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**Topics in Construction Safety and Health**  
**Struck-by and Caught-in Hazards:**  
An Interdisciplinary Annotated Bibliography

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## **Struck-by and Caught-in Hazards: An Interdisciplinary Annotated Bibliography**

Arboleda, C. A. and D. M. Abraham (2004). "Fatalities in trenching operations—analysis using models of accident causation." *Journal of Construction Engineering and Management* 130(2): 273-280.

More than 65 construction workers are killed each year due to trench related accidents. Accident prevention begins with having a clear understanding of the causes of these accidents. This paper discusses the analysis of 296 fatality reports related to trenching operations from the Occupational Safety and Health Administration (OSHA) in the 1997-2001 time frame. In this paper, two models will be considered to analyze the fatality reports and to find the major relationships between the 'how' and the 'why' of trenching fatalities. The first model considers the causes related to physical processes, and the second model evaluates causes that can be linked to human behavior. The understanding of the major links between these two models and other factors will help to develop more effective strategies to prevent trenching fatalities

Arditi, D., et al. (2007). "Fatal accidents in nighttime vs. daytime highway construction work zones." *J Safety Res* 38(4): 399-405.

INTRODUCTION: Awareness about worker safety in nighttime construction has been a major concern because it is believed that nighttime construction creates hazardous work conditions. However, only a few studies provide valuable comparative information about accident characteristics of nighttime and daytime highway construction activities. METHOD: This study investigates fatal accidents that occurred in Illinois highway work zones in the period 1996-2001 in order to determine the safety differences between nighttime and daytime highway construction. The lighting and weather conditions were included into the study as control parameters to see their effects on the frequency of fatal accidents occurring in work zones. RESULTS: According to this study, there is evidence that nighttime construction is more hazardous than daytime construction. The inclusion of a weather parameter into the analysis has limited effect on this finding. IMPACT ON INDUSTRY: The study justifies establishing an efficient work zone accident reporting system and taking all necessary measures to enhance safety in nighttime work zones.

Beavers, J., et al. (2009). "Steel erection fatalities in the construction industry." *Journal of Construction Engineering and Management* 135(3): 227-234.

Construction fatalities continue to occur during steel erection. Using 166 case files resulting from Occupational Safety and Health Administration (OSHA) investigations of steel erection fatalities during the years 2000–2005, the writers examined the data to determine the proximal causes and contributing physical factors. Of the 166 fatal events, results showed proximal cause “falls” represented 125 of the fatal events, “crushed/struck/hit by object” represented 40, and one was caused by electrocution. The rate of fatalities tended to reduce from 2000 to 2005. As a result, OSHA may be reaching one of its goals established following the introduction of the new steel standards in 2002, an annual reduction of 30 fatalities. The results of this study indicate that employer compliance with OSHA’s fall protection standards and instructing employees in recognition and avoidance of unsafe conditions could save lives.

Centers for Disease, C. and Prevention (2007). "Nail-gun injuries treated in emergency departments--United States, 2001-2005." *MMWR Morb Mortal Wkly Rep* 56(14): 329-332.

Speed, ease of use, and ready availability have made pneumatic nail guns a common tool used in work settings such as residential construction and wood-product fabrication. In addition, the tools

are now readily available to consumers, extending to the public what had been primarily a potential work-related hazard. To characterize nail-gun injuries in work and nonwork settings, patients with nail-gun injuries treated in U.S. hospital emergency departments (EDs) were studied by using the U.S. Consumer Product Safety Commission's (CPSC's) National Electronic Injury Surveillance System (NEISS) and the NEISS occupational injury supplement (NEISS-Work) maintained by CDC's National Institute for Occupational Safety and Health (NIOSH). This report describes the results of that analysis, which indicated that during the 5-year period 2001-2005, an average of approximately 37,000 patients with injuries related to nail-gun use were treated annually in EDs, with 40% of injuries (14,800) occurring among consumers. In addition, data on ED-treated injuries indicated that, in 2005, nail-gun injuries among consumers were approximately three times higher than in 1991 (4,200). Additional measures are needed to prevent nail-gun injuries among both workers and consumers.

Chen, G. X., et al. (2000). "Expanded analysis of injury mortality among unionized construction workers." *Am J Ind Med* 37(4): 364-373.

**BACKGROUND:** To evaluate the utility of expanding the number and precision of injury categories used in previous occupational mortality studies, this study reanalyzed data from four previous studies of unionized construction workers (construction laborers, ironworkers, sheet metal workers, and operating engineers), by expanding the number of injury categories from 6 to 33. **METHODS:** Proportionate mortality ratios (PMRs) were computed using the distribution of deaths from the National Occupational Mortality Surveillance System, a mortality surveillance system from 28 states, as a comparison. A blue collar comparison group was also used in additional analyses to adjust for socioeconomic and other factors. **RESULTS:** This reanalysis identified significantly elevated PMRs in at least one of the four worker groups for falls, motor vehicle crashes, machinery incidents, electrocutions, being struck by falling objects, being struck by flying objects, explosions, suffocation, and water transport incidents. Limiting the comparison population to deaths among blue collar workers did not change the results substantially. **CONCLUSIONS:** This study demonstrates that increasing the precision of categories of death from injury routinely used in mortality studies will provide improved information to guide prevention. *Am. J. Ind. Med.* 37:364-373, 2000. Published 2000 Wiley-Liss, Inc.

Cheng, T. and J. Teizer (2014). "Modeling tower crane operator visibility to minimize the risk of limited situational awareness." *Journal of Computing in Civil Engineering* 28(3).

Many construction fatalities involving cranes and ground workers are caused by contact with objects and equipment, in particular being struck by crane loads and parts. One of the main risks in operating a tower crane is the limited visibility of the crane operator. An approach is presented that aims at increasing the situational awareness of a tower crane operator by aligning enhanced understanding of construction site layout with increased operator visibility of ground level operations. The developed method uses sensors to collect two data types, as follows: (1) a laser scanner measures the as-built conditions and geometry of a construction site, and (2) real-time location-tracking technology gathers the mostly dynamic location of workers on the ground. Several algorithms are presented to (1) identify blind spaces from the collected point cloud data that limit the visibility of a crane operator, (2) process real-time location-tracking data of workers on the ground, and (3) fuse the resulting data to create information that allows a quantitative assessment of the situational awareness of a tower crane operator. Results to a field trial are presented and show that a tower crane operator using the developed approach can increase understanding of where and when occluded spaces and ground-level operations occur. The developed methods for creating safety information from range point cloud and trajectory data is a promising approach in significantly improving the currently unsafe

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operation of tower cranes, one of the most utilized pieces of equipment in construction. © 2014 American Society of Civil Engineers.

Chirumamilla, V., et al. (2016). "Pericardiocentesis followed by thoracotomy and repair of penetrating cardiac injury caused by nail gun injury to the heart." *Int J Surg Case Rep* 23: 98-100.

**INTRODUCTION:** Work site injuries involving high projectile tools such as nail guns can lead to catastrophic injuries. Generally, penetrating cardiac injuries are associated with a high mortality rate. **PRESENTATION OF CASE:** A construction worker was brought to the emergency room having sustained a nail gun injury to the chest. The patient was hypotensive, tachycardic with prominent jugular venous distention, and had a profound lactic acidosis. Bedside ultrasound confirmed the presence of pericardial fluid. Pericardiocentesis was performed twice using a central venous catheter inserted into the pericardial space, resulting in improvement in the patient's hemodynamics. Thereafter he underwent left anterolateral thoracotomy and repair of a right atrial laceration. He recovered uneventfully. **DISCUSSION:** Penetrating cardiac injuries caused by nail guns, although rare, have been previously described. However, pericardiocentesis, while retaining a role in the management of medical causes of cardiac tamponade, has been reported only sporadically in the setting of trauma. We report a rare case of penetrating nail gun injury to the heart where pericardiocentesis was used as a temporizing measure to stabilize the patient in preparation for definitive but timely operative intervention. **CONCLUSION:** We propose awareness that pericardiocentesis can serve as a temporary life saving measure in the setting of trauma, particularly as a bridge to definitive therapy. To our knowledge, this represents the first reported case of catheter pericardiocentesis used to stabilize a patient until definitive repair of a penetrating cardiac injury caused by a nail gun.

Cho, Y. K., et al. (2017). "Improving Work Zone Safety Utilizing a New Mobile Proximity Sensing Technology." CPWR Report.

Choi, S. D. and K. Carlson (2014). "Occupational safety issues in residential construction surveyed in Wisconsin, United States." *Ind Health* 52(6): 541-547.

Residential construction is a high-risk industry in the U.S. due to the exposure to workrelated safety hazards and fall injuries. This study aimed to examine the safety training and safe work practices of construction workers within the small residential construction industry. In order to achieve the study objectives, a survey was designed and sent to approximately 200 Wisconsin based residential construction contractors. About one third of the respondents stated that they did not have any form of safety programs. The study indicated that the most common types of workrelated injuries in residential construction were slips/trips/falls and cuts/lacerations. The survey findings also suggested that the residential construction contractors needed to increase the utilization of fall protection safety equipment. Further education and subject matter expert training could provide benefits to improve occupational safety and health of the small business workforce in the residential construction industry. © 2014 by National Institute of Occupational Safety and Health.

Courtney, T. K., et al. (2002). "Disabling occupational injury in the US construction industry, 1996." *J Occup Environ Med* 44(12): 1161-1168.

In 1996 the US construction industry comprised 5.4% of the annual US employment but accounted for 7.8% of nonfatal occupational injuries and illness and 9.7% of cases involving at least a day away from work. Information in the published literature on the disability arising from construction injuries is limited. The construction claims experience (n = 35,790) of a large workers' compensation insurer with national coverage was examined. The leading types and sources of disabling occupational morbidity in 1996 in the US construction industry were identified. Disability duration was calculated

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from indemnity payments data using previously published methods. The average disability duration for an injured construction worker was 46 days with a median of 0 days. The most frequently occurring conditions were low back pain (14.8%), foreign body eye injuries (8.5%), and finger lacerations (4.8%). Back pain also accounted for the greatest percentage of construction claim costs (21.3%) and disability days (25.5%). However, the conditions with the longest disability durations were sudden-onset injuries, including fractures of the ankle (median = 55 days), foot (42 days), and wrist (38 days). Same-level and elevated falls were the principal exposures for fractures of the wrist and ankle, whereas elevated falls and struck by incidents accounted for the majority of foot fractures. Manual materials handling activities were most often associated with low back pain disability. The results suggest that these most disabling injuries can be addressed by increasing primary prevention resources in slips and falls and exposures related to injuries of sudden-onset as well as in reducing manual materials handling and other exposures associated with more gradual-onset injuries.

Deatherage, J. H., et al. (2004). "Neglecting safety precautions may lead to trenching fatalities." *Am J Ind Med* 45(6): 522-527.

**BACKGROUND:** Trench collapses ranked as the seventh leading cause of the possible twenty-nine causes of OSHA-inspected fatal construction events during the period 1991-2001. This study aims to examine why these fatalities occurred. **METHODS:** Forty-four case files from OSHA inspections of fatal trench collapses were reviewed. **RESULTS:** Improper protection of the excavation site where work was taking place was the leading fatality cause. Several organizational or physical conditions were present at many fatal sites; the most frequent was that no training had been provided for trenching. **CONCLUSIONS:** Presence of a competent, diligent person at the site would have prohibited most fatalities. The top cited violation was lack of protection, that is, benching, shoring, sloping, trench boxes, etc. (29 CFR 1926.652 (a) (1)).

Dement, J. M., et al. (2003). "Nail gun injuries among construction workers." *J Occup Environ Hyg* 18(5): 374-383.

