# CHAPTER 13

# Construction: Accessing and Working on Elevated Work Surfaces Safely

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**Abstract:** This chapter provides general information and educational resources that can explain methods to safely access elevated worksites in the construction industry and develop teaching and training tools from the provided content. Fatality data are presented to emphasize the dangerous nature of construction work at elevations. These data verify that falls from elevations are still the primary cause of fatal injuries in the construction industry. The NIOSH Fatality Assessment and Control Evaluation (FACE) program is highlighted throughout the chapter. The NIOSH FACE database of fatality reports identifies risk factors and recommendations for mitigating future fatal injuries. Additionally, NIOSH research activities are discussed that relate to fall prevention and protection. The activities discussed are a sample of popular fall protection techniques available to construction workers. They emphasize creating a safe working environment using ladders, scaffolds, and lifts through proper training and awareness. Proper planning, training, and practice can reduce the potential of fatal fall-related incidents from occurring.

**Keywords:** Construction, Falls, Fatalities, Hazards, Ladders, Lifts, Roofs, Safety, Scaffolds, Surveillance, Training.

## INTRODUCTION

This chapter intends to provide general information and educational resources that the reader could use in a variety of ways, for example: (a) to access elevated work sites safely in the construction industry and (b) to develop teaching and training tools from the provided content. Fatality data are presented to emphasize the dangerous nature of construction work at elevations. In addition, research activities related to fall prevention and protection and the Fatality Assessment and Control Evaluation (FACE) program conducted by the National Institute for Occupational Safety and Health (NIOSH) are presented.

Construction workers are exposed to many hazards on a daily basis. Working at

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**Ki Moon Bang (Ed.)**

elevations with the potential to fall to a lower level predominates in the industry. The Construction Industry has been considered one of the most dangerous industries in the U.S [1]. Roughly 20% of all work-related deaths occur in construction, and falls account for close to 40% of those fatalities. The need for fall protection is required for a variety of occupations, such as roofers, painters, structural iron and steelworkers, sheet metal workers, facade installers, and laborers while working at elevations. Safety precautions and relevant training about moving from a lower level to an elevated level are particularly significant in reducing fatal falls to a lower level.

There are four distinct segments in the construction industry: commercial-industrial, heavy-highway, bridge, and residential. This chapter focuses on the commercial-industrial and residential industries. They both utilize multiple methods of reaching elevated levels, such as ladders, scaffolds, mast climbing work platforms (MCWPs), and aerial lifts. The workers may require different areas of safety training depending on the method used. Despite the differences, it is important to note that there are elevating techniques and training programs similar to both industries, such as the proper use of extension ladders.

Both segments must be concerned about falls from elevations. Residential buildings can sometimes involve smaller or individually-owned companies that may have less access to the proper safety equipment and training programs and might be less likely to be unionized. A commercial building is usually larger scale, may or may not involve unions and typically has more in-depth training opportunities and greater access to safety equipment. Safety precautions for both residential and commercial construction that follow the training procedures about moving from a lower level to an elevated level and vice versa are particularly significant in reducing fatal falls to a lower level.

There is a lot of crossover between necessary construction skills, but a construction specialist in one segment is not a specialist in the other. These two segments differ at the core of their building materials. In the U.S., residential building typically uses wood, and commercial building uses steel as their main materials. There are numerous potential hazards on both residential and commercial building projects. NIOSH has reported that residential construction contractors are typically lacking in access to safety programs and in utilizing fall protection equipment [2]. According to the Occupational Safety and Health Administration (OSHA), workers engaged in residential construction six feet or higher must use a conventional fall protection system, such as guardrails, a personal fall arrest system (PFAS), or safety nets [3]. There are certain additional worker protection requirements depending on the location of the task being performed, for example, leading edges, the slope of the work platform, and guarding of the edges and surface of the work platform.

Training opportunities are delivered in a multitude of ways or environments such as: Toolbox Talks, classroom settings, conferences, Train the Trainer courses, and online media like the OSHA fall prevention training guide for employers to use to train workers [4].

## EMPLOYMENT IN U.S. – SELECTED DEMOGRAPHICS

The data presented in this section are to show the trends in the workforce as it pertains to age and race/ethnicity over a six-year period, 2014 to 2019 [5]. Historically, employment within the Construction industry has a higher percentage of workers of Hispanic Ethnicity compared to all other industries, but the annual trends follow a similar pattern to the general working population in the U.S [6]. Construction workers are increasing in age annually, similar to the general working population [7]. Trends of the overall US employment and construction employment often follow the economy. Unfortunately, the breakdown by age and race/ethnicity is not available for the construction sector.

In this section, the authors describe the most recent U.S. employment data available to understand the trends overall that have been historically similar to the Construction industry. The total U.S. employment in private industry has grown steadily from 135.7 million to 148.3 million workers over the period from 2014 to 2019. Similarly, employment in the construction sector has grown steadily from nine million to almost 11 million workers. During those six years, the construction workforce as a percentage of all U.S. employment ranged from 6.6% to 7.3%. The steady increase in construction workers, from 9.0 million to 10.85 million, represents a 21% increase in employment over the six-year period (Table **1**).

**Table 1. Total Employment for U.S. Private Industry, Construction Sector, and Two Occupations, 2014 – 2019. Data collected from References [10, 13, 16, 19, 22, 24]**

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| Total U.S. Employment, Private Industry | **135,722,500** | **137,931,000** | **141,550,000** | **142,988,500** | **146,263,500** | **148,300,000** |
| Total Construction Workers | 9,024,000 | 9,281,000 | 9,765,000 | 10,400,000 | 10,659,000 | 10,850,000 |
| Percent of Total | 6.6% | 6.7% | 6.9% | 7.3% | 7.3% | 7.3% |
| Roofing Workers | 178,000 | 189,000 | 208,000 | 201,500 | 184,500 | 200,000 |
| Structural Iron & Steel Workers | 53,000 | 57,000 | 63,500 | 42,000 | 63,500 | 50,000 |

Table **2** presents a breakdown of the employment for U.S. private industry by age group and corresponding percentage of total employment for the years from 2014 to 2019. The age group 65 years and older increased the most, slightly more than 2,000,000 (33.4%) among the six age groups over the six years reported. Four of the remaining five age groups (≤ 24, 25-34, 35-44, and 55-64) increased 11.5%, 13.1%, 7.6% and 12.2%, respectively. Surprisingly the 45-54 age group slightly decreased by 200,000 (0.6%).

