



Evaluation of guardrail systems for preventing falls through roof and floor holes

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ABSTRACT

Introduction: Fall-related occupational injuries and fatalities are serious problems in the U.S. construction industry, especially incidents related to unguarded holes. The National Institute for Occupational Safety and Health, Division of Safety Research, Morgantown, WV conducted a project to evaluate the effectiveness of guardrail systems to prevent falls through roof and floor holes. **Methods:** Two commercial edge-protection products were evaluated when used as perimeter guarding around a roof hole. Installations of the commercial products were compared to job-built guardrails constructed of 2" x 4" construction-grade lumber. Occupational Safety and Health Administration (OSHA) regulations require that "a force of at least 200 pounds" must be supported by the top rail of a guardrail system "in any outward or downward direction at any point along the top edge." A laboratory testing system was developed to evaluate this requirement. A dynamic 200-lb force was generated against the top rail using a weighted manikin mounted on a hinged steel frame. Nine construction workers, who served as test subjects, each built five different guardrail configurations. **Results:** All 45 configurations met the 200-lb OSHA requirement. Installation time for one commercial product was 32% quicker than the job-built configuration (25.6 min vs. 37.9 min). **Impact on Industry:** This study: (a) indicates that the two edge-protection products can be used as perimeter guarding; (b) highlights the importance of using proper materials and fasteners to construct guardrails to protect workers from falling into unguarded roof and floor holes; and (c) discusses an overall-strength-testing methodology that can be used by fall-protection researchers.

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1. Introduction

Occupational injuries and fatalities caused by falls-from-elevation are serious problems in U.S. workplaces. Previous research (Parsons, Pizatella, & Collins, 1986; Personick, 1990) indicated that the construction industry, and that roofers and slate masons in particular, had elevated fatality and injury rates. Analyses of data from the Census of Fatal Occupational Injuries (CFOI), which is maintained by the Bureau of Labor Statistics (BLS), consistently indicate that falling to a lower level is the leading cause of fatality in the construction industry. An important subset of the fall-to-lower-level category involves workers falling through existing holes in floors or roofs, or through skylight fixtures.

1.1. Fatal Incidents

A previous analysis of CFOI data indicated that a total of 432 deaths occurred when workers fell through roof holes, floor holes, and skylights during the nine-year period of 1992–2000 (yearly average of 48 deaths; Bobick, 2004). A follow-up analysis of the CFOI data for the five-year period of 2003–2007 (BLS, 2003a,b, 2004a,b, 2005a,b, 2006a,

b, 2007a,b) has indicated that 333 workers lost their lives from falling through roof holes, floor holes, and skylights for a yearly average of 67 worker deaths, a 39.6% increase in these types of deaths since the 1992–2000 time period. The 333 fatalities are 9.6% of the total fall-to-lower-level fatal incidents that occurred in all U.S. industries during 2003–2007.

1.2. Serious Non-fatal Injuries and Corresponding Days Away From Work

Thousands of serious non-fatal injuries also result from fall-through events. Serious injuries are defined by BLS as those that cause a worker to miss at least one day away from work (DAFW) beyond the day the incident occurred. The previous analysis of injuries used the Survey of Occupational Injuries and Illnesses (the Annual Survey from each year) for 1992–2000 (Bobick, 2004). That analysis indicated that 11,417 serious injuries occurred when workers fell through roof holes, floor holes, and skylights (yearly average of 1,269 serious injuries) that resulted in an estimate of 182,637 total DAFW (yearly average of 20,293 DAFW). The follow-up analysis of the Annual Surveys for the five-year period of 2003–2007 has indicated that 4,870 serious injuries occurred when workers fell through roof holes, floor holes, and skylights (yearly average of 974 serious injuries, a 23% reduction from 1992–2000) that resulted in an estimate of 89,315 total DAFW (estimated yearly average of 17,863 DAFW, a 12% reduction

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from 1992–2000). The 4,870 fall-through serious injuries are 1.25% of the total fall-to-lower-level serious non-fatal injuries that occurred in all U.S. industries during 2003–2007.

Despite this small percentage, fall-through injuries are among the most severe cases when ranked by median number of DAFW. The previous analysis indicated that for the period 1992–2000, the median number of DAFW was 35, 11, and 36 for injuries caused by falls through roof holes, floor holes, and skylights, respectively, compared to 10 DAFW for all types of fall-to-lower-level cases in U.S. industries during the same period (Bobick, 2004). The follow-up analysis for the five-year period 2003–2007 has revealed that the median number of DAFW was 44, 9, and 47 for falls through roof holes, floor holes, and skylights, respectively, compared to 14 DAFW for all types of fall-to-lower-level cases in U.S. industries during the same five-year period. Thus, injuries resulting from falls through roof holes and skylights were 3½ times more severe than all other types of falls to a lower level during 1992–2000, and 10 years later, were still 3 to 3½ times more severe than all other types of falls-to-a-lower-level.