Pneumatic nail guns greatly increase worker productivity and are extensively used in wood frame building construction, with especially high use in residential construction. One surveillance report of nail gun injuries in Washington State has been published; however, other literature consists largely of case reports and case series in trauma journals. The major objective of the current study was to investigate the occurrence of nail gun-associated injuries among construction workers and to identify preventable work-related factors associated with these injuries. Nail gun-related injuries occurring among a cohort of 13,347 carpenters in Ohio who worked union hours during the time period January 1, 1994, until September 30, 1997, were identified by matching the cohort with workers' compensation claims made to the Ohio Bureau of Workers' Compensation. We also analyzed workers' compensation claims for North Carolina Home Builders Association members for the period July 1996-November 1999 to identify nail gun-related injuries. Analyses included stratified analyses of claims by nature and body part injured, calculation of nail gun injury rates, and analyses of free text descriptions of injuries. Overall, nail gun injuries were responsible for 3.9 percent of workers' compensation claims with 8.3 percent to 25.5 percent of claims involving paid lost work time. The overall rate of nail gun injuries (cases per 200,000 work hours) was 0.33 in North Carolina and 0.26 in Ohio, reflecting the greater concentration of wood frame construction workers in the North Carolina population studied. Higher rates of injury were observed for carpenters in North Carolina and among residential carpenters in Ohio. The predominant body part injured was the hands/fingers, with 80 to 89 percent of injuries being nail punctures. Analyses of free text information for puncture injuries found approximately 70 percent of injuries to occur during the framing/sheathing stage of construction. Our data suggest that approximately 69 percent of puncture injuries may be due to an inadvertent gun

discharge or misfire, preventable in large part by the use of sequential triggers. Worker training and education also are important components of nail gun injury prevention.

Dong, X., et al. (2014). "Fatalities in the construction industry: findings from a revision of the BLS Occupational Injury and Illness Classification System." *Monthly Lab. Rev.* 137: 1.

Dong, X. S., et al. (2014). "Risks of a lifetime in construction Part I: Traumatic injuries." *Am J Ind Med* 57(9): 973-983.

Background: Estimates of occupational risk are typically computed on an annual basis. In contrast, this article provides estimates of lifetime risks for fatal and nonfatal injuries among construction workers. A companion paper presents lifetime risks for occupational illnesses. Methods: Using 2003-2007 data from three large data sources, lifetime risk was computed based on the number of fatal and nonfatal injuries per 100 FTEs for a working lifespan of 45 years. Results: For a working life in construction, the risk of fatal injuries were approximately one death per 200 FTE, and the leading causes were falls and transportation incidents. For nonfatal injuries resulting in days away from work, the adjusted lifetime risk was approximately 78 per 100 FTEs, and the leading causes were contact with objects/equipment, overexertion, and falls to a lower level. Conclusions: Lifetime risk estimates help inform both workers and policymakers. Despite improvements over the past decades, risks in construction remain high. *Am. J. Ind. Med.* 57:973-983, 2014. © 2014 Wiley Periodicals, Inc.

Flynn, M. A. and J. M. Sampson (2012). "Trench Safety-Using a Qualitative Approach to Understand Barriers and Develop Strategies to Improve Trenching Practices." *International Journal of Construction Education and Research* 8(1): 63-79.

Despite efforts to ensure workplace safety and health, injuries and fatalities related to trenching and excavation remain alarmingly high in the construction industry. Because properly installed trenching protective systems can potentially reduce the significant number of trenching fatalities, there is clearly a need to identify the barriers to the use of these systems and to develop strategies to ensure these systems are utilized consistently. The current study reports on the results of focus groups with construction workers and safety management personnel to better understand these barriers and to identify solutions. The results suggest several factors, from poor planning to pressures from experienced workers and supervisors, which present barriers to safe trenching practices. Based on the results, it is recommended that safety trainings incorporate unique messages for new workers, experienced workers and management in an effort to motivate each group to work safely as well as provide them with solutions to overcome the identified barriers. © 2012 Taylor and Francis Group, LLC.

Fortunato III, B. R., et al. (2012). "Identification of safety risks for high-performance sustainable construction projects." *Journal of Construction Engineering and Management* 138(4): 499-508.

The United States Green Building Council (USGBC)-sponsored Leadership in Energy and Environmental Design (LEED) green building program represents the largest program in the United States for the measurement, verification, and certification of green buildings. A recent study found that LEED-certified buildings have accounted for a higher injury rate than comparative traditional non-LEED buildings. This finding served as the impetus for the present study, which aimed to identify and evaluate the safety and health risks associated with the design elements and construction management practices implemented to achieve LEED certification. To explore this topic, six detailed case studies and two validation case studies were conducted following a strict protocol developed from guiding literature. The results indicate that (1) workers on LEED construction projects are exposed to work at height, with electrical current, near unstable soils, and near heavy equipment for a greater period of time than workers on traditional projects; (2) workers are exposed to new high-risk tasks such

as constructing atria, installing green roofs, and installing photovoltaic (PV) panels; and (3) some credits result in a positive impact on construction worker safety and health when low volatile organic compound (VOC) adhesives and sealants are specified. It is expected that these results can be used by practitioners to focus attention and resources on new high-risk work environments. © 2012 American Society of Civil Engineers.

Gambatese, J. and F. Zhang (2016). "Impact of advisory signs on vehicle speeds in highway nighttime paving project work zones." *Transportation Research Record* 2555: 65-71.

Pavement preservation projects typically require construction workers to conduct their work in close proximity to ongoing traffic. During paving operations, workers are located within a protected work zone. Some are situated nearby or engaged with the equipment, while others may be a long distance from the equipment and on foot. The study reported here was conducted to investigate how temporary advisory speed signs located periodically in a work zone affected vehicle speeds within highway paving project work zones. The study used an experimental approach that involved a multilane paving project on a high-speed roadway in Oregon. The posted regulatory speed on the roadway was 65 mph, which was reduced temporarily to 50 mph in the work zone. During construction, 35 mph advisory signs were posted along with other traffic control devices (e.g., "Speed 50" signs with radar speed display and portable changeable message signs on rollers), and the impact they had on vehicle speed and speed variability was evaluated. The research findings indicated that use of the 35 mph signs led to lower vehicle speeds within the work zone. The reduction in speed was greater by passenger cars than by trucks. The use of 35 mph advisory signs in work zones is recommended to help reduce vehicle speeds through the entire work zone and to minimize safety risks, especially to workers on foot and situated away from major equipment. © 2016, National Research Council. All rights reserved.

Gambatese, J. A. and S. Rajendran (2012). "Flagger illumination during nighttime construction and maintenance operations." *Journal of Construction Engineering and Management* 138(2): 250-257.

Ensuring the safety of flaggers, motorists, and workers is the primary consideration for flagging operations during nighttime construction and maintenance. A research study was conducted to evaluate four different types of light equipment—a light tower, 12 V spotlight, 12 V high-intensity discharge (HID) floodlight, and balloon lights—with regards to their level of illumination and uniformity over the flagging area and on the flagger's body. For each type of equipment, three input variables—lamp output, offset angle, and luminaire height—were varied to create a total of 44 different light equipment configurations. Each configuration was evaluated in terms of illumination, uniformity, and visibility in an urban/suburban setting. The study revealed that a light tower with 2,000 W output, 0 offset angle, and raised to a height of 20 feet was the highest ranked type of equipment. However, when ease of use, mobility, and cost were added as output measures, a 12 V spotlight with 0 offset angle and raised to a height of 10 feet received the highest ranking. Smaller light systems are easy to operate and transport, inexpensive, and more applicable for short-term flagging operations and for operations that need to be relocated frequently. Highly ranked configurations were typically those at 0 offset with luminaires elevated to 10 feet or higher. Configurations with higher luminaire heights and lamp outputs from 250 to 2,000 W may perform better depending on the roadway setting, duration of flagging operation, and amount of artificial background lighting. © 2012 American Society of Civil Engineers.

Golovina, O., et al. (2016). "Heat map generation for predictive safety planning: Preventing struck-by and near miss interactions between workers-on-foot and construction equipment." *Automation in Construction* 71: 99-115.

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The construction industry measures safety performance through lagging indicators such as counting numbers of illnesses, injuries, and fatalities. Active leading indicators, for example capturing hazardous proximity situations between workers-on-foot and heavy construction equipment, provide an additional metric for construction site personnel safety performance without incurring accidents. This article presents a method for recording, identifying, and analyzing interactive hazardous near miss situations between workers-on-foot and heavy construction equipment. Spatiotemporal GPS data are analyzed to automatically measure a hazard index that is visualized in form of a heat map. The graphical representation of computationally identified individual values in up-to-date building information models allows automatically generated personalized safety performance reports. These are based on specific near miss locations, environmental conditions, and equipment types. The presented research is based on previous isolated research efforts in equipment blind spot measurement, real-time location tracking, and proximity alert technology. It contributes the definitions and experimental validation of new safety parameters – such as entry of worker-on-foot in equipment blind spot – to determine the root causes that lead to equipment- and visibility-related fatalities on construction sites. Analysis of these root causes is important in preventing accidents in the first place. © 2016 Elsevier B.V.

Grant, A. and J. Hinze (2014). "Construction worker fatalities related to trusses: An analysis of the OSHA fatality and catastrophic incident database." *Safety science* 65: 54-62.

This study was conducted to gain a better understanding of the risks associated with truss installation in building projects. The Occupational Safety and Health Administration (OSHA) fatality and catastrophic incident database was analyzed for the years inclusive of 1990-2009. The database includes over 15,000 incidents, 211 of which pertain to trusses. The incidents were analyzed as to the number of fatalities per incident, the type of truss, the truss material, the activity taking place at the time of the accident, the release of the hoisting equipment, the initiation of the accident, the presence of bracing materials, the type of construction, the length of the trusses, the location of the incident, the type of accident (fall, caught-in/between, struck by, or electrocution), and the year the fatality occurred. Many of the accidents occurred at elevation and were initiated in large part by moving or falling objects. The study recommends that further research should focus on the stabilization of incomplete roof structures and the implementation of best practices for fall protection while performing truss-related work. © 2014 Elsevier Ltd.

Harris, E. B., et al. (2008). "Delayed femoral shaft fracture secondary to nail gun injury: a case report." *J Orthop Trauma* 22(7): 501-503.

Nail gun injuries are common workplace occurrences among construction workers; however, delayed fractures of the femur after a nail gun injury are not found in the medical literature. We report the case of a patient who presented with such a fracture 3 days after accidentally firing a nail into his thigh. The patient was taken to the operating room for intramedullary nailing, irrigation and debridement, and antibiotic beads. Standard postoperative hospital care was provided, and after 2 days of intravenous antibiotics, the patient was returned to the operating room for removal of the antibiotic beads and a delayed primary closure. At the most recent follow-up, over 1 year postinjury, he had radiographic healing and was asymptomatic. Although it is difficult to predict whether the stress riser created by a nail gun injury will lead to a fracture, weight-bearing status and the aggressiveness of treatment to prevent infection are factors that need to be carefully considered in patients with this type of injury.

Hassan, M. M., et al. (2010). "New Approach to Compare Glare and Light Characteristics of Conventional and Balloon Lighting Systems." *Journal of Construction Engineering and Management* 137(1): 39-44.

With the increasing needs to adopt nighttime construction strategies in order to avoid disruption of traffic flow, state agencies are currently experimenting with a new class of light towers known as balloon lights. Compared to regular lighting tower, balloon lights have been reported to reduce glare significantly and to provide more uniform lighting conditions at the site. The objective of this study was to measure light and glare characteristics of two balloon lighting systems in the field. Glare and lighting characteristics of this new class of light towers were compared to a conventional lighting system. For this purpose, field measurements were made of the pavement luminance and the horizontal and vertical illuminances on a predefined experimental grid. Results of this study indicated that while being comparable in terms of wattage and luminous flux, the tested balloon light systems differed in terms of light and glare characteristics. In addition, while conventional light tower provided greater illuminance at the light source than balloon lights, the disability glare was greater for conventional light tower than balloon lights when mounted at the same height. Results of this study revealed that optimum conditions should be sought in the work zone, through which adequate lighting conditions are provided for workers while disability glare is kept below a safe threshold for drive-by motorists. Plotting the maximum veiling luminance ratio (disability glare) against the workable distance provides a simple approach to consider the two factors concurrently in the design of work zone lighting.