**Table 2. Total U.S. Employment, Private Industry, by Age Group and Percent of Total, 2014-2019. Data collected from References [10, 13, 16, 19, 22, 24].**

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| **Total U.S. Workers, Age Groups** | **135,722,500** | **137,931,000** | **141,550,000** | **142,988,500** | **146,263,500** | **148,300,000** |
| ≤ 24 | 13,451,000 | 13,710,500 | 14,664,000 | 14,779,500 | 14,941,000 | 15,000,000 |
| Percent of Total | 9.9% | 9.9% | 10.4% | 10.3% | 10.2% | 10.1% |
| 25 - 34 | 30,718,500 | 31,392,000 | 32,547,000 | 33,120,500 | 34,164,000 | 34,750,000 |
| Percent of Total | 22.6% | 22.8% | 23.0% | 23.2% | 23.4% | 23.4% |
| 35 - 44 | 30,341,500 | 30,517,000 | 30,946,000 | 31,255,500 | 32,164,000 | 32,650,000 |
| Percent of Total | 22.4% | 22.1% | 21.9% | 21.9% | 22.0% | 22.0% |
| 45 - 54 | 32,082,000 | 32,137,500 | 32,294,000 | 31,966,500 | 32,067,500 | 31,900,000 |
| Percent of Total | 23.6% | 23.3% | 22.8% | 22.4% | 21.9% | 21.5% |
| 55 - 64 | 22,988,500 | 23,525,000 | 24,162,000 | 24,673,500 | 25,338,500 | 25,800,000 |
| Percent of Total | 16.9% | 17.1% | 17.1% | 17.3% | 17.3% | 17.4% |
| ≥ 65 | 6,147,000 | 6,649,000 | 6,937,000 | 7,193,000 | 7,588,500 | 8,200,000 |
| Percent of Total | 4.5% | 4.8% | 4.9% | 5.0% | 5.2% | 5.5% |

Fig. (**1**) presents the distribution of different age groups shown in Table **2** in a visual format. The percent values for the six age groups are shown along the y-axis. The six years are shown in each grouping, from 2014 to 2019, left to right along the x-axis. The reader can observe the variation of the percent values across the six years for any specific age group. There is a clear increase in the 25-34 age group and the ≥65 age group over the six-year period, while there is a definite decrease in the 45–54 age group.

Table **3** presents a breakdown of the employment for U.S. private industry, by race/ethnic groups and corresponding percentage of total employment, for the years 2014 to 2019. White, non-Hispanic workers is the largest category, ranging from 62.3% to 66.9% of the total workforce across the six years. The second-largest category is the Hispanic/ Latino workers, ranging from 16.0% to 17.5% of the total workforce. Over the six-year period, the White, non-Hispanic workers increased only 2.9%, from 89.6 million to 92.2 million workers. On the other hand, the Hispanic/ Latino workers increased 20.9%, from 21.7 million to 25.9 million workers. The "Other" category includes Native Americans, Alaska Natives, and the South Pacific Islanders.


**Fig. (1).** Total U.S. Workers by Age Groups, 2014-2019.

**Table 3. Total U.S. Employment, Private Industry, by Race / Ethnic Groups and Percent of Total Employment, 2014 – 2019. Data collected from References [10, 13, 16, 19, 22, 24].**

| | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|
| **Total U.S. Workers Race / Ethnicity** | **135,722,500** | **137,931,000** | **141,550,000** | **142,988,500** | **146,263,500** | **148,300,000** |
| White, non-Hispanic | 89,619,000 | 89,926,000 | 90,836,600 | 90,847,500 | 91,869,500 | 92,200,000 |
| Percent of Total | 66.0% | 65.2% | 64.2% | 63.5% | 62.8% | 62.2% |
| Black, Afr-Amer, non-Hisp | 14,595,500 | 15,181,000 | 15,664,500 | 16,148,000 | 16,779,000 | 17,150,000 |
| Percent of Total | 10.8% | 11.0% | 11.1% | 11.3% | 11.5% | 11.6% |
| Asian, non Hispanic | 7,691,000 | 7,947,500 | 8,448,000 | 8,644,500 | 8,997,500 | 9,300,000 |
| Percent of Total | 5.7% | 5.8% | 6.0% | 6.0% | 6.2% | 6.3% |
| Hispanic, Latino | 21,685,500 | 22,505,000 | 23,415,500 | 23,982,000 | 25,109,000 | 25,950,000 |
| Percent of Total | 16.0% | 16.3% | 16.5% | 16.8% | 17.2% | 17.5% |
| Other Not Defined | 2,131,500 | 1,461,500 | 3,185,400 | 3,366,500 | 3,508,500 | 3,700,000 |
| Percent of Total | 1.6% | 1.1% | 2.3% | 2.4% | 2.4% | 2.5% |

Fig. (**2**) presents the data from Table **3** in a visual format. The five Race/Ethnic groups are listed across the x-axis. The layout is the same as for Fig. (**1**), with the six years shown in each grouping, 2014 to 2019, left to right. The reader can observe the variations in the percent values across the six years for each specific grouping.

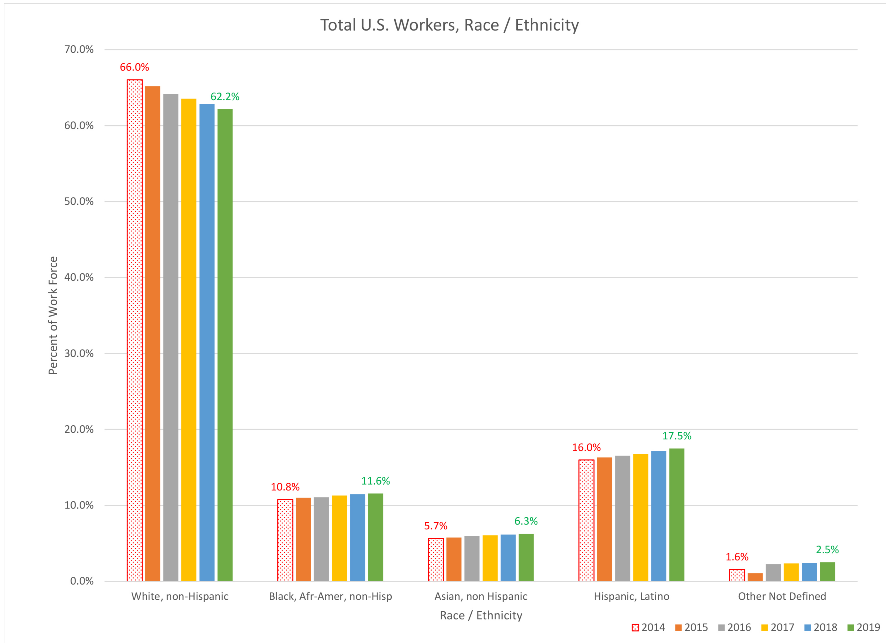


**Fig. (2).** Total U.S. Workers by Race / Ethnicity, 2014-2019.

## Construction Fatalities

The source of this section is based on publicly accessible data available from the Bureau of Labor Statistics (BLS), specifically the Census of Fatal Occupational Injuries (CFOI) [5]. Construction is a large employment sector with a high prevalence of small businesses. Small construction businesses with ten or fewer employees represent nearly 84% of all construction businesses and nearly one-third of the construction workforce in the U.S [25]. These small businesses face significant risks and challenges from market volatility and worksite hazards, which will be described later. The construction industry sector, which employed 10.85 million workers in 2019, had the greatest number of fatal fall-related traumatic injuries compared to other sectors [23, 24], which has been true for the last two decades [26].

