Trend and Causes of Fatal Accidents in the US Construction Industry

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Historically, construction workers experience more fatal and nonfatal injuries from accidents requiring them to take time off more than workers of other industries. In recent years, the construction industry has taken many steps to ensure safe working conditions and safe work practices, yet the occupation remains to be a hazardous. . It is, therefore, important to monitor national trends in construction safety and health by providing the basis for targeting and evaluating problems to prevent the occurrence of the most serious workplace injuries and illnesses. Because of the complex and unique nature of the construction industry, defining the key causes of accidents enables the industry to measure the effects of their productivity and economic performance. From the result of this study, it was found that five of the 29 proximal causes are responsible for 305 (40.5 percent) of the fatal events. It was also revealed that Thursday is the most dangerous work day of the week for the construction industry and that the time between 11 a.m. and 12 noon is the most dangerous hour of the day.

Key Words: Construction, Safety, Accidents, Causes, Fall

Introduction

In recent years, the construction industry has become increasingly aware of the importance of ensuring worker safety and health on job sites. In addition to a general concern for worker safety and well-being, the interest in improving safety and health is driven by several factors such as rising costs and legal liability associated with injuries. Research shows that declining number of qualified workers, the need to retain a well-trained, productive workforce, and the recognition that safety improvements can benefit worker productivity and overall project quality (Hinze, 2005). The construction sector continues to account for a disproportionate share of work-related deaths in the United States. In 2003, construction workers were 7 percent of the U.S. workforce, but suffered 21 percent of the nation's 5,575 reported work-related deaths (Dong et al 2005). Between 1992 and 2003, employment in construction increased by 44 percent from 7.0 million to 10.1 million workers. During the same time, the number of deaths from injuries increased 22 percent, from 963 to 1,171. The total costs of fatal and nonfatal injuries in the construction industry were estimated at $11.5 billion in 2002, 15 percent of the costs for all private industry (Dong 2005 and Waehrer 2008). The average cost per case of fatal or nonfatal injury is $27,000 in construction, almost double the per-case cost of $15,000 for all industry in 2002. Five industries accounted for over half the industry's total fatal and non-fatal injury costs.

Research Methodology

In 2005, the Occupation Safety and Health Administration (OSHA) inspected 753 fatal construction incidents (excluding non-work related causes), involving 770 fatalities. In this paper, the direct causes of fatal events in the construction industry occurring in calendar year 2005 are based on the inspected fatalities rather than total fatalities and compared with 12 earlier studies of Construction Industry Research and Policy Center (CIRPC). CIRPC analyzed the causes of fatal events in this industry in 1991-1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003 and 2004.

The data analyzed in this report, provided by OSHA Form 170 consists of narrative descriptions of the 753 fatal events inspected by OSHA resulting from accidents which occurred in construction during 2005. The OSHA Act of 1970 States with the option of administrating the Act themselves or accepting federal administration of the Act. In 2005, OSHA inspected 753 fatal construction incidents (excluding non-work related causes), involving 770

fatalities. 29 States and the District of Columbia chose federal administering and the remaining 21 states and two territories chose self administration under state plans.

The results reported here do not provide a year-to-year analysis of the numerical trend of fatal events or individuals killed on construction sites. Each narrative record typically consists of a brief description of the event leading to the fatality, although this is not always the case. Where the narrative description was omitted, inconclusive or completely unclear, the event cause was coded "unknown cause or other"; otherwise, each narrative was analyzed and classified into one of 29 cause categories, although a great deal of collective judgment was often required to classify the cause of many of the accidents.

In the earlier CIRPC studies, non-accidental fatalities on construction sites or contractor yards (such as deaths from non-work related heart attacks, strokes, seizures, etc.) and fatalities of construction workers killed off-site in traffic accidents were excluded from the analysis although these fatalities accounted for about three percent of OSHA-inspected fatal construction events between 1991-2004, but about 5 percent had been accounted for in 2005. Although the OSHA Act of 1970 requires employers to report fatalities to OSHA within eight hours of the occurrence of the event, all fatalities on construction sites are not inspected by OSHA. For example, OSHA does not inspect fatal construction events involving independent contractors with no employees.

