. construction industry has had the highest rate of injury of any major industry group in the Bureau of Labor Statistics annual survey (Bureau of Labor Statistics 1997). Mobile cranes are the backbone of the U.S. construction industry. MacCollum, a recognized authority on crane hazards, has estimated that cranes are involved in 25 to 33% of fatal injuries in construction and maintenance (MacCollum 1993).

The type and number of injuries related to cranes are difficult to quantify, because reported statistics on work-related injuries usually group cranes in larger categories such as "industrial vehicles and equipment" or "equipment and machinery." According to the Bureau of Labor Statistics (BLS), the category "industrial vehicles and equipment" accounts for 17% of fatal injuries in U.S. construction (Bureau of Labor Statistics 1993). But the proportion of injuries actually involving *construction* vehicles and equipment is probably greater. For instance, "electrocution," "falls," and "struck by objects" — all of which might include cranes and are significant sources of fatal injuries in construction — are separate categories not included in "industrial vehicles and equipment."

A study of OSHA reports by Hinze and Bren (1996) found that cranes were reported to be involved in 108 (38%) of 284 fatal electrical injuries in the construction industry that involved heavy equipment. (OSHA is the U.S. Occupational Safety and Health Administration.) In England, cranes reportedly are involved in 17% of fatal injuries in construction (Health and Safety Executive 1978).

The proportion of accidents involving cranes that result in a death or serious injury is unknown. A study in Finland showed that about 12% of accidents involving cranes result in death or permanent disability (Hakkinen 1978).

MacCollum (1980) lists 13 common failure modes of cranes:

1. Overloading
2. Side pull
3. Outrigger failure
4. Hoist limitations
5. Two-blocking
6. Killer hooks [without a throat latch]
7. Boom buckling
8. Upset/Overturn
9. Unintentional turntable turning
10. Oversteer/crabbing
11. Control confusion
12. Access/egress
13. Power-line contact

In addition, serious injuries involving cranes can occur as a result of:

14. Improper assembly or dismantling
15. Rigging failure and fall of load or lifting tackle
16. Being struck by a moving load
17. Accidents related to manlifts
18. Working or standing within the swing radius of a cab or counterweight.

Note: "Two-blocking" occurs when the traveling block suspended by the crane cables is pulled up into the stationary block at the tip of the crane, causing the cable to separate and dropping the traveling block and the load. "Killer hooks" are crane hooks that lack a mechanism for keeping the load sling in the hook, if the load should bounce or the sling move.

There are engineering controls for prevention of crane accidents. Anti two-blocking devices, outrigger extension sensing systems, overload sensors, and limit switches can eliminate or reduce certain failure modes (Jarasunas 1987). Warning devices and limit switches increase safety by providing more information to the operator and reducing the need for guesswork. However, it is unlikely that engineering controls will make crane operation a simple matter.

Dugan (1972) conducted a survey of members of the International Union of Operating Engineers (IUOE) Local 3, which compared their work injury rates with the frequency of safety training, attitudes about risk, and whether routine jobsite safety meetings were held. Safety training, job safety meetings, and attitudes about risk taking were all felt to be related to the risk of injury in construction.

The present pilot study has investigated whether OSHA reports could be used to furnish additional information on fatal work-related injuries involving cranes and to identify opportunities for prevention by increased worker safety training or other means.

Methods

Data Source

A comparison of sources of data on the U.S. construction industry indicates that OSHA investigation files provided the most detailed information about workplace deaths, at least until the Census of Fatal Occupational Injuries was established in 1992 (see National Institute for Occupational Safety and Health 1993). (table 1).*

Table 1. Reported work-related deaths in the U.S. construction industry, various sources, 1980-89

Source of death reports	*Deaths per year*	*Population covered*
Death certificates 1980-89	1,143	50 states and District of Columbia
BLS Annual Survey, 1988	850	50 states and District of Columbia
OSHA 1985-89	699	47 states and District of Columbia[a]
BLS-Census of Fatal Occupational Injuries, 1992-95[b]	1,012	50 states and District of Columbia

a. California, Michigan, and Washington state are excluded.

b. Unpublished data.

Source: For death certificates, National Institute for Occupational Safety and Health 1993; for BLS Annual Survey, Bureau of Labor Statistics 1990; for OSHA 1984-89, U.S. Occupational Safety and Health Administration 1990

The OSHA Office of Management Data Systems provided the authors with data from OSHA reports in the OSHA Integrated Management Information System.