From 2014 to 2019, there were between 345-401 fatal falls to a lower level annually in the construction industry. In 2018, more than seven times as many fatal falls occurred in the construction industry as compared to the manufacturing industry, which had the second-highest number of fatal falls [22]. Other construction occupations that have an increased risk of fatal falls include roofers, painters, structural iron and steelworkers, sheet metal workers, facade installers, and laborers [22].

A compilation of data for the years from 2014 to 2019 from the CFOI database is presented in Table **4** [8 - 24][a]. Table **4** includes the total number of fatalities in all U.S. industries (row 1) and the total number of construction-related fatalities (row 4), and the total number of deaths caused by falls to the lower level for all U.S. industries (row 2) and for the construction industry (row 5). Fall-to-lower-level fatalities averaged about 13% of all fatalities occurring in all U.S. industries from 2014 to 2019. In the construction industry, fall-to-lower-level fatalities averaged about 37% of all construction-related fatalities during the same period.

**Table 4. Selected fall-related fatalities, all U.S. Industries, and the Construction Industry, with overall rates of fatal occupational injuries for Structural Iron & Steel Workers *versus* the Construction Industry and All U.S. Industries, 2014-2019 Data Collected from References [8 - 24][a]**

| Category | | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|---|---|
| 1 | Total U.S. occupational fatalities | 4821 | 4836 | 5190 | 5147 | 5250 | 5333 |
| 2 | Total U.S. occupational fatal falls to lower level[b] | 660 | 648 | 697 | 713 | 615 | 711 |
| | Percentage of falls from the total U.S. occupational fatalities | 14% | 13% | 13% | 14% | 12% | 13% |
| 3 | Overall fatality rate[c] for all U.S. industries | 3.4 | 3.4 | 3.6 | 3.5 | 3.5 | 3.5 |
| 4 | Total Construction fatalities | 899 | 937 | 991 | 971 | 1008 | 1061 |
| 5 | Total Construction fatal falls to lower level | 345 | 350 | 370 | 366 | 320 | 401 |
| | Percentage of falls to a lower level from the total Construction fatalities | 38% | 37% | 37% | 38% | 33% | 38% |
| 6 | Overall fatality rate[c] for construction industry | 9.8 | 10.1 | 10.1 | 9.5 | 9.5 | 9.7 |
| 7 | Total number of fatalities, Structural Iron & Steel Worker | 15 | 17 | 16 | 14 | 15 | 18 |
| 8 | Fatality rate[c], Structural Iron & Steel Workers | 28.3 | 29.8 | 25.1 | 33.4 | 23.8 | 26.3 |
| 9 | Total number of fatalities, Roofers | 83 | 75 | 101 | 91 | 96 | 111 |
| 10 | Fatality rate for Roofers | 46.1 | 39.7 | 48.6 | 45.2 | 51.5 | 54 |
| 11 | Construction Fatalities, Roof -related | 109 | 106 | 123 | 121 | 114 | 146 |
| 12 | Construction Fatalities, Ladder Related | 68 | 65 | 79 | 70 | 70 | NA |
| 13 | Construction Fatalities, Scaffold -related | 58 | 55 | 60 | 54 | 46 | NA |

a

Source: Publicly accessible data from Bureau of Labor Statistics, Census of Fatal Occupational Injuries [5].
[b] Fatal falls are defined by BLS Occupational Injury and Illness Classification Systems (OIICS). Data for 2014-2019 are based on OIICS version 2.01.
[c] The fatality rate is the number of fatal occupational injuries per 100,000 full-time equivalent workers.

Other BLS data indicate that structural iron and steel workers and roofers are two high-risk work groups. The overall fatality rates for all U.S. industries and the construction industry are compared with the overall fatality rates for iron and steel workers and roofer occupations from 2014 to 2019 (rows 3, 6, 8 and 10, respectively). For 2019, the fatality rate for iron and steelworkers was 26.3 deaths per 100,000 full-time equivalents (FTE) workers, which is 2.7 times the fatality rate of all construction workers, which was 9.7 deaths per 100,000 FTE workers [24]. Included in the 7th row is the total number of fatalities for the iron and steel worker occupation during the same 6-year period. For 2019, the fatality rate for roofers was 54.0 deaths per 100,000 FTE workers, which is 5.6 times the fatality rate of all construction workers (9.7). Included in the 9th row is the total number of fatalities for the roofer occupation, which ranged from 75 to 111 deaths during the 6-year period.

Fig. (**3**) presents data from rows 1 and 4 in graphical form for the total fatalities in all U.S. industries and in the construction industry. Fig. (**4**) shows data for rows 2 and 5 in graphical form for the total fatalities from falls to lower levels for all U.S. industries and the construction industry.