Hinze, J. (2005). "Use of trench boxes for worker protection." *Journal of Construction Engineering and Management* 131(4): 494-500.

Safe work practices for the use of trench boxes identified by a survey of utility contractors are presented. Trench boxes are designed to protect workers from cave-ins, but human error and judgment can lead to unnecessary risks. The practices include the prevention of workers leaving the trench by the backfill and the provision of frequent training courses

Hinze, J. and G. Giang (2008). "Factors associated with construction worker eye injuries." *Safety science* 46(4): 634-645.

This paper reports on the results of a study of construction worker eye injuries collected by a firm that provides medical treatment services to over 40,000 construction workers each year. The records maintained by these clinics were examined for information related to injury causation and specific factors associated with construction worker eye injuries. A study was conducted on a random sample of a portion of the data involving construction workers eye injuries. The objective was to identify factors that were associated with eye injury causation. Over 600 eye injuries were examined. There was an equal distribution of right eye and left eye injuries. It was noted that for nearly 80% of the eye injuries, no eye protection was worn at the time of the injury. When dust particles were involved in the injury, no eye protection was worn in 97% of the instances. Specific patterns of injuries were noted. For example, when grinding metal, 66% of the injuries were to the right eyes. Additionally, the use of drills was associated with significantly more right eye injuries, while the use of hammers was associated with significantly more left eye injuries. These findings suggest that right or left eye injuries are associated with certain tools and tasks, suggesting that additional research is warranted in this area. Eye protection is one means of reducing these types of injuries, but it appears that task layout and tool design may also have an influence.

Hinze, J., et al. (2005). "The nature of struck-by accidents." *Journal of Construction Engineering and Management* 131(2): 262-268.

## **9 Topics in Construction Safety and Health: Struck-By and Caught-In Hazards**

Construction accidents are broadly categorized into five basic groups, namely falls (from elevation), shock (electrical), caught inbetween, struck-by, and other. 'Struck-by' accidents accounted for 22% of all construction-related fatalities recorded by the Occupational Safety and Health Administration between 1985 and 1989. Recent (1997 to 2000) data show that the percentage of struck-by accidents constituted 24.6% of the fatalities and serious construction worker injuries. Struck-by accidents primarily involve workers struck by equipment, private vehicles, falling materials, vertically hoisted materials, horizontally transported materials, and trench cave ins. Determining possible causation factors of these accident types is often difficult, due to the broad categories utilized in the accident coding system. This study resulted in gaining insights about the root causes of the struck-by injuries. By finding the root causes, effective methods for accident prevention can be developed

Hinze, J. W. and J. Teizer (2011). "Visibility-related fatalities related to construction equipment." *Safety science* 49(5): 709-718.

Research was conducted that isolated fatalities in which vision or lack of good visibility was the principle factor or contributing cause. The objective of examining the details surrounding these fatalities was to uncover the contributing factors and to identify the agents that compromised visibility. The study identified 659 fatality accidents from a data pool of 13511 OSHA-investigated cases. It was discovered that blind spots, obstructions and lighting conditions were the most common factors contributing to vision-related fatalities. This research also analyzed the specific conditions associated with particular pieces of construction equipment.

Howard, J., et al. (2017). "The new ANSI nail gun standard: A lost opportunity for safety." *Am J Ind Med* 60(2): 147-151.

Pneumatic nail guns have been shown in published studies to cause injury and death to both workers and consumers, but those equipped with sequential trigger mechanisms provide much greater safety protection against unintentional discharge than those equipped with contact triggers. In 2015 the American National Standards Institute (ANSI) approved a revision to its 2002 nail gun standard, but failed to require sequential triggers. Substantive and procedural deficiencies in the ANSI standard's development process resulted in a scientifically unsound nail gun safety standard, detracting from its use as the basis for a mandatory national safety standard and ultimately from its ability to protect worker and consumer users. *Am. J. Ind. Med.* 60:147-151, 2017. (c) 2016 Wiley Periodicals, Inc.

Hsiao, H., et al. (2008). "Effect of scaffold end frame carrying strategies on worker stepping response, postural stability, and perceived task difficulty." *Hum Factors* 50(1): 27-36.

**OBJECTIVE:** This study determined the most favorable strategy for carrying scaffold end frames while minimizing the risk of injuries from being struck by an object, falling, and overexertion. **BACKGROUND:** Scaffold erectors are at risk of high exposure to the aforementioned hazards associated with the dynamic human-scaffolding interface and work environments. Identifying an optimal work strategy can help reduce risk of injuries to the worker. **METHOD:** Three carrying methods, four types of work surfaces, two weights of scaffold frames, and three directions of stepping movement were tested in a laboratory with 18 construction workers. **RESULTS:** The effects of carrying method on postural instability and task difficulty rating were significant for handling the 22-kg end frame. Response time, postural instability, and perceived task difficulty rating were significantly reduced when the 9-kg end frame was used as compared with the 22-kg frame. **CONCLUSION:** The symmetric side-carrying method was the best option for handling 22-kg scaffold end frames. A 9-kg end frame (e.g., made of reinforced lightweight materials) has the potential to reduce injury risk among scaffold handlers during their scaffold erection and dismantling jobs. **APPLICATION:** Scaffold erectors may want to adopt the

symmetric side-carrying method as the primary technique for handling the 22-kg scaffold end frame, which is currently the one most used in the industry.

Jackson, S. A. and D. Loomis (2002). "Fatal occupational injuries in the North Carolina construction industry, 1978-1994." *J Occup Environ Hyg* 17(1): 27-33.

Occupational injury is a major public health problem and the cause of high rates of fatalities. The construction industry is one of the leading industries for on-the-job fatalities. The North Carolina Medical Examiner's system was used to identify all fatal unintentional injuries that occurred on the job in the state's construction industry between 1978 and 1994. The populations at risk were estimated from the 1980 and 1990 U.S. censuses. There were 525 identified deaths. All except two decedents were male, and the majority were Caucasian (79.2%). The mean age of decedents was 39 years. Death rates were higher among older workers. The crude fatality rate for the overall study period was 15.4 per 100,000 worker-years, with higher rates found among African-Americans (22.9) than among Caucasians (14.5). Occupations within the industry with the highest rates were laborers (49.5), truck drivers (43.2), operating engineers (37.2), roofers (32.8), and electricians (29.0). Falls (26.7%), electrocutions (20.4%), and motor vehicle accidents (18.9%) were found to be the leading causes of death. These findings suggest a need for continued attention to the hazards of heights and electric currents and a need for occupational safety standards for motor vehicles. This study also suggests that the hazards facing construction laborers require further investigation.

Kica, J. and K. D. Rosenman (2014). "Surveillance for work-related skull fractures in Michigan." *J Safety Res* 51: 49-56.

Objectives: The objective was to develop a multisource surveillance system for work-related skull fractures. Methods: Records on work-related skull fractures were obtained from Michigan's 134 hospitals, Michigan's Workers' Compensation Agency and death certificates. Cases from the three sources were matched to eliminate duplicates from more than one source. Workplaces where the most severe injuries occurred were referred to OSHA for an enforcement inspection. Results: There were 318 work related skull fractures, not including facial fractures, between 2010 and 2012. In 2012, after the inclusion of facial fractures, 316 fractures were identified of which 218 (69%) were facial fractures. The Bureau of Labor Statistic's (BLS) 2012 estimate of skull fractures in Michigan, which includes facial fractures, was 170, which was 53.8% of those identified from our review of medical records. The inclusion of facial fractures in the surveillance system increased the percentage of women identified from 15.4% to 31.2%, decreased severity (hospitalization went from 48.7% to 10.6% and loss of consciousness went from 56.5% to 17.8%), decreased falls from 48.2% to 27.6%, and increased assaults from 5.0% to 20.2%, shifted the most common industry from construction (13.3%) to health care and social assistance (15.0%) and the highest incidence rate from males 65 + (6.8 per 100,000) to young men, 20-24 years (9.6 per 100,000). Workplace inspections resulted in 45 violations and \$62,750 in penalties. Conclusions: The Michigan multisource surveillance system of workplace injuries had two major advantages over the existing national system: (a) workplace investigations were initiated hazards identified and safety changes implemented at the facilities where the injuries occurred; and (b) a more accurate count was derived, with 86% more work-related skull fractures identified than BLS's employer based estimate. Practical Applications: A more comprehensive system to identify and target interventions for workplace injuries was implemented using hospital and emergency department medical records. © 2014 Elsevier Ltd.

Lipscomb, H. (2010). "Knowledge and Recommendations of Sales Personnel Regarding Pneumatic Nail Gun Safety." CPWR Report.

## **11 Topics in Construction Safety and Health: Struck-By and Caught-In Hazards**

In this small project we collected data from points of sale or rental of framing nail guns to document knowledge of staff regarding the safety mechanisms on the tools they sell or rent and their recommendations for use. Less than 25% (24.4%) of sales/rental personnel mentioned any differences in triggers on the tools and of those who did, 60% of that group described the differences correctly. Overall, 29% correctly described the trigger differences including personnel who had to be directly asked. Less than half (40.6%) of the personnel we talked with provided us with any safety information about the tools

Lipscomb, H., et al. (2010). "Surveillance of nail gun injuries by journeymen carpenters provides important insight into experiences of apprentices." *New Solut* 20(1): 95-114.

Experienced journeymen conducted detailed surveillance interviews with injured apprentice carpenters (n = 413). Nail gun injuries commonly occurred due to inadvertent discharge, ricocheting or projectile nails, and penetration of the wood surface. Framing nailers with contact trip triggers were most often involved; these triggers allow nail discharge anytime the trigger and nose piece are both depressed including following recoil of the tool after firing. Injured workers made concrete and practical suggestions for prevention. Scenarios were identified where changes in work practice, safer triggers, and thoughtful training could prevent injuries. Most injuries were not reported through workers' compensation; this was often due to perceived lack of injury severity, but also involved subtle as well as overt pressures on apprentices not to report. These case-based analyses are consistent with reports that many injuries from nail guns could be prevented with existing safer trigger mechanisms and training. Efforts should also focus on improved injury reporting.

Lipscomb, H. J., et al. (2006). "Nail gun injuries in apprentice carpenters: risk factors and control measures." *Am J Ind Med* 49(7): 505-513.

**BACKGROUND:** Nail guns increase residential construction productivity but their use is associated with risk of injury. **METHODS:** Active surveillance data from 772 apprentice carpenters were used to document the injury risk associated with the use of nail guns and the potential impact of modifiable risk factors. Using reported work hours and nail gun injuries injury rates per 200,000 hr worked in the past year were calculated. Using estimates of hours of tool use, Poisson regression was used to calculate adjusted rate ratios for injury associated with time in the trade, trigger mechanism on the tools and training prior to injury. **RESULTS:** Forty-five percent of these apprentices had sustained a nail gun injury; injury rates in the past year based on hours of work were considerably higher than previously recognized. Those with less than 1 year in the trade compared to those with more than 5 years experience (RR = 2.7; 95% CI 1.2, 5.9) and those with no training in tool use (RR = 2.9; 95% CI 1.9, 4.4) were at greatest risk. After adjusting for experience and training, the rate of injury was twice as high with tools with a contact trip trigger compared to those with a sequential trigger (RR = 2.0; 95% CI 1.2, 3.3). **CONCLUSIONS:** Preventive measures should include change to the safer sequential trigger that prevents unintentional firing and early training in safe tool use. Because of the high prevalence of use of tools with contact trip triggers the greatest number of injuries among these apprentices could be prevented with an engineering solution.

