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Lessons Learned from Accident Reports of Falls in the US Construction Industry

Somik Ghosh[1], Matthew Reyes [1], and James Jenkins[2]
[1]University of Oklahoma, [2]Purdue University

Falls from height is one of the leading causes of fatal and non-fatal accidents in the US construction industry. As many accidents are due to system failure, analyzing accident reports can reveal underlying system failures and provide insights for developing effective control measures. This paper examined 100 full-text accident investigation reports compiled by the National Institute of Occupational Safety and Health (NIOSH) through the Fatality Assessment and Control Evaluation (FACE) program to explore the characteristics of the fall fatalities and learn about common trends in the accidents. Looking beyond quantitative information related to accidents, this paper presents the salient features of the accidents, demographics of the victims, and background of the victims' employers. Further analyses reveal that victims' actions and behaviors were critical causal factors. This research also suggest that lack of safety training programs might have contributed to the lack of awareness and unsafe behaviors of the victims.

Keywords: Construction safety, Falls, Accident reports

Introduction

The US construction industry is responsible for 4.4 percent of the nation's gross domestic product and employs more than eight million workers (BLS, 2024c). It is the legal and moral duty of construction companies to provide safe workplaces for this huge workforce and ensure they return home unharmed at the end of the day. However, the rates of fatal and non-fatal injuries in the construction industry prove it to be one of the most dangerous industries to work in (Hinze, 2008). This miserable safety record is reflected in the nearly four times higher fatal injury rate in this sector than that of the manufacturing sector, as reported by the Bureau of Labor Statistics (BLS, 2024a). In 2022, there were 1,069 fatal work-related injuries in construction at a rate of 9.6 fatalities for every 100,000 full-time equivalent employees in the United States whereas manufacturing had a rate of 2.6 per 100,000 (BLS, 2024a). The fatality rate for all US workers combined was 3.7 per 100,000 full-time equivalents in 2022 (BLS, 2024a). However, the construction industry has better results than other industries when it comes to non-fatal injuries and injuries that result in days away from work for the injured employee. The non-fatal injury and illness rate in the U.S. in 2022 was 3.0 per 100 full-time workers for all industries with 1.8 per 100 that resulted in days away from work. In the construction industry as a comparison, the rate of non-fatal injuries was 2.4 per 100 full-time workers with 1.5 per 100 that resulted in days away from work (BLS, 2024d). This inversion of statistics in fatal and non-fatal

injuries between the construction industry and all other industries likely indicates that when injuries do happen in construction, they are more severe.

The loss or injury of trained and experienced workers, and the resulting interruption in work progress undeniably represents a loss of production in construction. When left uncontrolled, these factors are financially disruptive with issues such as escalating workers' compensation insurance costs and the high cost of medical treatment and rehabilitation programs. The annual cost of construction-related fatalities, including lost productivity, reduced family income, and the associated costs of pain and suffering is estimated to exceed $5 billion (MEPI, 2017). This figure shows the significance of safety and the impacts of accidents in the construction industry, highlighting the importance of safeguarding the health and well-being of employees.

In the US construction industry, fall from height is considered one of the 'fatal four' according to the Occupational Safety and Health Administration (OSHA). Fatalities due to falls consistently account for more than 30% of total annual fatalities in the construction industry. This is by far the largest proportion of fatalities caused by any single cause with the closest being due to roadway incidents involving motorized land vehicles that accounted for a little over 15% of construction fatalities. Maintaining a similar trend in 2022, 397 deaths were due to falls to a lower level, accounting for 37% out of the 1,069 construction fatalities (BLS, 2024e). Also, the fatalities occurring due to falls to a lower level in the construction industry account for 57% of all fatalities of this cause across all industries, which is a disproportionate percentage of the overall workforce since approximately 5% of the US workforce is in construction (BLS, 2024b).

