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Construction remains the most hazardous industry in the United States in terms of the aggregate number of fatalities. Twenty percent of all occupational related fatalities occur in construction; approximately three construction workers die per calendar day. Moreover, this trend has been prevalent for too long. One method to reduce this trend is to involve architects and design engineers in considering construction safety during the design process. The concept of designing for construction safety is a viable intervention to improve worker safety. However, in the United States many barriers (legal, contractual, regulatory) exist that prevent this intervention from becoming part of a standard practice within the construction industry. Four-hundred and fifty construction accidents from two databases were analyzed and a link to the design for construction safety concept was determined. An objective investigation model was developed to make these determinations. A significant link between the concept of designing for construction safety and construction fatalities and disabling injuries was established. Specific construction project parameters linked to the concept of designing for construction safety include

the minimization of risk due to falls through and from roofs, skylights and structural steel construction; and the minimization of risk due of contact with electric and other utilities. It is recommended that the concept of designing for construction safety be considered by regulatory agencies, insurance companies, and the United States' construction industry as one intervention of a comprehensive safety agenda to reduce the disproportionate number of fatalities and disabling injuries.

Establishing the Link between Construction Fatalities and Disabling Injuries and the Design for Construction Safety Concept

by
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I understand that my dissertation will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my dissertation to any reader upon request.

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Michael Behm, Author

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Chapter 1 – Introduction

Construction remains the most hazardous industry in the United States in terms of the aggregate number of fatalities. In 2002, the construction industry experienced 1,121 total deaths or 20% of all work-related fatalities in the United States (Bureau of Labor Statistics, 2003a). In addition, the construction industry's overall injury and illness rate was 7.1 injuries and illnesses per 100,000 full-time workers, above the national average of 5.3 injuries and illnesses per 100,000 full-time workers (BLS, 2003b). The trend of the construction industry's safety problems (high fatality and injury rates) has been prevalent for too long; one breakthrough idea to reduce this trend is to involve architects and design engineers in considering construction safety during the design process (Korman, 2001).

It is often considered by construction industry safety professionals that many safety hazards are "designed into" construction projects (Gambatese, 2003). The features of the permanent facility can influence (both positively and negatively) the safety of the constructors. For example, when the height of parapet walls is designed to be 42", the parapet acts as a guardrail and enhances safety. However, when roof perimeters do not contain permanently designed-in fall protection features (anchorage points, guardrails), worker safety is compromised. Therefore, design professionals (i.e. architects and design engineers) are in a position for decision-making and influencing to help improve construction safety. By addressing safety during the design process, hazards will be eliminated or reduced during construction, thus improving the safety performance of the constructor.

The concept of designing for construction safety is viewed as a viable intervention to improve worker safety (Gambatese, 2003). However, design professionals continue to reject this intervention as part of their standard practice. One reason why it is not accepted as standard practice is because there are no motivating forces (i.e. legal, ethical, contractual, regulatory) for a design professional to adopt the concept as standard practice. In the traditional method of procuring construction, design-bid-build, legal precedent precludes a designer from considering construction site safety during the design process. Design professionals' codes of ethics, such as those established by the American Institute of Architects, set ethical priorities for final occupant safety, public safety, and safety of the finished product but ignore safety considerations during the construction phase. Construction contracts and regulatory requirements from the Occupational Safety and Health Administration (OSHA) clearly place the burdens for worker safety on the constructor. Project owners who place a priority on a safe construction site also place the burden of construction site safety squarely on the constructor by utilizing pre-qualification practices of selecting only those contractors with good safety performance, lower insurance rates, and written safety programs.

Occupational safety professionals recognize the concept of designing for safety as the foremost method for eliminating hazards and reducing risk regardless of the industry. Manuele (1997) provides this order of precedence as guidance for safety professionals:

1. Design to eliminate or avoid the hazard;
2. Design to reduce the hazard;
3. Incorporate safety devices after the fact;
4. Provide warning devices; and
5. Institute training and operating procedures.

Because the prevailing view of safety management in the construction industry is to delay the implementation of safety preparations until the construction phase begins, the ability to effectively design to eliminate, avoid, and reduce hazards is not realized.

One motivating force to accept the design for construction safety concept as standard practice within the construction industry is in the improvement of construction site safety, or rather to consider the negative effects of ignoring the concept. Recent research has focused on the positive aspects of designing for construction safety, i.e. the development of design modifications to improve safety (Gambatese, 1997) and the integration of construction safety knowledge into the design (Hecker and Gambatese, 2003). However, it is yet to be determined whether the lack of including the design for construction safety concept negatively influences project safety.

This research sought to establish the link between the design for construction safety concept and construction fatalities and disabling injuries and then determined the extent and magnitude of that link. A relationship between specific construction project parameters where the design for construction safety concept would be most appropriate in preventing accidents was defined.

The databases of construction accidents utilized in this research were from the State OSHA offices in California, Washington, and Oregon; and the National Institute of Occupational Safety and Health (NIOSH) Fatality Assessment Control and Evaluation (FACE) program.

Statement of the Problem

The problem addressed in this study was that of establishing the link between the design for construction safety concept and construction fatalities and disabling injuries and then determining the extent and magnitude of that link. A solution to this problem is contingent upon completion of the following tasks:

1. Locating a list of construction fatalities and disabling injuries where sufficient information existed to make a determination that the design for construction safety concept was or was not linked in the incident.
2. Developing a model based on previous research that enables the construction accidents to be evaluated consistently from a design perspective.
3. Utilizing the model to evaluate if the design for construction safety concept was linked to the accident and determining specifically how the design for construction safety concept was linked.
4. Analyzing the relationships between those accidents that were linked to the design for construction safety concept to the various project parameters.
5. Developing recommendations and conclusions based on the findings of this research.

Purpose

The purpose of this study was to make research-based data available to architects, design engineers, developers, project owners, and safety professionals that is meaningful in making decisions about utilizing the design for construction safety concept and implementing it in construction projects. Determining the extent and magnitude that construction fatalities and disabling injuries are linked to the design for construction safety concept will enable decisions to be made during the design process that reduce or eliminate the risk of those fatalities and disabling injuries.

Research Hypotheses

Several hypotheses were developed for the purpose of improving decision making regarding the design for construction safety concept. These hypotheses were tested and were dependent on the information that could be extracted from the incident investigation reports.

Hypothesis 1

$H1_A$: A noteworthy proportion of construction fatalities and disabling injuries are linked to the design for construction safety concept.

Hypothesis 2

$H2_A$: There is a difference in whether the design for construction safety concept was linked in accidents that resulted in a fatality compared to those resulting in a disabling injury (OSHA database only).

Hypothesis 3

$H3_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to the nature of the construction project (i.e. new construction, upgrade, and demolition).

Hypothesis 4

$H4_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to the type of construction project (i.e. residential, commercial, engineering, and industrial construction).

Hypothesis 5

$H5_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to whether OSHA issued a citation (OSHA database only).

Hypothesis 6

$H6_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to the design element being constructed at the time of the accident (design element is categorized as one of the 16 Divisions as specified by the Construction Specifications Institute).

Hypothesis 7

$H7_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to the injured contractor's Standard Industrial Classification (SIC) code.

Hypothesis 8

$H8_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to the designer's discipline (architectural, structural, civil, mechanical, electrical) involved in that aspect of the project that caused the fatality or disabling injury.

Hypothesis 9

$H9_A$: Construction fatalities that are linked to the design for construction safety concept are related to the size of the construction firm which experienced the fatality (NIOSH database only)

Significance of the Research

Objectively establishing the link between the design for construction safety concept to construction accidents and defining the extent and magnitude has never been performed. Determining the proportion and characteristics of construction accidents that are linked to the design for construction safety concept could drive change within the construction industry and/or OSHA. With new knowledge of the negative aspects of not including this viable concept, developers and owners seeking to fund a safe project would demand that design professionals take a greater role in construction site safety. Insurance companies seeking to reduce losses due to accident costs would also be interested in these results as they seek to minimize overall project risk and contingent liability. This research builds on past research, which suggests that design professionals have a role in reducing construction injuries and fatalities.

This research also determined the specific aspects of construction (i.e., type of construction work, designer discipline), which lend themselves to the design for construction safety intervention. By determining the specific characteristics of construction that are related to the design for construction safety concept, future research efforts will be able to utilize specific design concepts more efficiently and effectively. They will be able to develop and implement those standard design procedures which will have the most impact relative to the specific type of work. This research fills this gap and contributes to the existing body of knowledge with the purpose of directing and focusing such change. A conceptual model for designer accident investigation was developed for the purposes of future research and incident investigation.

Assumptions

1. That the traditional and recent approaches to safety management in the construction industry, i.e. ensuring OSHA compliance, behavior based initiatives, drug and alcohol programs, while effective, are limited by the fact that the design for construction safety concept is not accepted as a standard practice.

Limitations

1. The Occupational Safety and Health Administration (OSHA) and State OSHA offices investigate construction accidents (fatalities and disabling injuries) to determine non-compliance with Construction Safety and Health Standards. Within OSHA field notes are a detailed description of the accident including accounts from witnesses, observations of the site by the OSHA inspectors, drawings of the site, company generated investigation materials, etc. This information is useful not only in determining non-compliance but also in determining the many potential causal factors of the accident, including the design. It is recognized that some details are not contained within these files that would be useful to this research, such as architectural and engineering drawings and interviews with architects and engineers about the design and the plans and specifications for construction. OSHA inspectors do not specifically gather information related to pre-construction activities. This study is limited by the data collected by each OSHA inspector.
2. OSHA does not evaluate every construction fatality and disabling injury. They investigate only those fatalities and disabling injuries that are reported to them or that they discover through general information sources such as newspapers, news reports, other agency referrals, etc. This study is limited by the data available to OSHA.
3. Due to administrative and recordkeeping constraints at the State OSHA offices, this research evaluates data from 2000 through 2002. Files are purged after 5 years or are archived and unavailable for review according to the State OSHA contacts.
4. This research evaluates only cases that have been classified as closed. Cases that have not been officially closed by OSHA are unavailable for review.
5. The NIOSH FACE program investigates construction fatalities to determine causal factors in order to educate the construction industry to

prevent future accidents. The program does not specifically evaluate the design for construction safety concept or the influence of the design. Some reports reviewed did specifically mention that if the safety aspects of the job were considered in the design, the fatality may have been prevented. This study was limited by the data collected by each FACE investigator.

6. The NIOSH FACE program does not investigate every construction fatality. Fatalities are selected based on certain priority criteria. For example, current selection criteria include younger workers and non-English speaking workers who were killed on the job. There is a national FACE program and 19 states have or once had their own FACE program. There were 569 construction fatalities listed on their website as of February 17, 2004. This study was limited by the data available on the NIOSH FACE website.
7. The NIOSH FACE investigations do not contain certain information about the project, such as the constructor's SIC code. Data analysis was limited to the data found within these reports.

Delimitations

1. Due to economic constraints, this research evaluates construction accidents from Oregon, Washington, and California. In California, the research was further delimited to the following regional OSHA offices due to travel distance, time, and economic constraints: Torrance, Anaheim, Van Nuys, and Los Angeles.

Operational Definitions

<u>Construction</u> – all the on-site work done in building or altering structures, from land clearing through completion, including excavation, erection, and the assembly and installation of components and equipment (Harris, 1993).

Design – the process of developing and communicating all necessary information (drawings, plans, specifications) to complete a construction project.

Design for construction safety – the consideration of construction site safety in the design of a construction project. This includes modifications to the permanent features of the construction project and in the preparation of plans and specifications for construction in such a way that construction site safety is considered. It also includes the utilization of design for safety suggestions and the communication of risks regarding the design in relation to the site and the work to be performed.

Disabling injury – an incident that resulted in the temporary or permanent disablement of a worker.

Chapter 2 – Literature Review

The notion that exposures to safety hazards should be identified, evaluated, and controlled before they cause detrimental effects to workers is common knowledge among safety professionals. For example, the semiconductor industry utilizes a management strategy known as design for environment, safety, and health (DfESH). In DfESH, the technical and management strategies of ESH become integrated with the design of products, processes, and technologies with the goal of minimizing future risk and cost burdens associated with addressing these risks throughout the life cycle (Veltri, 2002). In the construction industry, the integration of environmental issues during the design process has become increasingly popular with the advent of sustainable development models, green buildings, and the formation of the United States Green Building Council's (USGBC) certification process. However, construction safety issues have not been integrated into the design process and have remained solely the burden of the constructor, rather than incorporating a holistic approach where construction safety in considered throughout the project's life cycle.

In order to better understand the extent and magnitude that the design for construction safety concept is linked to construction fatalities and disabling injuries, a literature review was conducted to evaluate research regarding the design for construction safety concept and accident causation in the construction industry. The literature review revealed numerous barriers to the concept's implementation. Understanding these barriers is important to incorporating the concept as a standard practice in the construction industry. Linking the design for construction safety concept to construction fatalities and disabling injuries is a motivational force that will assist in removing these barriers in the construction industry. Specifically, this chapter presents a review of the literature associated with general safety concepts; the concept of designing for construction safety; implementation of the design for construction safety concept; major barriers to implementation; and research regarding the causes of construction fatalities and disabling injuries.

General Concept of Designing for Safety

The safety of any operation is determined long before the people, procedures, and equipment come together at the work site (Stephenson, 1991). Construction is not different in this respect from any other industry. It is a standard practice among safety professionals that hazards be eliminated rather than controlled through administrative means. Manuele (1997) provided an order of precedence that specifies design as the primary method to reduce risk. Andres (2002) presented a similar safety hierarchy:

1. Eliminate the hazard,
2. Provide engineering controls,
3. Warn,
4. Train, and
5. Provide personal protective equipment.

According to the Institute for Safety Through Design (ISTD), addressing safety in the concept or early design stages, rather than retrofitting to meet those needs, yields certain measurable benefits. Among the benefits are improving productivity, decreasing operating costs, avoiding expensive retrofitting to correct design shortcomings, and producing significant reductions in injuries, illnesses, environmental damage and attendant costs (ISTD, 2003).

The Concept of Designing for Construction Safety

In 1985, the International Labor Office (ILO) recognized the need for design professionals to be involved and to consider construction safety in their work. They recommended that consideration be given, by those responsible for the design, to the safety of workers who will be employed to erect proposed buildings and other civil engineering works (ILO, 1985). The European Foundation for the Improvement of Living and Working Conditions (1991) concluded that about 60% of fatal accidents in construction arise from decisions made upstream from the construction site. Specifically, these are due to shortcomings in design and organization of the work. This document provided the first claim that the design and the design process are linked to construction accidents. However, it is unclear how these figures were developed. Jeffrey and Douglas (1994) reviewed the safety performance of the United Kingdom's construction industry and contended that in terms of causation there is a definite link between design decisions and safe construction.

In the United States, Hinze and Wiegand (1992) conducted research on the design for construction safety concept as part of a survey of design firms and firms that conduct constructability reviews. They concluded that designers play a strong role in reducing the incidence of construction injuries and fatalities and that the evidence is clear that construction worker safety can be addressed during the design process. However, few design firms regard the safety of construction workers as being within their scope of responsibility.

According to Szymberksi (1997), the ideal situation is for construction safety to be a prime consideration in the conceptual and preliminary design phases. His time/safety influence curve, shown in Figure 1, illustrates that a significant portion of the ability to influence construction site safety is lost when its consideration remains absent until the construction phase.

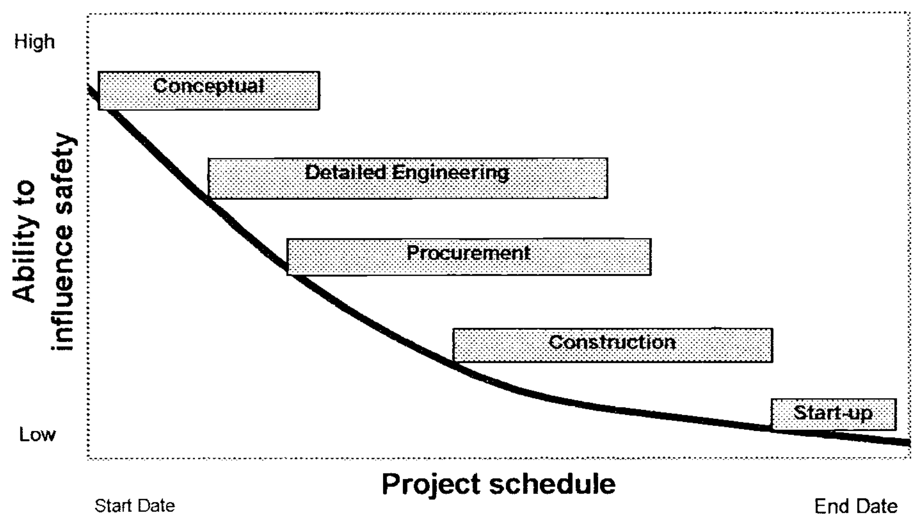


Figure 1. Time / Safety Influence Curve (Szymberksi, 1997)

Hinze (2000) recommended a holistic approach to designing for the entire life cycle of a building, including the construction process. He contended that to effectively address construction safety issues means the designer must consciously assess the implications on safety during each phase of construction.

Research on implementing the design for construction safety concept has been evaluated as part of the constructability review process (Gambatese, 2000b). If safety can be part of the constructability process, then design professionals can utilize the timely input of the constructor's knowledge regarding safety. Therefore, safety can be implemented during all phases of project planning and design.

Another method of improving the design for construction safety concept is to increase the coordination of designers and construction forepersons, particularly those with excellent safety records (Coble and Haupt, 2000). They contended that construction foremen can make significant contributions to the designing for safety effort, provided that designers recognize and harness their skills, site experience, and knowledge base.

The extent to which a design professional can influence construction site safety is dependent on the tools available for them to consider safety in the design process. Gambatese (1996) developed over 400 design suggestions that could be used by design professionals to minimize or eliminate safety hazards in their designs. These design practices were incorporated into a computer design tool titled "Design for Construction Safety Toolbox" (Gambatese et al., 1997). The design suggestions are categorized according to project components, such as project layout, structural framing, and foundations. For each component, the design suggestions are further grouped according to specific safety concerns.

WorkCover is the occupational safety and health regulatory authority of the State of New South Wales, Australia. In 2001, WorkCover led the development of a safety in design tool called Construction Hazard Assessment Implication Review (CHAIR). CHAIR's goal is to identify risks in a design as soon as possible in the life of a project and considers construction, operations, and maintenance activities (WorkCover, 2001). This process specifies that all stakeholders review the design in a prescribed and facilitated method to ensure that the occupational safety and health issues of these stakeholders are considered in the design phase of the project. Of particular interest is that the Australian Council of Building Design Professions and the Royal Australian Institute of Architects support the use of the CHAIR system to improve construction safety and health through design (WorkCover, 2001). Their perspective is in sharp contrast to their counterparts' view of the concept in the United States.

Barriers to Implementation

The concept of designing for construction safety is a relatively new intervention. In the United States, many barriers exist that preclude the implementation of the concept. This section will evaluate the barriers that exist, including legal and liability issues as well as case law; United States' regulatory actions; and construction contracts.

Legal and Liability Issues

A design professional's concern for increased liability has surfaced with the initial research on the design for construction safety concept. Hinze and Weigand (1992) reported that many designers commented that legal counsel specifically advised them not to address construction worker safety in their design. According to Coble (1997), due to the liability issue, only a small number of designers are taking the lead regarding designing for construction safety. Korman (2001) reported that the current legal and insurance system has caused architects to be uninterested, up to the point of being afraid of getting involved in safety. Gambatese (1998) highlighted the liability relationship between implementing design-for-safety knowledge and whether use of this knowledge constituted a standard practice for the profession. He concluded that when design for construction safety knowledge is implemented by a designer, their liability is not increased. However, when the safety knowledge is not implemented by the designer, they indeed can be held liable for injuries to construction workers.

Because liability concerns are a major barrier to implementing the concept in the United States, a legal case search was conducted using the Lexis-Nexis Legal Search database for the purposes of locating case law that evaluated a design professional's liability due to action or inaction in the design phase and the impact to construction safety. The parameters of the search included State case law (all 50 states, including the District of Columbia, Federal Court of Appeals, and District Courts); and the keywords "design", "construction", and "safety"; the search was then narrowed with either the word "architect" or "engineer". The overwhelming majority of case law precedents find that the design professional is not liable for construction fatalities and disabling injuries. This finding primarily stems from the delineation of safety responsibility in construction contracts which holds the constructor solely responsible and the fact that the designer is responsible for the safety of the final product and the final occupants, not the temporary occupants (construction workers). Two cases were found that held the design professional liable for injury to construction workers for not considering construction site safety in the design phase of a project. Reviewing applicable case law was important to this research because it helped establish that construction fatalities and disabling injuries are linked to decisions made in the design phase. Furthermore, the research results are important in understanding specific ways that designers can be involved in designing for construction safety and at the same time reduce their overall legal liability. The key points of these two cases are summarized below.

