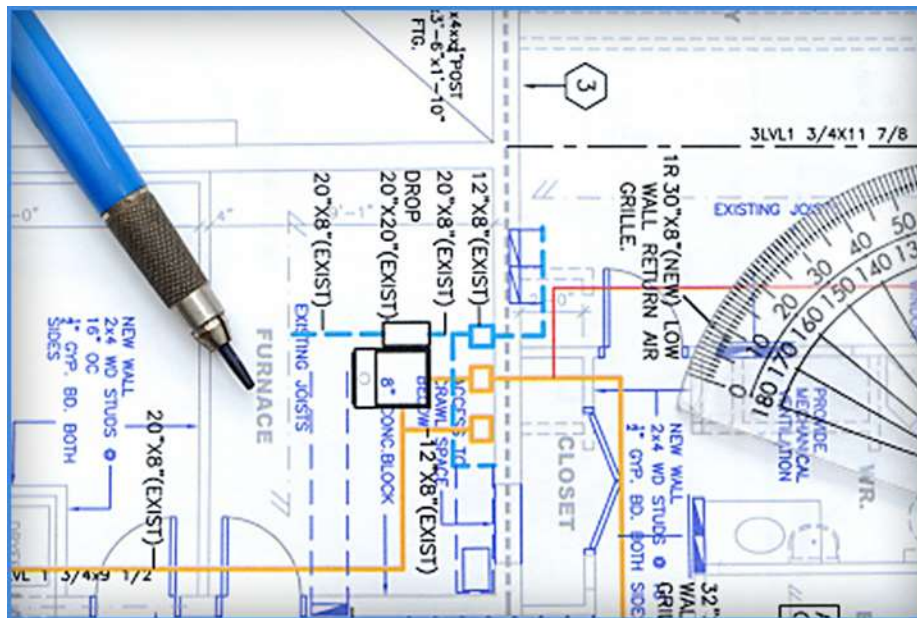


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# Design for Construction Safety

## Instructor Guide



## **Disclaimer**

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## INTRODUCTION

The construction industry has one of the highest fatality rates of any industry sector. In 2009 there were nearly 1,552,000 serious injuries and 834 deaths in construction. Construction has only 5% of the U.S. workforce, yet has 16.5% of the fatalities. These statistics have been fairly constant from year to year.

The very nature of the construction process increases the likelihood of an accident. In general industry, most work tasks take place under one roof, with one management structure. A construction project is different. An owner generally hires a design professional and a general contractor. The general contractor usually subcontracts some or all of the work to specialty trade contractors. Overall site management can be an enormous task. Construction projects move fast. The work, the subcontractors, and the material deliveries must be scheduled so that the project is completed on time and within budget. Then there are unexpected events and change orders. Site safety adds another whole layer to the overall task of managing the site.

What ends up happening is that hazards are managed during the construction process. Unanticipated hazards can arise due to sequencing changes. Workers may or not be trained. Decisions are made which may or may not prove to be safe. For example, a worker may tie off on a structural element that is unsound, or may not tie off at all if there is nothing to tie off to.

Studies have shown that a significant percentage of construction injuries and fatalities can be traced back to design issues. During the years 2000-2002 22% of injuries in Oregon, Washington, and California were linked to design. Across the United States, 42% of construction fatalities were related to design issues between the years 1990 and 2003. A 1991 study done in Europe found that 60% of fatalities were the result of decisions made before the site work even began. These studies and statistics suggest that design professionals can have a significant impact on construction injuries and fatalities by considering construction safety hazards in their designs.

In this course we will look at methods to identify and evaluate construction site hazards. Then we will look at the hierarchy of controls to select the best design feature to either eliminate the hazard or reduce the risk. Many examples will be presented which pertain to the 1926 regulations.

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## COURSE GOAL

Traditionally, design professionals prepare plans and specifications for construction projects. They have little involvement in the actual construction process. The contractors start with the plans and implement whatever means and methods are required to complete the project. The contractor has to manage hazards during the work. Certain design details and sometime the lack of other design details can make a building more hazardous to build.

