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Using Guardrail Systems to Prevent Falls Through Roof and Floor Holes

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Abstract

Fall-related occupational injuries and fatalities are serious problems in the U.S. construction industry. An important sub-set of falls-to-lower-level incidents is when workers fall through holes, collapsing surfaces, or skylights. OSHA regulations require that roof holes must be protected by a guardrail or cover and nearby workers must use personal fall-arrest systems. The National Institute for Occupational Safety and Health (NIOSH), Division of Safety Research, Morgantown, WV initiated a pilot project to evaluate the effectiveness of guardrail systems. Two commercial edge-protection products were evaluated as perimeter guarding around a hole in a wooden simulated roof deck. Installation methods for the edge-protection products, which had not been designed for use as guardrails for holes, are compared to job-built guardrails constructed of 2-in x 4-in lumber. To evaluate how well the edge-protection products comply with existing OSHA regulations as a hole guardrail, an experimental hypothesis and a laboratory-based testing system were developed. OSHA regulations require that "a force of at least 200 pounds" shall be supported by the top rail of the guardrail system. The governing variable (200-lb force) was generated by using a weighted rescue manikin mounted on a specially designed hinged steel frame. By adjusting the manikin's fall distance, a dynamic 200-lb force was generated at the top rail. Five different guardrail configurations were built using the two commercial products and the job-built guardrail. Test subjects were nine carpenters. Each subject constructed the five different configurations. Because of adequate fasteners and quality of construction, all 45 configurations met the 200-lb OSHA requirement. Installation time for one of the commercial products was 30% quicker than the normal job-built configuration (27.6 min versus 39.6 min). Even though a substantial initial outlay is required for that commercial product, after about 40 separate uses, the break-even point will be reached, where the initial cost will be repaid and that commercial product will begin to save money for the purchaser.

Introduction

Occupational injuries and fatalities caused by falls-from-elevation is a serious problem in U.S. workplaces. Previous research (Parsons, Pizatella, and Collins 13; Personick 27) indicated that the construction industry, and that roofers and slaters in particular, had elevated fatality and injury rates. Data from the Census of Fatal Occupational Injuries, maintained by the Bureau of Labor Statistics (BLS), indicate that during 1992-2000, 5,380 U.S. workers died as a result of a fall to a lower level. An important sub-set of the fall-to-lower-level category involves workers falling through existing holes in floors or roofs, or through collapsing floor and roof surfaces, including skylights. During 1992-2000, 605 workers lost their lives from fall-through events – 282 (46.6%) through roof and floor holes, 173 (28.6%) through collapsing roof and floor surfaces, and 150 (24.8%) through skylights (Bobick 897). Thousands of serious injuries also result from fall-through events. Serious injuries are defined by BLS as those that involve missing at least one day-away-from-work (DAFW) beyond the day the incident occurred. Analyses of the BLS Annual Surveys for 1992-2000 reveal that 21,985 serious injuries occurred from fall-through incidents, resulting in an estimated 350,934 total DAFW (Bobick 901).

Fall-through injuries are among the most severe cases for median number of DAFW. Considering all nine years (1992-2000), the median number of DAFW were 38, 25, and 36 for cases involving falls through roof holes, roof surfaces, and skylights, respectively, compared to 10 DAFW for all types of fall-to-lower-level cases in U.S. private industry during 1992-2000. Thus injuries resulting from falls through roof holes and skylights were more than 3½ times more severe than all other types of falls to a lower level (Bobick 906).

Good safety practice specifies that falls should be eliminated as the primary measure to protect workers. Thus, falls should be prevented from happening in the first place, instead of trying to protect the worker after a fall has occurred. The primary means of preventing falls is to use covers or guardrails to prevent workers from falling into the holes. If a cover is used, the material used (a) has to have sufficient strength, (b) has to be properly secured, and (c) has to be "marked with the word 'HOLE' or 'COVER' to provide warning of the hazard," as specified in OSHA regulation 29 CFR 1926.502(i)(4) (Mancomm 306). If it is not secured and marked, it is like setting a deadly trap for the other workers in the crew (Barnhard 10). Fatal injuries have occurred when a worker stepped on an unsecured covering. When the unsecured cover shifted, the worker fell through the newly created hole to his death (McVittie 290). The current study, however, is focused on evaluating the use of guardrail systems to prevent workers from falling into large-sized holes

The current regulations for the construction industry are contained in 29 CFR (Code of Federal Regulations) Part 1926. Specifically, Subpart M, which includes Sections 1926.500 through 1926.503 and Appendices A through E, lists the requirements that are related to workplace falls. Section 1926.501 discusses the requirements for fall protection. Subsection 1926.501(b)(4)(i) states that "Each employee on walking/working surfaces shall be (*i.e.*, must be) protected from falling through holes (including skylights) more than 6 feet (1.8 m) above lower levels, by personal fall arrest systems, cover, or guardrail systems erected around such holes." (restatement added) (Mancomm 302) In addition, the strength of guardrail systems must meet OSHA requirement 29 CFR 1926.502(b)(3) which states that "Guardrail systems shall be capable of withstanding, without failure, a force of at least 200 pounds (890 N) applied within 2 inches (5.1 cm) of the top edge, in any outward or downward direction, at any point along the top edge." (Mancomm 303)

Research Study

A NIOSH pilot research project evaluated the effectiveness of two commercial fall-prevention guardrail systems, which were designed for edge use, when they were installed as guardrails around a hole in a simulated roof work site. The pilot study evaluated the two commercial systems and a typical "job-built" guardrail to compare (a) installation times, (b) effectiveness of meeting the OSHA 200-lb requirement, (c) overall strength, and (d) overall cost of the three systems. To evaluate how well the commercial products complied with existing OSHA regulations for guardrails, an experimental hypothesis and a laboratory-based testing system were developed.

Test Subjects

A convenience sample of nine subjects was recruited from the Morgantown, WV area for this pilot experiment. The average age of the subjects was 29.6 years (standard deviation (SD) = 8.0 years), with a range of 19 to 42 years. The subjects had an average of 11.4 years of construction experience (SD = 7.1 years), with a range of 2 to 20 years of construction experience. Part of the requirements for being included in the study were that potential subjects had to have at least two years of working at elevation on residential roof work sites, and also that they had to be employed full-time for themselves doing roof construction or working full-time for a company that is doing roof construction.

