FINAL REPORT

CONSTRUCTION SAFETY ALLIANCE

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NIOSH Grant No.
1 RO1 OH07553

25 November 2003

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

ABC: Associated Builders and Contractors

AFL-CIO: American Federation of Labor and Congress of Industrial Organizations

AGC: Associated General Contractors

ANOVA: Analysis of Variance

ASCE: American Society of Civil Engineers

BLS: The Bureau of Labor Statistics

CDC: Centers for Disease Control and Prevention

CII: Construction Industry Institute

CFOI: Census of Fatal Occupational Injuries

CSA: Construction Safety Alliance

EMR: Experience Modification Ratio

GCOHC: Greater Cincinnati Occupational Health Center

IBEW: International Brotherhood of Electrical Workers

LWCIR: Lost Workday Case Incidence Rate

MOS: The Medical Outcomes Study Physical Functioning Measure

NCHS: National Center for Health Statistics

NHIS: National Health Interview Survey

NUCA: National Utility Contractors Association

OSHA: The Occupational Safety and Health Administration

The Occupational Safety and Health Act

PFAS: Personal Fall Arrest System

PPE: Personal Protective System

RDMS: Relational Database Management System

RIR: Recordable Injury Rate, Recordable Incident Rate

SIC: Standard Industrial Classification

SPSS: Statistical Package for the Social Sciences

SQL: Structured Query Language

TRIR: Total Recordable Incident Rate

UBC: United Brotherhood of Carpenters

LIST OF FIGURES

LIST OF TABLES

Section V

Section VI

Section VII

Section VIII

ABSTRACT

In order to make a significant impact in the safety and health culture of the U.S. construction industry, the Construction Safety Alliance (CSA) was funded in 2001 by the Centers for Disease Control and Prevention (CDC), the National Institute for Occupational Safety and Health (NIOSH). The alliance was established as a multi-university, interdisciplinary university-industry partnership to develop, implement and evaluate a National Research Program in construction safety and health. Major participants include the Division of Construction Engineering and Management and the School of Health Science at Purdue University, the University of Cincinnati Medical School, the College of Architecture, University of Florida, Gainesville, and the Construction Industry Institute at the University of Texas, Austin.

This report reflects work done by CSA during the period 2001-2003 relating to:

(1) Falls from Elevation

(2) Safer Trenching Operations

(3) The Owner's Role in Safety

(4) Issues related to Retired Workers and Small Construction Companies

(5) Web-Based Dissemination of Important Health and Safety Information to Construction Safety Professionals.

The projects described in this report form an initial structure for future work designed to provide a unified and quantitative approach to health and safety research. The research emphasizes methodologies and information dissemination intended to firmly establish health and safety as a key consideration in maintaining a robust and highly motivated work force in this important sector of the economy.

LIST OF FINDINGS

ANALYSIS OF CONSTRUCTION FALLS

Section I – pp. I-15 to I-16

Findings

Hazards on sites that may cause falls should be detected through rigorous examinations of construction sites and eliminated through effective preventive approaches. The accumulation of information of past accidents can disclose which are the most common hazards on construction sites. Operations susceptible to falls include roofing, erecting structural steel and exterior carpentry. Falls are often associated with workers on roofs, scaffolds, ladders, and on floors with openings. Occupations such as construction laborers, roofers, carpenters, and structural metal workers are commonly involved in falls and should be specifically addressed through fall prevention efforts. It should also be noted that fall hazards and human errors at elevations of less than 9.15 m (30 feet), where over half of the falls originated, warrant particular attention in terms of hazard analysis and safety inspections. Fall hazards mapping, as suggested by Gambatese and Stewart (1999), can serve as a very useful technology to indicate where fall hazards exist.

Through the analysis of fall accidents, fall-related near misses, as well as fall-related citations, the most hazardous locations on sites can be identified. Providing fall preventive equipment to workers, including full-body harnesses, along with the proper training, should reduce the number of falls. The lack of safety training is often a contributing factor for many falls. According to the analysis, misjudgment of workers may account for about one third of the construction worker falls. Especially for some workers employed in particular occupations that involve certain tasks, fall prevention training should be thoroughly provided. Effective training of workers can greatly decrease unsafe acts. Traditional safety training, restricted to the verbal and manual descriptions of the OSHA regulations, may not be sufficient to enable the workers to detect and eliminate all fall hazards. Innovative training approaches should be considered and thoroughly evaluated.

For researchers, many topics related to falls need to be investigated in greater detail. For example, the current personal fall arrest systems (PFAS) can effectively protect workers after they fall from elevation. While these may constrain the movement of workers, as with steel erection operations, such approaches should be examined further. Some workers fell because they did not tie-off their body harnesses, either because they felt it was troublesome to be tied off to a fixed anchorage or when they unhooked the lanyards to change their positions. More flexible PFAS might be able to save more lives. Different kinds of new technology, which can help prevent falls and protect workers from injury by falls, should be developed.

PREVENTION OF FALLS IN THE CONSTRUCTION INDUSTRY

Section II – pp. II-2

Findings

The specific aim of this project was to determine what elements of the safety programs of large construction companies were responsible for lower incidence rates of falls when compared to small construction companies and to explore the possibility of transferring those elements to small construction companies. The elements in order of importance were:

- Upper management commitment to support and promote safety as a top priority,
- Training of line supervisors in the area of supervision,
- Regular on-site training from the construction site superintendent,
- Promotion of safety awareness and accountability as a fundamental value, and
- Daily crew meetings where supervisors go over a daily work plan and job specific safety training for those potentially exposed.

Another key finding was the motivation behind large construction companies developing their safety programs. The motivating factors in order of their importance were:

- Concern for the well being of the employees and maintaining profitability (these generated an equal number of responses),
- Insurance company pressure and a high experience modification ratio, and
- Concern for the reputation of the company and compliance with OSHA regulations (these generated an equal number of responses).

A PILOT STUDY OF FUNCTIONAL IMPAIRMENT AND FALLS IN RETIRED UNION CONSTRUCTION AND NON-CONSTRUCTION MEMBERS

Section III – pp. III-1 to III-2

Findings

Over 27% versus 11% of construction and non-construction retirees, respectively, report having had a past work injury in need of medical attention. Construction versus non-construction retirees were two to four times more likely to report "severe to very severe" problems with their vision, neck/shoulder, elbow, knee and ankle/feet and joints. Construction versus non-construction retirees were two to three times more likely to describe their health as poor and report having "severe to very severe" body pain. It was surprising that 42.1% of construction retirees compared to only 14.0% ($p<.01$) of the non-construction retirees reported having fair to poor health. Construction versus non-construction retirees reported two to three times greater dissatisfaction with their level of physical activity and physical functioning.

In regard to the feasibility of doing a larger more inclusive survey, we determined that retirees are very interested in participating in health studies. This enthusiasm was demonstrated by their verbal engagement and participation in the focus groups. It was also demonstrated by their response rate, which was comparable to other studies with only one survey mailing. The instrument developed for the survey was easy to read and complete, and we had few blanks. The unions gave us considerable cooperation that included addressing and mailing the prepared packets.

A SURVEY TO COLLECT SAFETY-RELATED DATA FROM SAMLL CONSTRUCTION COMPANIES

Section IV – pp. IV-2

Findings

Although the AGC national office alerted the national membership to the web-based survey using both their website and their newsletter, the number of responses was only 89. One possible reason for lower than expected response was the length of the survey and possible confusion in using too many "continue" buttons. Future web-based surveys aimed at small businesses should be shorter and simpler to use. Results of those responding showed several notable points. Management was generally rated fairly high by non-management in terms of their commitment to safety. Responses across construction categories showed that the heavy highway construction companies were notably lower in safety concerns than other categories. Although construction workers are hired through a variety of sources, several types (temporary employment agencies, job banks, and unemployment offices) would be unlikely to have provided prior safety and health training.

SAFETY IN TRENCHING OPERATIONS

Section V – pp. V-2 to V-4

Findings

The significant findings are divided in two major categories. The first category shows the results based on the analysis of 296 trenching fatality reports from OSHA. This analysis was done applying two different models of accident causation. The second category presents the major conclusions of 16 interviews conducted with construction practitioners in the Midwest.

Based on the analysis of 296 trenching fatality reports from OSHA in the 1997-2001 time frame, the major findings of this study are:

- Based on the Type of Accident Model, the major type of accident in trenching operations is cave-ins, followed by caught in or compressed by equipment or objects and struck by object, usually backhoes or pipes during the installation process. Based on the *Behavioral Causes Model,* the major causes are: lack of safety equipment, practice of unsafe methods or sequencing, and lack of proper training.
- The analysis of fatality reports showed that sixty eight percent (68%) of the fatalities occurred in trenches with depth less than three meters (10 ft). The average depth of the trench was 3.1 m (10.3 ft). All the fatalities caused by electrocution occurred in trenches less than 3 m (10 feet) deep.
- When cave-ins occurred, 49% of the fatalities occurred in projects with costs under US$ 250,000 and 73% of the fatalities in projects with costs under US$ 1,000,000. Also, 31% of the accidents occurred in projects with fewer than 10 workers and costs

under US$ 250,000, i.e., when the project is smaller, the likelihood of a trench cave-in is higher. A possible reason is that the smaller projects are executed by small contractors who may not necessarily address the safety standards adequately or they do not have sufficient budgets to provide safety equipment.

- In projects with costs under US$ 250,000, the major causes of fatalities were lack of safety equipment (47%) and unsafe methods or sequencing (28%). In 55% of the projects with cost under US$ 50,000, the major cause was lack of safety equipment.
- Analyzing the number of employees on site when the fatality occurred, 63% of the cases the job site had fewer than 10 workers and 83% of the times the companies had fewer than 49 employees in total. When the project had fewer than 10 workers on site, in 48% of the fatalities the major cause was lack of safety equipment. When lack of safety equipment was identified as the major cause of the fatality, 84% of the companies had fewer than 50 employees in total.
- Trenching operations accidents can happen in any month of the year. However, during May and October, peaks in frequency of fatalities were observed.
- The distribution of fatalities based on the time of the day, is almost uniform from 8:00am through 4:00 pm. The highest number of cave-ins occurred between 12-2 pm.
- During the period 1997-2001, 46 states reported fatalities in trenching operations. The state with the highest number of fatalities is Texas (12%), followed by California (7%) and Michigan, Missouri and Ohio with (5%).
- Of the two hundred ninety six (296) trenching fatalities, 250 (84%) occurred on nonunion projects and 46 (16%) occurred on union projects.

Based on the interviews conducted with sixteen construction practitioners located in the Midwest, the major findings of this study are:

- The existing safety standards are deemed to be reliable and can help to prevent fatalities in trenching operations when they are correctly applied. However, in many instances, construction workers take unnecessary risks, and the "tough guy" culture continues to prevail on job sites.
- The interviews also indicated that the construction industry has learned how to identify the major causes of accidents based on the Type of Accident Model. In addition, it is important to note that the industry considers *cave-ins* accidents as the most important cause of fatalities, but also recognizes the existence of other type of accidents in trenching operations, such as *struck by object*, *caught in or compressed by equipment or objects,* and *contact with electric current.*
- Independent of their roles, all the practitioners considered *caught in or crushed in collapsing material (Cave-ins)* as the major cause of trenching accidents. This result is in accordance with the findings in the analysis of fatality reports from OSHA, and reflects a good understanding of the causes of trenching fatalities by the construction industry.
- Based on the interviews, it may be inferred that construction practitioners do not consider a single safety strategy as most important to prevent accidents in trenching operations. In addition, it appears that the companies are implementing several safety strategies simultaneously.

- The results of the interviews showed that the safety strategy *assess site conditions* is very important to the construction industry. However, the analysis of the OSHA reports showed that other strategies, such as *training, provide safety equipment,* and *plan and control of methods* are more important. This does not mean that the industry is unwise assigning these resources, but that the focus is not necessarily on the major strategies based on the analysis of OSHA reports.

THE USE OF TRENCH BOXES FOR WORKER PROTECTION

Section VI – pp. VI-13

Findings

Since the OSHA regulations appear to adequately address safe work practices with trench boxes, contractors are encouraged to make greater attempts to ensure that field operations fully comply with them. Additional guidance should be sought from the various suppliers of trench boxes.

As most of the serious safety problems are associated with worker behavior, contractors are encouraged to set up more stringent jobsite rules and to fully enforce them. When trenching operations are being conducted there is no opportunity to be lax on safety. A beginning point would be to conduct a series of training sessions to ensure that all workers are fully informed about the expectations of the company.

With the unacceptable number of serious safety infractions occurring on many trenching projects, it is incumbent on utility contractors to stress safety with their employees. Just as many companies have a zero tolerance for drug abuse, utility contractors should have zero tolerance for worker behavior that places their lives at risk.

THE OWNER'S ROLE IN CONSTRUCTION SAFETY

Section VII-21

Findings

This study was focused on identifying the owner's role in construction safety, which was demonstrated through the project context, the selection of safe contractors, the inclusion of safety requirements in the contract, and the owner's active participation in safety during project execution. Through analysis of the project interview data, it can be concluded that owners can positively influence project safety performances. Several practices of owners that were associated with better safety performances were identified.

Unlike twenty years ago, owners of large projects are more actively participating in construction safety management in each stage of project execution, including project design, contractor selection, the development of contract documents, and the construction phase. They are making efforts to improve the project safety performance, with a focus on setting their expectation on zero injuries, selecting safe contractors, and developing the safety culture on their projects (through safety training and safety recognition programs, for example). Their efforts have paid off by the decrease in injuries on their projects. This may explain, in part, why the injury rates decreased dramatically in the past decade.

The study also found that petro-chemical owners are among the most proactive owners in construction safety. This may be due to the traditional concern for safety in the chemical industry. Many petro-chemical owners stated that the safety attitudes in their major line of business impact their philosophy on construction safety. Safety is necessitated by the considerable hazards existing in the petrochemical industry. These reasons may help explain why the safety performances of petro-chemical projects are better than other types of projects.

SCALABLE DATABASE AND WEB-BASED DISSEMINATION OF IMPORTANT HEALTH AND SAFETY INFORMATION TO CONSTRUCTION SAFETY PROFESSIONALS

Section VIII – pp. VIII-1 to VIII-2

Findings

Data on occupational fatalities, injuries, and illnesses in the construction industry currently exist in many national, regional, and state data systems, which makes the access to safety data for researchers and safety professionals a frustrating chore. Hence, there is a need to develop a centralized database that provides single access point to all safety data. In addition, the Construction Safety Alliance partners also need a database that can store the new data collected from the research to facilitate data analysis and research collaboration. Therefore, a scalable database possessing the following features is developed.

- The database is designed to grow with the needs of research program and availability of new data.
- The database provides a comprehensive source for access to many different construction safety research and surveillance data sets.
- The database enhances user ability to query the database for specific items related to construction safety.
- The database creates new research opportunities by making the latest data sources available to researchers and policy makers.

The database currently houses occupational fatality, and injury and illness data for the construction industry collected from three publicly available data sources: the Bureau of Labor Statistic's (BLS) Injuries, Illnesses and Fatalities website, the BLS Census of Fatal Occupational Injuries (CFOI) website, and the National Center for Health Statistics' (NCHS) National Health Interview Survey (NHIS) website.

The Construction Safety Alliance Website was developed to serve as a portal for safety professionals and researchers to access up-to-date safety information. The information on the website can be accessed at two levels.

- The first level includes only CSA access for sharing data and information resources associated with ongoing research and surveillance projects. This access is password-protected for CSA members and their designated collaborators. Because CSA consists of researchers from different geographical locations, communication and collaboration through the website has proven to be very effective.

- The second level is for general use for accessing all information, published data, and resources as CSA makes it available. This level requires no password and will be advertised in trade journals and other construction-related publications.

EXECUTIVE SUMMARY

TABLE OF CONTENTS

EXECUTIVE SUMMARY

INTRODUCTION

The annual turnover of the U.S. construction industry exceeds 850 billion dollars, making this one of the biggest industries in U.S. There are close to 2 million firms operating in the construction sector and the number of people employed in this sector is estimated to be over 10 million. The fatality rates in this industry has ranked second. Compared with other industries in the U.S., construction has consistently experienced higher disabling injury rates than all other industries except for mining and agriculture. Disabling injuries occur at a rate exceeding two per minute each working day. Construction workers experience one of the highest rates of injuries and work-related illnesses that result in lost work days. Although construction employs 5-6% of the U.S. workforce, it accounts for more than twice this percentage in terms of workers' compensation costs (NIOSH 1999).

Socially and economically, fatal and non-fatal accidents and unsafe practices have taken a toll on the personal lives of construction workers and their families. Furthermore, they have severely impacted the productivity and quality in construction, and hence the costs of the constructed products. The total direct and indirect costs associated with these injuries and fatalities are in excess of $17 billion per year (CII 1996). Table 1 shows that the costs of construction site injuries are not trivial. Traditionally, there has been little sharing of information due to competition, shortage of resources, poor communication, lack of expertise in different areas, and a focus on short-term results instead of long-term planning.

The Construction Safety Alliance (CSA) was funded, in 2001, by the National Institute for Occupational Safety and Health, as a multi-university, interdisciplinary university-industry partnership, to develop, implement and evaluate a National Research Program in construction safety and health. The main focus of CSA is to embed safety measures as critical components in construction, and by doing so, link safety with quality and productivity.

Table 1. Average cost of construction site injuries (Hinze and Appelgate 1991)

Type of injury	Job Costs		Estimated Liability Costs (per injury)	Total Cost to Employer (per injury)
	Direct	Indirect		
Medical	$ 520	$ 440	$ 240	$ 1,200
Lost Work Day	$ 6,900	$1,600	$16,500	$25,000

Assuring safety and health in construction is complex, due to the following characteristics of the construction environment:

- Construction projects involve short-term work sites, changing hazards, and multiple operations and crews working in close proximity.
- Of approximately 600,000 construction companies, 90% employ fewer than 20 workers. Few companies have formal safety and health programs.
- Construction work is more dangerous now than in the past because more inexperienced people are working today (Heinz and Taylor 1998).
- Only 17.8% of the construction workers are unionized. Hence, challenges exist for directing efforts towards the non-union sectors of the construction industry.
- There are new demographic trends in the industry, with an increasing number of women and minority workers entering the workforce.

Another area of concern is the gross under-reporting of occupational illnesses in the construction industry. Because of the long latency period, it is difficult to identify illnesses as work-related. The time to manifest symptoms between initial exposures to a toxic substance and repeated load-dose exposures can take as long as 30 years. "In construction, the connection of a disease and employment is often difficult to establish because a construction worker may have a series of employers and varying tasks, each of which could involve different exposures to substances. A construction worker may also be exposed to toxins as a bystander to other workers' tasks (CPWR, The Construction Chart Book)."

"Until recently, most regulatory and corporate safety and health programs have relied on hindsight, i.e., statistics and accident investigations to determine where improvements can be made (CII 1996). Aggressive constructor and owner safety programs have made progress in reducing the number of on-site accidents on large construction projects. However, much more progress is needed to drive down the fatality and injury rates in this industry, especially for the smaller construction companies.

ROLE OF THE CONSTRUCTION SAFETY ALLIANCE

In order to make a significant impact in the safety and health culture of the construction industry, a vision that embraces meaningful and effective partnerships is critical. The Construction Safety Alliance (CSA) was funded, in 2001, by the National Institute for Occupational Safety and Health, as a multi-university, interdisciplinary university-industry partnership, to develop, implement and evaluate a National Research Program in construction safety and health. This alliance consists of national experts in construction engineering and management, health sciences, ergonomics, safety, industrial engineering, statistics, epidemiology and labor relations. It represents a cooperative effort that includes: universities, labor organizations, construction companies, owners of constructed projects, and trade associations. The goal of the Construction Alliance to link safety and health (including occupational ergonomics) with improved productivity and quality and hence, cost savings for the construction industry. Figure 1 shows a conceptual framework of this approach.

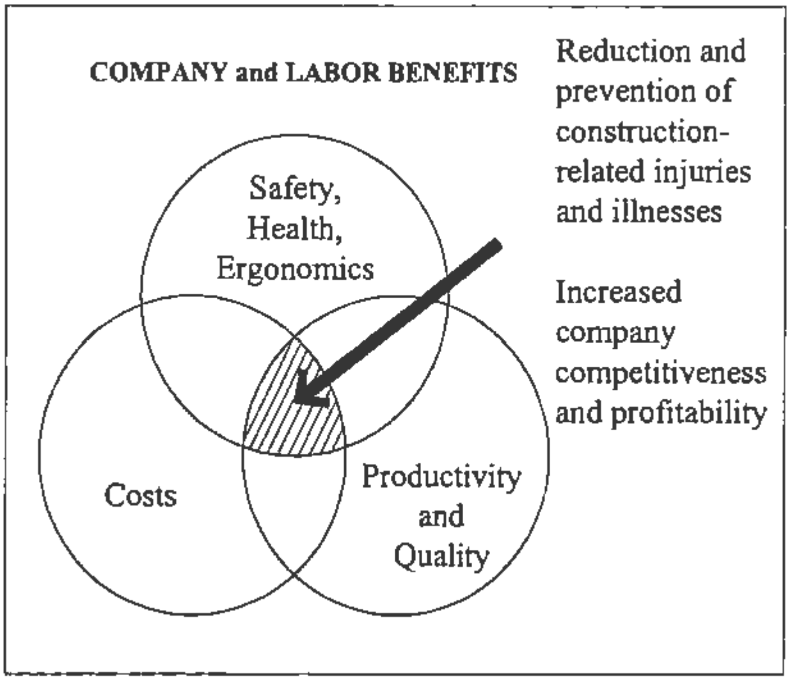

Figure 1. Interrelationships between safety and health interventions, costs and productivity and quality in construction.

This paper will describe the major findings of the lead projects undertaken by this alliance. These projects include: Falls from Elevations, Safer Trenching operations, the Owner's Role in Safety, and Web-based Dissemination of Project Findings to the stakeholders.

PROJECT 1: FALLS FROM ELEVATIONS

Background

The construction industry is consistently responsible for the largest number of fatal work injuries of any industry in the United States. Of those fatal injuries, falls from elevations are the leading cause (Hinze et al., 2002). In 2000, 734 deaths due to falls were recorded (Bureau of Labor Statistics, 2001). That number is surprising when you consider the regulatory intervention imposed on the industry and the advancements in fall protection devices made over the last several years. The key question that needs to be addressed is why do these fatalities continue to occur at such a high rate?

Large Construction Company Survey

Researchers from Purdue University's School of Health Sciences conducted a study to determine what elements of the safety programs of large construction companies were responsible for a reduced rate of falls in comparison to small construction companies (Construction Safety Alliance, 2003). Hinze et al. (2002) showed that the rate of falls decreased as the cost of construction projects increased. The objective of this study was to use the findings to help small construction companies, in particular small roofing companies (i.e., companies with less than 25 employees) reduce their rate of falls. Twenty-five construction companies whose typical construction contract amounts were in excess of $1,000,000 were contacted. Of those, sixteen companies chose to participate. Purdue researchers interviewed the safety directors of the sixteen companies by telephone and obtained statistical information about the company and its safety program as well as opinion-based information. In addition, a small roofing company also volunteered to answer the same series of questions and allowed us to observe one of their crews work on a residential roofing project.

The companies that participated in the interviews were large in terms of their construction contract size. The median contract amount was $9,000,000. The median Experience Modification Ratio (EMR) of the companies interviewed was 0.73. The EMR is a tool often used by insurance companies to determine premiums for workers' compensation insurance. It is the ratio of actual losses due to work-related injuries and illnesses over the expected losses. An EMR of less than one indicates that a company is suffering fewer losses than other companies in the same industry (Safety Management Group, 2002). Additional evidence of safety performance is seen in the number of years the construction companies had been practicing their current safety program. The median time was 11 years.

Large Construction Company Survey Outcomes

All of the construction companies indicated that they were affiliated with external safety organizations. The opportunity to network with other companies was listed as the primary benefit of membership. The network forum allows the sharing of information gained through experience and provides an expert panel to explore new ideas. Rather than a beneficiary role, the construction companies that were interviewed acted mostly in an advisory capacity to safety organizations, although, some of the companies benefited from training information provided through safety organizations.

Employee turnover is a concern because of the potential inexperience of new hires. The median rate of employee turnover was 145 per year and the median duration of employment was 18 months. The turnover rate is nearly half the number of employees that work at elevations over 6 feet. The median number of employees that work over 6 feet is 320 at any given time. In spite of the high employee turnover, fall injuries were relatively scarce.

The median number of injuries due to falls in the past year was two and the median number for the past five years was five. Only one company of the sixteen interviewed reported a fatality in the past year and no other fatalities were reported in the past five years. The exception was one contractor that experienced no injuries or fatalities themselves but had subcontractors who had experienced two fatalities in the past year and seven fatalities in the past five years. The lack of compliance to safety procedures by subcontractors was a common complaint.

Safety training is likely to be one of the elements responsible for such low numbers of injuries and fatalities. The median number of employees trained per year was 500. All but one company engages in refresher training on a regular basis so most existing employees can expect to receive refresher training every 12 months. The companies were split on whether they thought the employee turnover rate affected how their safety training programs were implemented. Companies who perceived that turnover had no effect may have been biased due to the existing level of intensity of the training program brought on by the anticipation of high turnover.

When considering training or safety equipment, cost can be an important issue. The construction companies interviewed in this study were asked to estimate their yearly expenditures for training and safety equipment per worker. The median of the estimated cost per year for training was $800 and the median of the estimated cost per year for safety equipment was $250. These numbers are minimal in comparison to the cost of injuries and fatalities from falls.

Large Construction Company Survey Conclusions

The construction companies were asked to list the five key factors that influenced them to implement their current safety program. Even though this was an opinion-based question, there were not a wide variety of answers. The fourth and fifth most common answers tied for the number of responses. They were concern for the reputation of the company and compliance with OSHA regulations. The third most common answer was insurance company pressure and a high EMR. The first and second most common answers tied for the number of responses. They were concern for the well being of the employees and maintaining profitability. A common theme found in these responses was money. The safety directors felt that a negative impact on a company's bottom line was critical to the development of a proactive attitude toward safety.

The construction companies were asked to list what they considered to be the most important elements of their safety training programs with respect to making them successful at reducing falls from elevations. Since this was an opinion-based question, there were a wide variety of answers, however, there were a few that were mentioned consistently.

Two answers tied for the fifth most common element. They were daily crew meetings where supervisors go over a daily work plan and job specific safety training for those potentially exposed to falls. The fourth most common element was the promotion of safety awareness and accountability as a fundamental value. In essence, the development of a safety culture where safety was a habit rather than a chore was expressed. The third most common element was regular on-site training from the construction site superintendent. The second most common element was the training of line supervisors in the area of supervision. The safety directors felt that supervisors were too often chosen for their adeptness at their particular trade rather than their ability to exercise supervisory skills over workers. The most commonly mentioned element was unique in that half of the companies mentioned it as the most important element of their safety training program. It was upper management commitment to support and promote safety as a top priority. The safety directors felt that financial support for the safety program and the presence of upper management at key meetings was how this was best demonstrated. By making safety the first item on the agenda at management meetings, upper management displayed its commitment to safety to lower level managers.

Periodically visiting jobsites and taking part in some onsite training was a way of displaying commitment to safety to line supervisors and workers.

Small Construction Company Outcomes (Pilot study of a small roofing company).

As mentioned earlier, because large companies have experienced a successful decrease in the rate of falls compared to smaller companies the objective was to use the findings from the large company survey to help small companies (roofing in particular) to reduce their rate of falls. As with the large construction companies, the small roofing company had an exemplary safety record. There had been no fall related injuries in the preceding five years and the EMR was 0.85. During the interview, the owner who was also the chief safety officer revealed that the company had no formal safety program. Discussions about safety only took place when workers were faced with projects where they would encounter extreme roof slopes or other hazardous conditions. He indicated that the discussions were no more than reminders to be careful and look out for each other. The most disturbing part of the interview was that the owner felt that those discussions constituted a safety program and that the program must be working because of their safety record.

Small Construction Company Conclusions

The results can be summed with three terms: motivation, training, and money. The primary reason for the success of large construction companies at reducing construction falls is that upper management has made a commitment to be safe. In making that commitment, they create momentum that motivates middle managers, construction supervisors, and finally, trade workers to be safe. Without the motivation from the top, there is little chance that a successful safety program will develop and almost no chance that a safety culture will develop. Prior research has shown that workers will perform their tasks in a manner that allows them to experience the least amount of inconvenience (Holmes et al., 1999 and Johnson et al., 1998). Unfortunately, safety is often seen as an inconvenience.

Appropriate training must follow effective motivation. Training is the method by which motivation is focused. The most important part of that training is training line supervisors in the area of supervision. Line supervisors are the most critical link in the safety chain because of their proximity to potentially dangerous situations. To effectively promote safety, line supervisors need to understand how to effectively communicate and motivate workers so that they will comply with safety procedures. The line supervisors also need to have a good understanding of regulations concerning safety. Since line supervisors are usually regular employees, provisions need to be made to insure that they receive training on a regular basis.

Worker training is next in importance. High turnover rates put the company in a position where new employees are constantly coming onto jobsites. In order to insure that workers receive the proper training, special training for new hires, regular onsite training, and daily crew meetings where daily work plans are discussed are crucial to reducing construction falls. This type of regular training allows the supervisor to effectively dictate the expectations of the company in the area of safety.

The factor that induces the motivation that initiates the training is money. Large construction companies discovered several years ago that it was profitable to be safe. Relatively small expenditures up front as shown by the costs of training and safety equipment can prevent large costs incurred after an accident. Lost time, loss of reputation, increased insurance costs, loss of competitiveness, and potential litigation are strong reasons to invest in safety.

The primary difference between large construction companies and small construction companies is that large construction companies who have good safety programs adopted those programs because of safety problems that made an impact on their profitability to the extent that they had no choice but to become safe. Large construction companies can build the extra cost into their bids because their competitors are faced with the same circumstances. Small construction companies, on the other hand, face competition that has likely never faced serious safety related problems and therefore, may have no incentive to build the cost of safety into their bids. Small construction companies that might desire to build in more engineering controls, safety equipment, and safety training could be priced out of the market and go out of business. If small construction companies are to ever develop effective safety programs modeled after large construction companies it seems that one of two scenarios must occur. Either, as with the large construction companies, small construction companies must understand the losses and metrics that forced the large construction companies into compliance, or a more effective method of regulating small construction companies must be put into place.

PROJECT 2: SAFER TRENCHING OPERATIONS

Trenching operations are executed principally by water, sewer, utility lines and heavy construction companies. The value of construction work executed by these companies represents 2.6% of the total volume of construction in the United States. In total, these companies experienced 166 fatalities during the year 2000. According to an analysis of workers' compensation claims in the Supplementary Data System of the

Bureau of Labor Statistics (BLS), there are approximately 1,000 works related injuries each year due to excavation cave-ins. Of these, about 140 result in permanent disability and 75 in death (NIOSH 1995).

The major causes of fatalities in trenching operations, their interactions, and the chain of events leading to accidents were identified in this project. Two different accident causation models to analyze the fatality reports were used as the relationships between these two models helped to develop the strategies to prevent trenching accidents. The first model (*Type of Accident* Model) considers the causes related to physical processes, and the second model (*Behavioral Causes* Model) evaluates causes that can be linked to human behavior.

***Type of Accident* Model vs. *Behavioral Causes* Model**

The significant findings of the project are divided in two major categories. The first category shows the results based on the analysis of 296 trenching fatality reports from OSHA. This analysis was done applying the two different models of accident causation. The second category presents the major conclusions of sixteen (16) interviews conducted with construction practitioners in the Midwest. Based on the analysis of 296 trenching fatality reports from OSHA in the 1997-2001 timeframe, the major findings of this study are:

The study revealed an alarming trend that smaller contractors (i.e., contractors having fewer than 50 workers), and those working on small projects (costs below US$250,000), tend to have higher rates of fatalities (Arboleda and Abraham 2003). The smaller contractors tend to be less prudent in adhering to the existing safety standards and in many cases, the fatalities can be attributed to their failure in providing adequate protection systems, failure to use these systems or failure to perform the work in a safe manner. Other major findings of the study are summarized as follows:

- Based on the *Type of Accident* Model, the major type of accident in trenching operations is cave-ins, followed by caught in or compressed by equipment or objects and struck by object, usually backhoes or pipes during the installation process. The distribution of accidents based on the Type of Accident Model is presented in Table 2. Based on the *Behavioral Causes Model,* the major causes are: lack of safety equipment, practice of unsafe methods or sequencing, and lack of proper training. The distribution of fatalities based on the Behavioral Causes Model is presented in Table 3.

- The analysis of fatality reports showed that sixty eight percent (68%) of the fatalities occurred in trenches with depth less than three meters (10 ft). The average depth of the trench was 3.1m (10.3 ft). All the fatalities caused by electrocution occurred in trenches less than 3m (10 feet) deep (Abraham, et al. 2003).
- When cave-ins occurred, 49% of the fatalities occurred in projects with costs under US$ 250,000 and 73% of the fatalities in projects with costs under US$ 1,000,000. Also, 31% of the accidents occurred in projects with fewer than 10 workers and costs under US$ 250,000, i.e., when the project is smaller, the likelihood of a trench cave-in is higher. A possible reason is that the smaller projects are executed by small contractors who may not necessarily address the safety standards adequately or they do not have sufficient budgets to provide safety equipment.

Table 2. Distribution of fatalities by the Type of Accident Model – BLS Codes

Group	Type of Accident	Code	Description	%
02	Struck by Object			**15.2%**
		021	Struck by falling object	5.4%
		029	Struck by object	9.8%
03	Caught-Compressed by equipment or objects			**16.6%**
		031	Caught in running equipment or machinery	1.4%
		039	Caught in or compressed by equipment or objects	15.2%
04	Caught-crushed in collapsing material			**54.7%**
		041	Excavation or trenching cave-in	51.4%
		044	Caught in or crushed in collapsing structure	1.7%
		049	Caught in or crushed in collapsing materials	1.7%
11	Fall to lower level			**0.7%**
		1124	Fall from ground level to lower level	0.7%
31	Contact with electric current			**7.8%**
		311	Contact with electric current of machine, tool, appliance, or light fixture	0.7%
		313	Contact with overhead power lines	5.1%
		314	Contact with underground, buried power lines	2.0%
38	Oxygen deficiency			**1.7%**
		381	Drowning, submersion	1.0%
		389	Other oxygen deficiency	0.7%
52	Explosion			**2.4%**
		522	Explosion of pressure vessel or piping	2.4%
99	Others			**1.0%**
		9999	Other events or exposure	1.0%

Table 3. Distribution of fatalities based on the Behavioral Causes Model

Major Cause	Fatalities (%)
Lack of proper training	16.6
Deficient enforcement of safety	6.8
Lack of safety equipment	42.2
Unsafe methods or sequencing	27.0
Unsafe site conditions	0.3
Not using provided safety equipment	2.7
Poor attitude toward safety	0.7
Isolated, sudden deviation from prescribed behavior	3.7

- In projects with costs under US$ 250,000, the major causes of fatalities were lack of safety equipment (47%) and unsafe methods or sequencing (28%). In 55% of the projects with cost under US$ 50,000, the major cause was lack of safety equipment.
- Analyzing the number of employees on site when the fatality occurred, 63% of the cases the job site had fewer than 10 workers and 83% of the times the companies had fewer than 49 employees in total. When the project had fewer than 10 workers on site, in 48% of the fatalities the major cause was lack of safety equipment. When lack of safety equipment was identified as the major cause of the fatality, 84% of the companies had fewer than 50 employees in total.
- During the period 1997-2001, 46 states reported fatalities in trenching operations. The state with the highest number of fatalities is Texas (12%), followed by California (7%) and Michigan, Missouri and Ohio with (5%).
- Of the two hundred ninety six (296) trenching fatalities, 250 (84%) occurred on nonunion projects and 46 (16%) occurred on union projects.

An Integrated Model for Safer Trenching Operations

Accidents in construction sites often result not from a single cause but from a chain of circumstances or events, and in many cases involve human error or human negligence. Therefore, focusing also on human contributions to the accident chain can be useful to prevent accidents. Based on the analysis of reports, the interviews with construction practitioners and the visits to construction jobsites, it is possible to conclude that the fatalities in trenching operations are the result of a combination of unsafe practices by the construction workers and management during the planning and execution process. The link between the strategies needed to prevent accidents and the activities involved in trenching operations is shown in Figure 2. In this figure, an integrated model of trenching operations is presented. This model considers:

a.) The strategies to prevent the fatalities based on the Behavioral Causes Model

b.) The activities to be executed during the planning and execution phases

The major causes based on the Type of Accident Model.

Construction Practices

Interviews with construction industry practitioners indicated that the existing OSHA safety standards are reliable and can help to prevent fatalities in trenching operations when they are correctly applied. However, in many instances, construction workers take unnecessary risks, and the "tough guy" culture continues to prevail on job sites. Independent of their roles (contractor, constructor manager, subcontractor, etc.) in the construction industry, all the practitioners considered ***caught in or crushed in collapsing material (cave-ins)*** as the major cause of trenching accidents. This result is in accordance with the findings in the analysis of fatality reports from OSHA, and reflects a good understanding of the causes of trenching fatalities by the construction industry.

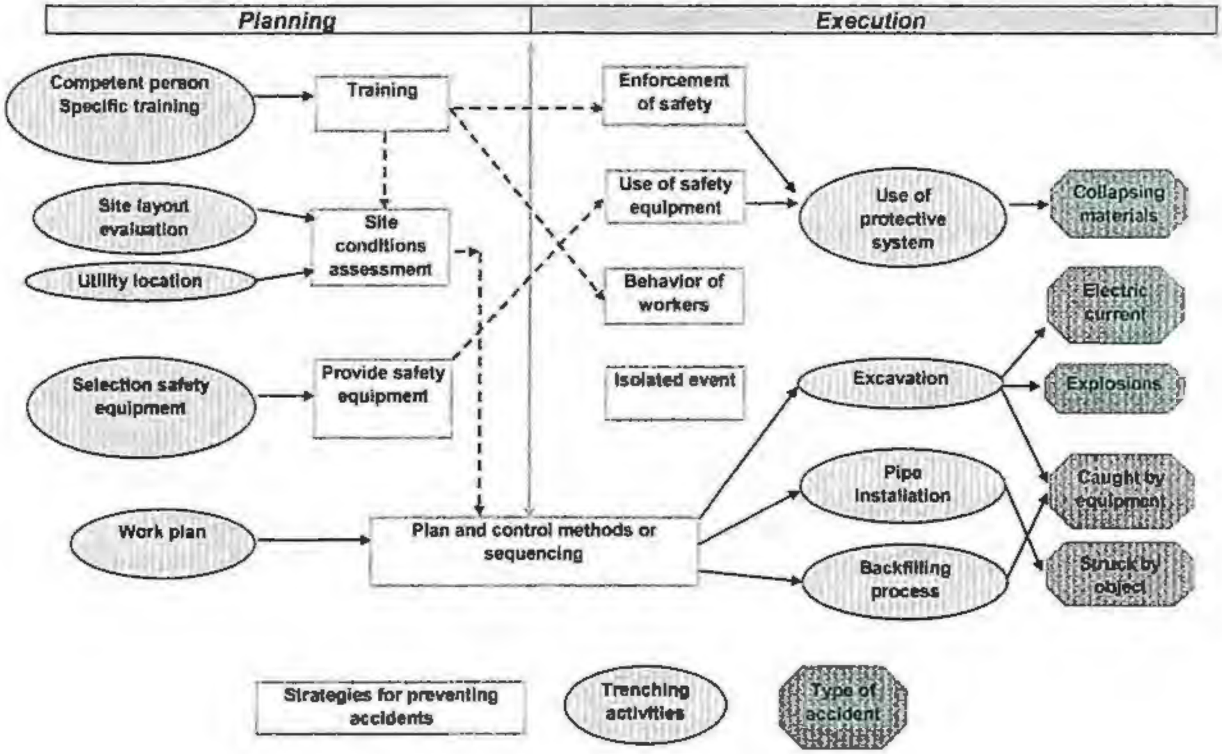

Figure 2. Integrated model of trenching operations (Arboleda 2002)

To prevent fatalities on job sites, the construction companies have been developing strategies (such as daily safety planning meetings, increasing involvement of owners in planning for safety, safety training, incentive programs increasing accountability by workers and support by top management, control of minor accidents, etc.) to improve the safety of workers. Table 4 summarizes some of the practices that have been reported to be successful in reducing accidents and preventing fatalities.

Table 4. Summary of the successful practices

Practice	Construction phase	Participants
Safety planning meetings	Planning	Design team, subcontractors, project engineers, foremen, a representative of the owner, insurance company, and contractor's safety officer
Daily safety meetings	Execution	Foremen, subcontractors
Safety training		
General safety training	Planning	Engineers, foremen, workers
Specific safety training	Execution	Subcontractors
Incentive programs	Execution	Engineers, foremen, subcontractors, administrative personnel
Top management support	Execution	Top management, project engineers
Owner's role	Planning Execution	Representative of the owner
Accounting practices	Execution	Project engineers, financial division
Increasing accountability of workers	Execution	Project engineers, foremen, workers
Control of minor accidents	Execution	Project engineers, foremen

PROJECT 3: FACILITY OWNER INFLUENCE ON CONSTRUCTION SAFETY

Many safety studies have focused on the role played by different parties involved in the construction process, most notably the general contractors. Others have also been examined in safety studies, including the roles of subcontractors and, more recently, the designers. Up to now, very little focus has been on the role played by facility owners (Business Roundtable 1982, Hinze 1997, Levitt and Samelson 1993, Samelson and Levitt 1982). The study of the role played by facility owners in construction safety was a research study conducted through the Construction Safety Alliance. This study was also sponsored by the Construction Industry Institute and was a follow-up study to research that suggested owners play a significant role in construction safety (Hinze 2002). This research identified three principal areas in which facility owners can and do influence safety performance on construction projects (Hinze 2003). These include the selection of safe contractors, carefully drafted contract documents and active involvement in safety during construction.

Contractor Selection

Owners have their first opportunity of influencing safety performance when selecting contractors that will be employed on the construction site. In general, the selection process is based on the principal that contractors that have performed safely in the past will perform safely in the future. Key to the selection process is in using the appropriate measure or measures (Hinze 1995).

Most owners emphasize safety to some extent when selecting contractors. These owners tend to regard demonstrated safety performance as a major prerequisite to be considered for a contract award. Most private owners will not consider awarding contracts to contractors with bad safety performances. Some owners maintain their own database of the safety performance history of all parties with whom they have contracted, including contractors, subcontractors, and vendors. From this, they develop and maintain an approved bidder list and only these firms are given the opportunity to submit bids on their projects.

The OSHA recordable injury rate (RIR) is a lagging indicator that is widely used as a means for selecting contractors. Projects where the owners used the RIR as a selection criterion reported better safety performances. Owners were also asked about the threshold value of the RIR when making selection decisions. The results show that when owners set more stringent threshold limits the safety performances were better (see Table 5). Safety performance was even worse when no threshold values were set.

