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Crane-Related Fatalities in the Construction Industry

by

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Table of Contents

List of Tables

Executive Summary

Construction fatalities continue to occur in the construction industry in spite of the Occupational Safety and Health Administration's (OSHA) comprehensive safety standards specified in the Code of Federal Regulations. The construction industry has the third highest fatality rate among the nine major economic sectors with 13.3 fatalities per 100,000 workers in 2001; only agriculture and mining exceeded this rate. One of the major causes of fatalities during construction is the use of cranes or derricks during lifting operations. Using the case files resulting from fatality investigations during the years 1997 through 2003, provided to the Construction Industry Research and Policy Center at the University of Tennessee by OSHA, the authors examined the data to determine the proximal causes of fatal events occurring during the use and maintenance of cranes/derricks in construction.

The results showed the use of mobile cranes with lattice and telescopic booms, truck or crawler mounted, represented over 84 percent of the fatalities in the use of cranes/derricks. Based on the findings of this study the authors have the following recommendations:

- Employers should have a system in place to assess the "hazardousness" of each of their construction worksites in relation to the potential for a crane-related incident. One way to do this could be to examine compliance with the fifteen most frequently cited OSHA standards listed in this paper as part of their occupational safety and health program.
- Based on this research the authors believe that several types of crane-related construction fatalities will not be reduced until crane operators are required to be qualified and/or certified.
- The authors also believe that riggers/laborers should be trained in the hazards of working near cranes, since over half of the victims were riggers/laborers.
- A "diligent" competent person (as defined in 29CFR1926.32(f)) must be in charge of all aspects of lifting operations. The authors add the word "diligent," because often-times a competent person was present at the site of a crane-related fatality but did not act in a diligent manner in assuring safety at the work site.
- OSHA should consider modifying its list of major crane-related fatality causes to match those observed in this study.
- Special attention regarding training and awareness should be paid to workers whose normal day-to-day activities do not involve crane-related work, but who may from time-to-time be required to work in lifting operations.
- OSHA should continue to improve its system of collecting information during fatality investigations, including emphasis on intervention strategies, from top management down to field staff. During the collection of data OSHA needs to ensure that the data are accurate and capture all relevant features of the situation in which the fatality occurred to improve usefulness to researchers and policymakers inside and outside of the Agency. This would provide data access to more researchers interested in studying the determinants of crane-related and other occupational fatalities.

1.0 Introduction

Construction fatalities continue to occur in the construction industry in spite of the Occupational Safety and Health Administration's comprehensive safety standards specified in Title 29, Part 1926, of the Code of Federal Regulations. The construction industry had the third highest fatality rate among the nine major economic sectors with 13.3 fatalities per 100,000 workers in 2001; only agriculture and mining exceeded this rate (Department of Labor 2003).

The United States Occupational Safety and Health Administration (OSHA or "the Agency") Compliance Safety and Health Officers (CSHOs) investigated 7,479 fatalities in the construction industry from 1991 to 2002. Under contract with OSHA's Directorate of Construction and Directorate of Evaluation and Analysis, Office of Statistical Analysis, the Construction Industry Research and Policy Center (CIRPC) at the University of Tennessee analyzed the electronic records of these fatalities, which are available in the Agency's Integrated Management Information System (IMIS). The IMIS records cover the entire nation including both Federal Program and State Program States. Federal Program States are those states (Alabama, Arkansas, Colorado, Connecticut, District of Columbia, Delaware, Florida, Georgia, Idaho, Illinois, Kansas, Louisiana, Maine, Massachusetts, Mississippi, Missouri, Montana, North Dakota, Nebraska, New Hampshire, New Jersey, New York, Ohio, Oklahoma, Pennsylvania, Rhode Island, South Dakota, Texas, West Virginia, Wisconsin) wherein OSHA conducts and manages the National occupational safety and health program. The State Program States are the remaining states that have assumed responsibility under state law to conduct their own safety and health program. As of 2004, approximately 57 percent of construction employment in the nation was in the Federal Program States (Department of Labor 2004)

In support of its analysis of the IMIS records, CIRPC developed a mutually exclusive list of 29 proximal cause codes of fatal construction events. Each fatal event occurring during the study period was classified and ranked by proximal cause and annual reports were submitted to OSHA (Schriver and Cressler 1991-2002). Table 1 shows the composite frequency of proximal causes. "Fall from/through roof" was the number one cause in terms of frequency, followed in rank order by "fall from/through structure (other than roof)," "crushed/run-over of non-operator by construction equipment," "electric shock by equipment contacting power source," and "hit, crushed, fall during lifting operations." These rankings are highly invariant by year (Schriver and Schoenbaum 2003). The five leading proximal causes encompassed 40 percent of the fatal construction events inspected by OSHA CSHOs throughout the nation from 1991 to 2002.

In light of the fact that cranes and derricks have become vital to construction work in the United States, and OSHA is currently in the process of updating its crane and derrick standard (Korman 2004) via the rule-making process, CIRPC reexamined the IMIS data from 1991 to 2002 to specifically look at crane-related fatalities (fatalities that involved cranes or derricks).

The reexamination showed that crane-related fatalities cut across several of the proximal cause codes originally developed by CIRPC. For example, crane-related fatalities occurred in a subset of the events originally classified as "hit, crushed, fall during lifting operations," "electric shock by equipment contacting power source," and "crushed, run-over by construction equipment during maintenance and modification." Adjusting the event frequency data into a crane-related

category resulted in a conservative estimate of approximately 600 fatal events from 1991 to 2002. This represents at least eight percent of all fatal construction events investigated by OSHA during that period.

Crane-related fatal injuries in the construction industry have been studied by others. For example, Suruda et al. (1999) examined the IMIS database for the years 1984 to 1994 and estimated that OSHA had investigated 502 deaths in 479 incidents. "Electrocution" was the largest category of crane-related deaths with 198 (39%) reported. Other major categories were "assembly/dismantling" (58 deaths, 12%), "boom buckling" (41 deaths, 8%), "crane upset/overturn" (37 deaths, 7%) and "rigging failure" (36 deaths, 7%). Only 34 percent of the construction firms employing the fatally injured workers had ever been inspected by OSHA. On the other hand, OSHA had cited employers for safety violations in 436 of the deaths it investigated during the study period (83%). Recommendations by Suruda et al. to reduce the frequency of crane-related fatalities included additional training of workers, increased OSHA inspections of construction worksites that use cranes, and more comprehensive crane inspection programs.

The current study examines comprehensively crane-related fatalities for the years 1997 to 2003 and should be of general interest in support of OSHA's current rulemaking effort for cranes and derricks. The study is intended to complement the earlier work of Suruda et al. by classifying recent fatal events by proximal cause, physical contributing factor, project end-use, construction operation, existence of an employer safety and health program, OSHA citations, and various other factors. The findings are discussed and conclusions given that include recommendations for preventing future crane-related fatalities.

2.0 Literature Review

A number of studies of crane-related fatalities have been undertaken in the last twenty five years. For the most part, these studies fall into one of two categories:

(a) Conceptual, or

(b) Empirical

While the "conceptual" studies often do contain some data, their focus is on possible human factors or equipment issues rather than on the statistical details of fatality cause. A prime example of studies of this kind is the MacCallum (1980) study which can be characterized as a hazard analysis of crane design. He concludes with a number of specific suggestions regarding crane design and operation. Jarasunas (1984a; 1984b) has studied the causes and prevention of crane accidents. In these studies he cautions against relying too heavily on placing "principal reliance on cooperation, training or constant attention on the part of the employee" in accident prevention. In his second paper he concludes his prevention research with the observation that; "from a safety engineering viewpoint, the first priority is to make the tools and equipment as safe as possible through the application of known state-of-the-art."

While not contradicting the Jarasunas conclusion, some contributors to the literature have made specific suggestions regarding operator training. For example, Neitzel, et al. (2001) reviewed crane safety in the construction industry and pointed out there is currently no federal U. S. standard requiring construction crane operators to be licensed or certified. They conclude that the number of injuries and fatalities associated with cranes remains high because of: (1) the inherent complexity of the design and operation of construction cranes, (2) the competence and skill of the crane's operators and related personnel, (3) lack of safety devices and procedures being used, and (4) the need for crane safety systems design, increased training requirements and frequent inspection by crane specialist.

In a similar vein, the American Society of Civil Engineers (ASCE) (1998) published a manual entitled "Crane Safety on Construction Sites." Within the manual ASCE published ASCE Policy Statement 424 which made eight recommendations to promote and specify safety improvements in eight areas of crane operations, including the encouragement and inclusion of courses for safe utilization of cranes and rigging in College and University Civil Engineering Construction and/or Continuing Education Programs.

Hakkenin (1993), in a paper on crane accidents in general, points out that as far as training goes, the education of all workers in the crane environment is important. In his limited data base he found that "most of the accident victims were workers fastening or loosening loads or steering loads with their hands during lifting". He concludes "that the main focus in the safety activity is to ensure safety for slingers, signalmen and other assisting workers . . . rather than crane drivers."