1.3. Estimated Costs of Fall-related Injuries

An analysis of all BLS Annual Surveys for the nine-year period 1992–2000 indicated that the median number (50th percent value) of days-away-from-work for falls through roof holes was 35. However, during those nine years, there were individual median values as high as 62 (1992) and 60 (1997) (Bobick, 2004). There were DAFW values that were less than 60 and 62 in those two specific years, but there were also incidents that had DAFW values that exceeded 60 and 62 missed work days. This gives an indication as to the severity of the injuries that occurred when workers fell through roof holes.

Similarly, across the nine-year period 1992–2000, analysis of the BLS Annual Surveys indicated that the median number of days-away-from-work for falls through skylights was 36. During those nine years, there were individual median values as high as 70 (1994) and 72 (2000) (Bobick, 2004). Because these are median values, there were workers who were injured severely enough to have missed work for periods of time that exceeded 72 work days (i.e., 14 work weeks or 3½ months).

A similar analysis of the BLS Annual Surveys has been conducted for the five-year period 2003–2007. For incidents involving workers falling through roof holes, the worst two years were 2003 (51 median days missed) and 2006 when the median value of days-away-from-work for the estimated 200 incidents that occurred that year was 147. Thus, half of the fall-through-roof-hole incidents in 2006 caused the injured worker to be away from work for periods of time that exceeded 147 days (29 weeks, or more than 7 months). Incidents that involved workers falling through skylights resulted in excessive days-away-from-work in 2003 (61 median DAFW), 2006 (77 median DAFW), and 2007 (81 DAFW). Since the outcome of falling through roof holes and skylights has resulted in such excessive time periods away from work, fall-prevention efforts should focus on these hazards.

“The estimated direct U.S. workers [sic] compensation costs for [10 categories of] the most disabling workplace injuries and illnesses in 2006 were \$48.6 billion. This finding ... [is] presented in the 2008 Liberty Mutual Workplace Safety Index” (Liberty Mutual on-line, 2008). Liberty Mutual defines *most disabling* as “those injuries that cause an employee to miss six or more days from work” (Liberty Mutual on-line). “To develop the 2008 Index, researchers applied Liberty Mutual 2006 workers [sic] compensation claims costs to the workplace injury frequency information reported by the U.S. Department of Labor’s Bureau of Labor Statistics for injuries occurring that year. The relative proportions of each injury type were then applied to the national estimates of the cost of workers [sic] compensation benefits from the National Academy of Social Insurance, which includes information from a broad range of insurance providers” (Liberty Mutual on-line).

For 2006, the fall-to-lower-level category is the third most costly (after overexertion and falls-on-same-level) with an estimate of \$5.3 billion in direct costs. The analysis of current BLS injury data indicates that in 2006, a total of 74,280 fall-to-lower-level incidents occurred in U.S. private industry. The total numbers of falls through roof holes, floor holes, and skylights are 530, 200, and 50, respectively, for an estimated total of 780 fall-through incidents. Of these 780 cases, a total of 340, 200, and 50 or 590 total cases involved workers missing six or more workdays, as per the definition of “most disabling.” These estimated 590 cases represent a total of 0.79% (590 / 74,280 = 0.0079) of all falls to a lower level in 2006. Using these data will provide a tentative estimate of \$41.87 million total (\$5.3 billion × 0.0079). Therefore, the cost of each of the 590 “most disabling” fall-through cases is estimated to be \$70,966 (\$41.87 million / 590).

If a fall-through incident does occur, the excessive cost associated with these potential tragedies (\$71,000 per disabling fall-through incident) 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 should be eliminated. The use of covers and guardrail systems are well established as effective measures to protect workers from falling through roof and floor holes. Guardrail systems, both commercially available and job-built configurations, can be used to provide protection for unguarded openings.

1.4. Construction-related Occupational Safety and Health Administration (OSHA) requirements

Good safety practice specifies that falls should be prevented as the primary measure to protect workers, 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. The current study was focused on evaluating the use of guardrail systems to prevent workers from falling into large holes.

Before discussing the guardrail study, a short discussion related to “Covers” is provided for completeness. If a cover is used, the material: (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, 2008, p. 290). If it is not secured and marked, it is like setting a deadly trap for the other crew workers (Barnhard, 2001). Fatal injuries have been reported when workers stepped on unsecured covers. One such incident occurred when an unsecured cover kicked away and the worker fell to his death through the newly created hole (McVittie, 1995).

Current regulations for the construction industry are contained in Code of Federal Regulations (CFR), Title 29 (Labor), Part 1926 (Construction). 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 protected from falling through holes (including skylights) more than 6 feet (1.8 m) above lower levels, by personal fall arrest systems, covers, or guardrail systems erected around such holes” (Mancomm, 2008, p. 286). The strength of guardrail systems must also meet OSHA regulation 29 CFR 1926.502(b)(3) which states, “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, 2008, p. 287).

2. Research Study

A research project conducted by the National Institute for Occupational Safety and Health (NIOSH), Division of Safety Research, Morgantown, West Virginia evaluated the effectiveness of two commercial fall-prevention guardrail systems, which were designed for edge use only, when they were installed as perimeter guardrails around a hole in a

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