Steel Erection Fatalities in the Construction Industry

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Abstract: Construction fatalities continue to occur during steel erection. Using 166 case files resulting from Occupational Safety and Heath Administration (OSHA) investigations of steel erection fatalities during the years 2000–2005, the writers examined the data to determine the proximal causes and contributing physical factors. Of the 166 fatal events, results showed proximal cause "falls" represented 125 of the fatal events, "crushed/struck/hit by object" represented 40, and one was caused by electrocution. The rate of fatalities tended to reduce from 2000 to 2005. As a result, OSHA may be reaching one of its goals established following the introduction of the new steel standards in 2002, an annual reduction of 30 fatalities. The results of this study indicate that employer compliance with OSHA's fall protection standards and instructing employees in recognition and avoidance of unsafe conditions could save lives.

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Introduction

Fatalities continue to occur in the construction industry in spite of the Occupational Safety and Health Administration's (OSHA) or "the Agency" having established comprehensive safety standards specified in Title 29, Part 1926, of the Code of Federal Regulations (OSHA 2003) and the fact that recommendations for safety in construction have been made from research conducted on the subject (Ringen and Stafford 1996). In 2004, the construction industry had the fourth highest fatality rate among the 14 major economic sectors with 11.6 fatalities per 100,000 workers. It should be noted, however, that in terms of numbers, construction led all sectors with 1,194 fatalities out of a total of 4,952 (U.S. Census Bureau 2008).

OSHA's Compliance Safety and Health Officers (CSHOs) investigated 10,504 work-related fatalities in the construction industry from 1991 to 2006 (CIRPC 1993). In earlier studies, 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 wherein OSHA 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 2007, 57.2% of construction employment in the nation was in the Federal Program States (Department of Labor 2007).

In support of its analysis of the IMIS records, CIRPC developed a mutually exclusive list of 29 proximal cause codes of all fatal construction events. Each fatal event occurring during the 16-year study period was classified and ranked by proximal cause and annual reports were submitted to OSHA (CIRPC 1993). Table 1 shows the frequency of the top five proximal causes. "Fall from/through roof" was the number one cause in terms of frequency, followed in rank order by "fall from/with structure (other than roof)," "crushed/runover of nonoperator by operating construction equipment," "electric shock by equipment contacting power source," and "hit, crushed, fall during lifting operations." These rankings have remained highly invariant by year (Schriver and Schoenbaum 2003). The five leading proximal causes encompassed approximately 40% of the fatal construction events inspected by OSHA CSHOs throughout the nation from 1991 to 2006.

Shifting focus to "operations" as distinct from "causes," one of the major construction operations involving fatalities is steel erection. Some research aimed at reduction of fatalities during steel erection has been undertaken over the past decade, but the high incidence of these fatalities in the United States continues despite this attention. To try to reduce these losses, on July 13, 2001, the Agency announced that its final steel erection standard would go into effect January 18, 2002 (OSHA 2005). At the time, the new rule was expected to prevent 30 fatalities and 1,142 injuries annually and save employers nearly $40 million/year.

To provide historical perspective, CIRPC reexamined the IMIS data from 1991 to 2005 to look specifically at fatal events in steel erection operations. Steel erection operation fatalities cut across several of the proximal cause codes originally developed by CIRPC. For example, the principal causes of fatalities during steel erection operations were as follows: "fall from/with structure (other than roof);" "hit, crushed, fall during lifting operations;" and "struck by falling object/projectile."

The current study examines steel-erection fatalities for the

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Table 1. Rank of Top Five Proximal Fatal Construction Event Causes: 1991–2006

Rank	Number of events	Percent (%)	Proximal cause
1	1,225	11.7	Fall from/through roof
2	891	8.5	Fall from/with structure (other than roof)
3	827	7.9	Crushed/run-over of nonoperator by operating construction equipment
4	696	6.6	Electric shock by equipment contacting power source
5	561	5.3	Hit, crushed, fall during lifting operations
Total[a]	10,504	100	

[a]Total number of events 1991–2006.

years 2000–2005. The findings are discussed and recommendations made for preventing future steel-erection fatalities.