Test Fixture

A wooden simulated roof deck was designed and built as the test fixture. The overall dimensions of the fixture were 8 ft wide by 20 ft long. It was made in two pieces, each 8 ft by 10 ft, and could be adjusted from having both sides lay flat (to simulate a commercial facility) to having the middle raised in a peak (at any angle) to simulate the roof of a residence. In residential construction, two popular pitches for roof construction are 6/12 (27°) and 8/12 (34°). To minimize the risk to the test subjects, the test fixture was positioned on the floor of the test laboratory, with the roof slope set at only 4/12 (18°). The peak of the roof was 43 inches above the floor, and the roof edge was only 6 inches above the floor. Each half of the fixture had a 2-ft by 3-ft hole cut into it. Only half of the test fixture, which has been set in the sloped configuration, is shown in Figure 1. Shown also in Figure 1 is the test manikin. It is described in the section, "Apparatus for Testing OSHA Criteria."

Research Task

The task of each of the nine subjects who participated in the study was to construct a guardrail system around the hole in the simulated roof structure. Each guardrail system was tested for OSHA compliance and for ultimate strength. Three different systems were tested – two commercially available edge protection systems (Guardrail 2000 and the Safety Boot), which are shown in Figure 2, and a 2 x 4 lumber and nail construction (Job Built). Over three days of testing for each test subject, a total of 5 guardrail systems were built around the two holes. Three were on a flat roof (Job Built, Guardrail 2000, and Safety Boot) and two were on a sloped roof (Job Built and Guardrail 2000; the Safety Boot is designed for flat surfaces only). The order was randomly presented to each subject to minimize learning bias.

Apparatus for Testing OSHA Criteria

To evaluate the guardrail set-up as per OSHA regulation 29 CFR 1926.502(b)(3) with a real-world feel, a testing procedure and a test apparatus were developed. The design philosophy was to simulate the fall of a worker, weighing 200 lbs or more, into the guarding structure as close to a

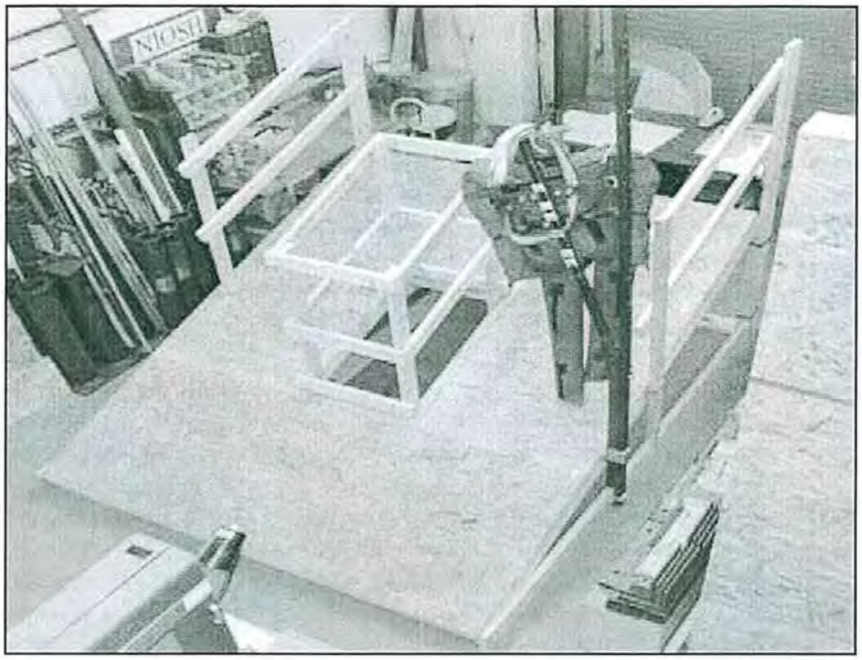

Figure 1. Laboratory set-up for the test fixture (one half only) showing two edge protective guards, with a job-built guardrail around the roof hole, along with the test manikin used to conduct the evaluation of the OSHA 200-lb test criteria.

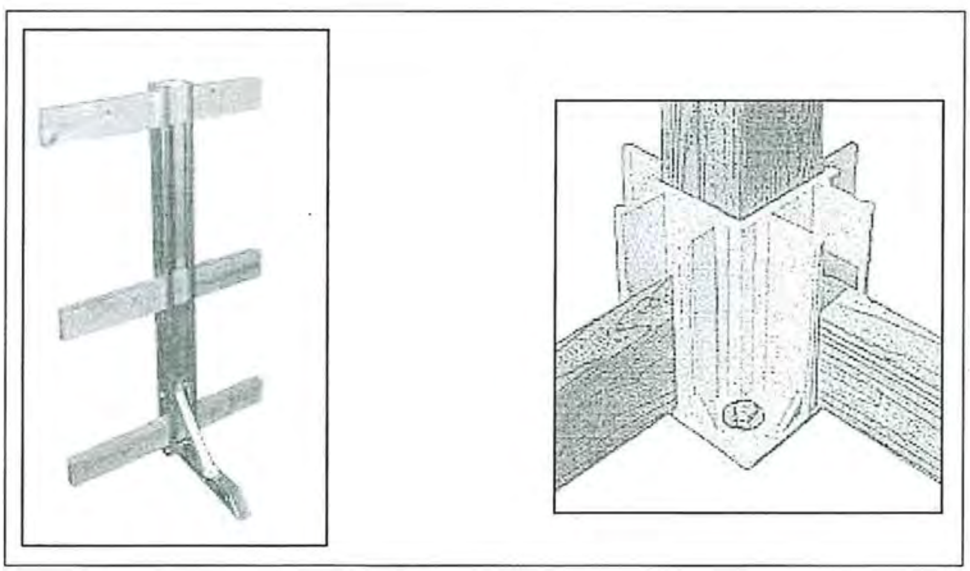

Figure 2. Shown are two commercial edge-protection guardrail products. Left: The Guardrail 2000 is adjustable to flat and three different slopes. Right: The Safety Boot is designed for use on flat surfaces only. ***(See the disclaimer at the end of the paper.)***

real event as possible. The 200-lb point load on the top rail was created by using a fire rescue test dummy or manikin. The manikin is a canvas human form that was filled with rubber pellets and sand to provide its humanoid shape. Once the manikin was filled to the desired weight, it was mounted on a steel frame and hinged at the knees. Hinging at the knees was chosen to best recreate the motion of a human tripping and falling (Figure 3).

