SUGGESTED PRACTICES FOR PREVENTING CONSTRUCTION WORKER FALLS

By

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To my wonderful parents and loving husband!

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The construction industry has a disproportionately large number of injuries and fatalities in comparison to other industrial sectors. The OSHA Standards specify the standards that need to be followed in order to reduce the number of work site injuries and fatalities occurring as a result of falls from scaffolds, ladders, leading edges, floor openings, roof openings, sky-lights and excavations as well as structural erections- concrete and steel. The fact that inspite of such rules and regulations being in place, there are unusually high number of injuries, indicates that there is still a need to study and improvise the solutions to prevent such falls on a construction site.

The more important fact is that most falls are preventable if proper safety precautions are taken and fall prevention techniques implemented. Most construction companies now have specific safety initiatives, injury-free work-place programs in place, but the threat of falls and accidents still continues to be a concern to the construction industry. This study will attempt to study methods to improve fall prevention on construction sites and shall also attempt to examine the opportunities and impacts of designing work at height during the design phase of projects and of addressing the requirements of the falls prevention for a project during the procurement process.

CHAPTER 1
INTRODUCTION

Problem Statement

In comparison with other industrial sectors, the construction industry has a disproportionately high percentage of injuries and fatalities, accounting for almost 20% of the fatalities of all industrial workers but employing only 6-8% of the industrial work force. It is important to acknowledge the fact that the construction industry accounts for nearly 15 % of the workers' compensation injuries. Of all the injuries and deaths occurring on construction sites, falls are the single largest cause, accounting for almost 38% of the construction worker deaths.

The OSHA regulations were promulgated to reduce the number of work site injuries and fatalities occurring as a result of falls. A significant portion of the regulations are focused on fall protection. Despite the OSHA regulations, there are an unusually high number of injuries which indicates that there is still a need to make further improvements to prevent construction injuries. The purpose of this study was to explore the best methods of fall prevention for different types of fall hazards commonly encountered on the construction sites.

Accidents happen on work sites as a result of negligence on the part of workers, hazards associated with the work, unsafe work-conditions, supervisory shortcomings, managerial mistakes and other factors. Even if construction workers are specialized in performing specific activities, they are exposed to more hazards than workers associated with other industrial trades.

While the safety record of the US Construction Industry has been far-surpassed by improvements made through the efforts of various large construction companies through their safety initiatives and injury free programs and other specific programs, the threat of falls is a continuing concern to the industry. The aim of this study was to devise means by which falls could be reduced through the implementation of specific techniques. This study examined how fall safety can be improved in the construction industry.

Scope of the Study

This study focused on developing means by which to prevent falls that commonly pose a risk on typical construction projects, including but not limited to the following:

- Falls form Scaffolds
- Falls from Ladders
- Falls from unprotected elevated floors
- Falls from leading edges
- Falls through floor openings
- Falls through roof openings and skylights
- Falls into excavations
- Falls on the same level (often resulting form slips or trips)
- Falls during structural erection-steel/iron and wood-framing work.

This study will attempted to put forth methods to improve construction fall prevention techniques and the stages of work at which they should be implemented. The aim of this study was also to examine the opportunities and impacts of designing work at height during the design phase of projects and of addressing the requirements of falls prevention for a project during the procurement process.

Objectives of this study

- Improve the level of compliance with falls prevention techniques within targeted construction sectors and sub-sectors.
- Improve the capability of builders and targeted subcontractors to recognize, manage and control fall-related hazards and risks.
- Increase builders’ and targeted subcontractors’ perceptions of the risk of detection

- Impose sanctions where non-compliance with fall prevention requirements is permitted.
- Identify and promote best practices and good innovations in managing and controlling fall-related hazards and risks of the targeted work areas.

CHAPTER 2
LITERATURE REVIEW

Overview

The construction industry has the highest number of fatalities of all industries according to OSHA studies. Injuries due to falls have been the most predominant cause of injuries and worker fatalities in the US construction industry. The Bureau of Labor Statistics reported that falls accounted for approximately 20% of all occupational accidents in 1985. By 2006, this number had risen to 38% of all occupational fatalities. OSHA (1999) reported that there were 3,940 fatal occupational falls from 1992 through 1997 in all industries. In 2006, there were a total of 1,226 fatalities due to falls in comparison to the total number of fatalities of 5,703 industry-wide. The Bureau of Labor statistics indicate that falls from higher elevations have been on a steady rise in the construction industry, with total of 600 fall related fatalities in 1992 to 809 fatalities in 2006.

This number of fatalities is surprisingly high when considering the regulations imposed on the industry by the government or OSHA and also the changes and updates in fall protection devices over the last several years. The main concern of industry professionals is to understand this increase in fatalities inspite of all the technological advancements. Several factors need to be considered as possible causes. The first set of factors that will be considered is to examine changes in the OSHA regulations and to analyze their effectiveness in reducing the rate of falls.

The second set of factors would be to consider the possible role of designers in reducing falls and thereby designing for worker safety. Another consideration would be to assess the role of construction companies and professionals in controlling the falls on the construction projects

The last set of considerations would be focused on the workers to analyze how their actions and attitudes can help in reducing the number of falls and becoming effective in making construction work-sites safer.

Several studies on the prevention of falls have been conducted since the 1980's. These studies have covered topics ranging from causes of falls, falls from falls from roofs, falls from scaffolds and studies of falls by type and scale of project.

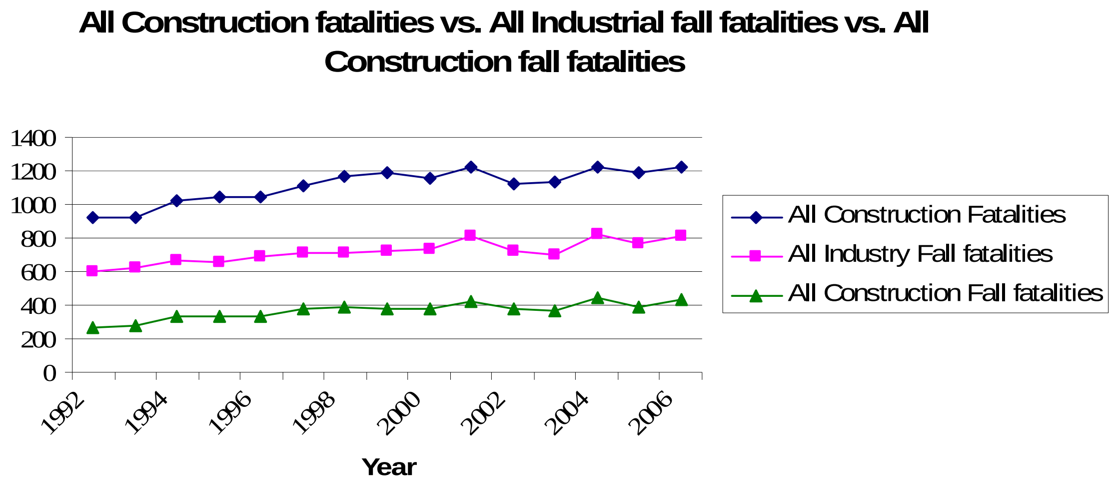


Figure 2-1. Fall fatalities on the basis of the type of fall description provided by Bureau of Labor Statistics (1992- 2006) (Source: Bureau of Labor Statistics, 1992-2006)

Construction Industry Statistics

According to the U S Department of Labor statistics, the construction industry has the highest number of fatalities recorded among all the industries. The construction industry employs about 6% of the U.S. industrial workforce, but has almost 20% of the fatalities, the largest number of fatalities reported for any of the industry sectors.

In 2006, the construction industry recorded 1,226 fatal work injuries, the most of any industry sector. This also indicates an increase of 3% from 2005. Fatalities among specialty trade contractors increased by 6% (from 677 fatalities in 2005 to 721 in 2006), mainly due to higher numbers of fatal work injuries among building finishing contractors and roofing contractors. This steady rise has been widened since 1992 to 2003 (OSHA 2003). In 1992, there were 919 construction fatalities and 600 of those were from different types of falls. In 2006, the total number of fall related fatalities was 809. This clearly indicates that the advancements in technology and awareness of safety on construction sites, has not made a sufficient difference in the rate of fall fatalities. The number of falls reached a record high of 822 in 2004 and has since remained in that range. In 2005, the Bureau of Labor Statistics (BLS) reported that 767 industrial workers died in fatal falls, a 7% decline from the previous year. The number of fall related deaths in 2006 increased by 6% to 809 fatalities. Table 1 summarized information on total fall fatalities by year.

Table 2-1. Detailed breakdown of different types of construction falls (1992-2006) based on BLS data

Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Total Falls in the year	600	618	665	651	691	716	706	721	734	810	719	696	822	770	809
Fall through existing floor opening	11	24	14	16	13	20	21	19	25	24	24	24	22	26	27
Fall through floor surface		4		4	3	4		7	6	5	-	4	3	3	7
Fall from ground level to lower level	10	4	5	7	4	4	3	7	5	6	4		4	6	8
Fall from ladder	78	76	86	97	97	116	111	96	110	123	126	114	135	129	129
Fall from roof	108	120	129	143	149	154	157	153	150	159	143	128	41	160	184
Fall through existing roof opening	8	6	11	18	15	20	12	14	15	11	11	10	16	17	13
Fall through roof surface	12	14	18	19	21	17	20	16	12	26	11	9	14	12	15
Fall through skylight	10	19	14	18	16	17	22	18	16	23	20	18	29	19	36
Fall from roof edge	44	38	41	36	46	56	47	70	69	55	62	67	71	65	82
Fall from scaffold, staging	66	71	89	82	88	87	98	92	85	91	88	85	90	82	88
Fall from building girders or other structural steel	37	40	34	34	38	48	44	49	44	41	41	29	25	25	33

Occupational Safety Health Administration (OSHA) requirements for Fall Protection

With the high number of fall fatalities, it is evident that efforts should be expanded to reduce fall fatalities. This effort should include various parties including designers, construction contractors, construction managers, other construction professional and workers.

OSHA states that identifying fall hazards and deciding the best approach to protect workers is the first step in reducing or eliminating fall hazards. There are a number of ways to protect workers from falls, including conventional systems such as guardrail systems, safety net systems and personal fall protection systems (fall arrest systems, positioning systems and travel restraint systems) as well as through the use of safe work practices and training. The use of warning signs, designated areas, controlled access zones and similar systems are permitted by OSHA in some situations and can provide protection by limiting the number of workers exposed to fall hazards. Alternative systems may be more appropriate than conventional fall protection systems when performing certain activities. While conducting a hazard assessment or developing a comprehensive fall protection plan, thinking about fall hazards and planning for them before the work begins will help to manage fall hazards and to focus attention on prevention efforts. If personal fall protection systems are used, particular attention should be given to identifying attachment points and to ensuring that employees know how to properly utilize the equipment and inspect the equipment.

OSHA Fall Protection requirements

OSHA has recommended a step by step control of fall hazards which includes the following:

- Attempt to eliminate or substitute tasks which can lead to falls.
- Implement various engineering controls and monitoring processes to guard against falls.
- Keep workers informed and aware of fall risks and how to avoid them.

- Ensure the appropriate use of personal protective equipment (PPE).
- With the sole aim of reducing fall accidents on construction sites, the OSHA regulations were modified in 1996 with respect to fall arrest systems and safety positioning device systems. As per the revised regulations, the use of body belts was no longer an acceptable method of personal falls arrest system. For proper protection for workers with risk of falls, body harnesses were required as a personal fall arrest system. Since January 1998, positioning devices also became unacceptable as a method of fall prevention.

Guardrails

While installing a guardrails system, OSHA requires the top rail height to be 39 to 45 inches above the working or walking surface, the mid rail at 21 inches above the walking/working level and a toe-board at the floor level. Top-rails and mid-rails made of wire rope must be at least 1/4 inch diameter to prevent cuts and lacerations. Wire rope rails must also be flagged at not more than 6 feet intervals with high visibility. Screens, mid-rails, mesh, intermediate vertical members, or equivalent intermediate structural members must be installed between the top edge of the guardrail system and the walking/working surface when there are no walls or parapet walls at least 21 inches high. Screens and mesh must extend from the top rail to the working level and along the entire opening between top rail supports. Intermediate members between posts shall not be more than 19 inches apart.