Literature Review

Few studies of steel erection-related fatalities have been undertaken in the last 25 years. A search with the phrases "steel erection fatalities," "steel erection safety," "construction safety," and "steel erection" using Google and the University of Tennessee Libraries yielded few scholarly papers that addressed the subject directly. However, a number of papers addressed the subject indirectly, primarily those related to "falls." For the most part, these studies fall into one of two categories: (1) conceptual or; (2) 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 Smith (1993) who addressed the issue of falls in the Department of Energy (DOE), Smith stated: "A crucial step in improving safety and health is identification of hazards. The construction industry has plenty of them."

Geiger (2004), in a paper on injuries and fatalities in falls from height during construction, operation, and maintenance of varied systems involving work at elevated locations, addressed a hierarchy of control measures which include: (1) elimination, i.e., designs that avoid the need for work at heights; (2) substitution, i.e., replacing the hazard with a less hazardous operation or process; (3) isolation, i.e., separating the hazard from employees, e.g., fixed barriers; (4) engineering controls required when the hazard cannot be eliminated; (5) administrative controls that include identifying and enforcing alternative work practices; and finally (6) personal protective equipment (PPE), e.g., fall arrest systems. Geiger concluded application of system safety evaluation and human factors engineering are likely to mitigate hazards while at the same time reducing construction and maintenance costs.

In a similar vein, Weinstein et al. (2005) address the "safety-in-design process." They contend that increased awareness, the development and continued refinement of safety-in-design check lists, and structured interaction between designers and builders during which safety implications of specific design features are discussed, can result in safer designs.

Wallace (2005) has recently remarked, somewhat facetiously "It's not the fall that hurts—it's the sudden stop." He goes on to say: "additional injuries occur from improper use of fall protection, i.e., utilizing a body belt instead of a full body harness, improper use of lanyards, or utilizing an inadequate anchorage point." Wallace concludes that a fall protection survey should be undertaken to identify potential fall hazards and that a fall protection policy should be developed and employees trained accordingly.

Recently, Irizarry et al. (2005) looked at the effect of safety and environmental variables on task durations during steel erection. These authors found that a quantitative approach using task durations is a viable alternative in analysis of the effect of safety and environmental factors on construction operation. More importantly, they also felt their study was of significance to practitioners in steel erection because it showed that the effects of safety-related and environmental factors can increase the duration of the position, connect, and unhook tasks, but that the impact of this increase on the total cycle time was minimal.

Three recent studies can be characterized as primarily empirical. In the first of these, Lipscomb et al. (2004) combined payroll data, coded worker compensation data, and text descriptions of injuries from construction of the Denver International Airport to create a more comprehensive picture of falls from height. As stated by Lipscomb et al. state: "the data on collapses or unstable surfaces point to continued need for appropriate selection and use of work practices on ladders and scaffolding, as well as attention to both covering openings and adequately securing coverings."

Derr et al. (2001) examined the IMIS database of fall fatalities for the years 1990–1999 to assess the impact of the February 1995, 29 Code of Federal Register (CFR) Part.1926 Subpart M OSHA fall protection standard. During the decade, Derr et al. found a statistically significant downward trend in fatal falls in all construction and within several construction categories. However, as they state: "…the study failed to show a statistically significant intervention effect of the new (1995) OSHA standards."

Paine and McCann (2004) looked at a specific decking fall protection system developed by a steel contractor. The fall protection system ensured that workers installing decking have 100% fall protection. Following this fall protection procedure resulted in a safer construction environment, required little change in work habits and produced a clear benefit. As noted in the section "Involvement of Decking or Structural Erection" implementation of this decking fall protection system would have reduced the decking fatalities cited herein.