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* *Editor's note:* Since 1992, when requested, the U.S. Bureau of Labor Statistics has provided data to researchers on crane-related deaths from its Census of Fatal Occupational Injuries, which is based on death certificates and other sources, including OSHA reports.

Selection of Cases

Fatal injuries involving cranes were identified by review of selected records from OSHA investigations. OSHA data were available from federal OSHA for 47 states and the District of Columbia for 1984-89 (excluding California, Michigan, and Washington state) and for all 50 states and the District of Columbia for 1990-94. All records coded for "hoisting apparatus" and all records of investigations in the construction industry (Standard Industrial Classification [SIC] 1500-1799) containing the following words or phrases in their narratives were reviewed: crane, boom, jib, rigging, load, lift, aerial.

Fatal injuries over which OSHA has no jurisdiction are not entered electronically. For instance, OSHA does not investigate or record a motor vehicle crash on a highway in which a worker is killed while on the job; OSHA has no jurisdiction. An auto accident — such as a vehicle striking a person — at a worksite under OSHA jurisdiction would be investigated and recorded. In addition, OSHA does not cover public-sector employees or the self-employed.

The authors selected all records of fatality investigations involving cranes for analysis. (OSHA investigates nonfatal injuries that lead to hospitalization of two or more people. The authors did not request records on nonfatal injuries from OSHA.) For 6 deaths, an initial determination could not be made as to whether a crane was involved and these cases were reviewed and resolved by Frank Fazzio (supervising safety and health inspector, State of New York). All deaths involving cranes were then assigned to one of the 18 categories previously assigned to "other" (see table 1) or to "insufficient information." Because of the unavailability of data indicating the number of construction worker full-time-equivalents at sites using cranes, fatality rates were not calculated. Death rates by establishment size were calculated, however, using employment data from the 1987 and 1992 Census of Construction Industries (corrected for the missing states [17% of U.S. population] for the appropriate years).

Study Limitations

This study has two main limitations, based on the use of OSHA data. First, the proportion of all crane-related deaths in construction which OSHA investigates is unknown and the detail available for analysis in the OSHA report summaries varies. Electronic reports were sometimes incomplete.

Second, the details in the OSHA electronic summary reports varied by type of incident. For instance, reports of deaths involving crane assembly or disassembly mentioned whether the crane was a tower crane, lattice-boom crane, or hydraulic crane. Reports concerning fatal injuries from falling loads from rigging failure rarely mentioned the type of crane involved. A study by the Construction Safety Association of Ontario of crane-related deaths in construction in Ontario during 1969-84 had enough information to distinguish the type of crane involved in each death (Dickie 1993); by contrast, the authors of this analysis of 502 crane-related deaths were unable to provide a tally for how many tower cranes vs. other types of crane were involved.

Results

For the 11 years 1984-94, 502 deaths occurred in 479 incidents involving cranes in the construction industry. There were 227 deaths (45%) in SIC 16, heavy construction, 202 deaths (40%) in SIC 17, special trade construction, and 73 deaths (15%) in SIC 15, general construction.

Electrocution by power-line contact was the most common type of incident, with 198 deaths (39%) reported. Other major categories were assembly/dismantling, boom buckling, crane upset/overturn, and rigging failure (table 3).

Crane operators accounted for only 65 (13%) of all deaths from all causes involving cranes (table 4). The distribution of deaths of crane operators by Standard Industrial Classification was similar to that of other deaths involving cranes. The greatest number occurred in SIC 16, followed by SIC 17 and SIC 15. More crane operators were killed in incidents involving upset/overturn or power-line contact than in other types of incidents, such as crane overloading (table 5). For workers who were not crane operators, deaths from power-line contact represented the largest category with 179 (42%) of the deaths in this group of workers.

Of the 58 deaths during assembly or dismantling, 54 deaths (93%) involved lattice-boom cranes, such as truck cranes and crawler cranes (table 6). Few (7%) involved tower cranes. Of the 54 deaths involving lattice-boom cranes, 48 occurred when a worker underneath the boom was knocking the boom pins out while the boom was held by the pendant line. When the lower supporting pins were removed, the boom fell onto the worker.

The most deaths from crane upset or overturn (table 7) involved cranes tipping while moving under load.

There were 36 deaths resulting from improper rigging or rigging failure that allowed a load to fall on a worker while being hoisted by a crane (table 8). There were 17 deaths in which the load slipped from the rigging, 14 deaths in which the rigging broke and allowed the load to fall, and 5 deaths in which the load broke into pieces while being lifted and fell.

