AN ANALYSIS OF FATAL EVENTS IN THE CONSTRUCTION INDUSTRY 2006

Prepared for: **Office of Statistical Analysis**
Occupational Safety and Health Administration
U. S. Department of Labor

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February 2008

This report is based upon OSHA-inspected fatal events in construction during calendar 2006. The data analyzed were provided by Dr. Joseph Dubois, Director, Office of Statistical Analysis, Occupational Safety and Health Administration. William R. Schriver, Ph.D., Director Emeritus and Thomas E. Cressler II, M.S., Associate Director Emeritus and conducted the study and prepared this report; they alone are responsible for all interpretations, conclusions and any errors found in the report.

Executive Summary

OSHA inspected 780 fatal construction incidents (excluding non-work related causes), involving 800 fatalities, in calendar year 2006. Five of the 30 proximal causes classified in this report accounted for 351 (45.0 percent) of the fatal events investigated. They were: (1) *Falls from/through Roofs*: 98 events (12.6 percent); (2) *Falls from/with Structures*: 72 events (9.2 percent);

(3) *Crushed/runover of Non-Operator of Construction Equipment:* 63 events (8.1 percent);

(4) *Electrocution from equipment installation/tool use*: 61 events (7.8 percent); and

(5) *Crushed/runover/trapped of Operator of Construction Equipment*: 57 events (7.3 percent).

A comparison of the year-to-year ranks of the proximal causes during the 1991-2006 period shows that they are highly and significantly correlated, i.e., the individual ranks of the causes vary very little from year-to-year.

Most of the fatal events involved a single victim, but 15 (1.9 percent) of the events were multi-fatality events which accounted for 35 (4.4 percent) of the fatalities.

Other findings were: (1) in 401 (51.4 percent) of the fatal events the victim was judged to be the primary initiator of the cause; in 10 events (1.3 percent) the victim and another employee were judged to be primary initiator of the cause; in 99 events (12.7 percent) another employee was judged to be the primary initiator of the cause; in 238 events (30.5 percent) the victim was judged to be simply in the wrong place at the wrong time; and the remaining 32 events (4.1 percent) could not be classified; (2) in 707 of the events (90.6 percent) the victim was judged to be performing work at the task site when injured; in 37 events (4.7 percent) the victim was going to or from work or not working when injured; and in 36 events (4.6 percent) no classification was possible; and (3) most fatal events happened on Wednesday with 168 (21.5 percent) events

occurring that day of the week, followed by Tuesday with 144 (18.5 percent) occurring that day; and most fatal events happened between the 13 and 14 hours (1:00 pm and 2:00 pm) with 91 (11.7 percent) events occurring during this time interval, followed by 11 and 12 hours (11:00 am and 12:00 pm) with 86 (11.0 percent) events occurring during this time interval.

An examination of the causes of fatalities occurring during highway/road construction, undertaken because of its unique exposure to external hazards-vehicular traffic, found that the leading cause of these 96 fatal events was “crushed/run-over by highway vehicle” accounting for 30 (31.2 percent) of the events. The leading contributing cause of these 30 events was when highway vehicles lost control and swerved into highway/road work sites, striking workers.

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I. Introduction

This paper reports on the direct causes of fatal events in the construction industry which occurred in calendar year 2006. Thirteen earlier studies[1] by the Construction Industry Research and Policy Center (CIRPC) analyzed the causes of fatal events in this industry in 1991-1992, 1993-1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2002, 2003, 2004 and 2005.

II. Data

The data analyzed in this report, provided by OSHA from Form 170's, consist of narrative descriptions of the 780 fatal events inspected by OSHA resulting from accidents which occurred in construction during calendar year 2006. The Occupational Safety and Health Act of 1970 provides States with the option of administrating the Act themselves or accepting Federal administration of the Act. Twenty-nine States and the District of Columbia chose administration under the Federal System, and the remaining 21 States and two Territories chose self-administration under State Plans[2].

In this report, as in earlier reports, analysis includes all OSHA-inspected fatal construction events regardless of Federal or State administration.

Also, as in the earlier 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; these

[1] An Analysis of Fatal Events in the Construction Industry, 1991-1992 (1993), An Analysis of Fatal Events in the Construction Industry, 1993-1994 (1995), An Analysis of Fatal Events in the Construction Industry, 1995 (1996), An Analysis of Fatal Events in the Construction Industry, 1996 (1997), An Analysis of Fatal Events in the Construction Industry, 1997 (1999), An Analysis of Fatal Events in the Construction Industry, 1998 (2000), An Analysis of Fatal Events in the Construction Industry, 1999 (2001), An Analysis of Fatal Events in the Construction Industry, 2000 (2002), An Analysis of Fatal Events in the Construction Industry, 2001 (2003), An Analysis of Fatal Events in the Construction Industry, 2002 (2004), An Analysis of Fatal Events in the Construction Industry, 2003, (2005), An Analysis of Fatal Events in the Construction Industry, 2004 (2006) and An Analysis of Fatal Events in the Construction Industry, 2005 (2007). Construction Industry Research and Policy Center , University of Tennessee, Knoxville.

[2] States in the Federal System are: AL, AR, CO, CT, DE, DC, FL, GA, ID, IL, KS, LA, ME, MA, MS, MO, MT, NE, NH, NJ, NY, ND, OH, OK, PA, RI, SD, TX, WV and WI. States and Territories under State Plans are: AK, AZ, CA, HI, IN, IA, KY, MD, MI, MN, NV, NM, NC, OR, PR, SC, TN, UT, VT, VI, VA, WA and WY.

fatalities accounted for about 3.4 percent of OSHA-inspected fatal construction events in 1991-2005 but about 5.4 percent in 2006. Although the Occupational Safety and Health 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. Therefore, the results reported upon here do not provide a year-to-year analysis of changes in the absolute number 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 31 cause categories, although a great deal of collective judgment was often required to classify the cause of many of the accidents.

This report also includes the following classification of each fatal event according to coding by the OSHA compliance officer who investigated the accident: (1) type of construction (new or addition, alteration or rehabilitation, maintenance or repair, demolition, other); (2) estimate of total project value (seven dollar-value categories beginning with "under $50,000" and ending with "$20,000,000 and over"); (3) 17 end-use categories, such as "single-family housing," "multi-family building," "commercial building," "street or highway," etc.; and (4) the construction operation being performed that caused the fatal event (selected from a list of construction operations such as "backfilling and compacting," "cutting concrete pavement," "erecting structural steel," "installing equipment (HVAC and other," etc.). However, CIRPC's review of over 1200 case files of fatal construction events occurring in 1997, 1998 and 1999

revealed that coded data for an event were sometimes internally inconsistent or did not comport with corresponding narrative descriptions. Consequently, the data analyzed in this report are restricted to the direct causes of the fatal events where the authors were able, in most cases, to classify the events with relative certainty according to 31 types of causes, essentially the same types as were used in CIRPC's previous fatality studies. However, coded data are included in Appendix C for the following: (1) end-use of structure; (2) type of construction; (3) occupation of the victim(s); (4) contract value of the construction project; and (5) construction operation associated with the fatality.