The need for further investigation related to falls in construction is supported by the National Occupational Research Agenda (NORA Construction Sector Council, 2008), in which fall hazards are identified as a key area within the construction sector. Due to the significantly higher number of fatalities occurring due to falls in comparison to other causal factors, several studies have been conducted to explore the various aspects of fall fatalities – investigating the causes, fall risk analysis, exploring the accident patterns, investigating the prevention measures, fall accidents in various trades, and so on (Halabi et al. 2022, Nadhim et al. 2016). The present study is in response to the continuing need to explore fall fatalities in an attempt to identify any trends and/or characteristics of fall accidents that can inform control measures. Shifting focus beyond the quantitative data typically emphasized in existing research, this study analyzed detailed accident reports of fall-related fatalities. The goal was to identify any underlying trends and provide insights for developing more effective fall prevention and control measures in the construction industry. This study used the full-text accident investigation reports compiled by the National Institute of Occupational Safety and Health (NIOSH) through the Fatality Assessment and Control Evaluation (FACE) program to provide qualitative information about accidents while exploring the characteristics of the fatalities and lessons learned from the occurrences.

Data Source

The FACE program was initiated by NIOSH to identify and study fatal occupational accidents. The FACE program provides full-text investigation reports for hundreds of accidents across the nation within different industry sectors. The overall goal of the program is to study the accident reports and identify the work conditions that are susceptible to frequent and fatal injuries, then develop and disseminate prevention strategies to those who can intervene in the workplace. By doing so, the FACE program aims to reduce the occupational fatalities occurring at workplaces across the nation.

There are several benefits of using the full-text accident investigation reports available through the FACE program. Detailed investigation reports contain more explicit narratives than only quantitative information based on investigations conducted by trained professionals (McKenzie et al., 2010). Further, the reports include detailed information about the sequential chain of events that led to the fatal accident that provides rich quantitative information essential to identify the root causes of the accidents, including any system errors. The fact that accidents cannot be simulated or replicated in a controlled environment makes the detailed documentation of the sequence of events and peripheral conditions present during the accidents more important. Learning from actual occurrences is the only option in regard to accidents and that is believed to be an effective way to prevent similar events in the future (Beavers et al., 2009).

Method

The scope of data collection for this study has been limited to examining the investigation reports published as part of the NIOSH FACE program from 1982 through 2012. The database was manually searched to identify investigation reports of fatal fall accidents occurring in the construction industry. This was done by sorting the database first by "industry" (construction in this case) and then by "cause of fatality" (falls in this case). The database was searched with both criteria to reduce accidental exclusion of investigation reports that are of interest to this study. The search resulted in 100 full-text fatality investigation reports, which were selected for the analysis. A content analysis of the selected investigation reports was completed to explore the characteristics and trends of the fatal fall accidents.

The content analysis of the accident reports began with the coding of each report. The authors reviewed the reports to identify key terms or phrases that summarized important features about the accident such as 'what', 'when', 'how', 'who', and 'why.' Following a first round of open coding, the authors identified patterns within the open codes that further developed into categories (second iteration). The categories identified from the content analysis of the accident reports match very closely with the factors identified by previous studies (Ling et al., 2009; Beavers et al., 2009; Huang and Hinze, 2003; Chi et al., 2009). Zhao et al. (2014) followed a similar process in their study in conjunction with a literature review and expert consultation to establish the factors. A total of 15 categories were identified from the open codes.

The authors adopted an exploratory data analysis strategy to analyze the data generated from the FACE reports. In the absence of any hypothesis to perform confirmatory data analysis, the authors maintained an open mind while exploring the data to consider all possible conclusions (lessons learned). This strategy was deemed appropriate for the objective of this study to learn from the accident reports.

Findings

The frequencies of the fatal accidents resulting from falls occurring by month and days of the week are presented in Figures 1 and 2. The number of fatal accidents peaked in the months of March and November (12% each) with the minimum recorded during February (3%). Based on the frequency distribution, there was not much to differentiate between the seasons with Fall being the season accounting for the highest share of the fatalities (30%). When considering occurrences by the weekdays, more than 50% of the accidents occurred during the end of the week (Thursday through Saturday).