<u>Evans v. Howard R. Green Co., Supreme Court of Iowa, 231 N.W.2d 907 (1975)</u>

Two constructors were killed by hydrogen sulfide gas asphyxiation during the construction of a sludge pit designed by Green, the Architect. Green knew of the potential for hydrogen sulfide gas accumulation in the pit and designed for such gas dissipation in the plans and specifications to ensure the safety of the facility's final occupant, but did not consider the potential hazard to construction workers. Green's main argument was that an architect could not be held liable for a claim until the project he designed was completed. The plans and specifications were not designed to provide for elimination of the hazard until after the project was completed. Green stated that the plans and specifications were produced for their final intended purpose. Furthermore, their argument was based on the presumption that the obligation for safety precautions and programs during construction rests solely on the contractor.

The Iowa Supreme Court found that Green was wrong in suggesting an architect's duty to exercise reasonable care lies suspended in construction and becomes binding and enforceable only when construction is completed. The Supreme Court of Iowa made several key statements to support the notion that an architect or design professional can be held liable for not considering construction worker safety and health in a project's design phase. The most relevant of these statements with respect to a designer's liability in the design of plans and specifications include:

- The Iowa Supreme Court does not agree that an architect can so easily wish off their duty to the general public for harm resulting from negligence in furnishing plans and specifications that result in damage during the work itself.
- An architect may be held liable for negligence for failing to exercise the ordinary skill of his profession, which results in the erection of an unsafe structure whereby anyone lawfully on the premises is injured (including construction workers).
- An architect's liability for negligence resulting in personal injury or death may be based upon his supervisory activities or upon defects in the plans.
- The liability of an architect is not limited to the owner who employed him.
- The claim brought against Green was that of a negligent design only.

Mallow v. Tucker, 245 Cal. App. 2d 700; 54 Cal. Rptr. 174 (1966)

In a second case, Mallow v. Tucker, a construction worker died from electrocution while jackhammering footings in the ground at the exact location called for by the architect's plans. The jackhammer broke into a high-voltage transmission line. Regarding the architect, the complaint alleged negligence of the architect in failing to warn of the existence and location of the high-voltage line, specifically by not showing it on the plans prepared for construction. A trial court, without a jury, found the architect negligent in preparing plans and specifications for construction. This negligence was the proximate cause of the accident. The architect appealed the decision, but The Court of Appeal of California found the architect to be negligent calling this case a paradigm case of an architect's negligence.

United States' Regulatory Actions

On April 23, 1987, a partially erected 16-story apartment tower, known as L'Ambinace Plaza, totally collapsed during construction killing 28 workers at the site (Heger, 1991). Heger (1991) described this incident as illustrative of the systemic failures with standard design and construction practice in the United States. Following this collapse, two separate but similar bills were introduced in Congress in 1988 that would have placed increased safety responsibility on the design professional. These bills were Senate Bill 2518 and House Bill 4856. The crux of these bills was that they involved the design professional in planning safety on construction sites and provided for a permitting system that would be approved by the design professional. Opposition to these bills from a large segment of the construction industry ultimately led to their failure (Gambatese, 2000a).

Comments from H. Berrien Zettler, Deputy Director of OSHA's Construction Directorate, support the notion that the Agency recognizes the impact a designer can have on construction site safety. Zettler maintains "OSHA believes that much could be done to improve safety and health on the worksite if we could get designers, engineers, and architects to pay attention from the beginning and design into blueprints measures that would lead to a safer workplace, to think of a construction process and design for that as well as for end use…." (Korman, 1999).

29 Code of Federal Regulations (CFR) 1926

In fact, OSHA has begun to recognize the impact of the design professional on construction safety through recent regulatory changes. In the safety standards for structural steel, Subpart R of 29 CFR 1926, OSHA recognizes the project structural engineer of record. This title is defined to mean the registered, licensed professional responsible for the design of structural steel framing and whose seal appears on the structural contract document.

As an example, OSHA now mandates a design criterion that requires all columns be anchored by a minimum of 4 anchor rods/bolts. In the public comment period, several commenters objected on the grounds that this section imposes design requirements for the structure. In their view, it is inappropriate for OSHA to set such requirements. Additionally, they indicated that engineers and designers specify by contract that the means and methods of construction are the contractor's responsibility. Another commenter questioned whether engineers and designers will follow the regulations in the design of the structure since the engineers and designers are not identified as being required to follow Subpart R since they are not the employer of the construction workers. Furthermore, it was added that engineers and designers design structures for compliance only with building codes and other related industry standards in mind to assure public safety after completion of the structure. OSHA, however, strongly believes that it is as appropriate for the Agency to require that avoidable safety hazards be engineered out for the protection of those erecting the building as it is for local jurisdictions to set design criteria for the safety of the building's occupants (Federal Register, 2001). This is a significant step for OSHA in recognizing the significant impact a design professional can have on construction site safety.

Washington State Building Code Council

In 1999, the Washington State Legislature considered a bill (House Bill 1224), which intended to minimize the number of falls to construction workers, maintenance workers, and home owners. The bill would have put a requirement in the State Building Code to design and install permanent anchor points on all buildings (WA State Building Code Council, 1999). Proponents of the bill stated that: it would decrease construction fatalities and decrease workers' compensation costs; injuries on roofs occur because existing structures have no permanent anchorage points for safety lines causing workers to ignore safety rules required by law; workers are more likely to use fall protection where anchor points already exist; and where permanent anchors exist falls are less common. Concerns with the bill's ideology were that anchor points are just one part of a fall prevention system; the safety of the permanent anchor over time is unknown and liability for future injury may be with the installer; and the presence of such an anchor would encourage a homeowner to perform work they would otherwise not perform. The bill failed in the State House, but the report provided detailed insight as to specifically how commercial and residential structures can be designed to facilitate construction safety, as well as safety during operations, maintenance, and demolition.

Construction Contracts

The nature of procuring construction is another barrier to implementing the design for construction safety concept. The life of a construction project is a phased process. First an owner or developer contracts with a designer to design a specific project; secondly, that design is offered to the public for an open bid; and lastly, the construction company who has been awarded the bid, usually based on a low bid system, builds the designed project. It is this separation of design and construction that is a barrier to implementing the design for construction safety concept in the construction industry. Contract language between designer and owner, and owner and constructor, clearly delineate that the constructor is fully and solely responsible for job site safety, means, methods, techniques, sequences, and procedures (Hinze, 2001).

Global Utilization of the Design for Construction Safety Concept

In Europe, since the advent of the Temporary and Mobile Construction Sites Directive of 1992, legislative duties have been placed on designers (Anderson, 2000). In response to this Directive, the United Kingdom passed into law the Construction (Design and Management) Regulations (CDM), which became effective March 31, 1995. Other European countries have since followed with similar regulations. The CDM regulations place requirements for construction worker safety and health on design professionals. The crux of the CDM regulations affecting the design profession is that it places a duty on the designer to ensure that any design prepared avoids foreseeable risk to construction workers (MacKenzie et al., 2000). The following text is from CDM Regulation 13, which specifically applies to design professionals.

> Requirements on designer
> 13.—(1) Except where a design is prepared in-house, no employer shall cause or permit any employee of his to prepare, and no self-employed person shall prepare, a design in respect of any project unless he has taken reasonable steps to ensure that the client for that project is aware of the duties to which the client is subject by virtue of these Regulations and of any practical guidance issued from time to time by the Commission with respect to the requirements of these Regulations.
> (2) Every designer shall—
>
> (a) ensure that any design he prepares and which he is aware will be used for the purposes of construction work includes among the design considerations adequate regard to the need—
>
> (i) to avoid foreseeable risks to the health and safety of any person at work carrying out construction work or cleaning work in or on the structure at any time, or of any person who may be affected by the work of such a person at work,
>
> (ii) to combat at source risks to the health and safety of any person at work carrying out construction work or cleaning work in or on the structure at any time, or of any person who may be affected by the work of such a person at work, and

(iii) to give priority to measures which will protect all persons at work who may carry out construction work or cleaning work at any time and all persons who may be affected by the work of such persons at work over measures which only protect each person carrying out such work;

(b) ensure that the design includes adequate information about any aspect of the project or structure or materials (including articles or substances) which might affect the health or safety of any person at work carrying out construction work or cleaning work in or on the structure at any time or of any person who may be affected by the work of such a person at work; and

(c) co-operate with the planning supervisor and with any other designer who is preparing any design in connection with the same project or structure so far as is necessary to enable each of them to comply with the requirements and prohibitions placed on him in relation to the project by or under the relevant statutory provisions.

(3) Sub-paragraphs (a) and (b) of paragraph (2) shall require the design to include only the matters referred to therein to the extent that it is reasonable to expect the designer to address them at the time the design is prepared and to the extent that it is otherwise reasonably practicable to do so.

The design profession has been slow in meeting their responsibilities under CDM (Baxendale and Jones, 1999). According to Anderson (2000), designers need clarity about what they are expected to achieve and guidance on how to complete those goals. Ash (2000) contended that success within CDM is often found when designers and constructors already work together more closely, such as in design-build and construction management companies. MacKenzie et al. (2000) highlighted five key issues impacting designer involvement and success within CDM. They are:

1. Many designers do not comply with the regulations, which place a duty to ensure that any design prepared avoids foreseeable risk.
2. Designers' knowledge of health and safety is limited and many are not interested.
3. Designers use off-the-shelf materials which causes implementation problems. They should do more to question what specifically causes construction fatalities and disabling injuries.

4. The Health and Safety Executive (UK's OSHA equivalent) must do more to encourage effective communication between designers and constructors at an early stage.

In Australia, three States (Queensland, South Australia, and Western Australia) have regulations in place that require the design professional to consider how the structure they design is going to be safely constructed (Bluff, 2003). The New South Wales State government requires that a management strategy exist for the design process which includes consideration, evaluation, and control of occupational safety and health during construction (New South Wales Construction Policy Steering Committee, 2000). Since 1998, this requirement has been mandatory for all State government construction projects having a value of AU$ 3 million or greater or on lesser-valued projects where the government agency determines there is a high safety risk.

The Influence of Design in Construction Accidents

Design professionals influence construction safety and health outcomes both directly and indirectly (Trethewy and Atkinson, 2003). These authors contend that direct designer influence would include the selection of a procurement system, preparation of contract documentation, sequencing of the construction process, and decisions regarding contract duration. Examples of indirect designer influence would include the selection of frame type, the specification of materials, and the design itself.

Smallwood (1997) interviewed general contractors in South Africa on a variety of construction safety issues. Fifty percent of the contractors identified the design as an aspect or factor that negatively affects health and safety, the highest of any component identified that negatively affected safety. Almost 90% of the contractors stated that there is a need for safety education at the university or technical college for architects and design engineers.

Abdelhamid and Everett (2000) evaluated and identified root causes of construction accidents in the United States and developed an accident root cause tracing model. The model developed is based on the existence of unsafe conditions and suggests these unsafe conditions are due to four causes: 1) management action/inaction; 2) unsafe acts of workers and coworkers; 3) non-human related events; and 4) an unsafe condition that is a natural part of the initial construction site conditions. This research is limited to activities and conditions on the construction site and ignores decisions upstream in the project concept and design phases.

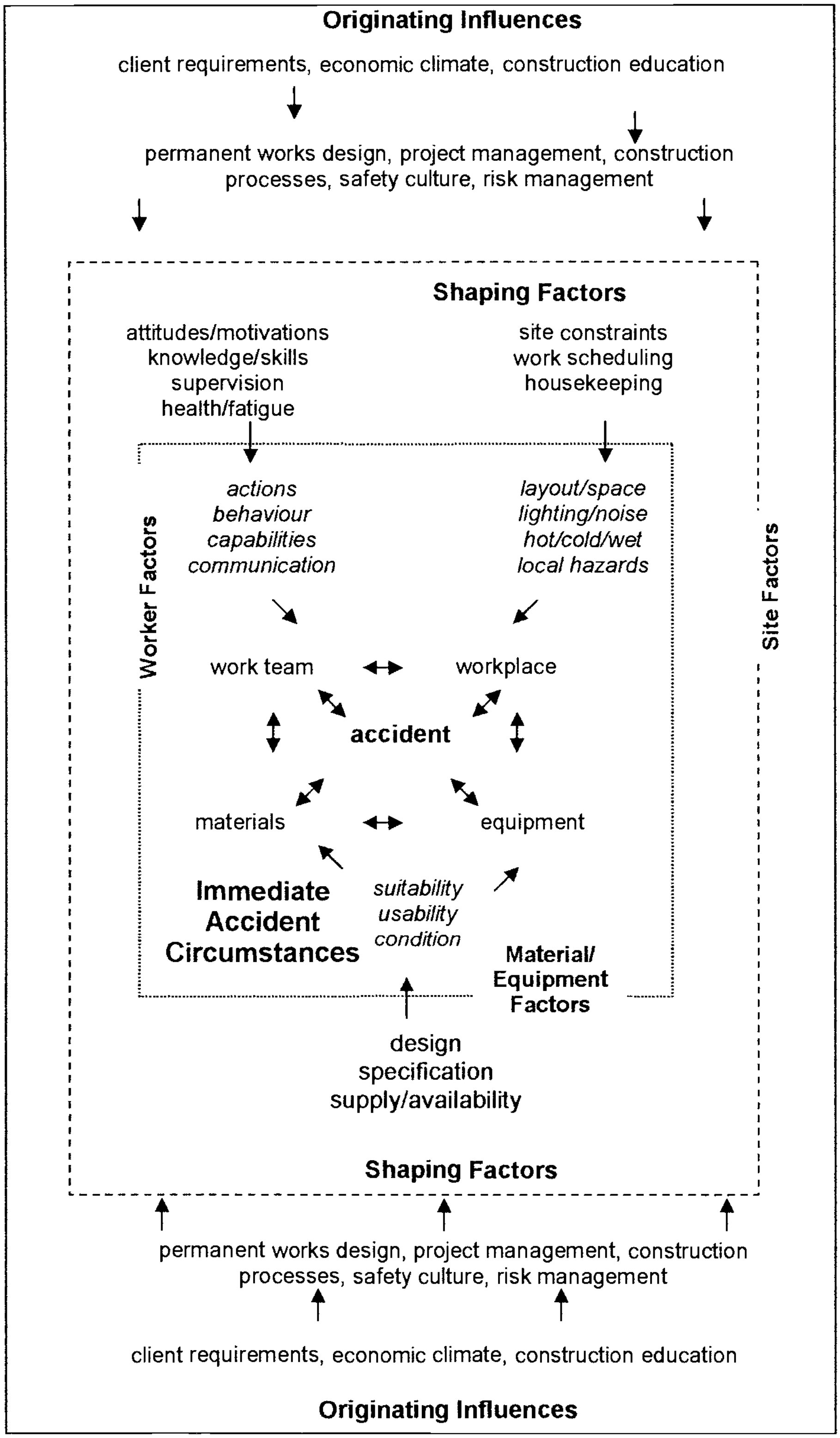
Haslam et al (2003) studied the causes of 100 construction accident in the United Kingdom and reported the associated causal factors. Permanent works designers (architects and design engineers) were found to could have reduced the risk associated in almost half the accidents. They also developed a construction accident causality model which describes immediate causes, shaping factors, and originating influences in construction accidents. They concluded that the permanent works design is an originating influence to the workers, the site, and the materials and equipment specified for construction. Their accident causality model is shown in Figure 2.

Beyond Previous Research

Gibb et al (2003) recommended that more research is needed to demonstrate the causal link between design and construction accidents. Smallwood (2000) recommended that extensive research be conducted to investigate the real influence of design to construction safety. To promote a clearer understanding of the relative importance of design as a factor in construction accidents, Saraji and Duff (2000) concluded that a more structured and detailed investigation process was necessary.

This research adds to the body of knowledge in several ways. The research tests the hypothesis that the design for construction safety concept is linked to construction fatalities and disabling injuries. The results can be utilized to remove the aforementioned barriers to implementation. By gaining an understanding of how the design for construction safety concept is linked to construction fatalities and disabling injuries, legal and regulatory views may shift and contract documents can be amended to include the utilization of the design for construction safety concept.

Figure 2. Accident Causality Model (Haslam et al, 2003)



This research goes beyond the previous research in several ways. First, in assessing causes of construction accidents, this research evaluates exclusively the design for construction safety concept in relation to construction fatalities and disabling injuries. The research adds the design for construction safety concept to Abdelhamid and Everett's research which evaluated only those root causes which could be influenced by the constructor during the construction phase. With regard to Haslam's recent research, this research will not only determine the percentage of construction fatalities and disabling injuries linked to the design for construction safety concept, but will also focus on those aspects of the project where the concept of designing for construction safety can have the most impact. Moreover, this research will utilize a newly developed design-construction incident investigation model. One of the self-reported weaknesses of the Haslam research is that the determinations of design influence depend on subjective judgment. By developing a design-construction incident investigation model, linking the design to construction incidents shifts that judgment from the subjective to the objective.

Chapter 3 – Methods

The problem addressed in this research was to determine the extent and magnitude to which the concept of designing for construction safety is linked to construction fatalities and disabling injuries. If a link can be established and understood, the concept of designing for construction safety can be effectively utilized to assist the construction industry to implement the concept of design for safety as an element of a systems approach to improving safety performance (i.e. reducing fatalities and disabling injuries). This chapter describes the methodologies employed to complete this research.

Acquiring Construction Accident Data

In order to understand how the design for construction safety concept is linked to fatalities and disabling injuries, a sufficiently large and representative database of these types of accidents must be available. Furthermore, the accident reports must contain sufficient information in order to evaluate whether the design for construction safety concept was linked to the causes of the incident.

One construction accident data source considered was to evaluate fatalities and disabling injuries as they occur. If a fatality or disabling injury occurred, a contact (e.g. regulatory agency, construction firm, insurance company) would notify the researcher. The research would then entail actually visiting construction sites and conducting an investigation which would also include such activities as reviewing the design, the plans and specifications for construction, and a discussion with the designer. While this source is believed to be a method that would yield the most useful data, this methodology was not pursued due to: access limitations in collecting data from construction sites; cost in visiting each site; the amount of time consumed for on-site visits to gather the appropriate information; and the total length of time to acquire a sufficient number of fatalities and disabling injuries for the database. For these reasons, it was decided to utilize an existing database of construction accidents.

The second source considered was the Occupational Safety and Health Administration (OSHA) website (www.osha.gov), which contains brief narratives of construction accidents for which an inspection was conducted. Upon review of the web site, it was found that the site does not contain updated narratives for construction accident inspections. In fact, very few of the reports contain an actual description of the accident. When a narrative report was available, the description was insufficiently brief; the report did not reveal information necessary to determine if the design for construction safety concept was linked to the incident.

A third potential source was the written accident inspection reports located at OSHA offices, which contain the inspector's field notes, pictures, copies of internal documents about the accident, witnesses and injured party statements, and architectural drawings. To obtain these OSHA inspection reports, permission from the Federal and/or State OSHA offices and their administrative assistance was needed. The researcher would travel to the respective OSHA offices to review the reports.

The fourth and final source considered was the National Institute for Occupational Safety and Health (NIOSH) Fatality Assessment Control and Evaluation (FACE) program. The FACE program is charged with the responsibility to investigate fatalities in all industries, to determine causal factors, and publish findings with the intent of providing educational materials so that accident causes can be eliminated or reduced. Approximately 500 construction industry fatality descriptions, which include a detailed narrative about the accident and the researchers' recommendations, are provided on the FACE internet site (www.cdc.gov/niosh/face/faceweb.html).

The OSHA field office reports and the NIOSH database of fatalities were chosen as the data sources for this research. Both databases are available to the public and are economically feasible to access. It is recognized that these organizations do not specifically collect data that evaluates accidents from a design perspective. Each database was evaluated to determine if sufficient information would be available to link the design for construction safety concept to the incident.

Information to determine whether the design for construction safety concept was linked to construction accidents can be extracted from OSHA construction accident inspection field notes. This was verified in a pilot test of 25 Oregon OSHA construction accident reports conducted in August 2003. A review of the NIOSH FACE web site showed that sufficient information is also contained within these reports.

OSHA Inspection Records

The Federal OSHA web site provides a database of construction inspections that were triggered by an accident. The web site collects and disseminates information on inspections performed in all States and Territories, includes all industries, and allows numerous search parameters including industry classification, State, year, and type of inspection. Each inspection is assigned a unique nine-digit identifier, known as an inspection activity number. This number was used to notify OSHA contacts which inspection reports were needed to conduct the research.

The States of Oregon, Washington, and California were included in this research because of their proximity to Oregon State University and because all cooperated with providing access to construction inspection records. Most State OSHA offices would not allow access to their files or set forth burdensome administrative requirements for access. For example, North Carolina required a 6-month notice of specific inspection activity numbers requested, and would only provide ten files at a time, which they would copy and send to the researcher for a fee. Virginia would only provide access to inspection activity records to an attorney or to family members of the injured party. Michigan was the only other state that granted access to inspection files for this research.