The guardrail system must be capable of withstanding a force of at least 200 lbs applied within two inches of the top edge in any outward or downward direction. Mid-rails, screens, mesh and every intermediate vertical member must be capable of withstanding a force of at least 150 lbs applied in any downward or outward direction at any point along their length. Guardrail systems shall be surfaced so as to protect workers from punctures or lacerations and to prevent clothing from snagging. When installed around openings or holes, guardrail systems must be set up on all unprotected sides or leading edges. When openings are used for the passage of materials, the hole shall have not more than two sides with removable guardrail sections. When the opening is not in use, it must be covered or provided with guardrails along all unprotected sides. If guardrail systems are used around floor or roof that are used as access points (such as ladder-ways), gates must be used or the point of access must be offset to prevent accidental walking into the hole. If guardrails are used at unprotected sides or edges of ramps and runways, they must be erected on each unprotected side or edge.

Safety Nets

Safety nets are required to be installed as close as possible to the working surface and not more than 30 feet below and shall extend at least 8 feet beyond the working surface. They should also be installed with sufficient clearance and must withstand the force of a 400 lb sand bag (28-32 inches diameter) being dropped from minimum height of 42 inches.

Safety nets shall be inspected at least once a week for wear, damage, and other deterioration. The maximum size of each safety net mesh opening shall not exceed 36 square inches and shall not be longer than 6 inches on any side. The openings, measured center-to-center, of mesh ropes or webbing, shall not exceed 6 inches. Each safety net or section shall have a border rope for webbing with a minimum breaking strength of 5,000 pounds.

Safety nets shall be installed with sufficient clearance underneath to prevent contact with the surface or structure below. Safety nets must extend outward from the outermost projection of the work surface as required. Items that have fallen into safety nets such as construction materials, scrap, equipment, and tools, must be removed as soon as possible and at least before the next work shift.

Fall Arrest System

A fall arrest system consists of an anchorage, lanyard, and a body harness, and it may include a deceleration device or lifeline. If a personal fall arrest system is used for fall protection, it must satisfy the following requirements:

- Limit maximum arresting force on an employee to 1,800 lbs when used with a body harness;
- Be rigged so that an employee can neither free fall more than 6 feet nor contact any lower level;
- Bring an employee to a complete stop and limit the maximum deceleration distance an employee travels to 3.5 feet and have sufficient strength to withstand twice the potential impact energy of an employee free -falling a distance of 6 feet or the free fall distance permitted by the system, whichever is less.

Dee-rings and snap-hooks must have a minimum tensile strength of 5,000 lbs. Snap-hooks shall be sized to be compatible with the member to which it will be connected, or shall be of a locking configuration. Irrespective of the positioning of the Dee-ring with the snap-hook attached, the Dee-ring cannot touch the outside of the keeper, thus depressing it open.

On suspended scaffolds or similar work platforms with horizontal lifelines that may become vertical lifelines, the devices used to connect to a horizontal lifeline shall be capable of locking in both directions on the lifeline. Horizontal lifelines shall be designed, installed, and used under the supervision of a qualified person, as part of a complete personal fall arrest system that maintains a safety factor of at least two.

Self-retracting lifelines and lanyards that automatically limit the free fall distance to two feet or less shall be capable of sustaining a minimum tensile load of 3,000 lbs applied to the device with the lifeline or lanyard in the fully extended position. Ropes and straps (webbing) used in lanyards, lifelines, and the strength components of body harnesses shall be made of synthetic fibers.

Anchorages shall be designed, installed, and used under the supervision of an authorized person, as part of a complete personal fall arrest system that maintains a safety factor of at least two. Anchorages used to attach personal fall arrest systems shall be independent of any anchorage being used to support or suspend platforms and must be capable of supporting at least

5,000 lbs per person attached. Lanyards and vertical lifelines must have a minimum breaking strength of 5,000 lbs. Each of these safety systems must be regularly checked for wear and tear, damage or deterioration.

The Occupational Safety and Health Administration (OSHA) standards relate to the safety of the construction site, the implementation of safe work practices, and the safety of temporary structures, such as fall protection, ladders, scaffolding, and excavations, all of which are typically part of the constructor's responsibility on a project. Techniques for fall prevention are well known but are often not implemented either as a result of neglect or over-confidence on the part of the worker. Easy to implement measures like reducing work level elevations, proper maintenance placement and tying off of ladders, and the use of appropriate climbing techniques, personal protection systems will go far to prevent many of the ladder and roof related falls. The dynamic nature of construction work and the transient nature of the work-force make control of simple hazards relatively difficult. OSHA requires contractors to develop, implement, and enforce a comprehensive, written fall prevention program that, at a minimum, complies with applicable OSHA fall prevention standards.

Analysis of Construction Worker Fall Accidents

In a study conducted by Hinze, et al. (Hinze, 2003), an analysis of construction worker fall accidents identified two specific aspects relating to construction fall accidents. The first considered common causes of construction accidents and any patterns related to them. The second investigated the effects of recent modifications to the regulations by OSHA and how these modifications have impacted fall prevention in the industry.

The study was focused on recent fall-related accidents, as these accidents had occurrences after the recent regulatory modifications had been implemented. The data that were analyzed consisted of 7,543 construction accidents of which 2,741 fall-related accidents. The study showed that there has been a steady rise in the percentage of fall-related fatalities from 1992 to 2001 and the proportion of all accidents related to falls rose from 34.1% in the earlier years to 38.4% in the more recent years.

The factors affecting falls were:

- Time of fall occurrence,
- Types of projects
- Fall heights.
- Location of falls

The study analyzed falls and the time of occurrence. The results showed that the accidents peaked in the summer months, especially during the month of July and the rate of falls decreased considerably during the winter months, the lowest being in the month of February. This reflects the general trend of construction activities peaking in the summer months and slowing during the winter months. With respect to fall occurrences and the day of the week, falls occurred uniformly during the workweek and dropped considerably during the weekends, when the work is typically slow. The results also showed that fall occurrences varied according to the time of the day, with more falls occurring between 10:00 to 11:00 am and the least occurred during the lunch period from 12:00 to 2:00pm. Most of these finding reinforced the finding of a previous study by Hinze (Hinze,1997).

Falls accidents vary with the kind of work and type of work being performed. That study concluded that most falls occur on new construction projects, followed by renovation and maintenance-type projects, with the least number occurring on demolition projects. The results of that study indicated that the number of falls on a project tend to be inversely proportional to the cost and scale of the projects. That is, projects costing less than $50,000 had 341 fall fatality accidents (28.10% of all falls) and projects costing over $20,000,000 accounted for 83 accidents (6.80% of all falls). Fall height was found to be related to the number of falls. Most falls occurred at heights lower than 21.35m (70 feet). The average fall height was about 35.4 ft and fall distance was about 34.9 ft. The study concluded that the implementation of fall-prevention techniques is too relaxed at lower elevations on many projects.

Causes of Fall

The most common causes of falls were:

- Nature of work performed,
- Locations of falls and
- Human Error factors.
- Lack of Training
- Lack of Safety Planning
- Negligence on the part of workers

In addition to all these factors, the number of falls would greatly depend on human factors such the age, gender and ethnicity of the workers. The nature of work being performed (roofing, steel erection, work on scaffolding, etc) becomes a determining factor of the amount of risk involved. Roofing was the cause of more than 33% of the fall accidents, followed by employees not providing personal protection equipments constituting about 13.5% of all falls. Over 11% of accidents occurred when workers were involved in non-typical types of tasks and safety for the particular activities was not adequately planned.

Location was also a factor impacting falls. More than 28% of the fall accidents occurred during the roofing activities followed by falls from scaffolds (13%) and falls from ladders (11%).These locations account for almost 52% of all construction related fall accidents. The study concluded that provision of personal protective equipment would be effective in reducing many of these falls. Human factors such as age of workers, ethnicity and improper use of PPE by workers also contribute to falls of construction workers. All these findings were a part of a study in 2003 (Huang & Hinze, 2003).

The conclusions and recommendations of that study included the following:

- Most falls are associated with roofing, steel erection, scaffolding activity and exterior carpentry.
- Providing full-body harnesses can prove effective in curbing the number of falls.
- Lack of training is a common cause of falls.
- Fall prevention should begin by initiating the process of fall prevention at the design stage.
- More diverse types of personal fall arrest systems should be devised

Types of Fall Accidents

In a fall study by Hinze and Russell (1995), of OSHA fatalities reported up to 1994, it can be determined that falls are the dominant type of accidents in the U.S. construction industry. The most common locations of falls on typical construction sites were:

- Off roof
- Collapse of scaffolding and off scaffolding
- Collapse of structure and off structure
- Through the floor opening, sky-lights
- Off ladder
- Through roof opening
- Off edge of floor opening
- Off beam support.

That particular study examined 508 fall-related deaths and it concluded that 68 percent of all falls could be attributed to these 10 categories of falls. The particular research attempted to study a trend in construction fatalities on the basis of data collected in 1980, 1985 and 1990. The study indicated that in 1980, highest number of accidents were related to scaffolding systems and in 1990, the highest number of accidents were as a result of improper and inadequate hazard communication systems.

Figure 2-2 shows the most the percentage of fall fatalities according to the types of falls reported by BLS in the year 2006. The figure clearly indicates almost 23% of construction accidents were as a result of falls from roofs, followed by 16% from ladders and 11% from scaffolds.

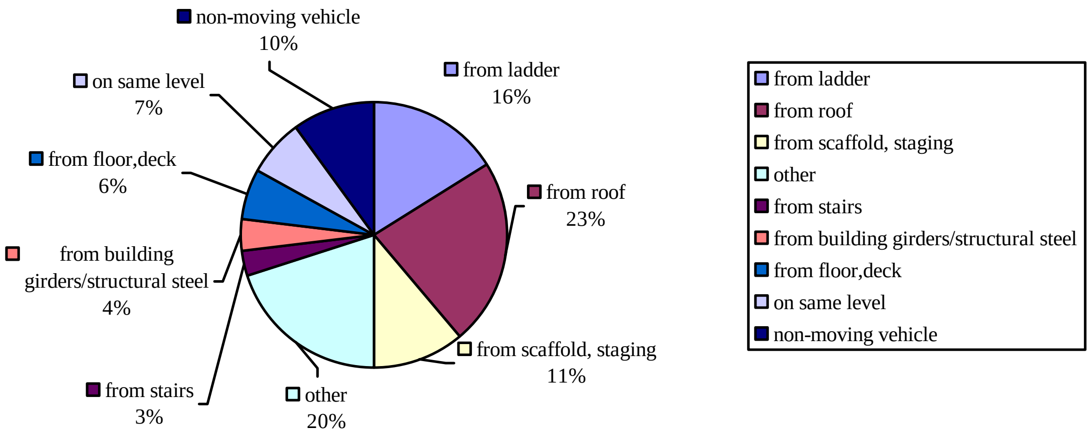


Figure 2-2. Fatalities by type of fall (2006) (Source: National Institute of Occupational Safety and Health, 2006)

Falls occurring on roofs

In 1998, Amarjit Singh conducted a study to analyze falls on low-rise roofs, specifically on residential projects. That study examined the prevailing fall prevention regulations and those typically implemented by contractors and homebuilders. The various fall protection systems analyzed as part of that study were guardrail systems, PFAS with roof truss anchor system and the safe T-strap system, combination warning line/ lifeline system, combination roof jack and fall restraint system, use of scaffold and work platforms and prefabrication systems (Singh,1998).

The study based on surveys and interviews concluded that any safety system should have the following characteristics:

- Economical
- Flexible
- Passive
- Feasible
- Simple to implement and use
- Protective with respect to the most common fall hazards.

The results indicated that of all the systems analyzed, prefabrication systems seemed to be the most effective method of fall protection, followed by fall arrest systems and its variations. If the prefabrication systems were modified for use over the entire roof system assembly it proved to be not only very effective but also extremely economical, feasible, passive yet highly protective and simple to install and use. PFAS and their variants were also found to be a fairly economical and protective option but were not found to be a particularly favorable alternative with the workers as these systems have a low degree of passivity. Thirdly, the roof jack system was found to be one which provides sufficient protection but did not prove to be an economical and flexible alternative.

In the study on fall protection on low-sloped roofs, specifically after construction, the focus was on the hazards of roof access and edge protection (Singh, 2000). The study suggested the use of permanent access methods like stairwells, ladder systems or ramps complete with guardrails, handrails and platforms. If a PFAS is to be used during roof access, a ladder safety system is recommended. The best method of protection from falls while working along edges was found to be the use of guardrails, safety nets and fall arrest systems. The key is to identify the risk of falls and then provide appropriate protective measures to prevent the falls.

Ladders

OSHA requires specific types of ladders to be used. Persons working on ladders should always face the ladder, and at all times maintain a three point contact with the ladder. Ensure that the ladder is set up with 4 to 1 slope to obtain the most stable position and stabilize the ladder using appropriate ladder footings. Workers must avoid standing on two steps of a step ladder. Regular or extension ladders shall always extend at least 3 feet above the upper landing surface.