The National Institute for Occupational Safety and Health (NIOSH) conducts a Fatality Assessment and Control Evaluation (FACE) Program to develop intervention strategies to reduce fatalities in the work force. This program is selective and does not evaluate every workforce fatality as does OSHA. However, NIOSH (1995) published a NIOSH ALERT with the warning "Crane operators and crew members may be electrocuted when they work near overhead power lines." NIOSH looked at five fatality cases and made the following recommendations: ". . . that employers take the following measures . . . Comply with OSHA Regulations . . . Follow ANSI Guidelines . . . Notify Power Line Owners . . . Develop Safety Program . . . Evaluate Jobsites . . . Evaluate Alternative Work Methods . . . Call for Help . . . Develop Safer Equipment . . ." Under

each one of these subject matter recommendations NIOSH had more specific detailed recommendations.

Two recent studies can be characterized as primarily empirical. In the first of these, Suruda et al. (1999) examined the IMIS database of crane fatalities for the years 1984 to 1994 and estimated that OSHA had investigated 502 deaths in 479 events. "Electrocution" was the largest category of crane-related deaths with 198 (39%) reported. Other major categories were "assembly/dismantling" (58 deaths, 12%), "boom buckling" (41 deaths, 8%), "crane upset/overturn" (37 deaths, 7%) and "rigging failure" (36 deaths, 7%). Only 34 percent of the construction firms employing the fatally injured workers had ever been inspected by OSHA. On the other hand, OSHA had cited employers for safety violations in 436 (83%) of the deaths it investigated during the study period. Recommendations by Suruda et al. to reduce the frequency of crane-related fatalities included additional training of workers, increased OSHA inspections of construction worksites that use cranes, and more comprehensive crane inspection programs.

Using the same data base of OSHA fatality narratives, as Suruda, and for essentially the same time period, Shepard, et al. (2000) established taxonomy for over 550 crane fatalities. Similar to Suruda et al., the data revealed that power line contact by the crane represented 190 (36%) of the fatal events studied, while 57% of those victims electrocuted was the person handling the load. Their results also showed "fall of suspended load" onto a victim represented 55 (10%) of the fatal events, "crane overturns" onto victim represented 36 (7%) events, "fall of lattice boom during dismantling" 30 (6%) events, and "caught between counterweight and crane structure" for 15 (3%) events.

The current study is in the mold of these two empirical studies described above. It differs from them in several respects, however. In the first place the data base involves the years 1997 to 2003 whereas the other studies ended in 1994 and 1995 respectively. Secondly, the data in the early studies were based upon the IMIS narrative reports while the authors' investigation had available the full OSHA case files which provided information not in the narrative. Furthermore this study is intended to complement the earlier work of others by classifying recent fatal events by proximal cause, contributing physical factor, project end-use, construction operation, existence of an employer safety and health program, OSHA citations, and various other factors. The findings are discussed and conclusions given that include recommendations for preventing future crane-related fatalities.

3.0 Methods

Potential crane-related fatalities were identified by performing a text search of the narrative information available in the IMIS database for the years 1997 to 2003 using the key words "crane," "derrick," or "boom." OSHA then provided CIRPC with copies of the case files compiled by the CSHOs in the field who inspected the identified fatalities, but only for the Federal Program States mentioned in the introduction. The State plan States were not asked by OSHA to send case files to CIRPC. Therefore, the input data for this study represent approximately half the states in the United States.

CIRPC received 335 fatality case files from OSHA (88% of the total requested) and manually reviewed them to confirm that a crane or derrick was involved in the fatality. This resulted in the selection of 125 case files involving 126 cranes and 127 fatalities for analysis (one fatal event, electrocution, resulted in three deaths). The selected case files were then reviewed again to determine for each fatal incident:

(1) Proximal cause and physical contributing factor(s)
(2) Victim's occupation
(3) Work site by end-use function
(4) Construction operation being performed by the crane
(5) CSHO's evaluation of the safety program of the victim's employer
(6) Union representation
(7) Type of crane involved in fatal event
(8) Number and type of OSHA citations by proximal cause

Also, an attempt was made to extract information from the fatality case files regarding training and certification of the crane operator, experience of the victim (if other than operator), presence of a competent person at the site of the crane operation, and type of rigging. However, even though analysis of this additional information could be useful to OSHA and its stakeholders, the majority of the case files did not contain information on these additional topics as there was no requirement by OSHA for its CSHOs to collect such data (OSHA 1998). Therefore, these factors could not be included in the final analysis.

The following seven mutually exclusive proximal causes of crane-related fatalities were used for classifying the 125 case files:

(a) Failure of boom/cable
(b) Crane tip over
(c) Electrocution
(d) Struck by load (other than failure of boom/cable)
(e) Falls
(f) Crushed during assembly/disassembly
(g) Struck by cab/counterweight.

Physical factors contributing to each proximal cause were also developed, but were not necessarily mutually exclusive. These were defined as the physical factor(s) that contributed to each fatality (e.g., "improper rigging" that led to the proximal cause "struck by load"). Finally, CIRPC developed a coded list of constructions operations (Schriver and Cressler 1991-2002) that was recently updated to include cleanup, electrical distribution and transmission, maintenance, and mobilization (Beavers 2004) for a total of 60 comprehensive construction operations.

4.0 Results

CIRPC manually reviewed 125 case files that described OSHA investigations of crane-related fatalities in the construction industry in the Federal Program States. Selected information was extracted from each case file and summarized. Microsoft Access and Excel were used for managing data and generating summary statistics.

4.1 Proximal cause and physical contributing factor(s)

The proximal cause and physical contributing factor(s) that led to each fatality are shown in Table 2 in order of frequency. "Struck by load" was the leading cause with 40 (32%) of the 125 events. The physical contributing factors for this cause were rigging failure, unbalanced load, load dropped, accelerated movement of the crane or load and/or equipment damage. Because the physical contributing factors are not necessarily mutually exclusive (e.g., in some cases two physical factors contributed to a single fatality), the sum of contributing factors does not always equal the total number of fatal events for a specific proximal cause (Table 2).

"Electrocutions" ranked second as a proximal cause, resulting in 34 (27%) of the fatal events. Six physical factors were identified as contributing to this cause; all 34 involved failure to maintain the OSHA-specified distance from energized power lines. The boom was the lifting component which most frequently made contact with a power line, followed by "cable contact," "headache ball/sling contact," "jib contact" and "load contact."

Fatalities caused by "crushed during assembly/disassembly" all involved a lattice boom crane, usually during disassembly, with the two major physical contributing factors being improper boom support and improper pin removal resulting in the boom section crushing the person underneath the boom. There were several physical contributing factors to fatalities resulting from "failure of boom/cable." These included boom buckling or collapse, overload of the cranes capacity, equipment damage, incorrect assembly, cable failure, and two blocking. The physical contributing factors leading to fatalities caused by "crane tip over" were overload, loss of center of gravity control, outrigger failure, high winds, side pull, and improper maintenance. Only two contributing factors were attributed to the proximal cause "struck by cab/counter weight:" intentional turntable turning and bridge crane in motion (i.e., moving the crane to another location). In the case of proximal cause "falls," missing hand rails, improper operations and improper maintenance were identified.

4.2 Victim's Occupation

The authors categorized the victims into four worker occupations: (1) crane operator, (2) rigger/laborer, (3) ironworker and (4) other. "Laborer" was included with rigger because often times the person doing the rigging was identified as a laborer. "Other" was a general occupation that consisted of carpenter, truck driver, pile driver, welder, etc. From the 125 case files the authors were able to identify the victim's occupation in 117 of the cases, including the three electrocution deaths. Twelve victims were crane operators, 67 were riggers/laborers, 11 were ironworkers and there were 27 others. Table 3 shows the proximal cause in relation to the victim's occupation. Crane operators experienced no fatalities in the highest ranked proximal

cause "struck by load" and the highest number of fatalities in the fifth ranked proximal cause "crane tip over" as would be expected.

4.3 Work Site by End-Use

The United States Census Bureau has developed codes to classify construction worksites by functional end-use (U.S. Census Bureau 1997). These codes are divided by the Bureau into "building construction" and "nonbuilding construction" for a total of 48 end-use codes. The frequency of crane-related fatality events by end-use are shown in Tables 4 and 5. Thirty-four of the 48 end-use types were involved in this study. The most frequent end-use types for building construction were "All other commercial buildings" (defined as buildings intended for use primarily in the retail and service trades, e.g., stores, restaurants, automobile service stations, etc.), "Manufacturing and light industrial buildings," and "Single Family Houses, detached." The largest number for nonbuilding construction was "Bridge and elevated highways," "Highways, streets and related work," "Other nonbuilding construction," and "Harbor and port facilities." "Bridge and elevated highways" represented 18.4 percent of the fatalities studied. This was the only end-use with a frequency greater than 10 percent. Only six were greater than 5 percent.

4.4 Construction operation

The frequency and rank order of crane fatality events by construction operation are shown in Table 6. The highest frequency of crane-related fatalities occurred during mobilization when lifting or moving equipment and materials at construction site lay down areas, or on the contractors' yards. Mobilization represented 31 percent of all fatal events included in the study. The erection of steel was the second highest at 15 percent. Demolition and pile driving followed in frequency at twelve and ten percent, respectively. These four construction operations represented 68 percent of the crane-related fatality events.