Table 5. Threshold value of RIR set for contractor safety performance

Threshold Value	# of Responses	Mean RIR	Level of Significance
<2	12	1.06	.01
>=2	21	1.66	
No Threshold Value Set	23	2.89	

* Level of Significance determined with Analysis of Variance (ANOVA)

Information that might be helpful in ensuring the safety of a project is to examine the credentials of the personnel to be assigned to the project. For example, results show that better safety performances were recorded when the qualifications of the contractor's safety personnel and the qualifications of the project management team were evaluated when selecting the contractors (see Table 6). These evaluations often included personal interviews and site visits to projects where they were assigned at the time.

Table 6. Evaluation of the Contractor's Personnel and Safety Performance

Type Personnel	Number Evaluated	Mean RIR	Number Not Evaluated	Mean RIR	Level of Significance
Safety staff	42	1.79	14	2.60	0.09
Project team	38	1.50	18	3.04	<0.01

Contract Requirements Related To Safety

While the selection of qualified contractors is a key beginning step to ensure project safety, additional assistance in safety is provided by clear contract language that defines the contractor's obligations concerning safety. The owner's philosophy about safety can be communicated with carefully drafted safety-related provisions.

The owner's representatives were asked about the contractual requirements related to safety. These requirements were examined with the objective of identifying those related to the safety performance realized on the projects. Of course, some provisions were present in virtually all of the contracts that were examined, so no discernible relationship could be identified. It can be inferred that since the mean injury rate of the projects was 1.95 (considerably below the national average for the U.S. construction industry) that the provisions found in all contracts were perhaps the foundation for project safety. The following list contains 17 contract provisions on safety that were examined. These contract provisions state the contractor must:

- comply with the local, state and federal safety regulations
- comply with safety requirements beyond the OSHA regulations
- place at least one full-time safety representative on the project
- submit the résumés of key safety personnel for owner's approval
- provide specified minimum training for the workers
- report all lost time injuries to the owner

- report all OSHA recordable injuries to the owner
- report all (including first aid) injuries to the owner
- include owner personnel in coordination meetings
- submit subcontractor list for owner approval
- implement a substance abuse program
- participate in site safety inspections
- conduct weekly safety meetings
- submit a site-specific safety plan
- submit a safety policy signed by its CEO
- provide specified PPE (hard hats, safety glasses, gloves)
- implement a permit system for hazardous activities (line breaks, lockout/tagout, excavations, proximity to power lines, confined space entry, hot work, etc.)

Most of the contract provisions on safety were found in a large majority of the contracts. One provision (contained in 83% of the contracts) related to notable improvements in safety was the requirement that the contractor must assign at least one full-time safety representative to the construction site. Another provision (contained in 71% of the contracts) required the contractor to submit the résumés of the key safety personnel (to be assigned to the project) for the owner's approval (see Table 7).

Table 7. Contract Provisions Related to Safety Performance

Contract Provision	# Included	RIR	# not Included	RIR	Level of Significance*
Full time safety rep. must be assigned to the project	49	1.75	10	2.96	0.04
Contractor must submit the résumés of the key safety personnel for approval	42	1.52	17	3.01	<0.01

* Level of significance based on Analysis of Variance (ANOVA)

The findings in general are that it is not the specific provisions that are included in the contract as all are important. This is shown in Table 8 that shows that safety performances were significantly better when all or all but one of the contract provisions were included in the contract. Note that the average RIR of projects using all 17 provisions was 1.02 while those including 16 contract provisions had a mean RIR of 1.26.

Table 8. Number of Safety Provisions in the Contract and Safety Performance

Contract Inclusion	16 or 17	Mean RIR	7 to 15	Mean RIR	Level of Significance*
Number of Contract Provisions	21	1.17	38	2.38	<0.01

* level of significance based on Analysis of Variance (ANOVA)

Owner Involvement During Construction

The active involvement of the owner's personnel in project safety had the most powerful impact on safety performance. This involvement includes the philosophical approach of viewing contractor injuries as being part of the owner's injury statistics. Also included are several practices of owners that are associated with better safety performances (see Table 9). These include the owner's participation in orientation training, safety meetings, and the safety recognition program of the contractor. Better safety performances were also noted on projects where the owner monitored safety inspection records and where the owner established a goal of zero injuries before construction began.

Table 9. Owner Practices and Polices and Safety Performance

Owner Practice or Policy	Performed	Mean RIR	Not Performed	Mean RIR	Level of Significance*
Maintains injury statistics by individual contractors	33	1.52	26	2.50	<0.03
Contractor injuries are included in owner stats	37	1.57	22	2.59	0.02
Owner participates in safety recognition program	44	1.61	12	3.29	<0.01
Owner participates in safety training	29	1.58	11	3.11	0.05

A test is given after orientation training	48	1.66	11	3.2	<0.01
Owner participates in safety meetings	46	1.67	10	3.33	<0.01
Owner monitors project safety inspection records	47	1.67	11	3.14	<0/01
Zero injury objective is set at job start	19	1.38	40	2.22	0.06

* Level of significance based on Analysis of Variance (ANOVA)

PROJECT 4: WEB-BASED DISSEMINATION

As part of the NIOSH funded project, a website has been developed to expedite the dissemination of safety procedures, methodologies and current research. The website contains pertinent summaries of research from partners in the Construction Safety Alliance and safety education and training material relating to the focus areas of CSA's research projects. The website serves as a clearinghouse for construction safety and health education and information resources. It also provides links to other relevant websites, such as those maintained by the National Institute for Occupational Safety and Health (NIOSH), OSHA, the Construction Industry Institute, the Center to Protect Workers' Rights, The Construction Safety Association of Ontario, and the Principal Contractors Safety Alliance. The website is designed to be user friendly and easily understandable to both safety professionals and construction workers. It also allows users to query the data and download extracts for additional analysis. This site is currently being tested by construction safety professionals and also serves as a communication portal for CSA members. The website can be accessed through the link (**https://engineering.purdue.edu/CSA**).

SUMMARY

The vision of the Construction Safety Alliance brings the best elements in the construction industry together with infrastructures of established research and education programs in engineering, public health, and construction management. This is the first time in the U.S., that a consortium of major research universities has committed to a coordinated effort in studying construction safety.

The Alliance provides a resource for all workers, owners, and contractors in answering questions of construction safety through the vehicles of education, training, research, product development, and process innovation. In addition to enhancing faculty research efforts in construction safety and health, six graduate students (five at Purdue University and one at the University of Florida), one doctoral research assistant (at Purdue University) and five undergraduate students (at Purdue University) were supported by the CSA grant. Of these, four graduate students have either completed or are pursuing their masters/doctoral research in construction safety. The undergraduate students who formed an integral core of the research team at Purdue University have been able to integrate some of the safety practices recommended by the research projects, in their summer internship activities on construction sites. The funding provided by NIOSH also enabled the research team to interact with NIOSH researchers in Cincinnati and Morgantown and to explore creative avenues for disseminating the results of these lead projects and other supplementary projects to industry and other research communities.

The leaders from academe, contracting/industry, engineering, management and labor who have formed this alliance have responded with answers that could not have been derived by acting alone. The Alliance showed a significant impact not only on the safety and the health of the construction industry, but also to influence the culture, content, and continuity of this industry. The Alliance formula proved to be successful because it brought together construction industry, government, labor and academic leaders to partner with workers to develop new information that builds on the theory and practice of construction safety.

THE PATH FORWARD

The CSA partnership offers a unique opportunity to work with a broad spectrum of companies and organizations in the construction industry to develop a unified and quantitative approach to better understand and implement procedures which will lead to a safe and healthy environment at the work site. Further research is needed in the following areas:

- The impact of an increasingly multi-cultural and diverse work force in which linguistic and cultural characteristics greatly impact training of individual workers and implementation of safety programs and health issues at the work sites.
- Investigation of the link between safety and construction productivity as well as the quality of the constructed facility.
- Issues relating to design for construction.
- Additional studies related to the difference in health and safety programs between large and mid-size to small construction companies.
- Additional study of retired construction workers to better understand the sources of health and safety problems impacting the quality of life of these workers as well as construction methodologies and equipment which can be implemented to reduce the adverse effects of work site conditions (e.g. improved lifting devices for man lifts as well as ergonomic solutions to working in difficult positions, etc.).
- Further study of falls to better understand factors leading to a higher degree of risk (e.g. age of worker, equipment, ethnic or cultural issues).
- Studies of improved devices to facilitate trench safety.
- Studies of steel erection to develop improved methods and procedures to enhance safety in this process area.

Quantitative methods offer a structured approach to improving safety and health on the construction site and achievement of a zero-accident and reasonably healthy work environment.

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SECTION I

Analysis of Construction Falls

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TABLE OF CONTENTS

ANALYSIS OF CONSTRUCTION FALLS

ABSTRACT

The Occupational Safety and Health Administration (OSHA) investigates most worker related fatalities and many accidents involving serious injuries. A research study was conducted in which the focus was on the data OSHA accumulated on construction worker accidents involving falls. In the construction industry, falls are the most frequently occurring types of accidents resulting in fatalities. The purpose of the study was to identify the root causes of fall accidents and to identify any additional information that might be helpful in reducing the incidence of construction worker falls in the future. While data from January 1990 through October 2001 were examined, particular emphasis was placed on fall accidents that occurred in the last five years of this time interval, a period when more data were accumulated and coded in the investigation. Results show that most fall accidents occur at elevations of less than 9.15 m (30 feet), primarily on new construction projects of commercial buildings and residential projects, projects of relatively low construction cost, that experience does not seem to diminish accident occurrence, that hazards are often misjudged by workers, and that various other patterns can be observed. Most alarming, the results show that fall accidents account for a growing proportion of the total number of construction worker fatalities.

INTRODUCTION AND LITERATURE REVIEW

Falls has been the highest cause of injuries and fatalities in the U.S. construction industry. For the inclusive years of 1985 to 1989, falls accounted for 33% of all construction worker fatalities (Department of Labor, 1990; Hinze, 1997).

Several past studies focused on prevention of falls by various methods. For example, Singh (2000) investigated fall accidents occurring on low-rise roofs and evaluated some innovative fall protection measures. He concluded that there was no single method of fall prevention that would prevent all falls on low-rise roofs; however, prefabrication was determined to be the most promising method, followed closely by the personal fall arrest system (PFAS) and its variants. Duncan and Bennett (1991) reviewed the performance of various fall protection systems, and they concluded that both active measures (those that prevent workers from falling, e.g., guardrails) and passive measures (those that protect workers after falling, e.g., safety nets) are useful in reducing fall injuries. Vargas et al. (1996a, b) developed an expert system for construction falls, which analyzed the causes of falls by using fault-tree methods. They concluded that guardrails, safety nets, and PFAS can all be inadequate, under differing circumstances.

Weisgerber et al. (1999) discussed the safety through design approach which is particularly appropriate for construction, and provided the outline of a comprehensive program to prevent falls at the design phase. Gambatese and Hinze (1996), similarly developed a software program that would help designers address safety in the design phase. Of the many suggestions incorporated in the program, 32.8% related to the prevention of falls.

OSHA (1998) also suggested several methods to control fall hazards, including: elimination or substitution of the operation which can lead to falls, the use of engineering controls to guard against falls, informing/reminding workers-at-risk to avoid fall hazards (through warnings and administrative controls such as training and inspections), and the appropriate use of personal protective equipment (PPE).

It is also noteworthy that the regulations for PPE have been implemented to influence the frequency and pattern of occurrence of falls. The most notable revisions of the OSHA regulations involving fall prevention were as follows:

(1) 1915.159 Personal fall arrest systems (PFAS). The 1996 revised regulations stipulate that it is not acceptable to use body belts as a personal fall arrest system. Body harnesses were mandated for PFAS to provide proper protection to workers who were involved in falls.

(2) 1915.160 Specifications on positioning device systems. This revision, which became effective on January 1, 1998, stated that a positioning device system was not to be used for fall prevention. As a result of this change, only properly tied-off body harnesses are regarded as qualified personal fall arrest systems.

These changes to the OSHA regulations were intended to drastically impact the incidence of fall accidents.

RESEARCH METHODOLOGY

This study was conducted to determine the causes of construction fall accidents and to identify any particular patterns related to fall accidents. It was recognized that by identifying the causes of accidents, this would provide some valuable insights by which to devise means of accident prevention. Since some significant changes were made to the OSHA regulations, it was also of interest to assess how or if these modifications might have impacted fall prevention in the construction industry.

To conduct this study, it was first necessary to identify a database that contained the information about fall accidents in the construction industry. The initial intent was to utilize the data that is already available on the Internet on the OSHA website. While some of the data were contained in this database, the database had not been fully updated since 1996. OSHA was contacted to determine when the database would be updated. The researchers were informed that the updating was time-consuming and would not occur in the immediate future. A special request was made to obtain the files directly from OSHA and this was granted. The data were provided in Microsoft ACCESS format and were easily converted to files that could be manipulated by the Statistical Package for the Social Sciences (SPSS).

The data provided by OSHA included all reported OSHA investigations in the United States of fatalities and serious injuries from January 1990 through October 2001. The analysis of the data examined all falls in the construction industry in that time period.

Subsequent analysis was focused on the most recent years, the period in which the new fall standards were being implemented. The data were examined in various ways to determine if there were any discernible patterns of accidents involving falls among construction workers.

DESCRIPTION OF FALL ACCIDENTS

The data for the time period from January 1990 through October 2001 included a total of 7,543 OSHA-investigated accidents. Falls (both from elevation and from the same level) accounted for 34.6% of the injuries (See Figures 1 and 2). It is obvious that the proportion of falls has increased with time in the past 12 years. The average proportion of falls was 34.1% during the years before 1996, and it increased to 38.4% in the following years. The total number of OSHA investigated construction accidents is relatively constant during the years. A simple analysis reveals that the Pearson's correlation between the proportion of the falls and the year is 0.841, which provides strong evidence that the proportion of fall accidents increases during the past 12 years. In the analysis of the other main types of accidents, the Pearson's correlations between the years and the proportions of accidents are: -0.492 for struck-by, -0.232 for shock, 0.469 for caught-in-and-between, and -0.672 for the other accidents. The data may suggest that the proportion of caught-in-and-between accidents has also increased during the years, while proportions of struck-by and shock accidents have decreased. With the classification of accidents more clearly defined, the proportion of "other" accidents has decreased drastically.

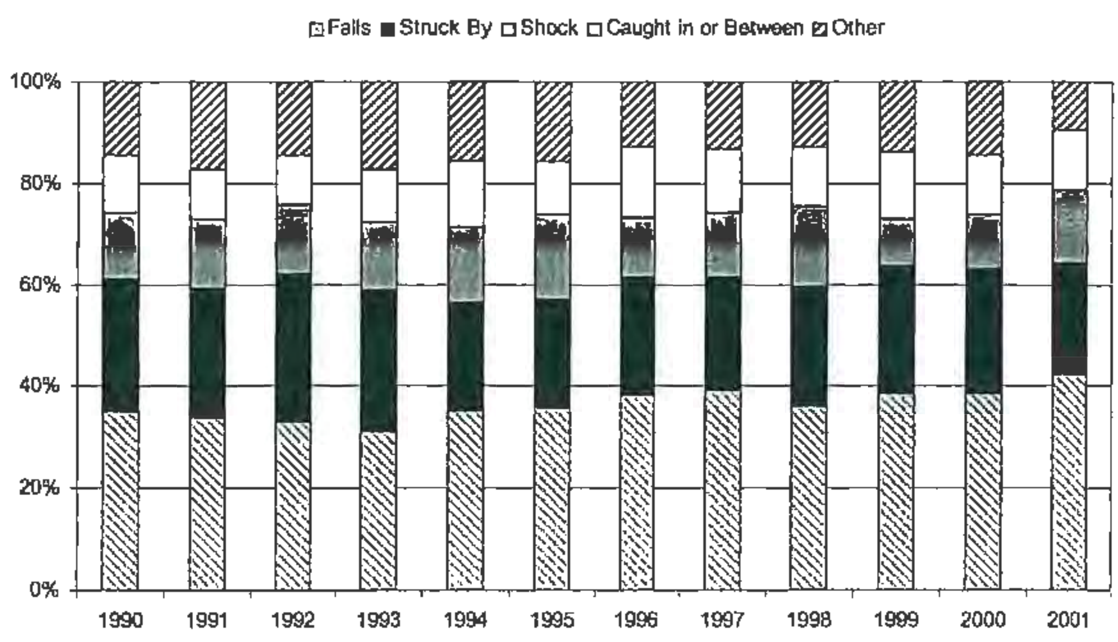

Fig. 1 Breakdown of OSHA investigated accidents in construction (01/90-10/01)

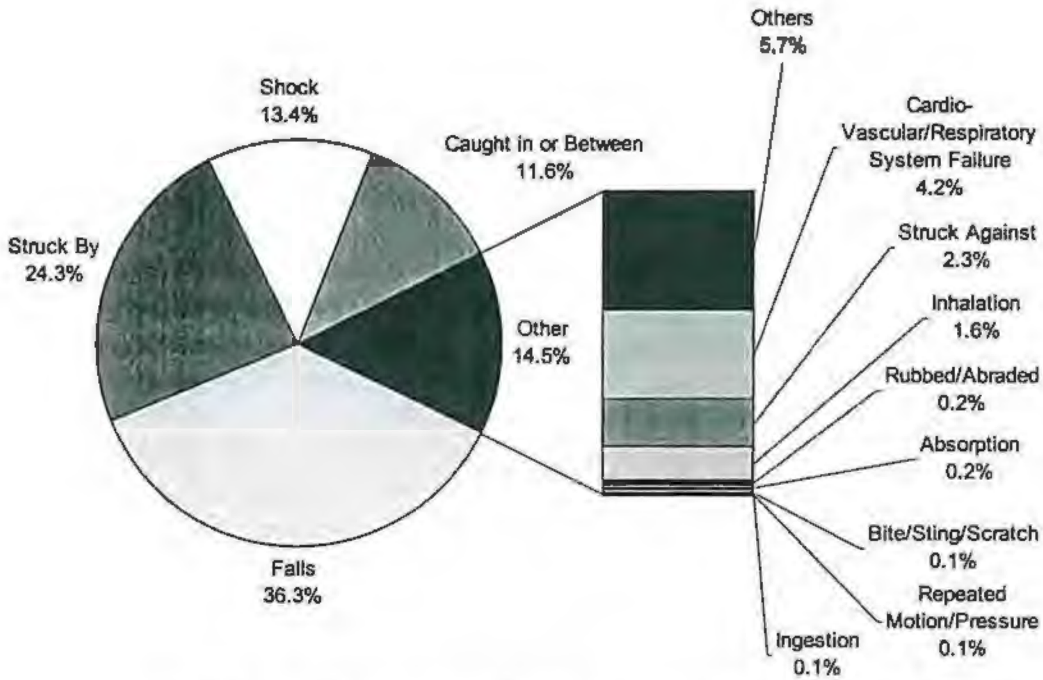

Fig. 2 Causes of construction fall accidents investigated by OSHA (01/90-10/01)

Among the 7,543 construction accidents between January 1990 to October 2001 investigated by OSHA, 2,741 were falls, with 2,687 falls from elevation and 54 falls from the same level. These accounted for 2,955 OSHA recordable fall injuries, with some accidents involving two or more workers. Note that in the analysis of the data, some records do not include all the information that is recorded in others. For this reason, the total number of cases analyzed for different descriptors may vary.

Time of fall occurrence

The timing of accidents was examined in this study. The occurrence of falls was then compared with the distribution of all injury accidents. As shown in Figure 3, July, with 820 accidents, is clearly the month when the occurrence of accidents reaches a peak (constituting 10.9 percent of all accidents), while February, with 493 accidents, is the month with the least accidents (constituting 6.5 percent of all accidents). Analysis also shows that in winter (Dec. to Feb.) the average proportions of falls and all accidents per month are 7.6% and 6.6% respectively, while in summer (Jun. to Aug.) the proportions are 9.1% and 10.3% respectively. This pattern is consistent with other data on construction worker injuries and probably reflects the heightened amount of construction activity occurring in the summer and the reduced level of activity in the winter. Regarding the distribution of fall accidents, the pattern is similar, with 266 falls in July and 196 falls in February, but these differences are not as striking. Even in winter, there are many falls.

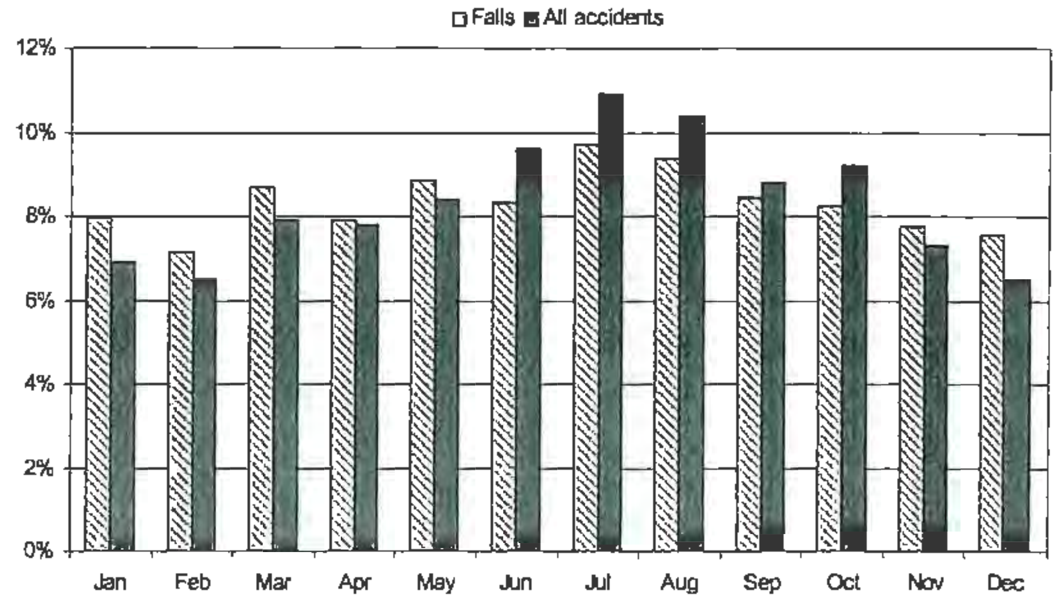

Fig. 3 Distribution of construction accidents by month of the year (01/90-10/01)

It is interesting that in the winter and spring months (Dec. to May) the proportion of falls is larger than that of all accidents, while in the summer and autumn months (Jun. to Nov.) the proportion of falls is smaller than those of all accidents. This might suggest that the cold weather in winter and spring tends to cause more falls than mild weather in summer and autumn, because the movements and reactions of workers are slower and the working surfaces on sites tend to be more slippery in the winter. As to the distribution of injuries by day of the week, the occurrence of falls did not show a definitive pattern of occurrence, with an even distribution among the days of the week, with the expected drop in occurrence over the weekend. The data were also examined from the perspective of the hour of occurrence of the accidents. As shown in Figure 4, the distribution of falls by hour of the day is similar to the pattern of all the construction accidents: with the least accidents occurring between noon and13:00 and most accidents occurring between 10:00 and 11:00 in the morning and between 13:00 and 14:00 in the afternoon. This pattern is similar to findings of previous research on accident occurrence times (Hinze, 1997).

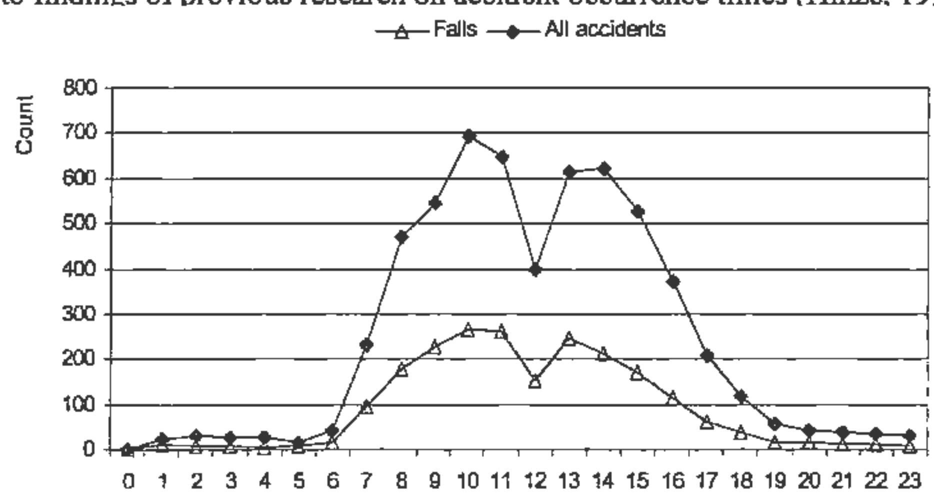

Fig. 4 Distribution of construction accidents by hours of the day (01/90-10/01)

Projects involving falls

Most of the data analysis was focused on the fall accidents that occurred in the most recent years, representing those falls occurring between January 1997 and October 2001. Some types of information were not systematically recorded in the earlier investigation reports. Thus, the more recent years of data provide a richer resource about the information related to falls.

One aspect of the accidents that was examined related to information that was available about those projects on which the fall accidents occurred. Results show that fall accidents occurred more frequently on certain types of projects, including new construction, renovation, maintenance and demolition work. From Table 1, it is evident that fall accidents are most frequent on projects involving commercial buildings and single family or duplex dwellings. These account for nearly half of the falls occurring in the years since 1997. The reasons might be that most commercial buildings are multi-story or high-rise buildings, where more fall-related hazards exist. Concerning single residential buildings, they are frequently constructed by small contractors, who often provide relatively informal safety training and inadequate PPE (Glenn, 2000).

Table 1. Distribution of accidents in projects by type of facility being constructed (01/97-10/01)

End use of the projects	**Falls**		**All accidents**	
	Count	**Percent**	**Count**	**Percent**
Commercial building	404	33.30%	715	22.80%
Other building	212	17.40%	412	13.10%
Single family or duplex dwelling	211	17.40%	503	16.00%
Multi-family dwelling	113	9.30%	183	5.80%
Manufacturing plant	79	6.50%	168	5.30%
Tower, tank, storage elevator	71	5.80%	103	3.30%
Bridge	28	2.30%	94	3.00%
Other heavy construction	21	1.70%	94	3.00%
Highway, road, street	16	1.30%	381	12.10%
Sewer/water treatment plant	14	1.20%	76	2.40%
Powerplant	13	1.10%	33	1.10%
Powerline, transmission line	10	0.80%	116	3.70%
Contractor's yard/facility	5	0.40%	42	1.30%
Pipeline	4	0.30%	91	2.90%
Shoreline development, dam, reservoir	4	0.30%	24	0.80%
Refinery	3	0.20%	21	0.70%
Excavation, landfill	2	0.20%	63	2.00%
Subtotal	**1,210**	**100%**	**3,119**	**100%**
Not known	5	-	23	-
Total	**1,215**	**-**	**3,142**	**-**

When the costs of projects were examined, it became evident that those projects with the lower costs of construction accounted for most falls. Nearly one half of the falls occurred on projects with costs of construction below $250,000, as shown in Table 2. The nature of efforts performed on construction projects was also examined. This analysis revealed that nearly 60% of the falls occurred in new projects or new additions (see Table 3). Regarding the costs of the projects and the types of construction effect, the patterns may simply reflect the volume of projects that fall in the lower cost category or that consist of new construction work.

Table 2. Distribution of accidents by project costs (01/97-10/01)

Cost of the projects	Falls		All accidents	
	Count	**Percent**	**Count**	**Percent**
Under $50,000	341	28.10%	990	31.50%
$50,000 to $250,000	229	18.80%	601	19.10%
$250,000 to $500,000	119	9.80%	289	9.20%
$500,000 to $1,000,000	134	11.00%	341	10.90%
$1,000,000 to $5,000,000	188	15.50%	464	14.80%
$5,000,000 to $20,000,000	117	9.60%	244	7.80%
$20,000,000 and over	83	6.80%	191	6.10%
Subtotal	**1,211**	**100%**	**3,120**	**100%**
Not Known	4	-	22	-
Total	**1,215**	-	**3,142**	-

Table 3. Distribution of accidents by nature of construction effort (01/97-10/01)

Type of construction effort	Fall		All accidents	
	Count	**Percent**	**Count**	**Percent**
New project or new addition	721	59.30%	1,640	52.20%
Alteration or rehabilitation	219	18.00%	565	18.00%
Maintenance or repair	189	15.60%	531	16.90%
Demolition	41	3.40%	101	3.20%
Other	41	3.40%	283	9.00%
Subtotal	**1,211**	**100%**	**3,120**	**100%**
Not Known	4	-	22	-
Total	**1,215**	-	**3,142**	-

Fall height

Of the 2,741 fall accidents, 1,018 of the investigation reports indicated the height of the projects and the number of stories. Of these projects where falls were involved, 807 projects (81%) are either one, two or three stories. The average facility height of the projects (whether a building or other type of facility) was 11.41 m (37.4 feet). That is, most falls happened on projects that were not particularly high.

Of the fall accidents that occurred since January 1997, investigation records provided additional information of interest that was not available for accidents occurring in earlier years. For example, the elevation from which the falls originated and the fall distances of the workers are now being consistently recorded for most accidents. Among the 1,215 falls that occurred since January 1997, more than 70% occurred at elevations of less than 21.35 m (70 feet). The distribution of the fall heights is shown in Figure 5. The average elevations of the fall height (the elevation where the fall originated) and fall distance are 10.8 m (35.4 feet) and 10.64 m (34.9 feet), respectively. It can be expected that more than 70% of the fall accidents occur within the elevation between 0 to 9.15 m

(30 feet). The elevation of a project can be regarded as one of the most hazardous aspects of the construction site. According to the OSHA regulations (CFR1926 Subpart M), fall prevention must be implemented at all elevations above 1.83 m (6 feet). It might be inferred that the implementation of fall prevention techniques might be too relaxed at the lower elevations in some projects.

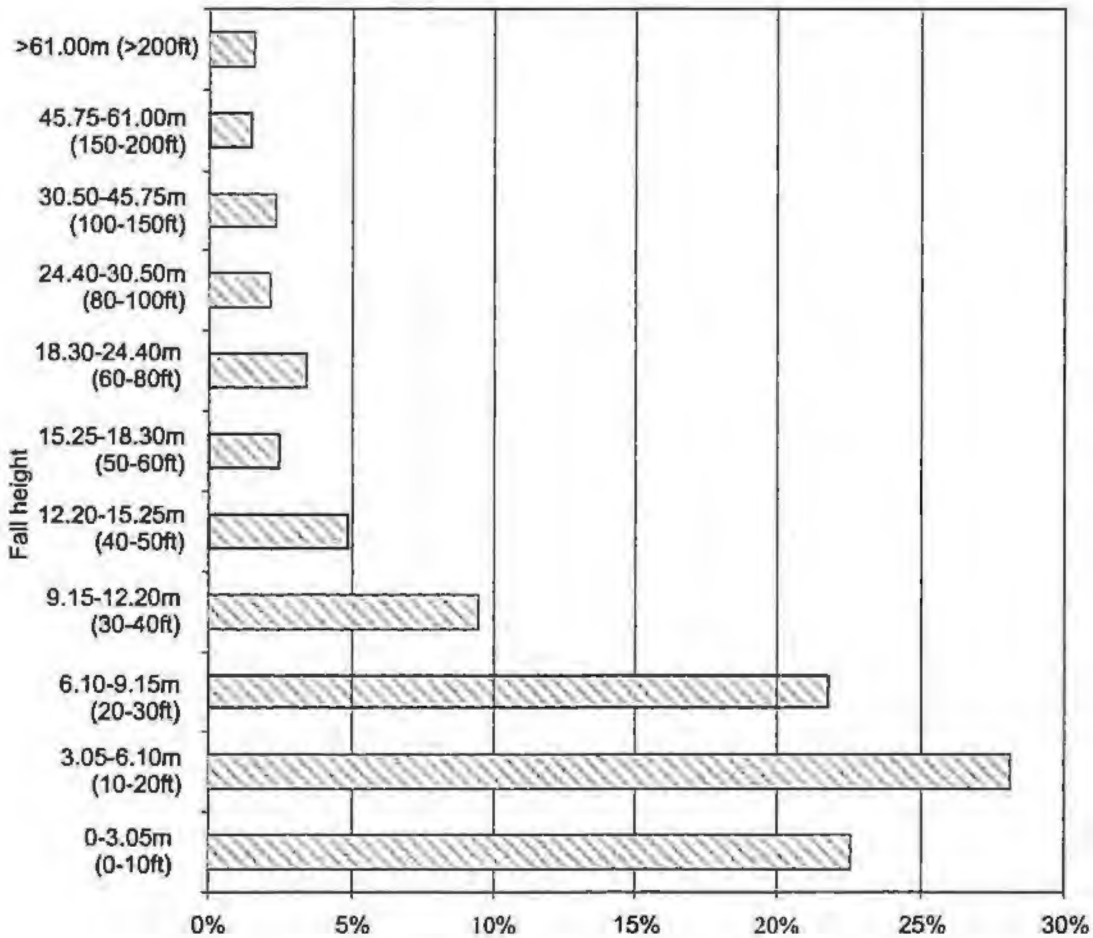

Fig. 5 Distribution of the height of construction fall accidents (01/97-10/01)

INJURIES RESULTING FROM FALL ACCIDENTS

In total, 2,741 fall accidents resulted in 2,955 injuries. The occupations of most injured workers are: construction laborers, roofers, carpenters, structural metal workers, painters, brickmasons and stonemasons, electricians, supervisors, drywall installers, plumbers and pipefitters. Since workers of these trades often work in environments with fall hazards, they are the most susceptible to injury by falls. Of the nature of the injuries resulting from falls, fracture, concussion, and bruise/contusion/abrasion are the most frequent types. They cover nearly two thirds of all the injuries. Half of the injured were hurt on their heads, and about one third of the injured suffered multiple injuries. Other parts of body that are often injured by falls include: chest, neck, back, abdomen, and legs. In comparison, for all the injuries (not restricted to fall accidents), the most frequent types are fracture, electric shock and concussion. Head injuries account for about one-fourth of all the injuries, followed by the multiple injuries. A sobering fact is that two thirds of the workers involved in falls were killed, which highlights the serious nature of this type of accident.

As to the age distribution of the injured (see Figure 6), the ages of those worker most frequently involved in falls are between 31 and 40, with the overall average being 38.3. The distribution is quite similar to the age distribution of all workers involved in accidents, which has an average of 37.2. Pearson's correlation of the proportions in different age ranges between the falls and all accidents is .987, which shows strong evidence of a positive relationship between them. It can be observed in Figure 6 that the proportions of those injured in falls younger than 35 are smaller than those injured in all accidents, while for the injured older than 35, the proportions of falls are larger than of all the accidents (except for the age group from 55 to 60). If the proportion of falls is calculated in different age groups, it is apparent that the proportions of age groups below 35 (about 32%) are lower than those above 35 (about 36%). The data may suggest that experience in construction for more years may not necessarily lead to a decrease in fall accidents. This might be caused by the fact that younger workers tend to be more alert and flexible when fall hazards occur. It should also be mentioned that among all the injured, 17 were below the age of 16 years. Generally, these young workers are injured when working as helpers on construction sites.

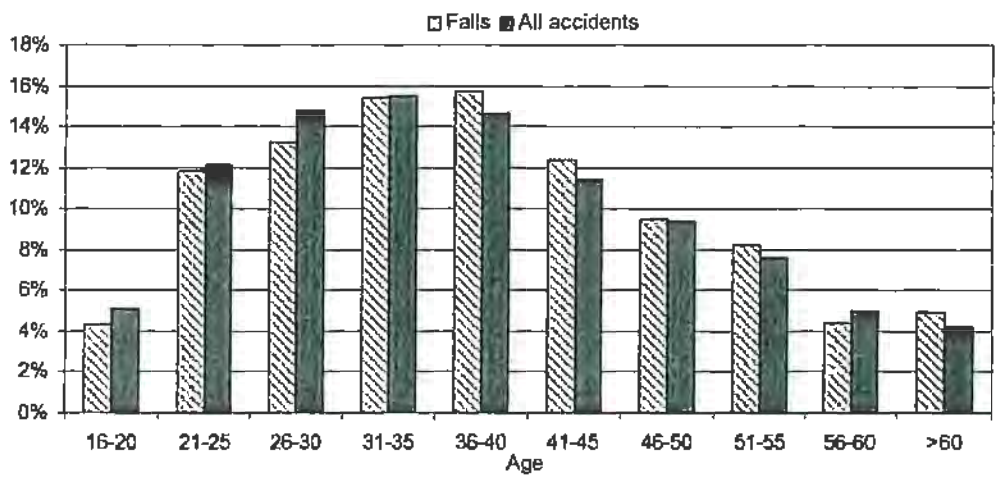

Fig. 6 Age distribution of workers injured on construction sites (01/90-10/01)

CAUSES OF FALL ACCIDENTS

Work operations and fall occurrence

The nature of the work being performed when the fall accident occurred was examined in this study. Table 4 shows the most frequent types of tasks performed when fall accidents occurred. Among the different tasks or types of work performed, roofing, erecting structural steel and exterior carpentry were most often associated with falls. Those are also operations that are necessary to be conducted at points of elevation or on temporary structures, where fall hazards are often present. Falls during these operations were generally related to certain human errors. For example, it is found that among the falls involving roofing, 33.3% were related to the misjudgment of workers about hazardous situations, 13.5% were associated with insufficient or lack of PPE, and 11.5% were caused by removed or inoperative safety devices. These falls occurred in relatively lower elevation. About 75% of the falls during roofing occurred at elevations of less than 9.15 m (30 feet), and 45% within 6.10 m (20 feet). This may suggest that workers on these projects may underestimate or ignore the fall hazards at lower elevations. To avoid falls, tasks performed above 1.83 m (6 feet) should be analyzed thoroughly and conducted with great care. Workers performing these tasks should be well trained and equipped with adequate and appropriate PPE.

Table 4. Type of task performed when fall occurred (01/97-10/01)

Working activities	Count	Percent
Roofing	252	21.63%
Erecting structural steel	99	8.50%
Exterior carpentry	89	7.64%
Exterior masonry	57	4.89%
Installing equipment (HVAC and other)	54	4.64%
Demolition	53	4.55%
Temporary work (buildings, facilities)	47	4.03%
Interior carpentry	44	3.78%
Exterior painting	43	3.69%
Installation Of Decking-Initial Laying Deck	33	2.83%
Installing interior walls, ceilings, doors	30	2.58%
Steel Erection Of Solid Web-Connecting	25	2.15%
Installing plumbing, lighting fixtures	22	1.89%
Forming	21	1.80%
Interior plumbing, ducting, electrical work	21	1.80%
Installing metal siding	18	1.55%
Fencing, installing lights, signs, etc.	17	1.46%
Installing windows and doors, glazing	17	1.46%
Other Activities-Installing Ornamental And Architectural Steel	16	1.37%
Other Activities-Post Decking Detail Work	16	1.37%
Others activities	191	16.39%
Subtotal	**1,165**	**100%**
Not known	50	-
Total	**1,215**	-

It is also noteworthy that about 11% of the accidents involved workers who were performing non-typical types of tasks. These unusual tasks are generally not included in the scheduled tasks that are planned and familiar to the injured. This was noted with accidents involving roofing, demolition, and temporary work. In one incident, a roofer finished his task and was in the process of descending to go to lunch on the ground, when he fell to the ground. These types of activities, although occurring less frequently, should be emphasized with workers, as they are often neglected in safety training.

Location of falls

More than half of the falls are related to environmental factors involving the working surface or facility layout conditions. Falls from roofs are undoubtedly the most frequent accidents, especially in commercial buildings and single family or duplex dwelling projects. Over 63% of falls from roofs since 1997 occurred on these projects. As shown in Table 5, most falls took place from roofs, from/with structure, from/with scaffold, from/with ladder, and through openings. These locations account for about 80% of all construction fall accidents. These are also the most hazardous locations where workers are susceptible to fall accidents. Provision of adequate preventive equipment in these locations is essential to avoid falls.

Table 5. Distribution of location of falls (01/97-10/01)

Location of falls	Count	Percent
Fall from roof	333	28.36%
Fall from/with structure (other than roof)	227	19.34%
Fall from/with scaffold	153	13.03%
Fall from/with ladder	133	11.33%
Fall, other	102	8.69%
Fall through opening (other than roof)	90	7.67%
Fall from/with bucket (aerial lift/basket)	37	3.15%
Fall from/with platform catwalk (attached to structure)	28	2.39%
Fall from vehicle (vehicle/construction equipment)	27	2.30%
Collapse of structure	13	1.11%
Other	31	2.64%
Subtotal	**1,174**	**100%**
Not known	41	-
Total	**1,215**	-

Human errors resulting in falls

Although human errors are not acceptable excuses for inefficient safety management practices, analysis on the human errors involving falls can assist in identifying the root causes of falls. As shown in Table 6, misjudgment of the hazardous situation is the most frequent type of human error involving falls, accounting for about one third of all the accidents. Further analysis shows that the distribution of misjudgment for different ages is roughly similar to the age distribution of fall injuries (see Figure 7), except for the age group between 21 and 25. Pearson's correlation between the proportions of falls by misjudgment and all falls in different age ranges is .979, which suggests a strong positive relationship between them. Further analysis shows that among the injuries in each age group, the proportion of human errors categorized as "misjudgment of hazardous situation" don't show significant differences. Most of the values are around 30%. It is possible that age or experience does not significantly improve judgment where hazardous situations are concerned. Also, it is noteworthy that workers between the ages of 21 to 25 should be trained and educated with greater care. Of course, it must be recognized that the "misjudgment of hazardous situation" is a subjective assessment and is difficult to verify.