Contact persons within the California, Oregon, and Washington OSHA offices were identified through phone calls and electronic mail to the local offices. Access to inspection reports prompted by an accident for organizations with a construction industry Standard Industrial Classification (SIC) code (15, 16, and 17) was requested. SIC Codes 15, 16, and 17 are identifiers unique to construction firms and represent Building Construction General Contractors, Heavy Construction Other than Building Construction Contractors, and Construction Special Trade Contractors respectively. Only cases that had been classified as closed were available for review. Closed cases are those inspections where no further review would occur; open cases are still pending review of the violations or are under a legal review. Due to organizations contesting citations, many cases remain open for months or even years. In the year 2003, approximately 40% of all inspections were open and unavailable for review. For this reason, 2003 was excluded as a year to request data. The contacts in California and Oregon suggested that, due to administrative burdens such as retrieving files from archives and because most closed files prior to 2000 were purged, requested inspection files would be limited to the year 2000 and later. Therefore, closed cases in SIC codes 15, 16, and 17 from 2000 to 2002 were used for the OSHA database. These criteria were utilized to search and find the entire population of cases from the Federal OSHA website.

In California, inspection records are maintained by each district office where the inspection occurred. The State has 22 district offices. Visiting all 22 district offices was considered infeasible due to economic constraints. The Los Angeles area was chosen because there are numerous offices within a 50 mile radius. Four offices were conveniently selected in conjunction with California OSHA contact persons. Those offices were Torrance, Los Angeles, Anaheim, and Van Nuys. Oregon and Washington maintain all inspection reports in a central office and therefore, all construction industry inspections from 2000 – 2002 were included in the potential database.

Sample size determination

Chi-square tests of independence were used to determine if a relationship existed between the various aspects of the construction project and whether the incident was linked to the design for construction safety concept. Cramer's V statistic tested the strength of the relationship among the variables. Cohen (1988) provides sample size tables for chi-square tests which are dependent upon alpha, power, effect size, and degrees of freedom. A standard alpha level of 0.05 and a conventional power level of 0.80 were utilized for sample size determination. Effect size is the degree to which the researcher believes that the null hypothesis is false. Cohen (1992) recommends categorizing effect size into small, medium, and large for the purposes of ease of effect size determination. For this research the effect size is assumed to be medium, and thus is set at 0.30 (Cohen, 1992).

The largest category in this research was the design element at the time of the accident as categorized as one of the 16 Divisions specified by the Construction Specifications Institute (CSI). CSI creates voluntary standards for the purposes of organizing construction and the various design elements. The original assumption was that some categories would be eliminated as some of the Divisions (i.e. general requirements; specialties; special construction) relate to few if any construction incidents. Furthermore, it was assumed that several of the Divisions would be combined for the analysis (i.e. electrical and mechanical; finishes and furnishings; equipment and conveying systems; masonry and concrete). Therefore, it was assumed that the levels would be collapsed into a maximum of 9 levels to meet the expected value assumption of 5 in each cell for chi-square tests of independence. Table 1 shows the original 16 CSI Divisions and the hypothesized combined categories.

The comparison category is the determining questions as to whether the design for construction safety concept was linked to construction accidents and has a maximum of 3 levels (Yes, Possibly, or No). This yields a maximum degrees of freedom (df) of 16 using the formula, df = (c-1)*(r-1); (9-1)*(3-1); 8*2; or 16. Cohen (1988) recommends a sample size for a chi-square test of independence (alpha = 0.05, power = 0.80, effect size = 0.30, and df = 16) of 214 cases. This was set as the minimum valid case goal for both the OSHA and NIOSH FACE databases. A small number of cases were actually classified as “Maybe”, and for all chi-square analyses the “Maybe” and ”Yes” responses were combined in order to meet the minimum expected frequency assumption of five in each cell (see Chapter 4 for more detail).

Table 1. Original 16 CSI Divisions and the hypothesized combinations

Original 16 CSI Divisions	**Hypothesized Combinations**
Division 1 – General Requirements	Eliminated
Division 2 – Site work	1. Site Work
Division 3 – Concrete	2. Concrete and Masonry
Division 4 – Masonry	Combined previously
Division 5 – Metals	3. Metals
Division 6 – Wood and Plastics	4. Wood and Plastics
Division 7 – Thermal and Moisture Protection	5. Thermal and Moisture Protection
Division 8 – Doors and Windows	6. Doors and Windows
Division 9 – Finishes	7. Finishes and Furnishings
Division 10 – Specialties	Eliminated
Division 11 – Equipment	8. Equipment and Conveying Systems
Division 12 – Furnishings	Combined previously
Division 13 – Special Construction	Eliminated
Division 14 – Conveying Systems	Combined previously
Division 15 – Mechanical	9. Mechanical and Electrical
Division 16 – Electrical	Combined previously

Case selection – OSHA inspection records

Individual OSHA inspection cases that met the criteria, and its corresponding nine-digit identification number, were found through the Federal OSHA website. A search was performed that included the 2-digit SIC code (15, 16, or 17), the individual State (OR, WA, or CA), and the date of inspection (01/01/2000 to 12/31/2002). This search was further narrowed by selecting only cases that were closed (denoted by non-italicized case numbers on the web site) and inspections that were prompted by an accident (as opposed to planned, program related, referral, or complaint-driven inspections). In California, these cases were further narrowed to the four offices selected for this research.

Six offices were utilized for the database of cases in this research. Based on the results of the pilot test it was hypothesized that 15% to 25% of the cases would either not be available or would contain incomplete information for a determination regarding whether the design for construction safety concept was linked to the incident. Before the data collection began a worst-case scenario of 75% success rate with the cases was assumed. The total number of cases selected from the six offices would be 286 to yield the 214 case minimum. This was determined by the following formula:

Number of cases needed = (number of cases selected)*(success rate)

Therefore, at least 48 cases would need to be selected from each office (286/6 = 48). Fifty cases were randomly selected from the list at each office using Statistical Package for the Social Sciences (SPSS) random case selection function. Only 35 cases were located from the Torrance office that met the requirements to be included in the study and all were requested for review. The case numbers were forwarded to each office so the files could be retrieved from archive. Seventy-nine percent (226 of 285) of the cases were actually utilized in the research. Reasons that individual cases were not utilized in the research were due to a lack of information in the file, the accident was deemed not work-related by the OSHA inspector (e.g. heart attack), or the file was not available. The total number of cases found from each office, the number randomly selected, and the number actually utilized in the study are given in Table 2.

Table 2. Summary of OSHA cases at each office

Office	**Total # of cases that met the criteria**	**# of cases selected**	**# of valid cases**
Oregon	108	50	44
Washington	62	50	34
California – Van Nuys	53	50	42
California – Anaheim	147	50	43
California – Torrance	35	35	26
California – Los Angeles	65	50	37
TOTAL	470	285	226

NIOSH FACE Database

The NIOSH FACE is a research program designed to identify and study fatal occupational injuries. The goal of the FACE program is to prevent occupational fatalities across the nation by identifying and investigating work situations at high risk for injury and then formulating and disseminating prevention strategies to those who can intervene in the workplace (NIOSH, 2003). The complete investigation reports for construction fatalities, as well as those for all industries, are available on the NIOSH FACE website. No specific contact information or formal information request for access is required.

The NIOSH FACE program does not investigate every construction fatality. Construction fatalities are selected based upon requests from OSHA and on special emphasis programs. For example, recent emphasis investigations targeted Hispanic workers, young workers, steel erectors, and roofers (Cassini, 2003). This adds a potential selection bias to the methodology. The list of cases from NIOSH is not inclusive of every construction fatality, and every fatality did not have an equal chance of being selected for investigation by NIOSH. A chi-square goodness of fit test compared the distribution of the fatalities in the NIOSH database to the actual distribution of construction fatalities in the United States as categorized by SIC Code. The distribution of fatalities analyzed from the NIOSH database is similar to the expected distribution of fatalities in the United States construction industry ($p=0.536$).

A review of the NIOSH FACE reports shows that over time the quality of the information in the reports improved and began to provide more detailed information. Reports from the 1990's contained more detailed information about the incident than did reports from the early 1980's. For this reason, only reports from 1990 forward were utilized for this research.

To meet the 214 minimum valid case goal, 230 cases were randomly selected from the NIOSH FACE database. It was assumed that a majority of the cases would be available and would contain sufficient information to determine whether the fatality was linked to the design for construction safety concept. Ninety-seven percent (224 of 230) of the cases were actually utilized in the research. The six cases not utilized were due to invalid web-links from the NIOSH FACE web site.

Design-Construction Incident Investigation Model Development and Use

The problem addressed in this research was to determine the extent and magnitude that the design for construction safety concept was linked to construction fatalities and disabling injuries. In order to evaluate whether the incident was linked to the design for construction safety concept, a specific and objective set of criteria would ideally be utilized. No objective model existed to facilitate linking the design for construction safety concept to construction incidents. Therefore, one was created utilizing previous research. Specifically, the incidents were evaluated to determine:

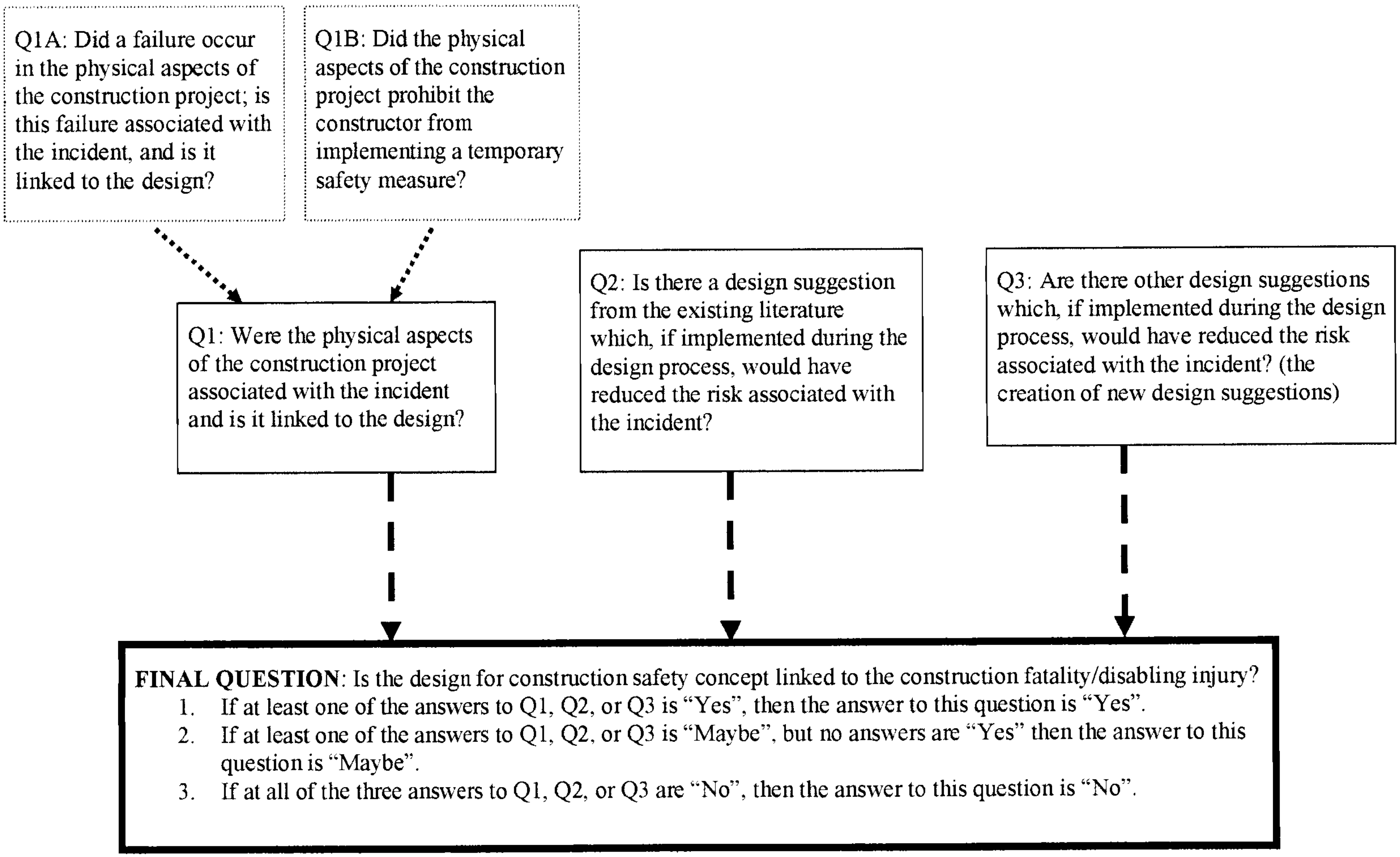
1. If the permanent features of the construction project were a causal factor in the incident. Linkage to the design for construction safety concept was affirmed if the structure failed during construction because it was not designed to withstand construction activities (e.g. L'Ambiance Plaza) or if the features of the permanent structure prohibited the constructor from implementing a temporary safety device (e.g. the constructor could not implement temporary fall protection systems due to the permanent features of the construction project).
2. If one of the previously developed design suggestions (Gambatese, 1996) could have been implemented in the design phase of the project. Linkage to the design for construction safety concept was affirmed if one or more of these design suggestions would have reduced the risk posed to the constructor or provided a greater opportunity for the constructor to reduce risk by facilitating the utilization of temporary safety measures and thus prevent the accident.
3. How the design or the design process could have been modified to prevent the incident. This portion of the research developed new design suggestions, adding to the existing body of knowledge in #2 above.

These three questions formed the model by which each incident was evaluated as to whether the incident could be linked to the design for construction safety concept. Each question was answered as a "Yes", "Maybe", or "No". This method is similar to Haslam's method of determining whether the design was a causal factor in the accident (Haslam, 2003). The model created for this research is shown in Figure 3.

Model Validity

The concept being measured is whether construction fatalities and disabling injuries are linked to the design for construction safety concept. There are no criterion tests or models by which to measure this concept nor is there a standard for determining how much validity an instrument for this purpose will exhibit. The model exhibits face and content validity as determined in consultation with the dissertation committee members during the November 3, 2003 dissertation proposal meeting. In addition, The Center to Protect Workers' Rights (CPWR) also reviewed the investigation model as part of a grant application procedure. The investigation model was developed from the literature review where the only objective list of design suggestions that could be utilized and potentially linked to construction incidents was developed by Gambatese (1996). Gambatese's suggestion is question 2 in the model and established face and content validity. Question 3 developed new design suggestions based on the review of the construction incidents. The development and initial use of these new suggestions is subjective and their use in this research established face validity only. Question 1 evaluated the link between the physical aspects of the construction and the incident (the structure itself can fail or prohibit the constructor from implementing a temporary safety measure). The incidents were reviewed to determine if the structural failure was caused by the constructor or by design decisions.

Figure 3. Design – Construction Incident Investigation Model



For all questions, if a definite link to the design for construction safety concept was determined, then the question was answered as a "Yes". When it appeared likely that the connection could be made to the design process but the information provided was insufficient to be labeled a "Yes", the question was answered "Maybe". If the incident was caused solely by the constructor or if there was no failure in the physical aspects of the project, then the question was answered "No". Examples of the detailed thought process for each determination question are contained in Chapter 4.

Model Reliability

Questions 1 and 2 presented an application which can be tested and determined by anyone with access to the databases of construction incidents and with access to the complete list of existing design suggestions. These determinations are objective; however, there is the possibility of measurement error due to biases and knowledge of the researcher. Consider if the researcher were a design professional. A design professional would have bias in that they would not consider incidents linked to the design for construction safety concept when in reality they actually were linked. This is due to the aforementioned barriers (legal/liability, contractual, regulatory) that preclude design professionals from implementing the concept as a standard practice. Consider if the researcher were a constructor. Because of the relationship between designer and constructor in the construction industry (separate entities), there would be a potential for a constructor to link incidents to the concept when in reality they were not linked. An adversarial relationship frequently exists between constructor and designer, particularly in the general contracting method of procuring construction (Hinze, 2001). Furthermore, knowledge of the design for construction safety concept is necessary in order to establish a link between it and construction fatalities and disabling injuries. Because the researcher is a safety professional with knowledge of the concept, a unique and unbiased perspective is produced. This position is unique because the researcher has no liability in making the decisions nor is any blame associated with the decisions. Measurement error over the large sample of cases in this study is random error. Some cases were linked to the concept when in reality they were not and others were not linked to the concept when in reality they were linked. The amount of measurement error, as random error, is small and was limited through the operational definitions (Chapter 1) and the design-construction incident investigation model.

Question 3, the development of new design suggestions, is subjective and prone to the bias and knowledge of the researcher conducting the measurement. The error is systematic in that the more knowledge one has of the design for construction safety concept, the more new design suggestions can be developed from the research. The amount of systematic error is small and was limited through the use of the operational definitions and by the design-construction incident investigation model.

One intent of the research was to encourage additional incident investigation that considers the link to the design for construction safety concept and this model provides a reliable method to accomplish further investigation. This research is reproducible and an external audit could be performed. The affirmative responses to each case reviewed are listed, summarized, and the decisions have been documented in Appendix A for the NIOSH FACE dataset and in Appendix B for the OSHA dataset.

Chapter 4 – Results and Discussion

The purpose of this chapter is to present and analyze data extracted from the Occupational Safety and Health Administration (OSHA) construction inspection reports and the National Institute for Occupational Safety and Health Administration (NIOSH) Fatality Assessment Control and Evaluation (FACE) program reports with regards to the design for construction safety concept. This section provides descriptive statistics, evaluates each hypothesis with the data collected, and provides discussion. Detailed statistical analysis from Statistical Package for the Social Sciences (SPSS) is attached as Appendix C for the NIOSH FACE data analyses and Appendix D for the OSHA inspection report analyses.

Hypothesis 1

$H1_A$: A noteworthy proportion of construction fatalities and disabling injuries are linked to the design for construction safety concept.

In their report, Healthy People 2010: Understanding and Improving Health, the United States' Department of Health and Human Services (DHSS) set work-related fatality and injury reduction objectives for specific industries. Using 1998 levels as a baseline, the goal for the construction industry is to reduce the percentage of both work-related deaths and injuries by 30% (U.S. DHHS, 2002). The OSHA database demonstrated that 21.2% of the incidents were linked to the design for construction safety concept and 4.0% were categorized as maybe being linked to the design for construction safety concept. For example, one residential constructor was working on a tilt-up wall laid on the second story near an open-sided platform at the top of a stair way. The worker fell over the unprotected side. If the design suggestion "design and schedule permanent stairways to be built as soon as possible in the construction phase and used by the construction workers" had been implemented, the risk associated with the incident would have been reduced and thus the incident may have been prevented. The NIOSH database proved to be more associated with the concept; 39.3% of the fatalities were linked to the design for construction safety concept while an additional 2.7% as maybe linked. For example, a constructor was in the process of covering ductwork with a fire blanket and either tripped on angle iron and fell into, or stepped backwards into, a skylight opening and fell. If the design suggestions "design domed, rather than flat, skylights with shatterproof glass or add strengthening wires and/or design guardrail protection around skylights" had been implemented, the risk associated with the incident would have been reduced and thus the incident may have been prevented. Detailed summaries of the incidents linked to the design for construction safety concept are attached in Appendix A for the NIOSH FACE dataset and in Appendix B for the OSHA dataset.

The difference in the results associated with the two databases is largely due to the purpose of each organization. OSHA investigates all fatalities and injuries that result in hospitalization. Other disabling injuries are also investigated as resources permit. OSHA's purpose is to determine compliance and therefore the inspector's notes are geared towards those facts which determine compliance status. The purpose of the NIOSH FACE program is to investigate fatalities and determine causal factors such that the information can be utilized to decrease the occurrence of fatalities. A greater percentage was linked in the NIOSH FACE database because the information gathered was more aligned with the purpose of this study; the reports contained detailed information, determined causal factors, and sometimes included mention of the design process. Therefore, these varied results were unsurprising.

It is of interest to note that a difference between fatalities and disabling injuries existed within the OSHA reports; 40.5% (15 of 37) of fatalities were linked to the design for construction safety concept, while only 22.2% (42 of 189) disabling injuries were linked to the design for construction safety concept. When OSHA conducted a fatality investigation much more information existed in the files compared to disabling injury reports. Because of the amount and type of information collected in fatality investigations, a greater percentage of fatalities were linked to the design for construction safety concept. There is no theoretical basis that would suggest fatalities are linked more often than disabling injuries; it is a matter of the amount and type of information gathered.

The results of each database are summarized in Table 3 and also include summaries of the three questions. The results strongly suggest adopting the concept of designing for construction safety in the United States. The implementation of this concept would support the DHSS's goals of reducing construction fatalities and injuries by 30% by 2010.