4.5 Employer's safety and health program

CSHOs are required to rate employers' safety and health programs during fatality investigations using the following scale: (a) nonexistent, (b) inadequate, (c) average, and (d) above average. Seven components of an employer's safety and health program are rated: (1) is there a written safety and health program and, if so, how does it compare to the OSHA guidelines, (2) how well has the employer communicated its safety and health program to the employees, (3) how well has the employer enforced its safety and health program, (4) what type of safety training program does the employer have, (5) what type of health training program does the employer have, (6) when the fatality occurred did the employer perform its own investigation program and how well was it performed, and (7) what type of preventive action had the employer taken to prevent the fatal event (OSHA 1998).

Of the 125 crane-related fatalities, only 112 of the case files examined contained copies of the form used to rate safety and health programs (OSHA Form 1A). In addition, not every form available for review included ratings for all seven categories. Table 7 shows the total number of CSHO employer ratings for each of the seven components and the specific component rating. For the 125 case files reviewed, 74 employers were rated on their written safety and health plan, 81 on their communication to employees, 75 on enforcement, 80 on safety training, 56 on health training, 66 on accident investigation and 63 on preventive action taken. For the data available

for review, 60 percent of the employers were rated as having "average" or "above average" programs while 40 percent were rated as having "nonexistent" or "inadequate" programs.

4.6 Union Representation

The OSHA case files contained information on whether the victim was represented by a union. Union representation was indicated in 37 (29.4%) of the cases. There were differences in the size of the victims' employers between those with union contracts and those without union contracts. For example, the average and median employment sizes for unionized employers in this fatality study were 1,136 and 85 employees, respectively. The average and median employment sizes for open-shop employers were 204 and 47 employees, respectively.

4.7 Type of Crane

While CSHOs are not required by OSHA to identify the type of crane involved in a fatal event, it is usually included in the descriptions provided in the case files, often in the witness interviews. The authors were able to identify the type of crane in 120 of the 125 case files. One case involved two cranes. Table 8 provides the frequency of crane fatal events with known crane type. Mobile cranes represented over 88 percent of the fatal crane-related events with mobile cranes with lattice booms involved in over 56 percent of the fatalities.

Crane type was also examined by proximal cause of the fatalities. The proximal causes "electrocution," and "crane tip over" were associated only with mobile cranes.

4.8 OSHA Citations

Tables 9 to 15 show the frequency of OSHA Standards being violated by the victim's employer and cited by the CSHOs who investigated each fatality as serious or willful (SW). For example, Table 9 includes the 40 fatality investigations classified as "Struck by Load." For this proximal cause, 133 SW citations were issued for an average of 3.33 SW citations per fatality. The citations are ranked in the table by the OSHA Standard Subparts.

In Table 9, Subpart N - Cranes, Derricks, Hoists, Elevators and Escalators was most frequently cited (36 citations), followed by Subpart M - Fall Protection and Subpart R - Steel Erection (14 citations each), etc., for a total of 12 different Subpart citations with numerous sections of each subpart being cited. The most frequently cited section under Subpart N was 1926.550(a)(19), "All employees shall be kept clear of loads about to be lifted and of suspended loads," with 12 SW citations and 1926.550(b)(2), "All crawler... cranes in use shall meet the applicable requirements for design . . .," with six SW citations. Subpart C 1926.21(b)(2) "The employer shall instruct each employee in the recognition . . . unsafe conditions . . ." was cited eight times.

Table 10 shows the SW citations for the 34 fatalities classified as "Electrocution." These fatal events resulted in 106 Part 1926 citations, two Part 1910 "Occupational Safety and Health Standard" citations and one Section of Act 5(A)(1) citation for a total of 109 citations, resulting in 3.2 citations per fatality. Subpart N was cited most frequently with 66 SW citations. Among the specific citations within Subpart N, 1926.550(a)(15)(i), "For lines rated 50kV. or below, minimum clearance between the lines and . . . the crane shall be 10 **feet,**" was issued 21 times. There were also three citations for 1926.550(a)(15)(ii), "For lines rated over 50 kV., minimum clearance between the lines and . . . the crane shall be 10 **feet** plus 0.4 inch for each 1kV. over 50kV. . . ." Subpart C – General Safety and Health Provisions ranked second with 18 SW violations.

Table 11 shows the SW citations for the fifteen fatalities classified as "Crushed during assembly/disassembly". These events resulted in 39 Part 1926 citations for an average of 2.6 SW citations per fatality. Subpart N ranked first with 20 SW citations. Among the specific citations within Subpart N, the most frequently cited were 1926.550(a)(1), "The employer shall comply with manufacturer's specifications . . ." and 1926.550(b)(2), "All crawler . . . cranes in use shall meet the applicable requirements for design . . . ." Subpart C – "General Safety and Health Provisions" ranked second with nine SW citations.

Tables 12 to 15 show the profile of SW citations by the remaining proximal causes. Fatalities caused by "failure of boom/cable" and "crane tip-over" resulted in 1.9 and 2.7 SW citations per fatality. Proximal cause "struck by cab/counterweight" resulted in 4.5 SW citations per fatality, and "falls" represented 2.7 SW citations per fatality. Proximal cause "struck by cab/counterweight" resulted in the highest number of citations per fatality.

Finally, the fifteen most frequently cited OSHA standards in this study for all 125 events are shown in Table 16 (the table excludes sixteen occurrences of OSHA's 5(a)(1) General Duty Clause).

5.0 Discussion

This study critically reviewed data from 125 crane-related fatal events in the construction industry from 1997 to 2003 that were investigated by OSHA in the Federal Program States. The primary purpose of the study was to supplement OSHA's current rulemaking effort for cranes and derricks to provide the Agency a backdrop of the causes and circumstances surrounding crane-related fatalities. For example, with respect to the highest proximal cause "Struck by Load," in Section 1425 "Keeping Clear of Load" of the C-DAC Consensus Document, (OSHA 2004b) it is stated that: "When employees are engaged in hooking, unhooking, or guiding the load, or in the initial connection of a load to a component or structure and are within the fall zone, the following criteria shall be met . . . The materials shall be rigged by a qualified rigger." As noted in this study, many times the rigging was being done by a laborer or other person who had little or no rigger training. In addition, in the case of the second highest proximal cause "electrocution," in Section 1427 "Operator Qualification and Certification" of the C-DAC Consensus Document it is stated that: "The employer must ensure that, prior to operating any equipment covered under Section 1400, the operator is either qualified or certified to operate the equipment . . ." Part of that training is stated in Section 1408 "Power Line Safety (up to 350kV) – Crane Operations," (g) "Training," "Operators and crew assigned to work with the equipment shall be trained on the following . . ." The authors only found certification evidence of nine operators for the 126 cranes, although certification information was missing in many case files. The authors believe that qualification and certification of operators and training of operators and crew working around power lines as may be required in future OSHA standards will reduce the electrocution fatalities related to cranes.

The study was also intended to complement the earlier work of Suruda et al. (1999) by classifying more recent fatal events involving cranes by proximal cause, physical contributing factor, project end-use, construction operation, etc. However, differences in the source data for this study and the Suruda et al. study should be considered. The main difference, other than the years investigated, was that the authors examined the full case files generated by CSHOs, to obtain data while Suruda et al. based their findings on the brief abstracted descriptions and coded information found in the electronic IMIS data base.

Based on the authors personal experience, OSHA does not yet have an effective tool (data entry form), training program, or quality control system in place to help CSHOs consistently and accurately code and enter fatality inspection data into IMIS. In addition, little formal guidance is given to CSHOs on how to write effective IMIS abstracts that capture key features leading to the fatality. As a result, the narrative descriptions contained in IMIS are not standardized and are often incomplete. Many are only one or two sentences long. For this reason, the fatality case files that were made available to CIRPC by OSHA were believed to be the most complete and accurate descriptions of the fatal events investigated by OSHA. The authors suggest that it would be in OSHA's best interest, and in the interest of its stakeholders, for the Agency to comprehensively improve the way fatality data is obtained by investigation and entered into the IMIS database. Currently the information collected in the investigation appears primarily to justify and support the violations cited. It should, additionally, provide comprehensive information useful in development of intervention strategies.

The current study also coded proximal causes differently from Suruda et al. which, on the surface, led to different findings. For example, Suruda et al. observed "electrocution" as the

most important proximal cause, representing 39 percent of the fatalities they reviewed. They observed "struck by moving load" as the cause of 4 percent of the fatalities with a number eight ranking. In this study, "struck by load" was the number one proximal cause at 32 percent and "electrocution" was ranked second with 27 percent of all fatalities reviewed. The difference between the two studies can be explained by examining the 2003 case files used in this study. Application of the Suruda et al. coding criteria to these case files produced nine "electrocution" events and only one instance of "struck by moving load." Using the authors' coding scheme, however, there were nine cases of "electrocution" and seven "struck by load." The Suruda et al. criteria coded the six missing entries for "struck by load" as four "rigger failure" and two "control confusion" causes. In this study, these factors were considered to be physical contributing factors to the proximal cause "struck by load." Nevertheless, as reconfirmed by this study, electrocution remains one of the primary causes of crane-related fatalities and serious efforts are being made by industry to reduce the problem (OSHA 2004b).

