SLIDE GUARD EFFE on Steep-Sloped Roofs

By Thomas G. Bobick, E.A. McKenzie Jr. and John R. Powers Jr.

WORKERS FALLING FROM ELEVATED WORK SITES is the primary cause of fatalities in the U.S. construction industry. A compilation of data for the years 2014 through 2018 from the Census of Fatal Occupational Injuries (CFOI) database, which is maintained by Bureau of Labor Statistics (BLS, 2016a, b, c; 2020a, b, c), is presented in Table 1. This table includes the total number of fatalities in all U.S. industries and the total number of construction-related fatalities (rows 1 and 3), as well as the total number of deaths caused by falls to a lower level for all U.S. industries and for construction (rows 2 and 4). Fall-to-lower-level fatalities accounted for about 13% of all fatalities occurring in all U.S. industries during this period. In the construction industry, fall-to-lower-level fatalities averaged about 37% of all construction-related fatalities. In Table 1, a separate listing of data is shown for construction workplace situations related to falls from roof edges (row 5).

Roofers are a high-risk work group. The overall fatality rates for all construction occupations are compared with the overall fatality rates for roofers from 2014 through 2018 (Table 1, rows 6 and 8). For 2018, the fatality rate for roofers was 51.5 deaths per 100,000 full-time equivalent (FTE) workers. This is more than five times the fatality rate of all construction workers, which was 9.5 deaths per 100,000 FTE workers (BLS, 2020c). Included in row 7 is the total number of annual roofer fatalities for the 5 years, which ranged from 75 to 101 during that period.

Actual circumstances of what causes a worker to fall are not typically noted in any incident report or in the fatality databases. Most assuredly, however, a loss of balance always precedes a fall. Typically, this loss of balance is caused by a person slipping or tripping. What happens after a worker falls has not been well documented. Depending on the slope of the roof, a worker may not slide far or may slide to the eave (the drip edge). In those instances, installation of a slide guard constructed with a combination of two-by-six and two-by-four lumber, which is a common residential construction practice, may help prevent a sliding worker from falling off the roof.

KEY TAKEAWAYS

- **Roofing contractors should consider using a slide guard as a supplemental means of fall protection when working on roof slopes that are 34° (8 in 12) or less, but a slide guard should never be considered as the sole means to achieve work site fall protection compliance.**
- **Using a slide guard on a 45° roof slope (12 in 12) would not be an effective fall protection supplement to comply with OSHA's fall protection requirements.**
- **Contractors should consider purchasing and using synthetic underlayment materials with higher coefficient-of-friction values. This type of information may be available from the suppliers of underlayment materials that are used on steep-sloped roofs.**

Fall-Related OSHA Requirements for Construction

Fall-related hazards in the construction industry are enforced by OSHA through Subpart M (Fall Protection) of the Code of Federal Regulations (CFR), Title 29 (Labor), Part 1926 (Construction). Subpart M became effective Feb. 6, 1995, and contains fall protection requirements for construction work. Specific requirements for residential construction are contained in section 1926.501(b)(13), which states:

> Each employee engaged in residential construction activities 6 ft (1.8 m) or more above lower levels shall be protected by 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. (OSHA, 2014)

On-site observations by the project team indicated that some contractors use a commercially available roofing bracket, also referred to as a "roof jack," to create a flat walking-working surface at the downslope edge (eave) of the roof for working purposes and for basic slide protection (Figure 1a, p. 30). Other contractors use a combination of two-by-six boards supported by two-by-four boards (Figure 1b, p. 30) to serve as a slide guard or to provide something to brace against while working on the roof. The commercial roofing brackets or fabricated wood slide guards are secured to the roof by nailing into the roof trusses (or rafters) to secure the lumber or metal brackets. The slide guard is repositioned as roofing work progresses up the roof, or additional slide guards are added at regular intervals upward, toward the roof peak, also shown in Figure 1a.