In classifying the events a rule of primacy was followed for multiple-cause fatalities the first cause in the chain of causes was recorded as the cause of the fatal event. Definitions of the causes are shown in Appendix A.

III. Analysis of Fatal Events by Cause

A. Distribution of Fatal Events by Cause

Table 1 shows the cause classification system, the number of times each cause represented a fatal event in 2006, the relative frequency of each cause and the number of victims killed.[3] It can be seen that "fall from/through roof" led all other causes in number of fatal events (98 or 12.6 percent of total fatal events), followed by "falls from/with structure (other than roof)" (72 or 9.2 percent). The third leading cause was "crushed/run-over of non-operator by operating construction equipment" (63 or 8.1 percent); the fourth leading cause was "electrocution from equipment installation/tool use" (61 or 7.8 percent); the fifth leading cause was "crushed/run-over/trapped of operator of construction equipment" (57 or 7.3 percent);

[3] Each event included at least one person killed and in several events additional workers were killed or injured.

Table 1. Construction Fatality Event Causes, 2006

Event Causes	Description	Number of Events and Victims: Events	Number of Events and Victims: Victims	Percent of Events
1.	asphyxiation/inhalation of toxic vapor	12	14	1.5
2.	caught in/struck by stationary equipment	7	7	0.9
3.	crushed from collapse of structure	33	35	4.2
4.	crushed/run-over of non-operator by operating construction equipment	63	63	8.1
5.	crushed/run-over/trapped of operator by operating construction equipment	57	57	7.3
6.	crushed/run-over by construction equipment during maintenance/modification	11	11	1.4
7.	crushed/run-over by highway vehicle	35	38	4.5
8.	drown, non-lethal fall	6	6	0.8
9.	electric shock by touching exposed wire	15	15	1.9
10.	electric shock by equipment contacting power source	35	35	4.5
		Event		Percent
	a. ladder	6		0.8
	b. scaffold	2		0.3
	c. crane/lifting equipment/boom/dump truck	15		1.9
	d. contact while handling materials such as gutters, iron rods, etc.	12		1.5
11.	electric shock from equipment installation/tool use	61	61	7.8
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	26	26	3.3
15.	fall from/through roof	98	99	12.6
		Event		Percent
	a. fall off of roof	61		7.8
	b. fall through roof other than skylight	17		2.2
	c. fall through skylight or other opening	20		2.6
16.	fall from highway vehicle/construction equipment	7	7	0.9
17.	fall from/with scaffold	35	36	4.5
18.	fall from/with bucket (aerial lift/basket)	14	15	1.8
19.	fall from/with structure (other than roof)	72	72	9.2
		Event		Percent
	a. fall with collapse of structure	13		1.7
20.	fall from/with platform or catwalk	20	21	2.6
21.	fall through opening (other than roof)	19	19	2.4

22.	fall, other or unknown	11	13	1.4
23	fire/explosion/scalding	14	19	1.8
24.	hyperthermia/hypothermia	6	6	0.8
25.	hit, crushed, fall during lifting operations	27	27	3.5
26.	struck by falling object/projectile (including tip-overs)	40	40	5.1
27.	crushed/suffocation from trench collapse	23	25	2.9
28.	crushed while unloading-loading equipment/material (except by crane)	17	17	2.2
29.	shock/burn from lightning	2	2	0.3
30.	crushed other	2	2	0.3
31.	unknown cause or other	8	8	1.0

		Event	Percent
a.	Other	3	0.4
Total		**780**	**800**	**100.0**

and the sixth leading cause was "struck by falling object/projectile (including tip-overs)" (40 or 5.1 percent). The number and relative frequencies of the remaining causes of the 780 fatal events analyzed may be read directly from Table 1. (Comparative frequencies for earlier years are shown in Figures B1 through B4 in Appendix B.)

At the risk of misleading the reader by over generalizing, it may be informative to describe frequently occurring specific examples of situations leading to the 10 most frequent causes of fatal events listed in Table 1.

Falls from /with/through Roofs. An inattentive roofer or laborer without fall protection walks backward and off the roof or steps into a skylight opening or on to a covered skylight opening.

Falls from/with Structures. An ironworker without fall protection slips or loses balance while erecting steel frame and falls or a carpenter or an ironworker falls as a result of a collapsing structure or structural component (14.3 percent of falls from/with structures were caused by collapses.)

Crushed, Run-over, Non-operator. A laborer guiding trucks while backing up, a grade checker or a laborer performing site clean-up in proximity of excavating machinery is run-over after getting out of the line-of-sight of an operator/driver.

Electrocution from Equipment Installation. An electrician, helper or lineman working "hot" inadvertently contacts an energized source by body, uninsulated tool or jumper.

Crushed/Run-over…Operator. Mobile construction equipment, such as dozers and fork lifts, goes over an embankment and rolls over or rolls over when encountering uneven terrain, resulting in the crushing of the operator. (The operator may be crushed inside the equipment or crushed by the equipment while trying to escape.)

Struck by Falling Object/Projectile. There were a wide variety of situations in which this type of event occurred, and no typical pattern was evident. Examples of situations were: struck by nails from nail guns, struck by cap on a pressurized line, debris falling during demolition, equipment falling from roof and falling trees.

Crushed/run-over by highway vehicle. Highway vehicle violates a construction zone, often at a high speed, running over worker(s) within the protected area.

Electric shock by equipment contacting power source. Most of these events occur when an equipment operator or worker positions or repositions a piece of equipment and the equipment contacts an overhead power line.
Fall from/with scaffold. A worker moving on a scaffold missteps or steps on a loose plank and falls from the scaffold. Workers also fall from scaffolds during entry/exit and fall from/ with scaffolds during assembly/disassemble.

Crushed from collapse of structure. Workers demolishing a structure that collapses on them or during construction the structure collapses for various reasons, wind, construction defects, etc.

The number of victims killed by each cause is also shown in Table 1 where it can be seen 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 fatalities. "Fire/explosion/scalding, excluding electrical burner/explosions" was the fatality cause which had the most victims killed per event, i.e., 14 events and 19 victims or 1.4 victims per event.

The Bureau of Labor Statistics (BLS) reported that during 1995-1999, 4 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.[4]

The OSHA data for construction fatalities in 2006 show that 15 of the fatal events, 1.9 percent of fatal events, had multiple fatalities, and they accounted for 35 fatalities, 4.4 percent of the individuals killed. The multiple-fatality construction incidents averaged 2.3 fatalities per incident. It should be noted that the BLS data included homicides, and they accounted for 19 percent of their multi-fatality incidents. Homicides were excluded from the analysis of OSHA data, but they were all single-fatality events.