Table 3: Summary of incidents linked to the design for construction safety concept

Database	**Q1: Physical Aspects?**			**Q2: Existing Design Suggestion**			**Q3: New Design Suggestion?**			**Is design for construction safety concept linked?**		
	Yes	*Maybe*	*No*	*Yes*	*Maybe*	*No*	*Yes*	*Maybe*	*No*	*Yes*	*Maybe*	*No*
OSHA	1.8	3.5	94.7	17.7	1.8	80.5	11.9	1.8	86.3	21.2	4.0	74.8
NIOSH	4.5	0	95.5	34.8	2.7	62.5	18.7	0	81.3	39.3	2.7	58.0

Results are in percentages

In determining the link between the incident and the design for construction safety concept, the design-construction incident investigation model was utilized as discussed in Chapter 3. Question 1 determined the link between the incident and the physical aspects of the project. Question 2 evaluated each incident with respect to the existing design suggestions. The existing design suggestions answered as a "Yes" or a "Maybe" are summarized in Table 4. Question 3 determined if new design suggestions could be developed; those that were developed and answered as a "Yes" or a "Maybe" are summarized in Table 5. A complete list of all "Yes' and "Maybe" responded cases, a brief description, the determinant answers to the three questions, and the design suggestion linked is provided in Appendix A for the NIOSH FACE data and Appendix B for the OSHA inspection report data.

Table 4. Summary of Existing Design Suggestions Utilized

Design Suggestion	FACE data	OSHA data	Total
Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.	47	23	70
Disconnect, reduce voltage, or re-route power lines around the project before it begins.	13	5	18
Include the name, address, and telephone number of local utility companies on the drawings.	12	4	16
Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure.	10	5	15
Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails.	7	4	11
Provide permanent guardrails around floor openings.	4	6	10
Design domed, rather than flat, skylights with shatterproof glass or add strengthening wires. Design guardrail protection around skylights.	6	1	7
Design the parapet to be 42 inches tall. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or future roof maintenance.	6	0	6
Review the condition and integrity of the existing structure and indicate any known hazards or deficiencies on the contract drawings.	4	2	6
Design and schedule permanent stairways to be built as soon as possible in the construction phase and used by the construction workers.	2	1	3
Minimize the amount of night work.	0	3	3
Design perimeter beams and beams above floor openings to support lifelines (minimum dead load of 5400 lbs.). Design connection points along the beams for the lifelines. Note on the contract drawings which beams are designed to support lifelines, how many lifelines, and at what locations along the beams.	2	0	2
Design the slope, width, height, turning radius, and surface treatment of traffic surfaces with consideration of the anticipated size, weight, and maneuverability of the construction equipment.	2	0	2

Table 4 continued

Design Suggestion	FACE data	OSHA data	Total
During road work, slow down the ongoing traffic as much as possible by closing down adjacent lanes, posting flag-people to control traffic, or running lead cars to guide the adjacent traffic.	1	1	2
Indicate on the contract drawings the locations of existing underground utilities and mark a clear zone around the utilities.	0	2	2
Note on the drawings the source of information and level of certainty on the location of underground utilities.	0	2	2
Orient the project layout or grade the site accordingly to minimize the amount of work on steep slopes.	1	0	1
Design the finished floor around mechanical equipment to be at one level (no steps, blockouts, slab depressions, etc.).	1	0	1
Allow for pedestrian traffic to be isolated from construction vehicular traffic.	1	0	1
Design and schedule materials and equipment to be painted and/or insulated prior to erection or placement.	1	0	1
Allow adequate clearance between the power lines and the structure.	1	0	1
Employ police officers to patrol around the project site to help with traffic control	1	0	1
For pre-cast concrete members, provide inserts or other devices to attach fall protection lines.	1	0	1
Re-route the power lines around the project site before construction begins.	1	0	1
Avoid road work and maintenance during peak traffic volume periods of the day.	1	0	1
For access doors through floors, use doors which immediately provide guarded entry around the hole perimeter when the door is opened	1	0	1
Design members which are of consistent size, light weight, and easy to handle.	1	0	1
Avoid stair landings constructed separate from the stairs.	1	0	1
Consider using prefabricated stairways which can be erected as one assembly.	1	0	1
Design and schedule safe tie-ins to existing utilities.	1	0	1

Table 4 continued

Design Suggestion	FACE data	OSHA data	Total
Ensure that the electrical system design meets all National Electric Code requirements and the requirements of National Fire Protection Association.	1	0	1
Consider using pre-fabricated metal timber fasteners for wood connections instead of end nailing or toe nailing.	0	1	1
Design handrails and the top rails of a stair rail system to withstand at least 200 lbs. applied within 2 in. of the top edge in any downward or outward direction, at any point along the top edge.	0	1	1
Design and schedule handrails, guardrails, and stairrails to be erected as part of the structural steel erection.	0	1	1
Provide a guardrail along the perimeter of the tank roof.	0	1	1
Provide connection points for lifelines at the center of the tank roof.	0	1	1
Consider the erection process when designing and locating member connections.	0	1	1
Consider alternative steel framing systems which reduce the number of elements and where beams are landed on supports rather than suspended between them.	0	1	1
Avoid performing road work on Friday and Saturday nights.	0	1	1
Detour public traffic around the project site.	0	1	1
To prevent accidents resulting from tired construction workers, do not allow schedules which contain sustained overtime.	0	1	1
In embankments directly adjacent to the road edge, provide an initial bench at the road grade to provide room for crews to work.	0	1	1
Provide structural support at the edge of roadways to keep heavy construction equipment from crushing the edge and overturning.	0	1	1
Totals	131	71	202

Table 5. Summary of New Design Suggestions

Design Suggestion	FACE data	OSHA data	Total
Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and /or holes in perimeter for guardrail attachment.	9	9	18
Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.	7	4	11
When design features, such as ventilation systems, trash chutes, chimneys, elevators, etc. cause floor openings to occur during construction, provide a warning in the plans and specifications for construction, and design in permanent guardrail systems and sequence them in early in the construction process for use by all contractors.	4	3	7
Before demolishing and renovating any roof structure which is damaged, ensure that an engineering survey is performed by a competent person to determine the condition of the roof, trusses, purlins, and the structure itself to evaluate the possibility of the structure and its components failing during the work, and to evaluate how fall protection devices will be incorporated into a damaged structure.	3	2	5
For tower type structures, design a cable-type lifeline system into the structure that allows workers to be hooked onto the structure and allows for their movement up and down the structure.	4	0	4
Design scaffolding tie-off points into exterior walls of buildings for construction and renovation purposes.	2	2	4
Design and schedule handrails, guardrails, and stairrails to be built as part of the erection process.	1	2	3
Before demolishing and renovating any structure, ensure that an engineering survey is performed by a competent person to determine the condition of the structure, evaluate the possibility of unplanned collapse, and plan for potential hazards.	2	0	2
Design appropriate tank anchor points on the interior of the tank for construction and maintenance purposes.	1	1	2

Table 5 continued

Design Suggestion	FACE data	OSHA data	Total
Consider the existing site and its potential hazards in relation to the heavy equipment required to perform the scope of work. Provide a warning and information to constructors.	0	2	2
Design appropriate and permanent fall protection systems for inside elevator shafts to be utilized during construction and maintenance. Consider anchorage points and lifeline attachments.	0	2	2
Consider alternative methods for pouring concrete when specifying concrete pours below or next to overhead power lines, such as the use of a pumping truck.	1	0	1
Consider pre-fabricating work stations and fall protection systems into the constructed structure.	1	0	1
Provide warning through the plans and specifications when electrical systems create floor openings.	1	0	1
Specify the need for a permit-required confined space program when utilizing flammable materials inside tanks.	1	0	1
When specifying roofing materials which are not suitable for walking, such as corrugated fiberglass panels, ensure they are distinguishable from safe secure walking surfaces on the roof, or install guardrails around the surfaces not suitable for walking.	1	0	1
When designing an atrium in a building, design permanent guardrails, anchor points, or other such fall protection mechanisms so they are sequenced early in to the schedule to allow their use by construction workers.	1	0	1
Where job site access is limited, consideration should be given to alternating work schedules or short term interruption of work tasks to allow additional clearance for crane set-up and use.	1	0	1
Do not design elevated exterior structures, equipment, etc. next to roof edges.	1	0	1
Design periodic turnouts into long straight roadways. This allows trucks to turn around, minimizes reverse motion, and allows for passing of other vehicles.	1	0	1
During roadwork, when the work zone of the trucks conflicts with the work zone of the flaggers, establish an alternate layout of the work zone, such as closing additional lanes of the highway.	1	0	1

Table 5 continued

Design Suggestion	FACE data	OSHA data	Total
For projects that occur on or near steep slopes, provide a warning and information about the site conditions in the construction documents.	1	0	1
In the design of commercial and industrial buildings, consider if sheet metal could be utilized as a walking surface (either intentionally or unintentionally), and specify appropriate sheet metal gauge for walking and the appropriate screws for strengthening.	1	0	1
During highway construction activities, posted speed limits should be reduced and strictly enforced to increase the safety of highway workers.	1	0	1
Consider that structural members can be utilized as work areas during construction, and design for their stability.	0	1	1
Consider the environmental conditions and the other construction work occurring near trenching and how it will affect the condition of the trench.	0	1	1
Do not specify trenching activities adjacent to existing structures. Review how the specified trenching activities will affect the adjacent structure.	0	1	1
Evaluate soil conditions, provide that information, and specify proper trenching and shoring based on the conditions in relation to the specified work.	0	1	1
Consider electrical conduit/wiring and sequence it in before permanent ceilings or walls are constructed which would limit access during installation.	0	1	1
Design wood framed walls to be no more than 8' high; when higher walls are specified, provide a warning to the constructors to not lift these higher walls manually.	0	1	1
Totals	46	33	79

Forty-six percent (70 of 151) of the incidents linked to the design for construction safety concept were linked by this suggestion: Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. This result strongly suggests considering the concept to reduce fall hazards. This existing suggestion was further narrowed to specific types of construction projects by the development of new design suggestions. Eleven percent (18 of 151) were specifically related to falls from residential construction; an additional 7.3% (11 of 151) were linked to commercial building construction. This finding supports the Washington State Legislature's efforts to change existing building codes to include permanent fall protection systems in residential and commercial construction.

Identifying, communicating, and considering overhead and underground electrical lines and other utilities in relation to the specified construction work exhibited considerable magnitude in reducing construction fatalities and disabling injuries. The following design suggestions were linked to construction incidents: disconnect, reduce voltage, or re-route power lines around the project before it begins (18 of 151, or 12%); include the name, address, and telephone number of local utility companies on the drawings (16 of 151, or 10.6%); and locate on contract drawing the existence of overhead power lines and their location in relation to the new structure (15 of 151, 10%). The prevailing view of construction safety suggests that the recognition and control of electrical contact hazards during construction projects is the burden of the constructor whose employees may come in contact with these hazards during the course of work. However, incorporation of the design for construction safety concept in pre-construction project phases provides the following safety benefits:

1. design professionals could alter the physical aspects of the project to minimize or eliminate the electrical contact hazards;
2. competent persons (engineers) have the opportunity to recognize, communicate, and minimize potentially hazardous conditions (which some constructors may not have the expertise to do so);

3. would allow, and potentially mandate, constructors to develop specific temporary safety measures and these measures could be incorporated into their bids; and
4. safety is emphasized as a project priority to all parties early in the project's life cycle.

Hypothesis 2

$H2_A$: There is a difference in whether the design for construction safety concept was linked in accidents that resulted in a fatality compared to those resulting in a disabling injury (OSHA database only).

This hypothesis was tested to determine the differences in amount of information generated by fatality and disabling injury investigations. As stated previously, there is no theoretical basis why fatalities and disabling injuries would yield different results. Of the 226 OSHA investigations reviewed, 37 were fatalities (16.4%) and 189 were disabling injuries (83.6%). Fatalities were more likely to be related to the design for construction safety concept than were injuries ($p = 0.019$, Cramer's $V = 0.156$). This finding is supported by the fact that the NIOSH database, which included only fatalities, provided a stronger link to the design for construction safety concept, as discussed in Hypothesis 1. However, the difference is due to the dissimilar amount of information between fatality and disabling injury reports; there was more information in the fatality reports which enabled a link to be made to the design for construction safety concept.

Hypothesis 3

$H3_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to the nature of the construction project (i.e. new construction, upgrade, and demolition).

The nature of the construction project was tested to determine in which project the concept of designing for construction safety would have the most impact in reducing fatalities and disabling injuries. New construction involves any new building or engineering work; upgrade includes maintenance, repair, renovation, and alteration work; and demolition involves any destruction of part or all of a previously constructed project. Of the 226 OSHA inspections analyzed, 209 or 92.5% were validly categorized by nature of the construction project. There were 8 demolition projects, 84 upgrade projects, and 117 new construction projects in the dataset. Since there were only 8 demolition projects, this affected the expected cell assumption of the chi-square test. Demolition projects can not logically be combined with new construction or upgrade, and therefore for the chi-square analysis they were deleted from the dataset; only new construction and upgrade construction were analyzed. In the NIOSH dataset, 219 or 97.8 % were validly categorized by nature of the construction project. Seven, or 3.1%, were demolition projects. Similar to the OSHA dataset, this small number affected the expected cell assumption of the chi-square test and the demolition projects were deleted from the analysis. Table 6 summarizes incidents by nature of the construction project.

Table 6. Summary of incidents by nature of the construction project

	OSHA	**OSHA %**	**NIOSH**	**NIOSH %**
New Construction	117	56.0	116	53.0
Upgrade	84	40.2	96	43.8
Demolition	8	3.8	7	3.2
Totals	209		219	

The OSHA dataset revealed that construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to the nature of the construction project ($p = 0.015$, Cramer's $V = 0.17$). Construction fatalities and disabling injuries that are linked to the design for construction safety concept are more likely in new construction projects compared to upgrade construction. In contrast to the OSHA dataset, the nature of the construction project had no relationship to fatalities linked to the design for construction safety concept in the NIOSH dataset ($p = 0.531$). The NIOSH data supports the notion that the design for safety concept can positively affect the safety of construction workers during the initial construction work and subsequent maintenance, renovation, and repair work. This finding is important because it proves that the concept affects more than just safety during initial construction; it highlights a motivation for owners to implement the concept as it will enhance the safety of subsequent maintenance activities. The differences in the results in the two databases are due to the dissimilar and varying amount of information in each database.

Hypothesis 4

$H4_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to the type of construction project (i.e. residential, commercial, engineering, and industrial construction).

The type of the construction project was analyzed to determine if project type is linked to the concept of designing for construction safety and which type has the most impact in reducing fatalities and disabling injuries. Residential construction includes single-family homes, townhouse and condominium communities, and apartments. Commercial construction includes institutional, educational, religious buildings, and light industrial buildings. Engineering projects include earth works and structures that are not architectural in nature. Examples include highways, bridges, utility trenches, and utility lines. Industrial construction includes projects associated with the manufacture and production of products, such as steel mills and electric generation stations. A descriptive summary of the breakdown of incidents classified by the type of construction project are shown in Table 7.

Table 7. Summary of incidents by type of construction project

	OSHA	OSHA %	NIOSH	NIOSH %
Residential	69	32.9	51	23.7
Commercial	78	37.1	73	34.0
Engineering	41	19.5	55	25.6
Industrial	22	10.5	36	16.7
Totals	210		215	

Analysis of the OSHA data showed that construction fatalities and disabling injuries that are linked to the design for construction safety concept were not significantly related to the type of construction project ($p = 0.059$, Cramer's $V = 0.188$). The NIOSH FACE dataset also revealed no relationship between construction fatalities that are linked to the design for construction safety concept and the type of construction project ($p = 0.214$, Cramer's $V = 0.144$). Fatalities that were linked to the design for construction safety concept were equally distributed across the type of construction projects. These results demonstrated that the concept can have a positive impact in reducing risk in all types of construction projects. The existing and newly developed design suggestions are not limited to specific types of projects.

Hypothesis 5

$H5_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to whether OSHA issued a citation (OSHA database only).

This hypothesis was tested to determine if there is any relationship to the fact that OSHA did not issue a citation because there is no regulation that includes the design for construction safety concept in the United States. There were 127 citations, or 56.2% of the cases. Construction fatalities and disabling injuries that are linked to the design for construction safety concept are unrelated to whether OSHA issued a citation to the injured or deceased's employer ($p = 0.22$). The NIOSH

FACE investigations do not report whether OSHA issued a citation to the deceased's employer and therefore no data was collected.

Hypothesis 6

$H6_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to the design element constructed at the time of the accident (design element is categorized as one of the 16 Divisions as specified by the Construction Specifications Institute).

This relationship was tested to determine if there are specific design elements that should be evaluated more closely or redesigned during the design process. To conduct the chi-square analysis with the expected frequency assumption, certain categories were combined. Division 7 (thermal and moisture protection) and Division 8 (door and windows) were combined into one category as these primarily encompass the exterior features of a constructed building (roof, weatherproofing materials, skylights). Electrical (Division 15) and Mechanical (Division 16) were combined as these are equipment related scopes of work. Concrete (Division 3), Masonry (Division 4), and Metals (Division 5) were combined; these features relate to the structure of the building. Categories combined as "Other" include: Finishes, Specialties, Equipment, Furnishings, Special Construction, and Conveying Systems. Although these categories are not all related, they were combined out of necessity to perform the chi-square analysis.

The categories in the NIOSH dataset also need to be combined in order to conduct the chi-square analysis. Similar categorical combinations to the OSHA dataset were considered, however, due to the equal distribution of "yes" and "no" responses, less combinations were required. Finishes was a separate category. Equipment and conveying systems were combined. As opposed to being combined with masonry and concrete, the metals category was a separate category. Table 8 summarizes the incidents in each dataset by design element.

Table 8. Summary of incidents by design element

	OSHA	OSHA %	NIOSH	NIOSH %
Specialties	2	1.0	0	-
Equipment	4	1.9	9	4.0
Furnishings	1	0.5	0	-
Special Construction	2	1.0	0	-
Conveying Systems	3	1.4	4	1.8
Mechanical	13	6.3	10	4.5
Electrical	17	8.2	17	7.6
Site Work	64	30.8	57	25.4
Concrete	11	5.3	14	6.3
Masonry	3	1.4	6	2.7
Metals	21	10.1	30	13.4
Wood and Plastics	23	11.1	12	5.4
Thermal and Moisture Protection	24	11.5	39	17.4
Doors and Windows	3	1.4	9	4.0
Finishes	17	8.2	17	7.6
Totals	208		224	

In the OSHA dataset, construction fatalities and disabling injuries linked to the design for construction safety concept were related to the design element being constructed at the time of the accident ($p = 0.000$, Cramer's $V = 0.329$). The combined category of thermal and moisture protection and doors and windows contained over 100% more "Yes" responses than expected. This is due to the number of falls from and through roofs and through skylights where anchorage points, guardrails, and other forms of fall protection, if designed into the permanent structure, would have prevented the accident.

In the NIOSH dataset, similar results to the OSHA dataset were found; the construction fatalities that were linked to the design for construction safety concept were related to the design element being constructed at the time of the accident ($p = 0.001$, Cramer's $V = 0.33$). The combined category of thermal and moisture protection and doors and windows contained 30% more "Yes" responses than expected. The metals category contributed highly to the significant result, with 37% more "yes" responses than expected. This is due to falls from structural steel framing and buildings where permanent anchor points, lifeline systems, and other forms of permanent fall protection can be designed into the permanent features of the constructed building.

Hypothesis 7

$H7_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to the injured contractor's Standard Industrial Classification (SIC) code.

SIC codes represent the type of work primarily performed by a construction firm. A relationship between SIC code and the design for construction safety concept is important to determine which constructor's would benefit most from the concept's implementation. Four-digit SIC codes were collected from both datasets. The distribution of incidents in both datasets was not equal and thus prevented a straightforward chi-square analysis. It is common practice to combine the SIC codes as 3-digit categories, however, doing so continued to violate expected frequency assumptions. Two-digit SIC codes were considered. While the assumptions of chi-square were met, this practice yields little practical information, particularly in SIC category 17 where the types of constructors are quite varied and any interpretation would not be meaningful. Therefore, the 4-digit SIC codes were combined into categories based upon the type of work each construction company performs. Table 9 shows the combinations utilized.

Despite this categorical combination, the OSHA database still yielded expected frequency assumption problems with the chi-square analysis. Therefore, only the NIOSH database was utilized for this analysis. The combined category of other specialty trades and trades not elsewhere classified contain work classifications that are not all related but were combined as "other" out of necessity to perform the chi-square analysis. Table 10 shows the descriptive summary from the NIOSH dataset.