There were 22 deaths in 20 incidents involving overloaded cranes (table 9). An overloaded crane overturned in 11 of the deaths. The year of manufacture of the cranes was not available from the OSHA reports. Therefore, it was not possible to determine if crane age was a contributing factor to the incidents.

Workers fatally injured by electrocution were somewhat younger than workers fatally injured by other means (table 10).

OSHA had conducted a previous inspection of the employer in 169 (34%) of the deaths (table 11).

When the number of reported deaths is considered by year of occurrence, the number of deaths peaked in 1990, when there were 70 fatalities (table 12). In that year, the OSHA database expanded to include Michigan and Washington state and to investigations by California OSHA (federal OSHA inspections in California during funding restrictions under then-Governor Dukmeijian in the three years 1987-89 were previously included in the OSHA data base). For 1990 there were 3 crane-related fatalities in California, none in Michigan, and 2 in Washington. Thus the increase in 1990 is not explained by the expansion of the OSHA database that year. (Whether construction employment was much higher in 1990 is unknown.) There was a slight decline in deaths from electrocution by power-line contact over time.

Discussion

This study confirms the findings reported previously that electrocution via power-line contact accounts for a considerable number of fatal injuries to construction workers involving cranes (MacCollum 1993; Hinze, Bren, and Bren 1995; Dickie 1993; Suruda 1988). There was a small decline in deaths from electrocution during the study period, with the largest number of such deaths (27) in 1986. A number of engineering controls such as proximity-warning devices have been proposed, but their utility has been questioned and they probably are not reliable for mobile cranes (Hipp and others 1980). The devices do not appear to have won marketplace acceptance. Thus, training of crane operators, spotters, and other construction workers would seem to remain the prevention method of choice for reducing electrocutions involving cranes.

Crane operators accounted for only 65 (13%) of all fatalities, less than the 20% reported by Hakkinen (1978) for crane accidents in Finland.

A surprising finding of this study was that assembly or dismantling of cranes was the second leading cause of fatal injury, causing 58 deaths. The proportion of deaths resulting from crane dismantling is three times the 4% reported in Ontario. Most of the deaths (48, or 83%) in this category were due to disassembling a lattice-boom crane by removing boom retaining pins while standing beneath the unsupported boom. Most lattice-boom cranes have retaining pins that can be installed from either direction. If the pins are installed from outside the boom, removal requires that the worker be underneath the boom to remove the pins by pounding on them with a hammer. Injuries occurring while dismantling lattice-boom cranes have been recognized as a serious hazard in Europe (Hakkinen 1978). At least one manufacturer has proposed the use of conically shaped boom pins which can be inserted only from inside the lattice and so can be removed without standing under the boom. This design has not found success in the crane market (William Smith, International Union of Operating Engineers, personal communication, 1996). Aside from engineering controls, such as unidirectional conical pins, increased training regarding crane assembly and disassembly should minimize this hazard.

In cases in which crane overload was not mentioned, deaths from crane upset or overturn were also the result of a variety of causes (table 7). Some of the incidents were the result of failure to follow generally accepted work procedures, such as extending crane outriggers, or backing a mobile crane off the side of a low-boy trailer.

Because data from California, Michigan, and Washington state were missing for 6 of the 11 years in this study, the number of crane-related deaths in the construction industry in 1984-94 probably exceeds the 502 reported here. The total number of such deaths is likely higher also because of OSHA's limited jurisdiction and because OSHA might have not been aware of some deaths (even where it did have jurisdiction) and, thus, not investigated them.

In conclusion, OSHA reports appear to represent a useful means for identifying causes of fatal injury related to the use of cranes in construction in the United States. Because construction cranes operate under varying conditions at multiple worksites, safe operation relies heavily on the skill of people responsible for planning and operation of cranes (Shapiro and Shapiro 1988). Based on the findings reported here, useful preventive measures for fatal injuries related to cranes would be:

- Training modules and certification for crane operators.
- Training modules for construction site managers and for workers involved in crane assembly, disassembly, and maintenance
- Crane inspection programs
- Retaining pins for lattice-boom cranes designed so that the pins cannot be removed by a worker standing under a boom
- Enforcement of existing regulations, such as the requirement to maintain a separation between equipment and high-voltage power lines of 10 to 45 feet, depending on the voltage
- An increase in the frequency of OSHA inspections of construction sites that use cranes.