Table 6. Distribution of human errors contributing to falls

Human errors	Falls since 1997		All fall accidents	
	Count	**Percent**	**Count**	**Percent**
Misjudgment of Hazardous Situation	374	30.78%	916	33.42%
Safety Devices Removed or Inoperative	170	13.99%	403	14.70%
Equipment in Use Not Appropriate for Operation or Process	106	8.72%	243	8.87%
Insufficient or Lack of Protective Work clothing and Equipment	104	8.56%	226	8.25%
Malfunction of Procedure for Securing Operation or Warning of Hazardous situation	68	5.60%	156	5.69%
Operational Position Not Appropriate for Task	59	4.86%	131	4.78%
Procedure for Handling Materials Not Appropriate for Task	40	3.29%	89	3.25%
Insufficient or Lack of Engineering Controls	38	3.13%	78	2.85%
Insufficient or Lack of Written Work Practices Program	36	2.96%	83	3.03%
Malfunction of Perception System with Respect to Task Environment	11	0.91%	33	1.20%
Malfunction of Neuro-Muscular system	6	0.49%	19	0.69%
Defective Equipment: Knowingly Used	5	0.41%	22	0.80%
Distracting Actions by Others	3	0.25%	8	0.29%
Malfunction of Procedure for Lock-Out or Tag-Out	2	0.16%	6	0.22%
Insufficient or Lack of Housekeeping Program	2	0.16%	4	0.15%
Insufficient or Lack of Respiratory Protection	1	0.08%	1	0.04%
Other	189	15.56%	322	11.75%
Subtotal	**1,214**	**100%**	**2,740**	**100%**
Not known	1	-	1	-
Total	**1,215**	-	**2,741**	-

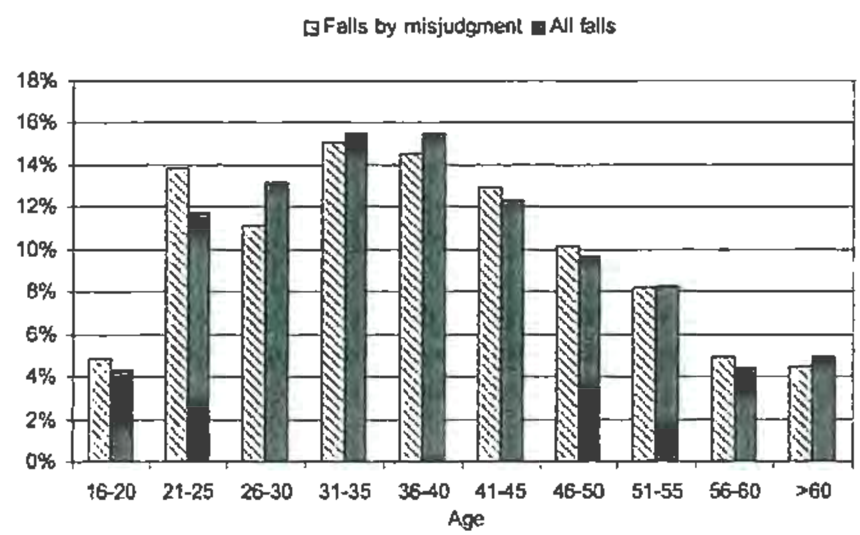

Fig. 7 Proportion of falls by misjudgment for different ages (01/90-10/01)

If the relationship between the fall height and the human errors is analyzed, it can be found that most falls associated with human errors occurred at lower elevations. For example, more than half of falls related to 'misjudgment of hazardous situation' were less than 6.10 m (20 feet) in elevation, and 23.5% of them were less than 3.05 m (10 feet). As to falls associated with 'insufficient or lack of protective work clothing and equipment', 40% were within the elevation of 6.10 m (20 feet). Therefore, it is plausible that workers tended to act unsafe more frequently in lower elevations, especially under 6.10 m (20 feet).

Inadequate or inappropriate use of fall protection PPE, and removed and inoperative safety equipment contributed to more than 30% of the falls. This situation does not change significantly after 1996, when the OSHA regulations on PPE were significantly revised. Typical examples are work being performed without tied-off full body harness when working at elevation. These have been major problems of falls on jobsites. There are also several falls that occurred when a body harness was unhooked to facilitate movement to a different location. Therefore, adequate provision and proper use of fall protective PPE are necessary to ensure worker safety.

Immediate sources of falls

A contributing factor in one-third of the fall accidents was the working surface (see Table 7). The accidents included typical situations where workers slipped on sloped roofs and fell to the ground, workers fell through floor openings, and workers slipped on the walking surface of scaffolds and fell. Inadequate fall preventive equipment in buildings/structures, and/or failure of buildings/structures also caused some workers to fall. These falls can be effectively prevented by the use of the appropriate fall preventive equipment.

Table 7. Distribution of immediate sources of falls (01/90-10/01)

Immediate sources of falls	**Count**	**Percent**
Working Surface	911	33.24%
Buildings/Structures	566	20.65%
Bodily Motion	338	12.33%
Ladder	246	8.97%
Hoisting Apparatus	138	5.03%
Materials Handling equipment	52	1.90%
Dirt/Sand/Stone	34	1.24%
Motor Vehicle (Highway)	27	0.99%
Motor Vehicle (Industrial)	25	0.91%
Other	404	14.74%
Total	**2,741**	**100%**

OSHA INSPECTIONS OF FALL ACCIDENTS

The states where falls occurred were also examined. This effort showed that Texas, Florida, California, New York, and Illinois are the top ranking states in the frequency of all accidents and in the frequency of fall accidents (see Figure 8). Among the top ten Standard Industrial Classification (SIC) codes associated with the largest number of falls, only six are listed in the top ten with most frequency of all accidents (see Table 8). These are: 1761 (Roofing, Siding, and Sheet Metal Work), 1791 (Structural Steel Erection), 1542 (General Contractors-nonresidential Buildings, Other Than

Industrial), 1799 (Special Trade Contractors, Not Elsewhere Classified), 1731 (Electrical Work), and 1711 (Plumbing, Heating and Air-conditioning). In contrast, SIC 1623 (Water, Sewer, Pipeline, and Communications and Power Line) and 1611 (Highway and Street Construction, Except Elevated Highways), that rank No. 1 and 2 in frequency of all accidents are only listed No. 15 and 20 in frequency of falls.

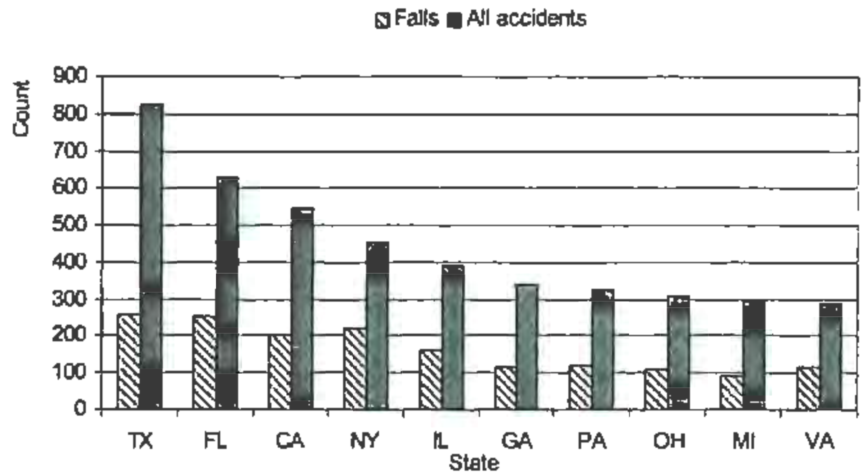

Fig. 8 Top states in frequency of falls and all accidents (01/90-10/01)

Table 8. The top ten construction-related SIC codes with frequency of falls (01/90-10/01)

SIC	Description of SIC	Frequency	Percent
1761	Roofing, siding, and sheet metal work	498	16.85%
1791	Structural steel erection	395	13.37%
1542	General contractors-nonresidential buildings, other than industrial	209	7.07%
1799	Special trade contractors, not elsewhere classified	206	6.97%
1751	Carpentry work	192	6.50%
1721	Painting and paper hanging	173	5.85%
1731	Electrical work	169	5.72%
1741	Masonry, stone setting, and other stone work	167	5.65%
1711	Plumbing, heating and air-conditioning	115	3.89%
1541	General contractors-industrial buildings and warehouses	115	3.89%
	Total	**2,955**	**100%**

When comparing fall accidents with all construction accidents, the average penalty on fall injuries is higher than on the aggregate of other accidents. For example, the average and median value of the imposed penalty for fall-related accidents were $8,917 and $2,250, respectively. This is in contrast to $7,757 and $1,800 for the overall accidents. Meanwhile, the number of violations in fall inspections, ranged from 0 to 118, with an average of 2.92. This is larger than that of all construction inspections that have an average of 2.68 violations. It was also found that there are more serious violations in fall inspections than in overall inspections. The Bureau of Labor Statistics (BLS) website (http://www.bls.gov/iif) provided the most frequent citations to Construction Special Trade Contractors (SIC 17, see Table 9), that account for most (about 80%) falls. Nearly half of the citations are associated with fall hazards on the jobsite or the lack of training on falls. It might provide a hint for the emphasis on construction fall protection: scaffolding, ladder, fall protection training, training for scaffolding, and so on.

Table 9. Standards Cited for SIC 17* (10/99 - 09/00)

Standard	Total citations	Total inspections	Total Penalties ($)	Description of the standards
1926.451	5,521	2,069	5,694,146	General Requirements for all types of Scaffolding
1926.501	2,969	2,585	3,555,916	Fall Protection Scope/Applications/Definitions
1910.1200	1,230	628	117,956	Hazard Communication
1926.1053	1,076	810	470,408	Ladders
1926.020	956	845	555,819	Construction, General Safety & Health Provisions
1926.503	877	802	440,888	Fall Protection Training Requirements
1926.100	840	832	485,562	Head Protection
1926.404	832	711	320,756	Electrical, Wiring Design & Protection
1926.454	823	718	377,922	Training Requirements for all types of Scaffolding
1926.405	800	595	222,703	Elec. Wiring Methods, Components & Equip, General Use
Total	27,613	8,824	$21,330,277	

* SIC 17 includes all construction special trade contractors.
(Data source: http://www.bls.gov/iif)

CONCLUSIONS AND RECOMMENDATIONS

Falls are the most frequent accidents on construction jobsites. From the analysis of fall accidents in the construction industry, it is obvious that falls are the cause of many serious injuries and fatalities. At the same time, the analysis of the data shows that falls have certain properties, which may help to devise preventive approaches.

In the past, OSHA, the construction industry, and various researchers have worked intensively to find countermeasures to prevent falls. However, some measures do not work as well as expected. For example, since the OSHA regulations on PPE for fall prevention were revised in 1996, neither the quantity nor pattern of falls on construction sites has changed significantly. In fact, the proportion of accidents that are caused by falls has actually increased. This may stem from the strong economy that the U.S. construction industry has enjoyed in the years following 1995. The strong economic growth has resulted in the hiring of many workers, a large proportion of which may be inadequately trained. Clearly a continued focus on falls by OSHA is well warranted and more training of the workforce is needed as well.

For the construction industry, fall hazards analysis and communication of related findings are necessary to ultimately impact the occurrence of fall accidents. It was noted that falls commonly occur on projects that can be characterized as being small and relatively low in cost, and involve new construction of commercial buildings and residential projects.

Hazards on sites that may cause falls should be detected through rigorous examinations of construction sites and eliminated through effective preventive approaches. The accumulation of information of past accidents can disclose which are the most common hazards on construction sites. Operations susceptible to falls include roofing, erecting structural steel and exterior carpentry. Falls are often associated with workers on roofs, scaffolds, ladders, and on floors with openings. Occupations such as construction laborers, roofers, carpenters, and structural metal workers are commonly involved in falls and should be specifically addressed through fall prevention efforts. It should also be noted that fall hazards and human errors at elevations of less than 9.15 m

(30 feet), where over half of the falls originated, warrant particular attention in terms of hazard analysis and safety inspections. Fall hazards mapping, as suggested by Gambatese and Stewart (1999), can serve as a very useful technology to indicate where fall hazards exist.

Through the analysis of fall accidents, fall-related near misses, as well as fall-related citations, the most hazardous locations on sites can be identified. Providing fall preventive equipment to workers, including full-body harnesses, along with the proper training, should reduce the number of falls. The lack of safety training is often a contributing factor for many falls. According to the analysis, misjudgment of workers may account for about one third of the construction worker falls. Especially for some workers employed in particular occupations that involve certain tasks, fall prevention training should be thoroughly provided. Effective training of workers can greatly decrease unsafe acts. Traditional safety training, restricted to the verbal and manual descriptions of the OSHA regulations, may not be sufficient to enable the workers to detect and eliminate all fall hazards. Innovative training approaches should be considered and thoroughly evaluated.

Allan St John Holt (2001, page 159) mentioned: "fall prevention is far more effective than fall protection, which often involves personal protective equipment. Reliance on people to make the 'right' decision about wearing personal protective equipment has been shown by events to be unsatisfactory – they forget, decide not wear it in view of the expected short exposure time, or do not wear or use it correctly. The first stage in fall prevention is during the design process, which influences the construction method." Although it is still difficult to recognize how many falls are directly caused by unreasonable designs, safer plans, developed through specific design decisions, can decrease the occurrence of falls.

For the researchers, many topics related to falls need to be investigated in greater detail. For example, the current personal fall arrest systems (PFAS) can effectively protect workers after they fall from elevation. While these may constrain the movement of workers, as with steel erection operations, such approaches should be examined further. Some workers fell because they did not tie-off their body harnesses, either because they felt it was troublesome to be tied off to a fixed anchorage or when they unhooked the lanyards to change their positions. More flexible PFAS might be able to save more lives. Different kinds of new technology, which can help prevent falls and protect workers from injury by falls, should be developed.

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SECTION II

Prevention of Falls in the Construction Industry

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TABLE OF CONTENTS

PREVENTION OF FALLS IN THE CONSTRUCTION INDUSTRY

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ABSTRACT

The most recent data from the Bureau of Labor Statistics shows that as the cost of construction projects increase, the incidence rates of falls decrease. This indicates that large construction companies, who typically have large construction projects, have lower incidence rates of falls from elevations than small construction companies. One possibility is that the greater financial resources of large construction companies allow them to develop more comprehensive safety programs. The focus of this research was to determine whether there were common elements of the safety programs of large construction companies that could account for the lower incidences of falls from elevations and to explore the possibility of transferring those elements to small construction companies, in particular roofing companies where the incidence of falls from elevations is high. Twenty-five construction companies with average construction contracts estimated at one million dollars or greater were selected from a list of companies that sponsor internships through the Construction Engineering Management (CEM) Division in the School of Civil Engineering at Purdue University. The safety directors of sixteen of those companies volunteered to answer a standardized questionnaire during a telephone interview with Purdue University researchers in the School of Health Sciences. The questionnaire consisted of twenty questions that focused on information about company safety performance, safety program structure, safety program implementation procedures, and the motivation and history behind the development of the safety program. The owner of a small roofing company volunteered to answer the same questionnaire and allowed Purdue researchers to observe the day-to-day operation of the company on a job site. The results from the large construction companies indicated that the primary element that contributed to reducing falls from elevations was the commitment of upper management to support and promote safety as a top priority. The development of a "safety culture" was the cornerstone of effective safety programs. The second most important element was training line supervisors in the area of supervision. The safety directors reported that a shortcoming of most line supervisors was that they lacked the necessary supervisory skills to effectively promote safety. The third most important element was regular onsite training from the construction superintendent. Task specific training was seen as the most important part of the onsite training. Transferring the findings to a small construction company may be difficult due to perceived financial constraints to support a safety infrastructure, and the possible lack of motivation of management to support and promote safety as a top priority.

SIGNIFICANT FINDINGS

The specific aim of this project was to determine what elements of the safety programs of large construction companies were responsible for lower incidence rates of falls when compared to small construction companies and to explore the possibility of transferring those elements to small construction companies. The elements in order of importance were:

- Upper management commitment to support and promote safety as a top priority,
- Training of line supervisors in the area of supervision,
- Regular on-site training from the construction site superintendent,
- Promotion of safety awareness and accountability as a fundamental value, and
- Daily crew meetings where supervisors go over a daily work plan and job specific safety training for those potentially exposed.

Another key finding was the motivation behind large construction companies developing their safety programs. The motivating factors in order of their importance were:

- Concern for the well being of the employees and maintaining profitability (these generated an equal number of responses),
- Insurance company pressure and a high experience modification ratio, and
- Concern for the reputation of the company and compliance with OSHA regulations (these generated an equal number of responses).

USEFULNESS OF FINDINGS

The goal of determining what elements of the safety programs of large construction companies contributed to their fall safety success was that those elements might be adopted by small construction companies to make them safer. If a small construction company is committed to fall prevention, adopting the elements listed in this study into their safety program will move them toward their goal. Three of the five elements: supervisor training, regular on-site training, and daily crew meetings, are directly related to training. Adopting new training strategies should be relatively simple because the concepts are clear and can be reinforced through repetition. Unfortunately, the most important element, upper management commitment, involves motivation. Motivation is harder to teach because it is a state of mind rather than a list of rules to be memorized and followed. This study found that regulation was low on the list of motivating factors for the development of a successful fall safety program. In the absence of any other motivating factors, a construction company might not be easily persuaded to implement a successful fall safety program. If any construction company is not committed to fall prevention then the information contained in this study will be of little use to them.

SCIENTIFIC REPORT

Background for the Project

The construction industry is consistently responsible for the largest number of fatal work injuries of any industry in the United States. Of those fatal injuries, falls from elevations are the leading cause (Hinze et al., 2002). In 2000, 734 deaths due to falls were recorded (Bureau of Labor Statistics, 2001). That number is surprising when you consider the regulatory intervention imposed on the industry and the advancements in fall protection devices made over the last several years. The key question that needs to be addressed is why do fatalities continue to occur at such a high rate.

Several factors may need to be considered as probable causes. Those factors can be broken down into three major categories. The first category has to do with possible regulatory inadequacies and whether changes in government regulation can effectively reduce the numbers of falls. The second considers the responsibilities of the construction companies and the steps that they can take to reduce the number of falls. The third category involves the workers themselves and how their actions can contribute to the reduction of falls.

Derr et al. (2001) examined how the implementation of the February 1995 29 CFR Part 1926 Subpart M OSHA fall protection regulations affected fatal fall rates. Looking at the period of 1990 through 1999, they found a significant reduction in the number of fatal falls. However, they were unable to show that the reduction in the number of fatal falls was due to the new regulation. In part, this may have been a result of the small number of events, which diminished the statistical power of the study. Another possibility is that regulations might not have the ability to effect changes standing by themselves. Nelson et al. (1997) looked into the combination of new regulations coupled with an extensive education campaign and found results inconsistent with Derr et al. (2001) in that there was not a significant reduction of falls. It should not be construed from these results that regulation and education have no value. On the contrary, they are the foundation on which safety is built. Other factors need to be coupled with them in order to insure their effectiveness.

Enforcement is a complementary component to regulation and education that has been shown to reduce the incidence of construction falls. Nelson et al. (1997) showed from their data that construction companies that received citations after an OSHA inspection experienced a significant decline in incidence rates of falls. One problem with government enforcement is that it needs to be comprehensive in order to be effective. The shear number of construction companies in the United States that need to be overseen makes it nearly impossible, from an economic standpoint, for OSHA to police the entire construction industry. As long as a company has a reasonable chance of being overlooked by OSHA, the benefit of being noncompliant may outweigh the risk of citation.

A contrast to government regulation is worker self-regulation. Workers should have a strong interest in safety since they are the ones most adversely affected by a construction fall. Abdelhamid and Everett (2000) cite three primary reasons for occupational accidents. They are: 1) failing to identify an unsafe condition that existed before an activity was started or that developed after an activity was started, 2) deciding to proceed with a work activity after the worker identifies an existing unsafe condition, and 3) deciding to act unsafe regardless of initial conditions of the work environment. All three reasons put the primary responsibility for safety on the worker because the worker is the person nearest and most likely to detect an unsafe situation. In the event that the worker has not been properly trained, many unsafe situations may go unnoticed. In that case, the line supervisor and ultimately, the employer also share in the burden of responsibility; however, the worker still plays the key role in the deciding what to do once an unsafe condition has been identified.

The question now becomes would a worker wish to continue work knowing that an unsafe condition exists? The answer may lie in a workers' own assessment of risk. Ellis and Warner (1999) concluded that successful experience at heights distorts a workers perception of risk. As workers gain experience and confidence working at heights, they tend to develop a false sense of security. Their ability to self assess risk is diminished by their own self-confidence. Even if they have been unfortunate enough to know someone who has suffered a fatal fall, they can continue to justify their own safety through their own self-confidence. Holmes et al. (1999) identified another method by which workers weigh the costs and benefits of potentially unsafe situations. If the necessary safety measure is perceived to present too great a level of effort, it will be ignored. The key problem with this perception is that the worker often misidentifies the true cost being weighed. The perception may be that the cost is the extra work effort required to implement the safety procedure. In reality, the true cost is death or permanent disability because of a fall. Johnson et al. (1998) came to the same conclusion but further showed that workers would forego personal safety if they felt that speed and comfort were more important.

Lingard and Holmes (2001) concluded that more than half of construction workers believe that their safety is the responsibility of the company or trade union. This responsibility is perceived to be in the form of better education and training. Cattledge et al. (1997) discovered that all of the claimants in their study received fall protection training but hardly any of them used fall protection devices indicating that training and education alone cannot be expected to make an impact on reducing falls from elevations. The missing component is that workers may need to have some sort of outside motivating factor that will promote the discipline necessary to keep them safe. Government regulation and enforcement have been shown to be somewhat ineffective in this regard so construction companies are left with the task of reducing falls from elevations.

Construction companies are really the most logical choice. They have the ability and opportunity to effectively train, equip, and communicate with workers. They also have the authority to promote and enforce compliance with safety procedures. This can best be demonstrated by examination of the Kuwaiti construction industry where there is little government regulation and little safety training outside of the construction companies. Kartam and Bouz (1998) evaluated injury and fatality data from the Kuwaiti construction industry and found that competent construction managers and pressure from upper management played a key role in reducing construction accidents. In the United States, another interesting trend can be shown that relates the cost of construction projects to the number of falls.

Hinze et al. (2002) have shown that as the cost of construction projects increase, the number of falls decrease. It stands to reason that larger construction companies tend to get large construction projects. In essence, large construction companies have lower incidence rates of falls from elevations than small construction companies. There are several factors that may be responsible for this trend. One possible reason is that there are greater financial resources available to large construction companies, a significant portion of which can be used for fall prevention. Another contributing factor might be increased scrutiny of large construction companies by OSHA. In contrast there are also reasons that large construction companies should have higher incidence rates of falls such as greater difficulty in managing larger groups of workers. The purpose of this study was to determine what factors were responsible for the lower incidence rates of falls experienced by large construction companies and to evaluate the feasibility of transferring that technology to small construction companies.

Problem Statement

More than a million people suffer from a slip, trip or falling injury each year. Slips, trips and falls account for 15 to 20% of all workers' compensation cases, with older construction workers having a higher percentage of falls compared to younger construction workers. Despite several field and laboratory studies to better understand the problem of slips, trips, and falls, the problem has not improved. This study proposed to focus on prevention of falls in the construction industry because recent data from large construction companies had fewer fall related injuries compared to smaller construction companies. It was hypothesized that the reason larger companies experienced a lower rate of falls among its construction workers was because they had strong safety programs. It was further reasoned that if certain patterns could be found in their safety programs that they could be used as a model or blueprint for smaller construction companies to implement thus decreasing the number of construction related falls.

This study focused on construction companies that had strong safety programs and low "falls from elevations" incidence rates. There were two study purposes: The first purpose was to investigate the relationship between safety program effectiveness and impact among construction companies with low incidence of falls from elevations. The second purpose was to develop an information database on work risk factors associated with falls from elevations among active and retired construction workers. The main effort of this study was to focus on active construction workers (in collaboration with researchers at the Construction Industry Institute (CII)/University of Texas, University of Florida). A secondary effort will examine the fall risk factors associated with older construction workers as well as the quality of life for retired construction workers (in collaboration with researchers at the University of Cincinnati). Reports from the University of Florida and University of Cincinnati are included in the larger body of this report. Because the Construction Industry Institute (CII)/University of Texas has to follow annual report guidelines provided by its board members, their report is presented in Appendix A of this report. In addition CII/University of Texas provided invaluable consultation opportunities at their annual conferences. Analysis of OSHA data on falls from elevations in the construction industry is provided by Hinze et., al in the front Falls section of this report, and the report on the quality of life among retired construction by LeMasters el. al., follows this section.

Specific objectives and results.

Objective No 1:

Select up to 15 large construction companies and visit and conduct interviews with its safety directors to learn and document the specific company policies regarding protection against falls, and how their company trains and educates workers on fall prevention practices. Information will also be sought on methods employed to enforce company policies and approaches that have been successful to overcome obstacles to implementation.

Results:

Twenty-five large construction companies were selected for this study, of which 16 of the company safety directors completed a standardized questionnaire administered by telephone to the safety directors of these companies. The questionnaires showed evidence of success in their safety programs by reporting:

- The average number of years the current safety program had been in effect was 10
- The median number of workers that work at elevations over 6 feet was 320
- No fall related fatalities in the past 5 years
- All but one company had fewer than 10 fall related injuries in the past 5 years, and half had 0
- All but one company had an EMR less than 1.0, and half were less than 0.7

Top 5 activities thought to be important for a strong safety construction program and to prevent falls

- Upper management commitment to support and promote safety as a top priority
    - Successful fall prevention depends on the primary motivation and primary enforcement coming from the top
    - None of the construction companies achieved fall prevention success until the commitment issue was resolved
- Training supervisors in the area of supervision
    - Historically, supervisors have been promoted from the ranks based on their ability to ply their trade

    - Fall prevention relies on the supervisors leadership and management capabilities
- Regular on-site training from the construction supervisor
- Promotion of safety awareness and accountability as a fundamental value
    - Safety should be promoted as an integral part of the job function rather than additional work piled onto the job
    - Daily crew meetings where supervisors go over a daily work plan
- Job specific training for those potentially exposed

Summary:

- Key findings that provided motivation that initiated and maintained momentum for safety programs
    - Maintaining profitability and concern for the employees
    - Insurance company pressure and high EMR
    - Concern for the reputation of the company
    - Compliance with OSHA regulations

Objective No 2:

Provide information from the Construction Industry Institute's (CII) injury data (including falls) highlighting their findings and compare these data to non-CII construction companies.

Results:

The CII (see Appendix A: 2002 Safety Report from CII) reported that "Nationally the Construction industry division experienced the highest number of fatalities that it ever has since the Census of Fatal Occupational Injuries was begun in 1992.[1] In 2001, the Construction industry division also had the highest number of fatal occupational injuries of any other industry as reported by the Bureau of Labor Statistics (BLS). With 1,225 fatal occupational injuries, the Construction industry division was followed by Transportation (911), Services (767), and Agriculture (740). Keeping in mind that fatality rates are determined by the number of persons employed in the industry, Mining had the highest fatality rate of any industry, 30.0, with a total employment of 566,000. This was followed by Agriculture with a fatality rate of 22.8 (3,208,000 employees). The Construction industry was third. The fatality rate was 13.3 (9,125,000 employees), an increase of slightly over 3% from the previous year.

The leading cause of fatalities among CII member companies was falls (38.5%), followed closely by contact with objects and equipment (35.9%), transportation (15.4%), exposure to harmful substances or environments (5.1%), fires and explosions (2.6%), and assault and violent acts (2.6%). The top three causes accounted for nearly 90% of all fatalities. In comparison, the three leading causes of fatalities in the Construction industry division as reported by BLS for the same year were falls (34.4%), transportation

[1] Bureau of Labor Statistics, "National Census of Fatal Occupational Injuries," Washington, D.C., September 2002

(26.0%), and contact with objects and equipment (18.1%); these accounted for nearly 79% of all fatal injuries."

The CII annual report goes on to say that "Fatalities increased slightly from the previous year for both CII member companies and the Construction industry in general. For CII member companies there was an increase of 2%, and the rate of increase for the Construction industry in general was 3%. Fatalities represent additional economic and ethical burdens to the industry. The direct and indirect costs of fatalitites far outweigh those of injuries alone. It was estimated that in 1992 the average direct and indirect costs of a work-related fatality were $565,170 compared to an average of $10,968 per work-related injury.[2] Beyond the economic considerations are the ethical ones that demand a safe work environment. The commitment on the part of CII member companies to preventing fatalities is clear: the CII member company fatality rate was 53% lower than the Construction industry rate."

The CII reported that despite the higher rate of fall-related fatalities compared to the BLS statistics, CII member companies safety performance exceeded that of the construction industry in general. In fact, the CII report says that in 2001, CII member companies recordable incidence rate performance was 7 times better than the construction industry and that the CII member company loss-work day case incidence rate performance was nearly 15 times better than the construction industry in general. The difference in safety performance level between CII member companies and the construction industry in general may be attributed to several things including a sustained strong commitment to safety programs by their member companies. The findings are consistent with the findings from the questionnaire results from the safety directors from the large construction companies, many of whom are CII members.

Objective No. 3:

Observe and document fall hazards from a small construction company (i.e., roofing companies) and see if the information gained from the safety directors of the large companies can be transferred to small roofing company. Note: this study focused on small roofing companies because this industry has a high rate of falls compared to the construction industry in general.

Results:

An owner of a small roofing company (25 workers) located in Indiana was interviewed. The primary objectives of the interview were to: 1) Learn about their safety program, and 2) Investigate whether the lessons learned from large construction companies would be useful. The safety record of this roofing company showed that: no fatalities occurred in the past 5 years, no fall related fall injuries in

[2] Leigh, JP et. al., "Occupational Injury and Illness in the United States: Estimates of Cost, Morbidity, and Mortality," Archives of Internal Medicine, 1997

the past 5 years, one employee fell from a roof working on his own house, and they had an EMR of 0.85 in 2002.

After interviewing the roofing company owner permission was requested to document their workers replacing shingles on a residential roof. Permission was granted and documentation of this process including video clips can be viewed on the Construction Safety Alliance website (https://engineering.purdue.edu/CSA/)

There are 7 basic steps in a residential roofing operation:

1. Property Protection (cover bushes and house parameter with tarp)
2. Old Roof Removal (two layers of shingles, old felt, all roofing nails, metal edging and flashing)
3. Deck Inspection and Repair (use power saw to remove damaged plywood, replace with good plywood)
4. Application of Waterproofing System (apply tar and new flashing material around all roof vents, skylights, chimney)
5. Apply new roof shingles
6. Application of Ventilation System (Cobra® vent)
7. Job Completion and Inspection (remove all nails, debris from property).

Of these, **Step 2 (old roof removal – Figure 1), Step 3 (deck inspection and repair – Figure 2), and Step 5 (applying new roof singles – Figure 3)** were reported by the roofers to be the most dangerous in terms of falling off the roof. The reason that these steps were considered more dangerous than the others is they all required working close to the edge of the roof (the drip edge) and if a fall occurred the workers did not have enough time to "orient themselves" where they could land feet first and sustain less injury.

Figure 1. Old deck removal. Note how close the workers are to the drip edge risking a fall.

In talking to the owner and to the workers at the work site, Purdue researchers could see no evidence of a formal safety training program. Instead the owner relied on the foreman to enforce safe work practices such as tying off the roof ladder, and using a shingle conveyor to carry shingles to the roof rather than hand carry them up the ladder.

Figure 2. Deck inspection and repair. Worker is throwing dry rot plywood to a dump truck 25 feet below the roof line. Nails protruding from the plywood can catch on the worker's hands pulling them off the roof.

As discussed earlier, for large construction companies successful fall safety programs may be driven by money. For the larger construction companies safety benefits outweigh the costs. However, with smaller construction companies safety benefits are not as obvious. For example, the roofing company reported an EMR of 0.85. The owner of this roofing company thought that this was a good EMR because it below 1.0. When the EMR goes above 1.0 insurance and workers' compensation costs tend to increase. In addition, if the roofing company does not experience a serious fall among its workers would they see a need to implement the same rules that apply to larger companies?

Figure 3. Worker placing felt pad and roofing shingles near drip edge of roof. Workers are very concerned about falls from the edge of a roof because they have very little time to react and get their feet aligned to the ground during a fall.

In addition, such companies compete with the 1 and 2 person roofing companies (called "Truck Slammers" in the roofing business) that have very little overhead. Small companies operate in an environment where their competitors may not build fall safety into their costs because fall prevention strategies take both time and money. For example, it takes time to construct and tear down engineering controls, and additional labor and material costs associated with engineering controls. Guard rails may be one of the best ways to prevent someone from going over the edge. However, roofing workers view them as impractical in residential roofing operations because they: 1) interference with leading edge work, 2) eaves are not structurally stable enough to provide support, and 3) ground based systems (such as scaffolds) would be costly and time consuming to erect and tear down.

As for personal protective equipment, harnesses are perceived to be impractical in residential roofing operations because: 1) tie off points would need to be installed, 2) constructing tie off points would interfere with the roofing operation, and 3) harnesses would restrict movement due to the limited amount of vertical drop (i.e., the roofer might end up hitting the ground before the lanyard is taught).

Roofing owners know the injury statistics for their industry. However, when confronted with the statistics of 421 deaths due to falls in the construction industry per year, this translates to about 9 deaths from falls per state per year. Given the number of construction projects occurring at any one time where someone is working at elevation is it reasonable to assume that the odds are in favor of someone not falling from an elevation during construction? Many workers and some small construction company owners may work on this assumption.

The safety culture of taking chances because the odds are with the company is a poor choice. The authors of this report have concluded that the facts need to be communicated better to educate small construction company owners and their workers. One of the most sobering statistics is that **on average one construction worker dies each day in the U.S. from a fall at elevation.** This is reason enough to put safety first no matter what size the company.

Methodology

Twenty-five construction companies whose typical construction contracts were estimated to be in excess of $1,000,000 were selected from a list of companies that sponsor internships through the Construction Engineering Management School at Purdue University. Letters were sent to the safety directors of each company explaining the importance of the research and indicating that they should expect a follow-up telephone call at which time a telephone interview would be conducted (an example of the letter is shown in Appendix B). A copy of the standardized questionnaire to be used during the telephone interview was enclosed with the letter to allow the safety directors time to gather information that was not readily available (a copy of the standardized questionnaire is shown in Appendix C).

Purdue University researchers in the School of Health Sciences conducted the telephone interviews. The safety directors were called during normal business hours. In the event that the safety director was not available, a message was left indicating the reason for the call and providing a telephone number with which to return the call. Calls were made on a daily basis until either all of the safety directors were interviewed or the predetermined time of six weeks allotted to conduct the interviews was reached. The safety directors of sixteen companies volunteered to answer the standardized questionnaire during the telephone interview.

The questionnaire consisted of twenty questions. Five of the questions were open-ended and designed to solicit opinions with minimal interference from the interviewer or prompting from the questionnaire. The remaining questions were related to statistical information. The information collected during the interviews was entered on an Excel® spreadsheet.

Numerical answers were analyzed by calculating the mean and median. The qualitative answers were evaluated two ways. First, the response was assigned a number based on its order of importance to each company. For example, when the question requested the top five answers ranked from most important to least, the most important answer was assigned a 1, the second most important answer was assigned a 2, and so on. Second, the number of times a particular response was recorded by all of the companies was noted. The ranking of the response relative to all other responses to a particular question was based on the evaluation of both the number of times the response was recorded and the numerical rank it received from the company who recorded it. A high ranking would indicate that a particular response received both high rankings from the companies and was recorded as a response by several companies.

To better understand how the findings of the study might be transferred to small construction companies, the Purdue University researchers interviewed the owner of a small roofing company, using the same questionnaire used to interview the large construction companies. We also observed the day-to-day operation of the roofing company to gain a better understanding of the challenges they face and to determine bow the primary elements of the safety programs of the large construction companies might be implemented.

Results

A summary of the questionnaire results is shown in Appendix D. The companies that participated in the interviews were large in terms of their construction contract size. The median contract amount was $9,000,000. According to Hinze et al. (2002), companies involved in construction projects of that magnitude are expected to have lower incidence rates of falls than companies involved with smaller projects. The median Experience Modification Ratio (EMR) of the companies interviewed was 0.73, which lends credibility to that study. The EMR is a tool used by insurance companies to determine premiums for workers' compensation insurance. It is the ratio of actual losses due to work-related injuries and illnesses over the expected losses. An EMR of less than one indicates that a company is suffering fewer losses than other companies in the same industry (Safety Management Group, 2002). Additional evidence of safety performance is seen in the number of years the construction companies had been practicing their current safety program. The median time was 11 years.

All of the construction companies indicated that they were affiliated with external safety organizations. The opportunity to network with other companies was listed as the primary benefit of membership. The network forum allows the sharing of information gained through experience and provides an expert panel to explore new ideas. Rather than a beneficiary role, the construction companies that were interviewed acted mostly in an advisory capacity to safety organizations, although, some of the companies benefited from training information provided through safety organizations.

Employee turnover is a concern because of the potential inexperience of new hires. The median rate of employee turnover was 145 per year and the median duration of employment was 18 months. The turnover rate is nearly half the number of employees that work at elevations over 6 feet. The median number of employees that work over 6 feet is 320 at any given time. In spite of the high employee turnover, fall injuries were relatively scarce.

The median number of injuries due to falls in the past year was two and the median number for the past five years was five. Only one company of the sixteen interviewed reported a fatality in the past year and no other fatalities were reported in the past five years. The exception was one contractor that experienced no injuries or fatalities themselves but had subcontractors who had experienced two fatalities in the past year and seven fatalities in the past five years. The lack of compliance to safety procedures by subcontractors was a common complaint.

Safety training is likely to be one of the elements responsible for such low numbers of injuries and fatalities. The median number of employees trained per year was 500. All but one company engages in refresher training on a regular basis so most existing employees can expect to receive refresher training every 12 months. The companies were split on whether they thought the employee turnover rate affected how their safety training programs were implemented. Companies who perceived that turnover had no effect may have been biased due to the existing level of intensity of the training program brought on by the anticipation of high turnover.

When considering training or safety equipment, cost can be an important issue. The construction companies interviewed in this study were asked to estimate their yearly expenditures for training and safety equipment per worker. The median of the estimated cost per year for training was $800 and the median of the estimated cost per year for safety equipment was $250. These numbers are minimal in comparison to the cost of injuries and fatalities from falls.

The construction companies were asked to list the five key factors that influenced them to implement their current safety program. Even though this was an opinion-based question, there were not a wide variety of answers. The fourth and fifth most common answers tied for the number of responses. They were concern for the reputation of the company and compliance with OSHA regulations. The third most common answer was insurance company pressure and a high EMR. The first and second most common answers tied for the number of responses. They were concern for the well being of the employees and maintaining profitability. A common theme found in these responses was money. The safety directors felt that a negative impact on a company's bottom line was critical to the development of a proactive attitude toward safety.

The construction companies were asked to list what they considered to be the most important elements of their safety training programs with respect to making them successful at reducing falls from elevations. Since this was an opinion-based question, there were a wide variety of answers, however, there were a few that were mentioned consistently.

Two answers tied for the fifth most common element. They were daily crew meetings where supervisors go over a daily work plan and job specific safety training for those potentially exposed to falls. The fourth most common element was the promotion of safety awareness and accountability as a fundamental value. In essence, the development of a safety culture where safety was a habit rather than a chore was expressed. The third most common element was regular on-site training from the construction site superintendent. The second most common element was the training of line supervisors in the area of supervision. The safety directors felt that supervisors were too often chosen for their adeptness at their particular trade rather than their ability to exercise supervisory skills over workers. The most commonly mentioned element was unique in that half of the companies mentioned it as the most important element of their safety training program. It was upper management commitment to support and promote safety as a top priority. The safety directors felt that financial support for the safety program and the presence of upper management at key meetings was how this was best demonstrated. By making safety the first item on the agenda at management meetings, upper management displayed its commitment to safety to lower level managers. Periodically visiting jobsites and taking part in some onsite training was a way of displaying commitment to safety to line supervisors and workers.

As with the large construction companies, the small roofing company had an exemplary safety record. There had been no fall related injuries in the preceding five years and the EMR was 0.85. A summary of the observations of the roofing company is shown in Appendix E. During the interview, the owner who was also the chief safety officer revealed that the company had no formal safety program. Discussions about safety only took place when workers were faced with projects where they would encounter extreme roof slopes or other hazardous conditions. He indicated that the discussions were no more than reminders to be careful and look out for each other. The most disturbing part of the interview was that the owner felt that those discussions constituted a safety program and that the program must be working because of their safety record.

Study Contributions and Discussion

The results can be summed with three terms: motivation, training, and money. The primary reason for the success of large construction companies at reducing construction falls is that upper management has made a commitment to be safe. In making that commitment, they create momentum that motivates middle managers, construction supervisors, and finally, trade workers to be safe. Without the motivation from the top, there is little chance that a successful safety program will develop and almost no chance that a safety culture will develop. As was shown by prior research (Holmes et al. (1999) and Johnson et al. (1998)), workers will perform their tasks in a manor that allows them to experience the least amount of inconvenience. Unfortunately, safety is often seen as an inconvenience.

Appropriate training must follow effective motivation. Training is the method by which motivation is focused. The most important part of that training is training line supervisors in the area of supervision. Line supervisors are the most critical link in the safety chain because of their proximity to potentially dangerous situations. To effectively promote safety, line supervisors need to understand how to effectively communicate and motivate workers so that they will comply with safety procedures. The line supervisors also need to have a good understanding of regulations concerning safety. Since line supervisors are usually regular employees, provisions need to be made to insure that they receive training on a regular basis.

Worker training is next in importance. High turnover rates put the company in a position where new employees are constantly coming onto jobsites. In order to insure that workers receive the proper training, special training for new hires, regular onsite training, and daily crew meetings where daily work plans are discussed are crucial to reducing construction falls. This type of regular training allows the supervisor to effectively dictate the expectations of the company in the area of safety.

The factor that induces the motivation that initiates the training is money. Large construction companies discovered several years ago that it was profitable to be safe. Relatively small expenditures up front as shown by the costs of training and safety equipment can prevent large costs incurred after an accident. Lost time, loss of reputation, increased insurance costs, loss of competitiveness, and potential litigation are strong reasons to invest in safety.

The primary difference between large construction companies and small construction companies is that large construction companies who have good safety programs adopted those programs because of safety problems that made an impact on their profitability to the extent that they had no choice but to become safe. Large construction companies can build the extra cost into their bids because their competitors are faced with the same circumstances. Small construction companies, on the other hand, face competition that has likely never faced serious safety related problems and therefore, have no incentive to build the cost of safety into their bids. Small construction companies that might desire to build in more engineering controls, safety equipment, and safety training would be priced out of the market and go out of business. If small construction companies are to ever develop effective safety programs modeled after large construction companies it seems that one of two scenarios must occur. Either, as with the large construction companies, small construction companies need to experience the losses that forced the large construction companies into compliance or an effective method of regulating small construction companies must put into place.

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SECTION III

A Pilot Study of Functional Impairment and Falls in Retired Union Construction and Non-Construction Members

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Research Associates

Laverne Mayfield (GCOHC) and Eric Borton

TABLE OF CONTENTS

A PILOT STUDY OF FUNCTIONAL IMPAIRMENT AND FALLS IN RETIRED UNION CONSTRUCTION AND NON-CONSTRUCTION MEMBERS

Research Team: Grace LeMasters and Amit Bhattacharya, University of Cincinnati, Research Associates: Laverne Mayfield (GCOHC) and Eric Borton

ABSTRACT

Once they leave the workplace, retirees are often forgotten. The adverse effects of their life's work, however, often remain with them during their retirement in terms of level of independence, pain, and overall quality of their life. Workers in the construction trades traditionally experience a lifetime of physically demanding job tasks that may cause cumulative degeneration of their physiological systems and injury. The purpose of this study was to conduct a pilot study to determine the physical health of retirees from the construction industry compared to those from less physically demanding occupations. Another purpose was to determine the feasibility of undertaking a larger health study in terms of cooperation from the unions as well as the retirees. In order to accomplish these purposes two approaches were undertaken. Three focus groups were held comprised of a total of 19 retirees to determine their concerns about the long-term effects of their jobs on their current health status and quality of life. In addition, 300 construction and 480 non-construction retirees were mailed a health survey and about one-third responded after just one mailing. This survey inquired about current physical functioning, limitations, pain, and past and current problems with falls and injuries. The results were striking with construction retirees, compared to non-construction retirees, having significantly poorer health ($p<.01$), and physical limitation of their daily activities ($p<.01$). Almost one in five (19.4%) construction retirees described themselves as having severe to very severe pain ($p<.05$) compared to 8.4% of the non-construction retirees. In comparison to non-construction retirees, construction retirees reported significantly greater problems with their vision, neck and shoulders, hands and wrists, hips, knees and ankle/feet joints. If these findings hold in a larger study of retirees in the construction trades, then the health, physical, emotional and financial costs of these construction jobs on our rapidly aging population are enormous.