Data Analysis and Discussion

Analysis of Fatal Events by Year

Figure 1 shows that construction is the third highest cause of fatal occupational injuries after agriculture and mining. Agriculture has the highest number of fatal accidents per 100,000 full time work hours and is increasing. In agriculture, about 30 workers died per 100,000 workers. While the absolute number of OSHA-inspected fatal construction events have had an upward trend since 1991, employment in construction establishments also increased significantly over the years by 44 percent. That is one of the reasons that fatal injury per 100,000 full-time work hours is either becoming stable (approximately 11) or decreasing over the time since 1992. Other reasons for better performance can be improved awareness of the industry, proper training of the field managers and workers, enforcement by OSHA, accountability of higher management, incentives programs, and proactive measures from the insurance companies. A distribution of fatal accidents per 100,000 workers has been shown in Table 1.

Distribution of Fatal Events by Cause

A comparison of the year-to-year ranks of the proximal causes during the 1991¬2005 period shows that they are highly and significantly correlated, i.e., the individual ranks of the causes vary very little from year to year (Table 3). Most of the fatal events involved a single victim, but 16 (2.1 percent) of the events were multi-fatality events which accounted for 33 (4.3 percent) of the fatalities. Other findings were: (1) in 400 (53.1 percent) of the fatal events the victim was judged to be the primary initiator of the cause; in 120 events (15.9 percent), another employee was judged to be the primary initiator of the cause; in 198 events (26.3 percent), the victim was judged to be simply in the wrong place at the wrong time; the remaining 35 events (4.6 percent) could not be classified. Of 597 of the events (79.3 percent), the victim was judged to be performing work at the task site when injured; in 105 events (13.9 percent), the victim was relocating between work stations or entering, leaving or away from their task site when injured; and in 51 events (6.8 percent), no classification was possible.

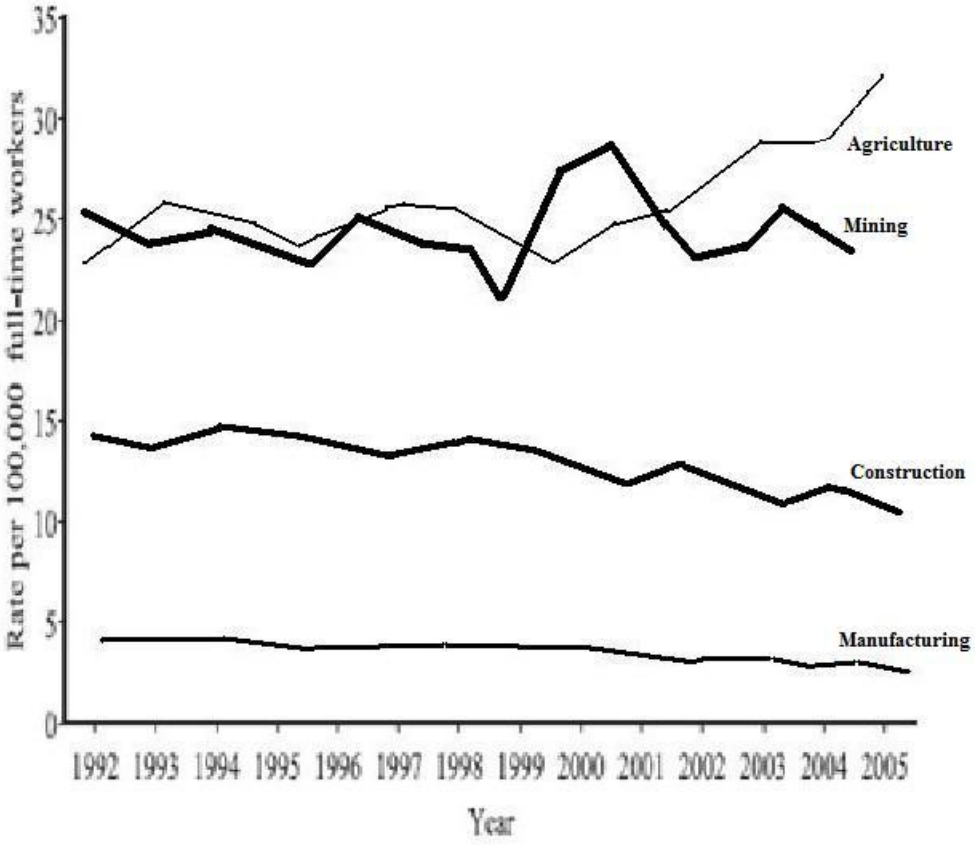

Table 2 shows the cause classification system, the number of times each cause represented a fatal event in 2005, the relative frequency of each cause and the number of victims killed. The number and relative frequencies of the remaining causes of the 753 fatal events analyzed can be read directly from Table 2.