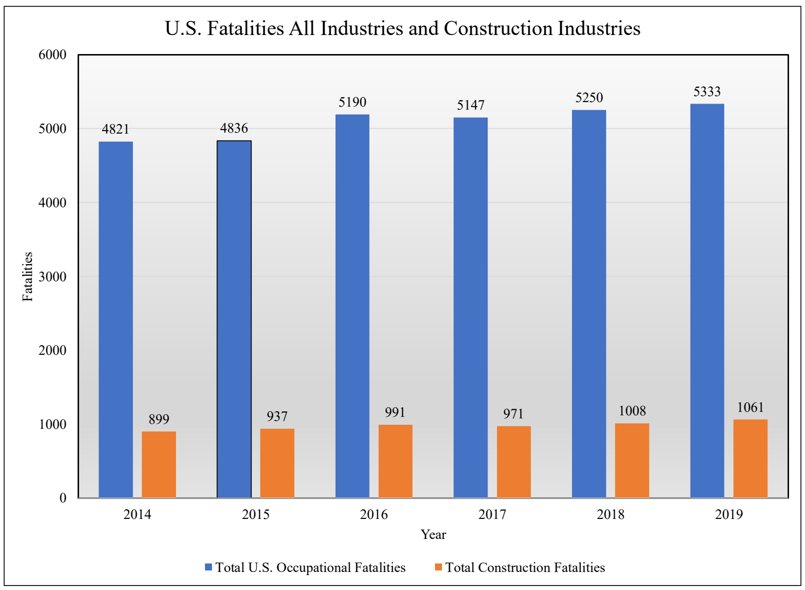


**Fig. (3).** Total U.S. Occupational Fatalities Highlighting Total Construction Fatalities 2014-2019.

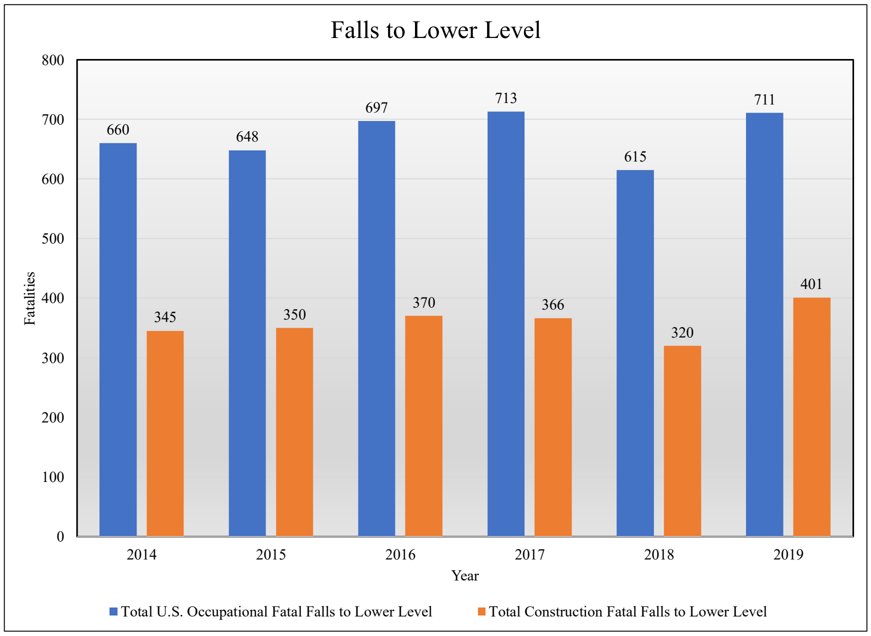


**Fig. (4).** Fatalities Caused by Falls to Lower Level for Total U.S. Occupations and Total Construction 2014-2019.

## NIOSH FATALITY ASSESSMENT AND CONTROL EVALUATION PROGRAM

Each day, approximately 13 U.S. workers die from a traumatic injury on the job. Investigations conducted by the NIOSH Fatality Assessment and Control Evaluation (FACE) program allow the identification of factors that contribute to these fatal injuries. This information is used to develop comprehensive recommendations for preventing similar deaths in the future.

The NIOSH FACE program https://www.cdc.gov/niosh/face/ [27] allows the investigator to identify and study fatal occupational injuries in this research program. The goal of the FACE program is to prevent occupational fatalities across the nation by identifying and investigating work situations at high risk for injury and then formulating and disseminating prevention strategies to those who can intervene in the workplace. The FACE program in the U.S. was initiated in 1982 and is currently comprised of two components: NIOSH FACE and the State-based Fatality Surveillance using the FACE Model (State FACE).

For the NIOSH FACE program, participating states voluntarily notify NIOSH of traumatic occupational fatalities resulting from targeted causes of death that have included confined spaces, electrocutions, machine-related, falls from elevation, working youth, and logging. NIOSH FACE is currently targeting investigations of deaths associated with: Law Enforcement Officer Motor Vehicle, Tow Truck Drivers, Tree Care/Arborist, Powered Industrial Trucks/Warehousing, Robot-Related, and Waste Collection/Sanitation Workers.

The State FACE project was initiated in 1989. Currently, seven State Health or Labor Departments have cooperative agreements with NIOSH for conducting surveillance, targeted investigations, and prevention activities at the state level using the FACE model. In addition to the NIOSH investigation targets, states conduct investigations of fatalities related to state-level targets. State FACE investigations have included fatalities related to renewable energy, logging, agriculture, transportation, commercial aviation and fishing, suicides and homicides, worker deaths involving toxicological issues, semi-truck and dump truck fatalities, public sector workers, incidents involving multiple workers, chemical-related fatalities, young workers under 25 years of age, older workers over 60 years of age, asthma-related deaths, temporary workers and volunteers, and tree trimmers.

The investigation results in FACE reports provide information on the circumstances surrounding work-related fatalities, and the recommendations are crucial for injury prevention.

The Construction FACE Database (CFD) [28] is an Excel database created by The Center for Construction Research and Training (CPWR) – to facilitate the use of the information provided by the FACE reports. The investigation results in FACE reports provide information on the circumstances surrounding work-related fatalities, and the recommendations are crucial for injury prevention. The CFD contains NIOSH and State FACE reports on 768 construction-related fatalities from August 16, 1982 to June 30, 2015. Across all industries, the NIOSH and State FACE reports total 2757; they are located at this link, NIOSH FACE program https://www.cdc.gov/niosh/face/ [27].

A new addition to the FACE Program database is FACE Digital Stories [29]. They are videos that are developed from completed FACE reports. The following two digital story examples demonstrate the summaries of the corresponding FACE reports in video format.

**Example 1**: Preventing Falls Through Skylights [30]

In this example, the video explains the events that led to a roofing supervisor's death after he fell 30 feet through a warehouse roof skylight onto a floor.

**Example 2:** A Simple Task [31]

In this example, the video describes how a worker washing windows during final clean-up of a new condominium fell from a ladder.

The FACE program and the CFD serve as excellent resources for the construction industry. The reports and the digital stories can be used as training materials and possible solutions for the safety concerns in the worksites of both residential and commercial building.

## OSHA FOCUS ENFORCEMENT AREAS AND TRAINING COMPONENTS

In the fiscal year 2019 (October 1, 2018 through September 30, 2019), five of the top 10 most frequently cited OSHA citations were issued in the construction sector, 29 CFR 1926. The five areas that were cited include: 1) Fall Protection, 3) Scaffolding, general requirements, 6) Ladders, 8) Fall Protection, training requirements, and 10) Eye and Face Protection [32].

Falls-from-heights are one of the “Fatal Four” or “Focus Four” safety hazards; the other three are caught-in/-between, electrocution, and struck-by hazards identified by OSHA. Fatalities caused by falls from heights continue to be a leading cause of death for construction workers. Fatal falls accounted for 38% of the construction industry fatalities in 2019 [23, 24].

Along with enforcement, OSHA encourages employer’s voluntary compliance with their OSHA Outreach Program [33] operated by the OSHA Training Institute Education Centers (OTIECs). These are a national network of non-profit organizations authorized by OSHA to deliver occupational safety and health training for all levels of workers. These centers typically teach the OSHA 500 trainer course for construction, which authorizes the student to become a trainer in the OSHA Outreach Program and to conduct both 10-hour and 30-hour construction safety and health courses. In FY 2019, 43% of construction workers completed the 10- or 30-hour training course [34]. The OSHA 10-hour course prepares construction workers for the potential hazards that may occur during their daily job. This includes how to protect workers from the top-four leading causes of fatalities in construction: falls, struck by objects, electrocution, and caught-in/-between. The OSHA 30-hour course is ideal for advanced-level safety training. It includes additional topics that will help workers monitor safety procedures and employers to create safety programs to keep their construction team safe while they are working. OSHA also awards Susan Harwood Grants to train hard-to-reach construction workers and those at high risk of incurring work-related injuries and illnesses, as well as to expand training in Spanish [35]. Training is a key component of a safety program to increase awareness and familiarity with personal protective equipment (PPE), and best practices for proper use of PPE. The emphasis on training within the construction industry is repeated throughout this chapter.

Since 2012, OSHA has partnered with NIOSH, CPWR, and the National Occupational Research Agenda (NORA)-Construction Sector on the Fall Prevention Campaign to raise awareness among workers and employers about common fall hazards in construction and how falls from ladders, scaffolds and roofs can be prevented. The ideas of fall prevention can be found on the OSHA's website OSHA.gov/stopfalls [36] shown in Fig. (**5**).