Table 2 shows a comparison of the ranks of the causes in 2006 with the average rank of the causes of fatal events during the period 1991 - 2005. It can be seen that the overall rank

[4] Drudi, Dino and Mark Zak," Work–Related Multi-Fatality Incidents," Monthly Labor Review, Vol. 127, No. 10, October 2004.

pattern of the causes in 2006 is very similar to the rank pattern in 1991 – 2005. An overall statistical comparison of the correlation of the rank in 2006 with the average rank in 1991-2005 was calculated using a Spearman rank correlation procedure.[5] The correlation obtained was + .94, $p < .001$, 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 – 2005 and 2006[6]. Since averaging the 1991 – 2005 ranks removed inter-year variance; a somewhat lower correlation would be expected between 2005 and 2006 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 2005 and 2006 causes was calculated and found to be + .94, $p < .001$, indicating that the 1991-2004 pattern changed very little between 2005 and 2006.

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.

While the number of OSHA-inspected fatal construction events have had an upward trend since 1991, employment in construction establishments has also increased.[7] The trend of these fatal events per 100,000 construction establishment employees is as follows: 1991 – 1992: 13.1; 1993 – 1994: 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; and 2006: 10.1.

[5] Sidney Siegel, Nonparametric Statistics for the Behavioral Sciences (New York: McGraw-Hill Book Co., Inc., 1956), p. 219.

[6] Five of the 719 fatal events in 2002 and 17 of 719 fatal events in 2001 had either no narrative or a narrative too incomplete to classify the cause of fatality. These records were coded as "unknown" cause; this was not done in prior years. They were omitted from the calculation of the Spearman Rank correlation in order to avoid data distortion.

[7] Bureau of Labor Statistics, National Employment, Hours, and Earnings.

Table 2. Comparison of Ranks of Causes of Fatal Events in 1991 - 2005 with 2006

Event	1991 - 2005 Average			2006		
	Number	Percent	Rank	Number	Percent	Rank
1. asphyxiation/inhalation of toxic vapor	8.4	1.3	22	12	1.5	20
2. caught in/struck by stationary equipment	6.2	1.0	23	7	0.9	24
3. crushed from collapse of structure	26.5	4.1	11	33	4.2	10
4. crushed/run-over of non-operator by operating construction equipment	50.9	7.9	3	63	8.1	3
5. crushed/run-over/trapped of operator by operating construction equipment	33.6	5.2	6	57	7.3	5
6. crushed/run-over by construction equipment during maintenance/modification	13.0	2.0	21	11	1.4	22
7. crushed/run-over by highway vehicle	24.7	3.8	12	35	4.5	8
8. drown, non-lethal fall	5.6	0.9	24	6	0.8	26
9. electric shock by touching exposed wire	23.3	3.6	13	15	1.9	17
10. electric shock by equipment contacting power source	44.1	6.8	4	35	4.5	8
11. electric shock from equipment installation/tool use	32.1	4.9	7	61	7.8	4
12. electric shock, other	3.9	0.6	28	0	0.0	29
13. elevator (struck/crushed by elevator or counter weights)	2.8	0.4	29	4	0.5	28
14. fall from/with ladder: includes collapse/fall of ladder	27.1	4.2	9	26	3.3	12
15. fall from/through roof	75.1	11.6	1	98	12.6	1
16. fall from highway vehicle/construction equipment	5.1	0.8	25	7	0.9	24
17. fall from/with scaffold	21.9	3.4	14	35	4.5	8
18. fall from/with bucket (aerial lift/basket)	13.8	2.1	18	14	1.8	18
19. fall from/with structure (other than roof)	54.6	8.4	2	72	9.2	2

Table 2. (continued)

Event	1991 - 2005 Average			2006		
	Number	Percent	Rank	Number	Percent	Rank
20. fall from/with platform or catwalk	15.3	2.4	16	20	2.6	14
21. fall through opening (other than roof)	17.1	2.6	15	19	2.4	15
22. fall, other or unknown	4.6	0.7	27	11	1.4	22
23. fire/explosion/scalding	13.5	2.1	19	14	1.8	18
24. hyperthermia/hypothermia	4.8	0.7	26	6	0.8	26
25. hit, crushed, fall during lifting operations	34.9	5.4	5	27	3.5	11
26. struck by falling object/projectile (including tip-overs)	27.0	4.2	10	40	5.1	6
27. crushed/suffocation from trench collapse	30.7	4.7	8	23	2.9	13
28. crushed while unloading-loading equipment/material (except by crane)	13.3	2.0	20	17	2.2	16
29. shock/burn from lightning, other	14.5	2.2	17	12	1.5	20
TOTAL	648.3	100.0		780	100.0	

IV. Analysis by Victim's Situation

An analysis was performed to classify the fatal events by four general categories: (1) victim(s) was primary, immediate contributor to the event; (2) person(s) other than victim(s) was primary, immediate contributor to the event; (3) no individual directly contributed to the event, the victim(s) being "at the wrong place at the wrong time"; and (4) unknown.

The first category includes, for example, most falls, crushing/runover of operators, electrocutions other than those occurring during lifting operations, asphyxiations and hypothermia. The second category includes, for example, most crushing/runover of nonoperators, lifting operations, loading/unloading of equipment/materials, struck by highway vehicles, falls from/with aerial lifts, and electrocutions from crane boom/tackle contacting overhead powerlines. The third category includes, for example, most structure and trench collapses, struck by projectile/falling objects, and lightening.

Although the classifications were often subjective due to a lack of precise information or conflicting information, following are the results for the 780 events: (1) victim primary initiator of event: 401 events (51.4) percent; (2) victim and another employee was primary initiator: 10 events (1.3 percent); (3) person other than victim was primary initiator: 99 events (12.7 percent); (4) "wrong place at wrong time": 238 events (30.5 percent); and (5) unknown: 32 events (4.1 percent).

An additional classification of the 780 fatal events was also performed to estimate the distribution of events by work status of the victim. As with the previously discussed classification of who initiated the event, the work status classifications were also subjective – perhaps even more so. Never-the-less, it may be useful in understanding in a general sense the situations in which construction fatalities occur. It was found that: (1) 707 (90.6 percent) of the

fatal events involved workers performing work at their task site; (2) 37 (4.7 percent) of the events involved workers going to or from work or not working; and (3) 36 (4.6 percent) of the events could not be classified.

The first category includes, for example, many roofing fatalities, fatalities resulting from structure and trench collapses, events involving crushing/runover of operators, electrocutions while installing electrical equipment, workers caught in stationary equipment, workers falling from/with aerial lifts and scaffolds and workers climbing/relocating on structures.

V. **Analysis of Fatal Events by Day of Week and Time**

The fatality data reported on OSHA Form 170 includes the date and time of day of most fatal events. Table 3 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 Wednesday had the largest number of events, 168, followed by Tuesday and Thursday with 144 and 135 events respectively, and Friday had the fewest number of fatal events, 124, when weekends are excluded. 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.