The current study is in the mold of the three empirical studies described above. It differs from them in several respects, however. It is obviously quite different from Lipscomb et al. which was based on a single project and Paine and McCann which was based only on decking. Derr et al. used the Agency's IMIS data to look at all falls in construction from 1990 to 1999. Paine and McCann limited their study to only decking. The instant study examines only fatalities in the construction operation "steel erection." While the data in the Derr et al. study were based upon the IMIS narrative reports, the authors' investigation had available the full OSHA case files provided to CIRPC by OSHA which contained detailed information not in the narratives. 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 recommendations presented aimed at reducing future fatalities.

Data and Methods

Potential steel-erection fatalities were identified by performing a text search of the narrative information available in the IMIS

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database for the years 2000–2005 using the key words "steel," "erection," "deck," "beam," "joist," "girder," and "truss." OSHA then provided CIRPC with copies of the case files for the Federal Program States compiled by the CSHOs in the field who inspected the identified fatalities.

CIRPC has broadly defined "steel erection" (or steel placement) as "raising, securing, or removing structural steel members (I-beams, channels, etc.) for columns, beams, and girders that carry loads (in addition to their own weight) imposed on the structure, including the installation or removal of metal decking for the base of floors and roofs" (Beavers 2005), resulting in two subsets of "steel erection:" (1) decking and (2) structural erection.

Of the 485 case files preliminarily identified as involving a steel placement fatality, CIRPC received 436 from OSHA (90% of the total requested) and each was reviewed. This resulted in the selection of 166 case files that were identified as containing one or more steel erection fatalities. The selected case files were then reviewed again to determine for each fatal event:

1. Proximal cause and contributing physical factor(s);
2. Work site by end-use function;
3. Involvement of decking or structural erection;
4. CSHO's evaluation of the safety program of the victim's employer;
5. Union representation;
6. Victim's activity at time of fatality;
7. Role of victim in the fatality; and
8. Number and type of OSHA citations by proximal cause.

Also, information was extracted from the fatality case files regarding: (1) victim's activity immediately preceding the fatality, i.e., working task, changing location, taking break, or starting/ending work; (2) presence of a competent person at the site; and (3) how the fatal event was initiated, i.e., by the victim, other employee, a combination of victim and other employer, or a case of being at the wrong place—wrong time, i.e., no immediate contribution by the victim or other employee.

Analysis showed that all 166 fatal events (one event had two fatalities) occurred with three categories of proximal cause:

1. Fall;
2. Crushed/struck/hit by object; and
3. Electrocution.

Contributing physical factors to each proximal cause were also developed, but they were not necessarily mutually exclusive. Contributing physical factors by definition precede in occurrence direct cause; exceptions are fall protection factors. They succeed "falls" but precede the fatal injury. That is, lack of fall protection did not precede the fall or contribute to the fall; it only contributed to the fatal injury after the fall.

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

Proximal cause	Contributing physical factors	Number of events (%)
Falls		125 (75.3)
	Lack of fall protection	58
	Fall protection not secured	38
	Lost balance	38
	Movement of walking/standing surface	22
	Improper climbing	13
	Equipment failure	8
	Improper fall protection	8
	Struck/hit by object (structural failure)	4
	Struck/hit by object (crane initiated)	2
	Victim taking medication	1
	High winds	1
Crushed/struck/hit by object		40 (24.1)
	Improper lifting by crane	20
	Inadequate connections	19
	Object falling	13
	Structural failure	12
	Struck by equipment	2
	High winds	1
Electrocution	Crane lifting object	1 (0.6)
Total		166 (100)

Study Findings

Proximal Cause and Contributing Physical Factor(s)

Proximal cause and contributing physical factor(s) leading to each fatality are shown in Table 2 in order of frequency. "Falls" were the leading cause with 125 (75.3%) of the 166 fatal events. The contributing physical factors for this cause in rank order were "lack of fall protection (FP)" "FP not secured," "lost balance," "movement of walking/standing surface," "equipment failure," "improper climbing," "improper FP," "struck/hit by object (structural failure)," "struck/object (crane initiated)," "victim taking medication," and "high winds."