Typically, the construction projects gather momentum and intensity as the workweek progresses. Also, the workers are more attentive and working cautiously during the beginning of the workweek. As the week progresses, the pressure of catching up (to increase productivity) could contribute to lower awareness towards potential fall hazards by the workers. In addition, the increase in physical exhaustion as the week progresses could impair the workers' mental alertness that they failed to identify potential hazards. On the other hand, a slightly higher occurrence of accidents during the Fall could signify a higher concentration of projects during this time or type of projects that involve working at height.

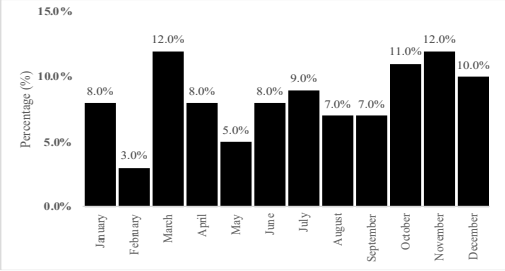

Figure 1. Frequency of accidents by months

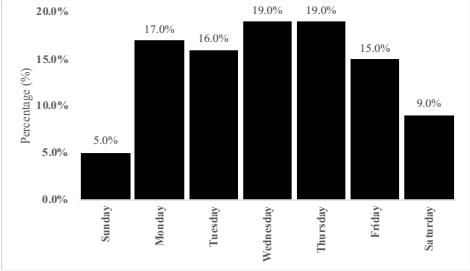

Figure 2. Frequency of accidents by days

Demographics of the Victims

The ages of the victims of the fatal accidents ranged from 16 years to 64 years, with most in the age group of 25 - 34 years (33%) followed by 35-44 years (27%) as shown in Figure 3. More than 90% of the victims were aged below 55 years. This could mean there were fewer workers aged 55 years and above in the workforce, or that workers above 55 years had reduced task assignments at height, or that workers above 55 years had higher awareness of potential fall hazards.

Reports indicated that the victims were predominantly male (97%, See Figure 3), which is reflective of the higher proportion of males working in the industry. Also, the victims were mainly (95%) non-Hispanic. With the increasing number of Hispanics in the construction workforce, the frequency distribution of the victims' race is not reflective of the workforce demographics at large. This disparity could be due to non-Hispanics tasked with activities that involves working at height or under-reporting.

Three occupations accounted for half of all the fatal accidents (See Figure 4) due to fall with the iron workers (20%) being most affected. General laborers and painters are tied for the second highest (15%) affected and both of these groups might not have received extensive fall safety training. Other professions that are affected by the fatal accidents due to fall were carpenters (13%), roofers (11%), and electricians (8%). Five percent of the victims involved in the fatal accidents were equipment operators who were involved in erecting towers. All the occupations contributing three or less percent of the accidents were combined in the 'others' category, that included drywall installers (3%), sheet metal workers (2%), inspectors (2%), plumbers (1%), masons (1%), and others.