Lipscomb, H. J., et al. (2010). "Perspectives of residential contractors on nail gun safety." *New Solut* 20(3): 337-348.

Perspectives on nail gun safety were sought from residential contractors as part of an injury surveillance and prevention effort (2005-2008). Anonymous surveys inquired about tool use, training, injury risk, and awareness of the 2003 American National Standards Institute (ANSI) standard calling for shipment of pneumatic nail guns used in wood framing with sequential actuation. Despite some awareness of inexperience, lack of training, speed and tool design in injury causation, 55 percent

consistently reported injuries resulted from worker carelessness. Contractors reported safety experiences of their employees were considerably better than those of other residential contractors. After five years, only 16 percent reported any awareness of the voluntary standard. These findings raise questions as to what gains can realistically be expected from passage of voluntary standards such as the one described here. Given that the epidemiology of acute injuries from pneumatic nail guns is now well-described, the safer sequential trigger should be required to protect workers.

Lipscomb, H. J., et al. (2015). "Musculoskeletal concerns do not justify failure to use safer sequential trigger to prevent acute nail gun injuries." *Am J Ind Med* 58(4): 422-427.

Background: Acute nail gun injuries can be controlled significantly by using tools with sequential triggers and training. Concern has been raised that sequential triggers, which require that the nose piece of the gun be depressed prior to pulling the trigger, could increase risk of musculoskeletal problems. Methods: We conducted active injury surveillance among union carpenter apprentices to monitor acute injuries and musculoskeletal disorders between 2010 and 2013. Results: Acute injury risk was 70% higher with contact trip rather than sequential triggers. Musculoskeletal risk was comparable (contact trip 0.09/10,000hr (95% CI, 0.02-0.26); sequential 0.08/ 10,000hr (95% CI 0.02-0.23)). Conclusions: Concern about excess risk of musculoskeletal problems from nail guns with sequential triggers is unwarranted. Both actuation systems carry comparable musculoskeletal risk which is far less than the risk of acute injury; there is clearly no justification for failure to prevent acute injuries through use of the safer sequential trigger. *Am. J. Ind. Med.* 58:422-427, 2015. © 2015 Wiley Periodicals, Inc.

Lipscomb, H. J., et al. (2008). "Prevention of traumatic nail gun injuries in apprentice carpenters: use of population-based measures to monitor intervention effectiveness." *Am J Ind Med* 51(10): 719-727.

INTRODUCTION: Nail guns are responsible for a significant injury burden in residential construction. Risk, based on hours of work, is particularly high among apprentice carpenters due in part to more frequent exposure to tool use. METHODS: Nail gun injuries were evaluated over 3 years among carpenters enrolled in two apprenticeship programs in the Midwest (2.3 million residential work hours observed) following initiation of training and a voluntary ANSI standard change calling for safer sequential triggers on framing nailers. Injury rates, based on hours of tool use, were calculated yearly. Rates and adjusted rate ratios were calculated with Poisson regression. Attributable risk percent (AR%) and population attributable risk (PAR%) were calculated yearly for modifiable independent risk factors for injury including lack of training in tool use and type of trigger mechanism on tools being used. RESULTS: As apprentices received training and safer trigger mechanisms became more widespread, injury rates decreased significantly (31%). While school training and hands-on mentoring were both important, injury rates were lowest among apprentices who received both. Although injury rates changed over the observation period, the relative risk comparing trigger mechanisms did not; contact trip triggers consistently carried a twofold risk. CONCLUSIONS: Although training and safer trigger use both increased, because of the relative prevalence of training and trigger exposures in this population, the engineering solution consistently had the potential to make more difference in population risk. Our findings demonstrate the utility of observational methods including measures of population-based risk in monitoring intervention effectiveness and making recommendations that lead to injury reduction.

Lipscomb, H. J., et al. (2010). "Continued progress in the prevention of nail gun injuries among apprentice carpenters: what will it take to see wider spread injury reductions?" *J Safety Res* 41(3): 241-245.

**PROBLEM:** Nail guns are a common source of acute, and potentially serious, injury in residential construction. **METHOD:** Data on nail gun injuries, hours worked and hours of tool use were collected in 2008 from union apprentice carpenters (n=464) through classroom surveys; this completed four years of serial cross-sectional data collection from apprentices. A predictive model of injury risk was constructed using Poisson regression. **RESULTS:** Injury rates declined 55% from baseline measures in 2005 with early training and increased use of tools with sequential actuation. Injury rates declined among users of tools with both actuation systems, but the rates of injury were consistently twice as high among those using tools with contact trip triggers. **DISCUSSION AND IMPACT:** Nail gun injuries can be reduced markedly through early training and use of tools with sequential actuation. These successful efforts need to be diffused broadly, including to the non-union sector.

Lipscomb, H. J., et al. (2011). "Buyer beware: personnel selling nail guns know little about dangerous tools." *Am J Ind Med* 54(8): 571-578.

**BACKGROUND:** Nail gun use is ubiquitous in wood frame construction. Accessibility and decreasing costs have extended associated occupational hazards to consumers. Compelling evidence documents decreased injury risk among trained users and those with tools with sequential triggers. To prevent inadvertent discharge of nails, this safer trigger requires the nose be depressed before the trigger is pulled to fire. The sequential trigger is not required by the Consumer Product Safety Commission (CPSC) or the Occupational Safety and Health Administration (OSHA) nor are there any guidelines for training. **METHODS:** We collected data from personnel at 217 points of sale/rental of framing nail guns in four areas of the country. **RESULTS:** Sales personnel had little understanding of risks associated with use of framing nail guns. Individuals who had used the tool and those working in construction outlets were more likely to be knowledgeable; even so, less than half understood differences in trigger/actuation systems. **CONCLUSIONS:** Consumers, including contractors purchasing for workers, cannot count on receiving accurate information from sales personnel regarding risks associated with use of these tools. The attitudes and limited knowledge of some sales personnel regarding these potentially deadly tools likely contributes to a culture accepting of injury. The findings demonstrate how influences on the culture of construction are not limited to workers, employers, or the places construction gets done.

Lipscomb, H. J., et al. (2008). "How much time is safety worth? A comparison of trigger configurations on pneumatic nail guns in residential framing." *Public Health Rep* 123(4): 481-486.

**OBJECTIVE:** Nail gun injuries are among the most common in wood frame construction. Despite evidence that the majority of injuries from unintentional firings could be prevented with a sequential trigger mechanism on the tools, the safer trigger has not been embraced in the fast-paced residential construction industry. An experiment was conducted in an attempt to realistically evaluate the magnitude of productivity concerns. **METHODS:** Ten journeymen carpenters built a yard shed on two occasions, using nail guns with two different trigger configurations, alternately, under controlled conditions. Mean differences in time required, nails used, and proper placement were evaluated considering the trigger used and whether the building was the carpenter's first or second project. **RESULTS:** The sequential trigger tool required a mean of 10 additional minutes of active nailing time, which represented 10% of mean nailing time (97 minutes) but only 0.77% of the total mean work time (1,298 minutes) to construct each shed. No significant differences were observed in nail count or placement. The majority of the time variability was related to who was using the tool, rather than the type of tool in the person's hand. **CONCLUSIONS:** Productivity concerns should focus more on improving the skill of the carpenter rather than on the trigger mechanism. Failure to place tools with the safer trigger configuration, which requires the nose piece to be depressed before the trigger is

pulled, in the hands of workers does not make sense given the frequency and potential repercussions of injuries associated with the use of these tools in wood framing.

Lipscomb, H. J. and A. L. Schoenfisch (2015). "Nail gun injuries treated in U.S emergency departments, 2006-2011: not just a worker safety issue." *Am J Ind Med* 58(8): 880-885.

**BACKGROUND:** Nail guns increase productivity in residential building but with a corresponding increase in worker injuries. They are also easily accessible, at low cost, to consumers. **METHODS:** Data from the occupational supplement to the National Electronic Injury Surveillance System (NEISS-Work) were used to calculate national estimates of work-related injuries from nail guns between 2006 and 2011. These were compared to estimates of consumer injuries obtained through online access to the Consumer Product Safety Commission's (CPSC) NEISS data. **RESULTS:** Approximately 25,000 ED-treated work-related and consumer nail gun injuries were estimated each year. During the construction economy collapse, injuries among workers declined markedly, closely following patterns of reduced residential employment. Reduction in consumer injuries was much more modest. **CONCLUSIONS:** Current nail gun injury patterns suggest marked blurring of work and home exposures. A united effort of CPSC, NIOSH, and OSHA is warranted to address these preventable injuries.

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Lipscomb, H. J., et al. (2010). "Non-fatal contact injuries among workers in the construction industry treated in U.S. emergency departments, 1998-2005." *J Safety Res* 41(3): 191-195.

**PROBLEM:** The National Occupational Research Agenda (NORA) for the construction industry calls for efforts to identify areas where guidance and regulation are needed to adequately prevent traumatic injuries resulting from a worker coming into contact with objects or equipment. **METHOD:** This descriptive study of work-related contact injuries in the construction industry that were treated in emergency departments (EDs) between 1998 and 2005 utilized records of work injuries captured through a national probability-based sample of U.S. hospitals with 24-hour ED services. **RESULTS:** Contact injuries accounted for 54% of all construction ED-treated injuries. Hospitalizations were most common for injuries from contact with discharged nails from pneumatic nail guns, with hand held power saws, and fixed saws. Some injuries were proportionally more serious and sometimes involved multiple workers including trenching injuries and those resulting from collapse of buildings under construction, walls, roofs, and scaffolding. **DISCUSSION AND IMPACT:** Given that nail gun use is limited primarily to wood frame construction, efforts are needed to control frequent serious injuries associated with these tools. Enforcement of existing trenching regulations is also needed.



Lipscomb, H. J., et al. (2010). "Nonfatal tool- or equipment-related injuries treated in US emergency departments among workers in the construction industry, 1998-2005." *Am J Ind Med* 53(6): 581-587.

**BACKGROUND:** Individuals in the construction industry are exposed to a variety of tools and pieces of equipment as they work. **METHODS:** Data from the National Institute for Occupational Safety and Health (NIOSH) occupational supplement to the National Electronic Injury Surveillance System (NEISS-Work) were used to characterize tool- and equipment-related injuries among workers in the construction industry that were treated in US emergency departments between 1998 and 2005. Based on a national stratified probability sample of US hospitals with 24 hr emergency services, NEISS-Work allows calculation of national injury estimates. **RESULTS:** Over the 8-year period between 1998 and 2005, we estimated 786,900 (95% CI 546,600-1,027,200) ED-treated tool- or equipment-related injuries identified by the primary or secondary source of injury code. These injuries accounted for a quarter of all ED-treated construction industry injuries. Although over 100 different tools or pieces of equipment were responsible for these injuries, seven were responsible for over 65% of the injury burden: ladders, nail guns, power saws, hammers, knives, power drills, and welding tools in decreasing order. **CONCLUSIONS:** Current injury estimates and their severity, marked by the proportion of cases that were not released after ED treatment, indicate interventions are particularly needed to prevent injuries associated with use of ladders as well as nail guns and power saws. Attention should focus on design and guarding to more efficiently prevent these injuries rather than simply calling for the training of workers in how to safely use a dangerous tool or piece of equipment.

Lombardi, D. A., et al. (2005). "Welding related occupational eye injuries: a narrative analysis." *Inj Prev* 11(3): 174-179.