Because of the popular use of slide guards in residential construction, in a 1995 directive, OSHA decreed that in specific instances slide guards could be used to fulfill the requirements for a fall protection system in residential construction. In 2011, OSHA rescinded the 1995 directive and eliminated the use of slide guards as the "sole means" of complying with the OSHA fall protection requirements. OSHA did not eliminate the use of slide guards. The agency indicates that the devices should be used in conjunction with following the regulations of 29 CFR 1926 Subpart M.

Residential Construction

Low-sloped roofs are defined as a slope of 4 in 12 (18.4°) or less. So, any slope above that angle will be considered a steep slope. However, the slope of many residential roofs can be extremely steep: 8 in 12 (34°) or even 12 in 12 (45°). When

ECTIVENESS

working on these extremely steep roofs, workers are at a greater risk of slipping and sliding downward to the eave (drip edge) of the roof. This is true whether the roof is under construction or whether repairs are being conducted on an existing roof.

When a residential structure is built, the intent is to get the roof on and protect the structure from wetness as quickly as possible. The skeleton of the roof is typically built with individual premade triangular roof trusses or jobsite-constructed rafters to build the triangular shape of the roof. The wood sheathing is either plywood or oriented strand board (OSB), which is attached to the skeleton structure to complete the roof. Roofing workers cover the wood sheathing as quickly as possible with underlayment materials to protect the sheathing from getting wet. Different underlayment materials are available. Typically, felt paper (sometimes called tar paper) is used, as well as a variety of commercially available synthetic materials.

Anecdotal information from several safety professionals has indicated that slide guards have been effective for preventing a sliding person from going over the roof edge. In fact, one roofing professional captured on video a successful stop by a slide guard (Reese, 2019). Other information suggests that slide guards have not been as effective in protecting a sliding worker. Regardless, the effectiveness of slide guard edge protection has not been evaluated in a controlled laboratory study.

Because slide guards are still commonly used by residential construction contractors, the "evaluation of their effectiveness" was the proposed focus for a pilot research study by NIOSH researchers. The current pilot study investigated roof slope, one of the many factors that workers typically encounter when using slide guards as fall protection.

Research Study

Objective

The objective of this pilot project was to evaluate whether a slide guard setup (Figure 1b, p. 30) will prevent a human-sized mannequin from sliding over the roof edge. The mannequin served as a surrogate for an unconscious worker sliding downslope on a small sample of typical building materials used in steep-sloped residential construction.

CHICTYPE/E+/GETTYIMAGES

Test Scenario

To provide some context for this laboratory testing, the scenario described here provides the details of a hypothetical residential construction situation. Sheathing has been installed on a roof structure, which is a small extension to a much larger roof. The extension is 15 ft from the drip edge (the eave) to the peak and 20 ft in length. In addition, the last row of sheathing (for three tests) and then the last row of underlayment material (for five tests) will have been installed. The slide guard has already been installed at the eave and will be used in conjunction with a personal fall arrest system, which is one of the three approved fall protection measures along with guardrail systems with toeboards and safety net systems, as specified in OSHA 29 CFR 1926.501(b)(11). The anchorage for the personal fall arrest system is a V-type bracket that will fit over the roof peak with both legs of the "V" being fastened to the roof with adequate nails. Part of this anchorage is an integral D-ring at the top to support a worker who will be tied off while walking on the sheathing materials (first three tests)

TABLE 1

FALL-RELATED FATALITIES FOR ROOFERS VS. CONSTRUCTION INDUSTRY, 2014-2018

Selected fall-related fatalities, all U.S. industries and construction, with overall rates of fatal occupational injuries for roofers vs. construction industry, for 2014 through 2018.