"Crushed/struck/hit by object" ranked second as a proximal cause, resulting in 40 (24.1%) of the fatal events. Six physical factors were identified as contributing to this cause and in rank order they were: "improper lifting by crane," "inadequate connections," "object falling," "struck by equipment," "structure failure," and "high winds."

"Electrocution" ranked third as a proximal cause, representing only one fatal event (electrocution of an ironworker acting as a rigger when the crane being used touched high voltage lines). For a more complete analysis of fatalities during crane operations see Beavers et al. (2006) and/or CIRPC (2007).

Reduction in Fatalities

For the years 2000–2004 there was a monotonic reduction of fatal events in steel erection, 40 in 2000, 34 in 2001, 29 in 2002, 20 in 2003, and 18 in 2004. Unfortunately, this trend did not last as there were 25 fatal events in 2005. However, comparing the average of fatal events for 2000 and 2001 (37) with 2004 and 2005 (21.5), the agency may be on its way to reaching one of its goals (a reduction of 30 fatalities) when introducing the new steel erection standard in January 2002, assuming the possibility of similar reductions occurring in the non-Federal Program states.

Work Site by End Use

The United States Census Bureau classifies construction worksites by functional end-use and value of construction work (U.S. Census Bureau 1997). These codes are divided by the Bureau into "building construction" and "nonbuilding construction" with a total of 53 end-use codes. Building construction as would be expected represented the bulk of the fatal events with 135 (81.3%)

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Table 3. Steel Erection Fatalities in Building and Nonbuilding Construction by End-Use Group

End-use group	Frequency	Percent (%)	Rate[a]
Building construction	135	81.3	0.149
Commercial	93	68.9	0.362
Industrial	21	15.6	0.269
Institutional	19	14.1	0.125
Residential	2	1.4	0.005
Nonbuilding construction	31	18.7	0.128
Transportation	15	48.4	0.134
Heavy	16	51.2	0.122
Total	166	100	0.145

[a]The rate is the number of fatalities divided by the value of construction work in 2002 in billions.

of the 166 fatal events (167 fatalities) while nonbuilding construction had only 31 fatalities (18.7%). The "building construction" end-use categories were combined into four groups; "residential," "industrial," "commercial," and "institutional," and "nonbuilding construction" end-use into two groups, "transportation" and "heavy." Table 3 shows the frequency of steel-erection fatality events by these end-use groups and the rate per billion dollars of construction value.

In steel erection, the most frequent end-use group was commercial with 93 fatalities (68.9%). In addition, it had the highest rate of any end-use group with 0.362 fatalities per billion dollars of construction value. End-use group residential had the smallest number of fatalities at three (1.4%) and the lowest rate at 0.005 as would be expected since residential construction is a large sector of the construction industry and uses little steel. In 2002, residential represented $416 billion out of a total value of construction in 2002 of $1,197 billion or 34.8%.

Involvement of Decking or Structural Erection

As discussed above, a significant number of fatal events involved decking as distinct from structural erection. This research revealed that 63 (37.7%) of the 166 steel erection fatal events occurred during the decking process as shown in Table 4. The main proximal cause of fatalities during the decking process was "falls," accounting for 61 (96.8%) of the 63 events. In the 61 falls from decking "lack of FP" was the major contributing physical factor, accounting for 33 (54.1%) of the 61 events as shown in Table 5. The contributing physical factors "FP not secure," "lost balance," and "unexpected movement of walking surface," were other contributing factors, accounting for 18 (29.5%), 16 (26.2%), and 13 (21.3%) of the 61 events, respectively. As noted in the "Literature Review" the fall protection system discussed by Paine and McCann (2004), if implemented and enforced, would have reduced the fatalities that occurred during decking.

Table 4. Steel Erection Activity and Proximal Cause of Fatality

Steel erection activity	Proximal cause	Fatalities
Decking	Falls	61 (96.8%)
	Crush/struck/hit by object	2 (3.2%)
	Other	0
Subtotal		63 (37.7%)
Structural	Falls	64 (61.5%)
	Crush/struck/hit by object	41[a] (39.4%)
	Electrocution	1 (1.0%)
Subtotal	—	106[a] (62.3%)
Total	—	169[a]

[a]One fatal event had two fatalities and two events were decking.