Table 3. Distribution of Fatal Construction Events by Day of Week 2006

Day	Number of Events	Percent
Monday	134	17.2
Tuesday	144	18.5
Wednesday	168	21.5
Thursday	135	17.3
Friday	124	15.9
Saturday	46	5.9
Sunday	22	2.8
Missing	7	0.9
Total	**780**	**100.0**

Table 4 shows the distribution of fatal events by hour (military) of the day. It can be seen that the 13 – 14 hour period and the 11-12 hour period contained the most fatal events, 91 and 86, respectively. As pointed out previously, without knowing the total hours worked in construction each hour, it is not possible to calculate hourly event rates. However, it may be reasonably assumed that the total construction hours worked each hour during the 8-12 hour period and the 13-17 hour period are approximately equal. Even if this were true, the hourly differences would not be statistically significant.

Table 4. Distribution of Fatal Construction Events by Hour 2006

Hour	Number of Events	Percent
0–1	5	0.6
1–2	2	0.3
2–3	6	0.8
3–4	2	0.3
4–5	5	0.6
5–6	1	0.1
6–7	9	1.2
7–8	21	2.7
8–9	73	9.4
9–10	72	9.2
10–11	81	10.4
11–12	86	11.0
12–13	47	6.0
13–14	91	11.7
14–15	79	10.1
15–16	77	9.9
16–17	49	6.3
17–18	31	4.0
18–19	15	1.9
19–20	3	0.4
20–21	6	0.8
21–22	2	0.3
22–23	4	0.5
23–24	6	0.8
Missing	7	0.9
Total	**780**	**100.0**

VI. Highway/Road Construction Fatalities

One might think that highway/street construction would be relatively safe, since most work activity at these sites occurs at or near ground level. Therefore, falls from elevations, the leading direct cause of construction fatalities, would have a low potential. However, in 2006, 99 workers were killed in 96 events while working on highway/street projects.

Table 5 ranks the direct causes of the fatal events by their frequency. The table shows that the leading causes were “crushed/run-over by highway vehicle” (30 events or 31.2 percent), followed by “crushed/runover of nonoperator by operating construction equipment” (24 events or 25.0 percent), and “crushed/runover of operator of construction equipment” (15 events or 15.6 percent). Other multiple-event causes were: “struck by projectile/falling object” (5 events or 5.2 percent); “crushed by maintenance of construction equipment” (4 events or 4.2 percent); “fall from construction equipment/vehicles” (3 events or 3.1 percent); and “lifting operations” and “loading/unloading equipment except by crane”, both with (2 events or 2.1 percent).

Since traffic on many or most highway/road varies by time of day, and most construction on highway/road occurs during the day, one might expect that most “crushed/run-over by highway vehicles” fatalities would occur during morning and afternoon commuting periods when traffic loads peak. Table 6 shows fatal events caused by victim being struck/run-over by highway vehicles by time of day (1- 24 hours).

It can be seen that the mid-day period (11:00 – 14:00) had the largest number of fatal events (10 or 33.3 percent), followed by the late afternoon period (14:00 -17:00) with 8 (26.7 percent) events, and the mid-morning period (8:00-11:00) with 6 (20 percent) events.

Table 5. Frequency of Fatality Causes in Highway/Road Construction, 2006

	Frequency	Percent %
Crushed/run-over by highway vehicle	30	31.2
Crushed/run-over of non-operator by operating construction equipment	24	25.0
Crushed/run-over/trapped of operator by operating const. equipment	15	15.6
Struck by falling object/projectile	5	5.2
Crushed-maintenance	4	4.1
Fall from vehicle (vehicle/construction equipment)	3	3.1
Lifting operations	2	2.0
Loading equipment/material	2	2.0
Asphyxiation/inhalation of toxic vapor	1	1.0
Caught in stationary equipment	1	1.0
Collapse of structure	1	1.0
Drown, non-lethal fall	1	1.0
Fall from/with bucket (aerial lift/basket/scissor lift)	1	1.0
Fall, other	1	1.0
Fire/explosion	1	1.0
Crushed	1	1.0
Electrocution-crane	1	1.0
Electrocution-other	1	1.0
Unknown cause-other	1	1.0
Total	96	99.5%

Table 6. Construction Fatalities Caused by "Crushed/Run-Over by Highway Vehicle" by Time of Day, 2006

Time	Frequency	Percent (%)
Early Warning: 24:00 - 5:00	2	6.7
Dawn: 5:00 - 8:00	4	13.3
Mid-Morning: 8:00 - 11:00	6	20.0
Mid-Day: 11:00 - 14:00	10	33.3
Late-Afternoon: 14:00 - 17:00	8	26.7
Evening: 17:00 - 20:00	0	0.0
Late Night: 20:00 - 24:00	0	0.0
TOTAL	30	100.0

It is interesting to note that the above pattern generally comports with findings by Simpson[8]. Simpson when studying 70 injury events in highway construction found that 38.7 percent of injuries occurred during the mid-day period (11:00-14:00); 34.0 percent occurred during the mid-morning period (8:00-11:00), and 19.6 percent occurred during the late-evening period (14:00-17:00).

Although it is not possible to calculate fatality rates for these time-of-day periods without knowing the hours worked in each period, it is possible to advance a hypothesis that could partially explain the pattern of occurrence. One hypothesis would be that fatalities and injuries in highway/road construction are a partial function of traffic loads, assuming that most highway/road construction activity occurs after the morning commuting peak and before the evening commuting peak.

Thus both OSHA's fatality data and Simpson's injury data appear to be affected by the mid-day traffic load. Both results are surprising, because the mid-day period likely has the fewest

[8] Simpson, James Mitchell. Analysis of Accidents on Tennessee Highway and Street Construction, unpublished Master's Thesis, Department of Environmental and Civil Engineering, University of Tennessee, August 2002.

hours of work of any of the daytime periods since lunch is generally taken by workers during this period. More information about the conditions which contribute to fatalities in highway/road construction caused by highway vehicles striking workers could save many lives. Therefore, it is suggested the National Institute for Occupational Safety and Health (NIOSH) investigate the conditions which contribute to highway/road construction injuries.

Since “crushed/run-over by highway vehicle” was the leading direct cause of fatal events occurring in highway/road construction, it may be helpful in protecting workers engaged in highway/road construction by looking for specific situations in which these fatalities occurred. The often brief summaries of highway construction fatalities in IMIS provided little or no information on speed limits, pavement conditions, visibility, protective barriers, work zone markings or potential impairments of vehicle operators involved in the fatalities. However, it was still possible to identify seven sub-categories of “crushed/run-over by highway vehicle”. Table 7 shows these sub-categories and their frequency.

This table shows that the largest numbers of fatal events occurred when highway vehicles lost control and swerved into work zones striking workers, accounting for 9 (30 percent) of the fatal events. This sub-category was followed by the situation where flaggers were struck by highway vehicles passing work zones, representing 5 (16.7 percent) of the events. Four other situations accounted each for 3 (10 percent) of the fatal events: workers struck by vehicles while installing signs or working on traffic signals; workers struck by vehicles which inadvertently drove into work zones; workers protected by shadow trucks crushed when vehicles rammed the shadow truck; and, workers run-over by vehicles entering poorly marked/protected work zones.