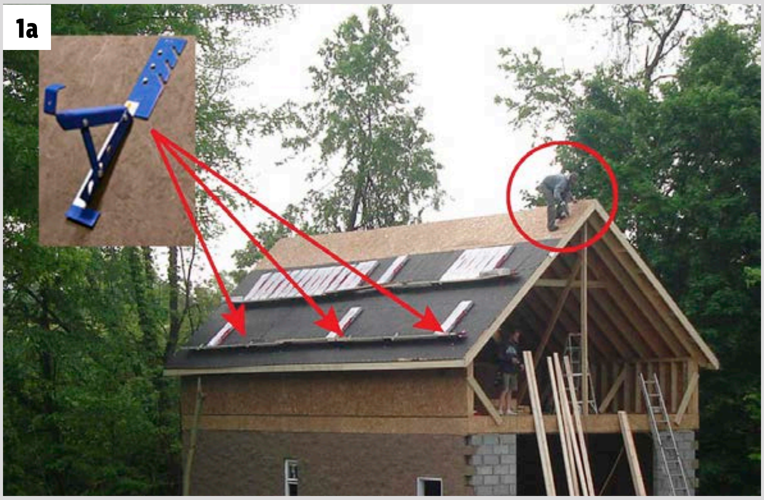
No.	Category	2014	2015	2016	2017	2018
1	Total U.S. occupational fatalities	4,821	4,836	5,190	5,147	5,250
2	Total U.S. occupational fatal falls to lower level[a]	660 (14%)	648 (13%)	697 (13%)	713 (14%)	615 (12%)
3	Total construction fatalities	899	937	991	971	1,008
4	Total construction fatal falls to lower level (percentage of "total construction fatalities")	345 (38%)	350 (37%)	370 (37%)	366 (38%)	320 (33%)
5	Construction fatal falls, roof edge only (percentage of "total construction fatal falls to lower level")	54 (16%)	50 (14%)	65 (18%)	56 (15%)	49 (15%)
6	Overall fatality rate[b] for construction industry	9.8	10.1	10.1	9.5	9.5
7	Total number of roofer fatalities	83	75	101	91	96
8	Overall fatality rate[b] for roofer occupation	47.4	39.7	48.6	45.2	51.5

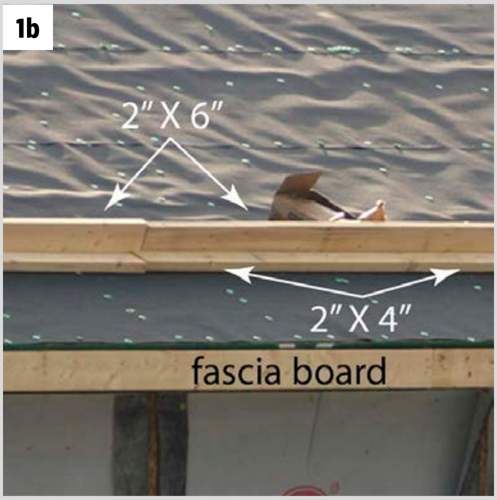
Note. Data from "Census of Fatal Occupational Injuries" by BLS, n.d., www.bls.gov/iif. [a]Fatal falls are defined by "Occupational Injury and Illness Classification System (OIICS)," by BLS. Data for 2014 through 2018 are based on OIICS version 2.01. [b]The fatality rate is the number of fatal occupational injuries per 100,000 full-time equivalent workers.

FIGURE 1

TWO EXAMPLES OF BASIC SLIDE PROTECTION

Figure 1a (left): Typical roof construction using roofing jacks (inset, upper left) for placement of supplies and for fall protection. An unrestrained worker is shown (in the circle) at the roof peak. Figure 1b (right): Typical roof construction, using two-by-six and two-by-four lumber for a fall protection slide guard.





and then the underlayment materials (five tests). The worker is ready to connect the lanyard to the roof-peak anchor. When bending over to tie-off, the worker suddenly becomes dizzy and passes out. The unconscious worker, who is not tied off, is now sliding freely. The type of materials (sheathing or underlayment) that the worker is sliding on will have a direct effect on how far and how fast the worker will slide.

Test Equipment

Equipment used for this evaluation included:

- a mock-up of a narrow section of a steep-sloped roof,
- a human-sized mannequin, and
- eight roofing materials: three sheathing materials and five underlayment materials.

Test Roof

The wood frame roof mock-up was constructed in the test lab using typical construction materials: two-by-six and two-by-ten lumber for the framework, and for the roof surface OSB material for the sheathing. The narrow roof portion was 8 ft wide and 15 ft in length. Figure 2 shows the two configurations tested. Both configurations [8 in 12 (34°) and 12 in 12 (45°)] were used for the testing. The base of the roof structure was fabricated using two-by-ten lumber and was positioned directly on the lab floor.