To create the desired load of greater than or equal to 200 lbs, the fall distance of the manikin was the control variable. Force data were collected by using the TestPoint data acquisition software, along with a National Instruments A/D board, and a PCB piezoelectric force transducer. The PCB 1000-lb piezoelectric force transducer was placed in-line between the manikin and an anchor point. By varying the fall distance of the manikin and then recording the resultant load, the desired resultant force ($\geq$ 200 lbs) was achieved through an iterative approach. The range of forces generated was from 200 to 381 lbs, with a mean value of 250.3 lbs and a SD = 38.8 lbs. To ensure that the force transducer would withstand the test procedure, a specialized mounting was developed that eliminated rotational and bending moments, thus producing a pure linear compressive force (Figures 4 and 5). The test against the guardrail was conducted by using an electromagnet to release the manikin against the center of the longest side of the top rail, as shown in Figure 3.

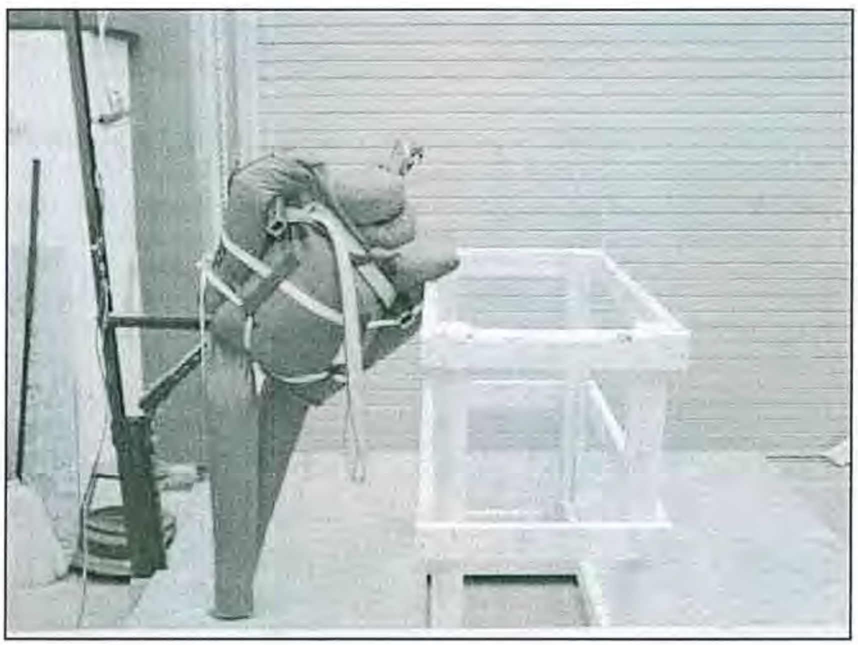

Figure 3. The test manikin, hinged at approximately knee height, is shown after having fallen against the top rail.

Design of the Apparatus for the Pull-to-Failure (PTF) Tests

The ultimate strength of each of the 45 configurations that were constructed was evaluated by performing a pull-to-failure (PTF) test. The design philosophy behind this test, which was devised by the research team, was to evaluate the strengths of the different job-built systems and compare them to the commercial products, even though they are being used differently than their original design. The PTF test was performed on a guardrail system after the manikin drop test was completed. The top rail was pulled to failure in the same direction that the manikin fell against the top rail in the drop tests (Figure 6). The PTF test imposed a larger, more sustained force to the center of the longest top rail. A maximum pulling force of 800 lbs was generated by using a 2-inch hydraulic cylinder, a battery-operated hydraulic pump, and a cable and pulley system (Figure 7). The design of the two testing methods and related apparatus was initially described in a previously published paper (McKenzie *et al.* 3-4). The data collection system, which was used in the initial drop tests to verify the OSHA 200-lb requirement, was also used for the PTF tests. The main variation for this testing was to place the force transducer between the PTF hydraulic cylinder and the top rail (Figure 6). The guardrail was then subjected to the force created by the PTF system, and the maximum strength (in lbs) was recorded. The Job-Built PTF test is shown in Figure 8, the PTF test for Guardrail 2000 is shown in Figure 9, and the PTF test for Safety Boot is shown in Figure 10.

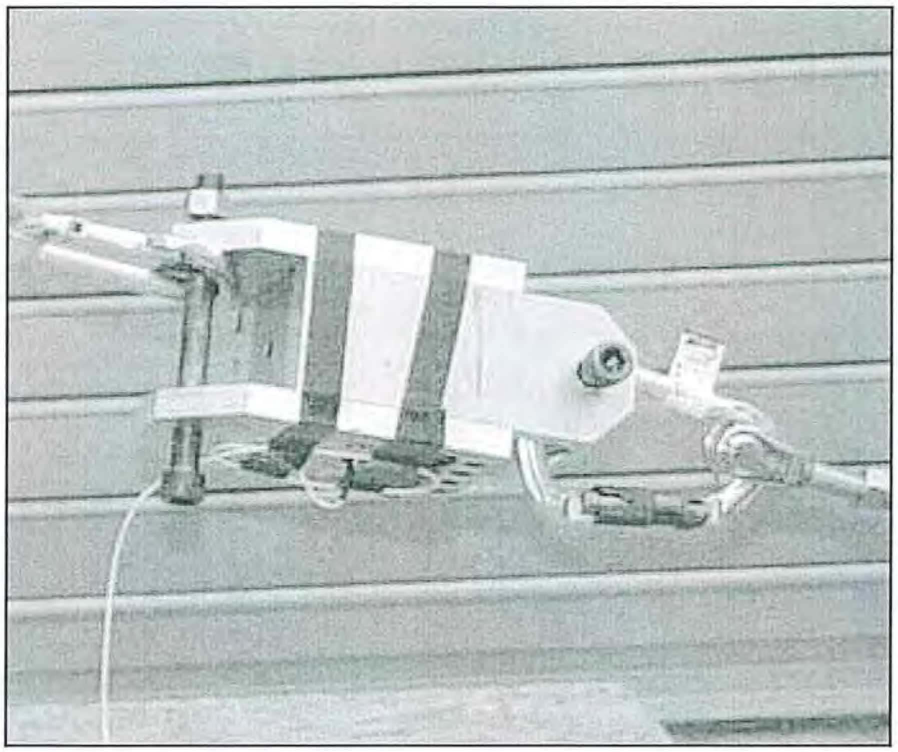

Figure 4. Shown is the protective housing for the in-line force transducer.