The goal is to provide contractors, owners, design/build firms, engineers, architects with information on how to recognize and anticipate construction hazards and how to eliminate them with well thought out design features.

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## SPECIFIC COURSE OBJECTIVES

The specific course objectives start with methods that can be used to identify factors which can contribute to construction injuries and fatalities and how to analyze work sites for hazards. Then the hierarchy of controls is applied to each hazard. Lastly, examples of how appropriate design features can eliminate or reduce the risk of injuries.

At the end of the course students will be able to:

- Identify factors which contribute to construction injuries and fatalities
- Explain how to analyze work sites for hazards
- Discuss the hierarchy of controls for construction hazards
- Provide methodology and examples of how appropriate design features can eliminate or reduce the risk of an injury

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## COURSE OUTLINE

First, we will discuss why Design for Construction Safety (DfCS) is needed. We will look at:

- Construction injury and fatality statistics
- “Conventional” construction
- Design for Construction Safety (DfCS) overview
- Factors that contribute to construction injuries and fatalities and how DfCS fits in.

Next we will look at Design for Construction Safety Methodology, specifically,

- Identify hazards- Consider Human Factors, Recognized hazards, Hidden hazards-"What if"
- Assess risk associated with each hazard
- Apply Hierarchy of Controls

We will look at the top three OSHA violations: fall protection, scaffolding, and ladders and what DfCS can offer in these areas.

OSHA 1926 contains a number of areas that have to be in compliance. We will look at these areas and how DfCS can be used. DfCS can also be beneficial when it comes to life cycle considerations. Lastly, We will look at the top three areas where DfCS can make the most impact.

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## COURSE MATERIAL INCLUDES

The course material that you were handed out includes:

- Group case study exercises
- "What If" analysis exercise
- Risk assessment exercise
- List of standards
- List of references
- Design Solution Sheets for Fall Prevention/Protection

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## DESIGN FOR CONSTRUCTION SAFETY

DfCS is not how to use safety protective devices or procedures such as fall protection, personal protective equipment, or confined space entry permits. DfCS is how to implement permanent design features that eliminate a hazard or reduce the risk without the need for safety protective devices or procedures. Citing some specific examples, DfCS is designing permanent features so the fall protection would not be needed. It's about designing buildings so that they are safer to build and maintain. It's about, for example, avoiding confined spaces so the confined space entry permits are not needed.

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## U.S. CONSTRUCTION ACCIDENT STATISTICS

Unfortunately, as many of us know, construction is one of the most dangerous industries to work in. In the U.S., construction typically accounts for just under 200,000 serious injuries and 1200 deaths each year. The fatality rate is disproportionately high for the size of the construction workforce. But statistics like these do not tell the whole story. Behind every serious injury, there is a real story of an individual who suffered serious pain and may never fully recover. Behind every fatality, there are spouses, children and parents who grieve every day for their loss.

Because we all recognize that safety is an inherently dangerous business, all of us—including architects and engineers--must do what we can to reduce the risk of injuries on the projects we are involved in.

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## CONSTRUCTION FATALITIES BY OCCUPATION

These are some of the construction fatalities based on occupation. As you can see, contractors that work mostly at height have the largest number of fatalities. After that, it is fairly evenly divided among all trades.

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## “CONVENTIONAL” CONSTRUCTION

Traditionally, design professional prepare plans and specifications so that the finished building complies with the building code. Their goal is the safety of the end user and required by codes, regulations, and statutes. There is little attention paid to how the building will be built. That’s left up to the contractor(s).

Hazards are managed during the construction process. We will see that this is not the most effective time to deal with hazards. There is a better way. Little thought is put into the safe maintenance of the building after the owner takes possession.