**Fig. (5).** Fall Prevention Ideas (Image from [36]).

## PLAN Ahead to Get the Job Done Safely

"When working from heights, employers must plan projects to ensure that the job is done safely. Begin by deciding how the job will be done, what tasks will be involved, and what safety equipment may be needed to complete each task" [36].

## PROVIDE the Right Equipment

"Workers who are six feet or more above lower levels are at risk for serious injury or death if they should fall. To protect these workers, employers must provide correct fall protection and equipment for the job" [36].

## TRAIN Everyone to Use the Equipment Safely

"Employers must train workers in recognizing hazards on the job" and proper use of safety equipment which can be found at OSHA StopFalls [36].

## PREVENTING CONSTRUCTION FALLS FROM ROOFS, LADDERS, AND SCAFFOLDS

Falls are the leading cause of construction worker deaths on the job. A recent emphasis of the FACE program is to focus on preventing construction falls from roofs, ladders, and scaffolds, as shown in the infographic Prevent Construction Falls from Roofs, Ladders and Scaffolds Infographic [37], see Fig. (**6**). The following text provides recommendations and resources to help employers, safety professionals, and workers mitigate fall injuries and deaths from roofs, ladders, and scaffolds.


**Fig. (6).** FACE Infographic (Image from [37]).

Ladders, scaffolds, and lifts are regularly used during the building process and for maintenance activities and to access another level of the roof. Ladders are used for simple jobs that do not require constant use or for long durations. They can be used for access to roofs, ceilings, and windows. Scaffolding is a temporary structure, stage, or elevated platform that aids construction and maintenance activities at heights. Scaffolds are usually preferred when it comes to tasks such as brick work or siding, and drywall finishing. These are longer tasks that require more time, and scaffolding offers a more secure working platform. Aerial and boom lifts are types of raised working platforms that can be positioned with minimal setup and can reduce fall exposure.

The following sections provide recommendations and resources to help employers, safety professionals, and workers to mitigate fall injuries and deaths from roofs, ladders, and scaffolds.

### Roofs

Low-sloped roofs are defined as a slope of 4:12 or less. Any slope above that angle will be considered a steep slope. However, the slope of many residential roofs can be extremely steep, 8:12 or even 12:12. When working on these extremely steep roofs, workers are at greater risk of slipping and sliding downward to the eave (drip edge) of the roof. This is always true whether the roof is under construction or repairs are being conducted on an existing roof.

Workers falling from elevated work sites is the primary cause of fatalities in the U.S. construction industry. Roofers are a high-risk work group, as presented previously in Table **4**. BLS data show that in 2019 roofers had a fatality rate of 54.0 deaths per 100,000 full-time workers, which is 5.6 times the fatality rate for the overall construction industry of 9.7 deaths per 100,000 full-time workers.

### *Safety on the Roof*

For residential construction, a guardrail system or the PFAS is typically used more often to protect the workforce from falling to a lower level. A safety net system is not normally used on residential construction sites because of the extra time involved in installing it. Safety nets, on the other hand, may be used on commercial and industrial construction sites since these jobs typically take longer to complete than a residential site.

Fall-related hazards in the construction industry are enforced by the OSHA through Subpart M (Fall Protection) of the Code of Federal Regulations (CFR), Title 29 (Labor), Part 1926 (Construction) [38]. Subpart M became effective on February 6, 1995 and contains fall protection requirements for construction work. Specific requirements for residential construction are contained in section 1926.501(b)(13). This section states that “Each employee engaged in residential construction activities 6 feet (1.8 m), or more above lower levels shall be protected by a guardrail system, safety net system, or personal fall arrest system unless another provision in paragraph (b) of this section provides for an alternative fall protection measure” [38].

The guardrail system and the PFAS are used most frequently in the residential construction segment. The purpose of a guardrail system is to prevent the fall to a lower level from occurring in the first place. There are a wide variety of guardrail systems that are commercially available for use on residential construction. The PFAS is a protective system that workers wear at the height that will arrest the fall after a worker has already fallen. The rescue must be as timely as possible due to restricted return blood flow from the legs caused by the extended suspension time [39]. PFAS consisting of full-body harnesses and related hardware, such as lanyards, lifelines, and anchorages, can be used to protect workers located at elevated work sites. They are also available from a multitude of manufacturers. Preventing the fall is usually more desirable and beneficial than having to rescue a suspended worker.

Researchers from NIOSH's Division of Safety Research (DSR) evaluated a small sample of commercial guardrails in controlled laboratory conditions. This investigation contributed to the development of a unique design of a guardrail system by NIOSH researchers in 2009 (U.S. Patent # 7,509,702). This system was further evaluated and modified in a NIOSH laboratory [40]. A residential contractor in north-central West Virginia evaluated the guardrail system in the field for a three-year period. The developed system was so well received by the contractors that the owners requested that they retain the system for continued use since this safety system "*was now part of our daily routine*" [41]. The NIOSH developed research output is now a life-saving commercial product that is available from a construction supply company located in Indianapolis, IN [42].

Slide guard usage in residential construction became so popular that OSHA decreed in 1995, in a Directive No. Standard 3.1, states that in certain specific instances slide guards could be used to fulfill the requirements for a fall protection system in residential construction [43]. This OSHA directive was rescinded in 2011 and eliminated the use of slide guards as the "sole means" of complying with the OSHA fall protection requirements. However, OSHA did not eliminate the use of slide guards on roof structures. They indicated that slide guards should be used in conjunction with the three fall protection options described in Subpart M of 29 CFR 1926.

Typical slide guard construction on residential roofs are fabricated using a combination of 2" x 6" boards supported by 2" x 4" boards as shown in Fig. (**7**) right. This combination of lumber was used as a slide guard, or to provide something to brace against while working on the roof. The fabricated wood slide guards were secured to the roof by nails. Additional slide guards were installed as the work progressed up the roof, as shown in Fig. (**7**), left.


**Fig. (7).** Left- Typical roof construction using roofing jacks (Inset upper left) for placement of supplies and fall protection. Right - Typical roof construction using lumber as a fall protection slide guard. (Images by NIOSH Staff).

In summary, “some factors that can contribute to falls from roofs are (a) Worker inexperience or lack of training; (b) No fall protection program or a personal fall arrest system; (c) No personal fall protection used; (d) Incorrect fall arrest system anchorage method; (e) Lack of fall arrest system lanyard connection point; (f) Incorrect working length of fall arrest system lifeline; (g) Working alone when working at elevations; and (h) Working during inclement weather (*e.g*., wind, rai n)” [37].

“Some recommendations to prevent falls from roofs include: (a) Implement a fall protection program; (b) Training on fall protection; (c) Wear fall protection and use it correctly; (d) Train and assign a person to inspect fall protection equipment before each use; (e) Use correct anchorage for fall arrest systems; (f) Extend the side rails of the ladder three feet above the roof edge; (g) Use a buddy system when working at heights; and (h) Monitor the weather” [37].