As in the other previous research and collected data, a "fall" was still the number one cause of all fatal accidents. About 38.8 percent of fatal accidents occurred related to a "fall" and 24.7 percent occurred related to being crushed by equipment. Among all the fatal falls, 12.2 percent were from the roof, 9.3 percent from or with the structure, 4.1 percent from ladders, 3.9 percent from scaffolds, 3.3 percent from or with platform or catwalk and 2.7 percent from an aerial lift. Among all the accidents, 8 percent are from being crushed or run-over of a non-operator by an operating construction equipment, 5.8 percent crushed/run-over/trapped of an operator by an operating construction equipment, and 3.9 percent being crushed from structural collapse.

Table 1: Number of Fatal Events per 100,000 employees by Year

Year	Number of Fatal Events/100000 Employees
1991-92	13.1
1993-94	11.8
1995	11.4
1996	10.5
1997	10.6
1998	10.4
1999	11.0
2000	9.5
2001	10.8
2002	10.7
2003	10.5

2004	11.4
2005	10.3

It can be assessed that "Fall from/through roof" led all other causes in number of fatal events (92 or 12.2 percent of total fatal events), followed by "Falls from/with structure (other than roof)" (70 or 9.3 percent). The third leading cause was "Crushed/run-over of non-operator by operating construction equipment" (60 or 8.0 percent); the fourth leading cause was Crushed/run-over/ trapped of operator when operating construction equipment" (44 or 5.8 percent); the fifth leading cause was "struck by "Falling object/projectile (including tip-over)" (39 or 5.2 percent); and the sixth leading cause was "Hit/crushed/fall during lifting operations" (38 or 5.0 percent). Thirty six workers were killed either due to being crushed or suffocated during trench collapse. Another interesting observation is that about 13 (1.4 percent) workers died due to either hyperthermia or hypothermia.

The number of victims killed by each cause is also shown in Table 2 where it shows that in most events, only one worker was killed per event. There were 20 fatality causes where no event had multiple fatalities; only 10 fatality causes included events with multiple deaths. "Asphyxiation/inhalation of toxic vapor" was the fatality cause which had the most victims killed per event, i.e., 14 events and 17 victims or 1.2 victims per event.

The Bureau of Labor Statistics (BLS) reported that between 1995-1999, four percent of all fatal work-related events involved multiple fatalities, and these multiple-fatality events accounted for 10 percent of the workers killed during the period. They averaged three fatalities per incident. The construction fatalities in 2005 show that 16 (2.1 percent) of the fatal events, had multiple fatalities, which accounted for 33 fatalities, or 4.3 percent of the individuals killed. The multiple-fatality construction incidents averaged 2.1 fatalities per incident.

Table 3 compares the ranks causes of fatal events in 2005 with the average rank during the period of 1991-2004. It is understood that the overall rank pattern of the causes in 2005 is similar to that of 1991-2004. An overall statistical comparison of the correlation of the rank in 2005 and 1991-2004 was calculated using the Spearman rank correlation procedure. The correlation obtained was + 0.91, $p < 0.001$, indicating that the ranks of the causes in the two time periods are highly and positively correlated, (i.e., did not change significantly between 1991-2004 and 2005). Since averaging the 1991-2004 ranks removed inter-year variance, a lower correlation would be expected between 2004 and 2005 ranks of causes, (i.e., a measure of the short-term cycle as opposed to a longer-term trend). The Spearman rank order correlation between 2004 and 2005 causes was calculated and found to be + 0.92, $p < 0.001$, indicating

Table 2. Construction Fatality Event Causes, 2005

Event Causes	**Description**	**Events**		
		Number	Victims	%
1	Asphyxiation/inhalation of toxic vapor	14	17	1.9
2	Caught in/struck by stationary equipment	10	10	1.3
3	Crushed from collapse of structure	29	31	3.9
4	Crushed/run-over of non-operator by operating construction equipment	60	60	8.0
5	Crushed/run-over/trapped of operator by operating construction equipment	44	44	5.8
6	Crushed/run-over by construction equipment during maintenance/modification	18	18	2.4
7	Crushed/run-over by highway vehicle	35	38	4.6
8	Drown, nonlethal fall	6	6	0.8
9	Electric shock by touching exposed wire	17	17	2.3
10	Electric shock by equipment contacting power source -Ladder -Scaffold -Crane/boom/drum truck -Contact while handling materials	30 6 2 14 8	31	4.0
11	Electric shock from equipment installation/tool use	35	35	4.6