In a study of falls from ladders by OSHA in 1991 and 1996, it was concluded that falls from ladders constituted 20 percent of all disabling falls in the U.S. construction industry. Another study concluded that 60 percent of falls occurred while the employee was standing on the ladder, 26% of the falls occurred while the employee was descending the ladder, and 14% of the ladder falls occurred while the employee was ascending the ladder (OSHA, 1991).

Scaffolds

OSHA requires the following while using scaffolding systems:

- The footing for scaffolds shall be sound, rigid, and be capable of carrying the maximum intended load without settling or failure.
- Scaffolds shall be assembled and placed in the presence of authorized persons.
- Guardrails and toe boards shall be installed on all open sides and ends of platforms more than 10 feet above the ground or floor level. The only exception in this case shall be needle beam scaffolds and floats. Scaffolds 4 - 10 feet in height having a minimum horizontal dimension in either direction of less than 45 inches, shall have standard guardrails installed on all open sides and ends of the platform.
- Scaffolds and their components must be able to withstand at least 4 times the maximum intended load.
- All planking or platforms must be overlapped (minimum 12 inches) and secured from movement. An access ladder or equivalent safe access must be provided. Planks must extend over their end supports not less than 6 inches or more than 18 inches. The poles, legs, or uprights of scaffolds must be plumb, and securely and rigidly braced to prevent swaying and displacement. Overhead protection must be provided while working in areas exposed to overhead hazards.
- Slippery conditions on scaffolds shall be eliminated immediately after they occur.

Sky-lights and Floor Openings

While working around sky-lights and floor openings, OSHA requires the following:

- The worksite shall be inspected by an authorized person before the work beings so as to identify fall hazards and to determine the appropriate fall prevention system for workers.
- While working around skylights, roof and floor openings, there shall be provision of one of the appropriate fall prevention systems that use one of the following:
- Covers or screens
- Railings or guardrails

- PFAS, including a full-body harness, lanyard, connectors and appropriate anchorage points (tie-offs).
- Workers associated with this type of work shall be trained to recognize fall hazards associated with this work and shall be trained in the correct fall prevention procedures.

In a study to examine the fall accidents due to skylights and roof openings, it was found that there have been 55-75 such fatalities each year since 1980 (NIOSH Publication # 156, 2004). The study concluded that employers should work towards providing more protection for their workers by instituting a comprehensive fall-protection program. Some of the key requirements include developing a site-specific fall protection plan; securely covering holes and openings; installing guardrails, safety nets, or sky light protection systems; providing workers with personal fall-arrest equipment and providing work-site supervisors, employees with appropriate fall-related safety training.

Leading Edge

Each employee who is constructing a leading edge 6 feet or more above lower levels shall be protected by either a guardrail system, safety net system, or personal fall arrest system. If the employer can demonstrate that it is infeasible or creates a greater hazard to implement these systems, the employer must develop and implement a fall protection plan that meets OSHA regulations. In addition to this, if a guardrail system is chosen to provide the fall protection, and a controlled access zone has already been established for leading edge work, the control line may be used in lieu of a guardrail along the edge that parallels the leading edge.

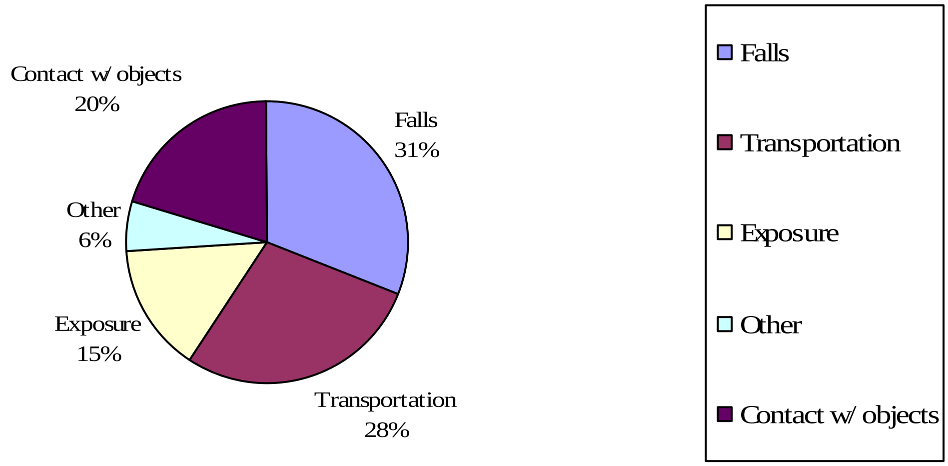


Figure 2-3. Distribution of leading causes of deaths from injuries in construction (1999)

In a study conducted by Hinze and Huang (2003), analyzed fall accidents from 1992 to 2001. They observed that 2,741 fall accidents resulted in 2,995 injuries. The most commonly injured workers were construction laborers, roofers, carpenters, structural metal workers, drywall installers, plumbers and pipe fitters.

In another study by the National Institute of Occupational Safety and Health, it was observed that falls constituted 31% of the fatal injuries and 21% of the nonfatal injuries in 1999 (Figure 2-3) Of these, 98% of the fatal falls were to a lower level, compared with 56% of the nonfatal falls.

The most common types of injuries resulting in deaths are from multiple head injuries, traumatic injuries, and massive internal injuries making up nearly 60% of the fatal injuries. The most common type of injuries as a result of falls include concussions, fractures and bruises or abrasions, while those as a result of falls specifically from roofs are fractures, sprains and strains.

The analysis of all fall accidents from 1990 to 2001 indicated that half of all the injured persons, received head injuries and about one-third of them received multiple injuries. Other body parts that typically received injuries were chest, neck, back, abdomen and legs. One of the most important findings of the study was that about two-thirds of the workers involved in falls were killed.

Nature of Injuries and Illnesses

Nature of injury or illness as defined by Bureau of Labor Statistics (BLS, 2002) is “the principal physical characteristic of a disabling condition”. The BLS has broken the various types of falls into eight major categories:

- Sprains and strains
- Fractures
- Cuts and punctures
- Bruises
- Heat burns
- Multiple traumatic injuries
- Back pain and
- All other natures

In the study, Occupational Injuries and Fatalities in the Roofing Contracting Industry, conducted at the University of Western Michigan, roofing injuries accounted for 36% of the total cases in 1999. Strains were the result of overstretched or torn muscles, and sprains were the result of torn ligaments. Other significant types of injuries were cuts and punctures with 14% of the total cases and fractures with 11%. In addition to these injuries, back injuries accounted for 25% of the total injuries, and the other types of injuries included fractures (7%), burns (7%) and eye injuries (5%).

With respect to the age group of the workers involved in the accidents, it was found that most workers were between 31 to 40 years of age and the proportion of workers involved in accidents declines significantly with increase in age. Other factors associated with the number of falls and accidents were gender of the workers, ethnicity and the trade (Hinze 2003).

Designing for Construction Worker Safety

Fall protection should ideally begin at the design stage and it should be the duty of the designers to work on the design with the aim of providing for worker safety. If the designers would incorporate certain requirements in the design to initiate the safety effort from the beginning of the project, it would greatly benefit the worker safety. “Designing for construction safety as an intervention is supported by the hierarchy of controls common to the safety and health professions which identifies designing to eliminate or avoid hazards as the preferable means for reducing risk (Manuele 1997).”

Traditionally, the role of the design professional has always been limited to designing a building, so that it conforms to the required engineering practices, local building codes, and one that complies with the requirements of the owner/developer. The safety of construction workers has always been considered the duty of the contractors. Recent studies have indicated that design professionals can influence worker safety by making modifications in the design and planning stages of a project. This would result in lesser decision fewer safety issues to be addressed by contractors and better safety conditions for workers.

Research presented by Behm (Behm, 2005) suggests that designers can have a strong influence on construction safety. In a 1991 study conducted by the European Foundation for the Improvement of Living and Working Conditions, it was found that about 60% of the fatal accidents in construction were the result of decisions made before the site work began.

In another study by Gambatese (2005), designers who were interviewed admitted that there exists a gap between the design process and actual construction. The designers often said that they appreciated the inputs they receive from constructors with respect to the location of valves, use of stairs instead of ladders and such other design decisions. The three-dimensional vision of the constructors was found to be extremely beneficial to designers.

Another study performed by Hinze & Gambatese (1997) showed that there was increasing awareness about the need for designing for worker safety. Discussions with owners highlighted the fact that the costs of construction accidents and injuries added to the construction costs, and as a result, they are becoming more demanding with respect to worker safety provisions. This insistence on the part of the owners has proven to be ineffective in bringing the design community to focus on this problem, primarily because of the liability issues that accompany this increased responsibility.

The involvement of designers in the process of worker safety would improve the overall safety on the work-site, mitigate common safety hazards and reduce the number of worker injuries (Hinze & Gambatese, 1997). The design recommendations developed in that study were developed through inputs from both design professionals and construction professionals, but the majority came from construction industry professionals. As many as 400 design recommendations were developed and with these inputs, a software tool was developed for use by construction professionals as a guide for improving construction job-site safety.

Owners are now more willing to focus on planning for better safety provisions for workers on their job-sites and require the contractors and designers to work in tandem to develop a comprehensive worker safety program. This effort has yet to be initiated on the industry-wide scale and needs to be taken up by all the parties involved in the construction process – owners, designers and contractors along with construction workers.

Process of Designing for Safety for eliminating fall hazards

John W. Mroszczyk (Mroszczyk, 2002) described Designing for Safety (DFS) as a process that incorporates hazard analysis at the beginning of a design.

- Identify the hazard
- Apply engineering measures to eliminate the risk.

- If not, then apply measures to reduce the risk/hazard by using safety and protective devices.
- If risk cannot be reduced with the use of safety devices, then reduce risk by warnings, and by providing extra instructions and training to the workers.

Designing for construction safety can influence design decisions that eliminate or significantly reduce the need for fall protection systems during construction and maintenance. It requires the ability to identify potential hazards associated with construction and maintenance workers during the design stage of a project. The skill of the design professional is then applied to eliminate the hazard (or significantly reduce the risk) by incorporating the appropriate design features.

The involvement of design professionals, specifically engineers, is not a new concept in the construction safety. Designing for construction safety takes the skill of the designers' one step further. Rather than designing temporary structures and systems for construction, design expertise is extended to include the safety aspects of permanent structures, including maintenance.

Construction is a dynamic process. The completion of the construction work on a project does not necessarily mean the end of the need for continuing the safety programs or initiatives on the project. After the completion of the construction work on a project, the control of the site passes from the contractor to the facility owner, along with the responsibility for providing fall protection for all occupants and the maintenance workers. Owners often take over the control and liability for the facility that has no provision for fall protection for maintenance operations that will be required during the facility occupancy and operation. Thus, fall protection does not need to be limited to the time of construction, as provisions for safety need to be made for permanent fall-protection.

CHAPTER 3
METHODOLOGY

With the disproportionately high number of fatalities in the construction industry, this study was aimed at developing a comprehensive fall prevention guideline, which could become a valuable reference for any construction company. The suggestions put forth as a part of this study shall provide information on how to reduce fall accidents on construction sites. This process began by researching many aspects of construction worker fall fatalities. The research included and assessment o the existing fall prevention techniques being employed along with the regulations promulgated by OSHA. The key limitation of this study was that it was based entirely on OSHA statistics and data. This was due to the physical limitation of not being able to visit construction sites to obtain information from a variety of projects constructed by different companies.

The research methodology for this study consisted following steps

- Previously documented research on construction worker falls was studied
- The existing fall prevention and protection recommendations that have been previously developed by various sources were examined.
- OSHA records from 1990-2001 were examined to form a comprehensive list of the most common types of falls and to study their causes.
- The most common types of falls were identified and then the prevalent provisions for fall prevention were analyzed in detail for each type. Some of the most common falls accidents /occurrences were cited. The last step was to develop extensive fall prevention techniques for each type of fall and where this was not possible, suitable fall protection solutions were suggested.

Phase 1: Study and analysis of all previous research and provisions for fall prevention

Examination of a fall protection manual developed in 1980's resulted in many useful recommendations that have been put forth with respect to reducing construction falls.

The first phase of this study began with performing a detailed study of all identified research that has been conducted on this topic. Construction fatalities and specifically fall related fatalities have been a growing concern for construction industry professionals. Despite the advancement of technology and stricter OSHA regulations, fall fatalities have kept increasing, thereby emphasizing the need to focus of this topic. Several studies have been conducted to assess causes of falls, types of falls and best practices with respect to fall prevention. The analysis of the previous studies helped to narrow down the list of the types of falls and those which are of the greatest concern.