This Massachusetts FACE case is an example of a fatal fall from a roof [27, 28]. This document describes a few of the contributing factors and recommendations listed above as they pertain to the fatal incident.

## Ladders

Ladders are built from one of three basic materials: wood, fiberglass, and aluminum. The type of ladder chosen is based upon the environment of the work site and the task to be completed. Workers who use extension ladders risk permanent injury or death from falls and electrocutions (two of the OSHA fatal or focus four). These two main hazards can be eliminated or substantially reduced by following good safety practices. The following examines hazards workers may encounter while working on extension ladders or step ladders, and explains what employers and workers can do to reduce injuries OSHA ladder safety document 3660 [44], Reducing Falls in Construction: Safe Use of Stepladders (osha.gov) [45] OSHA’s requirements for extension ladders are Subpart X—Stairways and Ladders of OSHA’s Construction Standards [46].

“Extension ladders, also known as “portable ladders,” typically have two sections that operate in brackets or guides, allowing for adjustable lengths, as illustrated in Fig. (**8**). Extension ladders are not self-supporting, which require a stable structure that can withstand the intended load applied during its use” [44].

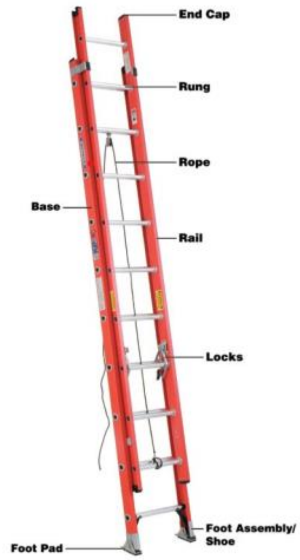


**Fig. (8).** Typical Extension Ladder (Image from [44]).

"A stepladder is a portable, self-supporting, A-frame ladder as shown in Fig. (**9**). It has two front-side rails and two rear side rails. Generally, there are steps mounted between the front side rails and bracing between the rear side rails" [45].

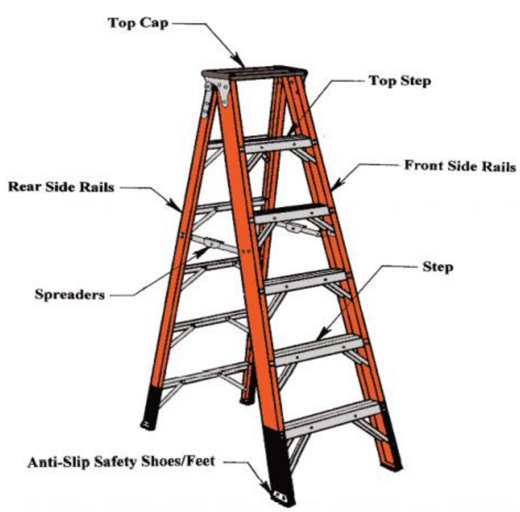


**Fig. (9).** Typical Step Ladder (Image from [45]).

"To prevent falls from ladders, it is best to plan for their proper use in the workplace. Some key points [44] are listed in the plan below.

- Use a ladder that meets the requirements set forth in Appendix A of 1926 Subpart X of OSHA's Construction Standards [46].
- Follow the manufacturer's instructions and labels on the ladder. Do not exceed the load rating and always include the weight of all tools, materials, and equipment.
- A competent person must visually inspect all ladders before use for visible defects on a periodic basis.
  - OSHA defines a "competent person" as "one who is capable of identifying existing and predictable hazards in the surroundings or working conditions which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them" [48]. Defects include but are not limited to: Structural damage, split/bent side rails, broken or missing rungs/steps/cleats, and missing or damaged safety devices.
- Allow sufficient room to step off the ladder safely. Keep the area around the bottom and the top of the ladder clear of equipment, materials, and tools.
- Set the extension ladder at the proper angle, approximately 75 degrees.
- Keep all ladders and other tools at least 10 feet away from any power lines. Before starting work, survey the area for potential hazards, such as energized overhead power lines.
  - Ladders shall have nonconductive side rails if they are used where the worker or the ladder could contact exposed energized electrical equipment.
- The ladder rails should be square to the structure against which it is leaning, with both footpads placed securely on a stable and level surface.
- When using a ladder in a high-activity area, secure it to prevent movement and use a barrier to redirect workers and equipment. If the ladder is placed in front of a door, always block off the door.
- Train workers to use ladders safely so that each worker can recognize and minimize ladder-related hazards" [44].

## NIOSH Ladder Safety App for Smart Phones

NIOSH developed a Ladder Safety app [47] for smart phone use. The app assists users in setting extension ladders to the correct angle of 75 degrees and provides information on proper step ladder use and selection. The NIOSH Ladder Safety app also provides user-friendly guides, training materials, and interactive tools to aid in preventing falls. Additionally, the app shows some ladder accessories that can be used to mitigate worker fall risk during ladder use, shown in Fig. (**10**).


**Fig. (10).** Extension Ladder Accessories (Images from [47]).

**"Angle Measuring Tool** Uses visual, sound, and vibration signals to set an extension ladder at the proper angle of 75 degrees and to check the verticality of extension ladders.

**Selection Tool** Provides a procedure to select the minimum required ladder duty rating corresponding to user characteristics and tasks.

**Inspection Tool Includes** Provides a checklist for ladder mechanical inspection.

**Proper Use Tool** Presents a set of guidelines for safe ladder use.

**Accessories Tool** Describes several available extension ladder safety accessories" [47].

***Get the Ladder Safety App***

The app is a free download from the Apple Store and Google Play. It is available in English and Spanish, Fig. (**11**). The NIOSH Ladder Safety App Infographic contains more detailed information about the app's contents.


**Fig. (11).** NIOSH Ladder App (Image from [47]).

"Some factors that can contribute to falls from ladders are (a) Worker inexperience or lack of training; (b) Improper ladder selection; (c) Improper use of a ladder; (d) Ladder overloading; (e) Ladder not set up on a level surface or at the proper angle; (f) Not extending the ladder above the roof line; and (g) Lack of safe access" [37].

In summary, "some recommendations to prevent falls from ladders are: (a) Get training on how to properly use ladders; (b) Choose the correct ladder for the job; (c) Inspect ladders regularly and ensure they are in good working order; (d) Use ladder on flat and level ground; (e) Secure and position the ladder in the safest location possible; (f) Extend the side rails of the ladder three feet above the roof edge; (g) Face the ladder at all times when climbing; (h) Maintain three points of contact with the ladder at all times; (i) Don't overload the ladder; and (j) Use the NIOSH Ladder Safety App, if available" [37].

This Massachusetts FACE case is an example of a fatal fall from a ladder [27, 28]. This document describes a few of the contributing factors and recommendations listed above as they pertain to the fatal incident.