Test Materials

Eight materials were evaluated in this pilot study. Three wood products used for roof sheathing were tested; these products were plywood, OSB and a newer product on the market that the research team referred to as "green board." Five underlayment materials were also evaluated: #30 felt paper and four synthetic materials. The four synthetic materials were described generically as 1. a material woven of heavyweight polymer fabric, 2. a material made of a polypropylene/polyethylene construction, 3. a polypropylene woven fabric with a unique nonwoven surface fabric, and 4. a proprietary synthetic underlayment.

Test Mannequin

The test apparatus was a human-sized mannequin with a stature of 74 in. and a weight of 234 lb. This represents the 92nd percentile for height and the 91st percentile for weight of the adult male population (age 18 to 65) of the U.S. (Harrison et al., 2002). This national database would correspond to the typical U.S. construction workforce but is not meant to correspond to any specific trade group, such as electrician, plumber or roofer. For this evaluation, the mannequin served as a surrogate for an unconscious worker: someone who passed out from heat stress or an illness or who was knocked unconscious from an impact to the head. Regardless of the cause, the unconscious worker would drop and start sliding without offering any resistance to sliding downslope. The mannequin was used with all eight roofing materials and the two different roof slopes. At the eave (the drip edge of the test roof), a two-by-six and two-by-four slide guard system was installed, which is shown in Figure 1b.

For the testing, a 5-ton capacity overhead crane was used to suspend the mannequin upright approximately 12 ft upslope from the slide guard installed at the eave. The mannequin was positioned in the same general location (within 12 in. left to right) by a NIOSH technician who was located on a ladder that was permanently located behind the top end of the test roof. The same technician was located on the ladder for each test. He leaned forward against the ladder for support while positioning the mannequin an arm's length downslope from the top of the test roof. At a set signal, the mannequin was released and collapsed onto the test setup. It slid downslope to the slide guard system, which was 8-ft long, so it covered the width of the test roof. Photographs showing the results of the 16 slides with the mannequin (eight materials, two slopes) are presented in Figure 3 (p. 32).

Test Procedure

Preparations were made to evaluate the mannequin sliding on each of the eight materials for the two different roof slope angles. The research team members decided not to use a wet condition. The mannequin is equipped with sensitive electronic circuitry in the neck, chest and lumbar regions, and the outer layer of the mannequin is not waterproof. The team did not want to damage any of the onboard data acquisition systems by sliding the mannequin on wet roofing materials.

Testing began with the test roof set to the lower of the two slopes, 34° (Figure 2a) using the mannequin, which was positioned at the top of the test roof in a standing orientation. Three sheathing materials and five underlayment materials were evaluated at the lower slope (34°), then the same eight materials were evaluated at the steeper slope (45°). One slide was tested for each of the 16 conditions. A new slide guard system was constructed and fastened to the test roof for each slide. New 16-penny nails (3.5-in. length) were used to fasten the lumber together and to fasten the slide guard to the roof. Only 16-penny nails were used in the testing since they are the nail type most commonly used by wood framers in the north-central West Virginia area. Using longer nails would not have been appropriate because the research team wanted to approximate the residential construction activities in West Virginia.

Results

For the tests with the mannequin, the research team's primary interest was to observe how a human-sized and -shaped object would slide on the various materials and how the sliding mannequin would interact with the slide guard system installed at the drip edge of the roof. The testing took place when the materials were dry. This testing generated a variety of results after the mannequin slid to the end of the roof where the slide guard system was located (Table 2, p. 33).

In eight of the 16 cases, the mannequin was stopped by the slide guard system (Table 2, p. 33). Seven of those were for the 34° roof slope condition and the eighth was for the 45° roof slope condition when synthetic material C was tested. In five cases (all with the roof set at 45° slope), the mannequin slid over the slide guard, going off the roof and causing varying degrees of damage to the slide guard system. In the other three cases (one at 34° and two at 45° roof slope), the mannequin was like a bulldozer and tore the slide guard system completely off the roof despite the fact that new 16-penny nails and new lumber were used for each different test.