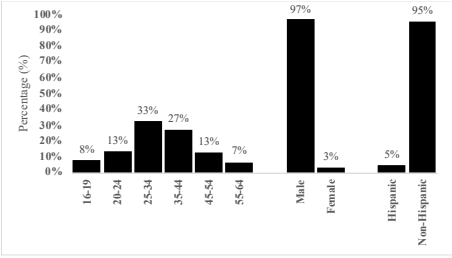

Figure 3. Demographics of the victims

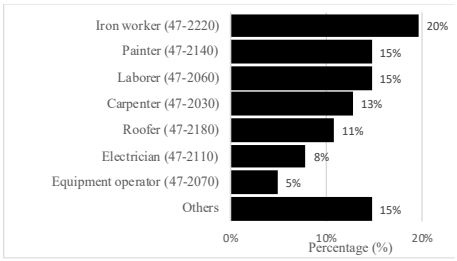

Figure 4. Occupation of the victims

Background Information of the Employers

Background information about the victims' employers is presented in Figure 5 where a quarter of all the fatal accidents due to fall were associated with the structural steel contractors. This is consistent with the numbers reported in the previous section (Figure 4) where iron workers topped the list of the victims' occupations. The structural steel contractors were followed by the commercial contractors (which is a broad category referring to the general contractor) accounting for 20% of the fatal accidents, the painting contractors (18%), and the roofing contractors (15%). The 'other specialty trade' that accounted for 12% of the fatal accidents refer to the contractors who install and operate specialized building equipment, such as cranes, boomed vehicles, elevators, and escalators.

The type of construction projects was used as an indicator of the employers' primary industry sector, divided into residential, heavy civil, and non-residential sectors. While there can be companies that are involved in more than one sector, it is not very common. Residential projects accounted for the largest share (46%) followed by heavy civil projects (32%), and non-residential projects (22%). Refer to Figure 6 for details. The most frequent heavy civil projects that involve incidents are waste treatment plant, bridge, and gas station projects. Residential building projects include the construction and repair of houses, apartments and condominiums. Non-residential building projects involve commercial office, warehouse, shopping mall, store, school, and manufacturing facility.

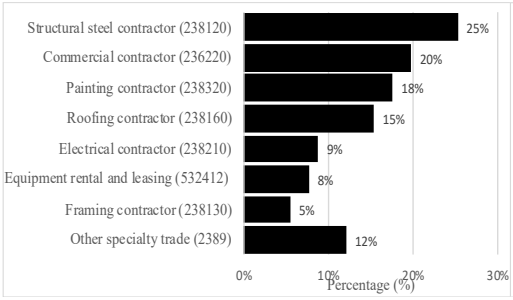

Figure 5. Employers' industry where incident occurred

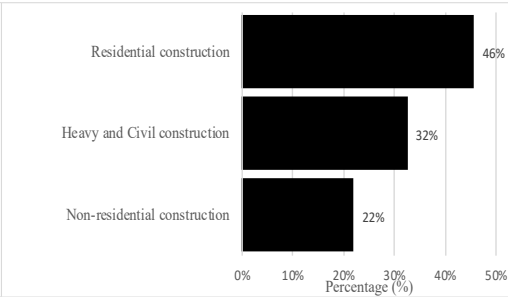

Figure 6. Project type where incident occurred

Nature of the Accidents

Data shows that almost half of employers neither had a written safety policy (48%) nor provided a safety training program (46%) to their employees. This is in spite of the OSHA mandate that employers maintain written safety policies and provide training to their employees related to safety and health. The absence of written safety policies and training programs could decrease worker awareness of potential hazards.

As shown in Figure 7, more than one third (34%) of the fatal accidents due to fall were caused by unsafe behavior of the victims who did not follow proper safety procedures. Improper use of tools/equipment by the victims were the second most frequent cause of fatal accidents due to fall (27%). Improper use of tools/equipment included improper use of ladders, fall protection devices, not securing scaffold properly, and similar actions. Failure of tools/ equipment, which was coded as a separate cause in this study accounted for 20% of the accidents. Causes of accidents such as collapsing of scaffold, snapping of a hoist line, winch cable failure, slippage of working platform on scaffold, and similar were coded as failure of tools/equipment. Not using personal protective equipment (PPE) or improper use of PPE was responsible for 12% of the fatal accidents due to fall. The immediate cause of 7% accidents could not be determined based on the FACE accident reports. The FACE reports were further examined to identify the origin of unsafe behaviors that caused more than one-third of the fatal accidents. It was found that in 76% of the instances the origins of the errors were the victims themselves. It is worthwhile to mention that 24% of the fatal accidents occurring due to fall were related to the conduct of a third party, where the victim was not at fault.

As shown in Figure 8, in nearly three-quarters (72%) of the accidents, the victims landed directly on the ground surface. The landing surface in these instances could be inside or outside of built facilities. In 14% of the instances, the victims hit something such as scaffold, trailer, etc. before landing on the ground. In 8% of the accidents, the victims fell from height to a surface below grade during construction of basement, tank, and similar.