SIGNIFICANT FINDINGS

Over 27% versus 11% of construction and non-construction retirees, respectively, report having had a past work injury in need of medical attention. Construction versus non-construction retirees were two to four times more likely to report "severe to very severe" problems with their vision, neck/shoulder, elbow, knee and ankle/feet and joints. Construction versus non-construction retirees were two to three times more likely to describe their health as poor and report having "severe to very severe" body pain. It was surprising that 42.1% of construction retirees compared to only 14.0% ($p<.01$) of the non-construction retirees reported having fair to poor health. Construction versus non-construction retirees reported two to three times greater dissatisfaction with their level of physical activity and physical functioning.

In regard to the feasibility of doing a larger more inclusive survey, we determined that retirees are very interested in participating in health studies. This enthusiasm was demonstrated by their verbal engagement and participation in the focus groups. It was also demonstrated by their response rate, which was comparable to other studies with only one survey mailing. The instrument developed for the survey was easy to read and complete, and we had few blanks. The unions gave us considerable cooperation that included addressing and mailing the prepared packets.

USEFULNESS OF FINDINGS

This feasibility study demonstrated that retirees in the construction industry clearly have reported significantly more health problems and a poorer quality of life as demonstrated with limitations to their role functioning and inability to fully enjoy their retirement years compared to other retirees. This study demonstrates to contractors and younger apprentice and journeyman that their current work practices and type of work performed will have significant and long lasting health consequences. Therefore future studies can be designed to develop intervention strategies for retired and non-retired construction workers. To help minimize future health problems among currently active workers, efforts can be directed towards identifying and reducing ergonomic risk factors associated with current work practices of various construction trades.

This was a pilot study to determine the interest of unions in having their retired members contacted. The enthusiasm of the unions demonstrated their concern about their retired membership and their willingness to not only write letters of support but also to address and mail the documents to their membership.

SCIENTIFIC REPORT

A. Risk Factors in Construction:

The construction trades include carpenters, welders, grinders, roofers, ironworkers, sheet metal workers, ship fitters, bricklayers, electricians, painters, machinists, laborers, pipe fitters, boilermakers, crane operators and laborers. Work in the construction trade involves considerable ergonomic risk. Frequently, heavy tools, equipment and materials must be handled and moved requiring pushing, pulling, twisting, bending and excessive reaching. These motions often require extreme force on joints, limbs, muscles and ligaments and have been shown to be associated with significant musculoskeletal disorders [1]. In the construction trade, the individual may spend extended time in awkward body positions and repetitive, forceful use of the back and upper and lower extremities. Besides these recurrent musculoskeletal stresses, those in the construction trades often perform job tasks under adverse conditions, e.g., on ladders and scaffolding, at high elevations, and in inclement weather. Thus, these conditions place the workers at high risk for falls, injuries and subsequent impairment during their retirement.

Hsiao and Stanevich [2] showed that the construction industry had the highest incidence of fatalities, injuries and illnesses per 100 full time workers in major industries. For the construction industry, the injury rate was 14.2 compared with a rate of 13.2, 11.6, 9.6, and 8.3 for the manufacturing, agricultural, transportation and mining industry, respectively. In Ohio, where this study was performed, construction workers reported a higher rate of work related musculoskeletal disorders than all other occupational groups [3]. Further, a study of older construction workers, between the ages of 40-64 years, showed that these workers compared to a white collar workforce had a significantly higher rate of hearing deficiencies, obstructive lung disease, and musculoskeletal abnormalities [4]. Carpenters and bricklayers had the highest prevalence ratios related to reduced mobility of the spine and symptoms in the arms and legs. Another study also demonstrated that bricklayers with longer than 10 years employment duration had increased symptoms of low back disorders compared to painters, carpenters or concrete builders [5]. In addition, to physical risk factors, construction workers are also exposed to neurotoxic chemicals such as epoxy resins and pitch for cement workers, coal tar pitch and solvents used by roofers and welding fumes and solvents used by the painters. These neurotoxic chemicals have been shown to cause neuromuscular impairment [6,7].

B. Objective, Purpose, Hypothesis, and Specific Aims

Objective and Purpose: This pilot study was a cross-sectional investigation of retired unionized workers who have been employed in the construction trades. It is a collaboration between the University of Cincinnati and the Greater Cincinnati Occupational Health Center. The *objective* of the study was to determine the long-term health consequences of having 20-30 years of very physically demanding jobs. The first purpose of this study was to conduct a pilot study to determine the physical health of retirees from the construction industry compared to those from less physically demanding occupations. The second purpose was to determine the feasibility of undertaking a larger health study in terms of cooperation from the unions as well as the retirees.

Hypothesis: The overall study hypothesis is that retirees previously employed in the construction trades will experience a poorer quality of life and impaired physical functioning than do retirees who had less physically demanding employment.

This investigation was a pilot study to gather preliminary information on the status of retired workers in the construction industry compared to a similar group of workers who had less physical demands on their neuromuscular system. There were two specific aims of the study.

Specific Aim 1: To conduct focus groups with retired union workers in the construction trades and non-construction work groups and learn how job activities performed during their work years may have affected their quality of life and experience of falls and slips with injuries thus far during retirement.

Specific Aim 2: To pilot test a survey instrument on a sample of unionized retirees from the construction trades and non-construction retiree unions in order to determine the feasibility and interest of retirees in participating and to describe the quality of their health during retirement.

C. Research Design and Methods

C.1. Focus groups (Specific Aim 1): Critical elements for an effective survey of workers and for efforts of enlisting worker cooperation for future studies include the following: needs assessment, establishing objectives, specifying training/education content and accounting for individual differences [8,9]. One direct method for obtaining this required information was to utilize focus groups involving retired individuals in six trade groups. The focus groups were undertaken to provide in-depth information on the attitudes, knowledge, perceptions and opinions of participants and their personal motivations, job related practices and retirement related experiences [10].

The specific purposes of the focus groups was: 1) to identify trade groups and job categories with high physical work demand, 2) to provide input for the development of the survey instrument, 3) to obtain the information necessary to implement the survey such as the best methods to gain cooperation for contacting subjects.

The Greater Cincinnati Occupational Health Center (GCOHC) is a union-supported center designed to support training and the health and well being of its members. The GCOHC Director, Ms. Laverne Mayfield, recruited retirees to attend the focus group. The retirees met at the GCOHC. Three focus groups were held in early 2002 lasting one and a half hours. Six unions/trade groups were represented. Each retiree signed an informed consent prior to their participation. They were given refreshments and a $25 incentive for their time and travel. These groups were audio taped and then transcribed.

A script was developed to moderate the group, and focused on answering three questions:

1. What areas of activities of daily living and recreation have been affected by your previous work environment?

2. What activities in your former work environments do you consider may affect your current health status and current quality of life related to your ability to do what you like or need to do?

3. What programs would you like to have offered in order to improve your physical functioning or quality of life?

C.2. Questionnaire survey (Specific Aims 2): Home addresses were available from union records. A letter was included in the mailing describing the purpose of the study. Another letter from the union president was also enclosed encouraging participation as well as a stamped self-return envelope and an informed consent to sign. A copy of the survey is found in appendix one. The unions addressed and mailed the packets in order to maintain privacy of the retirees' home addresses

The survey instrument was self-administered and required less than 10-15 minutes to complete. The purpose of the survey was to assess aspects of general health, medical status and quality of life on several dimensions including motor function, mobility, physical activity, dexterity, ability to undertake household activity, activities of daily living and issues related to pain. Questions were adapted from two well-validated forms described below. In addition, questions were included that addressed falls and injuries while employed and in the last 12-months, demographics, and how the unions could better serve the retirees.

The Short-Form-36 Health Survey: This self administered instrument has ordinal data. Many studies have evaluated its reliability (median alpha reliability is 0.80) and validity (correlations with other scales ranged from 0.51-0.82). Sensitivity to physiologic change had a demonstrated high effect size of 0.67 patients having musculoskeletal disorders [11]. It addresses areas including physical functioning, role limitations, pain, social functioning, mental health, vitality, and general health perceptions. It is applicable for older subjects regarding health and quality of life issues. Because of the length of this instrument it was not appropriate for mailing particularly for an older population. Therefore, four questions were selected, that were found to be relevant.

The Medical Outcomes Study Physical Functioning Measure (MOS): The MOS measures physical functioning and is sensitive at relatively high levels of physical function. Three items with high internal consistency for either physical functioning score and/or mobility were selected [11]. For the construction unions, surveys were provided to 50 retired members of the IBEW and 250 laborers. For the non-construction unions, 250 retired members of the teachers union (including support staff) and 230communication union members were mailed.

C.3. Data Management and Analysis (Specific Aims 1-2): The focus groups were recorded and summaries were transcribed. These summaries were reviewed by the investigators and then analyzed qualitatively.

The returned surveys were scanned and verified by Teleform®. A 10% quality check was done by verifying the Teleform® results with the hard copies. The data generated by the Teleform® system were converted into a format to be used for analysis by the SAS ® statistical software program. Responses to questions obtained from the SF-36 questionnaire were scored to create a categorical scale from 0 to 100. A higher score represented a better state of health. Questions with five category responses were coded in steps of 25. Scores for items in the same health dimension were averaged to create a scale from 0 to 100 with a higher score denoting better health. Questions related to demographics, job characteristics, and falls were ordinally or categorically coded with each response level assigned a specific value.

Analyses were undertaken in order to convey the responses of the construction group and the non-construction group. The non-construction group was compared to the construction group. Additional analyses were also undertaken to compare only the males in the non-construction group as to the construction group comprised of all males. The female non-construction retirees were also evaluated separately.

Data were analyzed using X^2 for testing significance at the 0.05 and 0.01 levels. When the sample size was less than 5, the Fischer's Exact two-sided test was used to evaluate significance at the 0.05 and 0.01 levels.

D. Results

D.1. Results of Focus Groups

There were three focus groups totaling 19 retired participants: 11 construction and 8 non-construction. The participants from the construction trades included laborer (3), plasterer (3), pipe fitters (2), hod-carrier (1), truck driver (1), and pile driver (1).

The non-construction members included offset printing (1), inspection/clerical/office (5), and teaching (2) Participants included 16 African Americans and 3 Caucasians. Of the 19 participants there were 14 males and 5 females. The mean age of the participant was 71.6 years with a range of 61-82. The average years worked in a trade/job was 33.5, with a range of 4-50. The average years retired was 9, with a range of 3-20. The unions represented by the participants included the Labor International, International Brotherhood of Electrical Workers (IBEW), American Federation of Labor and Congress of Industrial Organizations (AFL-CIO), United Brotherhood of Carpenters (UBC), Teamsters, and Teachers.

Falls, Exposures and Physically Demanding Tasks

Several participants reported serious falls at work made such comments as follows:

"Once had to jump out of the way of a concrete form falling. Foreman decided there were enough hands to raise it without use of a crane. I landed face down on a steel deck (fell 10 ft.) and was off work".

"While using a pry bar moving steel on a truck bed, I slipped and injured my back and am still affected".

Retired construction participants reported that their most previous physically demanding job tasks related to current health problems included climbing scaffolding, stairs and ladders, balancing heavy loads with head and neck, lifting heavy pipe overhead, using jackhammers, pouring concrete, and pulling on chains and cables. Those working in plastering and maintenance also expressed concerns related to exposure to asbestos and the lack of a surveillance program for their prior asbestos exposure.

All construction retirees, however, reported having considerable job satisfaction. They were proud of the buildings they constructed and made statements such as, "As a plasterer, I could be creative and get lasting satisfaction", and "When I drive by a building I can tell my family I helped build that".

Quality of Current Health and Family Life

Generally construction retirees do not encourage their children to go into trades because "They can make money easier doing other things". Safety is another concern as one stated, "You could always tell when OSHA was coming, you would see them (management) cleaning up and getting everything in order". Current health problems related to work in construction included knee and neck pain, back injuries related to unloading materials and hearing loss. They also reported that there was considerable "racial inequalities in the trades". Also of concern was the stress related to "getting along with people, how people treat you, how you are able to work together".

They felt their previous construction job had definitely impacted the quality of their retirement life in a number of ways. Shoulder pain has affected hobbies including fishing, "I have difficulty casting and reeling". Hearing loss has affected their ability to communicate. Knee and shoulder pain has impacted leisure activities such as golf "The pain affects my swing and walking the hills". Several participants reported difficulties with balance and falling.

They identified several ways the union could assist retirees in general:

- Provide more social activities
- Implement a retirees club
- Increase management's awareness of racial issues
- Increase pensions, improve health benefits and do more toward establishing a national health care system.
- "Seniors need help with prescription. They either go without their medicine or without other things they like to do."
- Extend insurance coverage both medical (past age 65) and life
- Seek more advice from membership
- Make workplace safer
- Provide more knowledge about exposure levels

The SF-36 was pilot tested at the end of the focus group to determine ease in administration and to determine the most relevant questions for these retirees. The sample size was too small for meaningful analysis. Results from one question for the SF 36 Health Questionnaire provides a summary of the overall findings, however. The question was "In general would you say your health is excellent, very good, good, fair or poor?" The difference in the responses of retirees by union membership was startling as 86.0% versus only 18.2% of non-construction and construction retirees, respectively, reported "very good to excellent". Thus the focus groups provided direction for development of the final survey instrument and additional areas of concern that needed to be addressed such as disabilities in certain body regions.

D.2. Results of Mailed Survey

There were 780 surveys distributed and 251 completed the survey with an overall participation rate of 32%. As shown in table 1 the participation rate from the construction unions was 25% (n=77) compared to 35% (n=174) for the non-construction unions. Approximately half the participants were divided between Caucasian and African Americans (table 1). Though all of the construction trade members were male, only 18% of the non-construction trades were male. Therefore, to deal with a potential gender bias all results are reported with the non-construction group combined as well as divided by gender. Over 85% of both groups had over 25 years employment. The vast majority of the construction (68%) and non-construction (69%) participants had been retired for longer (table 2). The retired construction participants were slightly older with 23% being 75 years or older compared to 7% of the non-construction retirees.

Table 3 shows results of health and physical limitation questions from the SF-36 and the MOS by construction versus non-construction and by each gender in the non-construction group compared to construction. The results did not differ greatly by gender, and therefore, are described herein primarily by construction versus non-construction. Construction versus non-construction retirees were significantly and three times more likely to describe their health as poor, 42.1% versus 14.0% and more than twice as likely to describe themselves as having severe to very severe bodily pain, 19.4% versus 8.4%, respectively. There was considerable dissatisfaction with their "physical ability to do what (they) want to do" with 22.4% versus 8.1% ($p \leq .01$) of construction versus non-construction retirees reporting being very dissatisfied. The construction retirees (26.0%) versus the male non-construction retirees (9.4%) reported significant differences in reporting that they were very limited in physical functioning, but there were no significant differences among the retirees regarding the need for assistance.

Very high role limitations were reported by 33.3% of the construction group versus 16.7 % of the non-construction and by each gender. The construction group reported significantly more often that their health reduce the time that they could spend on regular daily activities as well as the type of daily activities they could perform.

In regard to physical limitations by body region there was a significant difference with construction retirees reporting sever to very severe problems with their vision, neck or shoulders, elbow, hips, knees and ankle and feet (table 4). There was no significant difference in report of severe to very severe problems with hearing or upper and lower back pain. Questions were asked about injuries and falls occurring while at work prior to retirement. There was a significant difference in construction versus non-construction retirees reporting an injury requiring medical attention (27.3% versus 10.9%) and falls requiring medical attention (24.7% versus 5.6%) (table 5). Of interest, however the construction versus the non-construction group were less likely to report falling in the last 12 months 15.6% versus 23.0%, respectively.

Because these retirees were all still dues paying members of their unions we asked how the unions could better assist them during their retirement years. They were given a list of six items including: implementing a retirees club, use of their knowledge to train or teach others, organize trips and tours, provide other social activities, improve health benefits, and seek more advice from me/membership. Of great importance to both groups was improvement of health benefits (table 6). The retirees were asked about educational programs to improve health such as exercise, balance, dental, medication, yoga, tai chi, mediation, or craft activities. Both groups expressed considerable interest in an exercise program while the construction retirees were significantly more interested in having additional dental and medication information.

Discussion

Once they leave the workplace, retired workers are often forgotten. The adverse effects of their life's work, however, often remain with them until they die in terms of level of independence, pain and suffering. Workers in the construction trades traditionally experience a lifetime of physically demanding job tasks that may cause cumulative degeneration of all physiological systems and injury. Hence, it was hypothesized that they would sustain more traumas to their neuromusculature system than workers in more sedentary jobs. This hypothesis was confirmed. It is without question these construction retirees have a poorer quality of life than the non-construction group. Their former employment has seriously affected their ability to optimally enjoy their retirement years. Over forty percent of the construction, compared to 14% on the non-construction retirees described their health as fair to poor. A significant rate of construction versus non-construction retirees, 19.4% and 8.4% reported severe to very severe bodily pain, and 33.3% versus 16.3% respectively reported very high role limitations such as reduced time spent on daily activities and difficulty performing these activities. As described in the focus groups the retired construction workers are unable to optimally engage in their leisure activities such as fishing, golfing and walking.

Construction versus non-construction retirees reported a significantly higher rate of falls occurring at work that required some type of medical attention, 24.7% and 5.6%, respectively. Surprisingly, falls occurring in the last 12 months of retirement were lower in the construction group (15.6%) versus 23.0% in the non-construction group. One explanation for this lower rate of falls may be related to the more limited physical functioning of the construction retirees. It is hypothesized that because construction retirees are less active they may be less likely to be exposed to activities which tend to be associated with fall. It should not be overlooked, however, that both groups had a high rate of falls that were sufficiently serious for them to seek medical attention. Other investigators have indicated that the number of falls in the non-institutionalized elderly, as was our study population, is higher than for those who live in a controlled and supervised environment of geriatric care [12]. Another investigation reported the incidences of fall for those living in the community for 65 to 74 year olds is 25% to 30% and in those over 75 it is 35% to 50% [13-15]. The lower rate found in our cohort is likely related to differences in need for medical attention, as all members of our cohort had been in the work-force for many years, the well known healthy worker or "ex-worker" effect. In the Hamilton County, Ohio 1999 injury surveillance report (where this study was conducted), it was shown that persons above the age of 65 years accounted for about 71% of falls [16].

One important aim of the study was to investigate the feasibility of conducting a more comprehensive study such as this one in a larger population. We feel that this pilot study has shown that these studies are quite feasible. Those retirees that participated in the focus group expressed great appreciation that someone still cared about their work experiences and were concerned about their current quality of life. They all expressed gratitude for the opportunity to discuss their past and their present life experiences. Many of the focus group participants have remained actively engaged with additional activities organized by one of the investigators (LM) and continue to want to interact and be of service. The unions were very enthusiastic about participating in the study and demonstrated this enthusiasm by writing letters of support and addressing and mailing the packets. The response rate of the subjects with only one mailing was also typical of one-time mailings and quite good considering the age and health problems of the elderly. There was very minimal missing data demonstrating that retirees were able to understand, complete and return the instruments.

This research was a pilot study to determine if further work is needed in this area. As such, it has some limitations, and the results of the study should be interpreted with these in mind. The most important limitation is a potential response bias in the mailed survey as only 32% responded to the one time mailing. Although the response rate was somewhat lower in the construction group, this could be associated with their poorer health and somewhat older age. The lowest responding group was the communication union at 20%, who were one of the non-construction unions. This union was on strike, however, at the time of the study, which may have lowered their participation. Even if those responding were more likely to be the retirees with a health problem, (response bias) there remained major significant differences in the construction versus the non-construction group. Another potential bias is related to the non-comparability of the comparison group especially related to gender. Though the non-construction unions were more highly represented by women, the responses of the men and women in the non-construction group were quite comparable, and there were really relatively few differences between genders in the non-construction unions.

In conclusion, it was shown that the construction retirees reported significant physical limitations for almost all body regions and a poorer quality of life. Though they gave their best years to the jobs over twenty-five years, their job has given them a legacy of continued health problems long after they have left the workplace. These retirees have a wealth of value information that could be tapped by their unions as well as the larger society with respect to assisting in bringing about change in the work practices of their trades to help minimize health problems among future construction workers. As noted in table 6 members of all unions expressed interest in teaching or providing advice. What better example to younger workers who may think their bodies are invincible than hearing and seeing what may eventually be their "reward" in future years. Such examples will help provide fuel for developing intervention strategies to minimize ergonomic risk factors associated with their tasks.

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SECTION IV

A Survey to Collect Safety-Related Data from Small Construction Companies

Principal Investigator

Linda Goldenhar

TABLE OF CONTENTS

A SURVEY TO COLLECT SAFETY-RELATED DATA FROM SMALL CONSTRUCTION COMPANIES

Research Team: PI – Dr. Linda Goldenhar

Abstract

Much of the previous construction related safety research has focused on the unionized sector and on large construction companies. While this work has been extremely valuable in terms of identifying some of the major construction hazards, it may be limited due to the fact that approximately 80% of the construction workforces are not members of unions and 75% work for companies with fewer than 100 employees. The primary goal of the proposed study is to begin addressing this research gap by developing a survey instrument to collect safety-related data from owners of smaller (i.e. fewer than 100 employees) construction companies. Three focus groups were used to develop the survey instrument. After revision of the survey questions, a web-based instrument was developed. Potential respondents from small construction companies were contacted by the AGC office to alert them to the website and the importance of responding. Eighty-nine responses were received. Results indicated that management of small companies was rated fairly high in terms of support for safety programs. Employee safety was rated as an important company issue. Few differences in safety practices were found across categories of construction, but heavy highway construction exhibited somewhat less safety focus.

Significant Findings

Although the AGC national office alerted the national membership to the web-based survey using both their website and their newsletter, the number of responses was only 89. One possible reason for lower than expected response was the length of the survey and possible confusion in using too many "continue" buttons. Future web-based surveys aimed at small businesses should be shorter and simpler to use. Results of those responding showed several notable points. Management was generally rated fairly high by non-management in terms of their commitment to safety. Responses across construction categories showed that the heavy highway construction companies were notably lower in safety concerns than other categories. Although construction workers are hired through a variety of sources, several types (temporary employment agencies, job banks, and unemployment offices) would be unlikely to have provided prior safety and health training.

Usefulness of Findings

Although 89 responses does not provide a comprehensive view of safety practices among small construction companies nationwide, the results of this web-based survey may lead to better focused future research in this area. Results indicated that future web-based surveys should be shorter, more focused, and simple to use. The apparent lower focus on safety programs by the heavy highway construction companies suggests that future safety research into small construction companies should target that industry.

Background

Approximately 80% of the construction workforces are not members of unions where much of the research to date has been focused. In addition, 75% of all construction workers are employed by companies with fewer than 100 employees. These are the very companies that often can not afford extensive safety programs or ongoing safety training. Record keeping is either not required for very small companies or deficient in many others. Consequently, little is know about safety issues in companies with fewer than 100 employees. Accordingly, we set out to develop a method for both reaching out to such small companies (often without a safety officer) and also assessing their commitment to health and safety training.

Specific Aims

1) Develop a survey instrument to assess the degree of commitment to health and safety programs among small construction companies.
2) After survey instrument has been developed, utilize a web-based approach to reach a national sample of small construction companies and collect data on various safety issues.
3) Summarize survey data, interpret results, and make recommendations for future research.

Methods

A survey instrument for assessing health and safety training in open-shop construction companies was developed in earlier research (Goldenhar, et al, 2001). This instrument was used as the basis for refinement for use in surveying small construction companies. In order to better understand the safety concerns of small companies, three focus groups were held in the Cincinnati area. Professional facilitators were used to elicit areas where the original instrument should be refined. Results of the focus groups were used to refine the original questionnaire for use by small companies. The Dun and Bradstreet database was purchased to provide an estimate of the distribution of small companies across geographic locations and NAICS codes. In addition, the national office of the Associated General Contractors (AGC) was contacted and asked to assist us in making their membership aware of the coming survey. AGC agreed to put the survey on their website, as well as include an item concerning the survey in their newsletter.

The survey appeared on the AGC website in mid-January, 2003. The data was swept directly into an Access database maintained at the University of Cincinnati Institute for Health Policy and Health Services Research. Data was collected for approximately one month. Only 4 of the 89 companies responding answered all sections of the questionnaire. Most stopped at question 18 when more detailed information was requested. Fortunately, most of the important questions occurred in the first 18 items.

Results

The following tables summarize the data for 89 usable respondents.

Table 1 Respondent Description

Type of respondent	N	%
General contractors	32	36
S&H personnel	25	28
Other	32	36
Union shop	40	45
Open or Merit shop	49	55
Type of Construction		
Heavy highway	25	28
Building contractor	64	72
OSHA Region		
East (1, 2, 3)	18	20
South (4, 6)	21	24
Midwest (5, 7)	32	36
West (8, 9, 10)	18	20
Number of craft workers hired per year		
< 100	54	61
100 – 300	27	30
> 300	8	9

Table 2 Safety Ratings

Management support of H & S programs (scale: 1-10)

	Mean
Overall	8.11
Heavy Highway Contractors	5.71
Building Contractors	8.60
Union shop	8.38
Open/Merit shop	7.89

Importance given to safety (scale: 1-5; 5 is highest)

	Mean
Overall	3.10
Heavy Highway Contractors	2.56
Building Contractors	3.29
Union shop	3.07
Open/Merit shop	3.11

Table 3 Qualitative Summary of Results

A. Sources for Hiring Employees Rank Order of Use
   1) References
   2) Advertising
   3) Union Hall
   4) Apprenticeship Programs
   5) Manpower/Temps
   6) Recruit from Other Firms
   7) Unemployment Offices
   8) Job Banks

   By type of contractor:

   Building contractors - higher % from manpower
   Open/Merit shops – higher % from manpower & unemployment
   Midwest – higher % from union halls

B. Have workers had:

   1) Skills Training?
   2) Safety & Health Training?

   The majority of respondents said YES to both Qs.

   However, some categories of respondents had a somewhat high % of Nos. Including:

   - General Contractors
   - Heavy Highway Builders
   - Union Members
   - Located in the Western OSHA regions
   - Located in the Mid-West OSHA regions

C. Is safety a line item in the company's budget?
   &
   Is safety a part of project estimates?

   Majority of Heavy Highway Contractors said NO to:
   Line Item (No = 52%)
   Project Estimate (No = 61%)

   More open/merit shops (44%) than union shops (32%) said NO to Line Item question.

Table 3 Qualitative Summary of Results (cont'd.)

D. How is safety communicated to employees?

All 16 categories were checked by at least 5 respondents.

Those most cited were:

- Written policies
- Provision of safety equipment
- Weekly toolbox talks
- Formal programs
- Designated safety supervisor
- Knowledge that employee can be fired

Those least cited were:

- Task-specific training
- Incentives
- Give safety warnings

Discussion

The survey attempted to work through the AGC to reach a national sample of small construction companies. The number of respondents answering the survey through the AGC website was a somewhat disappointing 89 companies. However, since this was the first ever such effort to conduct a national survey of small construction companies, several valuable lessons were learned. The survey probably should have been shorter and more focused. In addition, the skip patterns and "continue" buttons seemed to confuse some respondents.

Results indicated that the heavy highway construction companies had a somewhat lower level of commitment to safety than building contractors. There appears to be little difference in commitment to safety between union and open shops.

The survey had several limitations that may affect its generalizability. Obviously, the relatively low sample size impedes our ability to make comparisons across types of construction, geographic regions, and union/open shop designations. Low sample size may also reflect selection bias such that the respondents may be different, e.g. more committed to safety, than the general population of small companies. Also, due to time constraints on the project, the survey was only available for one month. This could also have affected response rates.

Conclusion

We learned several things from this survey project that should be valuable to NIOSH in future studies of small construction companies. First, it is very difficult to collect data from small companies. Our web-based approach, while not as successful as hoped, reached all regions of the country. Future efforts using this approach should keep the survey instruments relatively short and simple to use. Second, of the various types of construction industry responding, heavy highway construction appeared to place less attention on safety programs than building contractors. Accordingly, highway construction by small companies could be an area that NIOSH may wish to target for additional safety research. Lastly, there was no evidence of a difference in commitment to safety between union and open shops.

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SECTION V

Safety in Trenching Operations

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TABLE OF CONTENTS

SAFETY IN TRENCHING OPERATIONS

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ABSTRACT

Excavation work is one of the most hazardous types of work done in the construction industry. More than 65 construction workers are killed each year due to trench related accidents (Arboleda 2002). Trench cave-ins cause serious and often fatal injuries to workers in the United States. Even though heavy construction equipment, such as crane or backhoe excavator, is used to perform the task of pipe laying in the trench, workers are required to be in the trench to guide trench excavation, pipe laying, and final alignment. The primary type of accident in excavation-related work is a cave-in. However other causes such as, unsafe equipment operations, encounters with of unidentified utilities, and contact with underground buried power lines have also been identified

Trenching operations are executed principally by water, sewer, utility lines and heavy construction companies. The value of construction work executed by these companies represents 2.6% of the total volume of construction in the United States. In total, these companies experienced 166 fatalities during the year 2000. According to an analysis of workers' compensation claims in the Supplementary Data System of the Bureau of Labor Statistics (BLS), there are approximately 1,000 works related injuries each year due to excavation cave-ins. Of these, about 140 result in permanent disability and 75 in death (NIOSH 1995).

The specific problem addressed in this study was "how" and "why" fatalities occur in trenching operations and what measures can be adapted to prevent them. The preventive strategies are based on the results of the data analysis, an evaluation of the existing safety standards based on OSHA, and an analysis of successful construction practices implemented by construction companies in the Midwest.

The primary objectives of this study were to: a.) Identify the major causes of fatalities in trenching operations, based on the statistical analysis of historical data from OSHA. b.) Identify the major correlations between the main causes of fatalities in trenching operations based on the analysis of fatality reports from OSHA. c.) Identify the chain(s) of events leading to fatalities in trenching operations based on the results of the data analysis, and the relationships between the two models selected to analyze the fatality reports. d.) Define strategies to prevent fatalities in trenching operations and compare these strategies with the existing standards. e.) Analyze successful practices adopted by construction companies in the Midwest in order to prevent accidents in

trenching operations, and the relationship between these practices and the major causes of fatalities.

The major causes of fatalities in trenching operations, their interactions, and the chain of events leading to accidents were identified in this study. Two different models to analyze the fatality reports were used as the relationships between these two models helped to develop the strategies to prevent trenching accidents. The first model considers the causes related to physical processes, and the second model evaluates causes that can be linked to human behavior. Finally, these strategies were compared with the existing standards in order to determine if it is necessary to add new procedures or modify existing standards in order to improve effectiveness in implementation in safety procedures.

The analysis based on two different accident causation models provided information regarding the "how" and the "why" of trenching fatalities. Under the Behavioral Causes Model, the major causes of trenching fatalities are: *lack of safety equipment, practice of unsafe methods or sequencing,* and *lack of proper training*. The Type of Accident Model, points out that the major causes of fatalities in trenching operations are: *caught in or crushed in collapsing material (cave-ins), caught in or compressed by equipment or objects,* and *struck by object*. In cases where *cave-ins* occurred, safety equipment was not provided in a majority of the cases

The findings of this study show an alarming trend that smaller contractors (for example, contractors having fewer than 50 workers), and those working on small projects (costs below US$250,000), tend to have higher rates of fatalities. The smaller contractors tend to be less prudent in adhering to the existing safety standards and in many cases, the fatalities can be attributed to their failure in providing adequate protection systems, failure to use these systems or failure to perform the work in a safe manner. To improve safety in trenching operations, it is necessary to provide adequate and appropriate safety equipment at the right time; reinforce specific training in the use of such equipment and safe construction procedures; and institute a more effective planning process prior to onset of trenching operations. In addition, it is important to identify the hazards on the job site and define the strategies to prevent accidents

SIGNIFICANT FINDINGS

The significant findings are divided in two major categories. The first category shows the results based on the analysis of 296 trenching fatality reports from OSHA. This analysis was done applying two different models of accident causation. The second category presents the major conclusions of 16 interviews conducted with construction practitioners in the Midwest.

Based on the analysis of 296 trenching fatality reports from OSHA in the 1997-2001 time frame, the major findings of this study are:

- Based on the Type of Accident Model, the major type of accident in trenching operations is cave-ins, followed by caught in or compressed by equipment or objects and struck by object, usually backhoes or pipes during the installation process. Based on the ***Behavioral Causes Model,*** the major causes are: lack of safety equipment, practice of unsafe methods or sequencing, and lack of proper training.
- The analysis of fatality reports showed that sixty eight percent (68%) of the fatalities occurred in trenches with depth less than three meters (10 ft). The average depth of the trench was 3.1 m (10.3 ft). All the fatalities caused by electrocution occurred in trenches less than 3 m (10 feet) deep.
- When cave-ins occurred, 49% of the fatalities occurred in projects with costs under US$ 250,000 and 73% of the fatalities in projects with costs under US$ 1,000,000. Also, 31% of the accidents occurred in projects with fewer than 10 workers and costs under US$ 250,000, i.e., when the project is smaller, the likelihood of a trench cave-in is higher. A possible reason is that the smaller projects are executed by small contractors who may not necessarily address the safety standards adequately or they do not have sufficient budgets to provide safety equipment.
- In projects with costs under US$ 250,000, the major causes of fatalities were lack of safety equipment (47%) and unsafe methods or sequencing (28%). In 55% of the projects with cost under US$ 50,000, the major cause was lack of safety equipment.
- Analyzing the number of employees on site when the fatality occurred, 63% of the cases the job site had fewer than 10 workers and 83% of the times the companies had fewer than 49 employees in total. When the project had fewer than 10 workers on site, in 48% of the fatalities the major cause was lack of safety equipment. When lack of safety equipment was identified as the major cause of the fatality, 84% of the companies had fewer than 50 employees in total.
- Trenching operations accidents can happen in any month of the year. However, during May and October, peaks in frequency of fatalities were observed.
- The distribution of fatalities based on the time of the day, is almost uniform from 8:00am through 4:00 pm. The highest number of cave-ins occurred between 12-2 pm.
- During the period 1997-2001, 46 states reported fatalities in trenching operations. The state with the highest number of fatalities is Texas (12%), followed by California (7%) and Michigan, Missouri and Ohio with (5%).
- Of the two hundred ninety six (296) trenching fatalities, 250 (84%) occurred on nonunion projects and 46 (16%) occurred on union projects.

Based on the interviews conducted with sixteen construction practitioners located in the Midwest, the major findings of this study are:

- The existing safety standards are deemed to be reliable and can help to prevent fatalities in trenching operations when they are correctly applied. However, in many instances, construction workers take unnecessary risks, and the "tough guy" culture continues to prevail on job sites.
- The interviews also indicated that the construction industry has learned how to identify the major causes of accidents based on the Type of Accident Model. In addition, it is important to note that the industry considers *cave-ins* accidents as the most important cause of fatalities, but also recognizes the existence of other type of

accidents in trenching operations, such as *struck by object*, *caught in or compressed by equipment or objects*, and *contact with electric current*.

- Independent of their roles, all the practitioners considered *caught in or crushed in collapsing material (Cave-ins)* as the major cause of trenching accidents. This result is in accordance with the findings in the analysis of fatality reports from OSHA, and reflects a good understanding of the causes of trenching fatalities by the construction industry.
- Based on the interviews, it may be inferred that construction practitioners do not consider a single safety strategy as most important to prevent accidents in trenching operations. In addition, it appears that the companies are implementing several safety strategies simultaneously.
- The results of the interviews showed that the safety strategy *assess site conditions* is very important to the construction industry. However, the analysis of the OSHA reports showed that other strategies, such as *training, provide safety equipment*, and *plan and control of methods* are more important. This does not mean that the industry is unwise assigning these resources, but that the focus is not necessarily on the major strategies based on the analysis of OSHA reports.

USEFULNESS OF FINDINGS

The study showed that the existing safety standards from the Occupational Safety and Health Administration - OSHA (OSHA 1989) are reliable and can help to prevent fatalities in trenching operations when they are correctly applied. However, according to the analysis of fatality reports, it is necessary to enforce the application these standards on the job site to prevent fatalities among construction workers.

The inclusion of the construction practitioner's perspective regarding the major strategies to prevent trenching fatalities, provided a clearer picture of the issues in trenching safety, and how the strategies developed by the construction industry differ from the strategies required based on the analysis of trenching fatalities from OSHA. Based on the analysis of results, it may be inferred that the construction practitioners do not consider a single strategy as most important to prevent accidents. In addition, it appears that the companies are implementing several strategies simultaneously, but the outcome of the application of these strategies is not necessarily the prevention of the fatalities because the focus is not necessarily on the major strategies based on the analysis of OSHA reports. This conclusion is based on the comparison between the results of the interviews and the analysis of the fatality reports from OSHA. The comparative analysis was done using the Bonferroni correction/adjustment procedure. This method allows multiple confidence intervals to be constructed while still assuring that an overall confidence coefficient is maintained.

To prevent fatalities on job sites, the construction companies have been developing strategies (such as daily safety planning meetings, increasing involvement of owners in planning for safety, increasing accountability by workers and support by top management, control of minor accidents, etc.) to improve the safety of workers. These strategies are based primarily on prior experiences of safety directors, and have the potential to decrease construction fatality rates. However, the impacts of these strategies have not been analyzed collecting data from the construction projects in order to know if these practices are effective in the prevention of trenching fatalities.

SCIENTIFIC REPORT

Background for the Project

According to OSHA (OSHA 2002), excavation work is one of the most hazardous types of work done in the construction industry. A significant component of the excavation work in the construction industry is trenching operations. These operations are performed using heavy construction equipment, such as crane or backhoe excavator. Nevertheless, workers are required to be in the trench to guide trench excavation, pipe laying, and final alignment. The primary type of accident in excavation-related work is a cave-in. However other causes such as, unsafe equipment operations, encounters with of unidentified utilities, and contact with underground buried power lines have also been identified based on the analysis of fatality reports.

When a trenching accident occurs, it is generally associated with the failure of the trench wall. In most incidents involving workers, the workers are either struck by earth, materials or they are caught in-between the trench walls that move together. Constructions companies have to follow the OSHA standards when working in excavations and trenching. The existing standards have all the information that the contractors need regarding the procedures, specifications, soil classification and possible alternatives to protect workers in trenching operations. Nevertheless, accidents still occur on the job sites. Poor safety not only hurts the workers but also the companies that hire them, the families of workers, and the community. The benefits of improved occupational safety include increased efficiency; competitiveness and profitability; reduced delays, disputes, and conflict; and positive publicity.

In addition to fatalities, injuries caused in construction activities are costly in terms of direct and indirect costs to the construction industry. The direct costs include medical costs and other worker's compensation insurance benefits. These direct costs of accidents are not fixed and they vary depending upon the prior safety records of the company and the magnitude of the accident. The indirect costs include lost productivity among co-workers and management, liability claims from injured workers who sue contractors for additional payments beyond their worker-men claims, job schedule delays, added administrative time, training of replacement personnel, and reduced worker morale, especially when fatalities occurred. Indirect costs have traditionally been calculated by multiplying the direct cost by an indirect cost multiplier. Various estimates of this multiplier range from 2 to 20 times direct costs. Everett and Frank (1996) established a range for the Indirect Cost Multiplier (ICM = Indirect Costs / Direct Costs) with values between 1.65 and 2.54. The benefits of improved occupational safety include increased efficiency; competitiveness, and profitability; reduced delays, disputes and conflict.

Problem Statement

Previous studies of fatalities in trenching operations have focused in "how" the fatalities occur. In this study, the specific problem addressed was the dual analysis of "how" and "why" fatalities occur in trenching operations and what measures can be adapted to prevent them. The major causes were found analyzing fatality reports from OSHA and the preventive strategies are based on an evaluation of the existing safety standards based on OSHA, and an analysis of successful construction practices implemented by construction companies in the Midwest.

The major causes of fatalities in trenching operations, their interactions, and the chain of events leading to accidents were identified in this study. Two different accident causation models to analyze the fatality reports were used as the relationships between these two models helped to develop the strategies to prevent trenching accidents. The first model considers the causes related to physical processes, and the second model evaluates causes that can be linked to human behavior. Finally, these strategies were compared with the existing standards in order to determine if it is necessary to add new procedures or modify existing standards in order to improve effectiveness in implementation in safety procedures.

Specific objectives and results

Objective No.1

Identify the major causes of fatalities in trenching operations, based on the statistical analysis of historical data from OSHA. (296 trenching fatality reports from OSHA in the 1997-2001 time frame were analyzed).

Results:

The distribution of accidents based on the Type of Accident Model is presented in Table 1. The major type of accident in trenching operations is cave-ins, followed by caught in or compressed by equipment or objects and struck by object, usually backhoes or pipes during the installation process.

The distribution of fatalities based on the Behavioral Causes Model is presented in Table 2. The major human causes in trenching accidents are: *safe equipment not provided* and *unsafe methods or sequencing*. The first cause names the lack of safety equipment is more relevant when cave-ins fatalities occurred. The second cause mentions the equipment and materials maneuvers that are necessary on site (i.e., to move the pipes into the trench and/or to install the protective systems, to move the trench boxes and to excavate and backfill the trench).

Table 1. Distribution of fatalities by the Type of Accident Model – BLS Codes

Group	Type of Accident	Code	Description	%
02	Struck by Object			**15.2%**
		021	Struck by falling object	5.4%
		029	Struck by object	9.8%
03	Caught-Compressed by equipment or objects			**16.6%**
		031	Caught in running equipment or machinery	1.4%
		039	Caught in or compressed by equipment or objects	15.2%
04	Caught-crushed in collapsing material			**54.7%**
		041	Excavation or trenching cave-in	51.4%
		044	Caught in or crushed in collapsing structure	1.7%
		049	Caught in or crushed in collapsing materials	1.7%
11	Fall to lower level			**0.7%**
		1124	Fall from ground level to lower level	0.7%
31	Contact with electric current			**7.8%**
		311	Contact with electric current of machine, tool, appliance, or light fixture	0.7%
		313	Contact with overhead power lines	5.1%
		314	Contact with underground, buried power lines	2.0%
38	Oxygen deficiency			**1.7%**
		381	Drowning, submersion	1.0%
		389	Other oxygen deficiency	0.7%
52	Explosion			**2.4%**
		522	Explosion of pressure vessel or piping	2.4%
99	Others			**1.0%**
		9999	Other events or exposure	1.0%

Table 2. Distribution of fatalities based on the Behavioral Causes Model

Major Cause	Fatalities (%)
Lack of proper training	16.6
Deficient enforcement of safety	6.8
Lack of safety equipment	42.2
Unsafe methods or sequencing	27.0
Unsafe site conditions	0.3
Not using provided safety equipment	2.7
Poor attitude toward safety	0.7
Isolated, sudden deviation from prescribed behavior	3.7

Objective No.2

Identify the major correlations between the main causes of fatalities in trenching operations based on the analysis of fatality reports from OSHA

Results:

The relationships between the Type of Accident Model and the Behavioral Causes Model are presented in Table 3. For each group in the Type of Accident Model, the major human causes are shown.