### Scaffolding

"A total of 86% of deaths from scaffolds occur in the construction industry" [40]. OSHA has several standards related to scaffold use. The requirements for specific types of scaffolds can be found in 29 CFR Part 1926.450 Subpart L [48]. Fig. (**12**) shows some examples of end frame scaffolding retrieved from elcosh.org (Electronic Library of Construction Occupational Safety & Health) [49]. For all scaffolds, employers are required to have a qualified person train workers who perform work on scaffolds to recognize the hazards and use scaffolds safely. OSHA defines a "qualified person" as "one who, by possession of a recognized degree, certificate, or professional standing, or who by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter, the work, or the project" [[48]].


**Fig. (12).** Examples of frame scaffolding (Images from [49]).

"Employers should ensure that only experienced and trained workers are involved in erecting, moving, dismantling, or altering scaffolds under the supervision of a competent person. The competent person must also train the workers engaged in these activities" [[48]]. "Only trained and authorized people should be allowed to work on scaffolding. The competent person is also responsible for inspection of the scaffold and scaffold components for visible defects before each work shift and after any occurrence that could affect its structural integrity" [[48]].

"When erecting scaffolding, workers risk serious injury from falls and tip-overs, being struck by falling tools, electrocution from energized power lines, and other hazards. Before starting any scaffold project, the employer should conduct a hazard assessment to ensure the safety of workers" [[50]]. OSHA's scaffolding standard has several key provisions, the complete list can be found in 29 CFR Part 1926.450 Subpart L and OSHA: Guide to Scaffold Use in the Construction Industry [50].

"Installing toeboards, screens, guardrail systems, debris nets, catch platforms, canopy structures, or barricades addresses another one of the top ten citations issued by OSHA (Eye and face protection)" [50]. To protect workers from falling hand tools, debris, and other small objects, the appropriate OSHA regulations must be followed, OSHA 1926.451(h)(1), h(2) and h(3) [50].

In summary, "some factors that can contribute to falls from scaffolding: (a) Lack of a fall protection program; (b) Worker inexperience or lack of training to identify, understand, and control fall hazards; (c) Lack of fall protection or a fall arrest system; (d) Unstable work surface; (e) Improper scaffold construction, selection, or use; (f) No use of guardrails; (g) Wheels are unlocked before mounting the work platform; and (h) Working alone from heights during off-hours" [37].

"Some recommendations to prevent falls from scaffolding include: (a) Train and assign a person to supervise scaffold setup; (b) Place on stable ground/surface; (d) Set up scaffolds per the manufacturer guidelines and OSHA standards; (e) Use guardrails or a fall arrest system when more than 10 feet above a lower level;(f) Inspect scaffolds and scaffold parts before each use; (g) Ensure scaffolds are fully planked; (h) Secure scaffold; and (i) Provide proper scaffold access" [37].

This Kentucky FACE case is an example of a fatal fall from scaffolding [27, 28]. This document describes a few of the contributing factors and recommendations listed above as they pertain to the fatal incident.

## Mast Climbing Work Platform

"Mast climbing work platforms (MCWPs), also known as mast climbers, are becoming more common on U.S. construction sites" [51]. MCWPs have a power-driven work platform that traverses a vertical tower to raise and lower the working platform giving variable height access to elevated work areas. In many cases MCWPs are more convenient and safer to use than other forms of access equipment such as ladders or fixed scaffolding.

"Although they were available in the U.S. in the 1980s, they became more common in the early 1990s when contractors began using them as an alternative to traditional tube-and-coupler scaffolding. Mast climbers offer many advantages over other forms of scaffolding. They are quicker to erect and dismantle, and they are potentially much better at reducing the risk of shoulder and lower back injuries to workers, since they can be adjusted to an optimum working height" [51 ]. Some of the advantages of using MCWPs are reaching hundreds of feet in the air with unlimited positioning options, reducing personnel climbing, and safe material handling. They are as safe as other scaffold types when installed and used correctly.

Some useful references about MCWPs are:

- IPAF Guidelines for the Safe Use of Mast Climbing Work Platforms USMCWPSafeUseGuidelines.pdf [52]
- Reaching Higher – Recommendations for the Safe Use of Mast Climbing Work Platforms CPWRReachingHigheronline.pdf [51]

To assist mast climber workers in becoming familiar with the environment and required safety guidelines, NIOSH has provided a free online training tool, NIOSH MCWP Daily Inspection Walkthrough [53], which allows mast climber users to navigate through what is commonly inspected during a pre-shift daily inspection. Fig. (**13**) illustrates the webpage of this tool. This online tool utilizes pictures of a typical mast climbing work platform configuration; however, they do not include all set-ups that may be present on site. The users can use this tool to select outlined sections and the related inspection points to review relevant safety regulations. The users can also refer to the NIOSH Infographic Mast Climbing Work Platforms - "Best Practices" [54].


**Fig. (13).** Best practices for using Mast Climbing Work Platforms (MCWPs or mast climbers) (Image from [54]).

## Aerial Lifts

Aerial lifts are typically used to elevate workers to different construction working levels. They come in many different configurations, from scissor lifts, rough terrain boom lifts, and lifts mounted to vehicles. Aerial devices mounted to vehicles can include aerial ladders and boom platforms (articulating or extensible), all of which can be found in 29 CFR 1926.453 [55]. Fig. (**14**) depicts several types of aerial lifts used in construction.

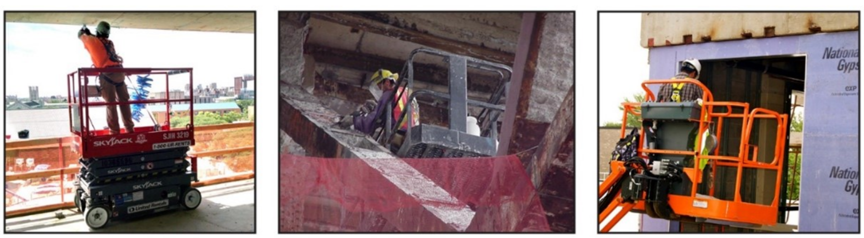

**Fig. (14).** Different types of aerial lifts used in construction: Scissor Lift, Rough Terrain Boom Lift, Boom Lift Bucket (Images [[49]]).

Some specific requirements of aerial lift operation 29 CFR 1926.453 [[50]] include the following:

- "Only authorized personnel can operate aerial lifts.
- The manufacturer or equivalent must certify any modification.
- The insulated portion must not be altered to reduce its insulating value.
- Lift controls must be tested daily.
- Controls must be clearly marked.
- Brakes must be set, and outriggers used.

- Boom and basket load limits must not be exceeded.
- Employees must wear personal fall arrest systems, with the lanyard attached to the boom or basket.
- No devices can be used to raise the employee above the basket floor" [[50]].

### *Aerial Lift Hazard Recognition Simulator*

The use of an aerial lift reduces the construction workers' risk of a fall since it replaces the use of an extension ladder or a scaffold system. If used properly it is a safe work platform. However, aerial lifts can expose workers to risks, such as falls, because they are mobile, used as elevating equipment, and are considered a restricted workspace. Aerial lifts are used in a number of different conditions, such as adverse weather conditions, high foot traffic, and continually changing worksites. These conditions create other hazards that expose workers to injury, including crushing/trapping hazards, electrocutions, and tip overs. Proper safeguarding can reduce or eliminate injury events when using aerial lifts.