Table 7. Frequency of Sub-Categories of "Crushed/Run-Over by Highway Vehicle", 2006

Sub-Category	Frequency	Percent (%)
1. highway vehicle lost control and entered (by swerving or inadvertently entering) well-identified work zone, striking victim	9	30.0
2. highway vehicle struck victim installing signs or traffic signals in unprotected work zone	5	16.7
3. highway vehicle struck victim (flagger) signaling traffic at beginning of marked work zone.	3	10.0
4. highway vehicle struck victim working (paving) in unprotected work zone	3	10.0
5. highway vehicle struck victim who walked into traffic zone	3	10.0
6. highway vehicle struck shadow vehicle protecting moving vehicle from which victim was performing work, crushing victim	3	10.0
7. highway vehicle struck victim by entering inadequately marked and protected work zone	1	3.3
8. unknown	3	10.0
TOTAL	30	100.0

APPENDIX A

Definitions of Fatality Causes

1. asphyxiation/inhalation of toxic vapor: lack of oxygen and/or inhalation of toxic gas, (excluding asphyxiation resulting from fire/explosion).

2. caught in/struck by stationary equipment: body or clothing caught pulling worker into equipment.

3. collapse of structure: building or other structure falling on worker, not including falling ladder, scaffold, aerial lift/ basket, platform, with a structure, trench collapse, or wall (earthen) collapse.

4. crushed/run-over of non-operator by operating construction equipment: non-operator run-over or crushed between equipment and ground or another object by an operator controlled piece of construction equipment.

5. crushed/run-over/trapped of operator by operating construction equipment: includes rollover and catching of body in equipment or between equipment and ground or other object while operating the equipment.*

6. crushed/run-over by construction equipment during maintenance/ modification: includes equipment/parts falling on worker while assembling or disassembling equipment.

7. crushed/run-over by highway vehicle: any run-over by non-construction equipment, including trains.

8. drown, non-lethal fall: non-lethal falls into water and flooding of container, trenches, etc.

9. electrocution by touching exposed wire/source: body part contacting the wire/source except when installing equipment or using a tool.

10. electrocution by equipment contacting wire

    a. ladder
    b. scaffold
    c. crane/lifting equipment/boom/dump truck:
    d. other: contact while handling materials, e g. gutters, iron rods, painting equipment, etc.

11. electrocution from equipment installation/tool use: includes failure to de-energize equipment, inappropriate energizing, contacting energized part with tool or body, and inadequately grounded tools or exposed tool wires.

12. electric shock, other and unknown cause

13. elevator (struck/crushed by elevator or counter-weights):

14. fall from/with ladder: includes collapse/fall of ladder.

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*Includes fatalities resulting from asphyxiation/fire/explosion/drowning of trapped operators.

15. fall from roof; fall through roof: skylight or other opening.

    a. fall off of roof
    b. fall through roof other than skylight
    c. fall through skylight or other opening

16. fall from vehicle (vehicle/construction equipment): falls from vehicle or equipment while in motion or at rest.

17. fall from/with scaffold: includes collapse/fall of scaffold.

18. fall from/with bucket (aerial lift/basket): includes collapse/fall of bucket.

19. fall from/with structure (other than roof): fall through opening in the side or through the floor (not opening in the floor) and with the structure in a collapse.

    a. fall with collapse of structure

20. fall from/with platform or catwalk (attached to structure: includes collapse/fall of platform).

21. fall through opening (other than roof): falls through stairwells, equipment openings, or other openings in a floor.

22. fall, other or unknown

23. fire/explosion/scalding, excluding electrical burns/explosions

24. heat/hypothermia

25. lifting operations: failure of equipment, inappropriate lifting, and all loading and unloading by crane operations except electrocution. (Includes objects falling and striking victim during lifting operation).

26. struck by falling object/projectile (including tip-overs): does not include collapse of structure, trench, earthen wall, or lifting operations.

27. trench collapse: includes earthen wall

28. unloading-loading equipment/material (except by crane): includes slipping and tipping over of construction equipment/material while loading and unloading.

29. lightning

30. crushed

31. unknown cause or other

    a. other

APPENDIX B

Figure B1. Comparison of Construction Fatal Events (1995-2005 with 2006)