**OBJECTIVE:** To determine the activities and circumstances proximal to a welding related occupational eye injury, a hybrid narrative coding approach derived from two well developed classification systems was developed to categorize and describe the activity, initiating process, mechanism of injury, object and/or substance, and the use of protective eyewear from the narrative text data reported for each injury. **METHODS:** Routinely collected workers' compensation claims over a one year period (2000) were analyzed from a large US insurance provider. An index term search algorithm of occupation, incident, and injury description fields identified 2209 potential welding related eye injury claims. After detailed review of these claims, 1353 welders and 822 non-welders were analyzed. **RESULTS:** During 2000, eye(s) as the primary injured body part accounted for 5% (n = 26 413) of all compensation claims. Eye injuries accounted for 25% of all claims for welders. Subjects were mainly male (97.1%) and from manufacturing (70.4%), service (11.8%), or construction (8.4%) related industries. Most injuries were foreign body (71.7%) or burn (22.2%) and 17.6% were bilateral. Common activities include welding (31.9%) and/or grinding (22.5%). Being struck by an airborne object occurred in 56.3% of cases. Non-welders showed similar patterns except that burns (43.8%) were more frequent and more often initiated by another worker (13.9%). **CONCLUSIONS:** Narrative injury text provides valuable data to supplement traditional epidemiologic analyses. Workers performing welding tasks or working nearby welders should be trained to recognize potential hazards and the effective use of proper safety equipment to prevent ocular injury.

Marks, E. D., et al. (2013). "Laser scanning for safe equipment design that increases operator visibility by measuring blind spots." *Journal of Construction Engineering and Management* 139(8): 1006-1014.

One-fourth of construction industry fatalities are caused by worker collisions with construction equipment. Nonvisible areas (blind spots) for equipment operators are contributing factors to many of these fatalities because equipment operators are unable to see ground personnel at certain locations around their equipment. Presented are the design and validation of a unique technique for measuring blind spots by using laser scanning data. The work demonstrates how the design of construction

equipment impacts the visibility of its operator. The contribution of the developed technique to the body of knowledge is that it can precisely evaluate and compare different equipment models and design characteristics. The blind spot measurement data for several similar pieces of equipment provides design suggestions that increase operator visibility. By increasing operator visibility through advanced equipment design, safety can be promoted on construction sites and in any other work environment, particularly with nearby ground workforce equipment.

Marks, E. D. and J. Teizer (2013). "Method for testing proximity detection and alert technology for safe construction equipment operation." *Construction Management and Economics* 31(6): 636-646.

The US construction industry continues to be among the leading industries for workplace fatalities after experiencing 818 fatalities in 2009. Approximately 21% of these fatalities resulted from workers being struck by an object or piece of construction equipment. The nature of construction sites often produces hazardous conditions by requiring ground workers and heavy construction equipment to operate in close proximity. The primary objective is to present a method for testing proximity detection and alert systems. Experimental trials were designed to deploy emerging radio frequency (RF) remote sensing technology to demonstrate the ability of the test method to evaluate the capability of proximity detection and alert systems to provide alerts when heavy construction equipment and workers are in too close proximity to each other. Numerous field experiments were designed and conducted to emulate typical interactions between workers on foot and construction equipment. These devices were installed on pieces of construction equipment in an outdoor environment to evaluate the test method for proximity detection and alert systems. Experimental results show that proximity detection and alert technologies can provide alerts to equipment operators at different pre-calibrated proximity alert ranges. The results suggest that the presented testing method adequately evaluated the reliability and effectiveness of the proximity detection and alert technology in the construction environment. © 2013 Taylor and Francis Group, LLC.

McCall, B. P. and I. B. Horwitz (2006). "Assessment of occupational eye injury risk and severity: an analysis of Rhode Island workers' compensation data 1998-2002." *Am J Ind Med* 49(1): 45-53.

BACKGROUND: Occupational eye injuries have been recognized as a serious health risk to workers and are in need of further investigation to develop effective interventions. METHODS: Rhode Island workers' compensation claims of ocular injury between 1998 through 2002 (n=8,877) were examined. The Current Population Survey was used to estimate occupational employment levels as a baseline for rate calculations. RESULTS: The estimated ocular injury claim rate was 32.9 per 10,000 workers (95% CI=32.3-33.6), with the cost of claims totaling \$1,514,666 and averaging \$171 per claim. The highest estimated claim rate of all occupations was found for construction laborers of 373.7 per 10,000 workers (95% CI=267.1-480.3). Relative to the durable manufacturing industry, the highest risk of injury resulting in disability indemnification was the wholesale trade industry (OR=2.18, 95% CI=1.19-4.01, P<0.05). CONCLUSIONS: Many of the eye injuries reported were likely preventable. Greater diligence, training, and safety precautions are needed to reduce the risk of eye injury to employees.

McCall, B. P., et al. (2009). "Occupational eye injury and risk reduction: Kentucky workers' compensation claim analysis 1994-2003." *Inj Prev* 15(3): 176-182.

BACKGROUND: Occupational eye injuries are a significant source of injury in the workplace. Little population-based research in the area has been conducted, and is necessary for developing and prioritizing effective interventions. METHODS: Workers' compensation data from the state of Kentucky for the years 1994-2003 were analysed by demographics, injury nature and cause, cost, and occupational and industrial characteristics. The US Bureau of Labor Statistics' Current Population

Survey was utilised to compute injury rates for demographic and occupational groups. RESULTS: There were 10,545 claims of ocular injury, representing 6.29 claims per 10,000 workers on average annually. A substantial drop in the claim rate was found after the state passed monetary penalties for injuries caused by employer negligence or OSHA violations. Claims by men were over three times more likely than those by women to have associated claim costs (OR 0.52; 95% CI 0.32 to 0.85;  $p = 0.009$ ). The highest eye injury rates per 10,000 of 13.46 (95% CI 12.86 to 14.07) were found for the helpers/labourers occupation, and of 19.95 (95% CI 18.73 to 21.17) for the construction industry. The total cost of claim payments over the period was over \$3,480,000, and average cost per claim approximated \$331. CONCLUSIONS: Eye injuries remain a significant risk to worker health, especially among men in jobs requiring intensive manual labour. Evidence showed that increased legislative regulation led to a decline in eye injuries, which was consistent with other recent findings in the area. Additionally, targeting groups most at risk, increasing worker training, providing effective eye protection equipment, and developing workplace safety cultures may together reduce occupational eye injuries.

McCann, M. (2006). "Heavy equipment and truck-related deaths on excavation work sites." *J Safety Res* 37(5): 511-517.

PROBLEM: Contact with objects and equipment is the third leading cause of death in construction. This study examines heavy equipment- and truck-related deaths in the excavation work industry in construction. METHODS: The Bureau of Labor Statistics Census of Fatal Occupational Injuries identified 253 heavy equipment related deaths on construction sites in the Excavation Work industry for the years 1992-2002. RESULTS: Heavy equipment operators and construction laborers made up 63% of the heavy equipment- and truck-related deaths. Backhoes and trucks were involved in half the deaths. Rollovers were the main cause of death of heavy equipment operators. For workers on foot and maintenance workers, being struck by heavy equipment or trucks (especially while backing up for workers on foot), and being struck by equipment loads or parts were the major causes of death. DISCUSSION: Ensuring adequate rollover protective structures for heavy equipment, requiring fastening of seat belts, adoption of a lock-out/tagout standard, establishing restricted access zones around heavy equipment, and requiring spotters for workers who must be near heavy equipment or trucks would reduce the risk of heavy equipment- and truck-related deaths in construction. IMPACT ON INDUSTRY: Safety of heavy equipment operators in particular is a major concern in excavation that needs to be addressed.

McCann, M. and M. T. Cheng (2012). "Dump truck-related deaths in construction, 1992-2007." *Am J Ind Med* 55(5): 450-457.

BACKGROUND: Dump trucks are universally used in construction and other industries to haul materials to the location and to remove waste materials. METHODS: The source for dump truck-related fatality data was the Bureau of Labor Statistics Census of Fatal Occupational Injuries (CFOI) Research File. RESULTS: From 1992 to 2007, 829 construction workers were killed in dump truck-related incidents nationwide. Of those, 336 were dump truck operators with 215 deaths occurring in street and highway incidents. Another 343 deaths involved workers on foot, three-quarters struck by dump trucks. Sixty-four of the construction workers killed were maintaining dump trucks, 22 when caught between the truck frame and a falling dump truck bed. Of the 86 other deaths, 55 involved streets and highways. CONCLUSIONS: Recommendations include: (i) improving the reporting of seat belt usage in fatality reports; (ii) requiring use of seat belts; (iii) requiring the use of backup alarms, spotters, or other methods to alert dump truck operators to workers in their blind spots; (iv) prohibiting direct dumping at river banks and embankments; (v) using cameras or radar to enforce stopping at railway

crossings; and (xi) enforcing worker safety practices (e.g., lockout/tagout procedures on elevated dump truck beds).

McCoy, A. J., et al. (2013). "Twenty years of work-related injury and illness among union carpenters in Washington State." *Am J Ind Med* 56(4): 381-388.

**BACKGROUND:** Individuals who work in the construction industry are at high risk of occupational injury. Robust surveillance systems are needed to monitor the experiences of these workers over time. **METHODS:** We updated important surveillance data for a unique occupational cohort of union construction workers to provide information on long-term trends in their reported work-related injuries and conditions. Combining administrative data sources, we identified a dynamic cohort of union carpenters who worked in Washington State from 1989 through 2008, their hours worked by month, and their workers' compensation claims. Incidence rates of reported work-related injuries and illnesses were examined. Poisson regression was used to assess risk by categories of age, gender, time in the union, and calendar time contrasting medical only and paid lost time claims. **RESULTS:** Over the 20-year study period, 24,830 carpenters worked 192.4 million work hours. Work-related injuries resulting in medical care or paid lost time (PLT) from work occurred at a rate of 24.3 per 200,000 hr worked (95% CI: 23.5-25.0). Medical only claims declined 62% and PLT claims declined 77%; more substantive declines were seen for injuries resulting from being struck and falls to a lower level than from overexertion with lifting. Differences in risk based on union tenure and age diminished over time as well. **CONCLUSIONS:** Significant declines in rates of reported work-related injuries and illnesses were observed over the 20-year period among these union carpenters. Greater declines were observed among workers with less union tenure and for claims resulting in PLT.

McMullin, N. and J. Queen (2004). "A construction worker with recent confusion, disorientation, and somnolence." *Cleve Clin J Med* 71(10): 809-814.

Worker struck in the head by falling object reported confusion, somnolence.

Mekker, M. M., et al. (2016). "Variable speed limit study upstream of an Indiana work zone with vehicle matching." *Transportation Research Record* 2555: 53-64.

Traffic management in work zones presents significant mobility and safety challenges for agencies. The goals of a work zone traffic management plan are to safely slow vehicles ahead of the work zone, maintain speeds that provide for the safety of motorists and construction workers, and manage the growth of queues. Historically, variable speed limits (VSLs) have been presented as a form of technology that can dynamically regulate speed in response to prevailing traffic conditions. However, techniques used to evaluate the impact of VSLs typically use aggregated statistics such as mean and standard deviation to determine the typical speed reduction. This paper presents a new methodology to evaluate the impact of VSL signage on the basis of individual vehicle matching. The speeds and speed changes of these matched vehicles were used to analyze individual driver response to the VSLs. This approach allows agencies to understand the impact that VSL signage has on the distribution of vehicle speeds. It was concluded that vehicles would need to observe multiple signs before any tangible reduction in speed limit would occur. The new vehicle-matching methodology showed that, after drivers observed a 15-mph drop in the speed limit for cars (10 mph for trucks) on three consecutive VSL signs, they reduced their speed by a median of 7.5 mph (5.8 mph for trucks). Overall, 4% of cars and 10% of trucks complied with the 55-mph speed limit after the observance of three VSL signs. © 2016, National Research Council. All rights reserved.

Mohan, S. and W. C. Zech (2005). "Characteristics of worker accidents on NYSDOT construction projects." *J Safety Res* 36(4): 353-360.