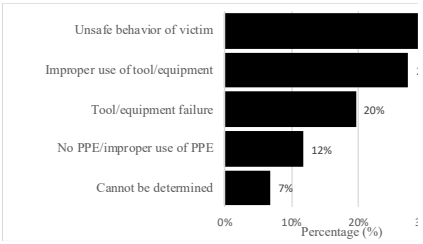

Figure 7. Immediate cause of fall by the victims

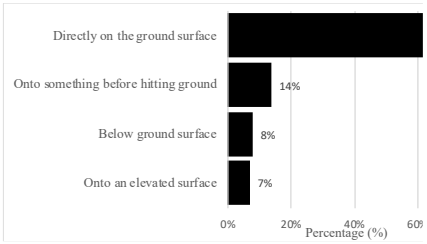

Figure 8. Landing surfaces of the victims

The analysis of the FACE reports indicates that a vast majority (90%) of the accidents due to fall occurred in exposed construction sites. There could be a variety of natural conditions associated with exposed construction sites such as wind, temperature, and humidity that could have played a role in the accidents. Working on scaffolds and ladders in windy conditions can be challenging and easily lead to accidents if safety procedures are not followed. Extreme temperature can add to it by increasing worker fatigue and possible causing safety lapses.

Recommendations for Accident Prevention

The FACE reports included several recommendations to prevent such accidents based on root-cause analyses of the accidents and identified the defect(s) in the system rather than putting the blame on any individual (Zhao et al., 2014). These recommendations can be used as lessons learned from these fatal accidents and can be used to inform future control measures. The authors examined all the recommendations provided in the 100 investigation reports considered for this analysis and categorized the recommendations. The most frequently identified recommendations are summarized in Table 1. Recommendations that occurred in less than 10% of the reports were not included in the table. The results show that more than half of the accident reports (53%) suggested that employers provide training to employees in fall hazard recognition and avoidance and the appropriate use of fall protection systems where hazards exist. Interestingly, the second most common suggestion was simply that employers ensure that fall protection devices and systems are in place when needed. The fact that this was a recommendation in less than half of the reports indicates that the absence of protective systems is not a core issue most of the time but rather that a lack of knowledge on how and when to use protective systems is a more common issue.

Table 1. NIOSH recommendations for control measures

NIOSH Recommendations	**Percentage**
Employers should ensure that all employees are provided with training in the recognition and avoidance of fall hazards and the fall protection system they are to use in the workplace where fall hazards exist, in a language and at a literacy level that all workers can comprehend.	53%
Employers should ensure that workers are protected against falling and fall protection is provided and used when the potential for falls exist on the worksite	47%
Employers should develop, implement, and enforce a comprehensive, written fall protection program that, at a minimum, complies with applicable OSHA fall prevention standards.	47%
General contractors should consider including in the sub-contract language, the requirement that subcontractors provide them with a written comprehensive safety program.	32%
Employers should continually stress to all employees the importance of always following established safety rules and procedures.	32%
Employers should ensure that equipment is properly installed prior to the start of work and used in accordance with manufacturer's specifications.	31%
Hazard analysis should be performed before any work is initiated and included as an ongoing part of each construction phase.	28%
Employers should provide adequate guarding for open-sided floors, platforms, and runways.	13%

Discussion

The findings of this study provide a comprehensive analysis of the frequencies, demographics, and causes associated with fatal construction accidents due to falls. These insights highlight critical areas requiring targeted intervention to improve safety outcomes.

The analysis revealed that fatal fall accidents peaked in March and November, while February recorded the lowest number. The highest number of fatalities occurred during the Autumn months,

potentially indicating a higher volume of projects or the nature of work due to project phases during this season. Similarly, over 50% of accidents occurred toward the end of the workweek (Thursday through Saturday). This trend may be attributed to increased workload pressure, reduced attentiveness, and physical exhaustion as the week progresses. These findings underscore the need for enhanced safety measures, particularly during these high-risk periods.