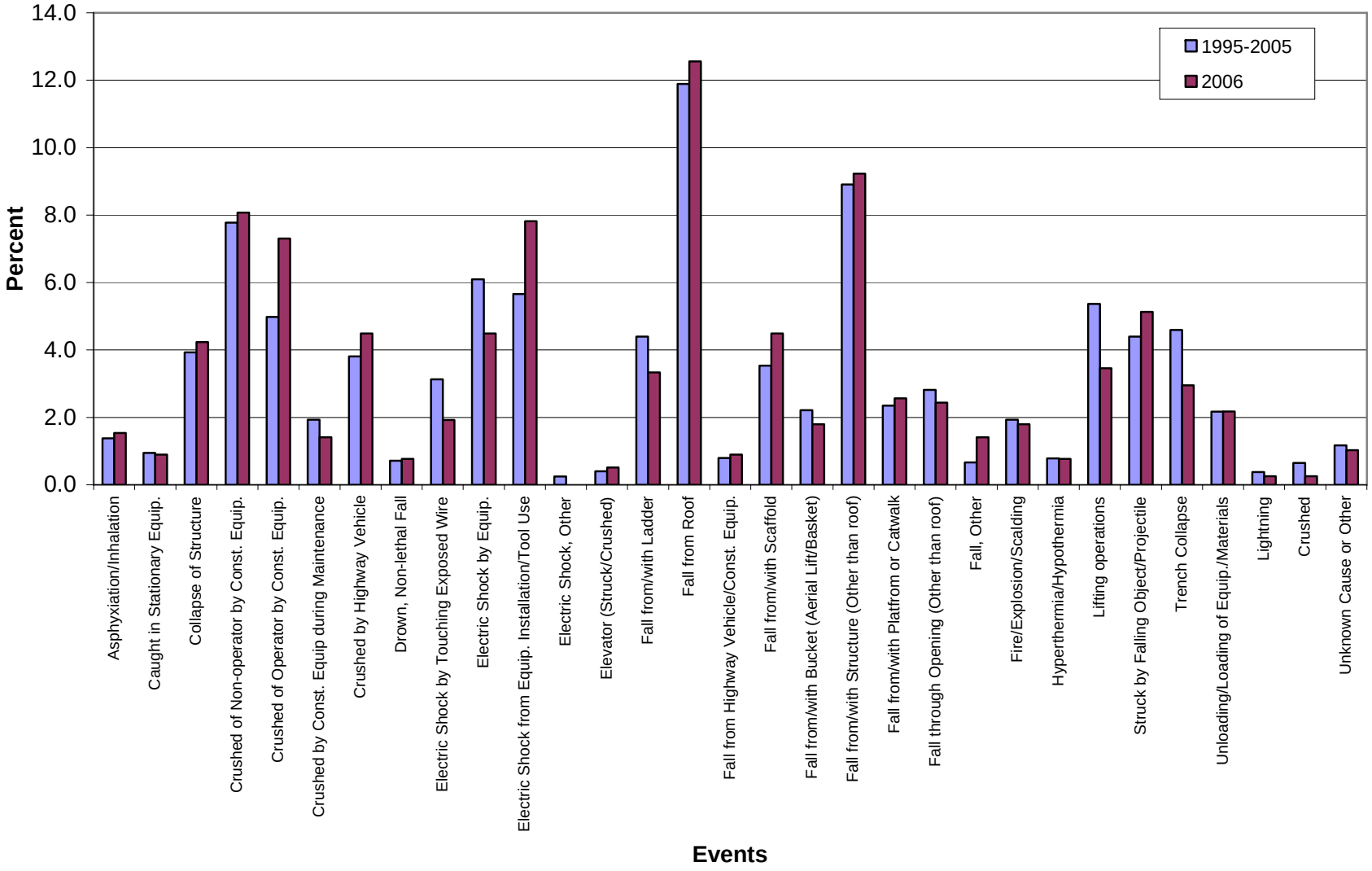


Figure B2. Comparison of Construction Fatal Events (2006)

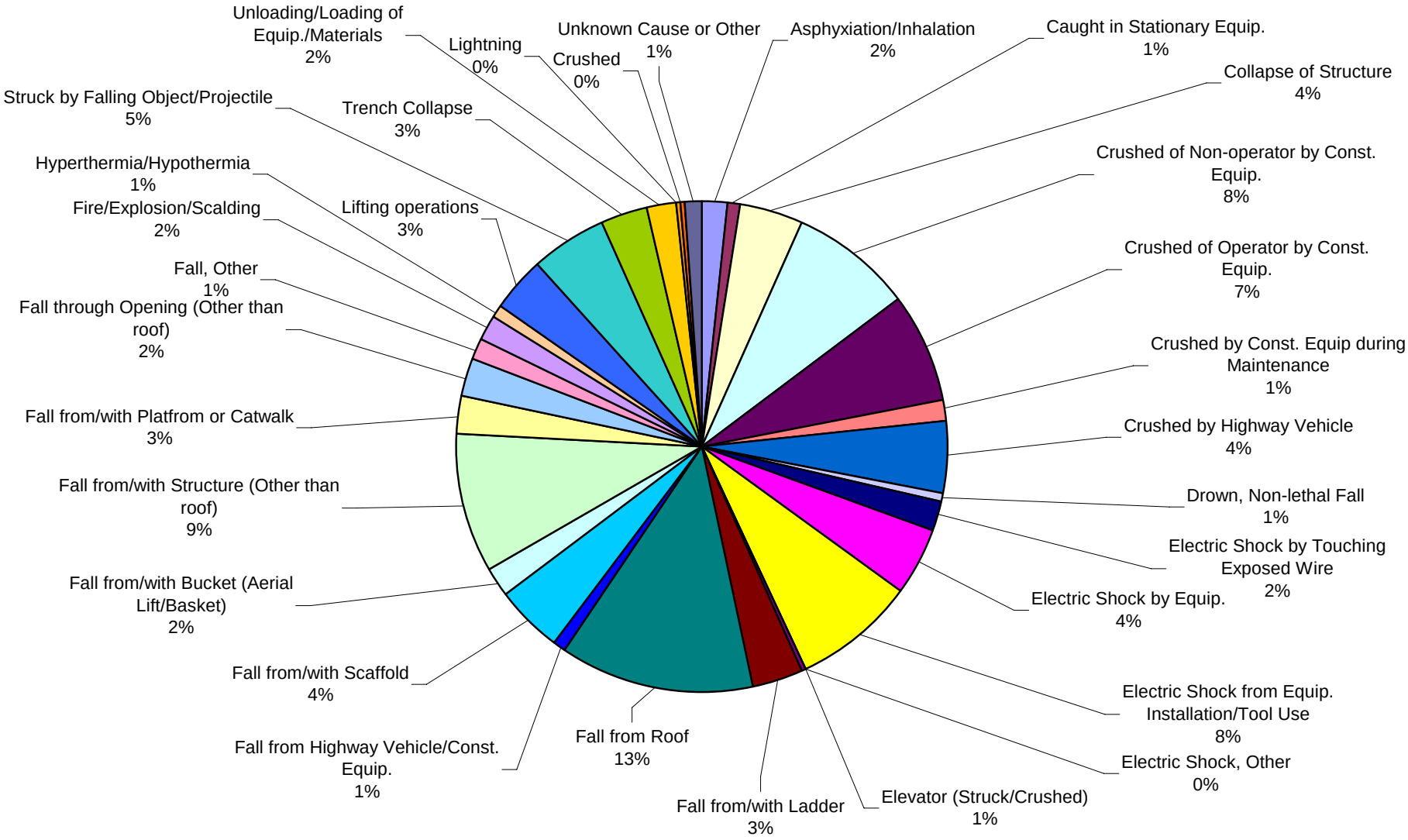


Figure B3. Comparison of Construction Fatal Events (1995-2005)