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Table 2. Crane-related deaths from injury, U.S. construction, 1984-94, by Standard Industrial Classification

SIC		*Number of deaths*
	General construction (73 deaths, 15% of the total)	
152	General building contractors - residential	14
154	General building contractors - nonresidential	59
	Heavy construction (227 deaths, 45%)	
1611	Highway and street construction, except elevated highway	39
1622	Bridge, tunnel, and elevated highway	77
1623	Water, sewer, pipeline, and communications and power line	55
1629	Heavy construction, not elsewhere classified	56
	Special trade construction (202 deaths, 40%)	
171	Plumbing, heating, and air conditioning	6
172	Painting and paper hanging	3
173	Electrical work	13
174	Masonry, stonework, and tile setting	4
175	Carpentry and floor work	9
176	Roofing and sheet metal work	14
177	Concrete work	18
178	Water well drilling	2
1791	Structural steel erection (ironwork)	64
1793	Glass and glazing work	1
1794	Excavation work	12
1795	Wrecking and demolition Work	14
1796	Installation or erection of building equipment, not elsewhere classified	11
1799	Special trade contractors, not elsewhere classified	31
Total		502

Note: This listing includes only crane-related deaths investigated by state or federal OSHA. Data for 1984-89 were available from federal OSHA for 47 states, excluding California, Michigan, and Washington; data for 1990-94 covered all 50 states and District of Columbia. (Deaths for the District of Columbia are included in the Maryland total. California data cover 1990-94 and some deaths in 1987-89 during suspension of the CALOSHA program.)

Source: Data from OSHA Integrated Management Information System.

Table 3. Circumstances of injury, crane-related deaths, U.S. construction, 1984-94

Circumstances of injury	*Number of deaths (percent)*
Electrocution	198 (39%)
Crane assembly/dismantling	58 (12%)
Boom buckling/collapse[a]	41 (8%)
Crane upset/overturn[b]	37 (7%)
Rigging failure	36 (7%)
Other	24 (5%)
Overloading	22 (4%)
Struck by moving load	22 (4%)
Accidents related to manlifts	21 (4%)
Working within swing radius of counterweight	17 (3%)
Two-blocking	11 (2%)
Hoist limitations	7 (1%)
Killer hooks	3 (1%)
Access/egress	2 (0%)
Control confusion	1 (0%)
Insufficient information	2 (0%)
Total	502 (100%)

a. Excludes 8 deaths when boom buckled due to overload.

b. Excludes 11 deaths in which overloaded crane overturned.

Note: Tables on this page include only crane-related deaths investigated by state or federal OSHA. Data for 1984-89 were available from federal OSHA for 47 states, excluding California, Michigan, and Washington; data for 1990-94 covered all 50 states and District of Columbia. (Deaths for the District of Columbia are included in the Maryland total. California data cover 1990-94 and some deaths in 1987-89 during suspension of the CALOSHA program.)

Source: Data from OSHA Integrated Management Information System.

Table 4. Crane-related deaths from injury to crane operators and other workers, by Standard Industrial Classification, U.S. construction, 1984-94

SIC	*Crane operators*	*Other workers*	*Not specified*	*Total*
15. General construction	10	62	1	73
16. Heavy construction	31	187	9	227
17. Special trade construction	24	177	1	202
Total	65 (13%)	426 (85%)	11 (2%)	502 (100%)

Source: Data from OSHA Integrated Management Information System.

Table 5. Types of deaths from injury involving cranes, by victim's occupation, U.S. construction, 1984-94

	Victim's occupation			
Class of Incident	*Crane operator*	*Other worker*	*Unknown*	*Total*
Power-line contact	17	179	2	198 (39%)
Assembly/dismantling	2	51	5	58 (12%)
Boom buckling	6	34	1	41 (8%)
Upset/overturn	23	12	2	37 (7%)
Rigging failure	3	33	0	36 (7%)
Other	1	22	1	24 (5%)
Overloading	8	14	0	22 (4%)
Struck by a moving load	1	21	0	22 (4%)
Related to manlifts	0	21	0	21 (4%)
Working with swing radius of cab	0	17	0	17 (3%)
Two-blocking	1	10	0	11 (2%)
Hoist limitation	1	6	0	7 (1%)
Killer hooks	0	3	0	3 (1%)
Access/egress	2	0	0	2 (<1%)
Control confusion	0	1	0	1 (<1%)
Side pull	0	0	0	0 (0%)
Outrigger failure	0	0	0	0 (0%)
Unintentional turning	0	0	0	0 (0%)
Oversteer/crabbing	0	0	0	0 (0%)
Unknown/insufficient info.	0	2	0	2 (<1%)
Total	65 (13%)	426 (85%)	11 (2%)	502 (100%)

Note: This listing includes only crane-related deaths investigated by state or federal OSHA. Data for 1984-89 were available from federal OSHA for 47 states, excluding California, Michigan, and Washington; data for 1990-94 covered all 50 states and District of Columbia. (Deaths for the District of Columbia are included in the Maryland total. California data cover 1990-94 and some deaths in 1987-89 during suspension of the CALOSHA program.)