Table 3. Relationships between the Type of Accident Model and the Behavioral Causes Model

Code	Type of Accident	Behavioral Causes	%
02	Struck by object		
		Unsafe methods or sequencing	58
		Lack of proper training	31
		Deficient enforcement of safety	4
		Others	7
03	Caught in or compressed by equipment or objects		
		Unsafe methods or sequencing	47
		Lack of proper training	37
		Isolated, sudden deviation from prescr	6
		Others	10
04	Caught in or crushed in collapsing materials		
		Safe equipment not provided	75
		Deficient enforcement of safety	9
		Unsafe methods or sequencing	7
		Others	9
31	Contact with electric current		
		Unsafe methods or sequencing	70
		Lack of proper training	30
52	Explosions		
		Unsafe methods or sequencing	43
		Deficient enforcement of safety	29
		Poor attitude toward safety	14
		Others	14

Objective No.3

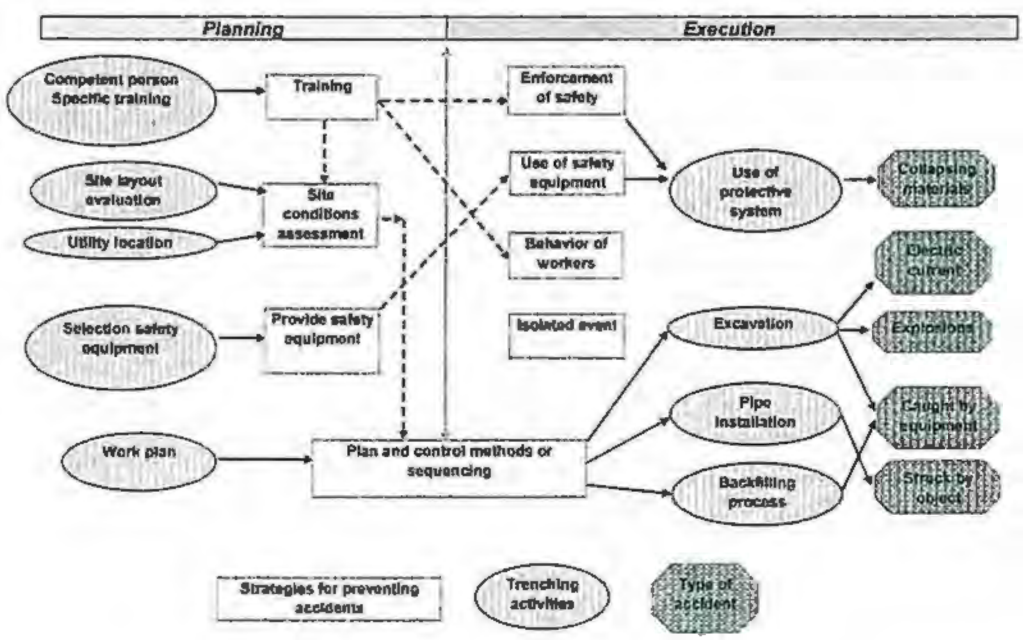
Identify the chain(s) of events leading to fatalities in trenching operations based on the results of the data analysis, and the relationships between the two models selected to analyze the fatality reports.

Results

Accidents in construction sites often result not from a single cause but from a chain of circumstances or events, and in many cases involve human error or human negligence. Therefore, focusing also on human contributions to the accident chain can be useful to prevent accidents. The results obtained from the Behavioral Causes Model and the Type of Accident Model provided meaningful guidance to illustrate how the trenching fatalities occur.

Based on the analysis of reports, the interviews with construction practitioners and the visits to construction job sites, it is possible to conclude that the fatalities in trenching operations are the result of a combination of unsafe practices by the construction workers and management during the planning and execution process. The link between the strategies needed to prevent accidents and the activities involved in trenching operations is shown in Figure 1. In this figure, an integrated model of trenching operations is presented. This model considers:

a.) The strategies to prevent the fatalities based on the Behavioral Causes Model
b.) The activities to be executed during the planning and execution phases
c.) The major causes based on the Type of Accident Model.



Objective No.4

Define strategies to prevent fatalities in trenching operations and compare these strategies with the existing OSHA standards.

Results

All the major causes of fatalities in trenching operations based on the Type of Accident Model can be addressed by the existing OSHA standards. However, when the Behavioral Causes Model is taken into account, some issues such as pre-planning and specific training in trenching operations are not addressed by the existing OSHA standards. For instance, the actual excavation standard does not mention the planning process as a requirement prior to commencement of trenching operations

Table 4. Comparison between causes based on the Type of Accident Model and the existing OSHA standards (OSHA 1989)

Group	Causes based on Type of Accident Model	Standard ID	Description
02	*Struck by object.* Ex: Struck by object, struck by falling objects, struck by swinging or slipping object	1926.651.e	No employees shall be permitted underneath loads handled by lifting or digging equipment. Employees shall be required to stand away from any vehicle being loaded or unloaded to avoid being struck by any spillage or falling materials
03	*Caught-Compressed by equipment or objects* Ex: Caught in or compressed by equipment or objects, caught in running equipment or machinery	1926.651.f	When mobile equipment is operated adjacent to an excavation, or when such equipment is required to approach the edge of an excavation, and the operator does not have a clear and direct view of the edge of the excavation, a warning system shall be utilized such as barricades, and or mechanical signals, or stop logs.
04	*Caught-crushed in collapsing material* Ex: Excavation cave-ins, caught in or crushed in collapsing structure, caught in or crushed in collapsing materials	1926.651.i 1926.621.j 1926.652.a 1926.652.b 1926.652.f 1926.652.g	Stability of adjacent structures Protection of employees from loose rock Protection of employees in excavations Design of sloping and benching systems Sloping and benching systems Shield systems
31	*Contact with electric current* Ex: Contact with electric current of machine, tool, appliance, or light fixture; Contact with overhead power lines; Contact with underground, buried power lines	1926.651.b	Underground installations. The estimated location of utility installations, such as sewer, telephone, fuel, electric, water lines, or any other underground installations that reasonably may be expected to be encountered during excavation work, shall be determined prior to opening an excavation
52	*Explosions* Ex: Explosion of pressure vessel or piping	1926.651.b	Underground installations.

Table 5. Comparison between causes based on the Behavioral Causes Model and the existing OSHA standards (OSHA 1989)

Causes based on Behavioral Causes Model	Standard ID	Description
Lack of safety equipment	1926.652.a.(1)	Each employee in an excavation shall be protected from cave-ins by an adequate protective system (Shoring, sloping, shielding or benching)
Unsafe methods or sequencing		No reference in the excavation standard
Lack of proper training	 1910.146.g 1910.132.f	No reference in the excavation standard Confined spaces. The employer shall provide training. General requirements. The employer shall provide training to each employee who is required to use personal protective equipment.
Deficient enforcement of safety	1926.650.b 1926.651.k	Competent person Daily inspections of excavations Exposed employees shall be removed from the hazardous areas once they are found by the competent person
Isolated, sudden deviation from prescribed behavior		No reference in the excavation standard

Tables 4 and 5 show the comparison between the existing safety standards and the causes of trenching fatalities based on the Behavioral Causes Model and the Type of Accident Model respectively.

<u>Objective No.5</u>

Analyze successful practices adopted by construction companies in the Midwest in order to prevent accidents in trenching operations.

<u>Results</u>

Eight (8) interviews were conducted with safety directors from companies located in the Midwest in order to have a better understanding of the safety issues in trenching operations and the strategies developed by the construction companies to prevent these accidents. Table 6 shows the questions asked and the issues explored.

The discussions with safety directors revealed that management has come a long way in recognizing safety issues. More and more top management are pledging their commitment and taking concrete actions in providing a safe working environment. In addition, many companies have comprehensive safety and health programs that include incentive programs (e.g., financial), as well as workers' accountability schemes. The safety directors realize that the importance of an integrated program and the need to inform workers that management is seriously reinforcing the programs. A summary of the practices described henceforth are shown in Table 7.

Table 6. Interviews with safety directors

Question asked	Issues to be explored
Trenching procedures developed in their companies	Trenching construction process
Major concerns that they have when trenching operations are under execution	Identification of potential hazards in trenching
Strategies to prevent accidents implemented in their companies	Successful procedures to prevent fatalities
Results obtained once the procedures were implemented	Strategy success (reduction of accidents rates, reduction of indirect costs)
Existing standards	Issues encountered when applying the existing standards
Description of accidents	Chain of events leading to accidents

Table 7. Summary of the successful practices

Practice	Construction phase	Participants
Safety planning meetings	Planning	Design team, subcontractors, project engineers, foremen, a representative of the owner, insurance company, and contractor's safety officer
Daily safety meetings	Execution	Foremen, subcontractors
Safety training		
General safety training	Planning	Engineers, foremen, workers
Specific safety training	Execution	Subcontractors
Incentive programs	Execution	Engineers, foremen, subcontractors, administrative personnel
Top management support	Execution	Top management, project engineers
Owner's role	Planning Execution	Representative of the owner
Accounting practices	Execution	Project engineers, financial division
Increasing accountability of workers	Execution	Project engineers, foremen, workers
Control of minor accidents	Execution	Project engineers, foremen

Methodology

The general research approach to the study was based on statistical analysis of the historical data of fatalities in trenching operations. The data was obtained from OSHA, BLS and NIOSH records. Two hundred ninety six (296) fatality reports were analyzed in order to identify the causes of the fatalities based on two different accidents causation models. This analysis assisted in identifying the major causes regarding accidents in trenching operations and the major correlations between these causes. Once the relationships between the major causes were identified, it was possible to find the chain of events leading to accidents.

The chain(s) of events helped in defining strategies to prevent accidents in trenching operations. The findings of the study were discussed with construction practitioners from the industry to acquire feedback (Figure. 2). The input from construction companies was obtained by sixteen (16) in-depth interviews. A comparison of the results obtained from the analysis of fatality reports and the results obtained from the interviews with construction practitioners, helped to define the successful strategies for preventing fatalities in trenching operations. These strategies are considered successful because they helped to reduce the number of injuries in trenching operations in the interviewed companies.

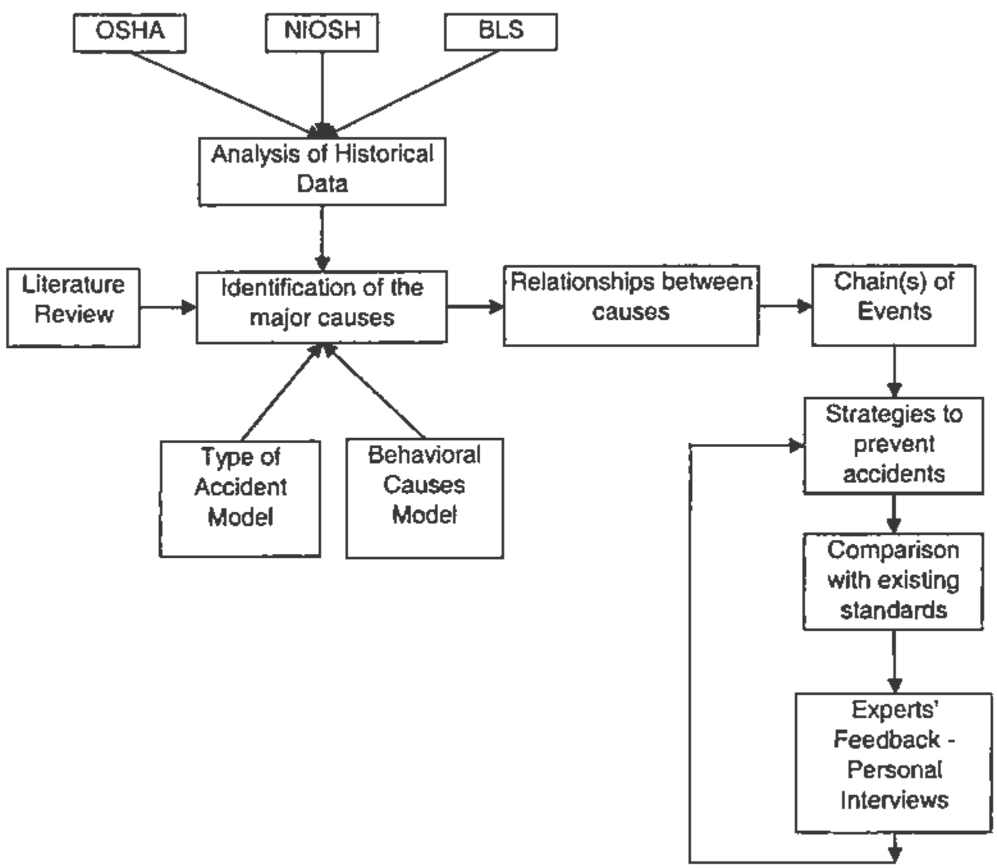


Figure 2. Research methodology

Results and Conclusions

The Behavioral Causes Model and the Type of Accident Model were selected to analyze OSHA reports of accidents in trenching operations in the 1997-2001 time frame. The analysis based on these two models provided information regarding the "how" and the "why" of trenching fatalities. Under the Behavioral Causes Model, the major causes of trenching fatalities are: *lack of safety equipment, practice of unsafe methods or sequencing,* and *lack of proper training.* The Type of Accident Model, points out that the major causes of fatalities in trenching operations are: *caught in or crushed in collapsing material (cave-ins), caught in or compressed by equipment or objects,* and *struck by object.* In cases where *cave-ins* occurred, safety equipment was not provided in a majority of the cases; when the victim in the trenching fatality was *struck by materials or equipment*, a lack of training and unsafe methods or sequencing were identified as the cause of the fatality based on the Behavioral Causes Model.

Based on the analysis of fatality reports, this study found that smaller contractors (for example, contractors having fewer than 50 workers), and those working on small projects (costs below US$250,000), tend to have higher rates of fatalities. The smaller contractors tend to be less prudent in adhering to the existing safety standards and in many cases, the fatalities can be attributed to their failure in providing adequate protection systems, failure to use these systems or failure to perform the work in a safe manner. To improve safety in trenching operations, it is necessary to provide adequate and appropriate safety equipment at the right time; reinforce specific training in the use of such equipment and safe construction procedures; and institute a more effective planning process prior to onset of trenching operations. In addition, it is important to identify the hazards on the job site and define the strategies to prevent accidents. The analysis of fatality reports showed that sixty eight percent (68%) of the fatalities occurred in trenches with depth less than three meters (10 ft) and according to the existing OSHA standards, it is necessary to provide adequate protective systems in trenches deeper than 1.5 m (5ft).

The interviews conducted with sixteen construction practitioners located in the Midwest ascertain that the existing safety standards are deemed to be reliable and can help to prevent fatalities in trenching operations when they are correctly applied. However, in many instances, construction workers take unnecessary risks, and the "tough guy" culture continues to prevail on job sites. For instance, in many cases, when the trench is to be open for less than three hours, the crews involved in trenching operations tend to ignore the safety requirements, i.e., use of safety equipment, detailed analysis of soil condition, presence of competent person, etc., because they believe that the pipelaying operation will be completed and the trench closed, without posing any safety risk.

The interviews also indicated that the construction industry has learned how to identify the major causes of accidents based on the Type of Accident Model. In addition, it is important to note that the industry considers *cave-ins* accidents as the most important cause of fatalities, but also recognizes the existence of other type of accidents in trenching operations, such as *struck by object, caught in or compressed by equipment or objects,* and *contact with electric current.* This indicates that the construction industry has learned the planning process in order to include other causes of fatalities.

Regarding the strategies to prevent fatalities in trenching operations based on the Behavioral Causes Model, the results showed an important variability compared with the results obtained from the analysis of OSHA fatality reports. The distribution of resources assigned by each individual in each strategy depends upon the type of company, size of the company, the role in the company, and the previous construction experience. However, it is possible to conclude that the construction industry does not allocate sufficient resources in the major strategies to prevent accidents.

To prevent fatalities on job sites, the construction companies have been developing strategies (such as daily safety planning meetings, increasing involvement of owners in planning for safety, safety training, incentive programs increasing accountability by workers and support by top management, control of minor accidents, etc.) to improve the safety of workers. These strategies are based primarily on prior experiences of safety directors, and have the potential to decrease construction fatality rates.

Study Contributions

a.) Major causes of fatalities in trenching operations.

Thus far, research in trenching safety has focused on the Type of Accident Model, implying that the "how's" of the accidents are known. In addition, the results of the interviews conducted with construction practitioners showed that the construction industry has a clear understanding of the different types of accidents involved in trenching operations. However, when the "why's" of the accidents are studied, it was found that the opinion of the construction practitioners regarding these human causes of accidents has a high variability. This indicates that the industry is not necessarily focused on the major strategies to prevent accidents.

This study showed the major causes of fatalities not only based on the Type of accident Model, but also based on the Behavioral Causes Model. When the major causes were identified, the major relationships between the models were explained. The understanding of these relationships will help to develop better strategies to prevent trenching fatalities.

b.) Integrated model of trenching operations.

In this study, an integrated model of trenching operations was presented. This model considered the strategies to prevent the fatalities based on the Behavioral Causes Model, the activities to be executed during the planning and execution phases and the major causes based on the Type of Accident Model. To prevent trenching accidents is necessary to enforce the application of the existing safety standards and it is also necessary to implement a systematic planning process prior to start the construction process, and appropriate supervision during the execution phase.

c.) Construction industry input regarding the major strategies to prevent trenching accidents.

The inclusion of the construction practitioner's perspective regarding the major strategies to prevent trenching fatalities, provided a clearer picture of the issues in trenching safety, and how the strategies developed by the construction industry differ from the strategies required based on the analysis of trenching fatalities from OSHA. Based on the analysis of results, it may be inferred that the construction practitioners do not consider a single strategy as most important to prevent accidents. In addition, it appears that the companies are implementing several strategies simultaneously.

d.) Safety practices implemented by the construction industry to prevent trenching operations fatalities

The major safety practices applied by the construction companies to prevent trenching fatalities were identified. These practices have been successful in these companies because their fatality rate has decreased since the practices were developed. Nevertheless, it is not possible to assure that these practices will be successful in others construction companies because they have not been studied a systematic basis.

PUBLICATIONS

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Arboleda CA, Abraham DM, Wirahadikusumah R, Irizarry J: Trench-related fatalities in construction: An Analysis of Fatality Assessment and Control Evaluation (FACE) Records. First International Conference on Construction in the 21st Century (CITC2002) - Challenges and Opportunities in Management and Technology. Ahmad, I., Ahmed, S.Y., and Azhar, S., Eds, Miami, FL, 277-282, April 25-26, 2002

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SECTION VI

The Use of Trench Boxes for Worker Protection

Principal Investigator

Jimmie Hinze

Graduate Students

L. Huang

TABLE OF CONTENTS

THE USE OF TRENCH BOXES FOR WORKER PROTECTION

Research Team: PI – Jimmie Hinze; Gradute Students: L. Huang

ABSTRACT

Work in trenches can be very dangerous if workers are not provided with adequate protection against trench cave-ins. One method of providing for worker protection in trenches is with the use of trench boxes. Trench boxes are engineered structures that permit workers to work safely in trenches. This protection is best assured when workers use good work practices and follow the applicable safety regulations. In a study consisting of a survey of utility contractors about their experience with the use of trench boxes several notable findings were discovered. These findings can assist contractors in implementing safe work practices when working in trenches. Trench boxes are widely used in the utility construction community and appear to generally provide well for the protection of workers in trenches. The typical contractor owned about ten trench boxes, indicating a high use of trench boxes relative to other protection methods that could be used in trenches. The study also revealed that most safety problems with the use of trench boxes are attributed to human error or judgment. For example, several respondents commented that workers were observed exiting from the trench boxes by walking up the backfill, a practice that exposes workers to the dangers of trench cave-ins. The importance of training was also evident in the results. Firms with better safety performance records conducted specialized training courses for their employees. In addition, better safety performances were observed among those firms that provided more frequent training courses for their employees.

INTRODUCTION

Each year, many construction workers die as a result of trench cave-ins, possibly as many as 100 workers. These deaths are needless losses as trenching work can be performed safely. Whenever workers are working in trenches, appropriate safety precautions are to be taken to ensure worker safety. There are three typical ways that workers can be protected in trenches. These include sloping the trench walls, placing shoring the trenches, and utilizing trench boxes. Various considerations will be involved when making the decision about the method to use. Sloping the trench walls to the angle of repose is perhaps the most preferred way of ensuring the safety of workers in trenches, but this is not always feasible. For example, sloping when trenches are deep will result in a very wide top of the trench that may encroach on other surface encumbrances (streets, buildings, fences, etc.). Shoring is a means by which the trench wall is supported by wood shores, screw jacks, or hydraulic shores. Trench boxes, the newest type of trench protection, are made of two heavily reinforced steel plates that are separated by strong strut members. Trench boxes are moved in the trench as work progresses. When properly used, trench boxes offer a very viable means of providing for worker protection in trenches.

Most information on trench boxes is prepared and publicized by the manufacturers of trench boxes. These brochures and pamphlets describe the physical features of trench boxes (material components, over size, width variation, etc.) and also basic instruction on the proper use of trench boxes in trenches. Trench boxes are widely used in the United States and they provide well for the protection of workers in trenches. Most workers who die in trench cave-in accidents work in trenches that were not shored or which were not sloped at the proper angle. Historic injury data confirms that relatively few workers die as a result of cave-ins that involve trench boxes. While trench boxes do not offer the perfect solution for every trenching situation, they are a viable safety consideration on many trenching operations. Unfortunately, little information is publicized about any of the problems that contractors should watch for when working with trench boxes. This paper presents information on a research study that obtained information that was focused primarily on the extent of trench box use in the construction industry and on some of the problems that contractors face when working with trench boxes.

REVIEW OF LITERATURE ON TRENCH BOXES

Although trench boxes are the most recent development to provide for worker protection in trenches, their introduction to the construction community is not recent. The earliest known reference to trench boxes was in 1938 when a "sliding trench shield" was mentioned that was originally developed by a Seattle, Washington utility contractor. This early form of worker protection in trenches consisted of a steel box made of steel plates used on edge and connected by welded steel cross braces (see Figure 1). There are now many different manufacturers of trench boxes. As trench box design has evolved, the trench boxes have become more versatile, with interchangeable cross braces and stackable side plates for various trench widths and depths (Otter, 1962).

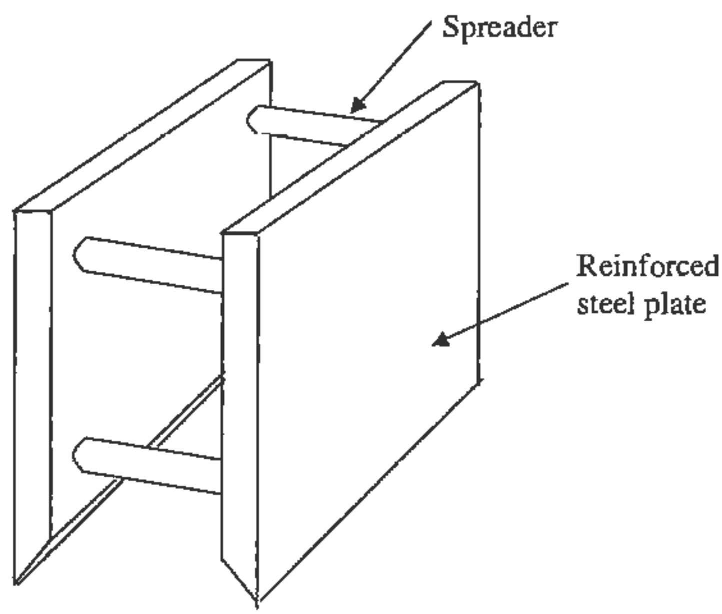

Figure 1. General configuration of a trench box

Trench boxes offer several clear advantages to the contractor. When compared with conventional shoring systems, trench boxes offer large open spaces within the trench. This makes it easier for workers to maneuver in the trench and it also makes it much easier to lower pipe lengths into the trench. Another advantage is that trench boxes tend to be conservatively designed so that they provide for worker protection in all types of soil types. Note that the term trench shield is often used interchangeably with the term trench box. There are also other names that have been used for trench boxes, but these tend to vary by region.

Contractors have recognized the advantages and value of trench boxes for many years. For example, in 1958, the Associated General Contractors (AGC) of America Manual of Accident Prevention in Construction stated when "bracing or shoring trenches is not practical or economical due to unstable ground, movable steel trench shields may be used effectively." Earth pressures generally increase with an increase in the depth of trench. Because of the significant potential earth pressures that might be encountered, the manual stressed that these shields "should be substantially constructed of steel plate sides, welded to heavy steel framework of structural shapes and/or pipe. Such shields should be so constructed as to be at least equivalent in strength to other forms of trench protection. Cross bracing should be adequate to support the earth pressure to which the shield may be subjected."

Another early reference to trench boxes was made in the First Edition of the Construction Safety Standards that was published by the United States Department of the Interior, Bureau of Reclamation in 1968. These standards stated, "Sheeting, sheet piling, bracing, shoring, trench boxes, and other methods of trench protection shall be designed and installed on the basis of the calculated pressures exerted by, and the condition and nature of, the materials to be retained. These calculations shall include the surcharge imparted to the sides of the trench by equipment and stored materials."

Although trench boxes were being used extensively before the passage of the Occupational Safety and Health Act of 1970s, the Occupational Safety and Health Administration (OSHA) standards made only a brief acknowledgement of the use of trench boxes. These standards (1926.652 (k)) stated, "Trench boxes or shields providing protection equal to or exceeding that of the wood shoring system are acceptable for employee protection." In the more recent version of the OSHA regulations trench boxes are discussed to a greater extent. The primary regulations pertaining to the use of trench boxes include the following:

- Trench boxes must be capable of resisting the lateral earth pressures
- Trench boxes must be installed so lateral movement of the shield is restricted
- Employees must be protected from cave-in when entering and exiting trench boxes
- Employees are not allowed in trench boxes while they are being installed, removed, or moved vertically
- The trench bottom is to be no more than 0.6 meters (2 feet) deeper than the bottom of the trench box

- The trench box shall extend no less than 0.45 meters (18 inches) above the top of the vertical trench walls

In a survey of AGC members involved in trenching operations, several interesting comments were received regarding the use of trench boxes (Salomone and Yokel 1979). For example, one respondent stated "The use of trench boxes is the best advance in trench safety in 20 years." Most comments about trench boxes by contractors were favorable.

In another study of trenching practices involving 100 utility contractors, specific information was sought regarding trench boxes. Several contractors commented that they were supportive of OSHA standards that would encourage the increased use of trench boxes. One contractor said, "OSHA should evaluate and strongly recommend the use of engineered steel trench boxes, with automatic fine credits given to those contractors who use them." The results of that study showed that utility contractors who made greater use of trench boxes also reported better safety performances (Hinze and Carino 1980).

The need to comply with good work practices when working with trench boxes is clearly stated in the OSHA. Others have also stressed this need, along with the various manufacturers of trench boxes. For example, in his text, Nunnally (1987) stated "Trench shields or trench boxes are used in place of shoring to protect workers during trenching operations… The top of the shield should extend above the sides of the trench to provide protection for workers against objects falling from the sides of the trench. The trench shield is pulled ahead by the excavator as work progresses."

Another author on the subject of trench boxes, Roberts (1987), noted the advantages of trench boxes. He stated, "For deep trenches and unstable ground, the trench box is the best shoring system. It's a large mobile box with enough strength to withstand the side pressure of deep excavations." In their text, Suprenant and Basham (1993) stated, "Trench shields are steel or aluminum boxes placed in the trench to provide a safe environment for workers. As the work progresses, the shield is pulled forward. The workers inside the shield are protected continuously from any caving in of the trench walls." It should be noted that trench boxes act differently than do tradition shores. Shores are designed to support the trench walls to prevent cave-ins. Trench boxes do not prevent cave-ins but they protect workers in the event of a cave-in. To be protected by the trench box, the workers must be inside the trench box, and it must be installed to prevent side-shift or lateral movement during a cave-in.

Ringwald (1993) described trench boxes steel or aluminum prefabricated support systems complete with cross braces. He noted that single trench box sections typically come, in 8' or 10' heights and lengths up to 20'. Trench boxes can be stacked if trench depths require it, with some conditions warranting three trench boxes being stacked in deep trenches. Most manufacturers build pre-engineered trench boxes that readily meet the OSHA standards.

In a recent study of 114 injuries and fatalities investigated by OSHA from 1984 to 2001, it was concluded that trench boxes "appear to give relatively good protection to workers in trenches." It was also concluded, "it is apparent that the OSHA regulations regarding trench shields appear to be adequate." Most accidents involving trench boxes were found to be the "result of the failure to comply with the OSHA regulations." Finally, it was concluded that minimizing injuries in trench boxes depends on "following good work practices and in complying with the OSHA regulations" (Hinze 2002).

RESEARCH METHODOLOGY

The objective of this study was to examine the current status of the extent of the use of trench boxes and to identify any worker practices that might compromise safety on a trenching project. A two-page survey on trench boxes was prepared. This survey was sent to 1000 contractor members of the National Utility Contractors Association (NUCA). This survey was sent out in October 2002. A total of 151 responses were received. These replies were analyzed and provide an overview of the current status of the use of trench boxes.

RESULTS

Relevant descriptive information about the utility contractor respondents was obtained in the surveys. In general, firms can be considered to be small, as half of the firms conducted annual volumes of business of less than $10 million. The typical utility contractor entered into less than 26 project contracts each year, employed less than 50 employees, and laid less than 7500 meters of sewer pipe each year. Since the lengths of sewer pipe laid each year is less than the total length of trenches dug each year, it is evident that other forms of utilities are also installed, e.g. water, gas, telephone, electric, etc. From the summary information shown in Table 1, it is clear that there is considerable variation in the size parameters of the responding firms.

Table 1 – Characteristics of Utility Contractor Respondents

Description of Firm	Mean	MEDIAN	Low Value	High Value
Annual Revenues (millions)	$20	$10	$.25	$250
Number of projects undertaken per year	67	26	3	1500
Number of Employees	98	50	4	1,000
Sewer pipe laid per year	21,000 m	7,500 m	0	260,000 m
Length of trench dug each year	39,000 m	18,000 m	0	400,000 m

Most responding firms were involved in the installation of sewer pipe and water pipe (see Figure 2). While company revenues presumably are derived from various types of work, most appear to be related to trenching work. For example, a few firms are involved in paving work, but this type of work is often associated with the installation of utilities where paving must be restored after utilities have been installed. The type of work being referenced by "other" includes diverse types of projects including bridges, excavations, grading, site development, concrete, etc.

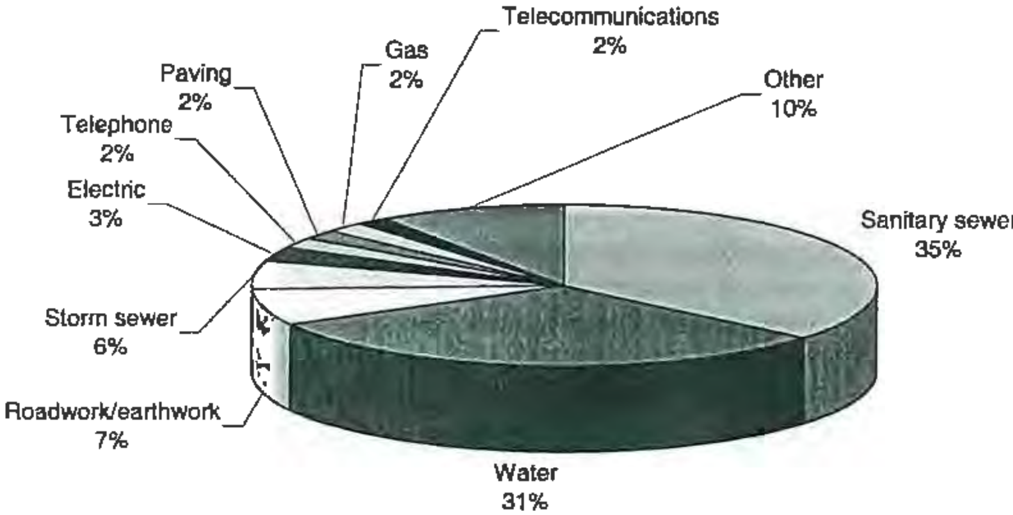

Figure 2. Work distribution of utility contractor respondents

The OSHA regulations require trenching work to be performed under the guidance of a competent person. Since the competent person on a trenching operation carries a major responsibility for the safety of the workers in and around the trench, the designation of the competent person is not a trivial decision. A question was asked about the identity of the individual who is generally designated as the competent person. The large majority of the replies show that the foreman is the individual who is most commonly designated as the competent person on trenching operations (see Figure 3). Seven percent gave this responsibility to assigned workers, but there was no information provided about the level of experience that these workers had. Some companies apparently have larger projects than others do as some indicated that the superintendent was designated as the competent person. Others gave this responsibility to the general superintendent or operator. On some utility construction operations, the entire crew could consist of the equipment (excavator) operator, two or three workers in the trench, and a loader operator. On such a project, the operator might very well be designated as the foreman of the crew. The survey did not ascertain if the foremen was also an equipment operator, but some did specifically state that the operator was the competent person on most of their projects.

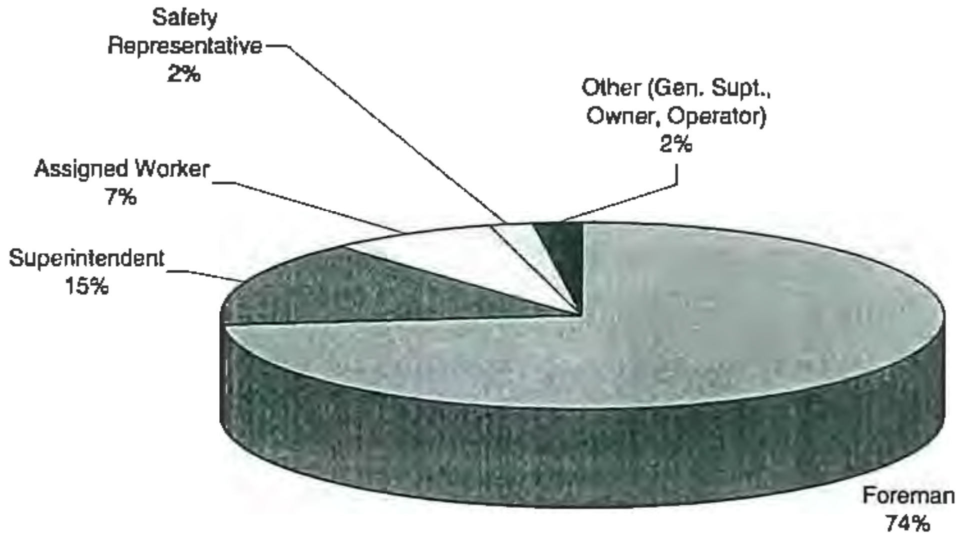

Figure 3. Individual generally designated as the competent person on trenching projects

Trench-related accidents can be complex in nature, making it difficult to ascertain the root causes of the incidents. The survey asked respondents about their perceptions of the most common causes of trench-related accidents. Respondents were to indicate with a ranking (ranging from 0 as the least common to 10 as the most frequent) of how often each of several factors were involved in accident causation. These factors were randomly placed in the survey, but as shown in Table 2, these causes can be grouped by related categories. The respondents stated that the most common causes of accidents were perceived to be worker related factors, including poor work practices, worker inexperience, and lack of training. Supervisory factors also received relatively high ranks, followed by physical conditions. Generally, there is low perception of inadequate OSHA regulations and poor construction documents being involved in trenching accidents.

Trenches that are deeper than 1.5 meters in depth must include the provision of some form of worker protection. Trench boxes are only one of these means, along with sloping the trench walls and the installation of trench shores. The survey asked about the type of worker protection generally provided in such trenches. Responding contractors indicated that trench boxes were the most common means (54%) of providing for the protection of workers in trenches deeper than 1.5 meters (see Figure 4). The next most common method is to us sloping, followed by benching which is a specialized form of sloping warranted by some soils. Although some utility contractors utilize shoring, it is not extensively used. Past studies have shown that shoring often become the only option for worker protection in trenches when the trenches begin to exceed the depth of 4.5 to 6 meters.

Table 2 – Perception of the causes of trench-related accidents

Cause of Trench Accidents	Mean Rank (0 to 10)
Worker Factors	
Poor work practices	7.8
Worker inexperience	6.5
Lack of worker training	6.1
Supervisory Factors	
Lack of supervision	5.9
Lack of planning	5.9
Physical Conditions	
Previously disturbed soil	4.8
Excess water	4.2
Spoil pile or equipment near the trench	4.0
Unforeseen soil conditions	3.8
Adverse weather	2.9
Nearby traffic	2.9
Other Factors	
Inadequate equipment	4.5
Poor contract documents	0.9
Inadequate regulations	0.9

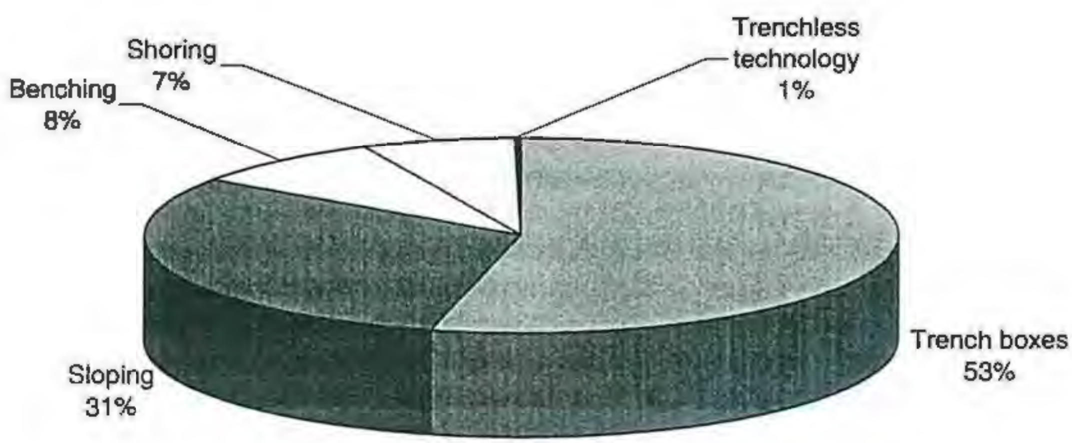

Figure 4. Frequency of use of methods to protect workers in trenches

Additional questions were asked about the trench boxes used by utility contractors. For example it was revealed that contractors generally reported that 60% of the trenches are deeper than 1.5 meters (see Table 3). When trench boxes are used, they are generally owned by the contractors with the average contractor owning an average of 11 trench boxes with another trench box being rented. This does not mean that the average contractor has 11 ongoing projects, as more than one trench box can be used on a single project. Even when there is only one trenching crew, more than one trench box may be required as about 20% of the projects involve trench depths that require the trench boxes to be stacked, at least at some locations.

Table 3 – Experiences with Trench Boxes

Description of Firm	Mean	MEDIAN	Low Value	High Value
Trenches deeper than 1.5 meters	60%	70%	1%	100%
Number of trench boxes owned	11	6	0	107
Number of trench boxes rented	0.9	0	0	25
Percent of projects with stacked trench boxes	20	10	0	100

With the average contractor using trench boxes in 60% of their trenches, there is obviously a considerable use of trench boxes. There are also many ways that trench boxes can be misused. Contractors were asked about the frequency of observing certain unsafe trenching activities. Specifically, they were asked to indicate how often specific unsafe trenching practices involving trench boxes were observed in the past year. The most frequently observed unsafe practice was using trench boxes without bulkheads (see Table 4). Workers can be placed in danger if they are asked to work near the open end of a trench box, without a bulkhead allowing debris to fall into the trench box. This next most common unsafe practice was workers venturing out of the safety of the trench box, possibly to exit the trench or to perform work in the unprotected portion of the trench. Some workers were exposed to cave-ins below the bottom of the trench boxes, by trench boxes being set too high or trenches being dug more than 0.6 meters below the bottom of the trench box. Another unsafe practice that was observed included workers exiting from the trench box without using ladders, probably walking up the backfill bank behind the trench box. Some workers were observed not staying clear of materials (pipe, ballast materials, or backfill) as they were lowered into the trench box. Some trenches were set too low in the trenches, allowing materials to fall into the trench box from the top. Finally, some respondents observed equipment (excavators, trucks, loaders, etc.) getting dangerously close to overhead powerlines.

It is particularly when workers exit trench boxes that safety must be observed. The survey asked about the means used by workers to exit trench boxes. The OSHA regulations state that trench boxes are to be exited by means of ladders within the trench boxes. Most respondents (70%) stated that ladders were used to exit trench boxes, but nearly 30% reported that workers exit trenches by going up the slope or backfill, a practice that places workers in harm's way (see Figure 5). One respondent reported that workers walked inside the large diameter pipe to the manhole to exit. One respondent stated that workers exited by way of a ladder placed "outside the trench box," a practice that is in clear violation of the OSHA standards and that would generally place workers in a hazardous situation.

Table 4 – Frequency that unsafe trench box practices were observed in the past year

Unsafe Practice Observed	Average Number of Observations in Past Year
Using a trench box without a bulkhead	4.6
Workers ventured out of the trench box	3.9
Setting trench boxes too high above trench bottom	3.6
Using trench boxes without ladders	2.0
Workers not staying clear of materials being lowered	1.6
Setting trench boxes too deep	1.5
Equipment getting dangerously close to power lines	1.1

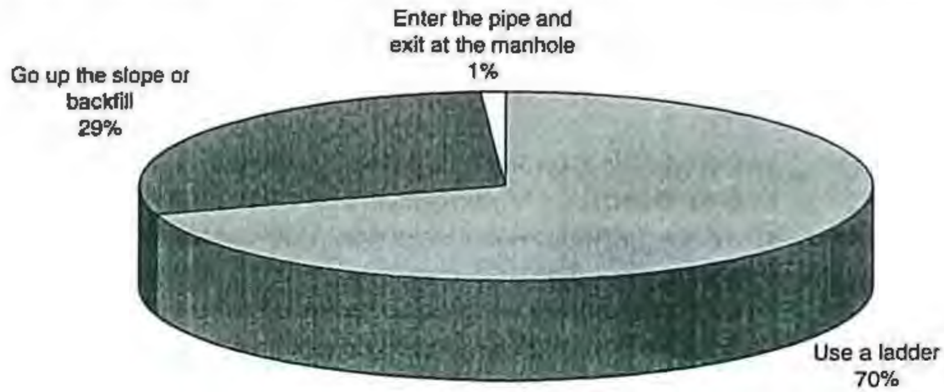

Figure 5. Methods of exiting from trench boxes

Survey participants were asked to offer additional comments about major concerns they had regarding the safe use of trench boxes. These comments are summarized in Table 5. The most frequent comment made was that workers were sometimes forced out of the trench box by the work being performed by the excavator in the trench box. They recognized the importance of keeping workers safely inside the trench box, but this was seen as compromising work productivity. A frequent comment made by several respondents was that trench boxes must be used when they are available and they should not be allowed to sit idly next to the trench when workers could be protected by them. One contractor recognized the life-saving features of trench boxes and said it is vital for trench box never to be regarded as "lawn ornaments." Several contractors mentioned the need to follow proper safety procedures when offloading trench boxes on the job site and also when setting them down in the trenches. Many other comments were provided and, when taken as a group, they provide valuable evidence of the complexity of maintaining safe trench box operations. It is also apparent that different contractors seem to have varying concerns related to the use of trench boxes. Note that no distinction was made in the analysis of the depth of trenches or the types of soil conditions that are commonly encountered. Clearly, the soil conditions vary considerably across the United States. The types of projects (whether water line, sewer line, gas line or other utility) would also influence the experiences of contractors. Further study would be warranted to discover more specific concerns related to trenching operations.