Table 5. Contributing Physical Factors to 61 Proximal Cause "Falls" during Decking

Contributing physical factors	Number	Percent[a] (%)
Lack of fall protection	33	54.1
Fall protection not secure	18	29.5
Lost balance	16	26.2
Unexpected movement of walking surface	13	21.3
Improper fall protection	3	4.9
Equipment failure	2	3.3
Struck/hit by object, structural failure initiated	2	3.3
High winds	2	3.3
Improper climbing	2	3.3
Taking medication	2	3.3
Struck/hit by object, crane initiated	1	1.6
Other	0	0
Totals	94	—

[a]Percentage of 61 "falls."

Fatalities involving structural erection represented 106 events (Table 4). Falls were the main proximal cause in structural erection with 64 (60.4%) fatal events. As with decking, Table 6 shows that "lack of FP" was the major contributing physical factor, accounting for 26 (40.6%), followed by "FP not secure" 22 (34.4%) and "lost balance" 19 (29.7%).

Employer's Safety and Health Program

CSHOs are required to rate employers' safety and health (SH) programs during fatality investigations using the following scale: (1) nonexistent; (2) inadequate; (3) average; and (4) above average. Seven components of an employer's SH program are rated: (1) is there a written SH program and, if so, how does it compare to the OSHA guidelines?; (2) how well has the employer communicated its SH program to the employees?; (3) how well has the employer enforced its SH program?; (4) what type of safety train-

Table 6. Contributing Physical Factors to 62 Proximal Cause "Falls" during Structural Erection

Contributing physical factors	Number	Percent[a]
Lack of fall protection	26	38.8
Fall protection not secure	22	32.8
Lost balance	19	28.3
Improper climbing	10	14.9
Equipment failure	10	14.9
Improper fall protection	7	10.5
Unexpected movement of walking surface	7	10.5
Struck/hit by object, structural failure initiated	4	6.0
High winds	2	3.0
Struck/hit by object, crane initiated	2	3.0
Other	1	1.5
Total	110	—

[a]Percentage of 62 "falls."

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Table 7. Compliance Safety and Health Officers Rating of Employer Safety and Health Program ($n=107$[a])

Program component	Ratings				Total
	"Nonexistent"	"Inadequate"	"Average"	"Above average"	
Written safety and health plan	11 (11.1%)	19 (19.2%)	59 (59.6%)	10 (10.1%)	99
Communication to employees	7 (7.2%)	40 (41.20%)	46 (47.4%)	6 (5.2%)	97
Enforcement	12 (12.1)	42 (42.4%)	38 (38.4%)	7 (7.1%)	99
Safety training	8 (8.0%)	41 (41.0%)	42 (42.0%)	7 (7.0%)	100
Health training	13 (14.9%)	18 (20.7%)	40 (46.0%)	6 (6.9%)	87
Accident investigation performed	12 (13.6%)	23 (26.1%)	45 (51.1%)	8 (9.1%)	88
Preventive action taken	7 (8.3%)	31 (36.9%)	39 (46.4%)	7 (8.3%)	84
Average	10.0 (10.8%)	30.6 (33.2%)	44.1 (47.9%)	7.3 (7.9%)	92.1

[a]Out of the 166 steel-erection fatality case files analyzed during the study period, 38 did not have information related to safety and health programs.

ing 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 166 steel-erection fatal events only 145 (87.3%) of the case files examined contained copies of the form used to rate SH 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. Not all employers were rated on all components. For the data available for review 56% of the employers were rated as having "average" or "above average," while over 40% were rated as having "nonexistent" or "inadequate" programs. These evaluation results are very similar to the ratings found in a study of crane fatalities (Beavers et al. 2006). For example, in 125 crane fatality cases 60% of the employers were rated as having "average" or "above average" over all programs while 40% were rated as having "nonexistent" or "inadequate" programs.