**INTRODUCTION:** This paper aims at providing cost-effective safety measures to protect construction workers in highway work zones, based on real data. Two types of accidents that occur in work zones were: (a) construction work area accidents, and (b) traffic accidents involving construction worker(s). **METHODOLOGY/RESULTS:** A detailed analysis of work zone accidents involving 36 fatalities and 3,055 severe injuries to construction workers on New York State Department of Transportation (NYSDOT) construction projects from 1990 to 2001 established that five accident types: (a) Struck/Pinned by Large Equipment, (b) Trip or Fall (elevated), (c) Contact w/Electrical or Gas Utility, (d) Struck-by Moving/Falling Load, and (e) Crane/Lift Device Failure accounted for nearly 96% of the fatal accidents, nearly 63% of the hospital-level injury accidents, and nearly 91% of the total costs. These construction work area accidents had a total cost of \$133.8 million. Traffic accidents that involve contractors' employees were also examined. Statistical analyses of the traffic accidents established that five traffic accident types: (a) Work Space Intrusion, (b) Worker Struck-by Vehicle Inside Work Space, (c) Flagger Struck-by Vehicle, (d) Worker Struck-by Vehicle Entering/Exiting Work Space, and (e) Construction Equipment Struck-by Vehicle Inside Work Space accounted for nearly 86% of the fatal, nearly 70% of the hospital-level injury and minor injury traffic accidents, and \$45.4 million (79.4%) of the total traffic accident costs. **CONCLUSIONS:** The results of this paper provide real statistics on construction worker related accidents reported on construction work zones. Potential preventions based on real statistics have also been suggested. **IMPACT ON INDUSTRY:** The ranking of accident types, both within the work area as well as in traffic, will guide the heavy highway contractor and owner agencies in identifying the most cost effective safety preventions.

Nadesan, K. (2000). "A fatal nail gun injury--an unusual ricochet?" *Med Sci Law* 40(1): 83-87.

An 18-year-old construction worker suddenly collapsed while handling a power-actuated nail gun and died shortly after. A neat, almost circular puncture wound was found on the front of his left chest. No fire-arm residues were detected on the surrounding skin. The police stated that it was an accidental injury, at a construction site, where a nail fired from a nail gun by the deceased had deflected off the wall and struck him on the front of the chest. Since the entry wound appeared to be a neat hole, and that too on the front of the left chest overlying the heart area, there was reluctance on the part of the pathologist to accept it as an accidental injury due to a ricochet. A visit to the scene, interrogation of witnesses, examination of the alleged tool and post-mortem X-ray of the deceased were undertaken prior to autopsy. A bent nail was found in the heart. The scene visit and the subsequent autopsy revealed that the nail took a roughly circular flightpath after it had struck the wall, all the while travelling with its pointed end directed forward. Within the body too, the nail maintained the same path. Various medicolegal issues are discussed pertaining to nail-gun injuries. The importance of a visit to the scene, examination of the alleged tool, interrogation of witnesses and the X-ray of the body, all prior to autopsy, are emphasized. The conclusion was: accidental death due to the unusual ricochet of a nail.

Nahmens, I. and L. H. Ikuma (2012). "Effects of lean construction on sustainability of modular homebuilding." *Journal of Architectural Engineering* 18(2): 155-163.

Construction activities and the built environment have an enormous effect on the environment, human health, and the overall economy. Sustainable homebuilding in all three dimensions of economic, environmental, and social effects is attainable through practical innovations and technologies. However, the greatest barrier to the widespread application of sustainable homebuilding is the higher initial costs largely attributable to the learning curve of workers building with these practical innovations and technologies, and the added cost resulting from ill-defined construction processes. To address these challenges and reach the ideal of sustainable construction, this paper proposes the use of lean construction as a viable and effective strategy, in particular the

lean tool kaizen. This paper uses several case studies to showcase the effect of lean on the triple bottom line of sustainability in modular homebuilding. Each case study highlights one dimension of sustainability. Lean construction resulted in a significant environmental effect by reducing material waste by 64%, a significant social effect by reducing or eliminating key safety hazards of excessive force, poor posture, and struck-by, and a significant economic effect by reducing production hours by 31%. Findings from this research will contribute to a better understanding of the effect of lean on homebuilding sustainability and will promote lean and safe building techniques in modular homebuilding. © 2012 American Society of Civil Engineers.

Odeh, I., et al. (2009). "Field experiments to evaluate and control light tower glare in nighttime work zones." *Journal of Construction Engineering and Management* 135(9): 911-919.

An increasing volume of highway repair and construction work is being performed during the off-peak nighttime hours to mitigate the impact of construction-related daytime traffic congestions and shorten the duration of construction operations. The utilization and placement of light towers to illuminate the work zone in this type of construction can cause harmful levels of glare for both drivers and construction workers. This paper presents the results of field experiments which were conducted to (1) study the levels of glare and lighting performance generated by light towers in and around nighttime work zones; (2) analyze the combined impact of the light tower set up parameters including its height as well as its aiming and rotation angles on glare and lighting performance; and (3) provide practical recommendations to reduce and control lighting glare in and around nighttime work zones. The results of these experiments confirm that the set up of light towers has a significant impact on glare and therefore it should be carefully designed and executed on nighttime highway construction projects to ensure the safety of the traveling public as well as construction workers.

Park, J., et al. (2016). "Performance test of wireless technologies for personnel and equipment proximity sensing in work zones." *Journal of Construction Engineering and Management* 142(1).

The dynamic nature and limited work space of roadway work zones contribute to dangerous working environments for construction workers. This environment can result in hazardous proximity situations because pedestrian workers are required to operate in close proximity to heavy construction equipment. A total of 609 work zone personnel fatalities were reported in 2012. Previous analysis of work zone fatality data found that the majority of the pedestrian worker and mobile object struck-by fatalities resulted when pedestrian workers were struck by construction equipment. These statistics indicate that current safety practices for pedestrian workers and equipment operators are inadequate. The objective of this study was to create and evaluate a proximity detection and alert system using Bluetooth sensing technology. The scope included hazardous proximity situations between pedestrian workers and construction equipment in roadway work zones at grade. Evaluation metrics were implemented to assess the tested proximity sensing systems including the cost, time and ease of calibration, required hardware, system capabilities, and many others. Commercially available radio frequency identification (RFID) and magnetic field proximity sensing systems were also evaluated to provide a basis for comparison. Various interaction scenarios between pedestrian workers and construction equipment were used in the evaluation of the system. The performance evaluation based on the statistical results showed that all the tested systems were considered reliable with minimal false alarm rates. However, the magnetic system showed a significant drop in its coverage range, while still providing reliable coverage measures, with a set of tests that were more dynamic than other sets of tests. The created Bluetooth system provided the highest level of simplicity with its minimized infrastructure, ease of calibration, and ease of installation. In sum, experimental results demonstrate that the created proximity detection and alert system (1) requires minimal infrastructure; (2) provides adequate alerts to equipment operators and pedestrian workers; and (3) provides, through an alert, an

additional layer of hazard avoidance in real time during hazardous-proximity situations in roadway work zones. © 2015 American Society of Civil Engineers.

Pierpont, Y. N., et al. (2008). "Nail-gun injuries to the hand." *Eplasty* 8: e52.

**BACKGROUND:** The nail gun is a commonly utilized tool in carpentry and construction. When used properly with appropriate safety precautions, it can facilitate production and boost efficiency; however, this powerful tool also has the potential to cause serious injury. The most common site of nail-gun injuries in both industrial and nonoccupational settings is the hand. **MATERIALS AND METHODS:** We report on two patients with nail-gun injuries to the hand. A review of the literature and discussion of clinical evaluation and treatment of nail-gun injuries to the hand are presented. **RESULTS:** Two patients present with soft tissue injuries to the hand with the nail embedded and intact at the injury site. Operative removal of the nail and wound care resulted in successful treatment in both cases. Nail-gun injuries to the hand vary in severity on the basis of the extent of structural damage. Treatment is based on the severity of injury and the presence and location of barbs on the penetrating nail. **CONCLUSION:** Healthcare providers must understand and educate patients on the prevention mechanics of nail-gun injuries. Nail-gun injuries to the hand necessitate appropriate evaluation techniques, understanding of surgical management versus nonsurgical management, and awareness of potential pitfalls in treatment.

Plog, B., et al. (2006). "Strategies to Prevent Trenching-Related Injuries and Deaths." CPWR Report.

Ray, S. J. and J. Teizer (2012). "Coarse head pose estimation of construction equipment operators to formulate dynamic blind spots." *Advanced Engineering Informatics* 26(1): 117-130.

Several hundred workers die in construction in the United States every year because equipment operators are unable to see their fellow workers during operation of their vehicle. In this paper we propose a step towards improving this situation by providing an automated method based on range imaging for estimating the coarse head orientation of a construction equipment operator. This research utilizes commercially-available low resolution range cameras to measure the continuously changing field-of-view (FOV) of an equipment operator in outdoor construction. This paper presents a methodology to measure so-called dynamic blind spot maps. The dynamic blind spot map is then projected on a known static equipment blind spot map that already exists to each construction vehicle. A robust computational coarse head pose estimation algorithm and results to three different pieces of construction equipment and multiple operators are presented. The developed method has the potential in automatically determining the spaces around vehicles that are currently not in the field-of-view of the vehicle operator thus providing eventually additional means and technology for improving safety in construction. © 2011 Elsevier Ltd. All rights reserved.

Ray, S. J. and J. Teizer (2013). "Computing 3D blind spots of construction equipment: Implementation and evaluation of an automated measurement and visualization method utilizing range point cloud data." *Automation in Construction* 36: 95-107.

Limited visibility due to blind spots of construction equipment was responsible for 55% of the visibility-related fatalities in the construction industry. Knowledge of blind spot aids in improving safety on construction sites and the design of equipment cabin itself. Existing approaches for blind spot measurement that follow international standards typically require a time-consuming set-up and are limited by the number of different visibility analyses that can be performed. A new approach to compute blind spot in a fast and efficient way using point cloud data of equipment is presented. The developed approach allows performing different analyses such as: volumetric blind spots, blind spot map, 12 m circumference visibility, rectangular 1 m boundary visibility, and worker visibility. In

addition, the above set of analyses can be performed from different viewpoints located virtually anywhere inside the equipment cabin. Validating against synthetic "noisy" point clouds, robustness and accuracy of the approach is established.

Schoenfisch, A. L., et al. (2013). "Work-related injuries among union drywall carpenters in Washington State, 1989-2008." *Am J Ind Med* 56(10): 1137-1148.

**BACKGROUND:** Drywall installers are at high-risk of work-related injury. Comprehensive descriptive epidemiology of injuries among drywall installers, particularly over time, is lacking. **METHODS:** We identified worker-hours and reported and accepted workers' compensation (WC) claims for a 20-year (1989-2008) cohort of 24,830 Washington State union carpenters. Stratified by predominant type of work (drywall installation, other carpentry), work-related injury rates were examined over calendar time and by worker characteristics. Expert interviews provided contextual details. **RESULTS:** Drywall installers' injury rates, higher than those of other carpenters, declined substantially over this period by 73.6%. Common injury mechanisms were struck by/against, overexertion and falls. Drywall material was considered a contributing factor in 19.7% of injuries. One-third of these drywall material-related injuries resulted in paid lost time, compared to 19.4% of injuries from other sources. Rates of injury were particularly high among workers with 2 to <4 years in the union. Notable declines over time in rates of overexertion injury in which drywall material was a contributing factor were still observed after controlling for secular temporal trends. Experts highlighted changes over the past 20 years that improved both work safety and, in some cases, production. **CONCLUSIONS:** Declines in drywall installers' injury rates over time likely reflect, in part, enhanced workplace safety, including efforts to reduce overexertion hazards associated with handling drywall. Continued injury prevention efforts are needed, particularly for less tenured workers. Given the potential for under-reporting to WC, additional sources of health outcomes data may provide a more complete picture of workers' health.