The age distribution of victims, predominantly under 55 years, reflects the dwindling number of baby boomers in the workforce or reduced task assignments at height for older workers. The overwhelming majority of victims were male and non-Hispanic, pointing to potential occupational roles assigned to these groups or under-reporting of incidents involving Hispanics. Ironworkers, general laborers, and painters were disproportionately affected, highlighting a gap in fall protection training for these trades. Structural steel erection contractors and residential projects accounted for the highest shares of fatal accidents. This aligns with the high risk associated with ironworkers. Additionally, the absence of written safety policies and training programs among employers remains a critical concern, as it directly impacts workers' hazard recognition and adherence to safety procedures. The findings are supported by existing literature, which states that accidents could occur from errors stemming from a lack of knowledge and deficiencies in training (Read, Lenne, & Moss 2012; Hasan & Jha, 2012).

Regarding the causes of fatal falls, unsafe behavior, improper use of tools, and equipment failure were found to be in the lead. The significant role of unsafe behavior, often stemming from the victims themselves, emphasizes the need for behavior-based safety programs and consistent reinforcement of safety policies and procedures. These findings are consistent with those of Haslam et al. (2005), who claimed that workers' actions and behaviors are critical factors in determining the causes of construction accidents. Furthermore, the prevalence of accidents on exposed construction sites indicates that environmental factors such as wind and extreme temperatures can exacerbate risks, particularly when safety procedures are not strictly followed.

Key recommendations provided by NIOSH for reducing falls emphasize the importance of comprehensive safety programs, including worker training in hazard recognition, proper use of protective equipment, and ongoing hazard analysis throughout construction phases. These measures, coupled with fostering a safety-conscious culture and stricter enforcement of safety standards, could significantly reduce the frequency and severity of falls.

Conclusion

The US construction industry continues to experience a high number of fatal accidents, many of which stem from falls. These fatalities reveal systemic shortcomings, providing critical lessons for improving safety protocols and practices. This study analyzed 100 full-text fatality investigation reports found in the database of the FACE program compiled by the NIOSH from 1982 through 2012, identifying trends and gaps in safety practices. The high-risk factors identified were residential construction projects, the latter part of the workweek, and adverse environmental conditions. Furthermore, unsafe worker behaviors, coupled with a lack of safety policies and training, were major contributors to these fatal incidents. A key limitation of this study is the temporal scope of the data, which concludes in 2012. As a result, it may not capture more recent advancements or emerging trends in construction safety practices. This underscores the importance of ongoing and updated analyses to maintain the relevance and effectiveness of safety interventions.

Traditional safety training methods are often limited in addressing the complexities of modern construction environments. Recent advances in technology offer promising alternatives for enhancing worker knowledge, preparedness, and engagement. Virtual Reality (VR) and simulation-based

training are emerging as innovative tools for safety education. VR training creates immersive environments that replicate real-world construction scenarios, enabling workers to practice hazard recognition and response without the associated risks. Studies have shown that VR-based training improves hazard perception and retention compared to conventional methods (Li et al., 2018). Similarly, simulation-based training allows workers to rehearse safety protocols and emergency responses in controlled environments, reinforcing practical application (Sacks et al., 2013). Interactive digital platforms and mobile applications further complement these approaches by offering on-demand access to training materials and real-time feedback. Gamification, where safety principles are integrated into game-like challenges, has also shown promise in improving engagement and compliance among workers (Zhang et al., 2013).

To effectively mitigate fall-related fatalities, construction companies can consider integrating these modern training approaches into their safety programs. By leveraging advanced training technologies and promoting proactive safety measures, the construction industry can significantly reduce fall-related fatalities, improve worker preparedness, and establish a more resilient safety culture. The integration of innovative methods will not only address existing gaps but also future-proof safety training in an evolving construction landscape.

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