NIOSH has developed an aerial lift hazard simulator for training purposes, Fig. (**15**) [56]. It puts the user on the elevated work platform of the aerial lift and goes through a series of training exercises. It provides "realistic workplaces with multiple dangerous hazard types that scissor and boom lift operators can navigate from the safety of a computer. Experienced operators can use the simulator to refresh their knowledge, and new operators can familiarize themselves with hazards they may encounter on the job. Using the simulator is not a substitute for required training to operate aerial and boom lifts" [57]. This simulator is a free tool to use and can be accessed on the NIOSH web site, and a screen shot is shown in Fig. (**16**).

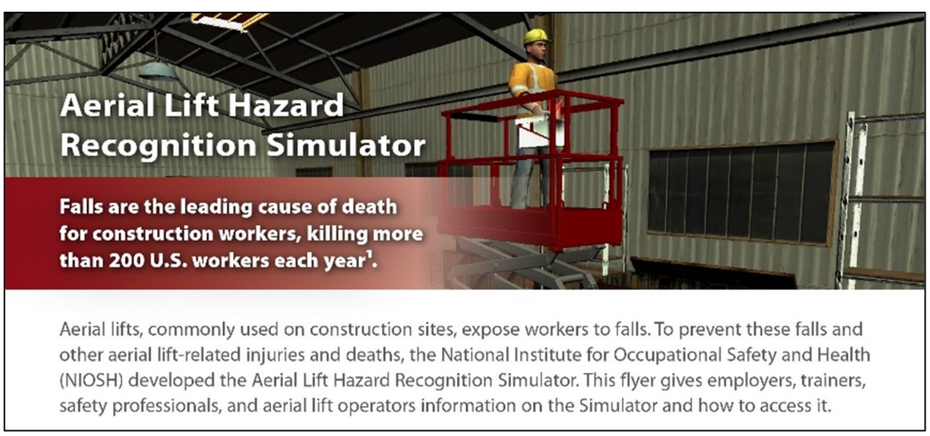


**Fig. (15).** NIOSH Aerial Lift Simulator PDF (Image from [56]).

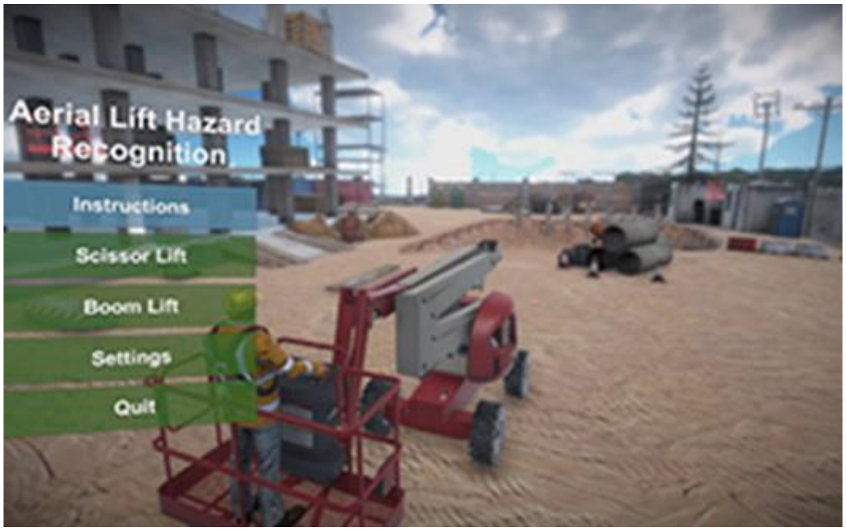


**Fig. (16).** NIOSH Aerial Lift Hazard Recognition Simulator (Screen shot from Simulator) (Image from [57]).

## SUMMARY

The material presented in this chapter included a variety of techniques to access elevated work levels in a safe manner. Those discussed were only a sample of popular techniques available to construction workers. They included ladders, scaffolds, and lifts. Proper training and usage are common denominators for creating a safe working environment. Also discussed were fall prevention and protection equipment and techniques. The statistics presented verified that falls from elevations are still the primary cause of fatal injuries in the construction industry. Risk factors and recommendations for mitigating future fatal injuries are presented in the NIOSH FACE report database. Proper planning, training, and practice can reduce the potential of fatal fall-related incidents from occurring. Through proper education, best practices, and techniques will help minimize fatal fall related injuries — learn it, use it, live it.

## DISCLAIMER

"The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention."

## CONSENT FOR PUBLICATION

Not applicable.

## CONFLICT OF INTEREST

The authors declare no conflict of interest, financial or otherwise.

## ACKNOWLEDGMENTS

The authors would like to recognize and thank Darlene Weaver for her assistance in the development of this document. The authors would also like to extend their appreciation to the reviewers who made this chapter possible.

## RESOURCES

OSHA

OSHA fall prevention training guide https://www.osha.gov/sites/default/files/publications/OSHA3666.pdf]

https://www.osha.gov/stopfalls/index.html

https://www.osha.gov/stopfalls/edresources.html

BLS

https://www.bls.gov/iif/

CPWR

https://www.cpwr.com/wp-content/uploads/DataBulletin-February-2021.pdf

https://elcosh.org/index.php

https://www.cpwr.com/research/data-center/the-construction-chart-book/

NIOSH FACE

Construction FACE Database (CFD)

https://www.cdc.gov/niosh/face/

https://www.cdc.gov/niosh/face/videos.html.

Preventing Falls Through Skylights

A Simple Task

CDC NIOSH FACE Infographic

Roofing

https://www.cdc.gov/niosh/face/stateface/ma/16ma001.html

OSHA Roofing safety publication 3755

OSHA3755.pdf Protecting roofing workers

Suspension Trauma SHIB Suspension Trauma.Final.10.25.11.pmd (osha.gov)

Ladders

OSHA ladder safety document 3660

Subpart X—Stairways and Ladders of OSHA's Construction Standards.

https://www.cdc.gov/niosh/docs/2017-129/

OSHA Appendix A of 1926 Subpart X

NIOSH ladder safety App

Apple Store external icon

Google Play external icon

https://www.cdc.gov/niosh/face/pdfs/15ma037.pdf

Scaffolding

29 CFR Part 1926.450 Subpart L

OSHA: Guide to Scaffold Use in the Construction Industry

Scaffolding eTool - Supported Scaffolds (osha.gov)

https://www.cdc.gov/niosh/face/stateface/ky/17ky007.html

MCWP

https://www.cpwr.com/wp-content/uploads/publications/CPWRReachingHigheronline.pdf

NIOSH MCWP Daily Inspection Walkthrough

mast_climbers_11nr.jpg (1201×1501) (cdc.gov) https://www.cdc.gov/niosh/topics/falls/mastclimb.html

Aerial Lift

https://www.cdc.gov/niosh/docs/2017-103/default.html

https://www.cdc.gov/niosh/topics/falls/aeriallift.html

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