Table 9: Categorical combinations of SIC codes to perform chi-square test

4-digit SIC codes utilized	**Combined Category**
1521 *General Contractors-single-family Houses* 1522 *General Contractors-residential Buildings, Other Than Single-family*	General Building Contractors-residential
1541 *General Contractors-industrial Buildings and Warehouses* 1542 *General Contractors-nonresidential Buildings, Other Than Industrial*	General Building Contractors-nonresidential
1611 *Highway and Street Construction, Except Elevated Highways*	Highway and Street Construction, Except Elevated Highways
1622 *Bridge, Tunnel, and Elevated Highway Construction* 1623 *Water, Sewer, Pipeline, and Communications And Power Line* 1629 *Heavy Construction, Not Elsewhere Classified* 1794 *Excavation Work*	Heavy Construction, Except Highway and Street
1711 *Plumbing, Heating And Air-conditioning* 1731 *Electrical Work* 1796 *Installation Or Erection Of Building Equipment, Not Elsewhere Classified*	Electrical, Mechanical, and Equipment
1751 *Carpentry Work*	Carpentry
1761 *Roofing, Siding, And Sheet Metal Work*	Roofing
1741 *Masonry, Stone Setting, And Other Stone Work* 1742 *Plastering, Drywall, Acoustical, And Insulation Work* 1743 *Terrazzo, Tile, Marble, And Mosaic Work* 1771 *Concrete Work*	Masonry and Concrete
1791 *Structural Steel Erection*	Structural Steel Erection
1721 *Painting And Paper Hanging* 1781 *Water Well Drilling* 1795 *Wrecking And Demolition Work* 1793 *Glass And Glazing Work* 1799 *Special Trade Contractors, Not Elsewhere Classified*	Other specialty trades and trades not elsewhere classified

Table 10. Summary of incidents by SIC Code

	NIOSH	NIOSH %
General Building Contractors-residential	20	9.0
General Building Contractors-nonresidential	18	8.1
Highway and Street Construction, Except Elevated Highways	19	8.5
Heavy Construction, Except Highway and Street	31	13.9
Electrical, Mechanical, and Equipment	31	13.9
Carpentry	13	5.8
Roofing	23	10.3
Masonry and Concrete	19	8.5
Structural Steel Erection	26	11.7
Other specialty trades and trades not elsewhere classified	23	10.3
Totals	224	

Construction fatalities that are linked to the design for construction safety concept were not significantly related to the injured contractors Standard Industrial Classification (SIC) code ($p = 0.058$, Cramer's $V = 0.272$). Although not statistically significant, the results exhibited practical significance; Cramer's V showed evidence of a moderate relationship. Roofing and structural steel constructors would benefit most from the implementation of the concept. Electrical and mechanical constructors would benefit the least. These findings are directly related to the previous hypothesis which found that the categories of work most affected by implementing the concept were thermal moisture protection, doors and windows, and metals; work typically performed by roofing and structural steel contractors.

Hypothesis 8

$H8_A$: Construction fatalities and disabling injuries that are linked to the design for construction safety concept are related to the designer's discipline (architectural, structural, civil, mechanical, electrical) involved in that aspect of the project that caused the fatality or disabling injury.

A relationship between certain design disciplines and the design for construction safety concept would enable those designers and those seeking to implement the concept on a project to focus efforts by those designers who would have the most impact in reducing risk. A descriptive summary of the breakdown of incidents classified by the associated design discipline are shown in Table 11.

Table 11. Summary of incidents by design discipline

	OSHA	OSHA %	NIOSH	NIOSH %
Architectural	45	26.3	55	24.6
Civil	53	31.0	66	29.5
Structural	40	23.4	54	24.1
Mechanical	18	10.5	16	7.1
Electrical	15	8.8	16	7.1
Totals	171		207	

In the OSHA dataset, construction fatalities and disabling injuries that were linked to the design for construction safety concept are related to the designer's discipline ($p = 0.001$, Cramer's $V = 0.244$). Architects have the greatest opportunity to be involved in designing for construction safety and have a positive impact compared to civil, electrical, and mechanical engineers. Although previous analysis revealed that structural steel as a design element and structural steel constructors were related to the design for construction safety concept, structural engineers were found to be unrelated to the concept. The design activities of structural engineers include brick, concrete, and wood structures which were not related to the concept of designing for construction safety.

The results in the NIOSH dataset were similar to the OSHA dataset and were also significant ($p = 0.015$, Cramer's $V = 0.314$). Architects again were more likely to have a positive impact on construction safety compared to electrical, mechanical, and civil engineers. Structural engineers showed a slight tendency to be involved in the concept and have a positive impact.

Hypothesis 9

$H9_A$: Construction fatalities that are linked to the design for construction safety concept are related to the size of the construction firm who experienced the fatality (NIOSH database only).

Many smaller construction firms do not have the resources necessary to implement temporary safety measures. If the design for construction safety concept were a standard practice in the construction industry, it is hypothesized that implementing many temporary safety measures (such as fall protection) would be less difficult and therefore more common among smaller firms. Firm size was reported in 211 or 94.2% of the NIOSH Face reports. Firm size was categorized into firms having 20 or fewer employees and greater than 20. Construction fatalities that were linked to the design for construction safety concept are not significantly related to the size of the construction firm who experienced the fatality ($p = 0.166$). However, it was noted that the smaller firms had a higher observed count than expected in the "Yes" category compared to larger firms. While the result is not significant, smaller firms were more often linked to the design for construction safety concept compared to larger firms. If the concept of designing for safety were more prevalent in the construction industry, it is hypothesized that smaller firms might utilize those permanent safety features; their use would be better facilitated compared to the current method of installing temporary safety measures. This is an area of further research.

Examples of Determinations

The following section provides examples of specific cases reviewed and the determinations utilized in making a decision whether the incident was linked to the design for construction safety concept.

Structural Failure (Question 1)

The following example was answered positively because the structure itself failed during construction activities and consideration of its potential failure is linked to the design process. An employee was working in a crane next to a brick wall, removing roof sections attached to the brick wall. The brick wall was not designed to be free standing. When the roof section was removed, the brick wall collapsed onto the crane and crushed the worker. This incident review led to the development of the following new design for construction safety suggestion: before demolishing and renovating any structure, ensure that an engineering survey is performed by a competent person to determine the condition of the structure, evaluate the possibility of unplanned collapse, and plan for potential hazards.

The following example was answered affirmatively in that the physical aspects of the project prohibited the constructors from implementing effective temporary safety measures. Two employees went to an industrial building to repair electrical equipment located on the roof of the building. The roof contained many corrugated fiberglass panels (non-load bearing) which were indistinguishable from panels designed as a walking surface. The employees fell through the corrugated fiberglass panels. This design prohibited the constructors from recognizing a hazard and from implementing a temporary safety measure or utilizing a different technique to perform the work. A different design would have considered the construction and maintenance work on the roof and considered an appropriate walking surface for such activities.

Even though the design for construction safety concept can positively influence construction site safety, it is important to recognize that the constructor plays a major role and must adhere to the design specifications if the design for construction safety concept is utilized. Consider an incident where iron workers fabricated a steel skeleton for an automotive repair shop. The building plans and procedures specified that ¾ inch steel sway bracing rods be installed and kept in place immediately after hoisting the beams into place for the purposes of maintaining structural stability. The constructors ignored this design specification and this was one of the main causes of the structural collapse as reported by the NIOSH FACE program investigation team. Thus, this incident was not linked to the design for construction safety concept.

Existing Design Suggestions (Question 2)

Forty-three existing design suggestions were linked to the construction incidents. They are summarized in Table 4 on page 42. The following example demonstrates how an existing design suggestion was linked to a construction incident. An employee was laying insulation on flat roof. He stepped backwards and fell off the roof edge 30' to ground. The two design suggestions linked to this accident are:

- Design the parapet to be 42 inches tall. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or future roof maintenance, and
- Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.

New Design Suggestions (Question 3)

Thirty new design suggestions have been developed from the analyzed reports and are summarized in Table 5 on page 45. For example, one new suggestion is: design anchor points on the interior of the tank for construction and maintenance purposes. This suggestion was extracted from NIOSH FACE report 90-16. A small construction company was contracted to sandblast and paint the interior of a tank. They planned to use suspension scaffolding to reach all sections of the 48' high and 30' diameter tank. Before the suspension scaffold was raised into position, the victim used a ladder to weld steel brackets to the walls at the top of the tank. The brackets were used to anchor a horizontal steel cable which was to be used as a fall protection anchor cable. The nylon suspension ropes, which were used in the suspension scaffold system, were lying on the floor of the tank while the brackets were being welded. After the welding, the owner inspected the suspension ropes by passing each rope length through his hands, but did not notice any apparent damage to the ropes. The suspension rope broke when the employee pulled it to move the scaffold higher. The scaffold failed and the employee fell 40' to the bottom of the tank. There were numerous causes of the accident. One cause was the employees did not follow OSHA 29 CFR 1926.451(a)(18) which states that "No welding, burning, riveting, or open flame work shall be performed on any staging suspended by means of fiber or synthetic rope." An OSHA investigation after the incident determined that the rope had broken at a point where it had been burned probably because the rope was on the ground below where welding the anchor points occurred. However, another cause is linked to the design for construction safety concept. Consider if there were already anchor points designed in to the tank's interior. The employee would not have been required to field fabricate anchor points to safely use the scaffolding required to perform the work. Thus, this accident would have been prevented because a direct cause, welding anchor points, would have been removed from the scenario. The NIOSH FACE report states similar language supporting the implementation of such design for construction safety measures. They state "Permanent structures of this type are known to require extensive maintenance when they are designed. It is essential that designers/owners of these facilities incorporate appropriate anchor points on tanks to which workers can adequately secure scaffolds and lifelines. Omission of designed anchor points causes workers to improvise anchors or not use them at all. This increases the possibility that a scaffold will be erected using improper procedures and components."

Chapter 5 – Conclusions

The purpose of this chapter is to present significant findings, conclusions, and recommendations extracted from the collection and analysis of data from the Occupational Safety and Health Administration (OSHA) construction inspection reports and from the National Institute for Occupational Safety and Health Administration (NIOSH) Fatality Assessment Control and Evaluation (FACE) program reports with regards to the design for construction safety concept.

Findings

As a result of the data collection and analysis, the following relevant findings were discovered:

1. Forty-two percent (94 of 224) of fatalities from the NIOSH database were linked to the design. In the OSHA database, 40.5% (15 of 37) of fatalities were linked to the design for construction safety concept.
2. Twenty-two percent (42 of 189) of the disabling injuries from the OSHA database were linked to the design for construction safety concept.
3. Thirty new design for construction safety suggestions were developed as a result of this research.
4. Forty-six percent (70 of 151) of the incidents linked to the design for construction safety concept were linked by this suggestion: Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Eleven percent (18 of 151) were specifically related to falls from residential construction; an additional 7.2% (11 of 151) were linked to commercial building construction.
5. Identifying, communicating, and considering overhead and underground electrical lines and other utilities in relation to the specified construction work exhibited considerable magnitude in reducing construction fatalities and disabling injuries. The following design suggestions were linked to construction incidents: disconnect, reduce voltage, or re-route power lines

around the project before it begins (18 of 151, or 12%); include the name, address, and telephone number of local utility companies on the drawings (16 of 151, or 10.6%); and locate on contract drawing the existence of overhead power lines and their location in relation to the new structure (15 of 151, 10%).

6. The OSHA dataset showed that construction fatalities and disabling injuries linked to the design for construction safety concept are related to the nature of the construction project ($p = 0.015$). In contrast to the OSHA dataset, the nature of the construction project had no relationship to fatalities linked to the design for construction safety concept in the NIOSH dataset ($p = 0.531$).
7. The OSHA data showed that construction fatalities and disabling injuries linked to the design for construction safety concept were not significantly related to the type of construction project ($p = 0.059$). The NIOSH FACE dataset revealed no relationship between construction fatalities linked to the design for construction safety concept and the type of construction project ($p = 0.214$).
8. Construction fatalities and disabling injuries that are linked to the design for construction safety concept are unrelated to whether OSHA issued a citation to the injured or deceased's employer ($p = 0.22$).
9. In the OSHA dataset, construction fatalities and disabling injuries linked to the design for construction safety concept were related to the design element being constructed at the time of the accident ($p = 0.000$). In the NIOSH dataset, similar results to the OSHA dataset were found; construction fatalities linked to the design for construction safety concept were related to the design element being constructed at the time of the accident ($p = 0.001$). This relationship exhibited the strongest association among those tested, as evidenced by Cramer's V coefficient (0.329 for the OSHA dataset and 0.330 for then NIOSH dataset).
10. Construction fatalities linked to the design for construction safety concept were not significantly related to the injured contractors Standard Industrial

Classification (SIC) code (p = 0.058, Cramer's V = 0.272). Although not statistically significant, the results exhibited practical significance; Cramer's V showed evidence of a moderate relationship. Roofing and structural steel constructors would benefit most from the implementation of the concept.

11. In the OSHA dataset, construction fatalities and disabling injuries linked to the design for construction safety concept are related to the designer's discipline (p = 0.001). The results in the NIOSH dataset were similar to the OSHA dataset (p = 0.015).
12. Construction fatalities linked to the design for construction safety concept are not significantly related to the size of the construction firm who experienced the fatality (p = 0.166).

Conclusions

Based on these findings, the following conclusions can be drawn:

1. The concept of designing for construction is linked to construction fatalities and disabling injuries. The incorporation of this concept would reduce risk and enhance the opportunity for worker safety on construction sites. The implementation of the design for construction safety concept is not a panacea; rather it is one strategy in a proactive systems approach for minimizing risk and reducing fatalities and disabling injuries in the construction industry.
2. The difference in linkage to the design for construction safety concept between fatalities and disabling injuries is due to the dissimilar amount of information in the reports; there is no effect between fatalities and disabling nor is there a theoretical basis for such a conclusion.
3. Implementation of the concept of designing for construction safety would greatly reduce risks of falls and hazardous contact with electric and other utilities.
4. During the design process, considerable consideration should be given to the concept for designing for construction safety when specifying roofs, skylights, and structural steel construction.

5. The concept of designing for construction safety can have a positive effect on construction safety during both new construction and renovations.
6. The concept of designing for construction safety can have a positive effect on construction safety on all types of projects (residential, commercial, industrial, and engineering).
7. Roofing and structural steel constructors would benefit most from the implementation of the design for construction safety concept. Electrical and mechanical constructors would benefit the least.
8. Architects are more likely to have a positive effect on construction safety by implementing the concept of designing for construction safety. Structural, electrical, mechanical, and civil engineers can have a positive impact of safety but to a lesser degree.
9. The concept of designing for construction safety has a positive effect regardless of the size of the firm.

Recommendations

Based on these conclusions, the following recommendations are provided:

1. The Department of Health and Human Services should consider broad-based methods and initiatives to integrate the concept of designing for construction safety into construction projects to achieve their goal of reducing fatalities and injuries by 30% by the year 2010. These initiatives should include guidance documents regarding implementation of the design for construction safety concept, recommendations to OSHA for consensus standards that include design for safety, and funding for further study.
2. The United States' construction industry should implement the concept of designing for construction safety as a standard practice to reduce overall project risks. The prevailing view places the burdens of construction safety solely on the constructor. Utilization of this concept allocates construction safety risks to design professionals who are in a position to make decisions about construction safety and reduce those risks before they reach the

construction site. This makes practical sense from a traditional safety perspective – the recommended hierarchy of controls mandates that hazards be designed such they are eliminated or reduced before workers are exposed or administrative and temporary controls are implemented.

3. Owners or financiers of construction projects seeking a safe construction site should consider mandating that design professionals and construction managers utilize the design for construction safety concept. Other incentives for owners and financiers to implement the concept, in addition to a safer construction site, include the benefits of reduced risk during building maintenance and reduced insurance premiums of constructors, which translate into lower costs to the project. Owners are increasingly seeking to minimize insurance costs for all project parameters and are purchasing owner controlled insurance programs (OCIP's), which lump project risks together for all parties and thus economies of scale are realized. Utilization of the design for construction safety concept is a method that can be utilized within an OCIP to reduce costs associated with workers' compensation insurance premiums. This use must be further investigated within the insurance industry and on projects utilizing an OCIP as a method to reduce overall project risk.
4. The economic benefit of the design for construction safety concept to all entities in construction (designer, owner, and constructor) must be sufficiently evaluated. The constructor will benefit from the reduction of risk associated with implementing the concept; however, they are not in a position within the construction industry to drive the concept. To adequately drive and implement the concept, the owner and/or designer must recognize benefits that translate into economic terms.
5. Safety professionals who investigate construction accidents and fatalities should consider whether the design for construction safety concept was linked to the causes of the incident. The safety profession is viewed as an expert panel for incident investigation. Currently, the prevailing view in

construction incident investigation does not include the design for construction safety concept. Once the safety profession understands the link between the concept and construction incidents, they will drive its implementation as a method to reduce overall project risk.

6. This research should be reproduced utilizing sources of fatalities and disabling injuries that can be inspected by an actual on-site construction investigation. This type of research would enable the gathering of specific design-related information and could test the feasibility of implementing each design for construction safety suggestion. The NIOSH FACE program is well-suited to investigate construction fatalities and their link to the design for construction safety concept. They should consider a special emphasis focus on the design for construction safety concept for future construction fatality investigations.
7. In conducting additional research, the following recommendations would strengthen such a study: eliminate maybe as a potential response and utilize only a yes / no answering method when linking construction incidents to the design for construction safety concept; utilize a second coder when recording the responses to increase reliability; and, consider utilizing a Delphi panel of construction industry professionals to examine the validity of the responses and determine the feasibility of implementing each linked design suggestion.

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Appendix A

Incidents Linked to the Design for Construction Safety Concept – National Institute of Occupational Safety and Health Fatality Assessment Control Evaluation Program

Case #	Incident Description	Q1			Q2			Q3			Design Suggestion(s)
		Yes	*Maybe*	*No*	*Yes*	*Maybe*	*No*	*Yes*	*Maybe*	*No*	
90-01	The crew was using a mobile elevating work platform to install sections of aluminum siding. They hit the power lines which were 34 feet off the ground. However, toward the north and of the warehouse, one of the lines was only 27 feet off the ground.			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins. Include the name, address, and telephone number of local utility companies on the drawings.
90-15	Employees installing equipment on metal platform 37' above ground; ventilation stack hole went through floor; employee fell through opening.			X	X			X			Provide for permanent guardrails around floor openings. <u>New design suggestion</u>: When design features, such as ventilation systems, trash chutes, chimneys, elevators, etc. cause floor openings to occur during construction, provide a warning in the plans and specifications for construction, and design in permanent guardrail systems and sequence them in early in the construction process for use by all contractors.
90-16	Employee had previously welded some steel brackets to the inside top wall of the tank in order to install a fall protection anchor cable. Employees were raising one end of the scaffold platform during a sandblasting operation, the rope broke. OSHA determined that the rope broke at a point where it had been burned, presumably when the steel brackets were welded.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New suggestion:</u> Design appropriate tank anchor points on the interior of the tank for construction and maintenance purposes.