Union and Nonunion Representation

The OSHA case files contained information on whether the victim was or was not represented by a union. Union representation of the victim was indicated in 41 (24.7%) of the cases. There were differences in the size of the victims' employers between those with union contracts and those without. Those with union contracts usually were larger. For example, the largest union employer had 1,000 employees while the largest open-shop employer had 786 employees. Further examination of employment showed the average and median employment sizes for unionized employers as 69 and 14 employees, respectively, while the average and median employment sizes in the open shops were 34 and seven employees, respectively. No inferences can be made about the relative fatality rates of union verses nonunion workers, because the relative share of the work being performed by union and nonunion workers is unknown.

The writers investigated differences between union and nonunion SH programs. Table 8 contrasts these differences with regard to average SH ratings and average employment size for each year, 2000–2005, and their overall averages. The data in Table 8 include only those records with both scores on the safety and health program and employment. OSHA defines employment as total contractor employment, i.e., not on-site employment.

Since employer size and union status could both influence SH rating, multiple regression was used to estimate the statistical relationship between SH rating and the effects of employment and union status. Table 9 shows the regression results of two equation specifications: (1) a linear equation of the form SH$=f$ (union status, employment); and (2) a semilog equation of the form SH $=f$ [union status, ln (employment)]. Neither equation form produced estimates of a significant relationship between SH rating and union status nor employment size at the 0.10 level of significance.

Table 8. Average SH Rating and Average Employment for Union and Nonunion Contractors

Year	Union		Nonunion	
	Average[a] SH rating	Average number of employees	Average SH rating	Average number of employees
2000	2.1	21	2.5	6
2001	1.8	29	1.5	23
2002	1.5	172	1.6	14
2003	2.1	47	1.3	31
2004	2.0	8	1.7	135
2005	1.6	19	1.4	35
Average	1.85	49	1.7	42

[a]Ratings: 1=nonexistant; 2=inadequate; 3=average; and 4=above average. An average score of 2.0 means the SH rating was Inadequate across all seven program evaluation components rated. An average score of 4.0 means the SH rating was above average across all seven program evaluation components rated. Nonrated scores were not counted.

Victim Activity

The writers attempted to determine the victim's activity at the time of the fatality. To do this five activity categories were devel-

Table 9. Regression Results: Estimate of Effects of Contractor Employment and Union Status on HS Rating

Variable	Coefficient	Significance
Linear Eq. (1): $R^2=0.013$		
Intercept	1.658	0.000
Union status (1 if union, 0 if nonunion)	0.000	0.604
Employment	0.172	0.301
Semilog Eq. (2): $R^2=0.028$		
Intercept	1.824	0.000
Union status (1 if union, 0 if nonunion)	0.232	0.180
Employment	–0.080	0.205

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Table 10. Victim Activity at Time of Fatality

Steel erection type	Total fatalities	Working task	Changing locations	Taking break	Starting/ending work	Unknown
Decking	63	41 (65.1%)	14 (22.2%)	2 (3.2%)	4 (6.3%)	2 (3.2%)
Structural	104	82 (78.8%)	15 (14.4%)	4 (3.8%)	2 (1.9%)	1 (1.0%)
Total	167	123 (73.7%)	29 (17.3%)	6 (3.6%)	6 (3.6%)	3 (1.8%)

oped: was the victim: (1) working his/her task; (2) changing location; (3) taking a break; (4) starting or ending work; and (5) unknown. Table 10 shows these data by decking or structural steel placement. There was little difference in victim activity trends between decking or structural erection. Of the 167 steel-erection fatalities 123 (73.6%) of the victims were working their task; 29 (17.4%) were changing location; six (3.6%) were taking a break; and six (3.6%) were starting/ending work. Three victims' activities were unknown.