Discussion

The idea for testing how the mannequin would interact with a slide guard system originated from a discussion that took place during a professional meeting dealing with safety in construction. The discussion centered on whether a slide guard would stop a worker from sliding off the roof or whether the slide guard would act as a speed bump with the worker sliding off the roof. The supporters of both ideas made excellent points. However, the researchers realized that these ideas could be tested at their facilities. Of course, actual workers could never be tested, but a full-sized test mannequin could be used.

This testing evaluated the interaction of a human-sized and -shaped apparatus with a slide guard system, which is the combination of two-by-six lumber in a vertical orientation supported by two-by-four lumber positioned horizontally. As noted, the mannequin serves as a surrogate for an unconscious worker. When falling, neither offers any kind of resistance to the sliding.

This one-of-a-kind testing provided an opportunity to document what happens when a 234-lb human-sized object slides down two extremely steep surfaces to the edge of the test roof. Note: The four synthetic materials must remain unidentified to avoid being viewed as an endorsement for any product by the federal government.

For the 34° slope (dry condition), the mannequin was stopped by the slide guard system in seven of the eight conditions (three sheathing products and five underlayment products). The condition in which the mannequin slid quickly enough to knock the slide guard system completely off the roof was synthetic material A.

When sliding on the dry 45° slope, the mannequin knocked the slide guard system off the roof for two materials (synthetic material A and B), slid over the slide guard system like a speed bump (and off the roof) for five of the materials, and for the

FIGURE 2

TEST ROOF CONFIGURATIONS

Figure 2b (left): Test roof configuration for the 8 in 12 (34°) slope. Figure 2b (right): Test roof configuration for the 12 in 12 (45°) slope.

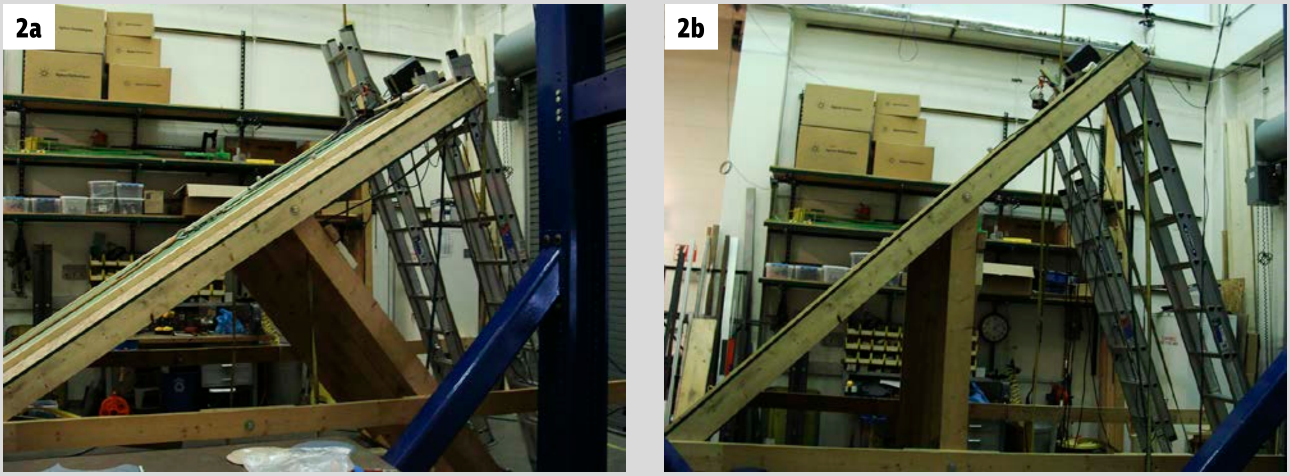


FIGURE 3

RESULTS OF 16 MANNEQUIN SLIDES, DRY CONDITION ONLY

34° slope, OSB | 34° slope, plywood | 34° slope, green board | 34° slope, felt paper

34° slope, synthetic material A | 34° slope, synthetic material B | 34° slope, synthetic material C | 34° slope, synthetic material D

45° slope, OSB | 45° slope, plywood | 45° slope, green board | 45° slope, felt paper

45° slope, synthetic material A | 45° slope, synthetic material B | 45° slope, synthetic material C | 45° slope, synthetic material D

eighth material (synthetic material C), the mannequin slid slowly enough to stay on the roof.