Phase 2: Examinations of OSHA Data and Identifying the Types of Falls

The second phase of the research began by examining the OSHA/ BLS data for Fatal Occupational Injuries recorded from 1990 to 2006 with a focus on fall fatalities. A detailed study of these incidents was helpful in determining the most prevalent types of falls and their causes. The categories of falls that would be considered for the purpose of this study were narrowed to the following:

- Falls from roofs
- Falls from skylights and roof openings
- Falls from floor openings
- Falls from ladders
- Falls from leading and unprotected edges
- Falls from scaffolds
- Falls in excavations/holes
- Falls during steel erection
- Falls during wood framing

Phase 3: Analyzing the Current Standards for Each Category of Falls from Various Organizations

After identifying the categories of falls, the existing regulations and requirements were examined for each of these categories. Existing OSHA regulations were analyzed in depth based on two stages:

- Fall Prevention
- Fall Protection, in case the fall hazard could not be eliminated.

The relevant subparts of the OSHA regulations were examined as a part of this phase. The fall prevention categories were scaffolds, steel erection , leading edges, ladders, excavations and regulations for sky-lights, floor openings, holes and wood-framing. The fall protection categories included personal protective and life saving equipment like lanyards, safety harnesses, safety nets and guardrails.

This phase also included an examination of the safety programs implemented by various contractors and construction companies. There were several construction companies which have been on the forefront of focusing on safety issues on their project sites. With the high project costs and high worker turnover, the companies can dedicate the funds that are essential to initiate advanced safety programs. Another important factor is that the companies have to bear higher costs and insurance premiums if they have accidents on their project sites. As a result of this, many owners and construction companies are willing to actively participate in safety initiatives on their projects.

Phase 4: Developing Design and Construction Stage Suggestions for Fall Prevention

The final phase of the project involved focusing on individual types of falls as listed above.

Stage 1: For each type of fall, all the cases reported to OSHA were compiled in a MS Excel spreadsheet. The spreadsheet provided a narrative description of each accident. This helped in identifying the most common occurrences and their causes.

Stage 2: The aim was to identify the safety measures implemented in each of the selected cases. A few typical cases for each type of fall were identified along with illustrations. This was followed by suggestions and recommendations for each type. The solutions devised included traditional suggestions, which are commonly implemented on some projects and some innovative approaches to reduce falls on construction sites. Recommendations were suggested for each of the stages, including design, planning, pre-construction, construction and maintenance.

Stage 3: The review of all the documentation on construction falls helped to set the minimum standards and define the best practices in the key risk areas. After identifying the risk areas, the focus was on developing appropriate technical solutions for the same. Key performance indicators (KPI's) were established to benchmark and constantly monitor the effectiveness of the solutions suggested. Since best practice would be a moving and improving target, it is important to remember that the benchmarks and KPI's will have to be constantly reviewed and adjusted.

CHAPTER 4
RESULTS

Need for Safety Program

The safety of construction workers needs to be addressed at each stage of a construction project beginning with the planning and continuing with the design, construction and maintenance phases. The process should start at the planning and design stage of the project. It should continue through the pre-construction phase and into the construction and maintenance stages of the project. The critical factor in reducing the extent of work related injuries on job-sites is the effective management of worker safety and health protection. To assist employers and employees in developing effective safety and health programs, OSHA provides recommended guidelines in the form of Safety and Health Program Management Guidelines (January 26, 1989 [54 Federal Register (18): 3908-3916]). OSHA provides these guidelines to help companies to establish their own safety programs and to develop them for each job-site.

Using the background of the data obtained from OSHA and BLS, study of existing regulations by OSHA, Army Corps of Engineers, Australian, UK and Canadian Standards for fall prevention, this researcher has put forth the following suggestions.

The guidelines identify five general elements that are critical to the development of a successful safety and health management program:

- Management commitment and employee involvement;
- Worksite analysis;
- Hazard identification, assessment and control;
- Safety and health training;
- Compliance

Construction is the stage of the project during which most accidents are likely to occur. These accidents are considered the responsibility of the contractor and construction management personnel. The success of a project ultimately depends on the level of planning for the project and the decisions made on the site during the course of the project. A large number of construction accidents occur as a result of the lack of proper training, deficient enforcement of safety, unsafe equipment, unsafe methods or sequencing, unsafe site conditions, not using the safety equipment that was provided, and negligence on the part of the employees towards safety. The roles of the parties involved are often not clear, thereby each party transferring the responsibility to another party (designer assuming that the contractor will be responsible, contractor assuming that the subcontractor shall be responsible). It is important to acknowledge that creating a safe work place is the responsibility of every party and each of them should contribute towards this goal.

Every employer must, as far as is practicable:

- Provide a safe workplace so as to ensure that no employee or any other person on the work site is exposed to any unsafe work conditions or hazards.
- Provide every employee with proper information, instruction and training regarding safe work practices and ensure that all tasks are performed under proper supervision by authorized personnel;
- Provide training to all employees to enable them to identify hazardous situations and work conditions and take appropriate safety measures.
- Provide adequate protective clothing and safety equipment where hazards cannot be eliminated; and
- Establish a site-specific safety program for every job-site: the program shall address workplace policies and procedures. Policies and procedures should be developed and implemented for each job-site to ensure safe systems of work. The process of developing a safety program shall include the following steps:

    1. Establish safe work methods (such as job or task procedures);
    2. Identify hazards and perform a risk assessment;
    3. Implement orientation and training programs;

4. Monitor performance and review control measures;

5. Organize a system for reporting and recording information after hazards have been identified;

6. Establish ongoing inspection and maintenance programs;

7. Establish emergency rescue procedures; and

8. Establish a line of communication for consulting with employees - employees working on particular tasks are better equipped to suggest safer methods of performing the work, thereby providing helpful input in developing the safety program.

9. Periodic review of safety management policies and procedures with management and employees working on site.

10. It shall address:

    a) Environmental conditions,
    b) Multi-language differences,
    c) Alternative methods/equipment to perform assigned tasks,

Identifying Hazards, Risk Assessment and Risk Control Procedures

Every employer shall ensure that employees are not exposed to hazards at the workplace. This can be achieved by following a risk management process to prevent falls at the work-site, which involve the following:

- Identify hazards;
- Assess risks; and
- Control risks.

To assist in identifying risks of fall and related hazards and controlling the risks, consideration should be given to the following:

- Prepare a detailed safety program for the site taking into consideration all the applicable safety regulations.
- Consider previous accidents, 'near miss' incidents or accidents as a result of falls that have occurred at the workplace or other similar projects;
- Consult with workers, safety and health representatives, contractors, sub-contractors and management personnel to determine the issues and concerns associated with performing the assigned activity;

- Prepare a job safety analysis chart for each activity and regularly conduct thorough inspections of the workplace.

Risk Assessment

The risk assessment process involves determining the possibility of a fall/accident occurring at the work site and, if a fall does occur, the extent of any injury and damages as a result of the fall. This approach shall help in determining the high-risk areas or activities and should also aide in the formulation of a plan of action. The risk assessment plan should include the following:

- Location, type of activity/work with which high risk is associated (height, level, leading edges, work on sloped roofs)
- Number of employees/workers exposed to the risk and their experience in the trade or task
- Duration and type of task
- Work conditions and
- Past occurrences on projects of similar nature.

Risk assessment requires a breakdown of each work activity into a series of smaller tasks and an assessment of the risks associated with each one of them. A job safety analysis chart is created for each activity that is analyzed. It is beneficial to formulate a detailed safety and hazard management plan which will be useful in controlling the hazards identified during this process.

Risk Control

The risk control plan includes the following steps:

1. *Elimination of hazard or hazardous situation:* determine if the risk associated with the work can be eliminated at the design stage or by changing work practices (e.g. avoiding working on ladders by using long-handle tools).
2. *Substitution*: If the risk cannot be eliminated, substituting or replacing a hazard or hazardous work practice with a less hazardous one (e.g. if work on roof cannot be

performed by any other means, providing an alternative means of access such as a safe walkway so the risks of falls are avoided; or installing an elevating work platform for work at heights and providing means for tie-off).

3. *Isolation*: If the work related hazard cannot be eliminated or substituted, then an attempt should be made to separate the hazard or hazardous work practice from people involved in the work or people in the general work areas (perimeter or edge protection with guardrails). Establish a controlled access zone to the area, thereby only workers actively involved in the work shall be allowed access and use of protective equipment shall be mandatory for them.
4. *Engineering control*: If proven that the hazard cannot be eliminated, substituted or isolated, the use of an engineering control is then deemed acceptable. Use of engineering control shall include the use of restraint systems or fall arrest systems as lanyards and full body harness.
5. *Administrative control*: This type of control is for management and shall be used in conjunction with any one of the previously mentioned control measures. The management personnel play a very critical role in ensuring the safety at the work site and their responsibility should include introducing measures to ensure that safety or control procedures are properly implemented, all the workers are well instructed of the hazards, properly trained with the safety procedures and warning signs are in place to warn and protect persons exposed to falls.

Training

For the success of a properly developed safety program, the commitment of the upper management is critical. Training is an important part of ensuring safety on the job site. All employees shall be provided orientation and training with respect to their work requirements and skills. The focus shall be to support and promote safety as a top priority.The type of instruction and training given should include the following:

1. Basic safety orientation with a focus on work place policies including the responsibilities to create safe work places, individual responsibilities and rules of compliance. Basic training for all the employees shall include proper use of equipment, ladders, tools, PPE, emphasis on the use of fall arrest systems (tie-offs), safety nets, etc.

2. All employees shall be provided training specific to the tasks or work they need to perform;

3. In addition to this, as per the needs of the job, employees shall be provided on the job training;

4. Depending on the specific requirements of the job, employees shall have to complete certificate courses an OSHA training for confined spaces, Red Cross first-aid or AED/CPR courses.

5. Line supervisors and foremen shall be provided training in exercising supervisory skills.

6. Employees shall be trained with regards to their rights to stop work if and when any unsafe practices are observed.

7. Detailed records shall be maintained for all training sessions with descriptions of topics covered and names of workers trained.

8. Initiate employee participation and involvement in the safety program development, it is crucial to implementing an effective fall protection program.

Compliance

As a part of the safety program, it is the responsibility of the management and supervisors to ensure that the employees understand the importance of complete compliance with the company policies regarding safety. The supervisors shall make every effort to help the employees understand that the safety policies and instructions are for their personal safety and health or for the safety or health of other persons associated with the work. It is essential to establish a strong and clear line of communication and ensure that all employees feel comfortable to voice their opinions and concerns.

Job Safety Analysis

The aim of developing a safety program is to reduce the risk of injury or harm for any person who may be affected by the work. This includes employers, contractors, all workers, visitors and other parties who may be at or near a work site. A job safety analysis (JSA) is a way of providing information to everyone involved in a particular task. It should clearly state the procedure to identify the hazards and how to manage them on the site. JSA's are a method of maintaining records and checklists for contractors, management and supervisors to coordinate the work. JSA's should be completed before work begins for all the activities that will be performed on the site. The JSA form shall be a simple form to be completed for each activity and it should be completed by persons responsible for particular tasks as per the Limit of Authority concept.

Following steps shall be followed to create a JSA

- Each task shall be sequentially broken down into small steps.
- The hazard column should list all the possible risks of accidents, taking into consideration workers as well as people not directly involved with the task.
- In the risk column, list all the ways by which the task could be done in a safer manner or the manner in which the risk could be reduced.
- Every task should be assigned to an authorized person who will complete the job safety analysis and ensure complete compliance. The JSA is to be reviewed and updated regularly.

Designing For Worker Safety

Every party participating in construction project has an ethical duty to ensure worker safety on the project, but in addition to this, there are practical reasons for each party to participate in the process of designing for construction worker safety. Designers specifically need to work with a focus on worker safety while designing and planning their projects. This can eliminate common safety hazards and reduce worker injuries to a great extent. Designers who work towards worker safety will be considered progressive and team-oriented professionals and will greatly contribute in making zero incident work-sites a reality. Designers who are a part of design-build company or project will ultimately benefit financially from the reduced accident rates experienced during construction. Also, this will contribute positively towards the corporate image of their company. These facts have been understood and well proven but the liability issues are the major cause of designers being reluctant to take the responsibility of designing for worker safety. The important fact is that the work will not change greatly, except that there will be additional notes and specifications for worker safety or additional construction details that would enhance the safety on the site. This is an achievable target for designers if owners, developers, contractors and subcontractors work as a team. The recent years have seen changes in the positive direction and continued improvements are needed.