90-21	The roof has 15 rectangular smoke-dome-type, curb-mounted skylights (42 inches by 80 inches). Employee went over to talk to the supervisor, when he returned he stepped through skylight and fell to surface below.			X	X					X	Design domed, rather than flat, skylights with shatterproof glass or add strengthening wires. Design guardrail protection around skylights.
90-24	Employee and another visually inspected the beam and noticed it had ice on it. Employee ignored supervisor and walked on beam and fell 50'. The NIOSH report mentions nothing about fall protection in the report but focuses on the defiance of the employee to work on the beam.			X		X				X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design perimeter beams and beams above floor openings to support lifelines (minimum dead load of 5400 lbs.). Design connection points along the beams for the lifelines. Note on the contract drawings which beams are designed to support lifelines, how many lifelines, and at what locations along the beams.
90-29	A crane would be used to position a 1-yard bucket during the pouring of the concrete. Utility engineers determined the power line could not be relocated because the adjacent swampy ground would not permit the proper anchoring of the utility poles.			X	X				X		Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins. Include the name, address, and telephone number of local utility companies on the drawings. <u>New design suggestion</u>: Consider alternative methods for pouring concrete when specifying concrete pours below or next to overhead power lines, such as the use of a pumping truck.
90-38	Employees removing a submersible pump from the well, used crane and crane hit overhead power lines.			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power

											lines around the project before it begins. Include the name, address, and telephone number of local utility companies on the drawings.
91-07	The rake angle sets the wall line at the top of a bldg and provides anchor points for the structure's exterior panels. On the day of the incident the employee and a coworker were installing 10' sections of rake angle iron to the outer roof edge of the structure. No lifelines or catenary lines were present on the roof. The men would tie off to the 4-inch steel purlins (ceiling joists) only when sitting and making connections.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.
91-11	Employee was in the process of covering ductwork with a fire blanket and either tripped on the angle iron and fell into, or stepped backwards into, a skylight opening.			X	X					X	Design domed, rather than flat, skylights with shatterproof glass or add strengthening wires. Design guardrail protection around skylights.
91-18	The walkway platform section being worked on was approx. 6' wide by 10' long. Employee was welding supports for the section and was on structural supports above a 22.5' pit. Both workers were wearing safety belts and lanyards. However, neither worker was tied-off to a secure point, nor were lifelines present to use as a tie-off point.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design perimeter beams and beams above floor openings to support lifelines (minimum dead load of 5400 lbs.). Design connection points along the beams for the lifelines. Note on the contract drawings which beams are designed to support lifelines, how many lifelines, and at what locations along the beams.
91-26	6" square wooden beams that were to be used as final supports for the addition were present at the site; they were not installed at this time. These beams were to anchored in	X					X			X	Structure failed during construction because the final design criteria were not implemented early in the construction phase. NIOSH report states that if a review of the work were done

	the ground and the addition would be set on top of the beams. Structure failed during construction because the final design criterion was not implemented early in the construction phase.										in the design phase this would have been implemented.
92-04	Employer had been contracted to set steel beams and lay the metal decking for a bridge overpass that would span an existing state highway. The beams were to be set across two concrete pillars, one on each side of the highway. Each connector was standing on a plywood platform 6' 3" long by 1' wide. 2" x 4" boards were nailed underneath the entire length of each side of the platforms to serve as braces. The platforms were positioned between two beams.			X	X				X		Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Consider pre-fabricating work stations and fall protection systems into the constructed structure.
92-08	Employee was re-aligning some shingles from previous work, when he fell off the roof.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
92-27	Employee was using a metal extension ladder to paint side of house, he moved ladder, it fell backwards and hit high voltage line			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins.
93-21	Employees pouring cement for a 3-story			X	X			X			Provide for permanent guardrails around floor

	addition to a textile mill. One half of the floor of the second story was being poured. The floor measured 84' wide by 119' long and contained 8 unguarded openings 32" X 18'. These openings were to be used as vents and ducts for service cables. The floor also contained a 13' x 9' 8" opening for an elevator shaft; the opening was guarded by a steel rope barrier. A cement finisher stepped backward and fell thru an opening.										openings. New design suggestion: Provide warning through the plans and specifications when electrical systems create floor openings in the work area.
93-23	Employee entered tank where supervisor (wearing airline respirator) was using epoxy inside water tank, a confined space. Employee collapsed and fell off ladder.			X			X	X			New design suggestion: Specify the need for a permit-required confined space program when utilizing flammable materials inside tanks.
95-18	Employees re-roofing house, they used 2x4 toeboards for protection. Employee near roof edge and fell to ground.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
95-19	Employees removing roof panel sections and replacing insulation and installing new sheet metal panel. Employee stepped thru one of the openings.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline

											attachments, and/or perimeter holes for guardrail attachment.
96-05	Employees went to a locomotive repair building to repair electrical equipment located on the roof of the building. The roof contained many corrugated fiberglass panels which were barely distinguishable from the safe walking surface.	X					X	X			Employees to repair electrical equipment located on the roof of the building, the roof contained many corrugated fiberglass panels which were barely distinguishable. The structure prohibited the employees from implementing a temporary fall protection system. New design suggestion: When specifying roofing materials which are not suitable for walking, such as corrugated fiberglass panels, ensure they are distinguishable from safe secure walking surfaces on the roof, or install guardrails around the surfaces not suitable for walking.
96-16	Employee operating scraper and moving fill for side of highway project. When in cut area the machine tipped over. The cut area was not large enough for the machine to move adequately.			X		X				X	Design the slope, width, height, turning radius, and surface treatment of traffic surfaces with consideration of the anticipated size, weight, and maneuverability of the construction equipment. Orient the project layout or grade the site accordingly to minimize the amount of work on steep slopes.
96-18	Employee was using platform to install lights in a newly completed department store from a man lift vehicle. The vehicle's wheel went into a floor opening and the man lift tipped over.			X	X					X	Design the finished floor around mechanical equipment to be at one level (no steps, blockouts, slab depressions, etc.).
96-19	Employee salvaging electrical equipment and conductors from de-energized lines that were next to energized lines. (3' away). As one of the conductors was released, the tension on the remaining conductors caused			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins.

	the second pole to lean into the energized powerline, energizing the salvage powerline.											Include the name, address, and telephone number of local utility companies on the drawings.
97-08	Employee, working near the edge of landing near atrium, was plugging in an extension cord and went outside the red warning tape on to a piece of plywood, plywood gave way and employee fell.			X	X			X				Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion</u>: When designing an atrium in a building, design permanent guardrails, anchor points, or other such fall protection mechanisms so they are sequenced early in to the schedule to allow their use by construction workers.
97-10	Employee was constructing a communications tower, standard practice is to move without the use of fall protection; employee unhooked fall protection to move down the tower and fell.			X	X			X				Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion</u>: For tower type structures, design a cable-type lifeline system into the structure that allows workers to be hooked onto the structure and allows for their movement up and down the structure.
97-11	Employee directed sand truck next to dumping station, went behind truck to collect manifests; a Caterpillar loader ran over him on the embankment. NIOSH reports states "Traffic flow at construction site should be designed prior to the start of operations, if possible, to minimize vehicular and pedestrian traffic interface. Personnel should be placed in a visible & stationary position, if possible..."			X	X					X		Allow for pedestrian traffic to be isolated from construction vehicular traffic.
98-02	Employee was in dump truck waiting for load, crane arm moved toward truck and			X			X	X				<u>New design suggestion</u>: Where job site access is limited, consideration should be given to

	crane tipped forward crushing the cab of the dump truck. The outriggers of the crane were fully extended on one side only so that excavation trucks could have access, and this limited the crane's capacity. The load was calculated and it exceeded the crane's capacity due to the outrigger configuration.										alternating work schedules or short term interruption of work tasks to allow additional clearance for crane set-up and use.
98-05	Employee was being lowered from the tower from a line that was being used to lower equipment after job was complete. There are no permanent methods to allow moving up/down on telecommunications towers safely.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion</u>: For tower type structures, design a cable-type lifeline system into the structure that allows workers to be hooked onto the structure and allows for their movement up and down the structure.
98-11	Employees were unrolling electrical conduit near floor opening between HVAC ducts. Permanent guardrails were there for the mechanical contractors and others, but not currently for electricians. He fell through this opening.			X	X			X			Provide permanent guardrails around floor openings. <u>New design suggestion</u>: When design features, such as ventilation systems, trash chutes, chimneys, elevators, etc. cause floor openings to occur during construction, provide a warning in the plans and specifications for construction, and design in permanent guardrail systems and sequence them in early in the construction process for use by all contractors.
99-18	Employees were demolishing a house and only a wall corner and a 26' high brick chimney remained. They were demolishing wall when chimney began to sway and crushed employee. NIOSH report says "before demolishing any structure, ensure that an engineering survey is performed by a	X			X			X			Review the condition and integrity of the existing structure and indicate any known hazards or deficiencies on the contract drawings. <u>New design suggestion</u>: Before demolishing and renovating any structure, ensure that an engineering survey is performed by a

	competent person to determine the condition of the structure, evaluate the possibility of unplanned collapse, and plan for potential hazards".										competent person to determine the condition of the structure, evaluate the possibility of unplanned collapse, and plan for potential hazards.
00-07	Employee painting and installing rest platforms and beacon on radio communications tower. He used hoist line to move personnel up/down the tower; line slipped and employees fell.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: For tower type structures, design a cable-type lifeline system into the structure that allows workers to be hooked onto the structure and allows for their movement up and down the structure.
01-04	Employee patching roof on industrial warehouse. He fell through skylight, the event was not witnessed.			X	X					X	Design domed, rather than flat, skylights with shatterproof glass or add strengthening wires. Design guardrail protection around skylights.
01-07	Employee removing roof materials and he fell backwards through skylight.			X	X					X	Design domed, rather than flat, skylights with shatterproof glass or add strengthening wires. Design guardrail protection around skylights.
99AK019	Employees were digging 3 environmental monitoring wells on an industrial site. The drill rig hit overhead electrical lines and employee was electrocuted.			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins. Include the name, address, and telephone number of local utility companies on the drawings.
94CA005	Employee was removing ceiling panels due to earthquake damage. He was removing panels from the purlins by pulling the nails out, the purlin was not stable due to the earthquake damage and it shifted, causing the panel to fall and employee fell.	X			X			X			Demolition/renovation on earthquake damaged roof, roof section failed. Review the condition and integrity of the existing structure and indicate any known hazards or deficiencies on the contract drawings. New design suggestion: Before demolishing

											and renovating any roof structure which is damaged, ensure that an engineering survey is performed by a competent person to determine the condition of the roof, trusses, purlins, and the structure itself to evaluate the possibility of the structure and its components failing during the work, and to evaluate how fall protection devices will be incorporated into a damaged structure.
94CA013	Employee working from scaffolding was installing metal frames to residence; scaffold tie-offs were cut and he pulled a nail out and the scaffold fell.			X		X		X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion:</u> Design scaffolding tie-off points into exterior walls of buildings for construction and renovation purposes.
94CA017	Employee repairing tile on elevator located outside on top level of parking garage. Elevator is located next to roof edge; ladder fell and employee fell over guardrail.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion:</u> Do not design elevated exterior structures, equipment, etc. next to roof edges.
96CA006	Employee using large boom crane to lift up water well pump for inspection; overhead power lines above well. These lines were not indicated in the work order. They hit power lines with boom.			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins. Include the name, address, and telephone number of local utility companies on the drawings.
98CA010	The structural steel order was short one beam (bar joist). When this bar joist finally arrived, the roof decking could be			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports,

	completed. The last piece was a tight fit. Employee hitting steel with hammer and fell through opening.										lifelines, guardrails, and scaffolding.
98CA016	Employee preparing to lay clay tiles on roof, installing anchors for the tiles (not for fall protection); he pulled on one the anchors and he fell backwards off the roof, had no fall protection.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
98CA017	Employees using scaffolding to spray on fireproofing insulation to structural steel, scaffold failed and fell.			X	X					X	Design and schedule materials and equipment to be painted and/or insulated prior to erection or placement.
00CA005	Asphalt truck backed up and hit another employee. The distance the trucks had to back up at this site was 1100 feet.	X			X			X			The physical features of this access road to this housing development limited the trucks to be driven safely, considering the ever changing conditions and employee movements on a construction site. Design the slope, width, height, turning radius, and surface treatment of traffic surfaces with consideration of the anticipated size, weight, and maneuverability of the construction equipment New design suggestion: Design periodic turnouts into long straight roadways. This allows trucks to turn around, minimizes reverse motion, and allows for passing of other vehicles.
00CA006	As the dump truck approached the work site the decedent would remove one of the			X			X	X			New design suggestion: During roadwork, when the work zone of the trucks conflicts

	tubular markers to allow the truck access into the #1 lane. Once the truck was inside the secured lane, the decedent replaced the tubular marker and continued to monitor the traffic with his back to the truck that just entered. The dump truck driver needed to get as close as possible to the median to dump the load of dirt. After pulling into the #1 lane, the truck driver pulled forward of the actual dump location. He then proceeded to back the truck as close as possible to the median. The driver stated he looked into both of his tractor's side rear view mirrors as he preceded backwards, approximately 2-3 mph, and did not see the decedent.										with the work zone of the flaggers, establish an alternate layout of the work zone, such as closing additional lanes of the highway.
01CA002	The angle of the ravine varied between 50 and 60 degrees and the slope was approximately 30' in length. The bottom of the ravine was approximately 10' wide. The victim descended the ravine with the tractor bucket pushing the earth in front of it. Just before he reached the bottom of the ravine, he raised his bucket & attempted to make a left turn while still on the incline. While in the process of turning left, the tractor rolled-over and came to rest on its right side at the bottom of the ravine.			X			X	X			New design suggestion: For projects that occur on or near steep slopes, provide a warning and information about the site conditions in the construction documents.
92CO065	Applying sheets of plywood to the roof trusses of a two story home under construction. Employee was cutting sheets of plywood for the other two employees. He was standing on a portion of the roof that had already had the plywood applied and fell.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction

											and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
94CO035	Several workers were spray-painting the exterior of an industrial building. The workers were using aluminum ladders to access the upper portions of the wall on which they were working. A worker descended his ladder, and lifted it from the wall to move it past his coworker and continue painting. As he was moving the ladder in a vertical position, it contacted a 7,620-volt power line.			X	X					X	Disconnect the power lines, or decrease the voltage, before construction begins. Allow adequate clearance between the power lines and the structure. Include the name, address, and telephone number of local utility companies on the drawings.
96IA067	Employee installing sheet metal on roof, walking on purlins slipped onto to sheet metal, screws came out and he fell through top ground.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: In the design of commercial and industrial buildings, consider if sheet metal could be utilized as a walking surface (either intentionally or unintentionally), and specify appropriate sheet metal gauge for walking and the appropriate screws for strengthening. New design suggestion: Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
93IN103	The decedent was standing on a flat roof support holding a piece of ridge-pan			X	X					X	Design special attachments or holes in members at elevated work areas to provide

	flashing (2'x10'x18 gauge), when witnesses on the ground saw the ridge-pan flashing wrap around the decedent and he fell 31 feet 10 inches to the concrete floor.										permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design the parapet to be 42 inches tall. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or future roof maintenance.
95IN059	Employee on 13' flat garage roof; he fell off roof to ground.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design the parapet to be 42 inches tall. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or future roof maintenance. New design suggestion: Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
90MA003	Employee laying insulation on flat roof, stepped backwards and fell 30' to ground.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design the parapet to be 42 inches tall. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or future roof maintenance.
92MA003	Applying new siding to a private multi-family dwelling and were nearing			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in

	completion of the project. In the course of dismantling pump jack scaffolding, both men were manning a single 30' aluminum staging pole specifically in the effort to avoid damage to the building and to not hit the powerlines. they difficulty in up righting the staging pole or a gust of wind caused the staging pole to sway resulting in contact with the inner most power distribution line located some 70 inches from the dwelling itself.										relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins. Include the name, address, and telephone number of local utility companies on the drawings.
92MA005	Employee on scaffolding at roof edge clearing snow off of roof, no fall protection, no guardrails on scaffolding, fell to ground			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
93MA008	Victim was aiding in the retrieval of a suspended cable running along the bridge when he fell from outside the bridge's suicide barrier at the highest center span of the bridge.			X		X				X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.
93MA013	Employee working on roof; fell through chimney opening.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: When design features, such as ventilation systems, trash chutes, chimneys, elevators, etc. cause floor

											openings to occur during construction, provide a warning in the plans and specifications for construction, and design in permanent guardrail systems and sequence them in early in the construction process for use by all contractors. <u>New design suggestion</u>: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
94MA011	Employee fell approximately 20' through a roof opening to ice covered ground. The victim was not wearing any fall protection. On the day of the incident the victim and his coworkers were positioning and welding metal decking to the structural steel beams.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails.
94MA067	Crew members were situated in the excavation as the crane was lowering the five ton end cap into the excavation to be placed and bolted to the tank opening. Crane was lowering concrete cap attached to the pre-fabricated anchorages from the manufacturer. The eye bolt anchors snapped and crush employee in excavation.	X					X			X	Pre-fabricated anchorages were attached a concrete tank cap from the manufacturer. A crane was lowering to the cap into an excavation. The eye bolt anchors snapped and crushed employee in the excavation.
95MA016	Employee was assisting a co-worker to lay out and fasten metal decking to structural steel for a motor vehicle ramp when the incident occurred. The victim stepped on an unsecured piece of decking, and fell through the opening. He was wearing a safety			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.

	harness and six foot lanyard; the co-worker stated that they did not tie off their lanyards because they were moving about the work area. They were also not provided an anchor point to which to tie their lanyard.										
99MA002	Employee bolting a steel beam; he walked to another section around a column that had a bolt keg holder attached to it which protruded out into the walking area. The employee grabbed on to the bolt keg holder walked around it and let go and tripped and fell. NIOSH report says the employee had a lanyard but there were no anchorage point to tie-off to.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails.
94MD041	The victim had arrived at the site during a heavy rain storm, exited the vehicle, and accessed the roof from a low hanging eave. The barn was built against a slope so the eave of the roof on the uphill side of the barn was about 2 1/2' above ground level. The victim began to walk up the slope of the roof with a measuring tape trailing behind and a notebook and pencil in hand. As he reached an area about 16' above the eave the roof gave way and he fell through the roof landing on the concrete floor 30' below.	X					X	X			The roof structure failed, but this deterioration could have been identified and communicated in the design phase. <u>New design suggestion:</u> Before demolishing and renovating any roof structure which is damaged, ensure that an engineering survey is performed by a competent person to determine the condition of the roof, trusses, purlins, and the structure itself to evaluate the possibility of the structure and its components failing during the work, and to evaluate how fall protection devices will be incorporated into a damaged structure.
98MD016	Employee on scaffold to paint the cornice, scaffold tipped away from wall and he fell.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion:</u> Design scaffolding tie-off points into exterior walls of buildings for construction and renovation purposes.

92MN014	Flagman working in highway construction zone at night, speed limit through construction zone was not reduced, and remained set at 55 mph; pick-up truck drove through area and hit flagman.			X	X			X			Employ police officers to patrol around the project site to help with traffic control. New design suggestion: During highway construction activities, posted speed limits should be reduced and strictly enforced to increase the safety of highway workers.
92MN022	The victim, a cement finisher, was assigned, after the formwork had been pulled, to hand-finish the outer side of the bridge support and the area on the outer side of the bridge where the joint had been replaced. He was working alone and using a trowel to finish the concrete near the joint replacement after the formwork had been pulled. He was standing at the top of the wing-wall when he fell approximately six feet onto some concrete construction.			X	X					X	For pre-cast concrete members, provide inserts or other devices to attach fall protection lines. Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding
93MN062	Concrete workers repairing tractor using excavation boom as an aid; boom hit overhead power lines and lines hit employee on ground.			X	X					X	Re-route the power lines around the project site before construction begins. Disconnect the power lines before construction begins. Include the name, address, and telephone number of local utility companies on the drawings.
94MN013	Employees descending ladder on 50' wind turbine tower; they were supposed to use fall protection w/ 2 lanyards to secure themselves on the way down, they were getting hit by ice from an employee above them; they did not use fall protection b/c it was too slow.			X	X				X		Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: For tower type structures, design a cable-type lifeline system into the structure that allows workers to be hooked onto the structure and allows for their movement up and down the structure.
94MN020	Employee in crane next to brick wall,	X			X			X			Review the condition and integrity of the

	removing roof sections attached to brick wall, the brick wall was not designed to be free standing, and when the roof section was removed, the brick wall collapsed onto the employee.										existing structure and indicate any known hazards or deficiencies on the contract drawings. New design suggestion: Before demolishing and renovating any structure, ensure that an engineering survey is performed by a competent person to determine the condition of the structure, evaluate the possibility of unplanned collapse, and plan for potential hazards.
94MN031	A two-person crew was assigned to install steel pipes beneath the interstate highway. The victim and a coworker used a boring machine to drill holes beneath the highway. The victim crossed the highway lanes to mark the exit location of the hole currently being drilled and was hit. The incident occurred at 8:30 am on a heavily traveled interstate highway.			X	X					X	During road work, slow down the ongoing traffic as much as possible by closing down adjacent lanes, posting flag-people to control traffic, or running lead cars to guide the adjacent traffic. Avoid road work and maintenance during peak traffic volume periods of the day.
98MN001	Employee on slightly sloped roof, dropped tool, tool slid b/c of frost on roof, he went to grab it and went over the edge.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design the parapet to be 42 inches tall. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or future roof maintenance. New design suggestion: Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for

											guardrail attachment.
92MO023	Employee was welding on structural steel w/out fall protection, stating that b/c the employees had to move so often the fall protection was not utilized. He fell off structural steel.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails.
93MO154	Employee removing and replacing deteriorated roof; he fell thru to concrete below.	X			X			X			The roof structure failed, but this deterioration could have been identified and communicated in the design phase. Review the condition and integrity of the existing structure and indicate any known hazards or deficiencies on the contract drawings. <u>New design suggestion:</u> Before demolishing and renovating any roof structure which is damaged, ensure that an engineering survey is performed by a competent person to determine the condition of the roof, trusses, purlins, and the structure itself to evaluate the possibility of the structure and its components failing during the work, and to evaluate how fall protection devices will be incorporated into a damaged structure.
94MO120	The victim was finishing a screen door on the deck when he may have been attacked by stinging insects in the area. In the victim's attempt to escape the area, he fell from the deck. The deck was unguarded.			X			X	X			<u>New design suggestion:</u> Design and schedule handrails, guardrails, and stairrails to be built as part of the erection process.
95MO049	Employee installing flashing around chimney on condo roof, when he fell backwards off the roof.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.