Another difference between the authors' study and the Suruda et al. study is that the authors' study covered only the OSHA Federal Program States while the latter covered all states in the nation. The extent to which limited coverage would bias the authors' findings is unknown, although as pointed out earlier, in 2004, 57 percent of construction employment in the nation was in the Federal Program States.

It may also be of interest to compare the authors' findings with what OSHA has identified as the major causes of crane incidents (OSHA 2004a). OSHA defines the major causes as: (1) contact with power lines, (2) overturns, (3) falls, and (4) mechanical failures. These four causes are synonymous with the authors proximal causes of electrocution, crane tip over, falls, and failure of boom/cable. However, struck by load (other than boom/cable failure), crushed during assembly/disassembly, and struck by cab/counterweight are not included as major causes by OSHA. The Agency should consider modifying its list of major causes to match those observed in this study (Table 2).

The authors also examined the victims' occupations (Table 3). One finding that resonates from these data is the most workers who die from crane-related incidents are specialty trades workers (e.g., laborers, carpenters) who may not automatically be included in training programs related to crane safety. Special attention regarding training and awareness should be paid to these workers whose normal day-to-day activities do not involve crane-related work, but who may from time-to-time be required to work with cranes.

The end-use function of the construction worksites involving cranes were analyzed and summarized in Table 4 and 5. In Table 4 the highest crane fatalities occur in end use functions "All other commercial buildings" and "Manufacturing and light industrial buildings." This is probably due to the fact that these buildings are largely constructed of steel and steel erection requires the use of cranes more than 'Single family houses, detached" and the other listed end-use functions. In the case of Table 5, "Bridge and elevated highways" has the highest frequency of fatalities." Again, similar to steel erection, cranes must be used for bridge construction because lifting of heavy loads is required.

Table 6 provides a list of the construction operations in which cranes involved in fatalities were engaged. The table shows that "Mobilization" is the construction operation where the highest rate of fatalities occur more than twice the second highest rate. The high fatalities in

"Mobilization" would be expected because mobilization is a fundamental part of all construction operations and involves significant use of cranes for loading and unloading.

The study examined the existence and quality of employer occupational safety and health programs (Table 7). CSHOs are required to rate seven aspects of programs during fatality investigations, based on their OSHA training on the subject and professional judgment. On average 40 percent of the employers experiencing fatalities had occupational safety and health programs rates as "nonexistent" or "inadequate." Since similar data from construction employers at worksites without fatalities are not available, it is not possible to compare the results shown in Table 7 with construction industry norms. However, OSHA has noted a relationship between the application of sound management practices in the operation of safety and health programs and low incidence of occupational injuries and illnesses. The Agency advises all employers to institute and maintain in their establishments a program that provides systematic policies, procedures, and practices that are adequate to recognize and protect their employees from occupational safety and health hazards (OSHA 1989). It is possible that many fatalities could be prevented if more employers had comprehensive and meaningful safety and health programs in place at their work sites.

In this study, the authors observed that 29 percent of the fatal events involved employees represented by a union. This finding is similar to what Suruda et al. found, with union representation of 36 percent. Union workers were, on average, employed by larger companies, as noted earlier.

Regarding the types of cranes involved in the fatal incidents, mobile cranes represented 88.4 percent of the fatalities (Table 8). Electrocutions involved only mobile cranes and all were the result of a crane's boom and/or wire rope getting extremely close to or touching high voltage lines. With respect to crane tip over, mobile cranes by their nature are more susceptible to tip over than other types of cranes. The main contributing factors to crane tip over were overload and loss of center of gravity control. These two contributing factors were involved in over 57 percent of the crane tip overs. Crushed during assembly/disassembly occurred only with mobile cranes with lattice booms. This typically occurred when the boom was not supported correctly and the victim would get under the boom to knock out the pins holding the boom sections together.

There were no mobile crawler telescopic boom cranes involved in the fatalities reviewed here, perhaps due to their relative newness in the construction industry.

Finally, the authors examined the OSHA citations filed against the victims' employers by proximal cause for each fatal event (Tables 9-15). By reviewing its own citation experience OSHA may obtain a better understanding of how the current standards were applied to the most serious incidents involving cranes. The citation history also may be helpful in assisting employers to appreciate the types of safety deficits which relate to compliance with OSHA safety standards.

While it can be argued that there is some subjectivity applied by CSHOs as to the specific standards cited for a given situation (e.g., two CSHOs investigating the same fatality without knowledge of the other may cite a different mix and severity of OSHA standards), it is reasonable to assume that had the employers complied with all of the standards listed in Table 16, many, if not all, of the fatalities observed here would have been prevented.

6.0 Conclusion and Recommendations

Crane-related fatalities are significant, representing more than 8 percent of all construction fatalities investigated by OSHA , and most if not all are likely preventable. Most of the fatalities studied appear to be due to carelessness or inattention, such as working too close to energized power lines, improper rigging, or lifting loads that exceeded the weight capacities of cranes. However, it is not known to what extent "carelessness or inattention" resulted from management pressures to get jobs done quickly or the lack of quality training for workers, supervisors, and "competent persons."

The data allowed the authors to examine the proximal causes of fatalities (i.e., what happened immediately before the worker died) by a variety of factors. However, possibly more important than identifying the immediate causes of fatal events is understanding the distal (contributing factors) causes. For example, did the loads drop because the employers did not have effective systems in place to ensure that harnesses were in good working condition? One could even take a step further back and ask whether one type of insurance scheme used by the construction industry leads to more crane-related fatalities than other types do and if so, why? Unfortunately, this type of information is difficult to obtain and its association with the more obvious proximal causes usually cannot be reliably estimated.

The most frequently cited OSHA standards in this study focused on preventing both proximal and distal causes of fatalities (Table 16). For example, Sections 1926.550(a)(15), "Except where electrical distribution and transmission lines have been de-energized . . . equipment . . .shall be operated proximate to power lines only in accordance with the following:" and 1926.550(a)(19), "All employees shall be kept clear of loads about to be lifted and of suspended loads" clearly are meant to prevent serious injuries causes by "electrocution" and "struck by load" (specific proximal causes). However, Sections 1926.21(b)(2), "The employer shall instruct each employee in the recognition and avoidance of unsafe conditions . . . ." and 1926.550(a)(5), "The employer shall designate a competent person who shall inspect all machinery and equipment . . ." are more generic and effective compliance with these rules could prevent many of the proximal causes from occurring. As the OSHA standards indicate, actions taken both at the proximal and more distal levels by employers are needed to prevent serious crane-related incidents from occurring.

The following recommendations are provided based on the findings from this study.

- Employers should have a system in place to assess the "hazardousness" of each of their construction worksites in relation to the potential for a crane-related incident. One way to do this could be to examine compliance with the fifteen most frequently cited OSHA standards listed in Table 16 as part of their occupational safety and health program.
- Based on this research the authors believe that several types of crane-related construction fatalities will not be reduced until crane operators are required to be qualified and/or certified.
- The authors also believe that riggers/laborers should be trained in the hazards of working near cranes, since over half of the victims were riggers/laborers.
- A "diligent" competent person (as defined in 29CFR 1926.32(f)) must be in charge of all aspects of lifting operations. The authors add the word "diligent," because often-times a competent person was present at the site of a crane-related fatality but did not act in a diligent manner in assuring safety at the work site.

- OSHA should consider modifying its list of major crane-related fatality causes to match those observed in this study (Table 2).
- Special attention regarding training and awareness should be paid to workers whose normal day-to-day activities do not involve crane-related work, but who may from time-to-time be required to work in lifting operations.
- OSHA should continue to improve its system of collecting information during fatality investigations, including emphasis on intervention strategies, from top management down to field staff. During the collection of data OSHA needs to ensure that the data are accurate and capture all relevant features of the situation in which the fatality occurred in order to improve usefulness to researchers and policymakers inside and outside the Agency. This would provide data access to more researchers interested in studying the determinants of crane-related and other occupational fatalities.

Based on the authors review of the C-DAC Consensus Document (OSHA 2004b) most of these recommendations will be forth coming in the proposed new rule changes.