Schoenfisch, A. L., et al. (2010). "Nonfatal construction industry-related injuries treated in hospital emergency departments in the United States, 1998-2005." *Am J Ind Med* 53(6): 570-580.

**BACKGROUND:** This study documented the burden of nonfatal construction industry work-related injuries treated in hospital emergency departments in the United States (US) from 1998 through 2005 and described injured worker demographics and injury characteristics. **METHODS:** Data from the National Electronic Injury Surveillance System work-related injury supplement (NEISS-Work) were used to identify and describe construction industry-related injuries. Rates were estimated using data from the Current Population Survey. **RESULTS:** An estimated 3,216,800 (95% CI 2,241,400-4,192,200) construction industry-related injuries were seen in US emergency departments during the 8-year period; this represented an injury rate of 410/10,000 full-time equivalents and suggests that there are a greater number of construction injuries than reported through the Bureau of Labor Statistics' Survey of Occupational Injuries and Illnesses (BLS SOII). Common characteristics included diagnoses of laceration, sprain/strain, and contusion/abrasion; events of contact with an object/equipment, bodily reaction/exertion, and falls; and sources of injury of parts/materials; structures/surfaces; and tools/instruments/equipment. The upper extremities were most often affected. **CONCLUSIONS:** These data highlight the high burden of nonfatal construction industry-related injuries. The limitations of national occupational injury data sources inherent in relying on OSHA logs highlight the utility of NEISS-Work data in occupational injury research. While data captured from emergency departments are not immune to factors that influence whether a worker or an employer reports an injury as work-related or files a workers' compensation claim, emergency department data as collected through NEISS-Work do not rely on employer involvement in order to be classified as work-related.



Schoonover, T., et al. (2010). "Prioritizing prevention opportunities in the Washington State construction industry, 2003-2007." *J Safety Res* 41(3): 197-202.

**OBJECTIVE:** This study compares construction industry groups in Washington State by injury severity and cost, and ranks industry groups according to potential for prevention. **METHODS:** All Washington State workers' compensation compensable claims with date of injury between 2003 and 2007 were classified into North American Industrial Classification System (NAICS) industry groups. Claims were then aggregated by injury type and industry groups were ranked according to a prevention index (PI). The PI is the average of the rank orders of the claim count and the claim incidence rate. A lower PI indicates a higher need for prevention activities. The severity rate was calculated as the number of days of time loss per 10,000 full-time equivalents (FTEs). **RESULTS:** For all injury types, construction industry groups occupy 7 of the top 15 PI ranks in Washington State. The severity rate among construction industry groups was twice that for non-construction groups for all injury types. Foundation, structure, and building exterior contractors (NAICS 2381) ranked highest in prevention potential and severity among construction industry groups for most common injury types including falls from elevation, fall on same level, struck by/against, and musculo-skeletal disorders of the neck, back, and upper extremity (WMSDs). Median claim costs by injury type were generally higher among construction industry groups. **CONCLUSIONS:** The construction industry in Washington State has a high severity rate and potential for prevention. The methods used for characterizing these industry groups can be adapted for comparison within and between other industries and states. **IMPACT ON INDUSTRY:** These data can be used by industry groups and employers to identify higher cost and higher severity injury types. Knowledge about the relative frequencies and costs associated with different injury types will help employers and construction industry associations make better informed decisions about where prevention efforts are most needed and may have the greatest impact. The results of this study can also be used by industry stakeholders to cooperatively focus on high cost and high severity injuries and explore best practices, interventions, and solutions as demonstrated by efforts to prevent musculoskeletal disorders in masonry (Entzel, Albers, & Welch, 2007). Initiating construction industry groups to focus on high cost and high severity injuries may also help prevent other types of injuries.

Sheikh, N. M., et al. (2010). "Application of precast concrete barrier adjacent to steep roadside slope." *Transportation Research Record*: 121-129.

When concrete barriers are installed adjacent to drop-offs or steep roadside slopes such as 1.5H:1V, a cast-in-place concrete moment slab is usually attached to the base of the barrier to resist lateral and overturning forces during vehicle impact. Cast-in-place construction can require more time on-site to build forms, pour the concrete, and allow for curing. This time constraint results in an increase in disruption to traffic and more exposure for construction workers. Furthermore, the installation of a moment slab is very costly and requires an additional construction phase to build the slab. Because the slab is normally under the shoulder and possibly the lanes, the disruption of traffic flow is increased. A new application of a precast 42-in.-tall single-slope concrete barrier for use in front of steep slopes was developed that does not require a moment slab. The lateral movement of the barrier is restricted by embedding it in soil. This design also reduces the embankment behind the barrier to 2 ft. The embedded barrier application was successfully evaluated under Manual for Assessing Safety Hardware Test Level 3 criteria. The permanent deflection of the barrier was 5.5 in. The use of the embedded concrete barrier in lieu of the typically installed barrier with a moment slab is expected to result in cost savings of approximately \$300 per linear foot and reduced time to construct.

Shen, X., et al. (2016). "Hazardous Proximity Zone Design for Heavy Construction Excavation Equipment." *Journal of Construction Engineering and Management* 142(6): 05016001.

The construction industry continues to be among the leading industries for workplace fatalities in the United States. After experiencing 824 fatal injuries in 2013, the construction industry ranks as one of the most dangerous work environments when compared with other private industrial sectors in the United States. Conditions of construction sites often produce hazardous proximity situations by requiring pedestrian workers and heavy equipment to operate at close proximity. Injury and fatality statistics indicate that current safety practices of construction workers have proven inadequate. The research aims to design hazard zone around pieces of heavy construction equipment in which site personnel should not enter during construction operations. The scope is limited to construction sites and equipment at a horizontal grade and hazards between heavy construction excavation equipment and workers-on-foot. A framework for creating the hazard zone around a piece of construction equipment is presented including detailed methodology discussions for each step. A user interface is also presented that automatically creates a hazard zone around select pieces of construction equipment based on user-defined parameters. The hazard zone for a dump truck, excavator, and backhoe are shown using the created framework. Results indicate that hazard zones for pedestrian workers can be created around construction equipment to increase hazard awareness for workers. Contributions for this research include a user-friendly hazard zone creation tool and database for safety managers and scientific evaluation data of the created hazard zone framework. Safety standards can be formulated based on the design and implement hazard zones on equipment.

Smith, C. K., et al. (2010). "Temporary workers in Washington state." *Am J Ind Med* 53(2): 135-145.

**BACKGROUND:** Evidence regarding the unequal burden of occupational injuries between workers employed by temporary agencies and those in standard employment arrangements is unclear. Studies range from no significant differences in risk to substantial increased risk for temporary workers. The purpose of this study is to compare the workers' compensation experience of a large cohort of temporary agency employed workers with those in standard forms of employment. **METHODS:** Washington State Fund workers' compensation data were obtained for claims with injury dates from January 1, 2003 to June 30, 2006, resulting in 342,540 accepted claims. General descriptive statistics, injury rates (per 10,000 FTE), and rate ratios (temp agency/standard employer) were computed by injury type and industry. **RESULTS:** Temporary agency employed workers had higher rates of injury for all injury types, and higher median time loss (40 vs. 27 days) but lower time loss costs (median \$1,224 vs. \$1,914,  $P < 0.001$ ) and lower medical costs (\$3,026 vs. \$4,087,  $P < 0.001$ ) than standard arrangement workers. Temporary agency workers had substantially higher rates for "caught in" and "struck by" injuries in the construction (IRR 4.93; 95% CI 2.80-8.08) and manufacturing (IRR 4.05; 95% CI 3.25, 5.00) industry sectors. **CONCLUSION:** Temporary agency employed workers have higher claims incidence rates than those in standard employment arrangements. The rate ratios are twofold higher in the construction and manufacturing industry sectors. More research is needed to explore potential reasons for this disparity in occupational injuries. Industry or some measure of job exposure should be included when comparing injury rates in different types of employment in order to better identify areas for prevention.

Stern, L. C. and T. A. Moore (2011). "Nail gun injury to the sacrum: case report and review of the literature." *Spine (Phila Pa 1976)* 36(26): E1778-1780.

**STUDY DESIGN:** Case report. **OBJECTIVE:** Review the literature that relates to nail gun injuries to the spine using a case report illustration. **SUMMARY OF BACKGROUND DATA:** Approximately 37,000 patients present to the US emergency departments annually with injuries inflicted from nail guns, 60% of which occur in the workplace. **METHODS:** A case report of a nail gun injury to the sacrum is presented and the pertinent literature is then reviewed. **RESULTS:** A 21-year-old male roofer presented to the emergency department after suffering an accidental, self-inflicted nail gun injury to the midline

of his sacrum. The patient was neurologically intact and a computed tomography (CT) of the pelvis with rectal contrast noted the nail to be located midline within the spinal canal at the level of S3 without injury to the rectum. The patient was taken to the operating room for removal of the nail under general anesthesia and exploration of the wound, specifically looking for evidence of a dural tear, which was determined not to be present. The wound was closed primarily and the patient was given 24 hours of intravenous antibiotics followed by 2 weeks of oral antibiotics. At follow-up, the patient had returned to his roofing job full-time and there was no evidence of infection on examination or retained foreign bodies by radiograph. CONCLUSION: On the basis of our experience and a review of the literature, in terms of treating a nail gun injury to the sacrum we recommend the following: exploration in the operating room to investigate the possibility of a dural tear, thorough irrigation, and debridement, especially in the case of barbed nails, and consultation with general surgery to determine if there is any injury to intrapelvic contents before surgery. An infectious disease consultation postoperatively may also assist in proper selection and duration of antibiotic therapy.

Sun, C., et al. (2012). "Safety evaluation of sequential warning lights in tapers at nighttime work zones." *Transportation Research Record*: 1-8.

Safety improvement at nighttime work zones is important because of visibility concerns after dark. The deployment of sequential lights is an innovative method to improve driver recognition of lane closures and work zone tapers. Sequential lights are wireless warning lights that flash in a sequence to delineate clearly the taper at work zones. The effectiveness of sequential lights was investigated with the use of controlled field studies. Traffic parameters were collected at the same field site with and without the deployment of sequential lights. Three surrogate performance measures (the speeds of approaching vehicles, the number of late taper merges, and the locations where vehicles merged into an open lane from a closed lane) were used to determine the impact of sequential lights on safety. The results of this study showed that sequential warning lights had a net positive effect: the warning lights reduced the speeds of approaching vehicles and enhanced driver compliance, and the lights shifted overall merge behavior upstream. Statistically significant decreases of 3.56 km/h (2.21 mph) mean speed and 1.61 km/h (1 mph) 85% speed resulted with sequential lights. The shift in the cumulative speed distributions to the left (i.e., speed decrease) was found to be statistically significant with the Kolmogorov-Smirnov test. With sequential lights, there was a statistically significant increase of 1.47 km/h (0.91 mph) in the speed standard deviation, and the percentage of vehicles that merged earlier increased from 53.49% to 65.36%.

Tayabji, S., et al. (2012). "Joint load transfer and support considerations for jointed precast concrete pavements." *Transportation Research Record*: 74-80.