Designing for Safety Suggestions

This research attempted to identify and develop design suggestions or best practices, which could be implemented during various phases of the work and effectively reduce or eliminate safety hazards in the construction phase. The suggestions developed as a part of this research include all types of design disciplines, jobsite hazards, and construction components and systems.

The design suggestions were developed with the aim of providing many benefits like reduction of construction worker injuries, costs associated with the accidents like insurance and worker compensation costs, reduction in the time spent in planning for safety during the construction phase, hazards during maintenance work. The suggestions will be beneficial to owners, contractors, management, workers as well as members of public not directly associated with the work

Steel Design Suggestions

- Design steel columns and beams with holes in the webs and flanges at appropriate heights to provide support locations for guardrails and lifelines. This provision will make it easier to install the guardrails and lifelines as well as cut down the time required for installation, thereby motivating the workers to make use of these provisions.

- Design the beam to column double connections to provide continual support for beams during the erection and fabrication process. This can be achieved by adding a beam seat or additional bolt hole. This will eliminate falls as a result of misalignments and unexpected loading conditions.

- Clear notes shall be made on construction working drawings to identify those members that have been designed to support lifelines, the number of lifelines, and the specific locations along the beams/columns and where holes have been provided to support lifelines.

- Design members and connections so as to facilitate maximum fabrication at ground level.

- Consider use of beam gliders (tie-off anchor that attaches to horizontal steel members) for mobility during steel erection. The reason for avoiding the use of full-body harness during work at height is often lack of mobility due to the harness. A beam glider allows the worker mobility all along the length of the horizontal member, thereby making it a more acceptable method of tie-off. This is shown in Figure 4-1.

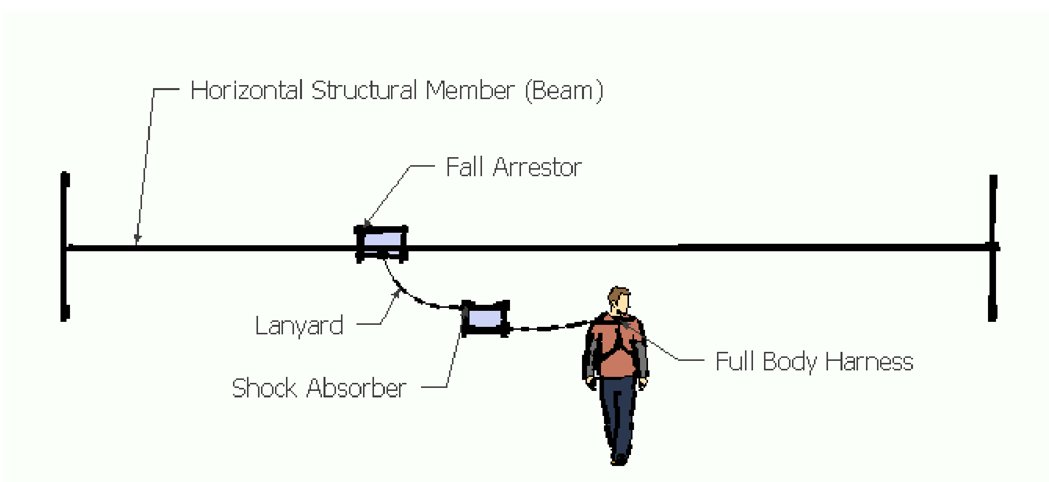
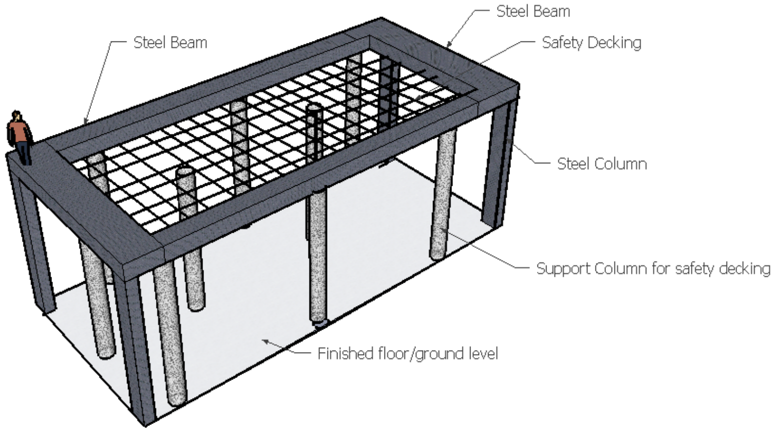


Figure 4-1. Tie-off to the Horizontal Member (Beam)

- Walking on the top plate while performing work on trusses is not acceptable. While working on trusses and connections, additional protection shall be provided by erecting a safety decking system (metal) underneath the trusses once the frame is erected (Figure 4-2(a) and (b)). This system shall provide walking and working surface and could prevent falls associated with this activity.

- Safety mats like air mats or soft fill mats could be used during steel erection when there are no structural members available for tie off and the frame work is being installed (steel columns, beams).

- Use overhead horizontal lifelines for anchorage during steel erection (trusses) as shown in Figure 4-1.



(A)

(B)

Figure 4-2. Metal decking system. (A) View of a Metal decking system during steel or timber erection work and (B) Metal decking system during masonry work (Source: Health Safety Executive Research Report 302, 2003).

- Design shall require as much work from cranes, aerial lifts or scissor lifts as possible, so as to reduce the risk of falls associated with working at heights. (Figure 4-3 shows use of scissor lift for masonry work)

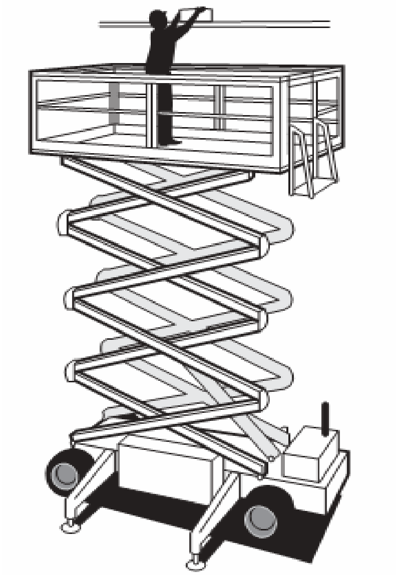


Figure 4-3. Scissor Lift Elevated Work Platform (Source: Australian Code of Practice- Prevention of Falls at work places, 2004)

Concrete Suggestions

- Design columns with holes to provide support locations for lifelines or guardrails or install built-in safety hooks for tie-offs.

- Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding as shown in Figure 4-4.

Figure 4-4. Provision of safety strap in a concrete column.

- Design perimeter beams and beams above floor openings with sufficient strength to support lifelines.

- Clear notes shall be made on construction working drawings to identify those members that have been designed to support lifelines, the number of lifelines, and the locations along the beams/columns and where holes have been provided to support the lifelines.

- Consider specifying the use precast or prefabricated members with standard sizes, so as to avoid falls during erection of formwork or while placing concrete. In addition to this, standardization of sizes would result in simplifying the design and thereby work on sites.

- Design reinforcement such that it can be assembled at the ground level and erected or put into place just before placing concrete. Specify the use of single or curtains of welded wire mesh for reinforced concrete walls and columns to allow placement of the reinforcing in large sections rather than many small pieces.

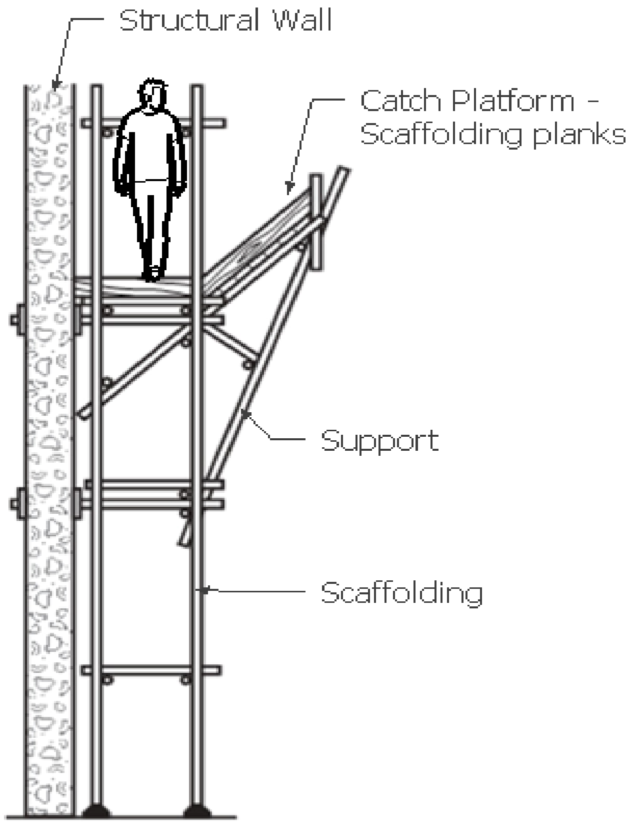
- For work performed at heights, provide “catch platforms” that provide additional protection from falls. A “catch platform is a temporary platform located below the work area, made from scaffolding planks and it should be provided all along the length of the work area. It should be capable of withstanding the maximum potential impact load (Figure 4-5 (a) and (b)).

  If the catch platform is designed from scaffolding material, it should:

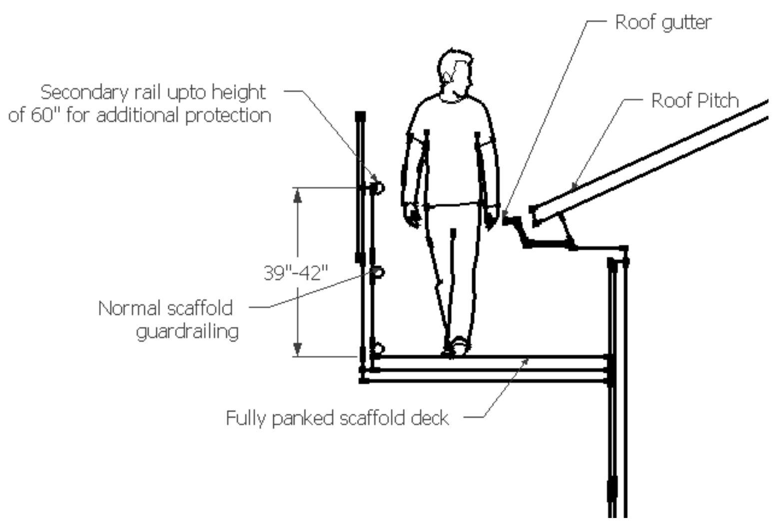
  - have a deck that is fully planked out and is as close as possible to the work level;
  - be no more than 6 feet below the work area;
  - extend a minimum of 6 feet beyond all unprotected edges of the work area;

- The design shall specify the use of metal decking and poured concrete for floor and roof slabs instead of using traditionally cast concrete floors thereby avoiding the need for complicated slab formwork that need to be erected and removed.

- To minimize the risk of falling, minimize the number of offsets, and make the offsets a consistent size and as large as possible.



(A)



(B)

Figure 4-5. Catch Platforms. (A) Catch platform below the work area and (B). Use of Catch platform while working on roof. (Source: Australian Code of Practice-Prevention of Falls at work places, 2004).

- During the erection of framing for metal studs or exterior cladding systems, provide netting and framing on the exterior to prevent falls. This framing should provide sufficient working space for the work and continually provide fall protection. As an alternative to providing framing, provide a catch platform system that can be very effective while performing this task. Every worker should be required to be tied off from the nearest structural members such as beams.

- Design structural members of standard sizes, so as to facilitate the repetitive use of formwork as well as reduce errors during construction. This could also be beneficial for use of prefabricated forms.

- Consider using shotcrete instead of poured concrete when practicable.

- No work shall be performed without guardrails and edge protection. Edge protection/perimeter protection shall be provided with wire rope installed with full height netting starting at 3rd floor level. The design shall require full height netting at every level above the 3rd floor after the concrete frame is in place. Full height netting requires the proper frame for toe boards, mid-rails and intermediate posts. Netting should not be a substitute for guardrails; both shall be required as a part of fall protection.

- Design columns with holes at 21 and 42 inches above the floor level to provide support locations for lifelines and guardrails.

- Provide safety straps cast in place in columns or beams or slabs for fall protection for later stages of work. Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.

- For precast concrete members, provide inserts or other devices to attach fall protection lines.

- Design scaffolding tie-off points into exterior walls of buildings for construction purposes.

Timber

- While working with timber roofing and trusses, attach roof anchors onto the structural members and fix the plywood to the rafters such that the roof anchors are spaced at 8 feet intervals. Another acceptable approach is to have the roof anchors fixed to the ridge line or ridge beam at 8 feet intervals to provide anchorages for tie-off.