7.0 Acknowledgement

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Table 1. Rank of Proximal Fatal Event Causes: 1991 through 2002

Rank	Number of events	Percent	Proximal cause
1	851	11.4	Fall from/through roof
2	612	8.2	Fall from/with structure (other than roof)
3	573	7.7	Crushed/run-over of non-operator by operating construction equipment
4	550	7.4	Electric shock by equipment contacting power source
	100		a. ladder
	23		b. scaffold
	297		c. crane/lifting equipment/boom/dump truck
	30		d. contact while handling materials such as gutters, iron rods, etc
5	407	5.4	Hit, crushed, fall during lifting operations
6	392	5.2	Crushed/run -over/trapped of operator by operating construction equipment
7	355	4.7	Electric shock from equipment installation/tool use
8	348	4.6	Crushed/suffocation from trench collapse
9	309	4.1	Fall from/with ladder: includes collapse/fall of ladder
10	308	4.1	Crushed from collapse of structure
11	301	4.0	Electric sock by touching exposed wire
12	293	3.9	Struck by falling object/projectile (including tip-overs)
13	290	3.9	Crushed/run-over by highway vehicle
14	247	3.3	Fall from/with scaffold
15	198	2.6	Fall through opening (other than roof)
16	177	2.4	Shock/burn from lightning
17	173	2.3	Fall from/with platform or catwalk
18	166	2.2	Fire/explosion/scalding
19	155	2.1	Fall from/with bucket (aerial lift/basket)
20	151	2.0	Crushed/run-over by construction equipment during maintenance/modification
21	138	1.8	Crushed while unloading-loading equipment/material (except by crane)
22	87	1.2	Asphyxiation/inhalation of toxic vapor
23	70	0.9	Drown, non-lethal fall
24	69	0.9	Caught in/struck by stationary equipment
25	64	0.8	Fall from highway vehicle/construction equipment
26	60	0.8	Fall, other or unknown
27	53	0.7	Electric shock, other
28	48	0.6	Hyperthermia/hypothermia
29	34	0.4	Fire/explosion/scalding
TOTAL	**7479**	**100**	

Table 2. Number of Fatal Events by Proximal Cause and Physical Contributing Factors

Proximal Cause	Contributing Factors	No. of Events (%)
Struck by Load (other than failure of boom/cable)		40 (32)
	Rigging failure	*24*
	Unbalanced load	*3*
	Load dropped	*10*
	Accelerated movement	*1*
	Equipment damage	*5*
Electrocution		34 (27)
	Failure to maintain required clearance	*34*
	Boom contact	*15*
	Cable contact	*12*
	Headache ball/sling contact	*5*
	Jib contact	*1*
	Load contact	*1*
Crushed during assembly/disassembly		15 (12)
	Improper assembly	*3*
	Improper disassembly - Pin removal	*10*
	Improper boom support	*6*
Failure of boom/cable		15 (12)
	Boom buckling	*2*
	Boom collapse	*5*
	Overload	*6*
	Equipment damage	*5*
	Incorrect assembly	*3*
	Cable Snap	*3*
	Two blocking	*1*
Crane tip over		14 (11)
	Overload	*5*
	Loss of center of gravity control	*3*
	Outrigger failure	*2*
	High winds	*2*
	Side pull	*1*
	Improper maintenance	*1*
Struck by cab/counterweight		4 (3)
	Intentional turntable turning	*3*
	Bridge crane in motion	*1*
Falls		3 (2)
	Missing hand rails	*1*
	Improper operation	*1*
	Improper maintenance	*1*

Table 3. Proximal Cause of Fatal Events in Relation to Victim Occupation

Proximal Cause	Victims	No of Events (%)
Struck by Load (other than failure of boom/cable)		40 (32)
	Operator	*0*
	Rigger/Laborer	*19*
	Ironworker	*9*
	Other	*10*
	Unknown	*2*
Electrocution		34 (27)
	Operator	*2*
	Rigger/Laborer	*25*
	Ironworker	*0*
	Other	*6*
	Unknown	*1*
Crushed during assembly/disassembly		15 (12)
	Operator	*3*
	Rigger/Laborer	*5*
	Ironworker	*1*
	Other	*5*
	Unknown	*1*
Failure of boom/cable		15 (12)
	Operator	*1*
	Rigger/Laborer	*9*
	Ironworker	*1*
	Other	*3*
	Unknown	*1*
Crane Tip Over		14 (11)
	Operator	*5*
	Rigger/Laborer	*5*
	Ironworker	*0*
	Other	*2*
	Unknown	*2*
Struck by counter weight		4 (3)
	Operator	*0*
	Rigger/Laborer	*2*
	Ironworker	*0*
	Other	*1*
	Unknown	*1*
Falls		3 (2)
	Operator	*1*
	Rigger/Laborer	*2*
	Ironworker	*0*
	Other	*0*
	Unknown	*0*

Table 4. Building Construction End-Use by U.S. Census Bureau Definitions

End-Use	Frequency	Percent
All other commercial buildings[1]	11	8.8
Manufacturing and light industrial buildings	10	8.0
Single Family Houses, detached	5	4.0
Apartment buildings	3	2.4
Office buildings	3	2.4
Educational buildings	3	2.4
Other building construction	3	2.4
Other, dorms, etc.	1	0.8
Manufacturing and light industrial warehouses	1	0.8
Commercial warehouses	1	0.8
Religious buildings	1	0.8
Health care and institutional buildings	1	0.8
Farm buildings	1	0.8
Amusement, social, and recreational buildings	1	0.8
Total	45	36.0

[1] "All other commercial buildings" is defined by the U.S. Census Bureau as buildings intended for use primarily in the retail and service trades, e.g., stores, restaurants, automobile service stations, etc.

Table 5. Nonbuilding Construction End-Use by U.S. Census Bureau Definitions

End Use	Frequency	Percent
Bridge and elevated highways	23	18.4
Highways, streets and related work	10	8
Other nonbuilding construction[1]	9	7.2
Harbor and port facilities	7	5.6
Power and communication transmission lines, towers, and related facilities	3	2.4
Power plants and cogeneration plants, except hydroelectric	3	2.4
Railroad construction	3	2.4
Marine construction	3	2.4
Tunnels	2	1.6
Sewers, sewer lines, septic tanks and related facilities	2	1.6
Water mains and related facilities	2	1.6
Blast furnaces, petroleum refineries, chemical complexes, etc	2	1.6
Sewage treatment plants	2	1.6
Tank storage facilities other than water	2	1.6
Oilfields	2	1.6
Pipeline construction other than sewer or water lines	1	0.8
Water treatment plants	1	0.8
Water storage facilities	1	0.8
Urban mass transit	1	0.8
Dam and reservoir construction	1	0.8
Total	80	64.0

[1] Other nonbuilding construction is other construction not covered by the other end-use functions listed in this table.

Table 6. Frequency of Crane Fatality Events by Construction Operation

Code	Construction Operation	Frequency	Percent
37	Mobilization	39	31
37a	Lifting/moving equipment and materials	(30)	(24)
37b	Assembly/disassembly of cranes	(9)	(7.3)
12	Erecting structural steel	19	15
6	Demolition	15	12
40	Pile driving	12	10
58	Trenching, installing pipe	4	3.2
21	Forming	3	2.4
42	Placing bridge girders and beams	3	2.4
48	Pre-cast installation	3	2.4
11	Emplacing reinforcing steel	2	1.6
17	Exterior carpentry	2	1.6
25	Installing HVAC including piping, ductwork and other equipment	2	1.6
44	Pouring concrete piers and pylons	2	1.6
43	Pouring floor decks	2	1.6
03	Cleanup	1	0.8
09	Electrical Transmission and Distribution	1	0.8
10	Elevator, escalator installation	1	0.8
22	Forming for piers or pylons	1	0.8
24	Installing culverts and incidental drainage	1	0.8
26	Installing plumbing, lighting fixtures	1	0.8
33	Installing interior painting and decorating	1	0.8
23	Installing interior walls, ceilings, doors	1	0.8
24	Installing underground plumbing, conduit	1	0.8
34	Landscaping	1	0.8
36	Maintenance	1	0.8
41	Placing bridge deck	1	0.8
46	Pouring concrete foundations and walls	1	0.8
49	Roofing	1	0.8
53	Stripping and curing concrete	1	0.8
56	Temporary work	1	0.8
	Total	124[1]	100

[1]One case had no information to determine construction operation.

Table 7. CSHO Rating of Employer Safety and Health Program (n=112[a])

Program component	Ratings				Total
	"nonexistent"	"inadequate"	"average"	"above average"	
Written Safety and Health Plan	12 (16.2%)	13 (17.6%)	44 (59.5%)	5 (6.8%)	74
Communication to Employees	14 (17.2%)	25 (30.9%)	38 (46.9)	4 (4.9%)	81
Enforcement	8 (10.7%)	27 (36%)	36 (48%)	4 (5.3%)	75
Safety Training	16 (19.7%)	21 (25.9%)	40 (49.3)	4 (4.9%)	81
Health Training	11 (19.6%)	12 (21.4%)	31 (55.4%)	2 (3.6%)	56
Accident Investigation Performed	8 (12.1%)	11 (16.7%)	42 (63.6%)	5 (7.6%)	66
Preventive Action Taken	10 (15.9%)	11 (17.5%)	39 (62%)	3 (4.8%)	63
Average Rating	11.3 (15.9%)	17.1 (24.2%)	38.6 (54.5%)	3.9 (5.5%)	

[a] Out of a total of 125 crane-related fatality case files analyzed during the study period, thirteen did not have information related to safety and health programs.