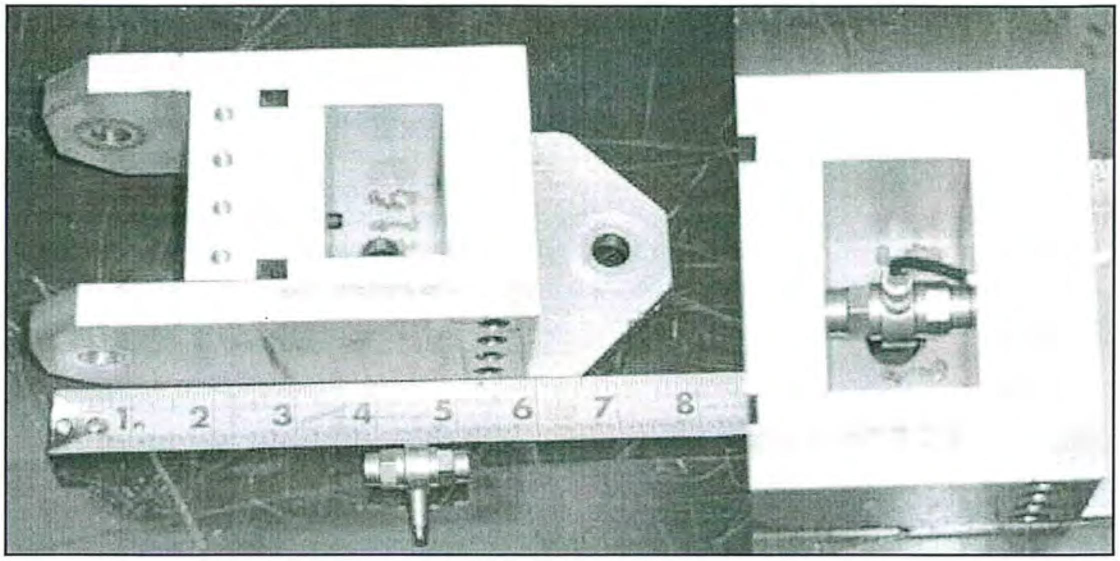

Figure 5. Shown are the mounting for the force transducer (left), and the force transducer exposed (right).

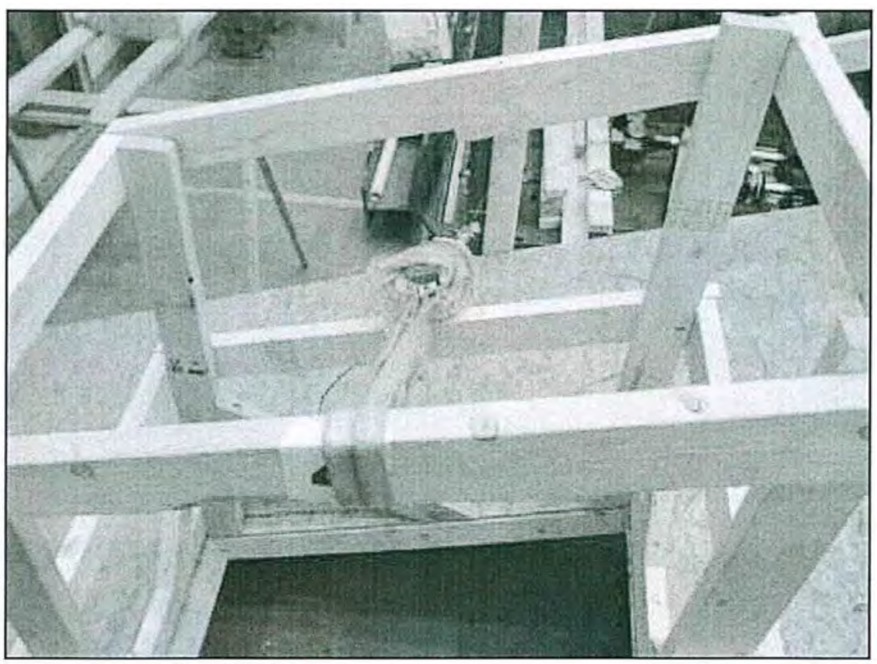

Figure 6. The force transducer is installed in-line with the pull-to-failure (PTF) hydraulic cylinder and the top rail of a Job Built guardrail system.

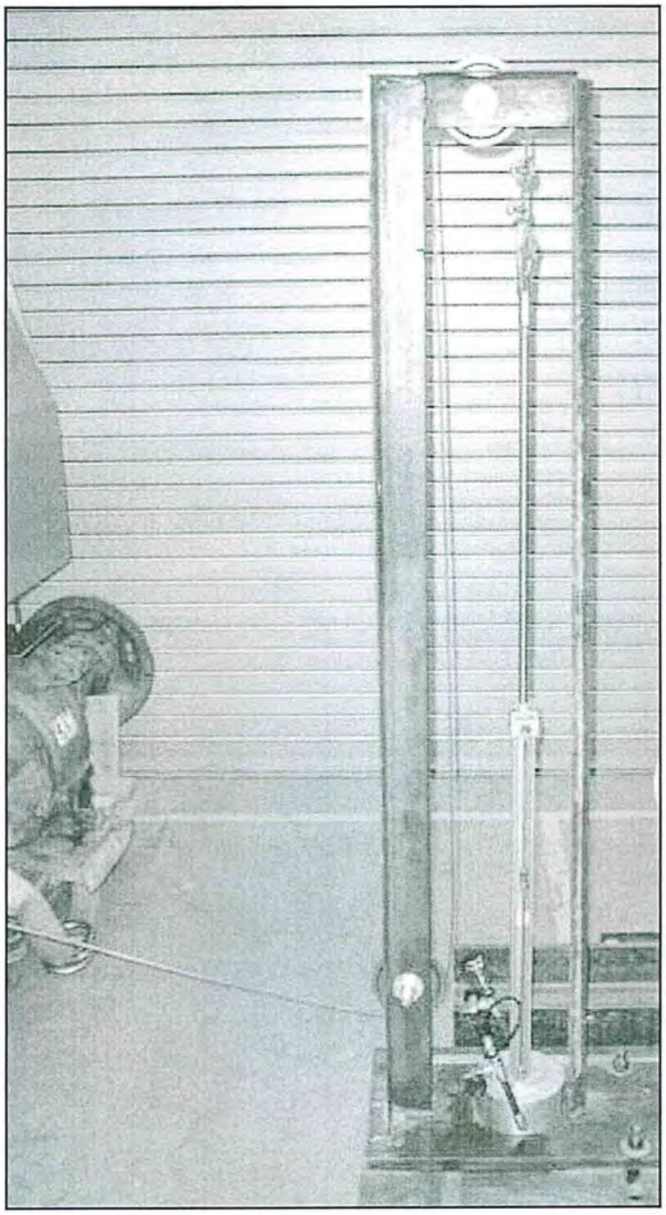

Figure 7 Hydraulic Cylinder and Pulley System for the Pull-to-Failure Test.