											New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
94NE012	The victim was constructing forms for pouring concrete flooring at the time of the accident. The victim was carrying bolts to attach to eyelets welded on the steel I beams he was walking on. He was "straddle walking" on the inner lips (approximately 3") of two I beams approximately 3 feet apart when he apparently slipped and fell to the concrete floor below. The victim was using no fall protection at the time of the accident.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails.
97NE035	Employee dragging decking material, walking on 7" girders; steel 5' apart; employee fell off girder; no fall protection while moving.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails.
98NE013	Employee descending ladder, he fell backwards and hit head, then fell down elevator shaft.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: When design features, such as ventilation systems, trash chutes, chimneys, elevators, etc. cause floor openings to occur during construction, provide a warning in the plans and

											specifications for construction, and design in permanent guardrail systems and sequence them in early in the construction process for use by all contractors.
98NE025	Employees installing cable lines; power company guy wires were in the way and they disconnected them improperly (should have called the power company)			X	X					X	Disconnect the power lines, or decrease the voltage, before construction begins. Include the name, address, and telephone number of local utility companies on the drawings.
90NJ007	Employee was replacing a skylight, when he fell through the skylight opening after he removed the glass. There was no place to tie-off to on the roof.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion:</u> Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
90NJ013	Employee on church roof with 5.25:12 pitch and fell off ; no fall protection utilized.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion:</u> Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
91NJ005	Employee on residential roof installing shingles, not tied off, fell 25'.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports,

											lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
91NJ008	Victim and his co-worker were painting elevated pipelines at a tank farm when he apparently lost his balance and fell to the asphalt below. NIOSH report provides 3 recommendations for engineers to provide fall protection.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.
91NJ009	The crew was moving the drill rig off the road when the boom contacted the 7,200 volt overhead power line. The power passed through the drill rig into the steel reinforced air hose, through the compressor, and into the dump truck.			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins. Include the name, address, and telephone number of local utility companies on the drawings.
91NJ015	The victim cut the plywood in a room off the second floor hallway and fell through stairway. The hallway was an open area measuring 5 feet by 6 feet 4 inches. Stairs were not yet installed in the house.			X	X					X	Design and schedule permanent stairways to be built as soon as possible in the construction phase and used by the construction workers.
92NJ006	Victim was preparing to install steel decking sheets to the peak of a roof. The victim had just climbed up to a stack of steel decking that was resting between two steel girders. He apparently moved to the side of the stack and was trying to separate the first sheet from the stack with a screwdriver			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.

	when he fell 20' to the concrete floor below.										
92NJ020	A crane handling materials hit overhead powerlines.			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins. Include the name, address, and telephone number of local utility companies on the drawings.
93NJ087	Workers were removing mud collected at the bottom of a newly constructed sewage wet well. The victim was standing at the top of the wet well to guide a 50 gallon drum that was being lowered into an equipment hatch. He was placing his foot against the drum, the chain holding the drum slipped off its supporting hook, causing the drum and the victim to fall into the wet well. NIOSH report specifically states that a guardrail system around the hatch opening would have prevented this accident.			X	X					X	Provide permanent guardrails around floor openings. For access doors through floors, use doors which immediately provide guarded entry around the hole perimeter when the door is opened.
93NJ112	Victim was marking a steel I-beam for placing steel joists and was last seen moving along the beam. He apparently lost balance while moving over an irregular section between two beams, fell and landed on a cement piling.	X			X					X	The federal OSHA investigation found that the beam the victim was on was directly connected to a smaller beam and concluded that the victim was unaware of this and lost his balance when his foot met the gap as he turned around. Design members which are of consistent size, light weight, and easy to handle. Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design columns with holes at 21 and 42

											inches above the floor level to provide support locations for lifelines and guardrails.
94NJ124	The victim was installing aluminum siding on the sides of the house. He and a co-worker were setting up anchors for a pole jack scaffold when the victim stepped on a bracket to test its strength. The bracket came loose from the building, causing the victim to fall 25 feet from the roof of the building to the driveway.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.
96NJ003	Employees were hired as temporary laborers to shovel snow from the roof of a large warehouse following a blizzard. On the roof were a number of plastic-domed fire-vents, which closely resemble skylights but are designed to melt away in a fire and allow smoke to escape. The victim decided to take a break. He sat down on the edge of one of the fire-vents, which collapsed under his weight. The victim went through the plastic dome, falling 30' to the warehouse floor.			X	X					X	Design domed, rather than flat, skylights with shatterproof glass or add strengthening wires. Design guardrail protection around skylights.
97NJ067	Employees were erecting and bolting steel beams together they fell 26'; had no fall protection. The crane operator lifted the beam to the victim, who reached out to it with one hand while holding the vertical beam behind him with his other hand.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails.
95NJ088	Employees were installing pre-manufactured stairwell (in 3 assemblies), landing separate from the stairs, stair fell away from the landing and employee fell.			X		X				X	Design and schedule a permanent stairway to be constructed at the beginning, or as close as possible to the start, of construction. Avoid stair landings constructed separate from the stairs. Consider using prefabricated stairways which

											can be erected as one assembly.
99OK009	The victim was part of a two-man crew installing sealing tape on metal roof decking. The laborer stood, turned, and stepped through a skylight opening that had been unsecured in preparation for installing the skylight and roof decking. The skylight buckled and he fell through opening.			X	X					X	Design domed, rather than flat, skylights with shatterproof glass or add strengthening wires. Design guardrail protection around skylights.
93WI214	Employee using extension cords without ground wires, through puddles, connected to temporary e-box installed by electric company. The power pole had been inspected and certified as meeting local municipality code requirements prior to having the utility company install the meter. However, testing after the incident disclosed the GFCI was inoperative, and the fuse box for the 120 volt single phase 15- and 20-ampere receptacle outlets located at the power pole contained two 40-ampere fuses.			X		X				X	Design and schedule safe tie-ins to existing utilities. Ensure that the electrical system design meets all National Electric Code requirements and the requirements of National Fire Protection Association.
93WI239	Victim was standing on the porch roof while installing the windows and a co-worker was providing assistance from the ground level. The co-worker was standing on the stair steps of the porch handing the victim a storm window when the incident occurred. When the victim leaned over the edge of the roof and grasped the window he lost his balance and fell to the ground striking his head on the concrete sidewalk.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
93WI254	Electrician to install conduit and wiring for a surveillance camera on the flat roof of a hospital. An 18" high ledge surrounds the			X	X					X	Design the parapet to be 42 inches tall. A parapet of this height will provide immediate guardrail protection and eliminate the need to

	roof edge, and a wire rope guard railing was located 20' from each roof edge. He was standing outside the guard railing using a reel pulling tape to pull de-energized electrical wire through a conduit. There were no witnesses to the incident, and it appears he inadvertently stepped to the edge of the roof and fell 55' to the ground.										construct a guardrail during construction or future roof maintenance.
94WI344	There was no fall protection equipment in use at the time of the incident. The victim and a co-worker were on the roof carrying a panel toward the leading edge of the roof, when the victim tripped and fell head first over the edge of the roof 24' below.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. Design the parapet to be 42 inches tall. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or future roof maintenance.
97WV055	The victim and a co-worker began placing chalk lines on the roof (chalk lines serve as a guide for straight and even shingle placement) when the victim fell from the roof.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion</u>: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.

Appendix B

Incidents Linked to the Design for Construction Safety Concept – Occupational Safety and Health Administration Inspection Reports

Case #	Incident Description	Q1			Q2			Q3			Design Suggestion(s)
		Yes	*Maybe*	*No*	*Yes*	*Maybe*	*No*	*Yes*	*Maybe*	*No*	
300847506	Employee was sweating a water line to connect a water meter, and an unidentified grey plastic line was next to it. He assumed it was for cable, other lines were identified, and gas line was 5' away. This grey line was gas and torch went through it and explosion.			X	X					X	Indicate on the contract drawings the locations of existing underground utilities and mark a clear zone around the utilities. Note on the drawings the source of information and level of certainty on the location of underground utilities. Include the name, address, and telephone number of local utility companies on the drawings.
120239785	Employee was installing interior gas lines and stood on a wooden truss to do so. The truss gave way and he fell 20'. The truss was only held by one nail, and other trusses were held by 3 nails. Another contractor stood on the same truss to do other work but did not fall.		X		X			X			Was the truss designed for use during construction? Were there supposed to be 3 nails in every truss? Would this still have prevented the collapse? Consider using pre-fabricated metal timber fasteners for wood connections instead of end nailing or toe nailing. New design suggestion: Consider that structural members can be utilized as work areas during construction, and design for their stability.
120309000	Employee was on ladder w/ one foot on top of wall, he fell backwards to ground. Foremen stated that the trusses were not sufficient to use fall protection.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider

											permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
119889087	Employee was applying roofing material and fell 19' to the ground.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
120240478	Employee was installing corrugated metal roofing on new storage units, and he fell 14' to concrete floor below.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.
119889392	A 30T crane tipped over and struck nearby worker. The crane's L-track sunk into an existing trench that was filled with aggregate. The pick at the time was well within the crane's capacity.			X			X			X	New design suggestion: Consider the existing site and its potential hazards in relation to the heavy equipment required to perform the scope of work. Provide a warning and information to constructors.
119889012	Employee was erecting steel and metal roofing, he fell 18' to ground below.			X	X					X	Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.
120303763	Employee working on the roof fell through 23'; the roof area was old and rotting. Inspector's notes say the deterioration could have been discovered before project began.	X			X			X			Deterioration in structure was a casual factor. Review the condition and integrity of the existing structure and indicate any known hazards or deficiencies on the contract drawings. New design suggestion: Before demolishing and renovating any roof structure which is

											damaged, ensure that an engineering survey is performed by a competent person to determine the condition of the roof, trusses, purlins, and the structure itself to evaluate the possibility of the structure and its components failing during the work, and to evaluate how fall protection devices will be incorporated into a damaged structure.
300854981	Employee was in trench about 3' deep locating electrical line when trench collapsed. Water trucks had been going by the trench and area was wet from the trucks, and contributed to trench collapse.			X			X		X		<u>New design suggestion:</u> Consider the environmental conditions and the other construction work occurring near trenching and how it will affect the condition of the trench.
300758273	Employee stepped on an unsupported portion of Peri Formworks, Inc. SKYDECK panel. The false-work decking had just been completed per the Peri Formworks, Inc. drawings, but the vertical supports holding up the panels adjacent to the floor beams were about 18" away from the formwork for the floor beam. Consequently, the portion of decking which extended past this support point to the floor beam was not supported.		X				X			X	It is possible that this hazard could have been recognized in the design phase and provisions made to design out the hazard or specify other requirements to reduce or eliminate the hazard.
120304357	Employee, who was not tied off, was kneeling on a fixed I-beam spreading some wire rope around another beam held by crane, and fell 15' to ground.			X	X					X	Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails. Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.
300759164	Employees were on scaffolding performing plaster work using a new technology called EIPS (Parax) which makes for a rough	X			X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports,

	looking surface. Inspector's note state "The configuration of the building is such that it does not have a surface to tie on to for the first 14'.										lifelines, guardrails, and scaffolding. <u>New design suggestion:</u> Design scaffolding tie-off points into exterior walls of buildings for construction and renovation purposes.
126062033	Employees using aluminum ladder were prepping area to be painted, when they came in contact with or got too close to 4800V overhead lines. Employees claimed they did not recognize the existence of the overhead power lines.			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins.
126097815	Employees removing I-beam, one end had strap and a tightening ratchet (come-along) with 2 bolts also holding it in place, when one employee removed the 'Come-along', the I-beam end fell and both employees fell.		X		X					X	The number of bolts specified could have played a role. Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails. Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.
126221894	Employee was using jackhammer to break thru concrete for street light connection and hit 34500 V underground power line.			X	X					X	Indicate on the contract drawings the locations of existing underground utilities and mark a clear zone around the utilities. Note on the contract drawings the level of certainty and source of information on the location of existing underground power lines. Include the name, address, and telephone number of local utility companies on the drawings.
126098151	Employee was wood framing; he was moving from the rafters to the scaffold but mis-stepped and fell 10' to the ground.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.

											New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
126100544	Employees were on roof and one on ground performing work. They had previously dug a trench which undermined two columns which supported the roof, these columns collapsed and roof collapsed, the employee on the ground was killed	X					X	X			The trench de-stabilized the existing columns. New design suggestion: Do not specify trenching activities adjacent to existing structures. Review how the specified trenching activities will affect the adjacent structure.
126108307	Employee was on third floor and fell thru a piece of plywood that was blocking a floor opening where the chimney would be put in place.			X	X			X			Provide permanent guardrails around floor openings. New design suggestion: When design features, such as ventilation systems, trash chutes, chimneys, elevators, etc. cause floor openings to occur during construction, provide a warning in the plans and specifications for construction, and design in permanent guardrail systems and sequence them in early in the construction process for use by all contractors.
362584534	Employee was nailing flooring sheathing near trash chute opening and fell down 5 floors to bottom floor inside trash chute.			X	X			X			Provide permanent guardrails around floor openings. New design suggestion: When design features, such as ventilation systems, trash chutes, chimneys, elevators, etc. cause floor openings to occur during construction, provide a warning in the plans and specifications for construction, and design in permanent guardrail systems and

											sequence them in early in the construction process for use by all contractors.
126159227	Employee was working at second story balcony protected by the permanent guardrail for this new home. He fell into railing and it broke, he fell 12'.		X			X				X	Design handrails and the top rails of a stair rail system to withstand at least 200 lbs. applied within 2 in. of the top edge in any downward or outward direction, at any point along the top edge. Not enough information to say "Yes".
126098706	Employee was laying underlayment on a roof, the employee lost his footing when the felt paper came loose and caused him to fall from the 5:12 pitched roof to the ground below.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion</u>: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
126058569	Employee was on wooden plank in elevator shaft, other employees were lowering equipment to that level, when the manila rope broke, the weight of the materials broke thru the wooden plank and employee standing there fell approx. 21' to basement level.		X				X		X		The design of elevators possibly contributes to accidents b/c employees cannot set-up adequate temporary safety measures for fall protection. If fall protection and work area is considered in the design of elevator shafts, then employees could perform work safely. <u>New design suggestion</u>: Design appropriate and permanent fall protection systems for inside elevator shafts to be utilized during construction and maintenance. Consider anchorage points and lifeline attachments.
126098532	Employee was at bottom of elevator shaft performing normal job duties. He stepped onto the fixed ladder in the shaft and then on		X				X		X		The design of elevators possibly contributes to accidents b/c employees cannot set-up adequate temporary safety measures for fall

	to a 40" high steel beam to gain an access, he slipped and fell.										protection. If fall protection and work area is considered in the design of elevator shafts, then employees could perform work safely. <u>New design suggestion</u>: Design appropriate and permanent fall protection systems for inside elevator shafts to be utilized during construction and maintenance. Consider anchorage points and lifeline attachments.
126102219	Employee was standing on utility ramp next to 8' excavation which was protected by temporary guard railing. Guard rail failed and employee fell into excavation.			X	X					X	Design and schedule handrails, guardrails, and stairrails to be erected as part of the structural steel erection.
119941839	Employee was measuring bolt holes at roof truss using ladder when he fell 18'			X	X					X	Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails. Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.
119941490	Employee working on top of tank, fell 33', no guardrails, accident investigation states that another anchor should have been provided on tank.			X	X					X	Provide a guardrail along the perimeter of the tank roof. Provide connection points for lifelines at the center of the tank roof.
119944437	Employee working around roof opening for skylight, which had a 10" raised curb and plywood over the opening, fell 25'.			X	X					X	Design domed, rather than flat, skylights with shatterproof glass or add strengthening wires. Design guardrail protection around skylights.
119942597	Employee was cleaning the site and fell thru the plywood covering the lube oil pit; this was a Jiffy Lube construction.			X	X					X	Provide permanent guardrails around floor openings.
120309471	Employee on roof w/ 7:12 pitch, climbed out of attic window on to roof and slipped and			X	X			X			Design special attachments or holes in members at elevated work areas to provide

	fell 8' to ground.										permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
126177450	A steel beam fell and hit block mason below. C.E. memo in file describes field changes to erected steel framing, base plate connections, beam-to-column connections, and angle iron supported steel framing			X	X					X	Consider the erection process when designing and locating member connections. Consider alternative steel framing systems which reduce the number of elements and where beams are landed on supports rather than suspended between them
126188697	Employee was spreading decking panels and welding leads close to the edge.			X							Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails. Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.
303657951	Employees were manually lifting a 12' tall by 32' long wood framed and sheathed wall, weighing ~2700 lbs. they began to lower the wall b/c it became too heavy during the lift, the wall then collapsed. Inspector's notes say that the difference in the center of gravity in a 12' high wall vs. an 8' high wall may be an important consideration in whether the wall should be safely lifted manually. Inspector notes 4 other walls 12' or> that have			X			X	X			New design suggestion: Design wood framed walls to be no more than 8' high; when higher walls are specified, provide a warning to the constructors to not lift these higher walls manually.

	collapsed in 4yrs.										
302947981	Employee was working on steel roofed building w/ low pitched roof and fell 12', no fall protection.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion</u>: Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
303363576	Employees using 100' steel tape measure to measure height of building. They were in a scissor lift that touched 72kv power line.			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins. Include the name, address, and telephone number of local utility companies on the drawings.
303658827	Employee was a flagger on Friday night / Saturday morning (1am Sat.), and was struck by a car at an intersection where he was standing. There is conflicting evidence if a work truck was blocking the view of the oncoming traffic.			X		X				X	Avoid performing road work on Friday and Saturday nights. Minimize the amount of night work Detour public traffic around the project site.
303440911	Employee in 17' deep trench and the trench caves-in. He was performing drainage pipe installation. The trench walls were vertical, Type A soil conditions.			X			X	X			<u>New design suggestion</u>: Evaluate soil conditions, provide that information, and specify proper trenching and shoring based on the conditions in relation to the specified work.
303440424	Employee driving from job on state road and involved in truck accident. They left the			X	X					X	To prevent accidents resulting from tired construction workers, do not allow

	home office at 6:00pm, got to site and started work at 10:45pm; worked all night on concrete pour; finished at 1:30pm the next day; accident occurred at 3:00pm. Employee was up all night (minimum 21 hrs), worked ~14.5 hrs.										schedules which contain sustained overtime. Minimize the amount of night work.
303791800	Employees were working from a scaffold constructing a new water tank. The temporary bracket weld to which the scaffold was affixed broke and the scaffold fell 24'. Inspector found that it was a deficient weld that failed.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New suggestion:</u> Design appropriate tank anchor points on the interior of the tank for construction and maintenance purposes.
304433618	Employee was working on a tilt-up wall laid on the second story near open sided platform at top of stair way. He fell over the unprotected side.			X	X					X	Design and schedule permanent stairways to be built as soon as possible in the construction phase and used by the construction workers.
304827330	Employee driving dirt truck and went around curve up embankment and tipped truck at 4:00am, after working ~9.5 hours. Speculation is that he fell asleep at the wheel.			X		X				X	Minimize the amount of night work.
304827330	Employee was directing a truck to back out of construction area on to State Road and was hit by a car. He did not have illuminating clothing, there were no road work signs posted, no traffic control plan. This work was warranty work per the contract and was of a short duration.			X		X				X	During road work, slow down the ongoing traffic as much as possible by closing down adjacent lanes, posting flag-people to control traffic, or running lead cars to guide the adjacent traffic.
305684078	Employee in trench positioning sewer pipe held by boom of trac-hoe. Trac-hoe boom hit an overhead power line and shocked employee in trench.			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins.