Table 8. Frequency of Crane Fatal Events by Crane Type

Crane Type	Frequency	Percent
Mobile Crane with Lattice Boom	68	56.2
Crawler	(37)	(30.6)
Truck	(31)	(25.6)
Barge	(1)	(0.8)
Mobil Crane with Telescopic Boom	39	32.2
Crawler	(0)	(0)
Truck	(39)	(32.2)
Tower Crane	5	4.1
Bridge Crane	3	2.5
Container Crane	3	2.5
Jib Crane	3	2.5
Total	121[1]	100

[1] One fatal event involved two cranes

Table 9. OSHA Citations Related to Struck by Load (Other than boom/cable failure)

SB[1]	F[2]	Citation No.	Requirements of Standard
N (36)[3]	1	1926.550(a)(1)	"The employer shall comply with the manufacturer's specifications . . ."
	1	1926.550(a)(2)	"Rated load capacities, . . . shall be conspicuously posted on all equipment. . . ."
	1	1926.550(a)(5)	"The employer shall designate a competent person who shall inspect all machinery and equipment . . ."
	2	1926.550(a)(6)	". . . annual inspection of the hoisting machinery shall be made by a competent person . . ."
	2	1926.550(a)(9)	". . . swing radius of the . . . crane, . . . barricaded . . . from being struck or crushed . . ."
	1	1926.550(a)(12)	". . . windows in cabs shall be of safety glass . . ."
	1	1926.550(a)(13)(ii)	"Guardrails, handholds, and steps shall be provided on cranes for easy access . . ."
	1	1926.550(a)(14)	"Fuel tank filler pipe shall be located in such a position . . . as to not allow spill or overflow to run . . ."
	1	1926.550(a)(15)	"Except where electrical distribution and transmission lines have been deenergized . . . shall be operated proximate to power lines . . ."
	1	1926.550(a)(16)	"No modifications . . . shall be made by the employer . . ."
	12	1926.550(a)(19)	"All employees shall be kept clear of loads about to be lifted and of suspended loads."
	6	1926.550(b)(2)	"All crawler . . . cranes in use shall meet the applicable requirements for design . . ."
	1	1926.550(b)(5)	". . .hammerhead tower cranes . . .shall meet requirements for design . . ."
	1	1926.550(f)(1)(iv)	"Mobile cranes on barges shall be positively secured."
	1	1926.554(a)(1)	"The safe working load . . . shall be . . . hoist, . . ."
	1	1926.554(a)(2)	"The supporting structure . . . shall have a safe working load . . ."
	1	1926.554(a)(3)	"The support shall . . . shall not restrict the hoist from lining itself up with the load."
	1	1926.554(a)(6)	"All overhead hoists . . . shall meet the applicable requirements for construction, design, . . ."
M (14)	3	1926.501(b)(1)	". . . Each employee on a walking/working surface . . . which is 6 feet (1.8 m) or more above a lower level shall be protected . . ."
	1	1926.501(b)(3)	"Each employee in a hoist area shall be protected from falling 6 feet . . . to lower levels by . . ."

[1] SB = OSHA Subpart no.
[2] F = Frequency of citation in the 125 case files
[3] Total citations in Subpart no.

Table 9. OSHA Citations Related to Struck by Load (Continued)

SB	F	Citation No.	Requirements of Standard
M (14)	1	1926.501(b)(4)(i)	". . . employee on . . . surfaces shall be protected from falling through holes . . ."
	1	1926.501(b)(12)	"Each employee . . . erection of precast concrete . . . shall be protected from falling . . ."
	1	1926.501(b)(15)	"… each employee on a walking/working surface . . .shall be protected from falling . . ."
	1	1926.502(b)(4)	". . . top edge of the guardrail shall not deflect to a height less than 39 inches . . ."
	1	1926.502(d)(10)	". . . each employee shall be attached to a separate lifeline."
	1	1926.502(d)(23)	"Personal fall arrest systems shall not be attached to guardrail systems . . ."
	1	1926.502(k)(1)	"The fall protection plan shall be prepared by a qualified person and developed specifically for the site . . ."
	2	1926.503(a)(1)	"The employer shall provide a training program for each employee . . . exposed to fall hazards."
	1	1926.503(a)(2)	"The employer shall assure that each employee has been trained, as necessary, . . ."
R (14)	1	1926.750(b)(2)(i)	". . . Skeleton steel erection . . . floor shall be maintained . . . 30feet . . . under . . . beams . . ."
	1	1926.751(a)	". . . load shall be not be released . . . until members are secured . . ."
	1	1926.751(d)	"Tag lines shall be used for controlling loads."
	1	1926.752(b)	"When bolts . . . are being knocked out, means shall be provided to keep them from falling."
	1	1926.752(d)(1)	"Connection of the equipment used in plumbing-up shall be properly secured."
	1	1926.753(c)(5)	"Safety latches on hooks shall not be deactivated or made inoperable except:"
	2	1926.753(d)(1)	". . . no employee is required to work directly below a suspended load except for:"
	1	1926.754(a)	"Structural stability shall be maintained at all times during the erection process."
	1	1926.758(g)	"Purlins . . . shall not be used as an anchorage point for a fall arrest system unless written approval . . ."
	2	1926.760(b)(3)	"Be provided, at heights over 15 . . . lower level, with a personal fall arrest system . . ."
	1	1926.761(b)	"The employer shall provide a training program for all employees exposed to fall hazards. . . ."
	1	1926.761(c)(2)	"The employer shall ensure that each connector has been provided training . . ."
L (13)	1	1926.451(f)(7)	"Scaffolds shall be erected . . . a competent person . . ."
	1	1926.451(f)(9)	"Where swinging loads are being hoisted . . . tag lines . . . shall be used."
	2	1926.451(f)(15)	"Ladders shall not be used on scaffolds . . ."

Table 9. OSHA Citations Related to Struck by Load (Continued)

SB	F	Citation No.	Requirements of Standard
L	1	1926.451(g)(1)	". . . shall be protected from falling . . ."
(13)	1	1926.451(g)(1)(vii)	". . . shall be protected by . . . fall arrest . . ."
	1	1926.451(h)(1)	". . . shall be . . . protection . . . hand tools. . ."
	1	1926.452(i)(8)	"Scaffolds . . . shall be designed by a registered professional engineer . . ."
	4	1926.453(b)(2)(v)	"A body belt . . . and a lanyard attached to the boom or basket when working from an aerial lift.
	1	1926.454(a)	"The employer shall . . . scaffold trained by a person qualified in the subject matter . . ."
C	1	1926.20(b)(1)	" . . . responsibility of the employer to initiate and maintain such programs . . ."
(12)	2	1926.20(b)(2)	"Such programs shall provide for . . . regular inspections of the job sites . . . ."
	8	1926.21(b)(2)	"The employer shall instruct each employee in the recognition . . . unsafe conditions . . ."
	1	1926.25(a)	"During the course of construction, alteration . . . protruding nails . . . shall be kept cleared . . ."
H	1	1926.251(a)(1)	"Rigging equipment for material handling shall be inspected prior to use on each shift . . ."
(10)	1	1926.251(a)(6)	". . . Each day before being used, the sling and all fastenings . . . shall be inspected . . ."
	1	1926.251(b)(2)	"Hooks, rings . . . shall have a rated capacity at least equal to that of the chain."
	1	1926.251(c)(5)	". . . eye splices, the U-bolt shall be . . . "U" section is in contact with the dead end . . .".
	1	1926.251(c)(8)	"Slings used . . . shall . . . loads balanced . . ."
	1	1926.251(e)(1)(i)	"The employer shall have each synthetic web sling marked . . . Name or trademark . . ."
	1	1926.251(e)(1)(ii)	"The employer shall have each synthetic web sling marked . . . Rated capacities . . ."
	1	1926.251(e)(1)(iii)	"The employer shall have each synthetic web sling marked . . . Type of material."
	1	1926.251(e)(8)	"Synthetic web slings shall be removed . . ."
		1926.251(e)(8)(iii)	Synthetic web slings shall be removed . . . : Snags, punctures, tears or cuts
	1	1926.251(e)(8)(iv)	"Synthetic web slings shall be removed . . . : Broken or worn stitches;"
E	5	1926.100(a)	"Employees . . . possible danger of head injury . . . shall be protected by protective helmets"
(8)	2	1926.104(b)	"Lifelines shall be secured . . . to . . . or structural member capable of . . . of 5,400 pounds."
	1	1926.106(d)	At least one lifesaving skiff shall be immediately available . . . working over . . . water."