Table 5 – Comments about concerns with using trench boxes

Type of Concern	N
Keep workers in the trench box and don't push them out with the excavator.	19
Trench boxes must be used when needed, instead of leaving them on the bank	15
Proper lifting and setting of boxes (offloading from lowboy)	12
Adequately sized/designed. Right size box for soil conditions	10
Workers being properly trained, Workers following safe procedures	8
Working around existing utilities	7
Set box too high, more than 2 feet (0.6 meters) above the trench bottom	6
Make sure all pins are in place (connectors & struts are in good repair) Kept in good condition	5
Trench boxes are used properly and not abused but get damaged from use	5
Assembly of boxes with wide spreaders (over 10' wide)	5
Workers getting accustomed to dangers, not staying alert	5
Proper exit/entry (into and from the trench box)	5
Trench boxes too short for 20 ft pipe and still have room for the hoe bucket Need long enough box to protect workers (need 26' box for 20' pipe and 20' box for 13'pipe)	4
Inadequate supervision	4
Lowering pipe and material into the trench box	4
Proper lifting cables/ improper rigging	3
Handling trench boxes above ground without cables	3
Spoil pile clearance	2
Too much overburden above box	1
Proper slope above box	1
Sizing the equipment to handle the box	1
Access from edge of trench to trench box	1
Inspection of boxes for cracked welds, wear	1
Proper placement in jacking pits	1
Operators pulling on cross braces with machines under pressure	1
Trench boxes should be in the trench before workers	1
Moving the box with workers in box	1
Using ladders	1
Qualified operator	1
Safe movement in the trenches	1
Foremen feel trench boxes slow them down	1
Always having a good top man to assist the pipe layer with the ladder and tools. Watching for danger	1
Planning so workers don't take shortcuts	1
Language problems (not knowing English)	1
Potential danger to pipe when pulling box	1

One question was asked about safety practices that were not specific to the use of trench boxes. Respondents were asked to indicate the types of safety program elements they had implemented on their projects. Note that only a small sampling of common safety program elements was listed. Of those listed, the most common practice employed by the utility contractors was the requirement for workers to wear hard hats followed by specific training provided on trenching safety (see Table 6). Most contractors hold pre-construction meetings. Less than half of the contractors use worker incentives or daily safety meetings.

Table 6 – Safety program practices employed by utility contractors

Safety Program Practice	Proportion of Respondents
Hard hats required to be worn	94.7%
Specific training in trenching safety	80.8%
Pre construction meetings	66.2%
Worker incentive program	41.7%
Daily safety meetings*	32.5%

*most respondents stated that safety meetings were held weekly

Detailed information about the safety programs of utility contractors was not obtained in this study, as this was not the primary objective of this study. Nonetheless, the safety program practices of utility contractors appear to be reasonably effective in reducing worker injuries. The utility contractors responding to the survey reported an average injury frequency rate of 3.02 OSHA recordable injuries per 200,000 hours of worker exposure. This level of safety performance is considerably better than the construction industry in general which is greater than 7.0. Of these practices, training was the practice with the most apparent impact on safety performance. For example, the firms stating they conducted no specialized trenching safety training sessions reported an average OSHA recordable injury rate of 5.78 while those offering specialized training sessions reported an average OSHA recordable injury rate of 2.56. In fact, the injury rate appeared to decline with an increase in the number of training sessions offered per year (see Table 7). It was also noted that the injury frequency rates were lowest among the smaller firms. That is, the injury rates appeared to increase with an increase in company size. The data did not provide any clear indication to explain this phenomenon, but this has been observed with other studies involving utility contractors (Hinze 1978).

Table 7 – Number of training sessions and safety performance

Number of Sessions per Year	OSHA injury frequency rate
none	5.78
1 or 2	3.04
3 or 4	2.90
6 or more	1.78

Since this study was not conducted to make solid conclusions about how safety performance is influenced by various practices, little more can be concluded about how utility contractors achieve their good safety performance records. There are obviously some practices that differ between the different respondents. These may very well also have an impact on the safety records.

CONCLUSIONS

While the use of trench boxes generally appears to be a simple sequence of operations, the results of this study indicate that safety concerns are presented at various times in their use. The most serious infraction that was noted is when trench boxes are available but not used. A common problem occurs with workers venturing out of the safety of trench boxes. Trench box safety begins when they are offloaded at the jobsite and they safety concerns continue as they are lowered into the trenches. Other safety infractions were also noted.

Although this study was not conducted to identify the types of safety practices that are most effective in ensuring good safety performance, some insights about safety performance were obtained. For example, the utility contractors generally enjoy a level of safety performance that is better than the construction industry as a whole. It was not determined how these safety performances were actually achieved, but the findings did indicate that training is probably one of the primary factors that improve safety performance.

There seems to be reasonable consistency in the utility construction community about the use of trench boxes and the types of problems that continue to exist on trenching operations involving trench boxes. The problems do not appear to be shortcomings in the OSHA regulations but rather the failure of workers to fully comply with the existing safety regulations. Additional guidance on safety practices is provided by trench box manufacturers.

RECOMMENDATIONS

Since the OSHA regulations appear to adequately address safe work practices with trench boxes, contractors are encouraged to make greater attempts to ensure that field operations fully comply with them. Additional guidance should be sought from the various suppliers of trench boxes.

As most of the serious safety problems are associated with worker behavior, contractors are encouraged to set up more stringent jobsite rules and to fully enforce them. When trenching operations are being conducted there is no opportunity to be lax on safety. A beginning point would be to conduct a series of training sessions to ensure that all workers are fully informed about the expectations of the company.

With the unacceptable number of serious safety infractions occurring on many trenching projects, it is incumbent on utility contractors to stress safety with their employees. Just as many companies have a zero tolerance for drug abuse, utility contractors should have zero tolerance for worker behavior that places their lives at risk.

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SECTION VII

The Owner's Role in Construction Safety

Principal Investigator

Jimmie Hinze

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X. Huang

TABLE OF CONTENTS

THE OWNER'S ROLE IN CONSTRUCTION SAFETY

Research Team: PI - Jimmie Hinze, Research Assistant – X. Huang

ABSTRACT

The construction industry is a dangerous industry by many standards and has consistently been one of the industries with the poorest safety records. This is despite the fact that dramatic improvements have been made in the safety performance of the construction industry in the past decade. The improvements are due, in part, to the concerted efforts of owners, contractors, subcontractors, and designers. While past studies have investigated the safety roles of contractors, subcontractors, and designers, the owner's impact on construction safety has not been thoroughly studied. This paper will report the results of a study on the owner's role in construction safety. Interviews were conducted on projects with large worker hours of exposure to collect data for the study. The relationship between project safety performance and the owner's influence was examined, with particular focus on the project context, the selection of safe contractors, contractual safety requirements, and the owner's participation in safety management during project execution. By identifying effective practices of owners that are associated with good project safety performances, guidance is provided on how owners can implement safety programs that directly impact safety performance.

INTRODUCTION

Accident data prepared by the Bureau of Labor Statistics (www.bls.gov) show that the construction industry has performed much worse than the average of all industries (see Figure 1). Although the safety performance of the construction industry have improved dramatically in the 1990's, injury rates in the construction industry are still 50% higher than that of all industries, lagging all industries by about 10 years. With an average employment of approximately 7% of the industrial workforce, the construction industry has regularly accounted for nearly 20% of all industrial worker fatalities (www.bls.gov). These accidents have also resulted in great economic losses. The research conducted by Everett and Frank (1996) concluded that the total costs of construction accidents accounted for 7.9-15.0% of the total costs of new, non-residential projects. A more recent but unpublished research by Coble and Hinze (2000) showed that the average workers' compensation insurance costs could be conservatively estimated as constituting 3.5% of the total project cost. An alarming fact is that each year around 1100 workers are killed on site, and this number has been increasing in recent years (www.bls.gov/iif).

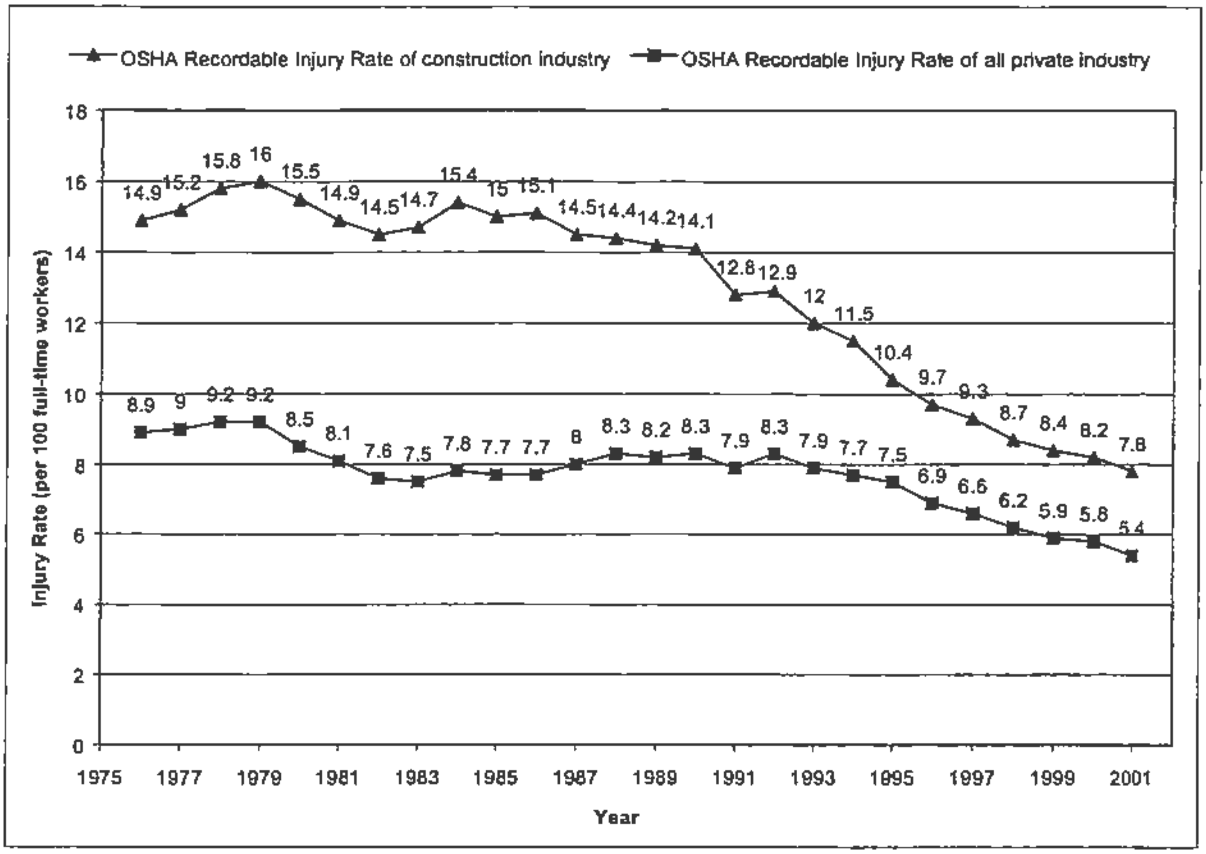

Figure 1 Injury rate of construction and all private industry (data source: www.bls.gov)

In order to reduce and eventually eliminate construction accidents, researchers have explored techniques implemented by different construction parties to realize the "zero injury objective". Owners, A/E firms (designers), contractors, and subcontractors have different roles in preventing accidents to achieve an injury-free worksite (Hinze, 1997; Gambatese, 1996; Toole, 2002). The contractor is undoubtedly the pivotal party to control jobsite safety. Practices and approaches taken by contractors to improve project safety have been thoroughly investigated in past research studies (Levitt and Samelson, 1993; Hinze, 1997; Hinze, 2002). Subcontractor safety as influenced by the general contractor in various sizes of projects was investigated by Hinze and Figone (1988, for small and medium projects), and Hinze and Talley (1988, for large projects). Designers can reduce safety hazards in the working environment by considering worker safety issues in their design decisions. Hinze and Gambatese (1996) gathered various "best practices" for designers to address safety issues in their designs and developed a safety design tool to help designers eliminate hazards when making decisions. The involvement of owners has been regarded as an essential requirement for the zero injuries objective (Hinze and Gambatese, 1996). However, no previous study has thoroughly investigated the owner's influence on construction safety.

The owners of projects (also called facility clients or project buyers) are the primary consumers of construction services, the sources of project financing, and, in many cases, the end users of the facilities (Hinze, 2001). Their impact on project construction safety is significant. For example, in the research conducted by Liska et al. (1993), it was found that an important prerequisite attributed to excellent safety performance was the involvement of the owner: in not only pre-project planning including financially supporting the contractor's safety program, but also in the day-to-day project safety activities. In the construction accident causation model developed by Suraji et al. (2001), construction accidents are caused by inappropriate responses to certain constraints and the environment. In the model, owner (client) responses are the actions (or inactions) of the owner in response to constraints during the development of a project brief. These include, for example, reducing the project budget, adding new project criteria, changing project objectives, and accelerating the design or construction efforts of the project. All these elements can play contributing roles in accident causation.

In the past, there was a reluctance of owners to become involved in matters related to construction safety for fear of incurring added liability exposure (Sikes et al., 2000). However, since the 1980's more owners, especially owners with large construction budgets, have voluntarily expanded their role to proactively promote worker safety. A series of studies conducted at the University of Washington in the early 1990's demonstrated that owner's concern for construction safety was increasing (Hinze, 1997). The major reasons include:

- The rising costs of health care and workers' compensation are not being ignored by owners (Hinze and Appelgate, 1991). Owners realize that the costs of injuries are ultimately reflected in the costs of their construction projects (Gambatese, 2000).
- Litigation involving owners has escalated in the past three decades. For example, in the case of Phillips v. United Engineers & Constructors, Inc., and Plasteel Products Corp., 500 N.E. 2d 1265 (1986), the owner was sued, but was not held responsible, for a worker's fall from a catwalk during steel erection. In another case Rigatti v. Reddy, 723 A.2d 1283 (1999), the owner was similarly cleared of being responsible for a roofer's fall. A different court sentiment appeared in the case of Stark v. Rotterdam Square, 603 N.Y.S.2d 347 (1993), where the owner of a mall was held liable for injuries suffered by a roofer when he fell through a hole cut into the roof. Because of these types of lawsuits, many owners have come to realize that reducing the frequency and severity of construction injuries is the only sure way of reducing their potential liability for worker injuries (Levitt and Samelson, 1993).

As a result of these changing attitudes about liability, many owners are taking more active roles in construction safety. The study described here investigated the relationship between project safety performances and the owner's involvement in construction safety.

LITERATURE REVIEW

Owners can favorably impact construction safety by selecting safe contractors, encouraging designers to address safety issues in the designs, and participating in safety management during construction (Hinze, 1997). To the extent possible, the owners, through their project representatives, should participate with the contractors in all project safety activities, including but not limited to new employee orientation, safety meetings, audits and accident investigations, training, incentive programs and other safety related programs (Gambatese, 2000).

One of the earlier studies on the owner's role in construction safety by Levitt et al. (1981) reached the conclusion that construction owners who selected or prequalified contractors based on safety performance, and/or who got involved in construction safety management, had fewer accidents on their projects. In the study conducted for the Business Roundtable (1982), questionnaires were sent to owners and contractors to identify safety requirements owners placed on construction contractors and specific practices of owners that emphasized safety with contractors. The responses that were associated with better safety performances included: requiring the use of a system of permits for potentially hazardous activities, requiring the contractor to designate a responsible supervisor for safety coordination on the job site, providing the contractor with safety guidelines that must be followed, and so on.

In Levitt and Samelson (1993), it was stated that the owners with the safest construction projects tended to use many of the following strategies with their contractors:

- Stress safety as part of the contract during the pre-job walk-around.
- Require short-term permits, rather than ongoing permits, for hazardous activities.
- Conduct safety audits of the contractor during construction.
- Require safety training of all project employees.
- Maintain statistics on the contractor's safety performance.
- Set goals for construction safety.
- Include general safety guidelines in the body of the contract.
- Set up a construction safety department to monitor contractor safety.
- Require immediate reporting of all worker accidents.
- Investigate the contractors' accidents.
- Always include safety on the agenda at owner-contractor meetings.
- Provide contractors with special safety guidelines they must follow.
- Require the contractor to assign safety coordination responsibilities to someone on site.
- Reimburse the contractor's safety costs in full.

The American Society of Civil Engineers (ASCE) moved to the forefront in the trend to involve owners in safety when it issued ASCE's Policy Statement 350 on construction site safety in 1998. The statement outlines ASCE's view that "improving construction site safety requires attention and commitment from all parties involved." The policy states that safety should be addressed "for each project on a project specific basis," and that owners should "take an active role in project safety." Various ways owners can actively address safety were given in the policy:

- Assigning overall project safety responsibility and authority to a specific organization or individual (or specifically retaining that responsibility) that is qualified in construction safety principles, rules, and practices appropriate for the particular project.

- Including prior safety performance as a criterion for contractor selection.
- Designating an individual or organization to monitor safety performance during construction.
- Designating in the contract documents those parties responsible for the final approval of shop drawings and details.

An owner, to be actively involved in construction safety, might consider several contractual issues. Many of the issues relate to the safety obligations placed on the contractor. Hinze (1997) suggested that contract provisions may include the following requirements:

- Submittal of a project-specific safety plan
- Job hazard analysis
- Regular safety meetings with supervisory personnel
- A designated project safety coordinator
- Mandatory reports on accident investigations, safety inspections, and safety meetings
- Inclusion of subcontractors in the safety program
- Compliance with the owner's safety guidelines
- Establishment of an effective worker orientation program

Gambatese (2000) summarized various ways in which owners can actively address safety, including:

- Establish a clear position on safety.
- Ensure that safety is addressed in project planning and design.
- Consider safety performance when selecting a constructor.
- Address safety in the construction contract.
- Assign safety responsibility during construction.
- Participate in project safety during construction.

In summarizing the literature, the owner's involvement in construction can be demonstrated through their selection of safe contractors, arrangement of contractual safety requirements, and proactive participation in safety management during project execution.

METHODOLOGY

The purpose of this research study was to identify how and to what extent owners influence construction safety performances. It was decided that this type of study could be ideally conducted with input from construction practitioners. This would ensure the relevance of the findings to actual construction settings. Such findings could then be readily interpreted for direct field implementation by others.

This research began with a pilot study consisting of mailed surveys sent to large owner firms that were known to have large construction budgets, as listed in the ENR top

425 owners (ENR, 2001). The purpose of the pilot study was to establish and refine hypotheses to be tested in the research, based on information related to construction safety at the owner company level. The pilot study was followed by interview study in which representatives of owners were interviewed at selected construction sites. The interview data consisted of more detailed information than was obtained in the mailed pilot study, and therefore constituted the major data collection phase. All of the findings of the research reported here are based on the data collected through the project interviews.

In the project interview stage, the researchers used a questionnaire that was developed on the basis of the literature review, pilot study results, and refined through input from CII (Construction Industry Institute) Project Team #190. (Note that this research was funded by the National Institute for Occupational Safety and Health, but was also adopted as a project by the CII.) The questionnaire was finalized after the first three interviews were conducted. The questionnaire was focused on collecting information on the project safety performance, with information related to four categories:

- The project context;
- The owner's selection of safe contractors;
- The owner's safety requirements in the contract documents;
- The owner's participation in safety management during project execution.

Two major criteria were established in order for projects to be included in the study, including: projects must be under construction or be newly completed (within the past two years) and at least 100,000 hours must have been worked on the project.

Most of the projects were identified by members of the CII Project Team #190. Often either the owner or the contractor on the project, or both, were CII members; however, CII membership was not a criterion for inclusion in the study. Many owners of projects were not affiliated with the CII.

Persons interviewed were generally site representatives of the owners, including construction managers, safety managers, and safety coordinators. The face-to-face project interviews generally took one and a half hours to two and a half hours to conduct. Whenever face-to-face interviews were economically infeasible, the interviewee was asked to fill out the questionnaire and return it to the researcher by Fax or email. For questionnaires returned this way, a follow-up telephone interview, lasting about half an hour, was conducted to clarify any questions and to complete any incomplete responses.

In the data analysis of this study, the total OSHA recordable injury rate (the number of OSHA recordable injuries occurring for every 200,000 worker hours, hereinafter referred to as TRIR) was the response or dependent variable. The rationale of measuring project safety performance with TRIR was demonstrated in Hinze (1997). The practices of owners or characteristics of the project were the independent variables. In this research, two steps were conducted to analyze the data collected through project interviews:

- Frequencies of different safety management techniques were summarized to provide a holistic picture of the extent of use of safety techniques on the projects. The most common practices of owners to emphasize construction safety were summarized.
- Non-parametric statistical tests (mainly including Mann-Whitney U tests and Kruskal-Wallis tests) were conducted to compare the median safety performances of projects with and without a safety management technique. The techniques with significantly different values of TRIR were identified.

Since the study was an exploratory one, the significance level of hypothesis testing was set as 0.10, instead of 0.05. It means that there was only a 10% probability that the relationship is due to chance occurrence.

The Projects Interviewed

Of all the projects on which interviews were conducted, 59 projects provided the TRIR data and satisfied all the criteria to be included in the data analysis. These 59 projects included 49 U.S. projects, seven projects in Canada, and three international projects with U.S. owners and U.S. contractors. The study included primarily petro-chemical and manufacturing facilities with only a few civil, residential, and commercial projects. Project size descriptors (as measured in terms of worker hours and in total contracted project cost) and the TRIRs of the 59 projects included in the final analysis are shown in Table 1. Six projects reported having no OSHA recordable injuries (TRIR = 0). Although the safety performances and sizes of the projects ranged widely, it is apparent that the safety performances of most projects (median of 1.48) were much better than the construction industry average of about 7.8 for the year 2001 (see Figure 1). Thus, the projects included in this research generally enjoyed much better success in safety than the construction industry as a whole. This research primarily investigated those owner practices that had a direct impact on influencing the safety performances realized on the projects.

Table 1 Safety performances and sizes of the projects included in the research

		Total worker hours expended	Total estimated cost of the project*	Total Recordable Injury Rate
Mean		2,426,210	$379,440,000	1.95
Mode		200,000	$15,000,000	0
Std. Deviation		5,155,050	$861,740,000	1.94
Minimum		100,000	$3,500,000	0
Maximum		26,300,000	$5,000,000,000	9.25
Sum		143,146,400	$21,248,700,000	115.11
Percentiles	**25**	275,000	$15,250,000	0.58
	50	627,000	$78,350,000	1.48
	75	2,284,000	$306,250,000	2.73

*: These data are based on 59 projects, however, only 56 projects provided the project cost information.

Among the 59 projects, 46 reported information on all types of injuries, including lost-time injuries, OSHA recordables, and first-aid injuries. Injuries occurring on these projects were categorized by severity, and the ratio between the different types of injuries was determined, as shown in the injury pyramid in Figure 2. Heinrich (1959) suggested that the ratio between major injuries, minor injuries and no-injury accidents was 1:29:300. The pyramid in Figure 2 could be simplified by reporting the ratio between lost-time, OSHA recordable, and first-aid injuries as being roughly 1:10:300. Note that the information is based on 102,000,000 worker hours of exposure.

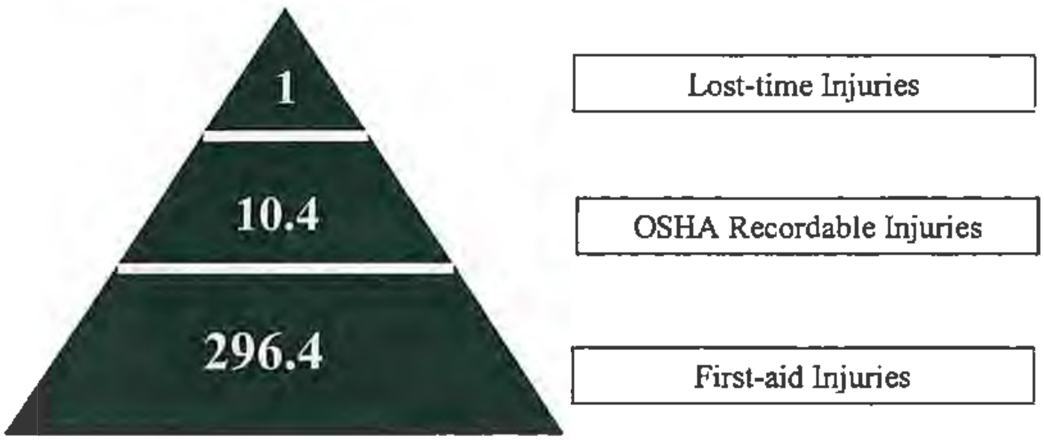

Figure 2 Injury pyramid for the projects

FREQUENCIES OF OWNER'S PRACTICES

Before testing whether different practices of owners could make a difference in the safety performances achieved on their projects, the most popular and frequently used safety practices were listed. These practices included:

- Prime contractor reported injury statistics to the owner (100%), and the types of injuries reported were: lost-time injuries (100%); OSHA recordable injuries (100%); environmental issues (91.5%); near misses (88.1%).
- The owner's site safety representative was generally an employee of the owner (88.1%) instead of a consultant (11.9%). This person was generally a member of the project management team (91.5%), and had authority to stop unsafe work (94.9%). The job responsibilities of the safety representative generally included:
  - Monitoring safety management and performance of the contractor on a daily basis (89.8%)
  - Enforcing safety rules (89.8%)
  - Conducting site safety inspections and audits (89.8%)
  - Reviewing safety performance on site and submitting reports to the home office (88.1%)
  - Reviewing contractors' safety reports (88.1%)
  - Coordinating safety efforts on site (81.4%)
- Owner's site safety representative reviewed the safety performance of the contractor on a regular basis (98.3%). They would check the project lost-workday injury rate (94.9%), the project recordable injury rate (94.9%), and the project first-aid injury rate (88.1%).
- When selecting contractors, safety was generally a consideration of most owners (94.9%). Among the criteria used by owners to evaluate the safety performances of

contractors, the overall quality of the safety program was the most frequently mentioned measure (88.1%). The owner's evaluation of contractor safety performance would make a difference between getting the contract or not (88.1%). When contractors had some safety statistics of concern, the contractors could show that they had made major changes in the program and still be considered for contract award (94.9%).

- Owners included a variety of safety requirements in their contracts, the most frequently used provisions are the following:
  - Contractor must comply with the local, state and federal safety regulations. (100%)
  - Contractor must report all lost time injuries to the owner. (98.3%)
  - Contractor must report all OSHA recordable injuries to the owner. (96.6%)
  - Contractor must report all injuries to the owner. (96.6%)
  - Contractor is required to provide specified PPE (hard hats, safety glasses, gloves). (96.6%)
  - Contractor must implement a substance abuse program. (96.2% of U.S. projects only, since drug testing is not common on Canadian projects)
  - Contractor must conduct weekly safety meetings for the workers. (93.2%)
  - Contractor must comply with safety requirements beyond the OSHA regulations. (88.1%)
  - Contractor must participate in site safety audits. (88.1%)
  - Contractor must implement a permit system when performing hazardous activities (line breaks, lockout/tagout, excavations, proximity to power lines, confined space entry, hot work, etc.). (88.1%)
  - Contractor must submit a site-specific safety plan. (84.7%)
- Owners impose the same safety requirements on subcontractors and lower tier subcontractors. (91.5%)
- Most owners require specific items to be included in the contractor's safety program (98.3%), and included the subcontractors in the safety program as well (94.9%). The safety program items that were required by most owners included:
  - Substance abuse program (95.83% for U.S. projects only)
  - Regular safety meetings (94.9%)
  - Incident reporting and accident investigations (93.2%)
  - Regular safety inspections (91.5%)
  - Training on the hazards related to the tasks being performed (89.8%)
  - OSHA specific regulations (88.1%)
  - Specific safety training sessions (86.4%)
  - Pre-project safety planning (86.4%)
- Other safety practices of owners included:
  - Construction safety issues were specifically addressed in the design. (98.3%)
  - Owner required every worker on site to receive orientation training. (96.6%)

RESULTS

Based on the data collected in the project interviews, non-parametric statistical analyses were conducted to establisb the strength of the relationships between the TRIR (response or dependent variable) and project characteristics and owner's practices (explanatory or independent variables) in four categories:

- The project context
- The selection of safe contractors
- The contractual safety requirements
- The owner's involvement in safety management

The project context

The size of the project, labor arrangements for the project, type of project, and other characteristics of the project may all be related to the project safety performance. These factors were analyzed, and the results are shown in Table 2.

Table 2 The relationship between TRIR and the project context

Project context	Categories	Counts	Median	Significance level*
(a) Type of projects	All Others	51	1.30	0.07
	Shutdown	8	2.20	
	Total	59	1.48	
(b) Type of projects (excluding shutdown projects)	Private	45	1.20	0.02
	Public	6	2.67	
	Total	51	1.30	
(c) Type of projects (excluding shutdown projects)	Petrochemical	25	0.84	<0.01
	Manufacturing	16	2.47	
	Total	41	1.20	
(d) Type of contract	Other	44	1.68	0.03
	Design-build	15	0.69	
	Total	59	1.48	
(e) Worker hours (in thousand hours)	100~1000	36	1.96	0.04
	1000 up	23	0.92	
	Total	59	1.48	
(f) Work shifts	1 shift	37	1.17	<0.01
	2 or 3 shifts	22	2.20	
	Total	59	1.48	
(g) Workdays per week	4 or 5	34	1.18	0.03
	6 or 7	25	2.00	
	Total	59	1.48	

*: One-tail level of significance by the Mann-Whitney U test

Shutdown projects (defined as upgrade and modification work of industrial plants) were found to have poorer safety performances than other types of projects (see Table 2(a)). The median TRIR of the eight shutdown projects included in this research was higher than the median TRIR of the other projects. Shutdowns are characterized as having tight schedules (typically from a few days to eight weeks), significant amounts of overtime work, frequently working multiple shifts, and generally having a rapid buildup of the workforce (with many workers new to the project). When workers and managerial personnel work extended hours for one or two months, the possibility of human errors increases, and so will the probability of injury causation.

It was suspected that private projects may have an advantage in achieving better safety performances than public projects (see Table 2(b)). Since many public projects must be awarded through the competitive bidding process, public project contracts are frequently awarded to contractors without regard to their ability to deliver a safe project. Private owners may take into account factors other than simply awarding the contract to the lowest bidder. Nevertheless, some public agencies, especially federal agencies, may require the contractor to comply with their own safety requirements, in addition to the OSHA regulations. However, the involvement of the owners in the safety management of public projects was generally viewed as being inadequate, when compared to the extent of owner involvement on private projects.

Safety performances on manufacturing projects were consistently not as good as on petrochemical projects (see Table 2(c)). Note that residential and commercial projects were not included in this comparison, primarily because only a few such projects were in the entire sample. From the limited data, it appeared as if the residential and commercial projects were not as good as the manufacturing projects in the area of safety. It should be mentioned that owners of many manufacturing projects were aggressive in their efforts to improve project safety performance. Several respondents stated that their emphasis on safety in the manufacturing sector was a relatively recent initiative. Since it takes time to be successful in making significant changes in the safety culture of a company, it may be only a matter of time before additional improvements in safety performance are realized on manufacturing projects. Although their safety performances were not as good as the petrochemical projects, the manufacturing projects in this study were already much better than the construction industry TRIR average of 7.8 (www.bls.gov).

One method of enhancing safety is to conduct a constructability review as part of the design process (Hinze and Wiegand, 1992; Hinze and Gambatese, 1996; Jergeas and Van der Put, 2001). This review helps to coordinate the safety efforts of designers and the work performed on site (Fischer and Tatum, 1997). Comparisons were made of the safety performances of design-build projects with projects constructed under other contracting arrangements. Design-build firms, including engineering, procurement, and construction (EPC) firms, have a direct incentive to focus on construction safety during the design phase as it is their own employees who are impacted by their design efforts. In other arrangements, the design team is often considered to be separate from the construction effort and does not address construction safety in the design. Results (see Table 2(d)) show that design-build (EPC) projects had significantly better safety performances than did projects with other forms of contracting arrangements. Although owners addressing safety during the design phase was not investigated in this study, nearly all owners reported they addressed construction safety in the design phase.

Despite the complexity involved, safety performances on the large projects were quite good (see Table 2(e)). This held true for all large projects, including shutdown projects, petrochemical projects, and manufacturing projects. Strong safety performances on large projects have been reported in other construction safety research. In general, the very large and quite small contractors have better safety performances, while medium sized companies have poorer safety performances (Hinze, 1997).

The number of shifts worked and the number of workdays worked per week are often dictated by the owner's schedule requirements. Tight deadlines often mean that shift work or overtime work will be necessitated. On the projects involved in this research, it was found that projects with one shift had significantly better safety performances than those with more than one shift (see Table 2(f)). Projects with four-day (primarily those working four-tens) or five-day workweeks had significantly better safety performances than those working more than five days per week (see Table 2(g)). Note that if the eight shutdown projects are excluded in the analysis, the difference of TRIR between projects with different shifts was still significant, while the difference of TRIR between projects with different workweeks was no longer statistically significant. From these results, it is reasonable to suspect that fatigue can contribute to increasing the number of human errors, and that days off for rest and recovery may contribute to injury-free work.

The selection of safe contractors

Selecting a safe contractor for project execution is an important function for the owner to achieve better safety performance. In this research, it was found that most private owners would not consider awarding contracts to contractors with poor safety performances. Some owners maintain their own database of the safety performance history of all parties with whom they have contracted, namely contractors, subcontractors, and vendors. From this, they develop and maintain an approved bidder list and only these firms are given the opportunity to submit bids on their projects. This study examined the selection criteria used by the owners to evaluate each contractor's safety performance (see Table 3).

Table 3 The relationship between TRIR and the selection of safe contractors

The selection of safe contractors	Categories	Counts	Median	Significance level*
(a) Importance of safety in review of contractor's overall performance	<=5	24	2.13	0.05
	>=6	35	1.2	
	Total	**59**	**1.48**	
(b) Was EMR used to evaluate contractor safety performance?	No	11	1.54	0.23
	Yes	45	1.48	
	Total	**56**	**1.51**	
(c) Was TRIR used to evaluate contractor safety performance? (excluding public works)	No	6	2.50	0.03
	Yes	44	1.32	
	Total	**50**	**1.89**	
(d) What is the threshold value of TRIR of contractors? (excluding public works)	>=2 or none	39	1.67	0.04
	<2	11	0.84	
	Total	**50**	**1.89**	
(e) Are qualifications of safety staff reviewed when evaluating contractors?	No	14	2.48	0.06
	Yes	42	1.32	
	Total	**56**	**1.51**	
(f) Are qualifications of the project team reviewed when evaluating contractors?	No	18	2.48	<0.01
	Yes	38	1.2	
	Total	**56**	**1.51**	

*: One-tail level of significance by the Mann-Whitney U test

The results of data analysis show that owners placing higher priorities on safety when reviewing the overall performances of contractors reported better safety performances (see Table 3(a)). The most proactive owners mentioned that during their review procedure, the weight of safety performance should be at least as high (6 or 7 on a scale of 1 to 7, with 7 as the highest level of emphasis on safety) as the weight of cost.

Questions were asked about how owners evaluated the past safety performances of contractors. Various measures of safety performance have been identified in the past researcb results of Diaz and Cambrera (1997), Garza et al. (1998), and Sawacha et al. (1999). The results of this study show that owners used varying criteria to measure safety performances of the contractors. Consistent with the findings by Hinze, et al. (1995), some owners felt that the workers' compensation experience modification ratio (EMR) is a lagging and inaccurate indicator, and no longer relied on it as a safety indicator. Owners using the EMR as a safety indicator did not report notably better safety performances (see Table 3(b)).

In contrast, the TRIR is also a lagging indicator, but safety performances of projects were significantly better when the owners used the TRIR as one of the measurements for evaluating contractors (see Table 3(c)). Note public works projects were excluded because public owners are often unable to take safety criteria into consideration when they award contracts. Those owners using the TRIR were asked if a threshold value of TRIR was established, namely a value above which safety performance was deemed to be unacceptable. The safety performances of projects with more stringent TRIR requirements (threshold values less than 2) were significantly better than on projects using more lenient threshold values (threshold values greater than 2) or projects where no TRIR limits were established (see Table3 (d)).

Qualifications of the contractor's safety personnel and qualifications of the project management team were used by some owners for the selection of contractors. The more proactive owners would review these qualifications by conducting pre-construction personal interviews with them and also by making site visits to projects where they were assigned at the time. The resultant TRIR was found to be lower on projects where the owner's had a practice of considering the qualifications of the contractor's safety personnel and also the qualifications of the project management team (see Table 3 (e) and (f)).

In summary, the most proactive owners no longer rely on the lagging indicators such as EMR to measure safety performance of contractors. Instead, they turn to dynamic measurements of safety performance, which can better portray the safety performance potential and safety management capabilities of contractors. Viable measures, or leading indicators, include an assessment of the contractor's safety program, reviewing the qualifications of the safety personnel, and reviewing the qualification of the project management team.

The contractual safety requirements

The construction contract is the legal document that prescribes the responsibilities of different parties involved in the project (Hinze, 2001). In the interviews, questions were asked about how the owners addressed construction safety in their contract documents. Among the seventeen listed safety requirements included in the questionnaire, two were found to be significantly related with project safety performances: "the contractor was required to place at least one full-time safety representative on site", and "the contractor was required to submit the résumés of key safety personnel for the owner's approval"(see Table 4). Three additional requirements (minimum training, site specific safety plan, safety policy of the firm) were found that were not significantly associated with the project safety performance, but considerable differences existed between the TRIRs (see Figure 3).

Table 4 The relationship between TRIR and contractual safety requirements

Contractual safety requirements		Counts	Median	Significance level*
The contractor was required to place at least one full-time safety representative on site	No	10	1.87	0.08
	Yes	49	1.3	
	Total	59	1.48	
The contractor was required to submit the résumés of key safety personnel for the owner's approval	No	17	2.81	<0.01
	Yes	42	1.2	
	Total	59	1.48	

*: One-tail level of significance by the Mann-Whitney U test

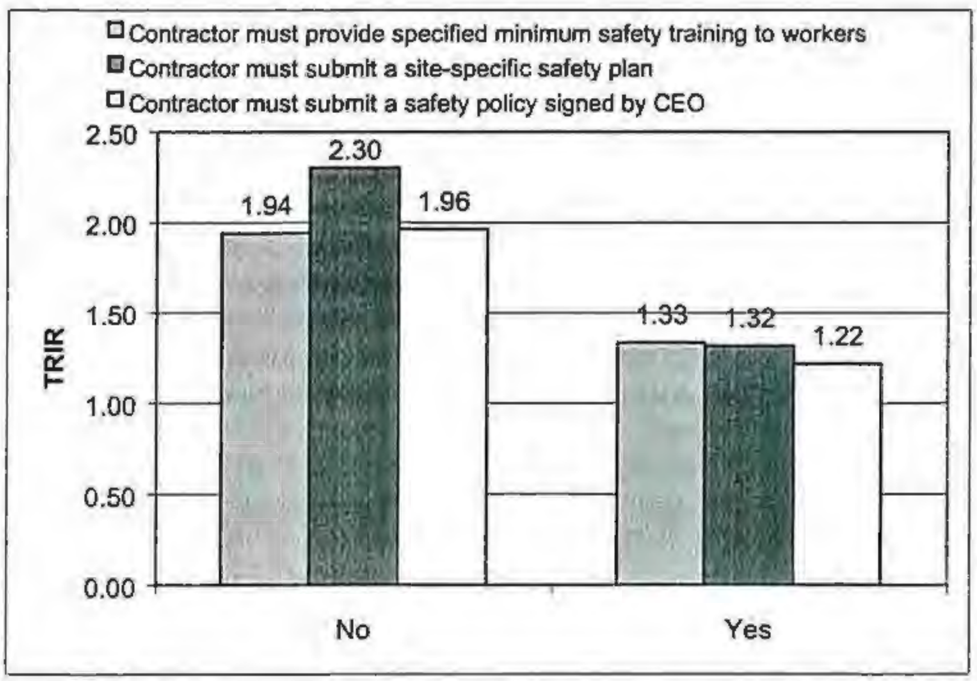

Figure 3 Other contractual safety requirements associated with TRIR (not statistically significant)

The owner's involvement in safety management

In addition to promoting project safety performance through the careful selection of contractors and the inclusion of carefully selected safety provisions in the contract, owners can be active participants in safety management during project execution. Several questions were asked about specific practices of owners that were expected to favorably influence safety performances of projects. These practices included owner participation in safety recognition programs, monitoring of safety performance, funding safety initiatives, accident reporting, accident investigations, safety training and orientation programs, and so on. Table 5 presents those owner practices that showed a positive influence on safety performances.

Table 5 The relationship between TRIR and the owner's requirements in contractor's project safety program

Owner's requirements in safety program	Categories	Counts	Median	Significance level*
(a) Does the owner require an emergency plan to be included in the contractor's safety program?	No	8	2.59	0.04
	Yes	49	1.22	
	Total	57	**1.43**	
(b) Does the owner require daily JSAs to be included in the contractor's safety program?	No	9	2.18	0.06
	Yes	48	1.21	
	Total	57	**1.43**	
(c) Does the owner require a substance abuse program to be included in the contractor's safety program?	No	4	3.25	0.02
	Yes	53	1.30	
	Total	57	**1.43**	

*: One-tail level of significance by the Mann-Whitney U test

Generally, owners impose requirements on the contents that contractor must include in their project safety programs. The inclusion of the following safety program elements was associated with better project safety performances (see Tables 5 (a) to (c)):

- Emergency plans (medical and hazardous materials)
- Daily JSA (job safety analysis) conducted on the project site
- A substance abuse program must be implemented

Generally, near misses are defined as unplanned events that might potentially cause human injury or property damage. Although different owners may have different definitions for near misses, many proactive owners require contractors to report near misses to them, and the owners then participate in investigating the near misses. They regard near misses as valuable, but inexpensive warnings of unsafe trends on site. Table 6(a) shows that better safety performances were achieved on projects where owners' safety representatives monitored near misses. Also, if the number of near misses recorded on the project exceeds the number of OSHA recordable injuries on the project, better safety performances were realized (see Table 6(b)).