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## TYPICAL CONSTRUCTION PROJECT ARRANGEMENT

Now getting back to the main subject, that is how designers can prevent or reduce construction accidents. Construction is unique from other industries. For example, in general industry, the designers, assembly workers, management, and owners are generally all under one roof and all work for the same entity. There is generally more of a chain of command, responsibilities are more defined. This is not true in construction. An owner may purchase plans from a design professional. The owner may then contract with a general contractor, construction manager, or other agent. Any of these entities may sub-contract out work. The safety responsibilities become blurred. Some contractors may pass safety responsibilities onto others. No one follows up. The contractor(s) must deal with job site safety, scheduling, material deliveries, materials shortages, the weather, change orders, unexpected conditions, such as, asbestos hidden in a

wall, or a hidden gas line. Many times the individual construction worker is left to make decisions on their own.

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## DESIGN FOR CONSTRUCTION SAFETY (DfCS)

Designing for Construction Safety is the process of addressing construction site safety and maintenance in the design phase of a project. The customary role of the design professional is protect the safety of the public and to comply with building codes. Designing for Construction Safety extends this role to include construction site safety. Well thought out design features can make a building easier to build and easier to maintain, taking some of the burden for site safety off the contractor.

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## DfCS PROCESS

There are several DfCS process models. This is one of them. Safety expectations are addressed in the beginning. There is design professional, trade contractor, QA, QC, owner, and contractor involvement throughout the design process. There are multiple reviews and re-designs. This all occurs before the drawings are finally issued for construction.

This graphic depicts the typical DfCS process. The key component of this process is the incorporation of site safety knowledge into design decisions. Ideally, site safety would be considered throughout the design process. It is recognized, however, that a limited number of progress reviews for safety may be more practical. The required site safety knowledge can be provided by one or more possible sources of such safety constructability expertise, including trade contractors, an in-house employee, or an outside consultant. In the future, perhaps state and federal OSHA employees may provide such expertise.

One question that sometimes is raised is whether the work product of a DfCS project looks different from that on standard projects. For now, the answer is “no.” That is, drawings and technical specifications on DfCS projects will likely at least initially look the same as typical documents, but they will reflect an inherently safer construction process. Eventually, it is hoped that construction documents resulting from a DfCS process will include safety enhancing details and notes that are not currently found on standard plans and specifications.

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## WHY IS IT NECESSARY?

There are currently no requirements for construction safety in modern building codes. The only building code construction safety requirement that currently exists addresses protection of the public during construction.

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## DESIGN CAN INFLUENCE CONSTRUCTION SAFETY

Studies have shown that design professionals can have significant influence on construction safety. These are some statistics from the US and Europe. Because we all recognize that safety is an inherently dangerous business, all of us—including architects and engineers--must do what we can to reduce the risk of injuries on the projects we are involved in.

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## OSHA 1926 ENGINEERING REQUIREMENTS

The involvement of design professionals in the construction process is not a new idea. There are currently many sections in the OSHA 1926 standards which require engineering controls in construction projects.

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## FACTORS THAT CONTRIBUTE TO CONSTRUCTION ACCIDENTS

If the world was perfect, there would be no (of few) construction injuries and fatalities. After all, OSHA regulations and other standards specify what safety procedures should be done in many if not most circumstances. If only contractors had enough time to carefully implement them. This is not to blame the worker when an accident occurs because even the best trained worker has momentary lapses, misjudges a situation, or makes a mistake. Construction projects move quickly. These are some of the factors that contribute to construction accidents. The result is that no decisions or poor decisions are made with regard to safety and someone gets injured or even killed. These are some of the root causes for construction accidents. Many of these causes are related to human error, but could have been prevented if a design feature would have eliminated the need for a site decision.

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## WHERE DO DESIGN PROFESSIONALS FIT IT

Design professionals fit in by considering construction safety issues during the construction and maintenance of the facility and addressing them in the design phase of the project. By anticipating hazards and applying their design skills to eliminate them, unsafe conditions can be reduced.

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## CONSIDERING SAFETY DURING DESIGN OFFERS THE MOST PAYOFF

One of the reasons that the DfCS concept is so compelling is that all safety professionals know that it is much more effective to design safety into a process than it is to try to manage safety within a process that is inherently unsafe.