12	Electric shock, other	0	0	0.0
13	Elevator (struck/crushed by elevator or counter weights)	4	4	0.5
14	Fall from/with ladder: includes collapse/fall of ladder	31	31	4.1
15	Fall from/through roof -Fall off of roof -Fall through roof other than skylight -Fall through skylight	92 62 14 16	93	12.2
16	Fall from highway vehicle/construction equipment	5	5	0.7
17	Fall from/with scaffold	29	30	3.9
18	Fall from/with bucket (aerial lift/basket)	20	20	2.7
19	Fall from/with structure (other than roof) -Fall through collapse of structure	70 12	71	9.3
20	Fall from/with platform or catwalk	25	25	3.3
21	Fall through opening (other than roof)	14	14	1.9
22	Fall, other or unknown	5	5	0.7
23	Fire/explosion/scalding	9	9	1.2
24	Hyperthermia/hypothermia	13	13	1.7
25	Hit, crushed, fall during lifting operations	38	40	5.0
26	Struck by falling object/projectile (including tip-over)	39	39	5.2
27	Crushed/suffocation from trench collapse	34	36	4.5
28	Crushed while unloading-loading equipment /material (except by crane)	18	18	2.4
29	Shock/burn from lightning, other	9	10	1.2
	Total	**753**	**770**	**100.0**

that the 1991-2003 patterns changed very little between 2004 and 2005. The correlation result is not surprising given that the general composition of construction output, and therefore the mix of construction operations required to produce the output, was probably very similar during the time periods examined. This interpretation implies that the rank of a cause is a function of the magnitude of exposure to the cause and/or the inherent danger associated with the cause.

Table 3. Comparison of Ranks of Causes of Fatal Events between 1991- 2004 with 2005

Event Causes	Description	1991-2004			2005		
		No.	%	Rank	No.	%	Rank
1	Asphyxiation/inhalation of toxic vapor	8	1.2	22	14	1.9	19
2	Caught in/struck by stationary equipment	5.9	0.9	23	10	1.3	22
3	Crushed from collapse of structure	26.3	4.1	10	29	3.9	12
4	Crushed/run-over of non-operator by operating construction equipment	50.3	7.8	3	60	8.0	3
5	Crushed/run-over/trapped of operator by operating construction equipment	32.9	5.1	6	44	5.8	4
6	Crushed/run-over by construction equipment during maintenance/modification	12.6	2.0	21	18	2.4	16
7	Crushed/run-over by highway vehicle	23.9	3.7	12	35	4.6	7
8	Drown, non-lethal fall	5.6	0.9	24	6	0.8	25
9	Electrical shock by touching exposed wire	23.7	3.7	13	17	2.3	18
10	Electrical shock by equipment contacting power source	45.1	7.0	4	30	4.0	11
11	Electrical shock from equipment installation/tool use	31.9	5.0	7	35	4.6	7
12	Electrical shock, other	4.1	0.6	28	0	0.0	29
13	Elevator (struck/crushed by elevator or counter weights)	2.7	0.4	29	4	0.5	28
14	Fall from/with ladder: includes collapse/fall of ladder	26.9	4.2	9	31	4.1	10
15	Fall from/through roof	73.9	11.5	1	92	12.2	1

16	Fall from highway vehicle/construction equipment	5.1	0.8	25	5	0.7	26
17	Fall from/with scaffold	21.4	3.3	14	29	3.9	12
18	Fall from/with bucket (aerial lift/basket)	13.4	2.1	19	20	2.7	15
19	Fall from/with structure (other than roof)	53.5	8.3	2	70	9.3	2
20	Fall from/with platform or catwalk	14.6	2.3	17	25	3.3	14
21	Fall through opening (other than roof)	17.3	2.7	15	14	1.9	19
22	Fall, other or unknown	4.6	0.7	26	5	0.7	26
23	Fire/explosion/scalding	13.8	2.2	18	9	1.2	23
24	Hyperthermia/hypothermia	4.2	0.7	27	13	1.7	21
25	Hit, crushed, fall during lifting operations	34.6	5.4	5	38	5.0	6
26	Struck by falling object/projectile (including tip-over)	26.1	4.1	11	39	5.2	5
27	Crushed/suffocation from trench collapse	30.4	4.7	8	34	4.5	9
28	Crushed while unloading-loading equipment /material (except by crane)	12.9	2.0	20	18	2.4	16
29	Shock/burn from lightning, other	14.9	2.3	16	9	1.2	23
	Total	**640.8**	**100**		**753**		**100**