Table 6 The relationship between TRIR and the owner's participation in project safety management

Owner's participation in safety management	Categories	Counts	Median	Significance level
(a) Does the owner's representative monitor near misses on the project?	No	11	2.18	0.06*
	Yes	47	1.22	
	Total	58	1.46	
(b) Comparison of OSHA recordable injuries and near misses recorded on the project	More recordables	26	2.43	<0.01*
	More near misses	33	0.84	
	Total	59	1.48	
(c) Does the owner maintain injury statistics by contractor?	No	26	2.13	0.03*
	Yes	33	1.19	
	Total	59	1.48	
(d) Are the contractor's safety performance statistics included in the owner's safety performance statistics?	No	22	1.88	0.03*
	Yes	37	1.19	
	Total	59	1.48	
(e) Are some funds provided to the contractor, above and beyond the contract amount, to promote project safety?	No	24	2.28	0.01*
	Yes	35	1.20	
	Total	59	1.48	
(f) The owner participates in the safety recognition program	No	12	2.92	<0.01*
	Yes	44	1.15	
	Total	56	1.46	
(g) Safety training methods used on the project	Contractor only	11	1.69	0.06**
	Owner only	17	2.18	
	Both	29	0.84	
	Total	57	1.48	
(h) Hours of monthly refresher safety training received by the workers	None	11	2.73	0.07**
	1 to 3 hours	34	1.64	
	>=4 hours	14	1.18	
	Total	59	1.48	
(i) Is there any means of verifying the comprehension of safety orientation?	No	11	2.53	<0.01*
	Yes	48	1.20	
	Total	59	1.48	
(j) The owner participates in safety meetings and toolbox meetings	No	10	2.26	0.01*
	Yes	46	1.19	
	Total	56	1.46	
(k) The owner's representative monitors project safety inspection records on a regular basis	No	11	1.69	0.01*
	Yes	47	1.20	
	Total	58	1.46	
(l) The owner's representative monitors the project near miss rate on a regular basis	No	11	2.18	0.06*
	Yes	47	1.22	
	Total	58	1.46	
(m) Is zero TRIR set as a safety objective by the owner before project commencement?	No	40	1.64	0.10*
	Yes	19	1.43	
	Total	59	1.48	

*: One-tail level of significance by the Mann-Whitney U test

**: Two-tail level of significance by the Kruskal-Wallis test

Projects where owners tracked the individual safety performances of each contractor on site had significantly better safety performances than projects where this was not done (see Table 6(c)). Evaluating the safety performance of each contractor can help in selecting safe contractors on future projects and this can also help the owner to identify any weaknesses in the current safety programs being implemented by each contractor. Additionally, it was found that if the owners incorporated the safety statistics of the contractors into their own safety performance statistics, the projects achieved better safety performances (see Table 6(d)). By including the safety records of the contractors in their own safety statistics, the owners essentially adopt the philosophy that any injuries on the project are a negative reflection on their own safety performances. Ideologically, the owner actually regards the contractor's employees as its own employees, and recognizes the value of protecting and caring for them.

Positive reinforcement is one mechanism by which individuals are encouraged to repeat certain types of behavior. One such approach in the area of safety is to implement a safety recognition program that recognizes and rewards workers who have exhibited good safety behavior. Analysis of the data shows that when the owner provided some funds above and beyond the contract amount to promote safety, projects were more likely to achieve better safety performances (see Table 6(e)). When the owner participated in the safety recognition programs, the safety performances were also better (see Table 6(f)). These results demonstrate the positive influence owners have on project safety performances.

Orientation of workers is essential to provide workers with necessary knowledge for them to work safely. Table 6(g) shows that when both the owner and the contractor were involved in the safety training, projects reported better safety performances. Also, more hours (four or more) of monthly refresher safety training for workers can improve project safety performances (see Table 6(h)). When the owner had a means to verify the comprehension of the safety orientation training received by workers, the safety performances were significantly better (see Table 6(i)). Generally, the owner will require a test or exam after the safety orientation session to verify the comprehension of the training.

The owner's site safety representative may have various responsibilities to fulfill. The study found that if the owner's safety representative participated in the safety meetings and tool-box meetings, the projects achieved better safety performances (see Table 6(j)). Another consideration relates to how the owner's safety representative monitors project safety performance. Nearly all the owner's representatives monitored project safety performance by monitoring the incident rates on the projects, including the lost workday case injury rate, TRIR, and first aid injury rate. It was noted that monitoring safety inspection records was associated with significantly better safety performances (see Table 6(k)). Also, when the owner's safety representative monitored the project near miss rate on a regular basis, the projects achieved better safety performances (see Table 6(l)).

Regarding the owner's expectations about safety performance, the results show that owners that established specific safety expectations reported better safety performances on their projects, especially those owners who set zero OSHA recordable injuries as their safety objective before project commencement (see Table 6(m)). One owner commented "One can achieve the level of safety as he demonstrates to expect."

ANSWERS TO OPEN-ENDED QUESTIONS

In the study, some open-ended questions were asked. One question asked about the most important way for the owner to improve project safety performance. This question was not formally included in the questionnaire, but was asked as a concluding question. Although the answers varied considerably, the following points were frequently made.

- Owner's management commitment: Both site management and home office personnel of the owner should have a clear understanding of the value of safety. Safety is no longer regarded as a priority only, instead, it should be integrated into the owner's values, always being placed first. Management should have a common view that zero-injuries can and should be the safety objective.
- Safety observation program: The philosophy is to address the front end of the accident chain and remind everyone on the project about safety. Techniques can include training and encouraging everyone to report unsafe acts, hazards on site, and near misses. This is followed by tracking the records and intervening when necessary to avoid unsafe acts.
- Personal accountability: Safety responsibilities of each site person, whether employed by the owner or the contractor, should be clearly defined and closely related to the overall personal performance evaluations.
- Safety communication: Owners should set their expectations on safety from the very beginning and reinforce their emphasis on safety through continual efforts. Safety communication conveys safety experience and knowledge to the contractor. This can be done by discussing safety issues at the beginning of each meeting and by providing firm and physical support of the safety efforts on sites.
- Implementation of the safety program: The safety program should be carefully developed, evaluated and modified in response to the changes on the project. Once defined, the safety program should be implemented firmly and consistently, and there should be no differences in the implementation for the employees of the owner, contractor or subcontractors.
- Physical walk-out and inspection: Owner personnel should not focus solely on the safety statistics reported by the contractors. They should "walk the talk", and be visible on the site to monitor the contractor's safety performance and show their support of the contractor's safety efforts.
- Safety/constructability review of the design: Proactive owners start tbeir safety efforts as early as the design phase, and it is an essential part of the total loss control program of many owners.
- Safety culture: Caring for human life and health, caring for colleagues, and recognizing safe acts should be the philosophy commonly held on the project. The

safety culture can be cultivated only through close cooperation of the owner and contractor, based on the values they share on safety.

SAFETY PERFORMANCE MODEL: HOW TO ACHIEVE BETTER SAFETY PERFORMANCE

Based on the data analysis, a project scorecard was developed to evaluate the safety performance of a project. Any owner can use the scorecard to evaluate the possibility of its project achieving good safety performance by referring to the scores obtained in the card. Also, the sub-score obtained in the different sections of the scorecard can help the owner identify which areas can be improved to achieve better safety performance. The scorecard is shown in Figure 4. Note that the scorecard is valid only after the following practices are already implemented on the projects: the owner requires the primary contractor to report OSHA recordable injuries; the owner assigns at least one safety representative to the project with high authority and responsibilities clearly defined; the owner's site safety representative monitors the contractor's safety performance regularly; the owner places a priority on safety when selecting contractors, and maintains an approved contractor list for awarding the contract; the owner specifies basic safety requirements in the contract document; the owner requires basic components to be included in contractor's safety program; and the owner addresses safety in the design phase.

The highest possible score of the scorecard is 100 percent. The scores of the projects in the study ranged from 40% to 92%. If the seven projects implementing at least 88% of the practices listed in the scorecard are compared with the eight projects that implemented less than 52% of the practices, the TRIRs are significantly different (refer to Table 7). The Spearman's correlation of the TRIR and the score generated on the scorecard for the 59 projects is 0.60, significant at the 0.001 level. This shows that the results of the scorecard are negatively correlated with TRIR, and the scorecard is a reliable instrument that can be used to evaluate the owner's impact on safety performance.

Table 7 The safety performances of projects with highest and lowest scores

Score	N	Mean	Std. Deviation	Median	ANOVA Sign. (1-tail)	Mann-Whitney Sign. (1-tail)
<=13 (52%)	8	4.64	2.90	2.92		
>=22 (88%)	7	0.53	0.34	0.50	<0.01	<0.01
Total	15	2.72	2.96	1.62		

Owner's Influence on Construction Safety Scorecard

Project Context, Contractor Selection, Contractual Safety Requirements and Owner Involvement in Project Safety	Answer	
Project context:		
(1) Does the project work one shift?	☐ Y	☐ N
(2) Does the project work five days a week or less?	☐ Y	☐ N
Selection of contractor		
(3) Is the TRIR requirement for the contractor selection less than 2.0?	☐ Y	☐ N
(4) Are the qualifications of the project team reviewed?	☐ Y	☐ N
(5) Are the qualifications of the safety staff reviewed?	☐ Y	☐ N
(6) Does the evaluation of each contractor's safety performance make a difference in awarding the contract?	☐ Y	☐ N
Contractual safety requirements		
(7) Does the project use a design-build contract?	☐ Y	☐ N
(8) Does the contract require the contractor to place at least one full-time safety representative on the project site?	☐ Y	☐ N
(9) Does the contract require the contractor to submit all safety personnel résumés for the owner's approval?	☐ Y	☐ N
(10) Does the contract require the contractor to prepare a site-specific safety plan?	☐ Y	☐ N
(11) Does the contract require the contractor to submit a safety policy signed by its CEO?	☐ Y	☐ N
(12) Does the contract require the contractor to provide a minimum specified amount of training to the construction workers?	☐ Y	☐ N
Contractor Safety Program Requirements		
Which of the following are required to be included in the contractor's safety program?		
(13) Contractor must prepare a plan for site emergencies	☐ Y	☐ N
(14) Contractor must conduct pre-task safety planning on the project site	☐ Y	☐ N
(15) Contractor must implement a substance abuse testing program	☐ Y	☐ N
Owner's involvement in project safety management		
(16) Does the owner's safety representative investigate near misses?	☐ Y	☐ N
(17) Are injury statistics on the projects maintained separately on each contractor?	☐ Y	☐ N
(18) Are all project injuries included in the owner's overall measure of safety performance?	☐ Y	☐ N
(19) The owner actively participates (gives presentations) during worker safety orientation?	☐ Y	☐ N
(20) Comprehension of safety training is evaluated through testing?	☐ Y	☐ N
Which of the following activities are performed by the owner's site safety representative?		
(21) Enforcing safety rules and regulations	☐ Y	☐ N
(22) Monitoring of the implementation of pre-task planning	☐ Y	☐ N
(23) Participating in safety recognition programs	☐ Y	☐ N
(24) Participating in safety and/or tool box meetings	☐ Y	☐ N
(25) Does the owner set zero injuries as its safety expectation before the commencement of site work?	☐ Y	☐ N

Total Count of Yes Responses		
Multiply the Yes Count by 4	(X 4)	%

What the score means:

88% or better is strong owner involvement
52% or less indicates weak owner involvement

Figure 4 Owner's influence on construction safety scorecard

Conclusions

This study was focused on identifying the owner's role in construction safety, which was demonstrated through the project context, the selection of safe contractors, the inclusion of safety requirements in the contract, and the owner's active participation in safety during project execution. Through analysis of the project interview data, it can be concluded that owners can positively influence project safety performances. Several practices of owners that were associated with better safety performances were identified.

Unlike twenty years ago, owners of large projects are more actively participating in construction safety management in each stage of project execution, including project design, contractor selection, the development of contract documents, and the construction phase. They are making efforts to improve the project safety performance, with a focus on setting their expectation on zero injuries, selecting safe contractors, and developing the safety culture on their projects (through safety training and safety recognition programs, for example). Their efforts have paid off by the decrease in injuries on their projects. This may explain, in part, why the injury rates decreased dramatically in the past decade (see Figure 1).

The study also found that petro-chemical owners are among the most proactive owners in construction safety. This may be due to the traditional concern for safety in the chemical industry. Many petro-chemical owners stated that the safety attitudes in their major line of business impact their philosophy on construction safety. Safety is necessitated by the considerable hazards existing in the petrochemical industry. These reasons may help explain why the safety performances of petro-chemical projects are better than other types of projects.

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SECTION VIII

Scalable Database and Web-Based Dissemination of Important Health and Safety Information to Construction Safety Professionals

Principal Investigator

Daniel W. Halpin, Rick Hornung, Mark Carrozza

Graduate Students

Shih-Yi Wang, Chung-I Yen

TABLE OF CONTENTS

SCALABLE DATABASE AND WEB-BASED DISSEMINATION OF IMPORTANT HEALTH AND SAFETY INFORMATION TO CONSTRUCTION SAFETY PROFESSIONALS

Research Team: PI – Dr. Daniel W. Halpin; Dr. Rick Hornung, Dr. Mark Carrozza; Graduate Students: Shih-Yi Wang, Chung-I Yen

ABSTRACT

Occupational fatality, injury and illness data for the construction industry currently exists in many national, regional, and state data systems. The Bureau of Labor Statistics annually reports on the number of workplace injuries, illnesses, and fatalities. The National Center for Health Statistics' (NCHS) National Health Interview Survey (NHIS) produces accident and injury data based on an annual nationwide survey. More detailed safety and health data at the individual worker level are collected and maintained by labor unions, individual construction companies, and trade associations.

A single, scalable database was designed and developed that is capable of housing occupational fatality, injury and illness data that are specific to the construction industry and are collected from disparate sources. The database was developed using Microsoft SQL Server, Version 7.0 and can grow efficiently and economically as new data are collected. It can maintain both summary level data (e.g. BLS data) as well as individual worker-level data collected by labor unions, individual construction companies, and trade associations.

A limited web-based application was also developed that allows access to the data over the Internet. This custom application, developed using the Internet "middleware" software ColdFusion, takes the user's selection criteria and builds a query using standard SQL (Structured Query Language) statements. The SQL is then used to query the underlying SQL database and returns the results to the users' web browser.

The Construction Safety Alliance (CSA) Website was developed in conjunction with the safety database to provide a portal to access data through the Internet. In addition, the website contains pertinent summaries of research from partners in the Construction Safety Alliance and other practical, up-to-date safety and health information.

SIGNIFICANT FINDINGS

Data on occupational fatalities, injuries, and illnesses in the construction industry currently exist in many national, regional, and state data systems, which makes the access to safety data for researchers and safety professionals a frustrating chore. Hence, there is a need to develop a centralized database that provides single access point to all safety data. In addition, the Construction Safety Alliance partners also need a database that can store the new data collected from the research to facilitate data analysis and research collaboration. Therefore, a scalable database possessing the following features is developed.

- The database is designed to grow with the needs of research program and availability of new data.

- The database provides a comprehensive source for access to many different construction safety research and surveillance data sets.

- The database enhances user ability to query the database for specific items related to construction safety.

- The database creates new research opportunities by making the latest data sources available to researchers and policy makers.

The database currently houses occupational fatality, and injury and illness data for the construction industry collected from three publicly available data sources: the Bureau of Labor Statistic's (BLS) Injuries, Illnesses and Fatalities website, the BLS Census of Fatal Occupational Injuries (CFOI) website, and the National Center for Health Statistics' (NCHS) National Health Interview Survey (NHIS) website.

The Construction Safety Alliance Website was developed to serve as a portal for safety professionals and researchers to access up-to-date safety information. The information on the website can be accessed at two levels.

- The first level includes only CSA access for sharing data and information resources associated with ongoing research and surveillance projects. This access is password-protected for CSA members and their designated collaborators. Because CSA consists of researchers from different geographical locations, communication and collaboration through the website has proven to be very effective.

- The second level is for general use for accessing all information, published data, and resources as CSA makes it available. This level requires no password and will be advertised in trade journals and other construction-related publications.

USEFULNESS OF FINDINGS

The data collected by government agencies such as the Bureau of Labor Statistics do not specifically pertain to the construction industry. The CSA database removes safety data in other industries and provides data that are more of interest to construction safety professionals and researchers.

The interviews with 16 safety directors of small to medium size mid-western construction companies showed the safety data available at government agencies such as the Bureau of Labor Statistics, while useful in providing a general assessment of industry-wide safety-related statistics, are not helpful from the perspective of benchmarking and self-improvement. A database that contains results from more specific surveys such as fall prevention or safer trenching practices is more pertinent to their interests.

The CSA website contains information of Construction Safety Alliances projects and other information related to construction safety. In addition to providing Internet access to the database, the website was also designed to make up-to-date safety research and products available to safety professionals and researchers. Most CSA partners' publications are available at the website. There are also fact sheets regarding new safety products and ongoing safety research. According to the past experience of developing Emerging Construction Technology website (http://www.new-technologies.org/ECT/), the construction practitioners are especially interested in information on new products and technologies and the fact sheets of new safety products will be useful to them.

To increase the usefulness of the website, regular updates on the fact sheets of safety research and products are required. To become a single access point to all construction safety data, the website will need to provide a complete list of links to other relevant websites and searchable web-based safety regulations. An online forum can be designed to allow safety professionals to exchange their ideas and experiences in construction safety practices.

SCIENTIFIC REPORT

Background for the Project

Results and recommendations from construction safety research and surveillance projects are of little use to the construction industry unless they reach audiences who most desire and need this information. Those audiences include other researchers working in the area of construction safety and ultimately of course, construction managers as well as the individual workers.

Construction safety and health researchers may not always be familiar with the vast sources of data that already exist to help them advance their research or what new areas of research are needed by the industry. Members of this target audience would benefit greatly by having access to one website that could supply them with this needed information.

For construction workers employed by large companies, research findings may be put into action through information dissemination and intervention strategies designed and implemented by safety and health professionals employed by the company. However, many small or medium sized construction companies are not able to hire safety and health professionals. Programs and sources of information on ways to reduce injuries and fatalities may not be as easily accessible to them.

The CSA members believe there is a need for a user-friendly web site that provides practical, useful information in laymen's terms that can be put into practice by safety professionals as well as construction management and individual construction workers. In addition to providing a means of communication on the latest research findings and other information useful to the construction community, the web site serves as a gateway to a master scalable relational database system.

Specific objectives and results

Objective No.1

Due to the lack of a centralized data repository, safety data collected regularly by government agencies at various levels are scattered at different locations. To allow safety professionals and researchers to access these data more easily and to promote research opportunities, a scalable database that can accommodate existing data and data collected from future research is necessary. This database will be advertised through CII and other members of the Construction Safety Alliance.

Results:

A relational database housing the occupational fatality, injury and illness has been implemented. The data are collected from three publicly available data sources: the Bureau of Labor Statistic's (BLS) Injuries, Illnesses and Fatalities website, the BLS Census of Fatal Occupational Injuries (CFOI) website, and the National Center for Health Statistics' (NCHS) National Health Interview Survey (NHIS) website.

The Bureau of Labor Statistics annually reports on the number of workplace injuries, illnesses, and fatalities. Since 1972, the survey has reported annually on the number of workplace injuries and illnesses in private industry and the frequency of those incidents. With the 1992 survey, BLS began collecting additional information on the more seriously injured or ill workers in the form of worker and case characteristics. Industry and illness data in the construction industry for the years 1989 – 2000 were downloaded from BLS. Table 1 lists the specific construction industry codes represented in the BLS data.

The BLS CFOI produces comprehensive, accurate, and timely counts of fatal work injuries. CFOI is a Federal-State cooperative program that has been implemented in all 50 States and the District of Columbia since 1992. To compile counts that are as complete as possible, the census uses multiple sources to identify, verify, and profile fatal worker injuries. Information about each workplace fatality--occupation and other worker characteristics, equipment involved, and circumstances of the event--is obtained by cross referencing the source records, such as death certificates, workers' compensation reports, and Federal and State agency administrative reports. To ensure that fatalities are work-related, cases are substantiated with two or more independent source documents, or a source document and a follow-up questionnaire.

Table 1. Industry Codes Represented in the BLS Injury, Illness and Fatalities Data

Industry Code	Description
1500	General Building Contractors
1520	Residential Building Construction
1530	Operative Builders
1540	Nonresidential Building Construction
1600	Heavy Construction, Except Building
1610	Highway and Street Construction
1620	Heavy Construction, Except Highway
1700	Special Trade Contractors
1710	Plumbing, Heating, and Air-Conditioning
1720	Painting and Paper Hanging
1730	Electrical Work
1740	Masonry, Stonework, Tile Setting, and Plastering
1750	Carpentry and Floor Work
1760	Roofing, Siding, and Sheet Metal Work
1770	Concrete Work
1780	Water Well Drilling
1790	Miscellaneous Special Trade Contractors

Fatality data in the construction industry for the years 1992 – 2000 were downloaded from BLS. Table 1 lists the specific construction industry codes represented in the BLS data. For each industry code, the data is summarized for the following events or exposures: (1) Falls, (2) Contact with Objects, (3) Fires/Explosions, (4) Transportation Incidents; and (5) Exposure to Harmful Substances. In addition to total and percent of fatalities provided by BLS, the number per 100,000 constructions workers is also estimated.

The National Health Interview Survey is a multi-purpose health survey conducted by the National Center for Health Statistics (NCHS), Centers for Disease Control and Prevention (CDC), and is the principal source of information on the health of the civilian, non-institutionalized, household population of the United States. The NHIS has been conducted continuously since its beginning in 1957. Data are released on an annual basis. The Family Core portion of the 1997-2000 surveys included questions about medically attended injuries and poisoning episodes that occurred to any member of the family within a three-month reference period. This information combined with other demographic information from the survey was used to generate annual injury and poisoning estimates in the construction industry.

The Family Core portion of the 1997-2000 NHIS surveys included questions about medically attended injuries and poisoning episodes that occurred to any member of the family within a three-month reference period. This information combined with other demographic information from the survey was used to generate annual injury and poisoning estimates in the construction industry (SIC 15, 16, 17 combined). Total injuries, percent, and number per 100,000 workers were estimated from these survey data. Table 2 lists the occupational categories and Table 3 lists the possible causes of injury used in the NHIS survey.

Table 2. NHIS Occupational Categories

Occupation Description
Mechanics and Repairers
Construction and Extractive Trades
Machine Operators and Tenderers, Except Precision
Motor Vehicle Operators
Material Moving Equipment
Construction Laborers

Table 3. NHIS Injury Categories

Cause Description
Transportation
Fire/burn/scald related
Fall
Poisoning
Overexertion/strenuous movements
Struck by object or person
Cut/pierce
Machinery

Objective No.2

To develop a web-based user-friendly query interface to allow users to retrieve data in the scalable database easily.

Results:

A limited web-based application was also developed that allows access to the data over the Internet. The custom application, developed using the Internet "middleware" software ColdFusion, takes the user's selection criteria and builds a query using standard SQL statements. The SQL is then used to query the underlying SQL database and returns the results the users' web browser.

Figure 1 shows the web-based interface to query the BLS Injury and Illness data contained in the database. The BLS Injuries and Illnesses data can be queried in a number of different ways. Users can specify one or more case types (e.g., total recordable cases) and incidence rates. Statistics can be generated for specific years or over all years of available data. Users can also select to have results generated for one or more specific industry codes.

Similar interfaces were developed for the BLS Census of Fatal Occupational Injuries data and NCHS National Health Interview Survey data.

Figure 1. Web-based Interface to CSA Database

<u>Objective No.3</u>

To develop a website that contains latest information on safety products and safety research to construction industry. The website also provides web-based query interface to allow easy access to the scalable database.

<u>Results</u>

The Construction Safety Alliance Website (http://www.construction-safety.org) was developed to provide practical, up-to-date safety and health information to construction companies, health departments, safety professionals, and construction workers. The Website currently contains the following information:

- Pertinent summaries of research from partners in the Construction Safety Alliance.
- Latest technologies and research related to construction safety and health.
- Web access interface to the scalable database.

- Links to other relevant resources, such as those maintained by NIOSH, OSHA, and Construction Industry Institute.

Methodology

A relational database system is designed to store the safety and health related information. With Relational Database Management System (RDMS), users can access/query the database through Structured Query Language (SQL). Therefore, the database can be stored or transferred to any database system that supports SQL. The current CSA database is developed using Microsoft SQL Server, Version 7.0. SQL Server provides a powerful and comprehensive data management platform that produces highly reliable, secure and scalable databases capable of maintaining large amounts of data, even when the data come from disparate sources.

The database contains a series of normalized data tables. Separate primary data tables were developed for each source of injury, illness, and fatality data. The database also contains a number of individual lookup tables that define individual codes used in the primary data tables. Figure 2 shows the table definition for the data of BLS fatal events.

C:\Documents and Settings\freyberw\Desktop\csa.mdb — Thursday, July 31, 2003
Table: BLS_Fatal_ByEvent — Page: 2

Properties

Date Created:	7/19/2002 11:28:20 AM	GUID:	Long binary data
Last Updated:	7/31/2003 2:53:13 PM	NameMap:	Long binary data
OrderByOn:	False	Orientation:	0
RecordCount:	541	Updatable:	True

Columns

Name	Type	Size
industry_code	Text	4
year	Text	4
category	Text	4
percent	Double	8
n_category	Double	8
number_100000	Double	8

Figure 2. Table definition of BLS fatal events

To establish a web access interface between end users and the relational database system, the ColdFusion Web application development system from Macromedia was utilized. ColdFusion is a complete Web application server for developing and delivering scaleable database applications. It provides a visual development tool as well as an innovative tag-based programming environment for rapid web applications developing. It also provides an open integration with RDMS and support most open standards such as directories, J2EE, .NET, XML, SOAP. With this system, the web interface can easily extend its functionality in the future to sever the need of the end users.

The CSA website is built on top of the Zope Web Application Server. Zope is an open source web application server primarily written in the Python programming lanuage. Zope features a transactional object database, which can store not only custom data, but also dynamic HTML templates, scripts, a build-in search engine, and relational database connections. Zope also features a strong content management ability through web browsers, allowing users to update and maintain the web site from anywhere in the world. To allow for this, Zope also features a tightly integrated security model, which can authorize different access privileges based on user login name for each individual object.

In the future, CSA website will provide different access levels with public access area and member restricted area. Hosting the CSA website on a Zope server can easily achieve this goal. The anywhere accessible web-based management interface also provides the flexibility to CSA members for managing the website.

Results and Conclusions

The scalable database, web-based query interface, and the CSA website are at testing stage. The database currently houses datasets from the Bureau of Labor Statistics and the National Center for Health Statistics. The web-query interface has been developed but not made available to the public yet. Despite the different structures of these datasets, the initial test result shows the database is flexible enough to accommodate these data and the users can retrieve information from different datasets through the very same interface. As the database is expanded to an improved level of functionality, the web-based query interface will be provided at the CSA website.

The feedback from the safety directors of 16 small to medium construction companies shows the need for developing surveys that collect surveillance data and practices from specific construction processes or construction methods. Existing data collected by government agencies can only provide a rough picture of the current safety situation in construction industry and how it is compared to other industries. Only surveillance data at process level can be used for benchmarking and developing strategies to improve jobsite safety.

The future plans for developing the scalable database are as follows:

1. Integrating more existing safety data in the public domain. Many safety data collected by government agencies have Internet access. In addition, there are

also data that have been collected but not yet made available to the public. The scalable database can include these data for data mining potential.

2. Developing surveys that collect surveillance data and safety practices at construction processes level. The interview with safety directors shows there is a need to develop safety surveys for benchmarking and developing strategies to improve safety in construction. The existing falls prevention and trenching safety surveys conducted by CSA partners provide a very good starting point. After data have been collected and analyzed, a short report summarizing the statistics and findings of the survey can be posted on the CSA website as a feedback to the safety professionals.

The CSA website can be accessed from the Internet and it contains CSA research findings and information on the latest safety products and safety research. The website currently serves as document repository and communication portal for CSA partners. The future plans for developing the website are the following:

1. Regularly updating fact sheets of safety products and research. One of the objectives of the CSA website is to provide the latest safety information to the construction industry. Experience from developing the Emerging Construction Technology (ECT) website shows new product information is the most used feature of the website.

2. Providing comprehensive links to various safety websites and safety-related regulations. Many safety professionals and researchers are not aware of the abundance of safety information available on the Internet.

3. Conducting web-based surveys. Experiences show safety professionals, while willing to participate in the surveys, are often wary of releasing background information for their projects or companies. Web-based survey can encourage participation and increase significance of survey findings due to a larger sample size. A web-based survey based on the trenching operation questionnaire has been developed for testing.

APPENDICES

APPENDIX A

2002 Annual Report from Construction Industry Institute

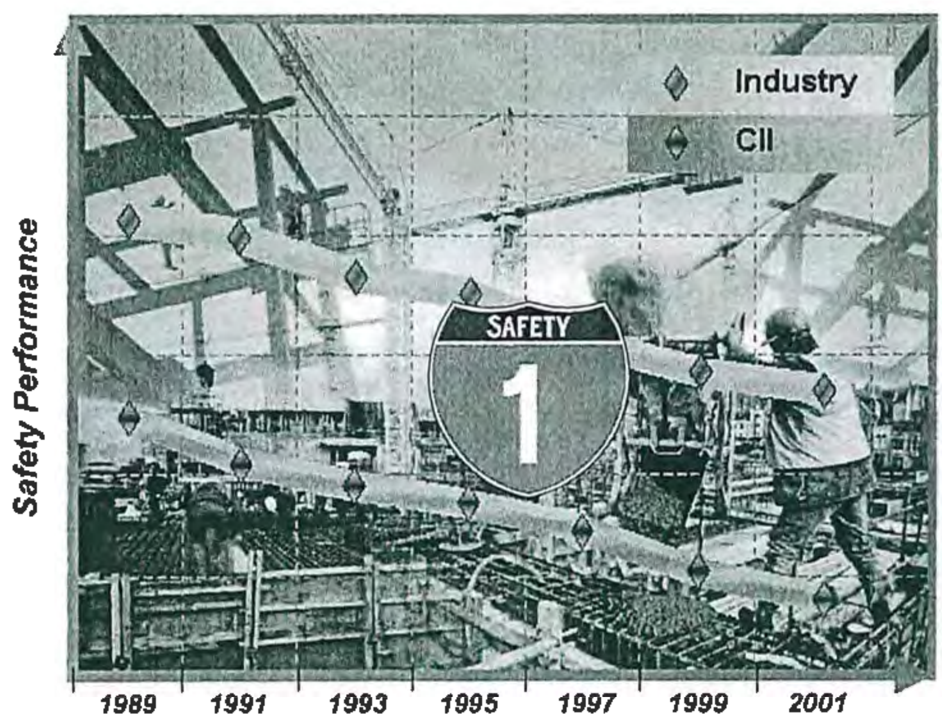
Construction Industry Institute™

Benchmarking & Metrics

3925 West Braker Lane
Austin, Texas 78795

2002 Safety Report

Stephen R. Thomas
Sang-Hoon Lee
Candace L. Macken



October 2002

CII™

Introduction

Safety is of prime importance to the owners and contractors responsible for the execution of capital facilities projects. Previous research has shown that the implementation of zero injury techniques can result in substantial increases in a company's profit margin by avoiding the expenditure of funds on the direct and indirect costs of injuries. In addition to the immediate cost of accidents through lost work time, training of replacement workers, and the administrative costs of incident investigation and documentation, future costs are sustained through increased worker's compensation premiums, also. The implementation of zero accident techniques is only the beginning of the effort to reduce the consequences, both financial and ethical, of work-related accidents, however. Monitoring company safety performance is essential to ensure that safety programs are effective.

This report summarizes the results of the 2002 Safety Survey conducted by the Construction Industry Institute™ (CII™). Safety data were provided by 54 member companies, of which 22 were owners and 32 were contractors, and represent the experience of 269 projects and over 1 billion total work hours. Both owners and contractors were asked to provide data for direct hire and contract (or subcontract) employees. Since contractor data were not uniquely identified in the owner-submitted responses, it is likely that there was some double reporting of contractor data, once by the owner for contract employees and once by the contractor for direct hires. The data were collected electronically with respondents entering their data via a Web-based interface.

As in the past, CII safety data for owners and contractors were compared to the latest illness, injury, and fatality data available from the Occupational Safety and Health Administration (OSHA), U.S. Department of Labor. Since OSHA data are published for all covered business establishments without regard to whether the employers are owners or contractors, comparisons are made for owners, contractors, and OSHA.

This year's survey also collected data on "near misses," a term often used to describe accidents that could have resulted in injuries, but did not. Interest in tracking near misses arose due to the declining accident-related incidence rates experienced by CII member companies and in the Construction industry in general. If the implementation of zero accident techniques were responsible for the declining rates, and there is no reason to assume that rates will not continue to decline, perhaps another indicator of safety performance is appropriate. While the concept of a near miss is accepted within the industry, and is even frequently referenced in OSHA documents, no standard definition for a near miss exists. Along with requesting the number of near misses on a project if near misses were tracked, owners and contractors were asked to provide their definitions so that the work to achieve consensus on a definition could begin. From the definitions provided, a consensus definition for data collection activities in the near future was arrived upon.

Summary of Aggregated Data

Table 1 presents aggregated data on recordable incidents, lost workday cases, lost workdays, fatalities, and total work hours for all projects and for both owners and contractors. Overall, the number of reported recordable incidents, lost workday cases, lost workdays, fatalities, and total work hours increased between 2000 and 2001. This was most likely due to the 17% increase in the number of companies that responded for the current year. Among owner-submitted private projects in particular, safety performance improved from the previous year with recordable incidents, lost workday cases, and lost workdays having decreased despite the fact that the total number of work hours increased. Among subcontracted projects, safety performance decreased somewhat with increases in recordable incidents and lost workday cases.

Table 1. Aggregated Safety Data, 2001

	All	Owner		Contractor	
		Public	**Private**	**Direct**	**Subcontractor**
Recordable Incidents[1]	5,721	283	736	2,901	1,801
Lost Workday Cases[1]	1,301	151	107	686	357
Lost Workdays	22,358	1,781	321	16,182	4,074
Fatalities	39	4	6	11	18
Total Work Hours	1,117,100,559	56,426,987	258,709,562	450,424,209	351,539,801

[1]See Attachment A for definitions.

Figure 1 compares the average duration of lost workday cases for public and private owners. The average duration was nearly 4 times greater for public owners than for private owners. While there are no other data collected in the safety survey that might help to shed light on the reasons for the difference, two plausible explanations are the severity of the accidents and record keeping practices. If accidents tended to be more serious in public sector projects, it would be expected that the average duration would be greater. The effects of record keeping practices are less predicable, since they might have resulted in either longer or shorter average durations depending on whether too many or too few accidents were recorded.

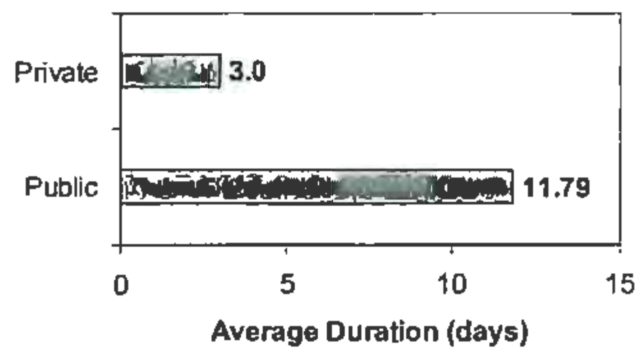


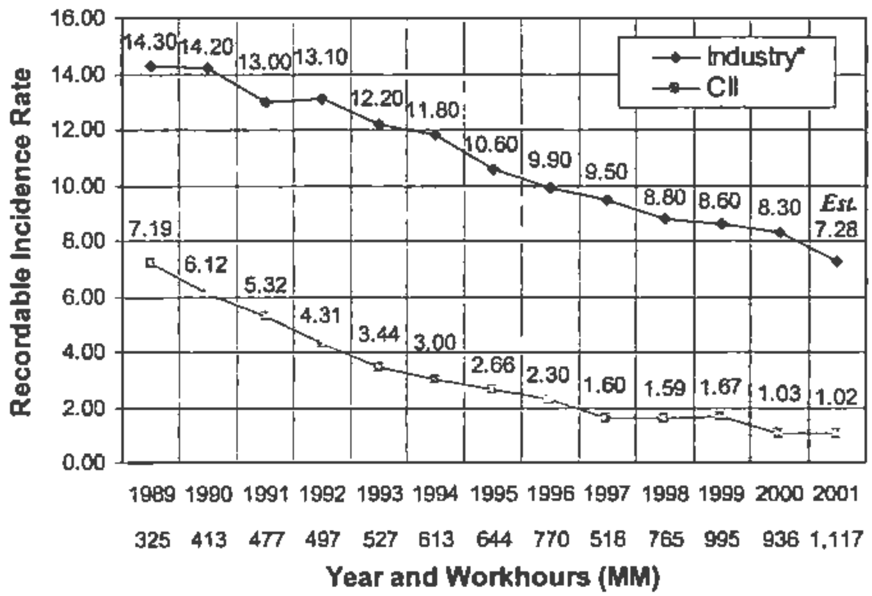
Figure 1. Average Duration of Lost Workday Cases, Public and Private Sector Projects

Table 2 provides incidence rates and percentage changes from 2000 to 2001. Overall, both the Recordable Incidence Rate (RIR) and the Lost Workday Case Incidence Rate (LWCIR) decreased from the previous year. The RIR decreased by 1% and the LWCIR decreased by 11½ %. As indicated by Table 2, owners continued to improve in safety performance, showing a 29.3% decrease in the RIR and a 38.5% decrease in the LWCIR, while contractors showed a 9.3% increase in the RIR and no change in the LWCIR from the previous period. The fatality rate increased by 2% overall, and by 4½% for owners and 1½ % for contractors. Note that the owner RIR, LWCIR and fatality rates shown here were calculated based on adjusted work-hours. This was done because the number of recordable and lost workday cases was not reported for one company, and the number of fatalities was not reported for four companies. The work hours reported by these companies were subtracted from the total number of work hours reported to more accurately reflect the rates of those companies reporting data.

Table 2. Incidence Rates and Percentage Changes, 2000 to 2001

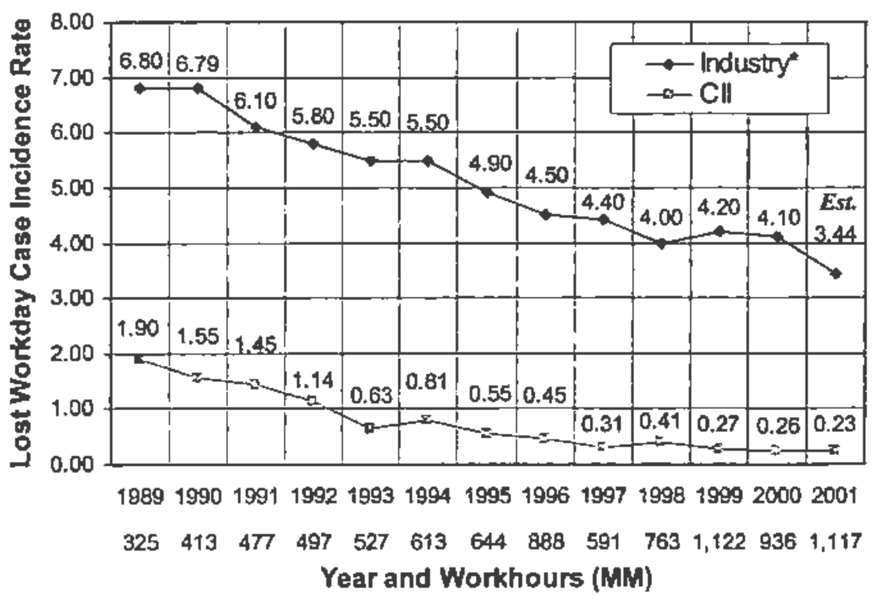
Rate	All			Owner			Contractor		
	2000	2001	Percentage Change	2000	2001	Percentage Change	2000	2001	Percentage Change
Recordable Incidence	1.03	1.02	-1.0	0.92	0.65	-29.3	1.07	1.17	9.3
Lost Workday Case Incidence	0.26	0.23	-11.5	0.26	0.16	-38.5	0.26	0.26	0.0
Fatality	6.90	7.04	2.0	6.25	6.53	4.5	7.12	7.23	1.5

Figures 2 and 3 depict thirteen years of RIR and LWCIR data taken from both the CII safety database and OSHA data. OSHA estimates of industry performance for 2001 were projected by the least squares regression technique since the data are not yet available for that year. Industry data are based on OSHA reported rates for the Construction industry division as classified in the Standard Industrial Classification (SIC) coding manual. The Construction industry division includes the following Major Groups: General Building (SIC 15), Heavy Construction except Building (SIC 16), and Special Trade Contractors (SIC 17). It should be noted that the OSHA data at this level of aggregation are not strictly comparable to the CII data because some of the industry groups included in the Construction industry division are excluded from the CII database, Residential Building Construction, for example. The reader may find the data included in Figures 4 and 5, which follow, more relevant for analysis.



**OSHA, Construction Division, SIC 15-17*

Figure 2. RIR, Aggregated Data, 1989-2001

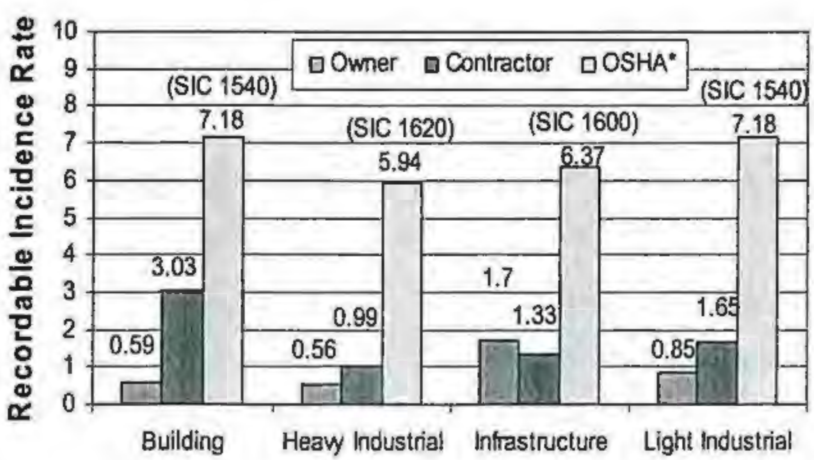


**OSHA, Construction Division, SIC 15-17*

Figure 3. LWCIR, Aggregated Data, 1989-2001

Industry Breakdowns

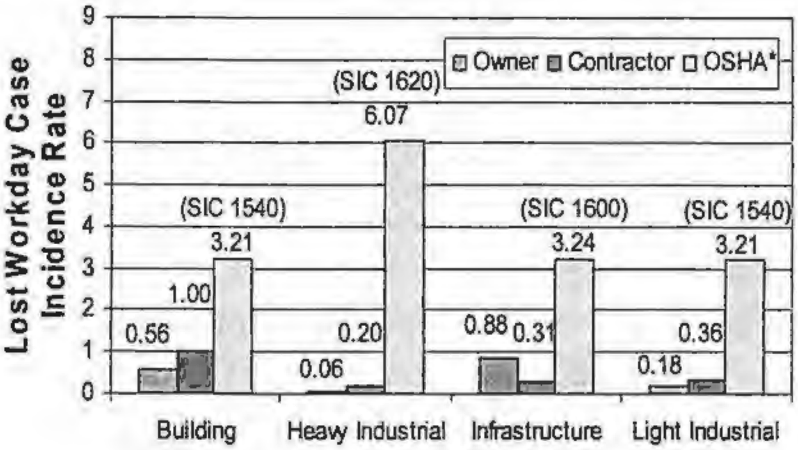
Figures 4 and 5 present comparisons of CII and OSHA RIR and LWCIR data at the industry group level. Although the data presented here may be more useful than the data presented in Figures 2 and 3, some qualifications are in order due to the different ways in which CII and OSHA categorize their data. CII reports data for four broad industry groups, Buildings, Heavy Industrial, Infrastructure, and Light Industrial. OSHA reports data by SIC only at the three-digit industry group level. Data at this level include not only projects classified in a manner similar to CII projects, but projects excluded from CII definitions, as well. For example, SIC 1600 includes heavy construction such as highways, bridges, and marine projects, but it also includes athletic field and golf course construction. More direct comparisons would be possible if OSHA data were published at the four-digit industry level. See Attachment B for a review of the SIC definitions for these industry groups. Note also that due to the small number of companies represented for many of the breakouts, conclusions regarding differences among industry groups should be drawn with caution.