- Design special attachments or holes in members at elevated work areas to provide permanent, stable connections for supports, lifelines, guardrails, and scaffolding.

- Encourage the use of pre-fabricated metal timber fasteners for wood connections instead of end-nailing or toe-nailing.

- Window sills shall be designed to be 39 inches minimum above the floor level, thereby eliminating the need of providing guardrails during construction.

General Design Suggestions

- Specify the use of precast or metal stairs as far as is practicable. Precast stairs or metal stairs are to be installed in the building during the early phases of construction, thereby providing safe, well designed access to the upper floors. With the use of metal stairs, guardrails can be welded or built-in before installation. Specify that permanent stairways and walkways are to be constructed in the early stages of construction as it would help in reducing the need to use of ladders and scaffolding to access higher levels.

- Eliminate the need for installing temporary barriers by designing higher parapet walls up to 39" minimum or include an integrated guardrail system along all roof edges;

- Design the floor plan such that the rooftop equipment is located away from the building perimeter to reduce fall hazards while installing the equipment and during future maintenance work.

- A building plan with too many offsets will make it difficult to erect edge protection/guardrails as well as to perform activities like painting, erecting scaffolds. Designers should attempt to simplify floor plans and have lesser offsets.

- Design multi-storied buildings so the exterior wall covering can be installed as soon as the framework is in place and before the interior work on the floors begins.

- Consider the installation of eye-bolts or other connections used for window maintenance in the early stage of construction so that they can be used during construction as well as during maintenance work.

- Design roof anchors or tie-off points along the building perimeter so as to provide anchorage points during window cleaning and routine maintenance operations.

- To avoid hazards associated with swing down while deploying a fall arrest system; supplement the system with guardrails protection. While installing the guardrails; the anchorage point shall be at a right angle to the position of the line at the perimeter edge. The use of mobile anchorages is preferred and secondary anchorage points shall be installed which could act as intermediate anchorages.

Ladders

- Where work at height is necessary determine if the task can be completed at ground level or without using a ladder or step-ladder.

  If it is deemed not practicable, then the following shall be the acceptable practices:

  - Limit the time that needs to be spent on ladders to ten minutes.
  - Follow the three-point rule of ascending and descending ladder by keeping two hands and one foot or two feet and one hand on the ladders at all times during the work (Figure 4-6).
  - The ladders shall extend at least three feet above the working surface and shall be properly tied to the surface or structural member.
  - Follow the belt-buckle rule of keeping the buckle within the plane of the side rails of the ladder at all times.

- Job made scaffolds, ladders shall not be permitted; if the ladders being used are modified for use on site, then the ladders shall be inspected by a competent authority and signed approval shall be required. Maintain proper records of any changes authorized for any safety system or equipment.

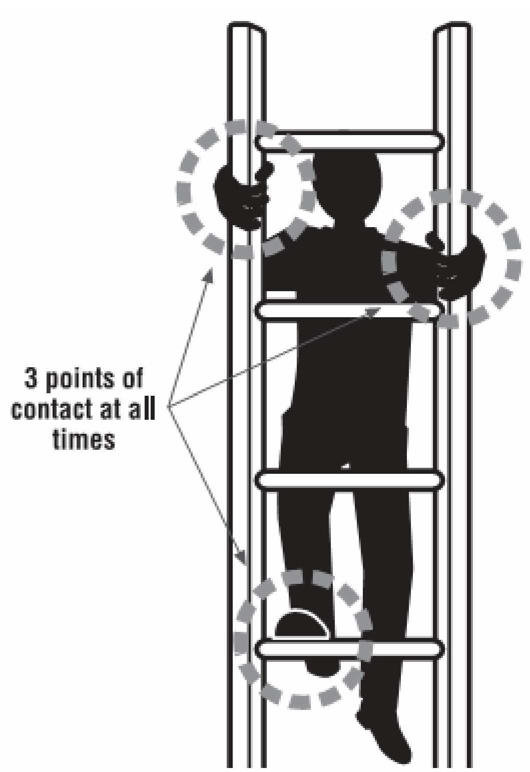


Figure 4.6. Three-point rule for use of ladders. (Source: Government of Western Australia, Code of Practice-Prevention of Workplace Falls, 2004)

Determine if the work on ceilings or walls can be performed without ladders. These are the steps that can be followed:

- Specify long handle-tools and equipment to be used to reach ceiling heights to perform finishing, plastering and painting work, thereby reducing the potential of falls occurring while performing maintenance and finishing tasks.

- Consider using folding podium steps, which provide a more stable work platform, to perform work such as finishing of drywall and painting, thereby avoiding working from ladders as shown in Figure 4-7 and 4-8. These types of steps provide a space to keep tools and some material on the working step. These devices lock in position as soon as a person steps on them, have guardrails around the steps as well as the working platform and are easy to assemble as well as move from place to place. Larger types of podium steps can be used as in place of scaffolds as they provide mobility in addition to a safe work platform. These could be used for activities like masonry work, exterior painting or maintenance work.

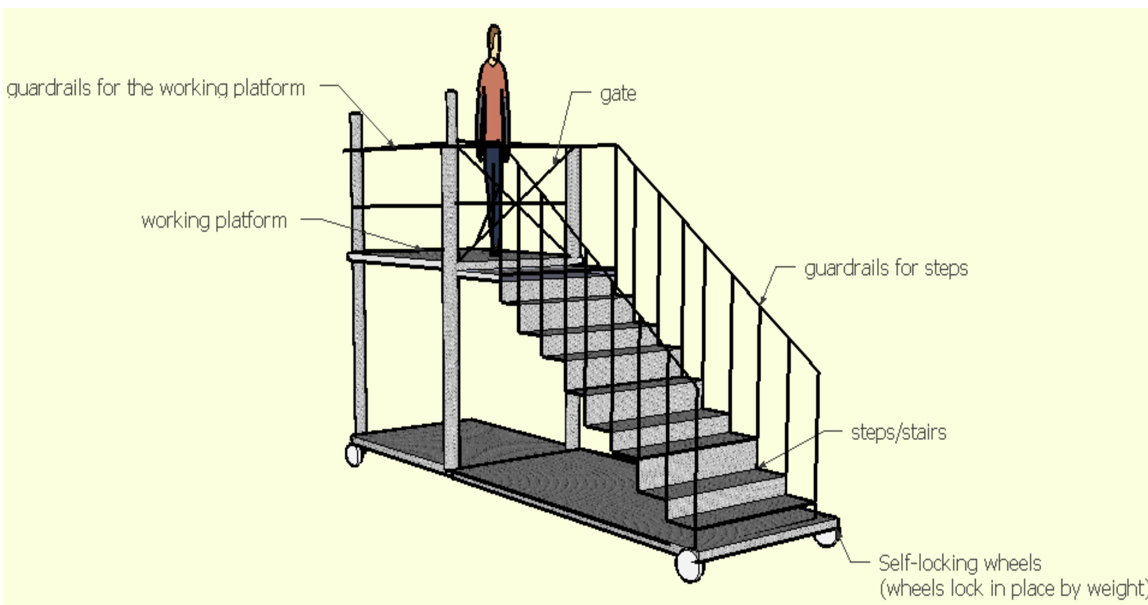


Figure 4-7. Podium Steps/Platform as an alternative for work on ladders.

- While working on ladders, ladder cages shall not be used as the only method of fall protection as the cage does not help to stop a fall but it simply funnels a fall. In addition to this, the cage around the ladder could give the worker a false sense of security. The workers shall be tied off from the nearest structural member while working on ladders at heights above 6 feet.

Figure 4-8. Podium steps which can be used for interior works like drywall finishing, painting

Scaffolds

- While working on scaffolds**,** cross bracing shall not be used as means of access to upper levels. Incomplete scaffolds systems shall not be used. A complete scaffold system shall consist of framing as per the design, scaffold platforms, cross bracing, guardrails and access ladders, complete with scaffold stair towers. Cross bracing shall not be used as an alternative for guardrails for scaffolds.

- Use of engineered or well-designed scaffolds shall be mandated. Scaffold components manufactured by different manufacturers shall not be intermixed unless the components fit together without force and the scaffold's structural integrity is maintained by the user. Ensure that no extensions or auxiliary parts are added to scaffolds unless designed and approved by an engineer. An example of well-designed scaffold system is shown in Figure 4-9.

- An authorized person shall inspect all scaffold systems in use on a daily basis and detailed records shall be maintained in the form of checklists. If any part of the scaffold needs to be modified or adjusted, a signed approval of the authorized person or the engineer shall be required.

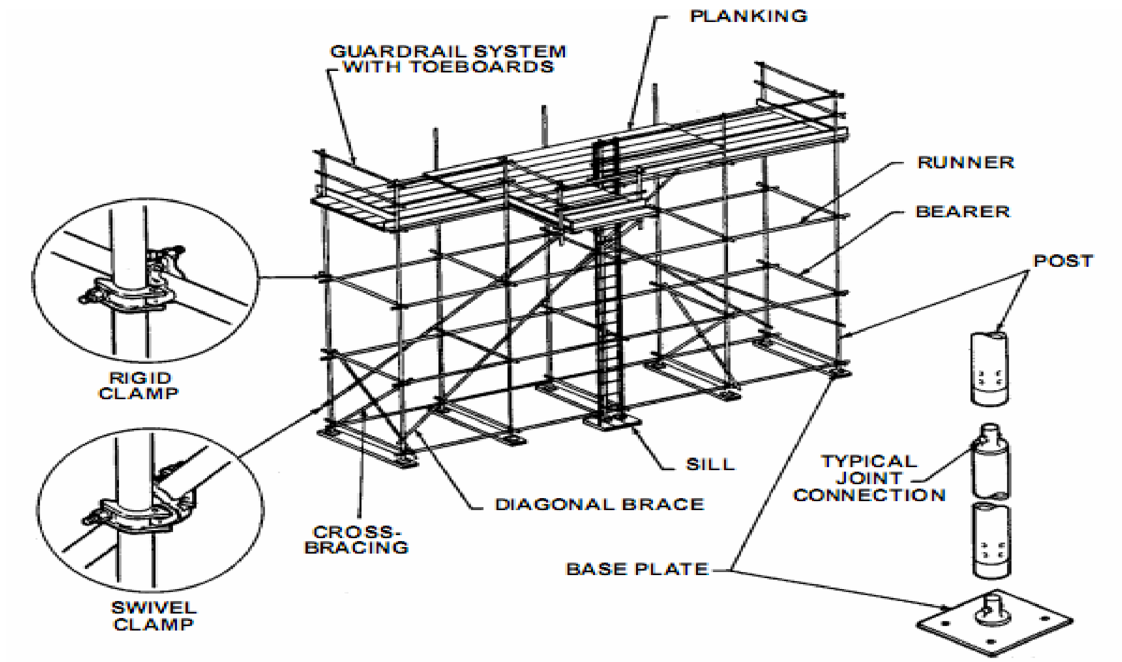


Figure 4-9. Well-designed Scaffold System (Source: North Carolina Department of Labor, Division of Occupational Safety and Health, January 2001)

- Ladders are not permitted on scaffolds to achieve extra heights. Hook on and attachable ladders provided with the scaffolds shall not be used to work at intermediate levels, these shall strictly be used to gain access to upper or lower levels.

- If outrigger beams are put in place for additional space or for material loading, then guardrails shall go around them as a means of fall protection.

- During the loading/ unloading of materials, the entire guard-rail shall not be removed as far as is practicable; the acceptable practice shall be to remove only the toe-board and the mid-rail and keep the top-rail in place all the time. The top rail shall be removed only for handling bulky materials. In that case, the person loading unloading the material shall be tied off to the nearest structural member. While loading or unloading material, if the railings have to be removed completely, then they shall be replaced as soon as practicable.

- Design the access to general work-floors to be a permanent solution at the beginning of the construction, as soon as is practicable. Where not practicable, temporary "stair towers" of adequate width and complete with handrails and guardrails shall be provided for access to upper floors or the roof. Stair towers (scaffold stairway/towers) shall be positioned such that their bottom step is not more than 24 inches above the scaffold supporting level. Figure 4-10 shows a well designed stair tower system.

- When work at height requires access to heights greater than 6 feet, then scaffold protection shall be required in the form of guardrails, cross-bracing and proper means of ladder access. Cross-bracing shall not be considered a substitute for guardrails, as it does not provide a toe-board and continuous mid-rail. As work height increases, providing an additional top-rail at the height of 60" shall be recommended.