Source: Data from OSHA Integrated Management Information System.

Table 6. Deaths from injury during crane assembly or dismantling, U.S. construction, 1984-94

Circumstances of death	*Number of deaths*
Dismantling lattice-boom cranes	
During removal of boom pins	48
During other activities	5
Assembling lattice-boom cranes	1
Dismantling tower cranes	3
Assembling tower cranes	1
Total	58

Note: Tables on this page include only crane-related deaths investigated by state or federal OSHA. Data for 1984-89 were available from federal OSHA for 47 states, excluding California, Michigan, and Washington; data for 1990-94 covered all 50 states and District of Columbia. (Deaths for the District of Columbia are included in the Maryland total. California data cover 1990-94 and some deaths in 1987-89 during suspension of the CALOSHA program.)

Source: Data from OSHA Integrated Management Information System.

Table 7. Deaths from injury during crane overturn, U.S. construction, 1984-94 (Without mention of overloading)

Circumstances of crane overturn	*Number of deaths*
Being unloaded from trailer	2
Being moved (other than from trailer)	9
On unstable ground	2
Failure to extend outriggers	7
Incomplete information	17
Total	37

Source: Data from OSHA Integrated Management Information System.

Table 8. Death from injury because of improper rigging or crane-rigging failure, U.S. construction, 1984-94 (Load falling on worker)

Circumstances of death(s)	*Number of deaths*
Load slipped from sling or webbing	11
Load slipped from "C" clamp	3
Load struck object during lift and was dislodged from rigging (no tag lines)	3
Rigging broke during lift	14
Load broke during lift	5
Total	36

Note: Tables on this page include only crane-related deaths investigated by state or federal OSHA. Data for 1984-89 were available from federal OSHA for 47 states, excluding California, Michigan, and Washington; data for 1990-94 covered all 50 states and District of Columbia. (Deaths for the District of Columbia are included in the Maryland total. California data cover 1990-94 and some deaths in 1987-89 during suspension of the CALOSHA program.)

Source: Data from OSHA Integrated Management Information System.

Table 9. Deaths from injury involving overloaded cranes, U.S. construction, 1984-94

Circumstances	*Number of deaths*
Overloaded crane overturned	11
Boom collapse of overloaded crane	8
Other	3
Total	22

Source: Data from OSHA Integrated Management Information System.

Table 10. Crane-related deaths from injury, U.S. construction, by circumstance and average age of victim, 1984-94

	Average age (years)
All deaths (502)	36.0
Electrocution (198)	33.2
Assembly/dismantling (58)	36.2
Boom buckling (41)	37.9
Upset/overturn (37)	39.4

Note: Tables on this page include only crane-related deaths investigated by state or federal OSHA. Data for 1984-89 were available from federal OSHA for 47 states, excluding California, Michigan, and Washington; data for 1990-94 covered all 50 states and District of Columbia. (Deaths for the District of Columbia are included in the Maryland total. California data cover 1990-94 and some deaths in 1987-89 during suspension of the CALOSHA program.)

Source: Data from OSHA Integrated Management Information System.

Table 11. Previous inspections by state or federal OSHA at scene of crane-related deaths from injury, U.S. construction, 1984-94

Type of inspection	
Previous routine inspection	62 (13%)
Previous-accident inspection	102 (20%)
Complaints or referrals	5 (1%)
No previous inspection	333 (66%)
Total	502 (100%)

* p<.05

Source: Data from OSHA Integrated Management Information System.

Table 12. Total crane-related deaths from injury, including electrocution, U.S. construction, 1984-94

Year of injury	*Total deaths*	*Electrocutions*
1984	42	15
1985	61	20
1986	56	27
1987	44	22
1988	30	15
1989	37	12
1990	70	22
1991	50	18
1992	44	16
1993	34	14
1994	34	17
Total	502	198

Note: This table includes only crane-related deaths investigated by state or federal OSHA. Data for 1984-89 were available from federal OSHA for 47 states, excluding California, Michigan, and Washington; data for 1990-94 covered all 50 states and District of Columbia. (Deaths for the District of Columbia are included in the Maryland total. California data cover 1990-94 and some deaths in 1987-89 during suspension of the CALOSHA program.)

Source: Data from OSHA Integrated Management Information System.