		Owner	Contractor
Bldg.	# Co's	4	13
	# WH	38.13 MM	35.28 MM
HI	# Co's	14	29
	# WH	211 MM	592 MM
Infra.	# Co's	3	12
	# WH	8.45 MM	133 MM
LI	# Co's	4	6
	# WH	57.78 MM	41.73 MM

**** Estimated 2001 OSHA data***

Figure 4. Recordable Incidence Rate by Industry Group



		Owner	Contractor
Bldg.	# Co's	4	13
	# WH	38.13 MM	35.28 MM
HI	# Co's	14	29
	# WH	211 MM	592 MM
Infra.	# Co's	3	12
	# WH	8.45 MM	133 MM
LI	# Co's	4	6
	# WH	57.78 MM	41.73 MM

**** Estimated 2001 OSHA data***

Figure 5. Lost Workday Case Incidence Rate by Industry Group

With regard to safety performance by industry group, two trends are evident over the three years in which data by industry group have been collected. Among CII member companies, Heavy Industrial projects outperform projects in the three other industry groups. This may be related to project size, since larger projects tend to make greater use of zero accident techniques. Moreover, CII member company safety performance outstrips Construction industry safety performance by companies in similarly defined SIC groups.

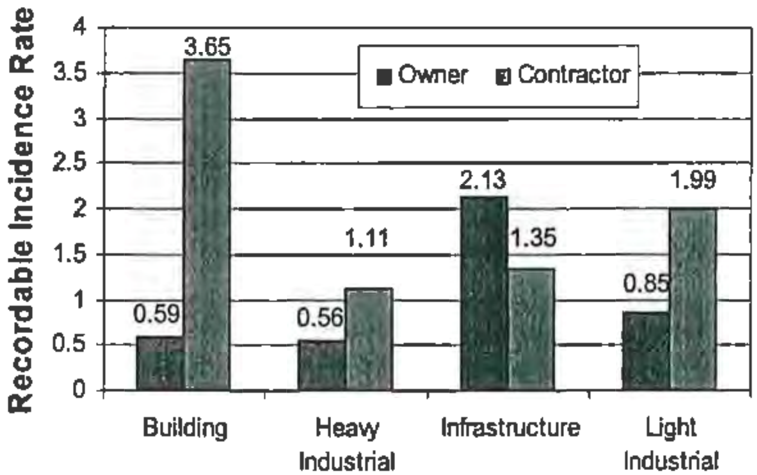
Table 3 presents more detailed safety data by industry group for owners and contractors, broken out by direct hire and contract (or subcontract in the case of contractors) employees. The data included in this table represent combined field and home office data. Among owners, direct hire employees had better safety performance than contract employees in the Building, Infrastructure, and Light Industrial industry groups. Contract employees in the Heavy Industrial group had better performance than direct hires with regard to the RIR, 0.53 vs. 0.80, and had worse LWCIR performance, 0.58 vs. 0.09. Among contractors, subcontract employee safety performance was better than direct hire safety performance in the Building and Heavy Industrial groups. In the Infrastructure group, subcontract employees had somewhat better RIR performance than direct hires and somewhat worse LWCIR performance. In the Light

Industrial group, direct hire employees had better RIR performance, 1.11 vs. 2.50, and somewhat worse LWCIR performance, 0.38 vs. 0.34. It should be noted, however, that the rates for owner companies in the Buildings, Infrastructure, and Light Industrial groups, and for contractor companies in the Light Industrial group may not be representative of rates in the entire industry due to the small number of companies that reported.

Table 3. Safety Data for Direct Hires and Contractors/Subcontractors

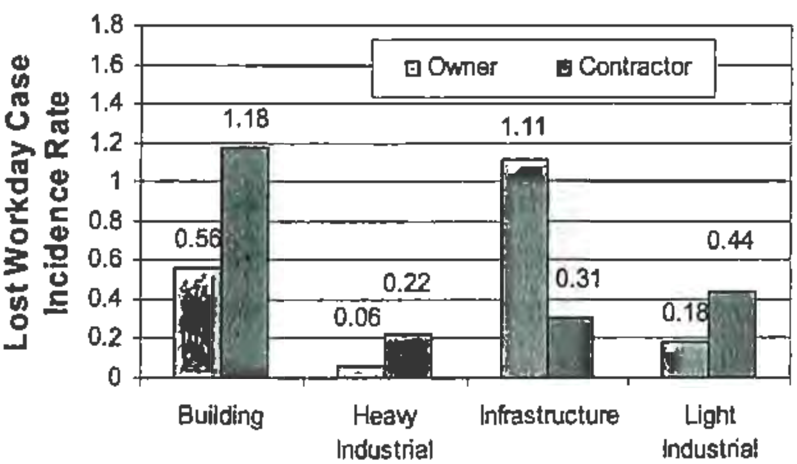
	Owner				Contractor			
	RIR		LWCIR		RIR		LWCIR	
	Direct Hire	Contract	Direct Hire	Contract	Direct Hire	Subcontract	Direct Hire	Subcontract
Building	**0.00**	**0.59**	**0.00**	**0.56**	**3.13**	**2.85**	**1.27**	**0.46**
Companies (#)	2	4	2	4	12	7	12	7
Work-hours (MM)	0.09	38.04	0.09	38.04	23.55	11.72	23.55	11.72
Heavy Industrial	**0.80**	**0.53**	**0.09**	**0.58**	**1.14**	**0.81**	**0.23**	**0.16**
Companies (#)	10	13	10	13	29	18	29	18
Work-hours (MM)	18.15	193	18.15	193	325	267	325	267
Infrastructure	**0.94**	**2.11**	**0.00**	**1.34**	**1.39**	**1.24**	**0.29**	**0.33**
Companies (#)	2	3	2	3	12	7	12	7
Work-hours (MM)	2.97	5.49	2.97	5.49	76.53	56.91	76.53	56.91
Light Industrial	**0.00**	**0.86**	**0.00**	**0.18**	**1.11**	**2.50**	**0.38**	**0.34**
Companies (#)	1	4	1	4	6	3	6	3
Work-hours (MM)	0.019	57.76	0.019	57.76	25.43	16.30	25.43	16.30

Figures 6 and 7 show rates for field data only. Home office data were removed in an effort to provide rates that were more comparable to the CII Benchmarking and Metrics program data, which also reflect field data only. Despite this, the data reported in this survey are still at variance with the project-level data contained in the Benchmarking and Metrics database. A possible reason for this may be that many, if not most, companies were unable to separate home office data. As shown here, the removal of home office data did not, in general, result in substantial changes in the two incidence rates. RIR and LWCIR rates for owners remained unchanged when home office data were removed in all industry groups except for Infrastructure. Both the RIR and the LWCIR increased for owner-submitted projects in the Infrastructure group. Among contractors, the RIR increased as expected when home office data were removed in all industry groups except Infrastructure. In that industry group, the RIR remained relatively unchanged even when home office data were removed. Conclusions regarding these data should be drawn with caution due to the small number of companies represented.



		Owner	Contractor
Bldg.	# Co's	3	13
	# WH	37.85 MM	28.75 MM
HI	# Co's	14	27
	# WH	197 MM	516 MM
Infra.	# Co's	3	12
	# WH	6.66 MM	131 MM
LI	# Co's	3	6
	# WH	57.70 MM	34.41 MM

Figure 6. RIR by Industry Group, Field Data Only

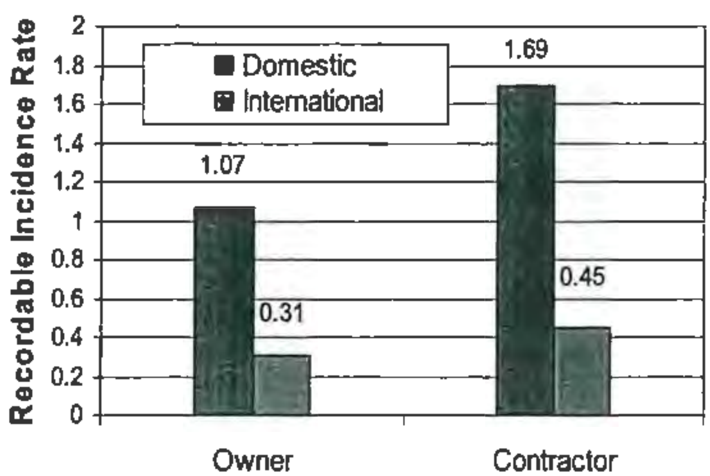


		Owner	Contractor
Bldg.	# Co's	3	13
	# WH	37.85 MM	28.75 MM
HI	# Co's	14	27
	# WH	197 MM	516 MM
Infra.	# Co's	3	12
	# WH	6.66 MM	131 MM
LI	# Co's	3	6
	# WH	57.70 MM	34.41 MM

Figure 7. LWCIR by Industry Group, Field Data Only

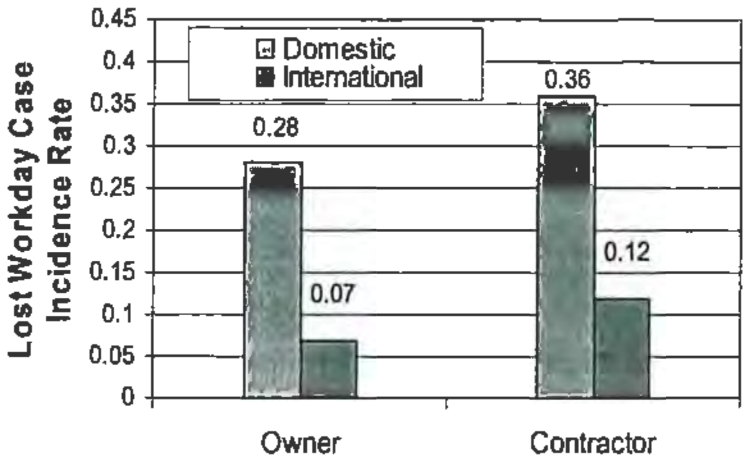
Rates for Domestic and International Data

Rates for domestic and international data are provided in Figures 8 and 9. Similar to what has been seen in the past, international projects' safety performance exceeded that of domestic projects in both safety metrics. While there are not sufficient data collected in this survey to tease out the reasons for such a difference, it may be due in part to the size differential in domestic and international projects. Based on project size data in the Benchmarking and Metrics database, international projects are larger than domestic projects. For owners, the ratio of domestic project size to international project size is 1:2.8. There is a similar size differential for contractors with a domestic to international project size ratio of 1:2.7. Previous research has shown that larger projects tend to implement zero accident techniques more often, which results in better safety performance.



		Domestic	Int.
Owner	# Co's	21	12
	# WH	139 MM	176 MM
Cont.	# Co's	32	15
	# WH	464 MM	337 MM

Figure 8. RIR by Respondent Type, Domestic and International Projects



		Domestic	Int.
Owner	# Co's	21	12
	# WH	139 MM	176 MM
Cont.	# Co's	32	15
	# WH	464 MM	337 MM

Figure 9. LWCIR by Respondent Type, Domestic and International Projects

Figure 10 compares the average duration of lost workday cases between domestic and international projects. Domestic projects had longer average durations than international projects. This was true for both owners and contractors. Several possible explanations may be offered for this. First, record keeping practices may have resulted in the under or over-reporting of accidents. With the data available it is difficult to state in which direction this might have occurred, and whether or not this affected domestic and international projects differently. Second, the accidents experienced in international projects may have been less severe, resulting in shorter average durations. Third, a limitation on the availability of worker's compensation or other insurance, or the limited provision of other benefits such as paid sick leave, may have resulted in shorter durations for international projects.

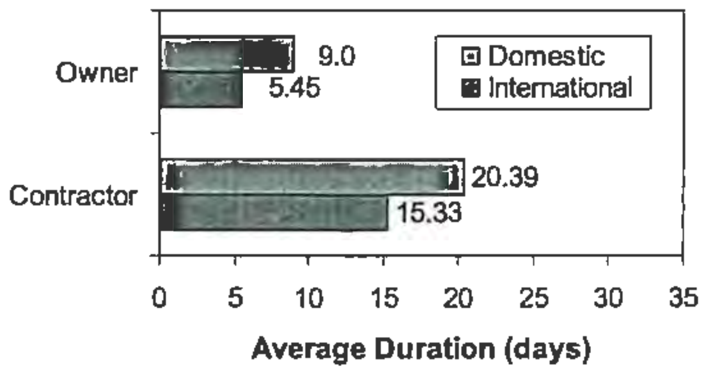


Figure 10. Average Duration of Lost Workday Cases, Domestic and International Projects

Near Misses

This year's survey collected information on whether companies tracked "near miss" accident data, how many near misses were recorded, and how they defined it. Table 4 shows some of the results for this item. Nearly 2,300 near misses were reported to have occurred during 2001. Companies that did and did not track near misses were split nearly in half. Four companies reported that tracking was done at the project level only.[1] It is surprising that contractors reported tracking near misses one-fourth as often as owners, yet they reported nearly two and one-half times as many near misses. This may be due to differences in the way a near miss was defined by individual companies.

Table 4. Near Miss Accidents and Near Miss Tracking

Near Misses	Total Number of Near Misses	Near Miss Tracking (# of Companies)	
		Yes	No
All	2,285	24	25
Owner	673	20	19
Contractor	1,612	4	6

[1] Three of these companies reported that they did track near misses, and one company reported that it did not.

Thirty-seven companies provided a definition of a near miss. The majority of these definitions, 24, defined a near miss as *any work-related incident that had the potential to cause harm to an employee, damage equipment or machinery, or impact the environment in a negative way, but did not merely by chance*. Another 5 companies defined a near miss as *an incident that caused property damage but no injuries, or incidents that caused property damage in which injuries did not meet the injury classification*. While the two are close, the second of these two was slightly more specific in that cases of property damage with minor injuries only or without injuries at all were always treated as near misses.

Fatalities

Fatality data for CII member companies and the Construction industry are shown in Table 5. Note that the fatality rate was defined as the number of fatalities per 100,000 full-time workers while the RIR and the LWCIR were based on 100 full-time workers. The RIR and LWCIR were computed using 1,117,060,559 work hours, and the fatality rate was computed using 1,108,136,317 work hours. These were somewhat less than the total number of work hours reported because the work hours for four owner companies were excluded due to missing data. The overall fatality rate for CII members was 7.04, and the fatality rate was lower for owners than for contractors. As shown previously in Table 2, fatality rates for both owners and contractors increased slightly from the previous year. The overall rate increased by 2%. The fatality rate increased by 4½% for owners and by 1½% for contractors.

Table 5. Fatality Rates, 2001

Fatality Rate[1]	All	Owner	Contractor
CII Members	7.04	6.53	7.23
Construction Industry[2]	13.3	N/A	N/A

[1] See Attachment A for definition.
[2] See Attachment B.

N/A Not Available

Nationally the Construction industry division experienced the highest number of fatalities that it ever has since the Census of Fatal Occupational Injuries was begun in 1992.[2] In 2001, the Construction industry division also had the highest number of fatal occupational injuries of any other industry as reported by the Bureau of Labor Statistics (BLS). With 1,225 fatal occupational injuries, the Construction industry division was followed by Transportation (911), Services (767), and Agriculture (740). Keeping in mind that fatality rates are determined by the number of persons employed in the industry, Mining had the highest fatality rate of any industry, 30.0, with a total employment of 566,000. This was followed by Agriculture with a fatality rate of 22.8 (3,208,000 employees). The Construction industry was third. The fatality rate was 13.3 (9,125,000 employees), an increase of slightly over 3% from the previous year.

The causes of fatal injuries for both CII and the Construction industry division are shown in Figure 11. These categories are consistent with the BLS Occupational Injury and Illness Manual.

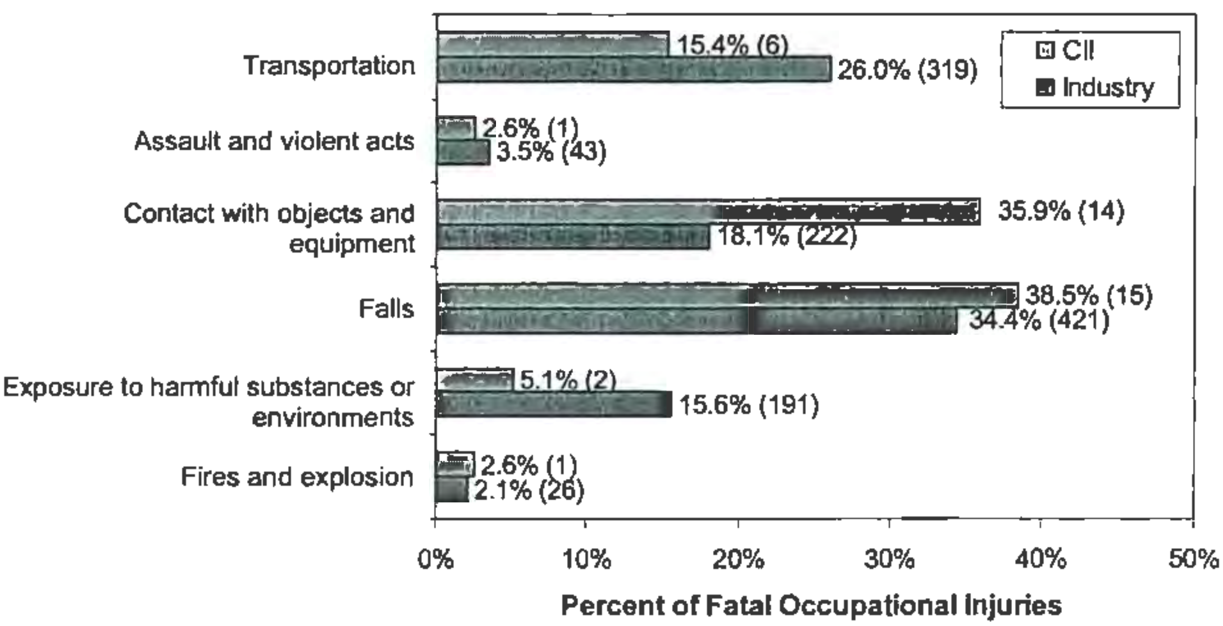


Figure 11. Fatal Occupational Injuries by Cause

[2] Bureau of Labor Statistics, "National Census of Fatal Occupational Injuries," Washington, D.C., September 2002

The leading cause of fatalities among CII member companies was falls (38.5%), followed closely by contact with objects and equipment (35.9%), transportation (15.4%), exposure to harmful substances or environments (5.1%), fires and explosions (2.6%), and assault and violent acts (2.6%). The top three causes accounted for nearly 90% of all fatalities. In comparison, the three leading causes of fatalities in the Construction industry division as reported by BLS for the same year were falls (34.4%), transportation (26.0%), and contact with objects and equipment (18.1%); these accounted for nearly 79% of all fatal injuries.[3]

Figure 12 compares the causes of fatal occupational injuries for CII member companies in 2000 and 2001. In 2000, the leading causes of death were contact with objects and equipment, falls, and transportation. These three accounted for nearly 94% of all fatal occupational injuries. In 2001, the same three causes led, but the order was reversed for the first two of these. Falls, contact with objects and equipment, and transportation accounted for nearly 90% of all fatal occupational injuries. Exposure to harmful substances or environments accounted for an additional 5% of fatalities in 2001.

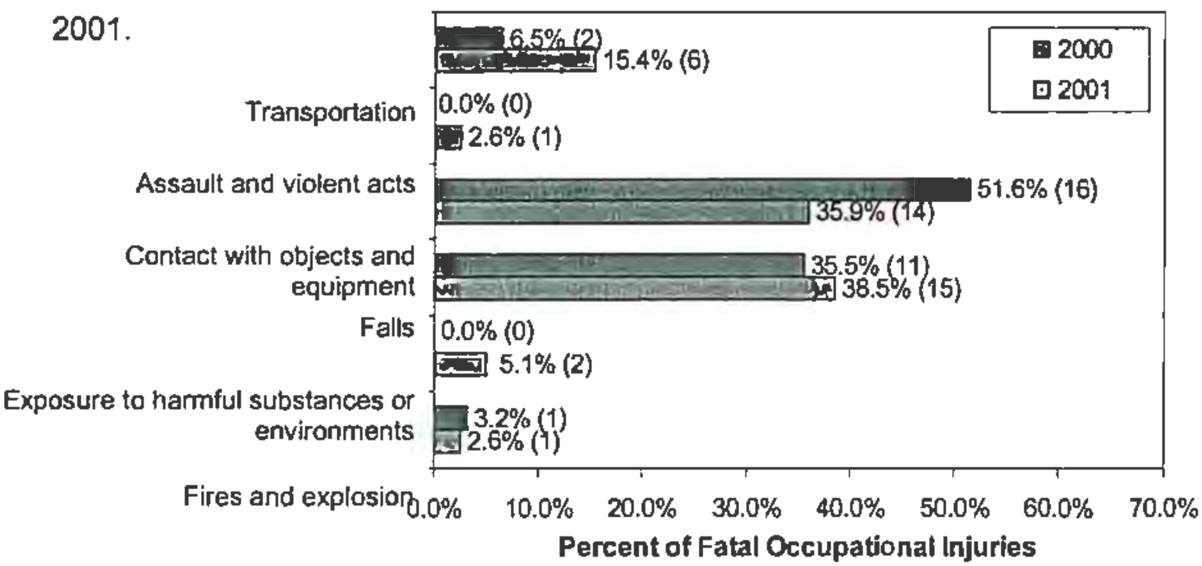


Figure 12. Fatal Occupational Injuries by Cause, CII 2000 and 2001

[3] These data do not include the 58 fatalities in the Construction industry division that resulted from the events on September 11, 2001.

Summary of Findings

The safety performance of CII member companies continued to exceed that of the Construction industry in general. In 2001, CII member company RIR performance was 7 times better than the Construction industry, and member company LWCIR performance was nearly 15 times better. Owners reported improvements in the RIR and the LWCIR with decreases of 29.4% and 38.5%, respectively. Contractor performance slipped somewhat with a 9.4% increase in the RIR. LWCIR performance was unchanged from the previous year.

Continuing the trend from previous years, international projects outperformed domestic projects in safety. The reasons behind this are unclear, but the findings in this survey are consistent with project data collected in the ongoing CII benchmarking effort.

Near miss data were tracked by nearly 50% of the companies that responded to the question on whether the company tracked such data. Based on the responses, it seems that near miss tracking is doable. More widespread tracking of near misses should be encouraged as an additional measure of safety performance. This is especially true in the case of small projects since these typically report zero safety-related incidents. Whether the company reported that it tracked data or not, slightly over 67% provided a definition of a near miss accident. From the responses given, a consensus definition of a near miss accident is proposed: *any work-related incident that had the potential to cause harm to an employee, damage equipment or machinery, or impact the environment in a negative way, but did not merely by chance.*

The factors that contribute to improved safety performance are at work industry-wide. Over the thirteen-year period from 1989 to 2001, the RIR and the LWCIR for the Construction industry (SIC 15-17) decreased by 49%. The results for CII member companies are even more impressive. Over the same time period, the RIR for member companies decreased by nearly 86%, and the LWCIR decreased by nearly 88%. CII members reported 5,721 recordable incidents and 1,301 lost workday cases for the 1,117 million work hours worked in 2001. Had they experienced rates of decrease similar to the Construction industry, 20,444 accidents and 5,368 lost workday cases would have been reported. Therefore, member company safety performance resulted in 14,723 fewer accidents and 4,067 lost workday cases in 2001. Based on CII research, the savings from avoiding lost workday cases alone would be over $239 million, adjusted for inflation.[4]

Fatalities increased slightly from the previous year for both CII member companies and the Construction industry in general. For CII member companies there was an increase of 2%, and the rate of increase for the Construction industry in general was 3%. Fatalities represent additional economic and ethical burdens to the industry. The direct and indirect costs of fatalitites far outweigh those of injuries alone. It was estimated that in 1992 the average direct and indirect costs of a work-related fatality were $565,170 compared to an average of $10,968 per work-related injury.[5] Beyond the economic considerations are the ethical ones that demand a safe work environment. The commitment on the part of CII member companies to preventing fatalities is clear: the CII member company fatality rate was 53% lower than the Construction industry rate.

[4] Construction Industry Institute, "Zero Injury Economics," 1993, Austin, Texas
[5] Leigh, JP et. al., "Occupational Injury and Illness in the United States: Estimates of Cost, Morbidity, and Mortality," Archives of Internal Medicine, 1997

Attachment A. Definitions

Terms	Descriptions
Recordable Incident	A recordable incident is a work-related death or illness and any injury, which results in: loss of consciousness, restriction of work or motion, transfer to another job, or requires medical treatment beyond first aid.
Lost Workday Case	An incident, which results in days away from work or restricted activity or both.
RIR	The recordable incidence rate (RIR) is the number of recordable injuries occurring annually among 100 full-time workers (2,000 hours per worker per year).
LWCIR	The lost workday case incidence rate (LWCIR) is the number of lost workday cases occurring annually among 100 full-time workers (2,000 hours per worker per year).
Fatality Rate	The fatality rate is the number of fatalities occurring annually among 100,000 full-time workers (2,000 hours per worker per year).

Attachment B. Standard Industrial Classification (SIC) Code

Terms	Descriptions
SIC 15-17	**Construction industry division**
SIC 1540	**Nonresidential building construction.** This group includes all building projects and light industrial projects. SIC 1541 : Industrial Buildings and Warehouses (Light Industrial) SIC 1542 : Nonresidential Buildings (Buildings)
SIC 1600	**Heavy construction other than building construction.** This group includes all infrastructure projects. SIC 1611 : Highway and Street Construction SIC 1622 : Bridge, Tunnel, and Elevated Highway Construction SIC 1623 : Water, Sewer, Pipeline, and Power Line
SIC 1620	**Heavy construction except highway and street.** This group is one of the subgroups of the SIC 1600. Although it includes some infrastructure projects such as 1622 & 1623, it also includes the 1629 group primarily engaged in all types of heavy industrial projects. (OSHA does not publish 1629 level data.)

Attachment C. Company Safety Statistics

The following table provides RIR and LWCIR statistics summarizing individual company rates for analyzing company performance. Since values in the table are statistical summaries of company rates, they will not be identical to the aggregated CII performance provided in Table 2.

	All			Owner			Contractor		
Percentile	RIR	LWCIR	Fatality	RIR	LWCIR	Fatality	RIR	LWCIR	Fatality
100%	9.39	9.39	163.34	9.39	9.39	163.07	6.94	4.77	113.28
75%	2.15	0.33	1.88	1.58	0.19	1.88	2.36	0.47	1.30
50%	1.16	0.16	0.00	0.74	0.14	0.00	1.40	0.20	0.00
25%	0.58	0.07	0.00	0.74	0.03	0.00	0.83	0.10	0.00
0%	0.00	0.00	0.00	0.44	0.00	0.00	0.19	0.00	0.00
mean	1.79	0.61	9.85	1.49	0.57	11.31	1.99	0.64	8.79
sd	1.91	1.53	29.91	2.13	1.98	35.53	1.75	1.17	25.87
n	54	54	54	22	22	22	32	32	32

Attachment D. References

Bureau of Labor Statistics, "National Census of Occupational Injuries in 2001," News: United States Department of Labor, September 25, 2002, Washington, D.C.

Liska RW, Goodloe D, and Sen R, "Zero Accident Techniques," Source Document 86, Construction Industry Institute, January 1993, Austin, Texas.

Leigh JP, Markowitz SB, Fahs M, Shin C, Landrigan PJ, "Occupational Injury and Illness in the United States," Archives of Internal Medicine, 57(3), pp. 1557-68, 1997.

Construction Industry Institute, "Zero Injury Economics," Special Publication 32-2, September 1993, Austin, Texas.

BLS Web Site

http://www.bls.gov/iif/oshsum.htm
http://www.bls.gov/iif/oshwc/cftb0146.pdf
http://www.bls.gov/cgi-bin/cpicalc.pl

APPENDIX B

SECTION II: Letters to Construction Companies

Appendix B
Letter to Construction Companies

July 15, 2002

Name
Safety Director
Company
Address
City, State Zip

We need your help.

The Construction Safety Alliance (CSA), was funded in November of last year by the Centers for Disease Control and Prevention (CDC), with the aim of reducing injuries and preventing fatalities in the construction industry. Purdue University is the lead institution in this effort, and Dr. Dan Halpin, Head of the Division of Construction Engineering Management, School of Civil Engineering, is the overall project officer.

One aspect of this study is to reduce the number of falls from elevations in the construction industry. We have been able to determine from existing data that large construction companies have lower incidence rates of falls from elevations than small construction companies. The purpose of this study is to look at the safety programs of large companies such as yours and determine what key elements in those safety programs make them most effective, especially in the area of fall prevention.

In the next few weeks, we would like to interview you over the telephone and ask questions similar to the questions on the enclosed questionnaire. We anticipate approximately 20 minutes of your time when we call.

The benefit to your company is that we will report back to you the collective results of our study. From these results, we hope to gain a better understanding of what elements in a falls from elevations program make it effective in terms of injury reduction and fatality prevention. Also, we are interested in costs and cost justification for your fall prevention program. An additional benefit will be the technology transfer of key information on fall prevention that can benefit smaller construction companies.

We will be conducting similar interviews with smaller companies, but as you know many of these companies do not have the resources you do. Our challenge is to find the common elements that no company can ignore when it comes to protecting its workers as well as company assets.

All information gathered from individual companies will be kept confidential. If you wish your company to be recognized as a contributor, we would be happy to do so. We look forward to talking with you. Thank you in advance for your help on this project.

Sincerely,

James D. McGlothlin, M.P.H., Ph.D., C.P.E.

Associate Professor of Health Sciences

APPENDIX C

SECTION II: Questionnaire

Appendix C
Questionnaire

Company Name:

Contact Person:

1. What are the primary types of construction projects your company does?

   a.

   b.

   c.

   d.

   What are the typical contract amounts? ________ Dollars

2. In the order of most important to least, what five key elements of your safety training program do you feel contribute the most to its success and why?

   a.

   b.

   c.

   d.

e.

3. How many workers do you train per year? ________

4. What is your employee turnover rate? ________ Average per year

5. What is your average employee length of employment? ________ In months

6. Does your employee turnover rate effect how your safety training is implemented?

Yes/No ________

How?

7. Do you have refresher training for existing employees? Yes/No ________

If so, what are the primary elements of refresher training?

a.

b.

c.

How often is it done? ________ In months

8. Is your company affiliated with any safety organizations? Yes/No ________

If so, how are they utilized by your company?

a.

b.

c.

9. What is your Experience Modification Ratio (EMR) rating? ________

10. How long has your company been practicing its current safety program? ________ In months

11 What were the five key factors that influenced your company to implement the current safety training program?

a.

b.

c.

d.

e.

12. Does upper management play a key role in the implementation of your safety training program?

Yes/No ________

13. Approximately how many workers work at elevations greater than six feet? ________

14. How many fall related injuries has your company experienced in the past year? ________

How many fatalities? ________

How many injuries and fatalities in the past five years?

Injuries ________

Fatalities ________

15. What was the primary cause of each fall related injury/fatality?

a.

b.

c.

d.

e.

f.

g.

16. What is your estimate of the yearly cost per worker of your safety training program? ________

17. What is your estimate of the yearly cost per worker of your fall protection equipment? ________

18. If cost ever became an issue, what three elements of your safety training program would you consider keeping, and what three elements would you consider cutting?

Keep

a.

b.

c.

Cut

a.

b.

c.

19. In your opinion and with reference to fall prevention, what 3 things make the safety difference in your company in reducing injuries and preventing fatalities?

a.

b.

c.

20. In your opinion and with reference to fall prevention, what 3 things do you wish you had that could make more of a difference in your company in reducing injuries and prevention fatalities?

a.

b.

c.

APPENDIX D

SECTION II: Summary of Results

Appendix D
Summary of Results

1. Mean amount or typical contract — $24,900,000
   Median amount of typical contract — $9,000,000

2. Top five elements of the safety training program that contribute the most to its success

   1. Upper management commitment to support and promote safety as a top priority
   2. Training supervisors in the area of supervision
   3. Regular on-site training from the construction superintendent
   4. Promotion of safety awareness and accountability as a fundamental value
   5. Job specific safety training for those potentially exposed
   5. Daily crew meetings where supervisors go over a daily work plan

3. Mean number of workers trained — 1,003
   Median number of workers trained — 500

4. Mean employee turnover per year — 343
   Median employee turnover per year — 145

5. Mean employee length of employment — 35 months
   Median employee length of employment — 18 months

6. Companies that feel that the employee turnover rate affects how their safety training is implemented — 7
   Companies that feel that the employee turnover rate does not affect how their safety training is implemented — 8

7. Companies that have refresher training for existing employees — 15
   Companies that do not have refresher training for existing employees — 1

Seven out of sixteen companies listed the OSHA 10 hour course as the primary element of refresher training

Mean length of time between refresher safety training sessions	18 months
Median length of time between refresher safety training sessions	12 months

8.	Companies affiliated with safety organizations	16
	Companies not affiliated with safety organizations	0

How companies utilize safety organizations

1. Opportunity to network with other companies
2. Resource for training information
3. Act in an advisory role to safety organizations

9.	Mean Experience Modification Ratio (EMR) rating	0.75
	Median Experience Modification Ratio (EMR) rating	0.73

10.	Mean length of time the current safety program has been practiced	123 months
	Median length of time the current safety program has been practiced	132 months

11. The five key factors that influenced the company to implement the current safety training program

1\. Concern for employees
1\. Maintaining profitability
3\. Insurance company pressure and high EMR
4\. Concern for reputation, good business to be safe
4\. Compliance with OSHA

12. Companies where upper management plays a key role in the implementation of the safety training program — 16

Companies where upper management does not play a key role in

the implementation of the safety training program	0

13.	Mean number of workers that work at elevations over 6 feet	872
	Median number of workers that work at elevations over 6 feet	320

14.	Mean number of fall related injuries in the past year	4
	Median number of fall related injuries in the past year	2
	Mean number of fall related fatalities in the past year	0.13
	Median number of fall related fatalities in the past year	0.00
	Mean number of fall related injuries in the past 5 years	13
	Median number of fall related injuries in the past 5 years	5
	Mean number of fall related fatalities in the past 5 years	0.58
	Median number of fall related fatalities in the past 5 years	0.00

15. Primary reasons for fall related injuries and deaths

    1. Twelve out of Eighteen incidents were due to a failure to follow safety procedures
    2. Seven of the incidents involved ladders
    3. Two of the incidents involved scaffolds

16.	Mean yearly cost per worker for the safety training program	$805
	Median yearly cost per worker for the safety training program	$800

17.	Mean yearly cost per worker for fall protection equipment	$999
	Median yearly cost per worker for fall protection equipment	$250

18. The top three safety training program elements that would be kept if budget cuts became necessary

1. Worker safety training
2. Supervisor training
3. New hire orientation

The top three safety training program elements that would be cut if budget cuts became necessary

1. Eight of Sixteen companies reported nothing would be cut
2. Incentive programs
3. Conferences

19. The top three things that that make the safety difference in reducing injuries and fatalities from falls

    1. Strong management commitment to safety
    2. Training
    3. Availability of equipment and willingness to spend money

20. The top three things that companies wish they had that could made a difference in reducing fall injuries and fatalities

    1. More money in the budget and larger safety staff
    2. Nothing
    3. More recent and relavent training at the crew level
    4. More research and development into better fall protection systems

APPENDIX E

SECTION II: Summary of Roofing Observations

Appendix E
Summary of Roofing Observations

Residential roofing is a dangerous operation. Over 70% of the fatalities in the roofing industry are due to falls (Bureau of Labor Statistics, 2001). Seven primary steps were observed in the task of replacing residential roofs. They were: 1) Ground preparation, 2) Shingle removal, 3) Roof deck replacement, 4) Installation of components beneath the shingle layer, 5) Shingle installation, 6) Vent cap installation, and 7) Clean up. Falls are generally not a risk during the ground preparation or the clean up. Ground preparation involves the laying of canvas around the perimeter of the dwelling to catch and contain falling debris and deflect it away from delicate shrubbery. The clean up step involves the removal of debris from the canvas, removal of the canvas, and inspection of the area surrounding the dwelling to remove any debris that was not contained by the canvas.

Shingle removal is the first step where falls become a risk factor. To gain access to the roof, the roofing crew first secured a ladder to the eave. The ladder is usually positioned at a section of roof where the elevation of the roof is low and there is plenty of space to make the climbing transition from the ladder to the roof surface. Once a position for the ladder was chosen, a 2X4 was placed in the gutter to support its outer edge against the horizontal force of the ladder. To prevent the ladder from tipping, a rope was used to secure top of the ladder to the eave and a small plywood sheet was used to prevent the legs of the ladder from sinking into the surrounding soil. The primary weakness in securing the ladder was the rope used to secure the ladder to the eave. The rope did not immobilize the top of the ladder and could allow the ladder to move enough to cause a worker to slip and fall. Movement of the ladder is also a concern when making the transition from the ladder to the roof surface. The top rung of the ladder serves as the only handhold. A slight slip in the position of the ladder at the right moment while making the transition from the ladder to the roof surface could lead to a fall.

The shingle removal step consists of removing the old shingles, drip edge, tarpaper and any vent seals or flashing. The primary instrument used for roof material removal is the potato fork. The potato fork is an instrument, adapted from the agricultural industry that allows relatively easy penetration of the space between the shingles and the roof sheeting and provides enough leverage to loosen large sections of shingles and facilitate their removal. The worker uses his body weight and forward momentum to gain the leverage necessary to push the potato fork under the layer of shingles. An unexpected loss of resistance of the potato fork or a sudden onset of additional resistance could lead to a sudden shift in the body's center of mass from which the worker would not be able to recover his balance and fall.

Loose shingle material was constantly being removed from the roof but it was also constantly being accumulated creating a situation where loose material was always present. Workers continuously reposition themselves as they remove shingles. As they reposition, loose shingles and other loose roofing materials are inevitably stepped on. Encountering a surface with a lower coefficient of friction than expected could lead to a loss of footing which in turn could lead to a fall.

Loose roofing material was loaded onto wheelbarrows that were used to transport it to the edge of the roof where it could be dumped into a trash receptacle on the ground. Maneuvering the wheelbarrows on the sloped roof littered with loose material presented ample opportunity for slips and subsequent falls to occur but the situation that lead to the highest risk for falling occurred while the wheelbarrows were being dumped. Workers dumped the materials from the wheelbarrow by pushing it to the edge of the roof and lifting the handles until it reached the vertical position. Roofing materials would slide out at this point. Two potentially hazardous events can occur while the wheelbarrow is in the vertical position at the edge of the roof. First, the wheel could roll over the edge of the roof causing the wheelbarrow to fall. Second, the roofing material could snag in the wheelbarrow preventing its release and allowing its rotational momentum to carry it over the edge of the roof. In either situation, an unfortunate worker whose clothing or gloves became snagged by wheelbarrow handles would be carried over the edge of the roof by the momentum of the wheelbarrow leading to a fall.

Once the shingles and any other loose materials had been removed, the roof sheeting was inspected for damage. Damaged sheets were pried from the roof trusses and tossed into the trash receptacle on the ground. As with the wheelbarrow, an unfortunate worker whose gloves or clothing became snagged on the damaged sheeting could be carried over the edge of the roof by its momentum. A worker on the ground, using the ladder as support lifted new roof sheeting to the edge of the roof. Each piece of sheeting was a 4x8 sheet of plywood. In retrieving the sheets, the worker assumed a posture facing down the slope of the roof and leaning over the edge of the roof to grip the sheet. The position of the worker combined with the weight and awkwardness of the plywood sheet put the worker at risk for losing balance and falling over the edge of the roof.

Installation of components under the shingle layer involves installing new vent seals, flashing, drip edge, and tarpaper removed when the old roofing materials were removed. Installing the drip edge and tarpaper present the greatest opportunity for a fall during this step in the roofing process. The location of the drip edge is at the bottom edge of the roof. Workers squat facing and leaning down the slope of the roof within inches of the edge to fasten the drip edge to the roof sheeting. This squatting posture is particularly hazardous because of the inability of a worker to use his legs to change his stance in the event of a loss of balance. Losing balance in this position will almost surely lead to a fall from the roof.

After securing the drip edge, tarpaper is installed on the roof. While tarpaper roles are not as awkward to handle as plywood sheeting, they are heavy and can affect the balance of the workers while they lean over the edge of the roof to retrieve them. Installing the tarpaper has its highest risk while the first row is being installed. As in the case of the drip edge, the workers squat facing and leaning down the slope of the roof within inches of the edge.

Similar risks of falling occur during the installation of shingles as were discovered during the installation of roof sheeting, drip edge, and tarpaper. The activity of lifting shingle bundles from the lift conveyer is particularly hazardous because the shingle bundles weigh from 50 to 85 lbs. The shingle bundles were retrieved from the conveyer while the worker was standing near the edge of the roof. A loss of balance while retrieving the bundles would likely result in the worker falling over the edge. Walking with the shingle bundle on the sloped roof also puts the worker in a situation where his balance could be compromised leading to a fall. The third situation during this step where a fall would likely occur is when the first three rows of shingles are secured to the roof. Again, the worker is required to squat while facing and leaning down the slope of the roof near the edge to perform this activity. A high degree of concentration, agility, and strength are required to place the shingle in the proper position and put the tip of the nail gun in the proper position and secure the shingle. A momentary loss of concentration or unexpected change in the body's center of mass would surely lead to a fall over the edge of the roof.

APPENDIX F

Acknowledgements

Appendix F

Acknowledgements

The CSA Research Team would like to thank the large number of construction professionals from companies and organizations throughout the U.S. who actively participated in this study. In particular, member companies within the Construction Industry Institute (CII) and sponsor companies supporting the internship program in the Division of Construction Engineering and Management at Purdue deserve special recognition.

APPENDIX G

References

Appendix G
References

References are cited at the end of the Executive Summary and Sections I-VIII in the main body of the report.

APPENDIX H

Publications: presented and anticipated

Appendix H
Publications: presented and anticipated

Publications prepared as part of this study and anticipated publications are listed at the end of Sections I, II, V, VI, and VII. See pages I-17, II-16 to 17, VI-14, and VII-23.