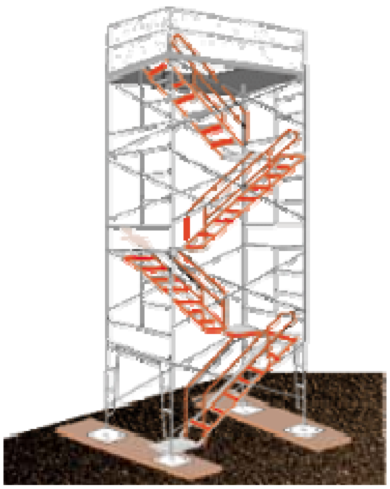
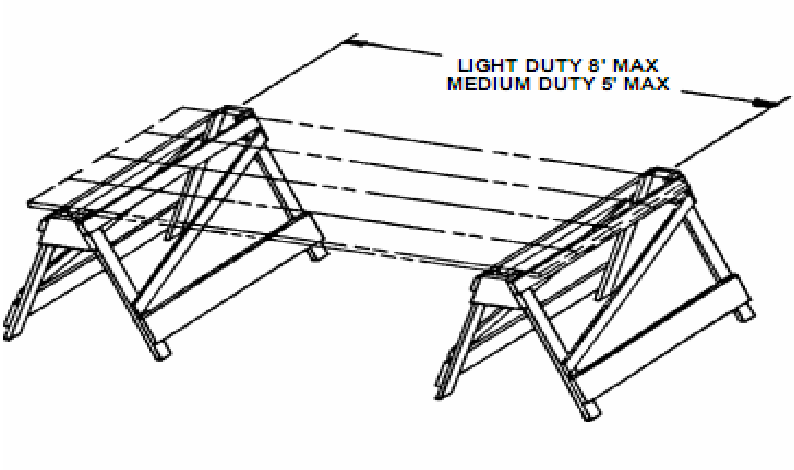


Figure 4-10. Stair-Tower with proper guardrails for access to scaffolds and upper levels. (Source: OSHA Scaffold Standards)

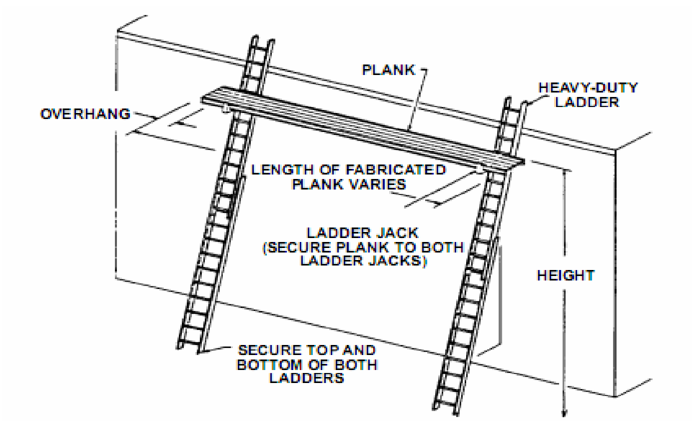
- Use of ladder jack scaffolds and horse (trestle) scaffolds shall not be permitted on the site. Ladder jack scaffolds are scaffolds in which the work platform/plank is supported on two ladders fixed to the wall/ working surface, thereby making it impossible to provide any form of guardrail protection or tie-off for the worker, thereby making it an unsafe work-practice. Also, Horse shoe scaffold, being a suspended type of scaffold, does not provide any edge protection or tie-off provision to the worker. As an alternative to either of these types of scaffolds, consider the use of scissor lifts or aerial lift as a means of performing work at heights. Figure 4-11(a) and (b) shows Ladder jack and Horse shoe scaffolds.

- A stationary scaffold shall be secured to the building or a fixed structure vertically every 25 ft starting at the base of the scaffold and horizontally every 30 ft.

- Outriggers may be used in lieu of tying off scaffolds, or scaffolds may be clamped together so that the height does not exceed three times the smallest base dimension without additional stabilization.



(A)



(B)

Figure 4-11. Types of Scaffold not recommended for use on construction sites (A) Horse-Shoe Scaffold and (B) Ladder Jack Scaffold.

- Allow limited amount of work to be performed on "boatswain scaffolds" and when they are being used, the workers have to be tied off from the nearest wall, surface or nearest structural member.

- While working in cherry pickers or other types of elevated platforms (Figure 4-12), it is mandatory to wear an anchored safety harness and lanyard incorporating a shock absorber as a precaution against mechanical failure of the basket. The lanyard should be as short as possible.

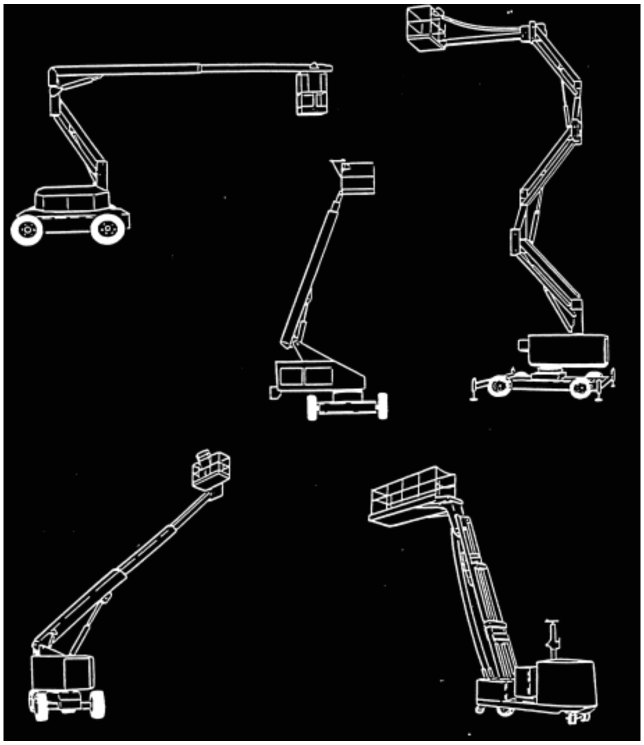
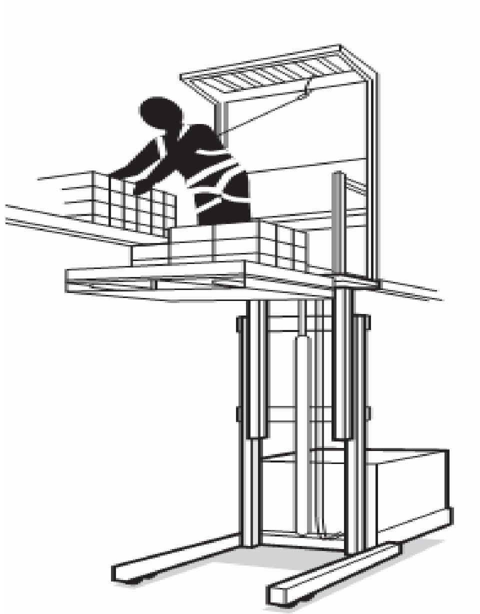


Figure 4.12. Types of Cherry-Pickers and elevated work platforms which can be used for work at heights. (Source: Oregon Occupational Safety and Health Division, Fall Protection-Personnel lifts used in construction, February 2007)

- While working on engineered devices (Figure 4-13) such as fork-lifts to carry persons with material, the worker shall not be permitted to stand on the forks of the equipment; the persons carrying material on such systems shall be tied off and shall not step onto ladders or scaffold to gain additional height while loading/ unloading material. When being used to perform a task at height, the aerial lift platform shall have a guardrail complete with full net or mesh and a gate to ensure the safety of the worker. A self locking mechanism for the door is essential before the mechanism is lifted.

(A)



(B)

Figure 4-13. Elevated work platforms. (a) Well-designed Personnel carrying equipment with safety harness and Restraint system and (b) Worker tied-off with safety harness and restraint line while loading the material on the platform. (Source: Government of Western Australia-Code of Practice - Prevention of Falls at work places, 2004)

Sky-Lights and Roof Openings

To create a safe work zone around roof openings and sky-lights the following shall be done:

- Roof openings shall be covered or protected depending whether they need to provide access or not.

  If they provide access, then provide one of the following (refer Figure 4-14):

  - Guardrails going all around it with a gate for access to the opening. Caution needs to be taken by the user that while accessing the opening, the gate shall be closed before the work begins or before accessing the opening.
  - Another alternative is to offset the guardrails but have wrap around the guardrails around with the access as shown in the Figure 4-14.

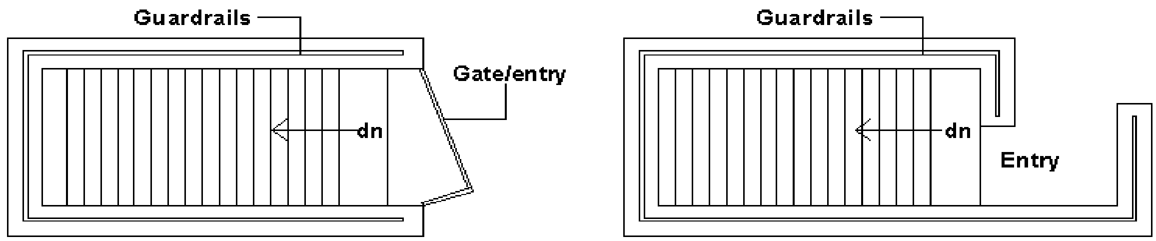


Figure 4-14. Alternatives for guardrails around the roof-opening.

- Design skylights with shatterproof glass or add strengthening wire for added protection or provide mesh over the glass so as to provide additional fall protection. Before the skylight opening is covered with glass, provide a temporary plywood cover such as plywood over it which shall be fixed to cover the opening. Also consider designing permanent guardrails around the sky-lights as soon as the opening is created. These can be designed so as to provide access through the opening.

- Design skylights so as to be located on flat areas of the roof.

- Locate skylights away from rooftop mechanical/HVAC equipment.

- Place skylights on a raised curb so as to clearly indicate the presence of an opening and to avoid any workers accidentally walking into it.

Roofing

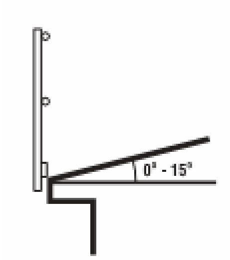
- Locate roof openings away from the perimeter of the structure.

- Minimize the number of roof openings and attempt to group roof openings together to create one larger opening rather than many smaller openings.

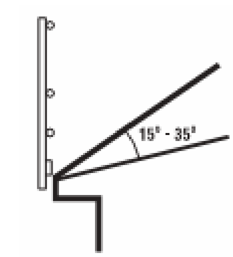
- Provide permanent guardrails around roof openings, roof accesses and along the perimeter of the roof.

- Establish control access zones but ensure that only persons performing work in the zone are allowed so as to prevent falls from heights. The only acceptable approach to prevent falls from heights is to have a parapet or guardrail system at a minimum height of 39”. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or for future roof maintenance.

- Guardrails and slide edge (Figure 4-15) shall be erected as soon as practicable along the roof edge to prevent falls during the sheathing or decking work on roof.



(a)



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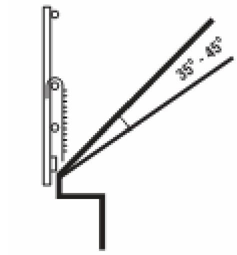
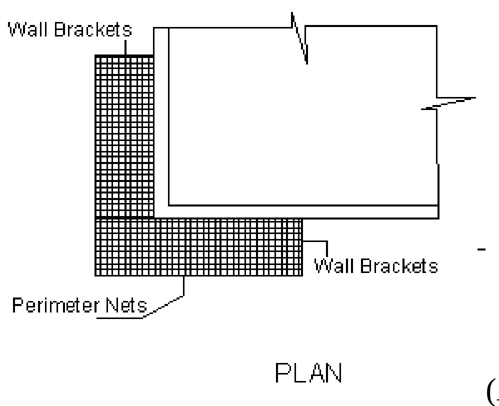


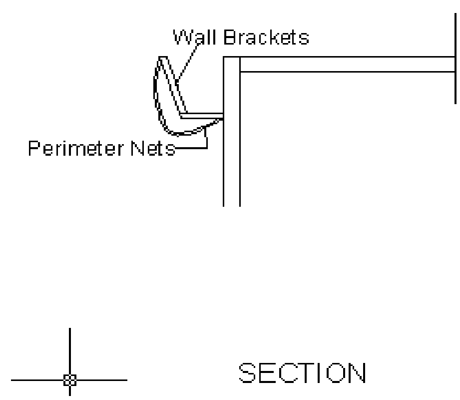
(c)

Figure 4-15. Slide edge erected to prevent falls from roofs.