Analysis of Fatal Events by Day of Week and Hour

The fatality data reported on OSHA Form 170 includes the date and time of day when most fatal events occur. Table 4 shows the distribution of fatal events by day of the week. Contrary to the popular conception that most fatalities occur on Mondays and Fridays, it can be seen that Thursday had the largest number of events. 151 (20.1 percent), followed by Wednesday and Tuesday with 148 (19.7 percent) and 144 events respectively, leaving Monday with the least number of fatal events, 105, excluding weekends. However, without knowing the total number of construction hours worked each day, it is not possible to conclude that any one day is more or less hazardous than another. Although it is difficult to explain that why mid week (T/W/TH) has the higher number of accidents compared to Monday and Friday, it can be due to the planning of more intensive jobs during that time which generally happens in heavy civil construction (e.g. huge concrete construction projects where concrete pouring is generally planned for Wednesday or Thursday because of the work week cycle and/or requirement of curing or removal of shoring and re-shoring).

Table 4. Distribution of Fatal Accidents by Day

Day	Number of Events	Percent, %
Monday	105	13.9
Tuesday	144	19.1
Wednesday	148	19.7
Thursday	151	20.1
Friday	130	17.3
Saturday	57	7.6
Sunday	15	2.0
Missing	3	0.4
Total	753	100.0

Table 4 shows the distribution of fatal events by military time. The tables shows that times worked between 11:00 and 12:00 and between 14:00 and 15:00 contained the most fatal events, 85 (11.3 percent) and 83 (11 percent), respectively. The unknown of total hours worked in construction each hour, making it impossible to calculate hourly event rates. However, it can be reasonably assumed that the total construction hours worked each hour during between 8:00 and 12:00 and 13:00 and 17:00 are approximately equal with a noon lunch break. Even if this were true, the hourly differences would not be statistically significant. But, in many cases construction starts at the early morning rather than in the regular work hour (between 8a.m, -5p.m.) and also construction workers take their breaks in different times rather than 12 noon.

Why most accidents happen between 11:00 and 12:00 is difficult to explain. Hypothetically, it can be due to the intensity of work since lunch is coming and workers want to complete a task before they break, they concentrate more on finishing the work quickly rather than safely. That can be a possible reason for more fatal accidents between 11:00 and 12:00. The second highest time when accidents happen, which is between 14:00 and 15:00, can occur because workers are tired in the afternoon or they are trying to improve their performance for the day.

Conclusions

It is evident from the overall discussion in this study that most fatal accidents happen due to a fall. The root cause for most of the construction fatal accidents 305 (40.5 percent) are Falls from/through roofs: 92 events (12.2 percent); Falls from/with Structures: 70 events (9.3 percent); Crushed/run-over of Non-Operator of Construction Equipment: 60 events (8.0 percent); Crushed/run-over/trapped of Operator of Construction Equipment: 44 events (5.8 percent); and Struck by falling object/projectile (including tip-over): 39 events (5.2 percent). It is also found that the proximal causes for fatal accidents during the 1991-2005 period shows that they are highly and significantly correlated, i.e., the individual ranks of the causes vary very little from year-to-year.

Table 5. Distribution of Fatal Accidents by Hour

Hour	Number of Events	Percent, %
0-1	5	0.7
1-2	2	0.3
2-3	1	0.1
3-4	1	0.1
4-5	2	0.3
5-6	4	0.5
6-7	4	0.5
7-8	36	4.8
8-9	60	8.0
9-10	63	8.4
10-11	74	9.8
11-12	85	11.3
12-13	55	7.3
13-14	64	8.5
14-15	83	11.0
15-16	80	10.6
16-17	45	6.0
17-18	33	4.4
18-19	23	3.1
19-20	9	1.2
20-21	7	0.9
21-22	1	0.1
22-23	5	0.7
23-24	8	1.1
Missing	3	0.4
TOTAL	**753**	**100.0**

In addition, it has been found that most fatal accidents happened on Thursday (151 fatalities) followed by Wednesday (148 fatalities), with the lowest number of fatal accidents occurring on Monday or Friday. On other hand, 85 fatal events happened between the 11:00 and 12:00 (11.3 percent), followed by 83 fatal events that happen between 14:00 and 15:00 (11.0 percent)

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