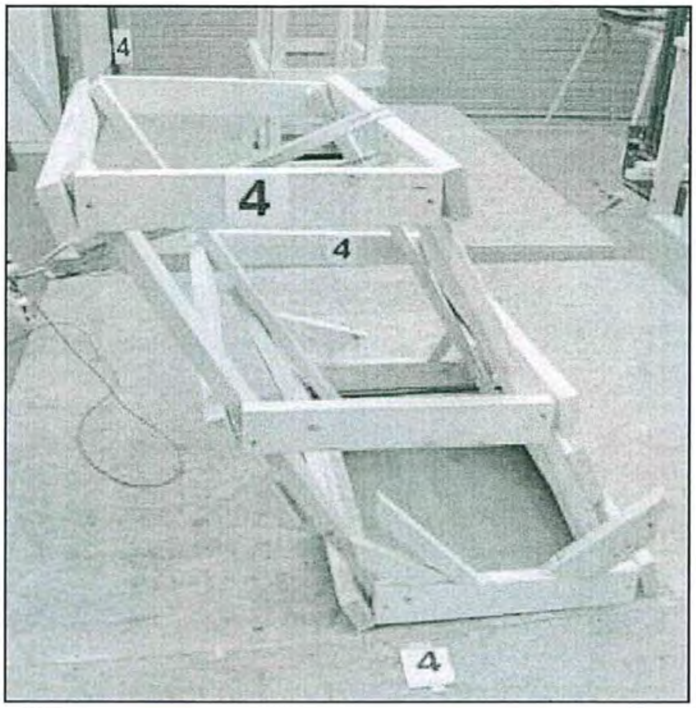

Figure 8. After the PTF test was conducted on a Job-Built system.

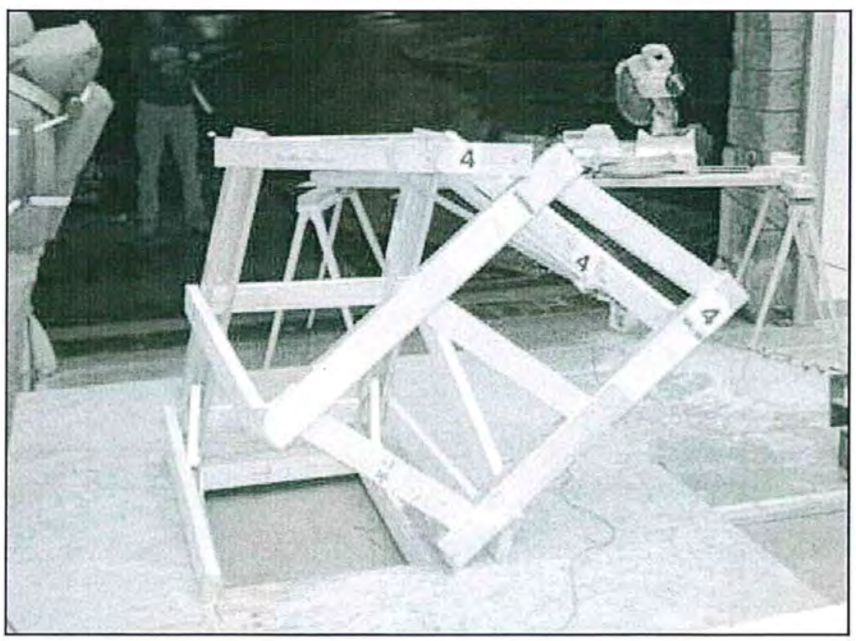

Figure 9. After the PTF test was conducted on a Guardrail 2000 system.

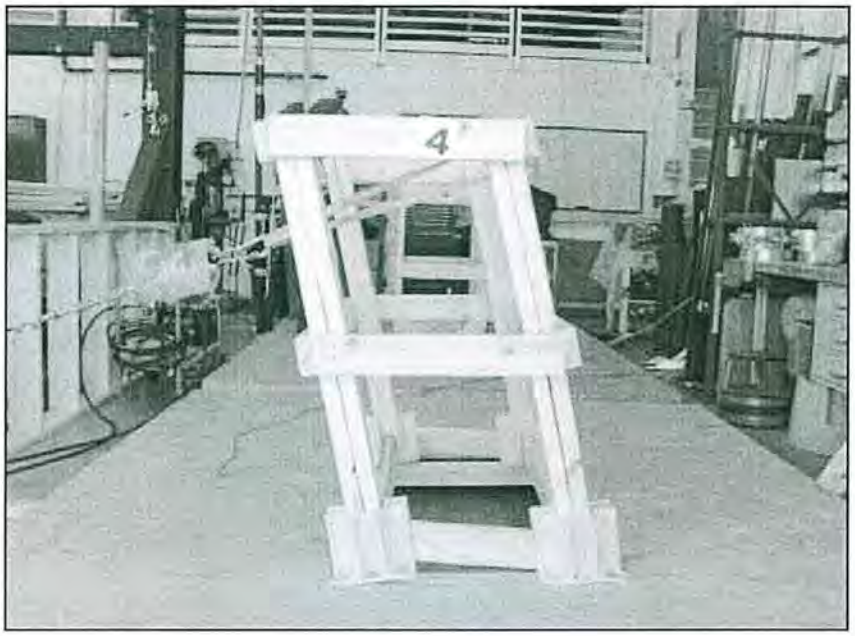

Figure 10. After the PTF test was conducted on a Safety Boot system.

Calibration Data for OSHA 200-lb Requirement

The calibration of the 200-lb drop force was an iterative procedure that was conducted by the researchers. These calibration drops were conducted to ensure that the manikin dropped against the top rail with a force of 200 lbs or more. For each new guardrail configuration, three drops were required, which used a force transducer to measure the resulting force output. The drops were measured and recorded with the force transducer located between the manikin and the anchor point. The drop distance of the manikin would be adjusted so the cable between the manikin and the force transducer would stop the manikin literally 1-inch from the top rail. If the force measurement was less than 200 lbs, then the drop distance was increased, resulting in an increased jolt to the force transducer, while still stopping the manikin just shy of the top rail. Only after three drops measured more than 200 lbs, then the OSHA drop test was conducted using the manikin only (force transducer removed). With the force transducer removed from the set-up, the manikin was permitted to fall freely (through the last inch) to impact the top rail. The research team assumed that the resulting force with which the manikin hit the top rail was similar to the previous three calibration drops. Because the requirement for the OSHA test was simply to support 200 lbs *or more*, we accepted force measurements that far exceeded 200 lbs, perhaps by 50% and more. Figure 11 provides a typical set of three force measurement curves generated by the manikin dropping against the force transducer.