Table 9. OSHA Citations Related to Struck by Load (Continued)

SB	F	Citation No.	Requirements of Standard
(7)	7	Section of Act 5(A)(1)	". . . shall furnish . . . employees . . . free from . . . hazards . . . to cause death . . ."
X (7)	2	1926.1051(a)	". . . ladder shall be provided . . . where there is a break in elevation of 19 inches . . ."
	1	1926.1053(a)(13)	". . . clearance between fixed ladder rungs, . . . any obstruction behind the ladder shall be . . . ."
	1	1926.1053(a)(19)	"Where the total length of a climb equals or exceeds 24 feet (7.3 m), fixed ladders shall be equipped with . . ."
	1	1926.1053(b)(1)	". . . ladders are used for access to an upper landing surface, . . . side rails shall extend . . ."
	2	1926.1053(b)(6)	"Ladders shall be used only on . . . level surfaces . . ."
O (6)	1	1926.603(a)(6)	"Guards shall be provided . . . to prevent the cable from jumping out of the sheaves."
	1	1926.603(c)(5)	"When it is necessary to cut off . . . driven piles, pile driving operations shall be suspended . . ."
	1	1926.605(b)(2)	". . . employees can step safely . . . wharf, float, barge, . . . safe walkway, shall be provided."
	1	1926.651(c)(2)	". . . A stairway . . . or other safe means of egress shall be located in trench . . . ."
	1	1926.651(k)(1)	"Daily inspections of excavations . . .shall be made by a competent person . . ."
	1	1926.652(a)(1)	"Each employee in an excavation shall be protected from cave-ins by an adequate protective system . . ."
Z (3)	1	1910.1200(e)(1)	"Employers shall . . . maintain . . . a written hazard communication program . . ."
	1	1910.1200(h)	"Employee information and training."
	1	1910.1200(i)(8)	"The . . . employee . . . request for information is denied . . . request to OSHA . . ."
D (2)	1	1926.59(g)(1)	"Chemical . . . obtain or develop . . . data sheet. . ."
	1	1926.59(h)(3)	"Training . . . shall include . . . methods . . . hazards . . . protection."
T (1)	1	1926.850(a)	". . . employees to start demolition operations, an engineering survey shall be made, . . ."

Table 10. OSHA Citations Related to Electrocution

SB[1]	F[2]	Citation No.	Citation Information (Requirements of standard)
N (66)[3]	3	1926.550(a)(1)	"The employer shall comply with the manufacturer's specifications . . ."
	4	1926.550(a)(2)	"Rated load capacities . . . shall be conspicuously posted on all equipment. Instructions . . . warnings shall be visible to the operator . . ."
	3	1926.550(a)(4)	"Hand signals to crane and derrick operators shall be those prescribed by . . . ANSI standard . . ."
	1	1926.550(a)(5)	"The employer shall designate a competent person who shall inspect all machinery and equipment . . ."
	7	1926.550(a)(6)	". . . annual inspection of the hoisting machinery shall be made by a competent person . . ."
	1	1926.550(a)(7)(ii)	"Wire rope shall be taken out of service when . . . Wear of one-third the original diameter . . . other damage . . ."
	1	1926.550(a)(8)	"Belts, gears . . . or equipment shall be guarded . . . are exposed to contact by employees . . ."
	1	1926.550(a)(9)	". . . swing radius of the . . . crane, . . . barricaded . . . from being struck or crushed . . ."
	1	1926.550(a)(12)	". . . windows in cabs shall be of safety glass . . ."
	1	1926.550(a)(14)(i)	". . . fire extinguisher . . . shall be available at all operator stations or cabs of equipment."
	21	1926.550(a)15(i)	"For lines rated 50 kV or below, minimum clearance . . . the crane or load shall be 10 feet;"
	3	1926.550(a)(15)(ii)	"For lines rated over 50 kV, minimum clearance . . . lines and . . . the crane . . . shall be 10 feet plus 0.4 inch for each 1 kV. over 50 kV. . . ."
	15	1926.550(a)15(iv)	"A person shall be designated to observe clearance . . . and give timely warning . . ."
	3	1926.550(a)(19)	"All employees shall be kept clear of loads about to be lifted and of suspended loads."
	1	1926.550(b)(2)	"All crawler . . . cranes in use shall meet the applicable requirements for design . . ."
C (18)	3	1926.20(b)(1)	" . . . responsibility of the employer to initiate and maintain such programs . . ."
	3	1926.20(b)(2)	"Such programs shall provide for . . . regular inspections of the job sites . . . ."
	12	1926.21(b)(2)	"The employer shall instruct each employee in the recognition . . . unsafe conditions . . ."

[1] SB = Subpart no.
[2] F= Frequency of citation in the 125 case files
[3] Total citations in Subpart no.

Table 10. OSHA Citations Related to Electrocutions (Continued)

SB	F	Citation No.	Citation Information (Requirements of standard)
K (10)	2	1926.416(a)(1)	"No employer shall permit an employee to work in such proximity to any part of an electric power circuit . . . unless the employee is protected . . ."
	8	1926.416(a)(3)	"Before work is begun the employer shall ascertain . . . electric power circuit . . . is so located . . . may bring any person into physical . . . contact with the electric power circuit."
H (5)	2	1926.251(a)(1)	"Rigging equipment for material handling shall be inspected prior to use on each shift . . ."
	1	1926.251(b)(6)	"Inspections."
	1	1926.251(b)(6)(i)	". . . thorough periodic inspection of alloy steel chain slings in use shall be made on a regular basis . . . once every 12 months."
	1	1926.251(c)(4)(iii)	"Eyes in wire rope bridles, slings, or bull wires shall not be formed by wire rope clips or knots"
D (2)	1	1926.50(b)	"Provisions shall be made . . . for prompt medical attention in case of serious injury."
	1	1926.50(c)	"In the absence . . . hospital . . . shall be available at the worksite to render first aid."
V (2)	1	1926.953(d)	". . . tag lines or other suitable devices shall be used to control loads being handled by hoisting"
	1	1926.955(a)(6)(ii)	"Lifting equipment shall be bonded to an effective ground . . ."
S (2)	2	1910.333(c)(3)(iii)(a)	"Any . . . equipment capable of having . . . its structure elevated near energized . . . lines shall . . . clearance of 10 ft. . . ."
P (1)	1	1926.652(a)(1)	"Each employee in an excavation shall be protected from cave-ins by an adequate protective system . . ."
Q (1)	1	1926.701(b)	". . . reinforcing steel, onto and into which employees could fall, shall be guarded . . ."
M (1)	1	1926.501(b)(1)	". . . Each employee on a walking/working surface . . . which is 6 feet (1.8 m) or more above a lower level shall be protected . . ."
(1)	1	Section of Act 5(A)(1)	". . . shall furnish . . . employees . . . free from . . . hazards . . . to cause death . . ."

Table 11. OSHA Citations Related to Crushed During Assembly/Disassembly

SB[1]	Frequency	Citation No.	Citation Information (Requirements of standard)
N (20)[2]	6	1926.550(a)(1)	"The employer shall comply with the manufacturer's specifications . . ."
	2	1926.550(a)(5)	"The employer shall designate a competent person who shall inspect all machinery and equipment . . ."
	2	1926.550(a)(6)	". . . annual inspection of the hoisting machinery shall be made by a competent person . . ."
	1	1926.550(a)(9)	". . . swing radius of the . . . crane, . . . barricaded . . . from being struck or crushed . . ."
	2	1926.550(a)(12)	". . . windows in cabs shall be of safety glass . . ."
	1	1926.550(a)(13)(ii)	"Guardrails, handholds, and steps shall be provided on cranes for easy access . . ."
	6	1926.550(b)(2)	"All crawler . . . cranes in use shall meet the applicable requirements for design . . ."
C (9)	1	1926.20(b)(2)	"Such programs shall provide for . . . regular inspections of the job sites . . . ."
	8	1926.21(b)(2)	"The employer shall instruct each employee in the recognition . . . unsafe conditions . . ."
M (6)	1	1926.501(b)(1)	". . . Each employee on a walking/working surface . . . which is 6 feet (1.8 m) or more above a lower level shall be protected . . ."
	1	1926.502(b)(1)	"Top edge height of top rails . . . shall be 42 inches . . . above the walking/working level."
	1	1926.502(d)(1)	"Connectors shall be drop forged, pressed or formed steel, or made of equivalent materials."
	3	1926.503(a)(1)	"The employer shall provide a training program for each employee . . . exposed to fall hazards."
E (1)	1	1926.95(a)	"Protective equipment, . . . shall be provided, used, and maintained . . ."
G (1)	1	1926.201(a)(1)	". . . flagmen or other appropriate traffic controls shall be provided."
O (1)	1	1926.601(b)(9)	"Seat belts and anchorages meeting the requirements of 49 CFR Part 571 . . ."
T (1)	1	1926.850(a)	". . . employees to start demolition operations, an engineering survey shall be made, . . ."

[1] SB = Subpart no.
[2] Total Citations in Subpart no.