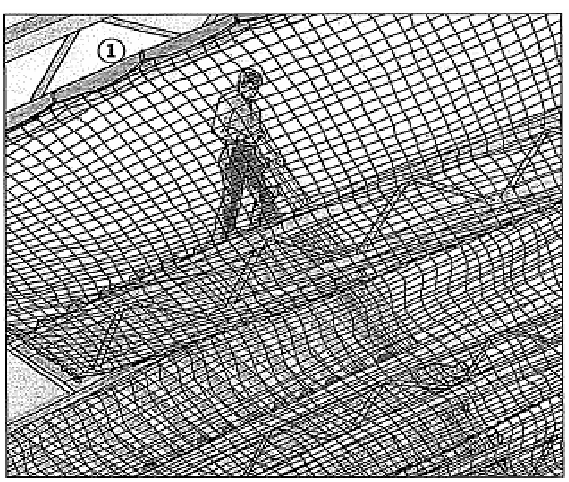
- Perimeter safety nets shall extend at least 8 feet beyond the leading edge of the working area (Figure 4-16). Perimeter safety nets are installed where there is no edge protection to prevent workers falling over the edges; if cables are installed along the length of the building or structure, safety nets are hung across these cables and moved along as the work proceeds; Safety nets should be able to withstand tension and all impact loads that it could be subjected to.



(A)



(B)



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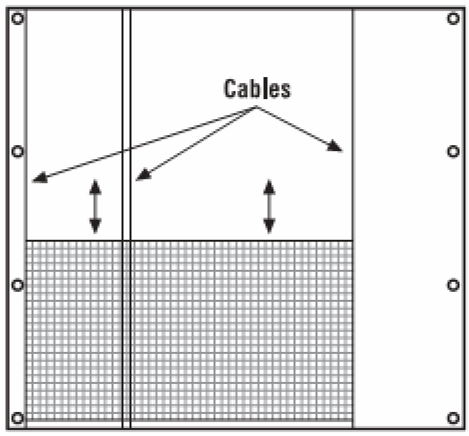
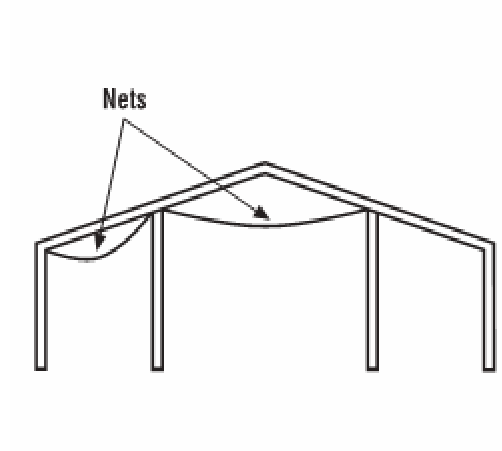


(D) Plan View (Safety nets)



(E) Section View (Safety nets)

Figure 4-16. Perimeter nets. (A) Perimeter nets installed on wall brackets in plan view, (B) Perimeter nets on wall brackets in section view, (C) Proper use of Safety Nets, (D) and (E) Safety Nets hung from cables in plan and sectional view (Source: Western Australian Government - Code of Practice for Prevention of Falls at work place, 2004)

- Provide walkways to access the rooftop mechanical equipment.

- Design roofs to have lesser pitch so as to reduce the chance of workers slipping and falling off the roof.

- Construction drawings and specifications shall clearly indicate the location all the floor openings and cut-outs such as ventilation systems, trash chutes, chimneys, elevators, skylights, etc. which will result in floor openings during construction. Design in permanent guardrail systems and sequence them early in the construction process for use by all contractors.

- Consider installing permanent anchorage points, lifeline attachments, and/or holes in perimeter walls for guardrail attachment. Roof anchors shall be provided on roofs to provide anchorage for life –lines and lanyards. Design appropriate and permanent fall protection systems for roofs to be used for construction and maintenance purposes. Roof anchors (Figure 4-17) shall be provided at 8 feet intervals along the ridgeline so as to provide permanent tie-off points for construction work and for routine maintenance work.

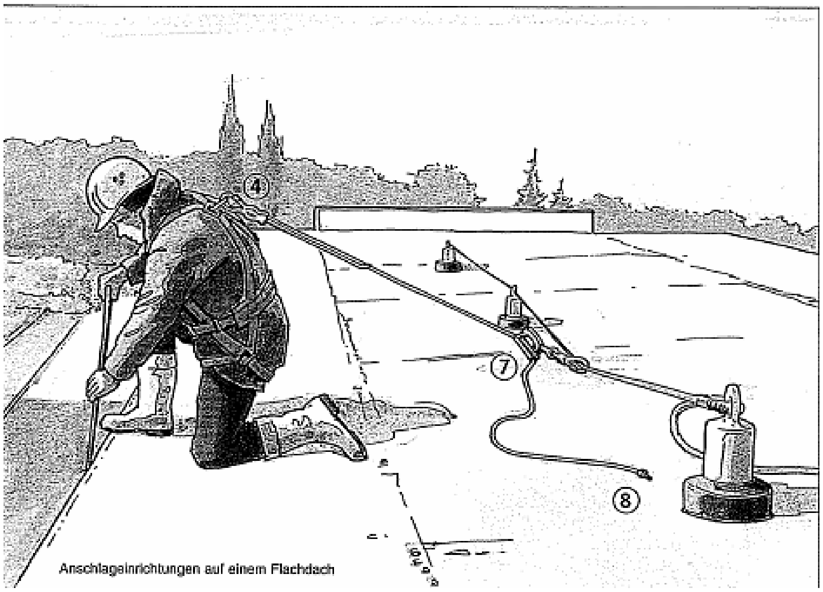


Figure 4-17. Roof anchor used for tie-off during roof maintenance work. (Source: Bausteine - German government construction safety standards)

Leading and Unprotected Edges

- Establish controlled access zones and ensure that only persons working in the zone are allowed access to the area as a measure to prevent falls. The only acceptable approach to prevent falls from heights is to have a parapet or guardrail system at the height of 39” or a maximum of 45”. A parapet of this height will provide immediate guardrail protection and eliminate the need to construct a guardrail during construction or future roof maintenance. Figure 4-18 shows leading edge work.

Figure 4-18. Leading edge work. (Source: OSHA fall protection guidelines).

Floor Openings

- Floor openings like elevator shafts and stairwells shall have full height netting or mesh/screens to prevent falls as well as to protect worker from falling materials. The elevator shafts shall have planking along with the rails so as to prevent falls while working on stilts or while working on flooring.

- Stairwell openings, where not practicable to cover the entire opening with wooden planks or metal grating, shall be provided with the use of safety nets and guardrails along all open edges. These can be used in combination or as independent of each other. For safety nets, provide tie-off points along the perimeter of the stairwell opening.

- Holes or openings in concrete floors must, where practicable, be protected with embedded wire mesh and grating provided that it is flush with the floor level. Figure 4-19 illustrates the acceptable method of covering a floor opening. The covering must be designed and installed with careful consideration all types of equipment (scissor lifts, ladders) and loads to which it that may be subjected to. Warning signs are essential at each location where a floor opening has been covered.

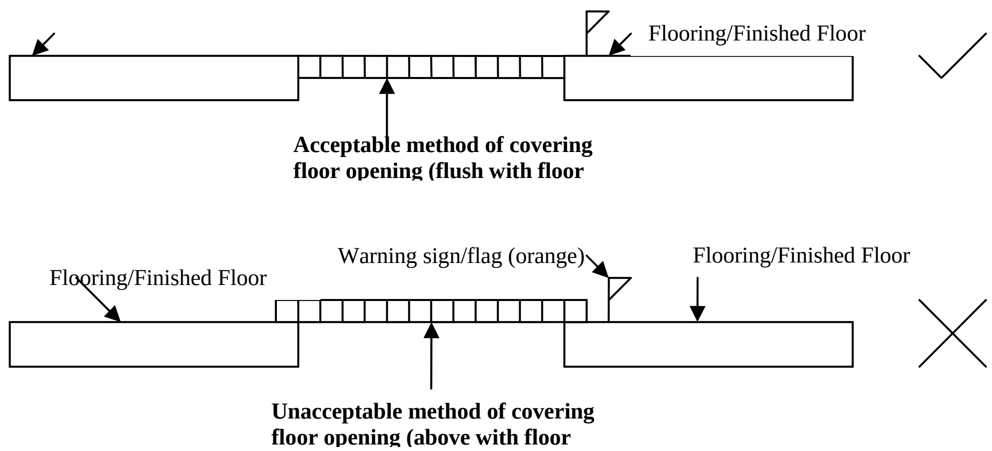


Figure 4-19. Method of covering a floor opening (acceptable and unacceptable practices)

- For erecting guardrails, design the stair platform/slab to have brackets to be cast in the concrete or welded in steel sections. These brackets can be useful to erect permanent guardrails at the beginning of the construction phase, thereby saving time and costs.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

The construction industry has continually recorded a very high number of injuries and fatalities. With stricter OSHA regulations as well as private companies taking special efforts to implement stricter safety policies on their projects, there has been some progress in terms of reducing falls and related accidents at work places. Working towards a goal of having zero accident work places will take a stronger commitment and concerted effort on behalf of owners, designers and contractors alike.

General Recommendations

Creating a safe job-site can be achieved by developing a comprehensive fall protection program for every project. Each of the parties involved in the project needs to become more cognizant about their role in making the job-site a safe work place. There has been a significant improvement in the safety performance of the construction industry during the 1990's. Perhaps the most significant factor which attributed to this improvement is the increased management commitment to safety (Hislop 1999).

Because of the increased awareness of the impact of the high costs of workers' compensation, the higher dollar value settlements in lawsuits, the increased OSHA fines for safety violations, along with the damaging effects of poor safety performance on the corporate image, the owners and upper management is now more willing to make a greater commitment to worker safety. Owners, who are determined to improve safety performance on their projects, should select contractors and subcontractors based on their safety performance. This will initiate the process at the early stages of the project and then the owner should continually remain involved in the development and implementation of the safety programs.

Acknowledging the fact that construction is an inherently dangerous business, all parties in must work towards reducing the risk of injuries on the projects being undertaken. The process should start at the contract preparation stage which typically indicates that the designers are not responsible for the safety of construction workers. If the designers could visualize an imminent hazard while planning the work, they should feel a moral obligation to take preventive steps to avoid any accidents at the site or any injuries to the workers. If designers would start working with such attitude, then planning for construction worker safety would become an integral part of designing process. This would take the industry one step closer to achieving the goal of zero incident job-sites.

Contractors have a responsibility to not only develop a comprehensive safety program for the job-site, but to ensure complete compliance. This can be achieved by having authorized persons to monitor the implementation of safe work practices and ensure compliance. For the successful implementation of a safety program and to achieve the goal of zero incident rates is to have 100% compliance with respect to the safety regulations and policies. It is not sufficient to just have a quality safety program in place, but it is equally important to have authorized persons responsible for its implementation at each stage of work. This can be established by recommending the concept of “limit of authority”. The aim will be to establish authorized person with respect to individual stages of work and authorized persons to report to in case of any issues or concerns. This shall be done for every stage of the project starting with design phase and continue through the stages of procurement, pre-construction, construction phase and maintenance. The liability issues are still a concern for designers, contractors and owners’ alike, leading to reluctance to contribute to the process of planning for worker safety.

Research Specific Recommendations

This research has attempted to document guidelines/best practices for fall prevention, some of which need to be incorporated at the design stages and some during the beginning of the construction process. It is important to remember that best practices are a moving and improving target, these practices will have to be constantly reviewed and revised.

Consideration could be given to studying the effectiveness of these guidelines when put into practice at different job-sites. It would be beneficial to conduct surveys regarding the difficulties encountered while implementing these guidelines on project sites and the level of compliance obtained. The information collected could be at different levels, such as superintendents and project managers as well as workers. Ongoing evaluation of a comprehensive fall protection program by upper management and safety personnel will ensure that the safety program will continue to improve as it evolves.

A large percentage of falls and related accidents can be avoided with complete compliance with the rules or safe practices. In addition to this, if a system of accountability could be introduced, then the safety program could be made more effective and it would automatically bring about better compliance. Further research could also focus on developing better means of achieving compliance and accountability.

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BIOGRAPHICAL SKETCH

Supriya Ghule was born and brought up in India. She pursued a high school diploma in Science and went on to study Architecture at the University of Pune, India. She completed her bachelor's in architecture in 2002. She worked for a couple of years in the architecture/ construction industry while working toward her registration in the Indian Institute of Architects. In 2006, she started her graduate program at the University of Florida with the School of Building Construction.