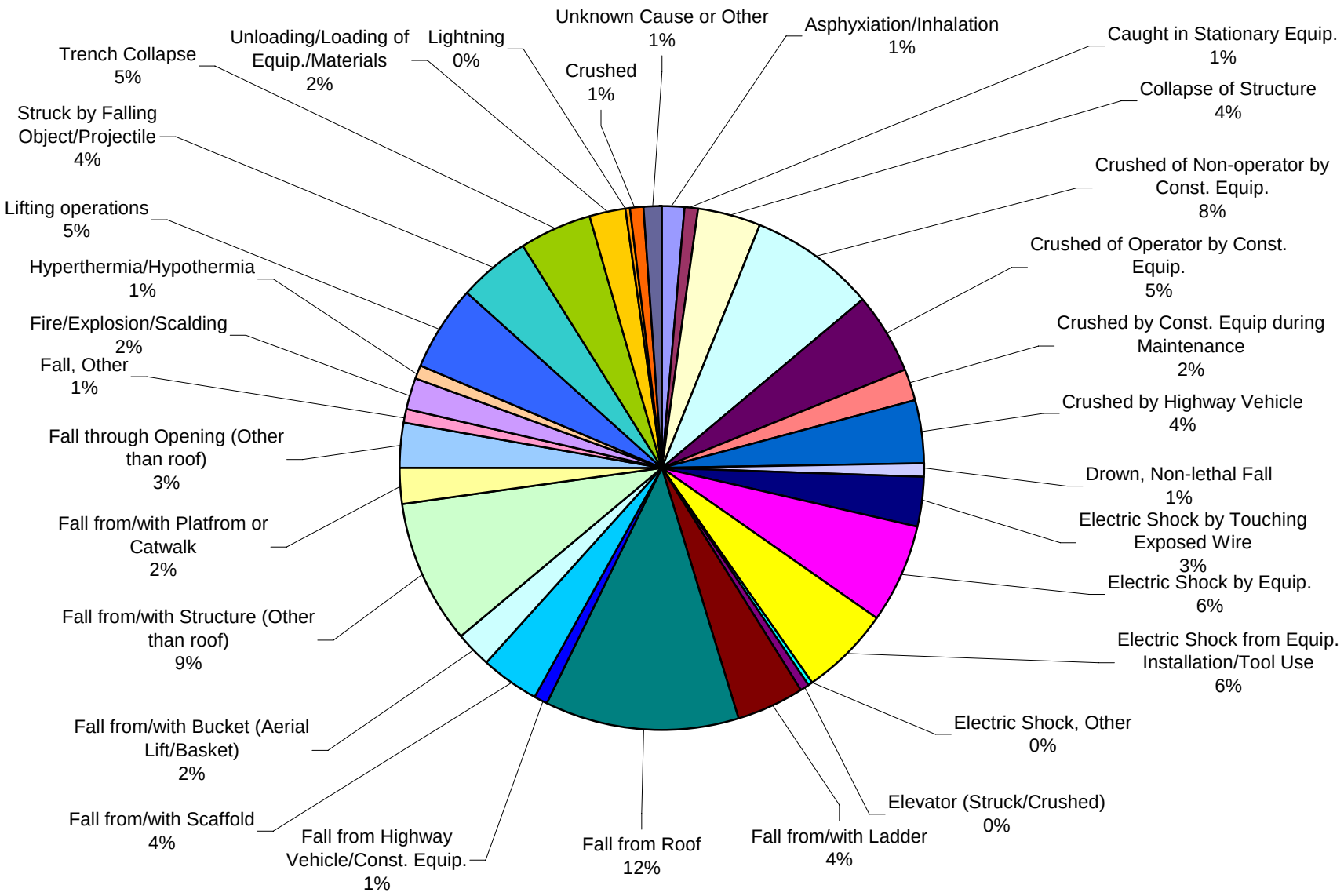
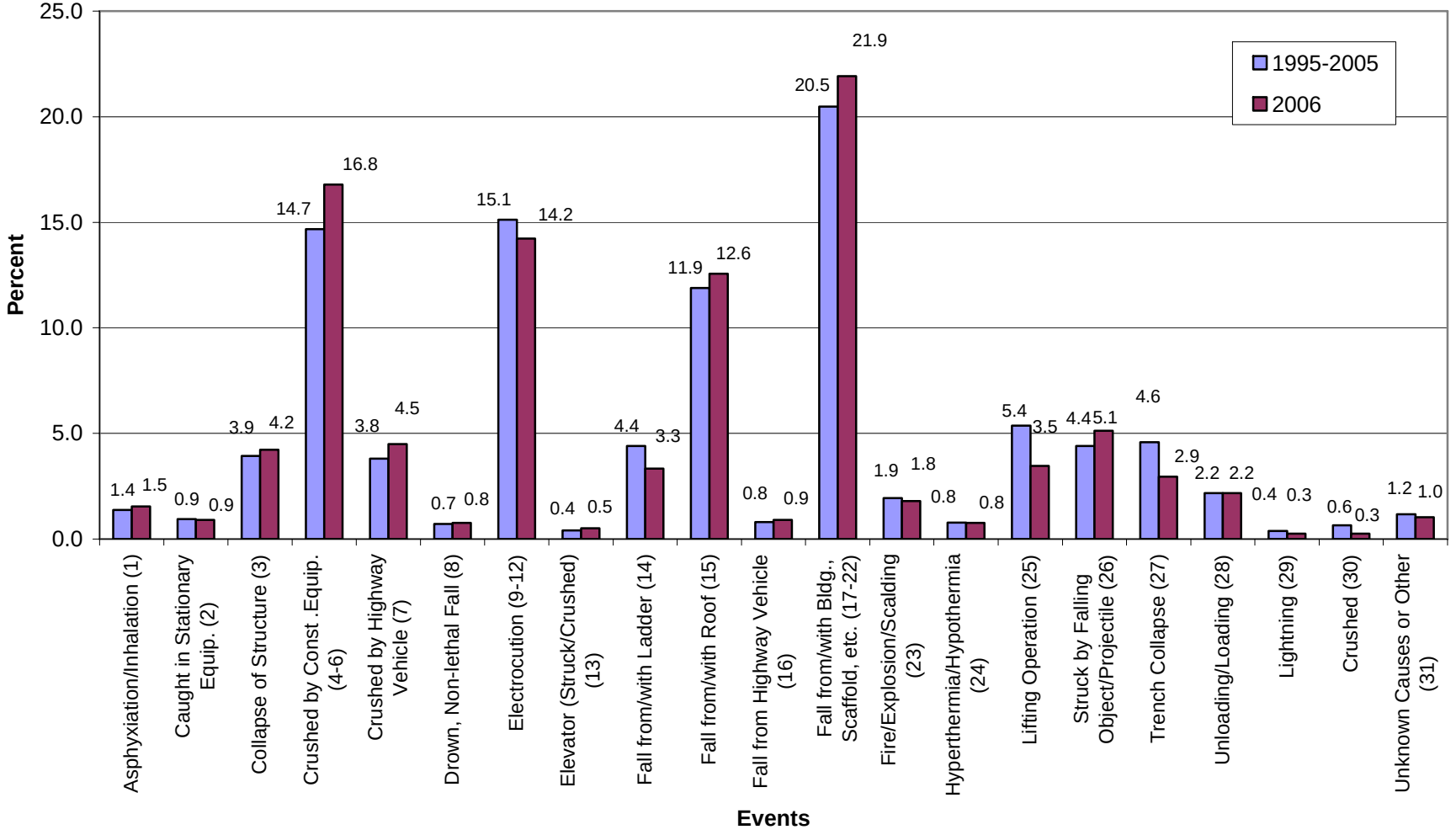


Figure B4. Comparison of Construction Fatal Events (1995-2005 and 2006)



APPENDIX C

Table C1. Construction Fatal Events by End-Use Type, 2006

End Use Type	Description	Number of Events	Percent	Cumulative Percent
1	Bridge	17	2.18	2.18
2	Commercial Building	160	20.51	22.69
3	Contractor's Yard/Facility	5	0.64	23.33
4	Excavation, Landfill	14	1.79	25.13
5	Highway, Road, Street	94	12.05	37.18
6	Manufacturing Plant	26	3.33	40.51
7	Multi-Family Dwelling	71	9.10	49.62
8	Other Building	98	12.56	62.18
9	Other Heavy Construction	24	3.08	65.26
10	Pipeline	18	2.31	67.56
11	Powerline, Transmission Line	19	2.44	70.00
12	Powerplant	7	0.90	70.90
13	Refinery	9	1.15	72.05
14	Sewer/Water Treatment Plant	10	1.28	73.33
15	Shoreline Development, Dam, Reservoir	7	0.90	74.23
16	Single Family or Duplex Dwelling	167	21.41	95.64
17	Tower, Tank, Storage Elevator	22	2.82	98.46
18	Missing	12	1.54	100.00
		780	100.00	

Table C2. Construction Fatal Events by Type of Project, 2006

Project Type	Description	Number of Events	Percent	Cumulative Percent
1	New, Addition and Alteration Construction	537	68.85	68.85
2	Maintenance, Repair and Demolition	177	22.69	91.54
3	Other	59	7.56	99.10
X	Missing	7	0.90	100.00
		780	100.00	

The coding for these data could not be verified.