A human-sized test mannequin can be effectively utilized when evaluating workplace conditions involving steep-sloped roofs without putting any human test subjects at risk. However, use of the mannequin would only be effective as a surrogate for an unconscious worker who should react like the mannequin.

Study Limitations

Because of time restrictions, only one test was conducted for each material and slope combination. At the conclusion of the pilot testing, the roof structure (described in the "Test Roof" section and shown in Figure 2, p. 31) had to be moved so that the next test setup could be constructed in the lab. The test roof was disassembled and set aside. Eventually, the lumber was used in other NIOSH research projects. Thus, no further opportunity exists for the researchers to conduct additional follow-up measurements for different variables such as a wet condition, different sized nails and different sized lumber for the slide guard. These are all excellent variables to be investigated by other researchers.

Conclusions

This pilot study focused on evaluating the use of a slide guard system to stop an unconscious worker (using a human-sized mannequin as a surrogate) from sliding off the test roof that was set at two extreme roof slopes (34° and 45°).

This pilot study determined that the use of a slide guard system installed at the eave of a roof with a slope of 8 in 12 (34°) or shallower can be an effective supplement for a company to comply with the OSHA fall protection requirements but should never be considered as the sole means of complying with those same requirements.

Using a slide guard system on a 12 in 12 slope (45°) roof would not be an effective fall protection supplement to comply with OSHA's fall protection requirements. The data presented in Table 1 (p. 29) shows that working on roofs is a dangerous occupation but is even more so when the slope is as extreme as 45°. In this pilot testing, seven of the eight materials failed to keep the sliding mannequin on the test roof. When working on 45° sloped roofs, all roof workers should always be required to use a personal fall arrest system. Because of the multiple restraint lines, a better option would be to install a

TABLE 2
RESULTS OF TESTING

Results of a human-sized mannequin (74-in. stature, 234-lb weight) sliding to the end of the test roof where new slide guard systems were installed.

	Mannequin stayed on roof (Yes/No); result description if no	
Material	**34° roof slope**	**45° roof slope**
OSB	Yes	No, went over slide guard like speed bump
Plywood	Yes	No, went over slide guard like speed bump
Green board	Yes	No, went over slide guard like speed bump
Felt paper	Yes	No, went over slide guard like speed bump
Synthetic material A	No, knocked slide guard off roof	No, knocked slide guard off roof
Synthetic material B	Yes	No, knocked slide guard off roof
Synthetic material C	Yes	Yes
Synthetic material D	Yes	No, went over slide guard like speed bump

guardrail system at the eave edge (Bobick & McKenzie, 2011). That would prevent the fall from happening in the first place.

By using the mannequin, this testing was unique for evaluating the effectiveness of a slide guard system installed on steep-sloped roofs for stopping a sliding unconscious worker. This pilot testing has indicated that contractors should consider purchasing and using synthetic underlayment materials with higher coefficient-of-friction values. This type of information should be available from the suppliers of underlayment materials that are used on steep-sloped roofs. **PSJ**

References

Bobick, T.G. & McKenzie, E.A. (2011, Jan.). Development of a multifunctional guardrail system. *Professional Safety, 56*(1), 48-54.