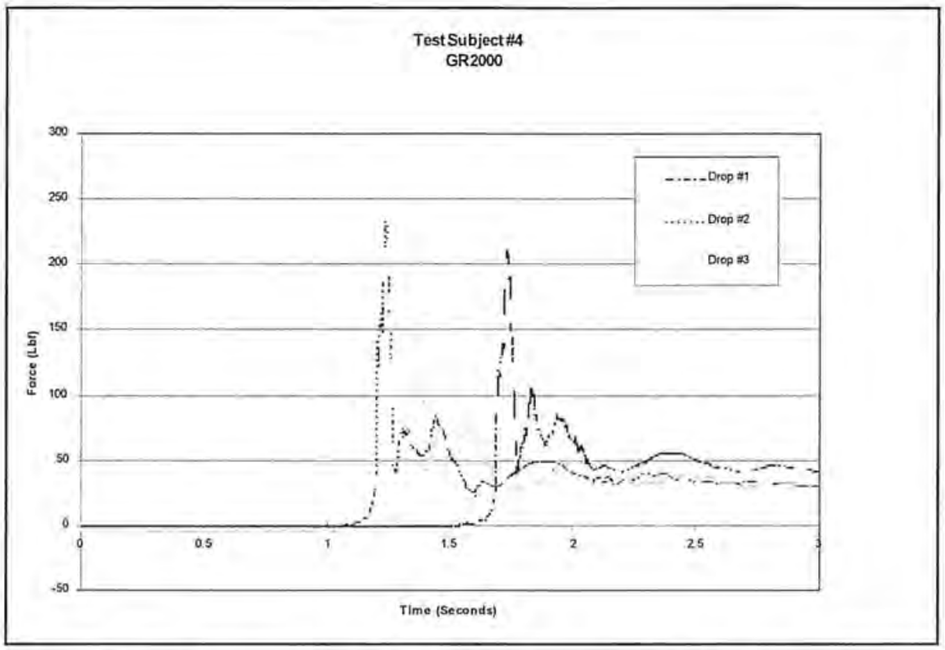

Figure 11. Shown are typical OSHA-Drop test calibration curves (test subject #4, Guardrail 2000 system).

The ≥200-lb load from the falling manikin was supported by all 45 different guardrail configurations. A critically important point to realize is that only 3½-inch (16-common [16-d]) nails were used in fastening the cross members (top rails, mid-rails, and toe boards) together during the construction of the guardrail systems. All nine test subjects stated that they use this nail size during typical framing operations and all of them thought this was the appropriate size of fastener to use for this testing. No other sized nails were evaluated with the calibrated manikin drop. Basically, the OSHA drop test evaluated how well the unit performed. This was a result of the number of fasteners utilized and the quality of the construction methods used by the subjects.

Pull-to-Failure Force Data

The pull-to-failure test was designed to evaluate how well the entire guardrail system was constructed as a unit, and also how well the upright supports were anchored to the roof test fixture. The pull-to-failure forces for Figure 8 (Job Built), Figure 9 (Guardrail 2000), and Figure 10 (Safety Boot) are shown in Figure 12.

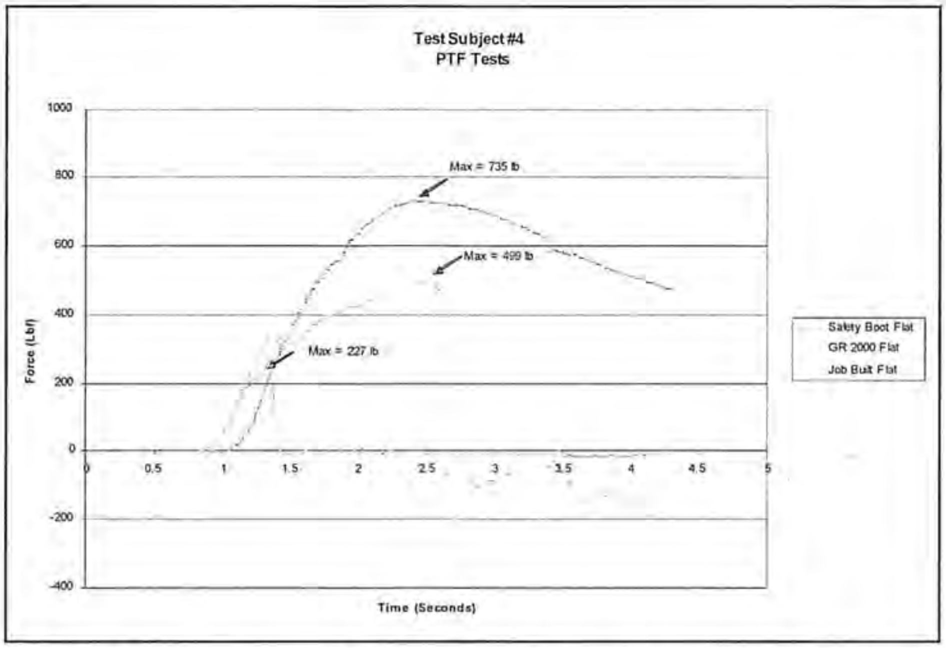

Figure 12. Shown are typical PTF curves for all three systems (subject #4).

This set of three typical curves is provided to show the general shape of the failure associated with the three different guardrail configurations. Specific force data for the three types of guardrail systems will be discussed in more detail in the following sections. It is appropriate to mention that all the job-built guardrails were fastened together and anchored to the test fixture using only 16-d nails. Guardrail 2000 was also anchored to the test fixture with 16-d nails. However, this commercial product provided additional locations in its design to use two 2-inch (8-d) nails to fasten the top and mid-rail to the aluminum upright. Lastly, the Safety Boot required 16-d nails to join two 2 x 4 boards together to create a solid upright post that was inserted into a high-strength plastic boot. Top rail and mid-rail were attached to the uprights with standard 16-d nails. However, each plastic boot was anchored to the wooden test fixture with (depending on the configuration) three or four 3/8-in x 3-in lag bolts and fender washers. These lag bolts were substantially stronger than the 16-d nails that were used to anchor the other two guardrail systems.

Results

The following sub-sections will present average values for the group of nine subjects for (a) time to install the guardrail, (b) total length of 2 x 4 boards, (c) total number of nails used for fastening and anchoring, (d) an estimate of total cost per guardrail system, and (e) pull-to-failure strength of each guardrail system. To reiterate, there were five guardrail systems constructed by each subject. They were (1) job-built on a flat surface, (2) job-built on a sloped surface, (3) Guardrail 2000 on a flat surface, (4) Guardrail 2000 on a sloped surface, and (5) Safety Boot on a flat surface only.