Table C3. Construction Fatal Events by Four-Digit SIC, 2006

Description	SIC	Number of Events	Percent	Cumulative Percent
General Contractors - Single Family Houses	1521	25	3.21	3.21
General Contractors - Residential Buildings Other than Single Family	1522	13	1.67	4.87
Operative Builders	1531	3	0.38	5.26
General Contractors - Industrial Building and Warehouses	1541	8	1.03	6.28
General Contractors - Non-residential Buildings, other than Industrial and Warehouse	1542	27	3.46	9.74
Highway and Street Construction, Except Elevated Highways	1611	74	9.49	19.23
Bridge, Tunnel, and Elevated Highway Construction	1622	15	1.92	21.15
Water, Sewer, Pipeline, and Communications and Power Line Construction	1623	56	7.18	28.33
Heavy Construction, Not Elsewhere Classified	1629	32	4.10	32.44
Plumbing, Heating and Air-Conditioning	1711	27	3.46	35.90
Painting and Paper Hanging	1721	21	2.69	38.59
Electrical Work	1731	64	8.21	46.79
Masonry, Stone Setting, and Other Stone Work	1741	20	2.56	49.36
Plastering, Drywall, Acoustical, and Insulation Work	1742	23	2.95	52.31
Carpentry Work	1751	42	5.38	57.69
Roofing, Siding, and Sheet Metal Work	1761	84	10.77	68.46
Concrete Work	1771	39	5.00	73.46
Water Well Drilling	1781	5	0.64	74.10
Structural Steel Erection	1791	40	5.13	79.23
Glass and Glazing Work	1793	5	0.64	79.87
Excavation Work	1794	43	5.51	85.38
Wrecking and Demolition Work	1795	24	3.08	88.46
Installation or Erection of Building Equipment, Not Elsewhere Classified	1796	13	1.67	90.13
Special Trade Contractors, Not Elsewhere Classified	1799	70	8.97	99.10
Missing		7	0.90	100.00
		780	100.00	

Table C4. Construction Fatal Events by Project Value, 2006

Project Value Code	Description	Number of Events	Percent	Cumulative Percent
1	Under $50,000	244	31.28	31.28
2	$50,000-$250,000	132	16.92	48.21
3	$250,000-$500,000	71	9.10	57.31
4	$500,000-$1,000,000	81	10.38	67.69
5	$1,000,000-$5,000,000	117	15.00	82.69
6	$5,000,000-$20,000,000	68	8.72	91.41
7	$20,000,000 and over	55	7.05	98.46
8	Missing	12	1.54	100.00
		780	100.00	

The coding for these data could not be verified.

Table C5. Construction Fatalities by Construction Operation, 2006

Code	Description	Number of Fatalities	Percent of Fatalities
01	Backfilling and compacting	23	2.9
02	Bituminous concrete placement	4	0.5
03	Construction of playing fields, tennis courts	2	0.3
04	Cutting concrete pavement	8	1.0
05	Demolition	45	5.6
06	Dredging	1	0.1
07	Elevator, escalator installation	8	1.0
08	Emplacing reinforcing steel	5	0.6
09	Erecting structural steel	15	1.9
10	Erection of coffer dams, caissons	1	0.1
11	Excavation	27	3.4
12	Exterior masonry	17	2.1
13	Exterior cladding	5	0.6
14	Exterior carpentry	43	5.4
15	Exterior painting	14	1.8
16	Fencing, installing lights, signs, etc.	12	1.5
17	Fireproofing	2	0.3
18	Forming	18	2.3
20	Installing interior walls, ceilings, doors	20	2.5
21	Installing metal siding	8	1.0
22	Installing windows and doors, glazing	8	1.0
23	Installing culverts and incidental drainage	7	0.9
24	Installing equipment (HVAC and other)	34	4.3
25	Installing plumbing, lighting fixtures	21	2.6
26	Installing underground plumbing conduit	6	0.8
27	Interior Tile Work (ceramic, vinyl, acoustic)	1	0.1
28	Interior masonry	1	0.1
29	Interior plumbing, ducting, electrical work	17	2.1
30	Interior carpentry	13	1.6
31	Interior painting and decorating	5	0.6
32	Landscaping	4	0.5
33	Loading dock forming and pouring	1	0.1
34	Paving	34	4.3
35	Pile driving	9	1.1
36	Placing bridge deck	3	0.4
37	Placing bridge girders and beams	6	0.8
38	Plastering	7	0.9
39	Pouring or installing floor decks	5	0.6
40	Pouring concrete floor at grade	4	0.5
41	Pouring concrete for piers and pylons	2	0.3
42	Pouring concrete foundations and walls	3	0.4
43	Roofing	79	9.9

44	Seawall construction, riprap placement	1	0.1
45	Site clearing and grubbing	10	1.3
46	Site grading and rock removal	22	2.8
47	Stripping and curing concrete	4	0.5
48	Surveying	2	0.3
49	Swimming Pool Construction	1	0.1
50	Temporary work (buildings, facilities)	33	4.1
51	Traffic protection	11	1.4
52	Trenching, installing pipe	34	4.3
53	Waterproofing	5	0.6
56	Steel Erection Of Solid Web-Welding/Burning/Grinding	3	0.4
58	Steel Erection Of Solid Web-Moving Point To Point	2	0.3
60	Steel Erection of Open Web Steel Joists-Connecting	1	0.1
61	Steel Erection of Open Web Steel Joists-Bolting-Up/Detail Work	2	0.3
62	Steel Erection Of Open Web Steel Joists-Welding/Burning/Grinding	4	0.5
66	Installation of Decking-Initial Laying Deck (Including Layout & Safety)	6	0.8
67	Installation of Decking-Final Attachment Deck (Welding/Shear Studs/Etc	2	0.3
68	Installation of Decking-Flashing of Decking	2	0.3
69	Installation of Decking-Hoisting Bundles	1	0.1
70	Other Activities-Installing Ornamental and Architectural Steel	6	0.8
71	Other Activities-Post Decking Detail Work	11	1.4
00	Missing	89	11.1
		800	100.0