Table 12. OSHA Citations Related to Failure of Boom/Cable

SB[1]	Frequency	Citation No.	Citation Information (Requirements of standard)
N (13)[2]	2	1926.550(a)(1)	"The employer shall comply with the manufacturer's specifications . . ."
	2	1926.550(a)(5)	"The employer shall designate a competent person who shall inspect all machinery and equipment . . ."
	1	1926.550(a)(16)	"No modifications . . . shall be made by the employer . . ."
	2	1926.550(a)(19)	"All employees shall be kept clear of loads about to be lifted and of suspended loads."
	5	1926.550(b)(2)	"All crawler . . . cranes in use shall meet the applicable requirements for design . . ."
	1	1926.550(f)(1)(iii)	". . . load ratings are reduced . . . a new load rating chart shall be provided.
C (6)	1	1926.20(b)(1)	" . . . responsibility of the employer to initiate and maintain such programs . . ."
	1	1926.20(b)(2)	"Such programs shall provide for . . . regular inspections of the job sites . . . ."
	1	1926.20(b)(4)	"The employer shall permit only . . . employees qualified by training . . . operate equipment . . ."
	2	1926.21(b)(2)	"The employer shall instruct each employee in the recognition . . . unsafe conditions . . ."
	1	1926.25(a)	"During the course of construction, alteration . . . protruding nails . . . shall be kept cleared . . ."
M (3)	1	1926.501(b)(1)	". . . Each employee on a walking/working surface . . . which is 6 feet (1.8 m) or more above a lower level shall be protected . . ."
	1	1926.502(h)(1)(iii)	"The safety monitor shall . . . within visual sighting distance of the employee . . ."
	1	1926.503(c)(3)	"Inadequacies in an affected employee's knowledge . . . "
E (2)	2	1926.100(a)	"Employees . . . possible danger of head injury . . . shall be protected by protective helmets."
I (2)	1	1926.300(b)(1)	". . . tools . . . designed to accommodate guards . . . shall be equipped with such guards . . ."
	1	1926.304(d)	". . . power-driven circular saws shall be equipped with guards . . ."
O (1)	1	1926.605(d)(2)	"Provisions for rendering first aid . . . shall be in accordance with Subpart D of this part."
(1)	1	Section of Act 5(A)(1)	". . . shall furnish . . . employees . . . free from . . . hazards . . . to cause death . . ."

[1] SB = Subpart no.
[2] Total Citations in Subpart no.

Table 13. OSHA Citations Related to Crane Tip Over

SB[1]	Frequency	Citation No.	Citation Information (Requirements of standard)
N (14)[2]	5	1926.550(a)(1)	"The employer shall comply with the manufacturer's specifications . . ."
	1	1926.550(a)(2)	"Rated load capacities . . . shall be conspicuously posted on all equipment. . . ."
	1	1926.550(a)(5)	"The employer shall designate a competent person who shall inspect all machinery and equipment . . ."
	2	1926.550(a)(6)	". . . annual inspection of the hoisting machinery shall be made by a competent person . . ."
	1	1926.550(a)(15)	"Except where electrical distribution and transmission lines have been deenergized . . . shall be operated proximate to power lines . . ."
	1	1926.550(a)(19)	"All employees shall be kept clear of loads about to be lifted and of suspended loads."
	3	1926.550(b)(2)	"All crawler . . . cranes in use shall meet the applicable requirements for design . . ."
(8)	8	Section of Act 5(A)(1)	". . . shall furnish . . . employees . . . free from . . . hazards . . . to cause death . . ."
L (6)	1	1926.451(b)(1)	". . . platform on all working levels of scaffolds shall be fully planked . . ."
	1	1926.451(b)(10)	"Scaffold components manufactured by different manufacturers shall not be intermixed . . ."
	1	1926.451(f)(4)	"Any part of a scaffold damaged or weakened . . . shall be . . . repaired or replaced. . ."
	1	1926.451(g)(1)(vi)	"Each employee performing . . . bricklaying operations . . . scaffold shall be protected . . ."
	1	1926.452(c)(2)	"Frames and panels shall be braced by cross, horizontal, . . ."
	1	1926.454(b)	"The employer shall have each employee who is involved in erecting, . . . trained . . ."
C (5)	5	1926.21(b)(2)	"The employer shall instruct each employee in the recognition . . . unsafe conditions . . ."
N (4)	1	1910.180(c)(2)	". . . rating chart with clearly legible letters and figures shall be provided with each crane . . ."
	1	1910.180(d)(4)	". . . inspections of the crane shall be performed at intervals as generally defined . . ."
	2	1910.180(h)(1)(i)	"No crane shall be loaded beyond the rated load, except for test purposes . . ."
D (1)	1	1926.59(e)(1)	"The employer shall have each synthetic web sling marked . . . Name or trademark . . ."

[1] SB = Subpart no.
[2] Total Citations in Subpart no.

Table 14. OSHA Citations Related to Struck by Cab/counter Weight

SB[1]	Frequency	Citation No.	Citation Information (Requirements of standard)
N (9)[2]	1	1926.550(a)(2)	"Rated load capacities, . . . shall be conspicuously posted on all equipment. . . ."
	1	1926.550(a)(4)	"Hand signals to crane and derrick operators shall be those prescribed by . . . ANSI standard . . ."
	1	1926.550(a)(5)	"The employer shall designate a competent person who shall inspect all machinery and equipment . . ."
	1	1926.550(a)(7)(ii)	"Wire rope shall be taken out of service when . . . Wear of one-third the original diameter . . . or any other damage . . ."
	1	1926.550(a)(8)	"Belts, gears . . . or equipment shall be guarded . . . are exposed to contact by employees . . ."
	2	1926.550(a)(9)	". . . swing radius of the . . . crane, . . . barricaded . . . from being struck or crushed . . ."
	1	1926.550(a)(13)(ii)	"Guardrails, handholds, and steps shall be provided on cranes for easy access . . ."
	1	1926.550(a)(14)(i)	"An . . . fire extinguisher of 5BC rating, or higher, shall be . . . at all operator stations or cabs . . . "
C (2)	1	1926.21(b)(2)	"The employer shall instruct each employee in the recognition . . . unsafe conditions . . ."
	1	1926.25(a)	"During the course of construction, alteration . . . protruding nails . . . shall be kept cleared . . ."
E (2)	1	1926.95(a)	"Protective equipment, . . . shall be provided, used, and maintained . . ."
	1	1926.106(a)	"Employees working over or near water . . . shall be provided with . . . life jacket . . ."
(1)	1	Section of Act 5(A)(1)	". . . shall furnish . . . employees . . . free from . . . hazards . . . to cause death . . ."
M	1	1926.501(b)(1)	". . . employee on a walking/working surface . . . which is 6 feet . . . shall be protected . . ."
K (1)	1	1926.416(a)(1)	"No employer shall permit an employee to work in such proximity to any part of an electric power circuit . . ."
L (1)	1	1926.454(a)	"The employer shall . . . scaffold trained by a person qualified in the subject matter . . ."
N (1)	1	1910.179(b)(8)	"Only designated personnel shall be permitted to operate a crane covered by this section."

[1] SB = Subpart no.
[2] Total Citations in Subpart no.

Table 15. OSHA Citations Related to Falls

SB	Frequency	Citation No.	Citation Information (Requirements of standard)
M (4)	2	1926.501(b)(1)	". . . Each employee on a walking/working surface . . . which is 6 feet (1.8 m) or more above a lower level shall be protected . . ."
	1	1926.501(b)(15)	"… each employee on a walking/working surface . . .shall be protected from falling . . ."
	1	1926.503(a)(1)	"The employer shall provide a training program for each employee . . . exposed to fall hazards."
N (2)	1	1926.550(f)(1)(iii)	". . . load ratings are reduced . . . a new load rating chart shall be provided.
	1	1926.550(f)(1)(iv)	"Mobile cranes on barges shall be positively secured."
K (1)	1	1926.403(b)(1)(iii)	"The employer shall ensure that electrical equipment is free from recognized hazards . . ."
X (1)	1	1926.1051(a)	". . . ladder shall be provided . . . where there is a break in elevation of 19 inches . . ."

Table 16. Fifteen Most Frequently Cited OSHA Standards by the Number of Serious and Willful (SW) Citations Issued to Employers Investigated for a Crane-Related Fatality

Citation No.	Requirements of Standard	No. SW Citations
1926.550(a)(15)	"Except where electrical distribution and transmission lines have been deenergized…shall be operated proximate to power lines…"	41
1926.21(b)(2)	"The employer shall instruct each employee in the recognition…unsafe conditions…"	36
1926.550(b)(2)	"All crawler…cranes in use shall meet the applicable requirements for design…"	21
1926.550(a)(19)	"All employees shall be kept clear of loads about to be lifted and of suspended loads."	18
1926.550(a)(1)	"The employer shall comply with the manufacturer's specifications…"	17
1926.550(a)(6)	"…annual inspection of the hoisting machinery shall be made by a competent person…"	13
1926.501(b)(1)	"…Each employee on a walking/working surface…which is 6 feet (1.8 m) or more above a lower level shall be protected…"	8
1926.550(a)(5)	"The employer shall designate a competent person who shall inspect all machinery and equipment…"	8
1926.416(a)(3)	"Before work is begun the employer shall ascertain…electric power circuit…is so located…may bring any person into physical…contact with the electric power circuit."	8
1926.550(a)(2)	"Rated load capacities, …shall be conspicuously posted on all equipment…"	7
1926.100(a)	"Employees…possible danger of head injury…shall be protected by protective helmets."	7
1926.20(b)(2)	"Such programs shall provide for…regular inspections of the job sites…"	7
1926.550(a)(9)	"…swing radius of the…crane, …barricaded…from being struck or crushed…"	6
1926.503(a)(1)	"The employer shall provide a training program for each employee…exposed to fall hazards."	6
1926.20(b)(1)	"…responsibility of the employer to initiate and maintain such programs…"	5