Often, when conducting a work change event, i.e., changing location, taking a break, or starting/ending work, the victim may unsecure (unhook) his/her fall protection or remove it completely. Table 11 contrasts work status with fall protection deficiencies. It can be seen that there were 35 fall protection issues, 26 (74.3%) involved the victim changing location (one changing location victim had "improper FP" and it was not secure), four (11.4%) while taking a break, and five (14.3%) starting or ending work. Table 11 also shows the distribution of fall protection issues with "lack of FP" at 48.6%, "FP not secure" at 45.7%, and "improper FP" at 5.9%.

While 123 fall victims were working their task, fall protection issues were a contributing physical factor 70 (56.9%) times. For these 70 events, "lack of FP" was cited 41 (58.6%) times as a contributing physical factor while "FP not secure" was cited 23 (32.9%) times and "improper FP" was cited six (8.5%) times.

Role of Victim in Fatality

From the case files the writers evaluated where possible who initiated the fatal event, i.e., the direct action which precipitated the fatal event. This excludes all indirect conditions and obligations of employers to provide jobsites free of known hazards. The direct action determination was made, often only inferentially, as to whether the victim's actions substantially contributed to the event; if so, the case was classified as "action by the victim." If the victim's action did not substantially contribute to the event, but the action of another worker substantially contributed to the event, the event was classified as "action by other worker." In cases where neither the victim's nor other workers' action substantially contributed to the event the event was classified as "wrong time/wrong place." As a result, five categories were developed. The first category, "victim," was defined as: immediate actions by the victim alone initiated the fatality. The second category, "other worker," was defined as: "actions by another worker initiated the fatality." The third category, "combined," was defined as: "immediate actions by both the victim and other worker initiated the fatality." The fourth category "wrong time/wrong place" was defined as: "no assignment of direct cause to a specific individual. A final and fifth category "unknown" was a designation to include those events where classification into one of the first four categories was not possible.

Review of the OSHA fatality case files also revealed that most events were the result of a momentary loss of concentration on the microenvironment and its potential for injury. For example, most fatal falls occurring during the placement of decking resulted from inattention by the victim while walking during the performance of a task. The burden upon construction workers (who by the very nature of their employment work in an environment with a high potential for serious injury) to perform their assigned tasks both correctly and safely is great. It is remarkable that construction fatalities are as few as they are, but one is too many.

Table 12 shows "victim" accounted for 107 (63.7%) of the events; "wrong time/wrong place" accounted for 42 (25.0%) events; "other employee" accounted for ten (6.0%) events; "combination" accounted for seven (4.2%) events; and "unknown" accounted for two (1.5%).

The implication of the findings that actions by the victims dominated the initiation of fatal events is straightforward. Notwithstanding employer enforcement of OSHA standards, particularly proving and demanding that PPE be used, would have prohibited most of these events, all training for construction mechanics and laborers should emphasize the need for constant awareness of the microenvironment and alertness to hazards, the necessity to use PPE properly at all times, and the immediate reporting of unsafe situations to management. The research by Irizarry et al. (2005) showed that implementation of PPE did not significantly increase the construction schedule.

OSHA Citations

One hundred fifty-six case files investigated revealed serious and willful (SW) citations for OSHA standard safety violations for a total of 556 citations averaging 3.54 citations per cited employer. Ten employers did not receive a citation. The writers determined

Table 11. Work Change Event versus Fall Protection (FP) Issues

	Work change event			
FP issues	Changing location	Break	Starting/ending work	Total
Lack of FP	13	2	2	17 (48.6%)
Improper FP	2		0	2 (5.7%)
FP not secure	11	2	3	16 (45.7%)
Total FP issues	26	4	5	35 (100%)

Table 12. Role of Victim in Fatal Event

Action take by	Number	Percent (%)
Victim	107	63.7
Wrong place wrong time	42	25.0
Other employee	10	5.9
Combination	7	4.2
Unknown	2	1.2
Total	168	100

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that there were 298 direct citations and 258 indirect citations (CIRPC 2007). Subpart R “Steel erection” was top ranked with 159 citations, 42 of which were under Article 1926.760 “Fall protection” and more specifically Citation 1926.760(a)(1) “…each employee…who is…more than 15 ft above a lower level shall be protected…” which was cited 29 times.