Installation Time

Table 1 provides descriptive statistics (the minimum and maximum values, the mean (average), and the standard deviation) for the time to install each of the five different configurations of guardrail system installed. The average time for the group to install a guardrail was quickest for Guardrail 2000 on the flat (25.6 min), followed by Guardrail 2000 on the slope (29.7 min), then the job-built on the flat (37.9 min), the job-built on the slope (41.3 min), and the slowest was Safety Boot (48.3 min). The most variability occurred for the job-built on the flat, with almost 14 minutes.

Table 1. Installation Times for Five Guardrail Configurations

	Installation Time (minutes)					
# Configuration	Mean	StdDev	1 StdDev Around Mean		Min	Max
1. Job-Built, Flat	37.9	13.8	24.1	51.7	24	64
2. Job-Built, Slope	41.3	10.8	30.6	52.1	31	56
3. Guardrail 2000, Flat	25.6	5.9	19.6	31.5	19	35
4. Guardrail 2000, Slope	29.7	7.6	22.1	37.3	21	42
5. Safety Boot, Flat	48.3	10.6	37.8	58.9	32	63

Lumber Used

Table 2 provides similar descriptive statistics for the amount of 2 x 4 lumber used in the construction of the five different guardrail systems. The average amount of lumber used by the group was least for Guardrail 2000 on flat (45.7 linear ft) and then sloped (46.6 linear ft), next most for the job-built guardrail on sloped (54.1 linear ft) and then flat (56.7 linear ft), and the most lumber was used in constructing the guardrails when using Safety Boot (66.4 linear ft). The most variability of lumber used was for the job-built-flat configuration, with a standard deviation of almost 13 feet of lumber.

Table 2. Amount of Lumber Used in Constructing Five Guardrail Configurations

	Board length used (feet)					
# Configuration	Mean	StdDev	1 StdDev Around Mean		Min	Max
1. Job-Built, Flat	56.7	12.9	43.8	69.6	48	90
2. Job-Built, Slope	54.1	4.1	50.0	58.2	48	60
3. Guardrail 2000, Flat	44.0	4.9	39.1	48.9	40	54
4. Guardrail 2000, Slope	43.8	5.7	38.1	49.5	39	56
5. Safety Boot, Flat	66.4	5.6	60.8	72.1	60	78

Fasteners Used

Table 3 provides descriptive statistics for the number of 3½-inch (16-d) nails used during the construction of the five different guardrail systems. The average number of 16-d nails used by the group was least for Safety Boot (59.8), followed by Guardrail 2000 on flat (63.2) and then sloped (65.4), with the most nails used for constructing the job-built on sloped (70.4) and finally job-built on flat (80.6). The most variability of nails used occurred for the job-built on flat configuration (18.1). It is important to realize that Safety Boot did not use any 16-d nails to anchor the vertical posts to the test fixture. Instead, either 12 or 16 lag bolts (3/8-in x 3-in) were used for anchoring the plastic base supports for the posts.

Table 3. Number of Nails Used in Constructing Five Guardrail Configurations

# Configuration	Number of Nails used					
	Mean	StdDev	1 StdDev Around Mean		Min	Max
1. Job-Built, Flat	80.6	18.1	62.4	98.7	49	105
2. Job-Built, Slope	70.4	14.9	55.6	85.3	51	92
3. Guardrail 2000, Flat	63.2	7.3	55.9	70.5	51	72
4. Guardrail 2000, Slope	65.4	12.8	52.6	78.3	52	96
5. Safety Boot, Flat	59.8	11.1	48.6	70.9	44	76

Pull-to-Failure Strength

Before presenting the group average data for pull-to-failure strength, remember that the Safety Boot was anchored to the test fixture with lag bolts, as opposed to the other four configurations that used 16-d nails for anchoring. The lag bolts were considerably stronger than the nails and the overall average strength values bear that out. Table 4 presents descriptive statistics on the group data for the pull-to-failure test. The average pull-to-failure strength for the Safety Boot was strongest at 711.6 pounds. For the other four configurations, Guardrail 2000 on flat was next strongest (553.0 lbs), followed by Guardrail 2000 on slope (454.0), then job-built on flat (253.4 lbs), and finally job-built on slope (227.4 lbs). The variability in the group strength data was highest for job-built on flat configuration (114.8 lbs) by more than a factor of two over the next highest standard deviation (53.8 lbs), which occurred for two configurations – job-built on slope and the Safety Boot.

Table 4. Pull-to-Failure Strength for Five Guardrail Configurations

# Configuration	Force (pounds)					
	Mean	StdDev	1 StdDev Around Mean		Min	Max
1. Job-Built, Flat	258.4	114.8	143.6	373.2	161	575
2. Job-Built, Slope	227.4	53.8	173.6	281.3	134	281
3. Guardrail 2000, Flat	553.0	44.6	508.4	597.6	499	620
4. Guardrail 2000, Slope	454.0	43.1	410.9	497.1	400	547
5. Safety Boot, Flat	711.6	53.8	657.8	765.4	605	787

Estimate of Total Cost per Guardrail Configuration

There are three variable costs associated with all five guardrail configurations. Those would include costs of labor, lumber, and nails. There is a fixed purchase price for both of the commercial products. The cost of a Guardrail 2000 is $100.00 each, with a set of four being $400.00. The cost of a Safety Boot (plus four lag bolts) is $26.50 each, so a set of four would be $106.00. Table 5 provides a breakdown of costs for the three variables (labor, lumber, and nails). The table provides the average cost for the five configurations of guardrail constructed, with the following assumptions applied. The labor cost was $25.00 per hour, the lumber cost is $0.40 per foot, and the cost of the nails is $0.02 per 16-d nail.