Many agencies recently have started investigating strategies for pavement rehabilitation and reconstruction that are faster to implement and can produce longer-lasting pavements than previous strategies. Most highway agencies no longer consider expedient rehabilitation that results in a shorter pavement lifespan acceptable. One promising alternative rehabilitation strategy is the effective use of modular pavement technologies, principally precast concrete pavement (PCP) systems, which provide for the rapid repair and rehabilitation of pavements and also result in durable, long-lasting pavements. Rapid construction techniques can significantly minimize the impact on the driving public because lane closures and traffic congestion are minimized. Road user and worker safety also are improved by reduced road users' and workers' exposure to construction traffic. The renewal focus area under Strategic Highway Research Program 2 (SHRP 2) emphasizes the need to complete highway pavement projects rapidly, with minimal disruption to highway users and local communities, and to produce pavements that are long lasting. One goal of this focus area includes applying new methods and materials to preserve, rehabilitate, and reconstruct roadways. The effective use of PCP technologies for

rapid repair, rehabilitation, and reconstruction of pavements addresses this goal. One of the projects funded under SHRP 2 is Project R05, Modular Pavement Technology. The objective of Project R05 was to develop better guidance for use by highway agencies to design, construct, install, maintain, and evaluate modular pavement systems, principally PCP systems. Findings related to joint load transfer and support considerations for jointed PCP from the Project R05 study are presented.

Teizer, J., et al. (2010). "Autonomous pro-active real-time construction worker and equipment operator proximity safety alert system." *Automation in Construction* 19(5): 630-640.

Over six hundred construction worker deaths occurred in the United States during the inclusive years of 2004 to 2006 that were related to construction equipment and contact collisions. This paper presents findings about emerging radio frequency (RF) remote sensing and actuating technology that can improve construction safety by warning or alerting workers-on-foot and equipment operators in a pro-active real-time mode once equipment gets too close in proximity to unknown or other equipment. A review is provided on the background and importance of safety related to various pieces of construction equipment. Pro-active real-time proximity and alert technology for daily construction operations is introduced to solve this problem. Results of various field experiments that tested the proximity and alert technology are presented. A discussion follows on how such technology can improve objective construction site safety data collection and lead to more effective construction workforce safety training and education. © 2009 Elsevier B.V. All rights reserved.

Theiss, L., et al. (2011). "Merging taper lengths for lane closures of short duration." *Transportation Research Record*: 64-70.

The merging taper lengths described in the Manual on Uniform Traffic Control Devices are assumed to apply to roadways of all types. Yet driver expectations and traffic operations differ greatly between the high-speed freeway and the lower-speed, signalized urban street. The research described in this paper investigated the operational impacts of reduced taper lengths on lower-speed urban arterials. The study found that drivers did react differently after merging taper lengths were modified. Both the merging taper and the work vehicle in the closed lane served as visual cues to drivers to vacate the closed lane. On longer taper lengths, channelizing devices were used to motivate drivers to change lanes. Vehicles with occluded views, however, were more likely to become trapped and to create mobility issues in the traffic stream. On shorter taper lengths, drivers reacted to the merging taper and the work vehicle itself. Although fewer vehicles became trapped near the merge point, that point was much closer to the work vehicle. Under the absence of taper conditions (i.e., mobile operations), in which the work vehicle was much larger than the trucks used during the merging taper observations, fewer drivers remained in the closed lane at comparable locations. Both motorist and worker safety must be considered in the selection of an appropriate merging taper length for work activities of shorter duration on urban arterials. Further research should investigate the implications for worker safety of installing and removing various merging taper lengths as compared with the time it takes to complete the work activity.

Tiesman, H. M., et al. (2011). "The epidemiology of fatal occupational traumatic brain injury in the U.S." *Am J Prev Med* 41(1): 61-67.

**BACKGROUND:** Although traumatic brain injury (TBI) is one of the leading causes of death and disability in the U.S., work-related TBI has not been well documented. **PURPOSE:** The aim of this study was to describe the epidemiologic characteristics and temporal trends of fatal occupational TBI in the U.S between 2003 and 2008. **METHODS:** A cross-sectional analysis of the Census of Fatal Occupational Injury database was performed. Both the Occupational Injury and Illness Classification System nature of injury codes and body part codes were used to define TBIs. Fatality rates were calculated using

denominators derived from the Current Population Survey. Fatality rates were compared among industries, cause of death, and demographics with rate ratios (RRs) and 95% CIs. Poisson regression was used to assess trends in fatality rates. Data were analyzed in 2009-2010. RESULTS: Nearly 7300 occupational TBI deaths occurred between 2003 and 2008, for an average fatality rate of 0.8 per 100,000 workers per year. The leading causes of occupational TBI death were as follows: motor vehicle (31%); falls (29%); assaults and violent acts (20%); and contact with objects/equipment (18%). Fatality rates were 15 times higher in men compared with women (RR=15, 95% CI=13.7, 16.3). Workers aged  $\geq 65$  years experienced the highest TBI fatality rate of all age groups (2.5 per 100,000 per year). Construction, transportation, and agriculture/forestry/fishing industries recorded nearly half of all TBI fatalities (n=1828, n=825, n=761, respectively). Occupational TBI death rates declined 23% over the 6-year period ( $p < 0.0001$ ). CONCLUSIONS: This study provides the first national profile of fatal TBIs occurring in the U.S. workplace. Prevention efforts should be directed at those industries with the highest frequency and/or highest risk. The construction industry had the highest number of TBIs, and the agriculture, forestry, and fishing industry had the highest rates. Additionally, workers aged  $> 65$  years in all industries would be a good target for future prevention efforts.

Vosbikian, M. M., et al. (2017). "The Impact of Safety Regulations on the Incidence of Upper-Extremity Power Saw Injuries in the United States." *Journal of Hand Surgery* 42(4): 296.e291-296.e210.

Purpose Over 50,000 power saw-related injuries occur annually in the United States. Numerous safety measures have been implemented to protect the users of these tools. This study was designed to determine which interventions, if any, have had a positive impact on the safety of the consumer or laborer. Methods We queried the National Electronic Injury Surveillance System database for hand and upper-extremity injuries attributed to power saws from 1997 to 2014. Demographic information including age, sex, date of injury, device, location, body part involved, diagnosis, and disposition was recorded. We performed statistical analysis using interrupted time series analysis to evaluate the incidence of injury with respect to specific safety guidelines as well as temporal trends including patients' age. Results An 18% increase in power saw-related injuries was noted from 1997 (44,877) to 2005 (75,037). From 2006 to 2015 an annual decrease of 5.8% was observed. This was correlated with regulations for power saw use by the Consumer Safety Product Commission (CPSC) and Underwriters Laboratories. Mean age of injured patients increased from 48.8 to 52.9 years whereas the proportion of subjects aged less than 50 years decreased from 52.8% to 41.9%. These trends were most pronounced after the 2006 CPSC regulations. Conclusions The incidence of power saw injuries increased from 1997 to 2005, with a subsequent decrease from 2006 to 2015. The guidelines for safer operation and improvements in equipment, mandated by the CPSC and Underwriters Laboratories, appeared to have been successful in precipitating a decrease in the incidence of power saw injuries to the upper extremity, particularly in the younger population. Clinical relevance The publication of safety regulations has been noted to have an association with a decreased incidence in power saw injuries. Based on this, clinicians should take an active role in their practice as well as in their professional societies to educate and counsel patients to prevent further injury. © 2017 American Society for Surgery of the Hand

Welch, L. S., et al. (2001). "Injury surveillance in construction: eye injuries." *Appl Occup Environ Hyg* 16(7): 755-762.

Occupational eye injuries are both common and preventable. About 20% of occupational eye injuries occur in construction. To investigate the nature of eye injuries among construction workers, we analyzed a large data set of construction worker injuries. In addition, we interviewed 62 workers with eye injuries to further explore circumstances of eye injury and workers' attitudes and behavior toward the use of eye protection. Eleven percent (363 cases) of the 3,390 construction workers in our data set

were treated for eye injuries. Welders, plumbers, insulators, painters/glaziers, supervisors, and electricians had a higher proportion of all injuries due to eye injuries than other trades. Nearly half of the diagnoses were abrasions (46%) followed by foreign objects or splash in the eye (29%), conjunctivitis (10%), and burns (5%). In the interviews with 62 workers, we found that employers very frequently required eye protection for all tasks or for high-risk tasks, and workers report wearing eye protection regularly. However, most did not wear eye protection with top and side shields; if we believe the injuries occurred because a particle or liquid passed between the glasses and the workers' faces, increased use of goggles or full shields would have prevented two-thirds of this group of injuries.

Welch, L. S., et al. (2005). "Occupational injuries among construction workers treated in a major metropolitan emergency department in the United States." *Scand J Work Environ Health* 31 Suppl 2: 11-21.

**OBJECTIVES:** The aim of this study was to profile construction workers' injuries for more information about the causes of nonfatal construction worker injuries and identify injury trends for further investigations and prevention programs. **METHODS:** An injury-tracking program for emergency departments was established in 1990 to gather the data needed for the study. Profiles were obtained for 2916 construction workers' injuries that were identified on hospital registration forms at the George Washington University Emergency Department in Washington, DC, from November 1990 through October 1997. Laborers and construction workers who did not specify a trade were combined, and together they made up the largest group--29% of the injured workers. **RESULTS:** The leading cause of injury was contact with cutting or piercing objects--most often pieces of metal, razors, knives, power tools, and nails. Workers striking against objects or being struck by objects (including falling objects) accounted for the second-largest group of injuries, and the third leading injury circumstance was falling--either from a height or on the same level. Detailed injury statistics are presented by trade, showing patterns of injury that reflect tasks of these trades and which injuries predominated in each trade. Although many previous reports have described construction workers' injuries, very few have provided detailed data by trade. **CONCLUSIONS:** The details presented in this analysis allow for a better understanding of the injury circumstances and provide a starting point for injury prevention programs.

Yuan, C., et al. (2016). "Vision-based excavator detection and tracking using hybrid kinematic shapes and key nodes." *Journal of Computing in Civil Engineering* 31(1).

Enhancing workplace safety continues to be a major task in the construction industry. Approximately 75% of struck-by fatalities are caused by inappropriate spatial-temporal relationships between construction workers and heavy equipment. Construction safety can be improved if the location and movement of heavy equipment are tracked in real time. However, detecting and tracking heavy equipment with kinematic joints and changing poses, such as excavators, is still a challenge for vision-based sensing methods. This study proposes to detect and track excavators using stereo cameras based on hybrid kinematic shape and key node features. Specifically, templates of excavator components are synthesized for detection following kinematic constraints of each component. Thereafter, a fast directional chamfer matching algorithm is used to detect the excavator components, and the detected components are articulated at the key nodes. Finally, the three-dimensional positions of the key nodes are tracked through triangulation to depict the excavator movements. Results from field experiments demonstrated that concatenating the detected components following a matching order enhances the detection performance. It is also found that the stereo triangulation enables efficient tracking of excavator movements by targeting at the key nodes. © 2016 American Society of Civil Engineers.

Zhang, F. and J. A. Gambatese (2017). "Highway Construction Work-Zone Safety: Effectiveness of Traffic-Control Devices." *Practice Periodical on Structural Design and Construction* 22(4).

Pavement preservation is a proactive approach to maintaining existing highways. Freeway-preservation projects typically require construction workers to conduct their work in close proximity to ongoing high-speed traffic. This exposure creates a dangerous situation for both workers and passing motorists. A recent study funded by the Oregon Department of Transportation (ODOT) implemented and evaluated different types of traffic-control devices on highway-preservation projects to reduce vehicle speeds and create safer work zones. The study implemented combinations of multiple traffic-control devices [speed-limit ("Speed 50") signs, portable changeable message signs (PCMSs), and radar speed displays] in two case study projects and evaluated their effects on vehicle speed. The researchers used fixed-location sensors and probe vehicle runs to collect data on traffic speed. The results indicate that using a combination of PCMSs and radar speed displays is the best choice. Although data from the probe vehicle runs could not be used for statistical analysis because of limitations on the number of runs conducted, the data provide a vivid and direct view of how individual motorists behave in a construction work zone. The study also provides valuable insight into the effectiveness of the traffic-control measures that contractors can use to design safety into their work operations and further improve the safety in work zones. © 2017 American Society of Civil Engineers.