The second ranked subpart in citation violations was Subpart M “Fall protection” and Subpart L “Scaffolds” each with 66 citations.

The third ranked subpart was Subpart C “General safety and health” with 57 citations. The top five subparts with citations accounted for 386 (69.4%) of the 556 total citations written on the 166 case files (167 fatalities).

Summary

This study critically reviewed data from 166 steel-erection fatal events in the construction industry from 2000 to 2005 investigated by OSHA in the Federal Program States. The primary purpose of the study was to determine what safety practices need to be improved in steel erection. The key findings are as follows:

1. The proximal cause “falls” dominated both steel decking and structural erection fatalities;
2. The leading contributing factors to the dominant proximal cause “falls” were “lack of fall protection” and “fall protection not secured;”
3. The construction operation “structural erection” was the primary operation where fatalities occurred;
4. “Placement of steel decking,” was also a major source of fatalities;
5. Commercial building construction had the greatest number of fatalities per billion dollars in value of construction work;
6. The victim’s own actions dominated the initiation of the fatal event;
7. While the majority of the employer SH programs overall were rated average and above, weakness occurred in enforcement, safety training, and communication with employees;
8. Three quarters of the victims (73.2%) were working at their task when the fatality occurred;
9. The immediate action of the victim was responsible for two thirds (63.7%) of the fatalities;
10. The dominant violations of OSHA standards were failure to communicate safe work practices and to provide adequate fall protection; and
11. The Agency may be approaching one of its major goals (reducing the number of fatalities by 30/year) when it introduced the new steel erection standard in 2002, if similar reduction in fatal events between the years 2000 and 2001 and 2004 and 2005 can be inferred for the non Federal Program states.

Recommendations

Data Enhancement

Data Entry

Based on the writers’ use of data from both IMIS and fatality case files, it is recommended that OSHA enhance the data collection and entry process. For example, in the case of OSHA Form 170, CSHO training should be implemented to ensure the accurate entry of data into the Form and the inclusion of cogent narratives which capture the essence of the situation in which the fatal event occurred, including “who, when, where, how, and why.”

Intervention Strategies

The writers suggest that it would be in the best interests of OSHA and its stakeholders for the Agency to improve the type and quality of data obtained in the fatality investigations. The information collected in the investigations appears primarily to justify and support the violations cited. It should, additionally, provide comprehensive information useful in the development of intervention strategies.

Other

Education

Clearly, one of the findings in this study was the lack of communication to employees. All employers, large or small, must communicate construction safety requirements to its employees through both formal and informal means and have regular job site safety meetings during the construction process.

Fall Protection

Based on this study, it is clear that the lack of fall protection was a major cause of fatalities during the steel-erection process.

A competent person must be on the construction site at all times to ensure the availability and use of personal fall protection and the installation of the appropriate fall protection systems, e.g., guard rails, covers, nets, barriers, etc. Safety nets should be used during the decking process, especially since the use of personal fall protection is inconvenient as was evident by the 48 (96%) fall victims out of 50 decking fatalities.

The employers must place special emphasis on fall protection standards and training of employees to understand fall protection standards, both while working the task and especially during work location changes where many fatal falls occurred.

It is sometimes believed that the use of fall protection equipment and procedures hinders worker productivity. The study by Irizarry et al. (2005) discussing the time involved in various steel erection tasks states “… that the effects of safety-related and environmental factors can increase the duration of the position, connect, and unhook tasks but that the impact of this increase on total cycle time is minimal.”

It is also believed by some that adherence to a fall protection system is avoided by the workers. Paine and McCann (2004) present evidence, however, that following the fall protection plan they describe for decking “… will be followed by workers, resulting in a safer construction environment.”

These findings by others suggest that the major cause of steel-erection fatalities identified and quantified here can be reduced or eliminated with little adverse effect on worker productively or acceptance.

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