Table 5. Breakdown of Costs for Five Guardrail Configurations

# Configuration	Average Cost ($)				
	Time	Lumber	Nails	Total	Rounded
1. Job-Built, Flat	15.79	22.67	1.61	40.06	40
2. Job-Built, Slope	17.22	21.64	1.41	40.28	40
3. Guardrail 2000, Flat	10.65	17.60	1.26	29.51	30
4. Guardrail 2000, Slope	12.36	17.51	1.31	31.18	31
5. Safety Boot, Flat	20.14	26.58	1.20	47.91	48

Using the mean (average) values from Tables 1, 2, and 3, a unit cost can be calculated for each configuration. As shown in Table 5, the job-built guardrails cost $40.06 and $40.28 for the flat and sloped configurations, respectively. The "after-purchase" costs of Guardrail 2000 are $29.51 and $31.18 for flat and sloped configurations, respectively. The difference in variable cost between Job Built and Guardrail 2000 is $10.55 for the flat configuration and $9.10 for the sloped configuration. This is how much is saved in construction costs (labor + lumber + nails) each time by using this commercial product. Dividing the cost of a set of Guardrail 2000 ($400) by the difference in the overall cost for the flat configuration ($10.55) results in a value of 37.9. Thus, after 38 guardrail systems have been built utilizing the Guardrail 2000 (according to the details of this study), the break-even point will have been reached where the initial purchase price of the Guardrail 2000 system will have been repaid and will subsequently begin to save money for the purchaser.

In a similar respect, dividing the cost of a set of Guardrail 2000 by the difference in the overall cost for the slope configuration ($9.10) results in a value of 43.96. Therefore, after 44 guardrail systems have been built on a slope using the Guardrail 2000 (according to the details of this study), the break-even point will have been reached where the initial purchase price of that commercial system will have been repaid and will then begin to save money for the purchaser.

Discussion

For the purpose of this research study, all of the job-built guardrail systems that were constructed used new 2 x 4 lumber for each new set-up. In the real world, re-using obviously damaged materials is considered an unsafe practice and should be avoided. If possible, use fresh lumber when constructing a guardrail system to obtain the maximum possible fastening strength. In fact, a fatal incident occurred where a worker fell to his death after leaning against a re-used guardrail. The guardrail had been reinstalled by utilizing the same nailed boards and nail holes to save on time and material costs. Instead of protecting the worker, the guardrail failure resulted in a tragic occurrence (privileged communication, construction company to remain anonymous, Jan 2005).

Estimated Costs of Fall-Related Injuries

During the entire nine-year period 1992-2000, the median number of days-away-from-work for fall-through-roof-holes was 35. During those nine years, however, there were individual annual median values as high as 60 (1997) and 62 (1992) (Bobick 903). This provides an indication as to the severity of the injuries that do occur from falling through roof holes. Fall-prevention efforts should address these types of hazards that are often quite obvious and fairly easy to rectify.

Total cost associated with these serious injuries is comprised of two components – direct and indirect costs. Direct costs include medical payment for the injuries, workers' compensation costs for missed work time, equipment or parts replacement if breakage occurred, and other ancillary expenses such as ambulance service charges and medical supplies used at the job site. Indirect costs include items such as downtime while the incident is investigated, clean-up costs, administrative time for dealing with the injury, training of replacement workers (especially if a new hire is required), and a decrease in productivity (because of new hire inefficiency or from a reassigned permanent worker unfamiliar with the new job duties).

A conservative estimate, which has been chosen for this discussion, is that direct and indirect costs are equal, and that the amount paid in medical expenses and workers' compensation payments actually represents only half of the overall costs. Other estimates have been more robust and have suggested that the indirect costs range from two to three times the direct costs (Gice 59) to three to five times the direct costs (Liberty Mutual *on-line*)

A Liberty Mutual press release (February 2001) dealt with the development of a *Workplace Safety Index*. The development of the *Safety Index* involved Liberty Mutual using its own claims information, along with data from the Bureau of Labor Statistics and the National Academy of Social Insurance, to determine the ten leading causes of work-related injuries and illnesses for 1998. The total amount paid in wages and medical payments (direct costs) was $38.7 billion (Liberty Mutual *on-line*). Falls-to-lower-level was fourth most costly (following overexertion, falls on same level, and bodily reaction) and accounted for 9.33% of the total ($3.61 billion). Using previously published data for 1998 (Bobick 900, 903), 2,069 fall-through incidents amounted to 2.17% of the 95,460 fall- to-lower-level cases. The corresponding direct costs for the 1998 fall-through injuries amount to $78.35 million (2.17% of $3.61 billion). Direct costs for each of the 2,069 fall-through incidents amounted to $37,869. Assuming that direct costs equal indirect costs, the total (combined) cost for each of the 2,069 incidents is twice the $37,869, or an average of $75,738 per incident.

Other information related to the cost of injuries indicated that fractures averaged $23,138 per claim (Fefer 81). Since this article was published in 1992, the assumption was made that this cost was from 1991. To determine a 1998 equivalent value (to match Liberty Mutual costs), an on-line inflation calculator (at www.bls.gov) was used. The direct cost for fractures, which is the likely result if a worker survives a fall through an unguarded roof hole, was $27,691 in 1998. Assuming that indirect and direct costs are equal, the total cost would be $55,382. This provides a reliable range ($55,000 to $76,000) for the cost of a 1998 serious injury caused by a fall-through event.

When compared to the total number of roofs being installed in a year throughout the U.S., a fall-through incident happens rather infrequently, and might actually be considered a rare event. However, when an incident does occur, the excessive cost associated with these potential tragedies could be economically disastrous to small- or medium-sized construction companies. The potential for a fall-through incident to occur is present on every job site, and can be eliminated fairly easily by using a guardrail system. The minor amount of time and costs involved in constructing guardrails when they are needed could be viewed as regular workplace insurance payments that may prevent a future financial catastrophe from occurring.

Job-built guardrails can be safely constructed using 2 x 4 lumber and nails and then left in place for protection. If supplies need to be brought up through that opening, or access is required for any reason, the job-built guardrail can be removed fairly easily. However, management must insist that the guardrail is quickly and properly replaced. If the 2 x 4 lumber is damaged when being removed, it should be discarded so that weakened materials are not reused in the structure.

Conclusions

1. Results of this pilot study indicate that Job-Built guardrail protection (made of 2 x 4 lumber and 16-d nails) can result in perimeter guarding that meets the OSHA 200-lb drop specification.

2. The pilot study has shown that the two commercial edge-protection products that were evaluated also met the OSHA 200-lb specification when used as perimeter guarding.

3. Considering the pull-to-failure results (Table 4), the two commercial products can be used to construct perimeter guardrail structures that are consistently stronger than Job-Built structures.

4. The cost of constructing a Job-Built guardrail, or even multiple units, is minimal when compared to the total cost of a serious injury caused by a worker falling through a roof hole

Disclaimer

NIOSH is primarily a research agency. It does not conduct any type of certification testing of fall-protection or fall-prevention equipment. Mention of any Brand Names is for informational purposes only, and does not constitute any endorsement by NIOSH, CDC, or any agency of the Federal government.

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