303978118	Employee was installing gutter a new apartment building from a scissors lift. The gutter hit power lines that were live.			X	X					X	Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure. Disconnect, reduce voltage, or re-route power lines around the project before it begins. Include the name, address, and telephone number of local utility companies on the drawings.
304663941	Employee was welding metal clips on steel and fell through a garage ventilation shaft.			X	X			X			Provide permanent guardrails around floor openings. <u>New design suggestion</u>: When design features, such as ventilation systems, trash chutes, chimneys, elevators, etc. cause floor openings to occur during construction, provide a warning in the plans and specifications for construction, and design in permanent guardrail systems and sequence them in early in the construction process for use by all contractors.
306004706	Employee repairing roof; he fell off roof edge, not wearing fall protection.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion</u>: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
305314874	Employee using crane to drive piles when it slipped from the cribbing and tipped contacting power lines. The sub-contactor			X	X			X			Locate on contract drawing the existence of overhead power lines and their location in relation to the new structure.

	never received a copy of the geotechnical report which alerted to the site conditions which caused the accident. The geotechnical eng. did their job but maybe the architect did not provide info to the subcontractors.										Disconnect, reduce voltage, or re-route power lines around the project before it begins. New design suggestion: Consider the existing site and its potential hazards in relation to the heavy equipment required to perform the scope of work. Provide a warning and information to constructors.
304166390	Employee was texturing near a second level landing which was not protected by standard guardrail; he stepped back and fell off landing.			X	X			X			Provide permanent guardrails around floor openings. Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design and schedule handrails, guardrails, and stairrails to be built as part of the erection process.
304107832	Employees were in the process of installing a fall protection system on a 12:12 (steep) pitched church roof. The scaffolding / ladder system failed and one employee fell off roof. A custodian from the church verbally attacked the crew for driving temporary anchors into the walls of the church to anchor the scaffolding used, so the crew did not continue to use the temporary anchor for the scaffolding.		X		X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment. New design suggestion: Design scaffolding tie-off points into exterior walls of buildings for construction and renovation purposes.
304817679	Employee working from roof and fell; no fall protection			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports,

											lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
303603013	Employee removing rotted roofing material and fell through rotted section. They utilized plywood planks nailed to structure to work from and employee went off the plank and on to rotted section.	X			X			X			Review the condition and integrity of the existing structure and indicate any known hazards or deficiencies on the contract drawings. New design suggestion: Before demolishing and renovating any roof structure which is damaged, ensure that an engineering survey is performed by a competent person to determine the condition of the roof, trusses, purlins, and the structure itself to evaluate the possibility of the structure and its components failing during the work, and to evaluate how fall protection devices will be incorporated into a damaged structure.
304062110	Employee was finishing placing sheathing and he slipped and rolled down roof to the ground below			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for commercial roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
303595367	Employee was operating a road roller;			X	X					X	In embankments directly adjacent to the

	vehicle sank in dirt near embankment and rolled down embankment and crush employee.										road edge, provide an initial bench at the road grade to provide room for crews to work. Provide structural support at the edge of roadways to keep heavy construction equipment from crushing the edge and overturning.
303312532	Employee was in the process of installing 2x4 footings for fall protection on an 8:12 pitched roof, when he fell 18' off roof.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion</u>: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
303599112	Employee was pressure washing chimney in preparation for painting, roof was 8:12 cedar shake. He fell on the wet shakes and fell 13' below. The chimney was next to skylight.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. <u>New design suggestion</u>: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.
303309538	Employee was sanding overspray on the edge of a 12' mezzanine when he stepped and fell over the edge. There was a temporary guardrail there previously, but was taken down by another contractor when they			X	X			X			Provide permanent guardrails around floor openings. Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports,

	finished their work.										lifelines, guardrails, and scaffolding. New design suggestion: Design and schedule handrails, guardrails, and stairrails to be built as part of the erection process.
302966130	Employee was installing electrical conduit in ceiling of a corridor that had been previously sheetrocked. The sheetrock limited the employee's access for installing the conduit. Inspection report states "he had to change his normal work practice to work above the ceiling rather than install conduit from a ladder below the ceiling.		X				X		X		New suggestion: Consider electrical conduit/wiring and sequence it in before permanent ceilings or walls are constructed which would limit access during installation.
302685482	Employee was adjusting ladder near roof's edge and he fell 17' off roof. He did not wear fall protection. OSHA investigation revealed that the roofers had temporary fall anchors installed but used incorrect means to secure anchors and routinely had 2 - 3 employees tied to the same anchor which is incorrect procedure.			X	X			X			Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding. New design suggestion: Design appropriate and permanent fall protection systems for residential roofs to be used for construction and maintenance purposes. Consider permanent anchorage points, lifeline attachments, and/or perimeter holes for guardrail attachment.

Appendix C

Chi-Square Tables – National Institute of Occupational Safety and Health Fatality Assessment Control Evaluation Program

SIC Codes compressed by type of industry / work performed X Final Question compressed

			BIGQCOMP		
			No	Yes	Total
SIC_COMP	General Building Contractors-residential	Count	10	10	20
		Expected Count	11.6	8.4	20.0
		Residual	-1.6	1.6	
		Std. Residual	-.5	.5	
		Adjusted Residual	-.7	.7	
	General Building Contractors-nonresidential	Count	11	7	18
		Expected Count	10.4	7.6	18.0
		Residual	.6	-.6	
		Std. Residual	.2	-.2	
		Adjusted Residual	.3	-.3	
	Highway and Street Construction	Count	13	6	19
		Expected Count	11.0	8.0	19.0
		Residual	2.0	-2.0	
		Std. Residual	.6	-.7	
		Adjusted Residual	1.0	-1.0	
	Heavy Construction, Except Highway and Street	Count	19	12	31
		Expected Count	17.9	13.1	31.0
		Residual	1.1	-1.1	
		Std. Residual	.3	-.3	
		Adjusted Residual	.4	-.4	
	ElecMech	Count	24	7	31
		Expected Count	17.9	13.1	31.0
		Residual	6.1	-6.1	
		Std. Residual	1.4	-1.7	
		Adjusted Residual	2.4	-2.4	
	Other Specialty trades	Count	13	10	23
		Expected Count	13.3	9.7	23.0
		Residual	-.3	.3	
		Std. Residual	-.1	.1	
		Adjusted Residual	-.1	.1	
	Carpentry	Count	8	5	13
		Expected Count	7.5	5.5	13.0
		Residual	.5	-.5	
		Std. Residual	.2	-.2	
		Adjusted Residual	.3	-.3	
	Roofing	Count	9	14	23
		Expected Count	13.3	9.7	23.0
		Residual	-4.3	4.3	
		Std. Residual	-1.2	1.4	
		Adjusted Residual	-1.9	1.9	
	MasonyConcrete	Count	13	6	19
		Expected Count	11.0	8.0	19.0
		Residual	2.0	-2.0	
		Std. Residual	.6	-.7	
		Adjusted Residual	1.0	-1.0	
	Structural Steel	Count	9	17	26
		Expected Count	15.0	11.0	26.0
		Residual	-6.0	6.0	
		Std. Residual	-1.6	1.8	
		Adjusted Residual	-2.6	2.6	
Total		Count	129	94	223
		Expected Count	129.0	94.0	223.0

Chi-Square Tests: SIC Codes compressed by type of industry / work performed X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	16.495[a]	9	.057
Likelihood Ratio	16.802	9	.052
Linear-by-Linear Association	.981	1	.322
N of Valid Cases	223		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.48.

Symmetric Measures: SIC Codes compressed by type of industry / work performed X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	.272	.057
	Cramer's V	.272	.057
N of Valid Cases		223	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Number of employees in the injured's firm X Final Question compressed

			BIGQCOMP		
			No	Yes	Total
EMP#COMP	< 20	Count	58	50	108
		Expected Count	63.0	45.0	108.0
		Residual	-5.0	5.0	
		Std. Residual	-.6	.7	
		Adjusted Residual	-1.4	1.4	
	> 20	Count	65	38	103
		Expected Count	60.0	43.0	103.0
		Residual	5.0	-5.0	
		Std. Residual	.6	-.8	
		Adjusted Residual	1.4	-1.4	
Total		Count	123	88	211
		Expected Count	123.0	88.0	211.0

Chi-Square Tests: Number of employees in the injured's firm X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.917[b]	1	.166		
Continuity Correction[a]	1.550	1	.213		
Likelihood Ratio	1.922	1	.166		
Fisher's Exact Test				.209	.106
Linear-by-Linear Association	1.908	1	.167		
N of Valid Cases	211				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 42.96.

Symmetric Measures: Number of employees in the injured's firm X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.095	.166
	Cramer's V	.095	.166
N of Valid Cases		211	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Nature of construction compressed X Final Question compressed

			BIGQCOMP		
			No	Yes	Total
NAT_COMP	New Construction	Count	69	47	116
		Expected Count	66.8	49.2	116.0
		Residual	2.2	-2.2	
		Std. Residual	.3	-.3	
		Adjusted Residual	.6	-.6	
	Upgrade	Count	53	43	96
		Expected Count	55.2	40.8	96.0
		Residual	-2.2	2.2	
		Std. Residual	-.3	.4	
		Adjusted Residual	-.6	.6	
Total		Count	122	90	212
		Expected Count	122.0	90.0	212.0

Chi-Square Tests: Nature of construction compressed X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.393[b]	1	.531		
Continuity Correction[a]	.237	1	.626		
Likelihood Ratio	.393	1	.531		
Fisher's Exact Test				.578	.313
N of Valid Cases	212				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 40.75.

Symmetric Measures: Nature of construction compressed X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	.043	.531
	Cramer's V	.043	.531
N of Valid Cases		212	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Type of construction project X Final Question compressed

			BIGQCOMP		
			No	Yes	Total
TYPEOF	Commercial	Count	47	26	73
		Expected Count	41.8	31.2	73.0
		Residual	5.2	-5.2	
		Std. Residual	.8	-.9	
		Adjusted Residual	1.5	-1.5	
	Engineering	Count	33	22	55
		Expected Count	31.5	23.5	55.0
		Residual	1.5	-1.5	
		Std. Residual	.3	-.3	
		Adjusted Residual	.5	-.5	
	Industrial	Count	16	20	36
		Expected Count	20.6	15.4	36.0
		Residual	-4.6	4.6	
		Std. Residual	-1.0	1.2	
		Adjusted Residual	-1.7	1.7	
	Residential	Count	27	24	51
		Expected Count	29.2	21.8	51.0
		Residual	-2.2	2.2	
		Std. Residual	-.4	.5	
		Adjusted Residual	-.7	.7	
Total		Count	123	92	215
		Expected Count	123.0	92.0	215.0

Chi-Square Tests: Type of construction project X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	4.485[a]	3	.214
Likelihood Ratio	4.479	3	.214
N of Valid Cases	215		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 15.40.

Symmetric Measures: Type of construction project X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	.144	.214
	Cramer's V	.144	.214
N of Valid Cases		215	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Design discipline compressed X Final Question compressed

			BIGQCOMP		
			No	Yes	Total
DES_COMP	Architectural	Count	23	32	55
		Expected Count	31.4	23.6	55.0
		Residual	-8.4	8.4	
		Std. Residual	-1.5	1.7	
		Adjusted Residual	-2.7	2.7	
	Civil	Count	44	22	66
		Expected Count	37.6	28.4	66.0
		Residual	6.4	-6.4	
		Std. Residual	1.0	-1.2	
		Adjusted Residual	1.9	-1.9	
	Electrical	Count	10	6	16
		Expected Count	9.1	6.9	16.0
		Residual	.9	-.9	
		Std. Residual	.3	-.3	
		Adjusted Residual	.5	-.5	
	Mechanical	Count	13	3	16
		Expected Count	9.1	6.9	16.0
		Residual	3.9	-3.9	
		Std. Residual	1.3	-1.5	
		Adjusted Residual	2.0	-2.0	
	Structural	Count	28	26	54
		Expected Count	30.8	23.2	54.0
		Residual	-2.8	2.8	
		Std. Residual	-.5	.6	
		Adjusted Residual	-.9	.9	
Total		Count	118	89	207
		Expected Count	118.0	89.0	207.0

Chi-Square Tests: Design discipline compressed X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	12.309[a]	4	.015
Likelihood Ratio	12.702	4	.013
N of Valid Cases	207		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.88.

Symmetric Measures: Design discipline compressed X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	.244	.015
	Cramer's V	.244	.015
N of Valid Cases		207	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Work performed compressed X Final Question compressed

			BIGQCOMP		Total
			No	Yes	
WPERFCOM	Equipment and conveying systems	Count	8	5	13
		Expected Count	7.5	5.5	13.0
		Residual	.5	-.5	
		Std. Residual	.2	-.2	
		Adjusted Residual	.3	-.3	
	Electrical and Mechanical	Count	19	8	27
		Expected Count	15.7	11.3	27.0
		Residual	3.3	-3.3	
		Std. Residual	.8	-1.0	
		Adjusted Residual	1.4	-1.4	
	Site Work	Count	41	16	57
		Expected Count	33.1	23.9	57.0
		Residual	7.9	-7.9	
		Std. Residual	1.4	-1.6	
		Adjusted Residual	2.5	-2.5	
	Concrete and masonry	Count	16	4	20
		Expected Count	11.6	8.4	20.0
		Residual	4.4	-4.4	
		Std. Residual	1.3	-1.5	
		Adjusted Residual	2.1	-2.1	
	Metals	Count	10	20	30
		Expected Count	17.4	12.6	30.0
		Residual	-7.4	7.4	
		Std. Residual	-1.8	2.1	
		Adjusted Residual	-2.9	2.9	
	Wood & Plastics	Count	7	5	12
		Expected Count	7.0	5.0	12.0
		Residual	.0	.0	
		Std. Residual	.0	.0	
		Adjusted Residual	.0	.0	
	Thermal / moisture protection AND Doors and windows	Count	19	29	48
		Expected Count	27.9	20.1	48.0
		Residual	-8.9	8.9	
		Std. Residual	-1.7	2.0	
		Adjusted Residual	-2.9	2.9	
	Finishes	Count	10	7	17
		Expected Count	9.9	7.1	17.0
		Residual	.1	-.1	
		Std. Residual	.0	-.1	
		Adjusted Residual	.1	-.1	
Total		Count	130	94	224
		Expected Count	130.0	94.0	224.0

Chi-Square Tests: Work performed compressed X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	24.464[a]	7	.001
Likelihood Ratio	24.922	7	.001
N of Valid Cases	224		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.04.

Symmetric Measures: Work performed compressed X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	.330	.001
	Cramer's V	.330	.001
N of Valid Cases		224	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Chi-Square Test

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Chi-square goodness of fit test: The distribution of data in the
NIOSH database is not significantly different from the expected
distribution based on actual distribution of fatalities in the
construction industry using 3-digit SIC Codes in 2002.
```

Frequencies

The categories

	Expected N	Observed N	Residual
152	19	20.0	-1.0
154	16	18.0	-2.0
161	17	19.0	-2.0
162	33	24.0	9.0
171	14	11.0	3.0
172	9	8.0	1.0
173	22	19.0	3.0
174	10	7.0	3.0
175	13	13.0	.0
176	23	23.0	.0
177	6	8.0	-2.0
179	38	50.0	-12.0
Total	220		

Test Statistics

	The categories
Chi-Square[a]	9.940
df	11
Asymp. Sig.	.536

a. 0 cells (.0%) have expected frequencies less than 5. The minimum expected cell frequency is 7.0.

Appendix D

Chi-Square Tables – Occupational Safety and Health Administration Inspection Reports

OSHA citation status X Final Question compressed

			BIGQCOMP		
			No	Yes	Total
CITATION	No	Count	78	21	99
		Expected Count	74.0	25.0	99.0
		Residual	4.0	-4.0	
		Std. Residual	.5	-.8	
		Adjusted Residual	1.2	-1.2	
	Yes	Count	91	36	127
		Expected Count	95.0	32.0	127.0
		Residual	-4.0	4.0	
		Std. Residual	-.4	.7	
		Adjusted Residual	-1.2	1.2	
Total		Count	169	57	226
		Expected Count	169.0	57.0	226.0

Chi-Square Tests: OSHA citation status X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	1.501[b]	1	.220		
Continuity Correction[a]	1.147	1	.284		
Likelihood Ratio	1.517	1	.218		
Fisher's Exact Test				.280	.142
Linear-by-Linear Association	1.495	1	.221		
N of Valid Cases	226				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 24.97.

Symmetric Measures: OSHA citation status X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	.082	.220
	Cramer's V	.082	.220
N of Valid Cases		226	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Fatality or disabling injury X Final Question compressed

			BIGQCOMP		Total
			No	Yes	
FAT_INJ	fatality	Count	22	15	37
		Expected Count	27.7	9.3	37.0
		Residual	-5.7	5.7	
		Std. Residual	-1.1	1.9	
		Adjusted Residual	-2.3	2.3	
	injury	Count	147	42	189
		Expected Count	141.3	47.7	189.0
		Residual	5.7	-5.7	
		Std. Residual	.5	-.8	
		Adjusted Residual	2.3	-2.3	
Total		Count	169	57	226
		Expected Count	169.0	57.0	226.0

Chi-Square Tests: Fatality or disabling injury X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.505[b]	1	.019		
Continuity Correction[a]	4.577	1	.032		
Likelihood Ratio	5.079	1	.024		
Fisher's Exact Test				.024	.019
Linear-by-Linear Association	5.481	1	.019		
N of Valid Cases	226				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 9.33.

Symmetric Measures: Fatality or disabling injury X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.156	.019
	Cramer's V	.156	.019
N of Valid Cases		226	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Nature of construction compressed X Final Question compressed

			BIGQCOMP		
			No	Yes	Total
NAT_COMP	New Construction	Count	78	39	117
		Expected Count	85.6	31.4	117.0
		Residual	-7.6	7.6	
		Std. Residual	-.8	1.3	
		Adjusted Residual	-2.4	2.4	
	Upgrade	Count	69	15	84
		Expected Count	61.4	22.6	84.0
		Residual	7.6	-7.6	
		Std. Residual	1.0	-1.6	
		Adjusted Residual	2.4	-2.4	
Total		Count	147	54	201
		Expected Count	147.0	54.0	201.0

Chi-Square Tests: Nature of construction compressed X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	5.960[b]	1	.015		
Continuity Correction[a]	5.199	1	.023		
Likelihood Ratio	6.158	1	.013		
Fisher's Exact Test				.016	.011
N of Valid Cases	201				

a. Computed only for a 2x2 table

b. 0 cells (.0%) have expected count less than 5. The minimum expected count is 22.57.

Symmetric Measures: Nature of construction compressed X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	-.172	.015
	Cramer's V	.172	.015
N of Valid Cases		201	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Type of construction project X Final Question compressed

			BIGQCOMP		
			No	Yes	Total
TYPEOF	Commercial	Count	53	25	78
		Expected Count	58.7	19.3	78.0
		Residual	-5.7	5.7	
		Std. Residual	-.7	1.3	
		Adjusted Residual	-1.9	1.9	
	Engineering	Count	36	5	41
		Expected Count	30.8	10.2	41.0
		Residual	5.2	-5.2	
		Std. Residual	.9	-1.6	
		Adjusted Residual	2.1	-2.1	
	Industrial	Count	19	3	22
		Expected Count	16.6	5.4	22.0
		Residual	2.4	-2.4	
		Std. Residual	.6	-1.0	
		Adjusted Residual	1.3	-1.3	
	Residential	Count	50	19	69
		Expected Count	51.9	17.1	69.0
		Residual	-1.9	1.9	
		Std. Residual	-.3	.5	
		Adjusted Residual	-.7	.7	
Total		Count	158	52	210
		Expected Count	158.0	52.0	210.0

Chi-Square Tests: Type of construction project X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.447[a]	3	.059
Likelihood Ratio	8.078	3	.044
N of Valid Cases	210		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 5.45.

Symmetric Measures: Type of construction project X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	.188	.059
	Cramer's V	.188	.059
N of Valid Cases		210	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Design discipline compressed X Final Question compressed

			BIGQCOMP		
			No	Yes	Total
DES_COMP	Architectural	Count	21	24	45
		Expected Count	30.8	14.2	45.0
		Residual	-9.8	9.8	
		Std. Residual	-1.8	2.6	
		Adjusted Residual	-3.7	3.7	
	Civil	Count	40	13	53
		Expected Count	36.3	16.7	53.0
		Residual	3.7	-3.7	
		Std. Residual	.6	-.9	
		Adjusted Residual	1.3	-1.3	
	Electrical Mechanical	Count	29	4	33
		Expected Count	22.6	10.4	33.0
		Residual	6.4	-6.4	
		Std. Residual	1.4	-2.0	
		Adjusted Residual	2.7	-2.7	
	Structural	Count	27	13	40
		Expected Count	27.4	12.6	40.0
		Residual	-.4	.4	
		Std. Residual	-.1	.1	
		Adjusted Residual	-.1	.1	
Total		Count	117	54	171
		Expected Count	117.0	54.0	171.0

Chi-Square Tests: Design discipline compressed X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	16.874[a]	3	.001
Likelihood Ratio	17.232	3	.001
N of Valid Cases	171		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 10.42.

Symmetric Measures: Design discipline compressed X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	.314	.001
	Cramer's V	.314	.001
N of Valid Cases		171	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Work performed compressed X Final Question compressed

			BIGQCOMP		
			No	Yes	Total
WPERFCOM	Other	Count	19	10	29
		Expected Count	21.2	7.8	29.0
		Residual	-2.2	2.2	
		Std. Residual	-.5	.8	
		Adjusted Residual	-1.0	1.0	
	Electrical and Mechanical	Count	28	2	30
		Expected Count	21.9	8.1	30.0
		Residual	6.1	-6.1	
		Std. Residual	1.3	-2.1	
		Adjusted Residual	2.7	-2.7	
	Site Work	Count	50	14	64
		Expected Count	46.8	17.2	64.0
		Residual	3.2	-3.2	
		Std. Residual	.5	-.8	
		Adjusted Residual	1.1	-1.1	
	Concrete / masonry / metals	Count	27	8	35
		Expected Count	25.6	9.4	35.0
		Residual	1.4	-1.4	
		Std. Residual	.3	-.5	
		Adjusted Residual	.6	-.6	
	Wood & Plastics	Count	17	6	23
		Expected Count	16.8	6.2	23.0
		Residual	.2	-.2	
		Std. Residual	.0	-.1	
		Adjusted Residual	.1	-.1	
	Thermal moisture protection AND Doors and windows	Count	11	16	27
		Expected Count	19.7	7.3	27.0
		Residual	-8.7	8.7	
		Std. Residual	-2.0	3.2	
		Adjusted Residual	-4.1	4.1	
Total		Count	152	56	208
		Expected Count	152.0	56.0	208.0

Chi-Square Tests: Work performed compressed X Final Question compressed

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	22.580[a]	5	.000
Likelihood Ratio	22.488	5	.000
N of Valid Cases	208		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 6.19.

Symmetric Measures: Work performed compressed X Final Question compressed

		Value	Approx. Sig.
Nominal by Nominal	Phi	.329	.000
	Cramer's V	.329	.000
N of Valid Cases		208	

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.