Bureau of Labor Statistics (BLS). (n.d.). Injuries, illnesses and fatalities. www.bls.gov/iif

BLS. (2016a). Fatal occupational injuries by event or exposure for all fatal injuries and major private industry sector, all United States, 2014 (Table A-9). www.bls.gov/iif/oshwc/cfoi/cftb0294.pdf

BLS. (2016b). Fatal occupational injuries by primary and secondary source of injury for all fatal injuries and by major private industry sector, all United States, 2014 (Table A-4). www.bls.gov/iif/oshwc/cfoi/cftb0289.pdf

BLS. (2016c). Fatal occupational injuries, total hours worked, and rates of fatal occupational injuries by selected worker characteristics, occupations, and industries, civilian workers, 2014. www.bls.gov/iif/oshwc/cfoi/cfoi_rates_2014hb.xlsx

BLS. (2020a). Fatal occupational injuries by industry and event or exposure, all United States, 2018 (Table A-1). www.bls.gov/iif/oshwc/cfoi/cftb0322.htm

BLS. (2020b). Fatal occupational injuries by primary and secondary source of injury for all fatal injuries and by major private industry sector, all United States, 2018 (Table A-4). www.bls.gov/iif/oshwc/cfoi/cftb0325.htm

BLS. (2020c). Fatal occupational injuries, total hours worked, and rates of fatal occupational injuries by selected worker characteristics, occupations, and industries, civilian workers, 2018. www.bls.gov/iif/oshwc/cfoi/cfoi_rates_2018hb.xlsx

Harrison, C.R., Robinette, K.M., U.S. Air Force Research Laboratory, Sytronics, Nederlandse Organisatie voor Toegepast-Natuurwetenschappelijk Onderzoek & Society of Automotive Engineers. (2002). CAESAR: Summary statistics for the adult population (ages 18-65) of the United States of America (AFRL-HE-WP-TR-2002-0170). U.S. Air Force Research Laboratory, Human Effectiveness Directorate, Crew System Interface Division, Air Force Materiel Command.

OSHA. (1995, Dec. 8). Interim fall protection compliance guidelines for residential construction (Directive No. STD 3.1). www.osha.gov/pls/oshaweb/owadisp.show_document?p_id=1823&p_table=directives

OSHA. (2014). Subpart M—fall protection (29 CFR 1926 Subpart M). www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=10922

Reese, J. (2019, June 21). My fall 3 minute ProRes444 shape mask with logo.mov—Google Drive [Video file]. http://bit.ly/2Y0cBrg

Thomas G. Bobick, Ph.D., P.E., CSP, CPE, is a research safety engineer with NIOSH in Morgantown, WV. Bobick holds a Ph.D. in Industrial Engineering from West Virginia University (WVU), an M.S. in Industrial Hygiene from University of Pittsburgh and a B.S. in Mining Engineering from Penn State University. His research focuses on preventing workers from falling from elevations. He has authored or coauthored more than 100 publications. Bobick is a professional member of ASSP's Greater West Virginia Chapter and a member of the Society's Construction, Ergonomics and Engineering practice specialties.

E.A. McKenzie Jr., P.E., is a research safety engineer with NIOSH in Morgantown, WV. He holds a B.S.M.E., an M.S.M.E. and a Ph.D. in Mechanical Engineering from WVU. His research focus is traumatic occupational injuries of construction workers, specifically falls from heights. Current research includes "Frictional Characteristics of Roof Materials" and "Swing Fall Analysis of Below D-Ring Anchorage."

John R. Powers Jr. is a supervisory general engineer and branch chief with the Evaluation and Testing Branch, National Personal Protective Technology Laboratory, NIOSH in Morgantown, WV. He holds a B.S. in Electrical Engineering from Penn State University. Powers has authored several publications related to the development of engineering controls to protect workers. His interests include development of real-time sensor technology for respiratory protection and development of conformity assessment programs for PPE.

Acknowledgments

The authors acknowledge James T. Wassell, Ph.D., associate director for biostatistical science, Division of Safety Research, NIOSH, for his input and assistance during the planning of this research study and for his review of this article, and Doug Cantis, physical science technician, Division of Safety Research, NIOSH, for his assistance during this testing.

Disclaimer

The findings and conclusions in this article are those of the authors and do not necessarily represent the official position of NIOSH. Mention of any company or product does not constitute an endorsement by NIOSH. Citation to websites external to NIOSH do not constitute NIOSH endorsement of the sponsoring organizations or their programs or products. Furthermore, NIOSH is not responsible for the content of these websites. All web addresses referenced in this document were accessible as of the publication date.