This chart has been adapted from the construction management literature. The ability to influence safety is on the vertical axis and the project schedule is on the horizontal axis. The chart shows that by including construction site safety as a consideration (along with production, quality, project scope, etc.) early in the project's life cycle, one has a greater ability to positively influence construction



site safety.

This concept is in contrast to the prevailing methods of planning for construction site safety, which do not begin until a short time before the construction phase, when the ability to influence safety is limited.

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## DfCS METHODOLOGY

DfCS is a five step process. The first step is to identify and anticipate potential hazards. For each hazard, the risk is assessed. That provides an indication as to whether or not valuable resources should be spent to address that hazard. Then the hierarchy of controls is applied. The drawings are then reviewed with the contractors and owner for additional input. Finally, the drawings are issued for construction.

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## STEP #1 IDENTIFY/ANTICIPATE POTENTIAL HAZARDS

The first step is to identify the potential hazards. There are obvious or recognized hazards. An open sided floor 6 feet or more above the ground is an obvious fall hazard, for example. There are also hidden hazards which can be much more difficult to uncover.

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## CONSIDER HUMAN FACTORS

Consider human factors. How can sequencing of work create unplanned hazards? What sort of situations might a worker find himself/herself in? What types of distractions might there be on the job? Will the workers be properly trained? What if they're not? Will there be inexperienced workers on the job?

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## RECOGNIZED HAZARDS

First, we'll look at sources for recognized hazards. Recognized hazards are those which are "obvious" or have been well documented from past experience.

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## VISIT SIMILAR FACILITIES

To help formulate a list of recognized hazards, visit similar buildings or facilities. Be skeptical about new processes, new equipment, and new facilities. Talk to people, get feedback. Get information on maintenance. This can also help uncover hidden hazards which we will discuss in a few more slides.

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## RECOGNIZED HAZARDS-SOURCES INDUSTRY STANDARDS

There are many government agency regulations and industry standards that will cite recognized hazards. A list of these regulations and standards are provided in the course material. A survey of these standards and regulations can help you identify areas that you need to look out for.

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## RECOGNIZED HAZARDS-SOURCES GOVERNMENT REGULATIONS

These are some of the government agency regulations that can be referred to help with recognized hazards.

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## HIDDEN HAZARDS

Then there are “hidden” hazards. “Hidden” hazards are just what the name implies. They are not readily apparent. These are hazards that can arise from complex interactions or scenarios. For example, a work task is taken out of sequence. A siding contractor shows up before scaffolding is put in place. “Hidden” hazards can also be latent. One sub-contractor walks down a planked walkway not knowing that a second sub-contractor has not finished putting the planks down.

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## HIDDEN HAZARDS-EXAMPLES

These are some examples of hidden hazards. There could be an electrical wire buried in a wall that would be uncovered during demolition. Rotted or decayed structural members are hidden hazards.

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## “WHAT IF” ANALYSIS

There are several analytical techniques that can help you uncover hidden hazards. One of them is ‘What if’ analysis.

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## HIDDEN HAZARDS - “WHAT IF” ANALYSIS

A “what if” analysis is a structured brainstorming session. The be effective it is important to select the boundaries of the review and assemble an experience team. Then gather as much information as you can... video tapes of similar facilities, design documents, how the various components of the building will be constructed, how the areas of the building will be maintained.

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## “WHAT IF” SITUATION QUESTIONS

In a “what if” analysis the design professional or design team needs to brainstorm things that can go wrong (“what if”). These are some of the questions you might pose. Always be thinking “what could go wrong”

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## “WHAT IF” ANALYSIS TEMPLATE

There are many templates that can be used for a “what if” analysis. Here is one of them. For each question, write down the answer, then assess the likelihood of it’s occurrence, what the consequences might be, and what the design recommendation is.

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## HIDDEN HAZARDS- “WHAT IF” ANALYSIS EXAMPLE

This is a sample of “what if” questions that might be included in the construction highway project. Each of the “what if” scenarios should be followed up by a design feature that can eliminate the hazard.

\*\*\*\*\*Now, let’s take a break and do a couple of “what if” analysis exercises that are in Appendix C of you materials \*\*\*\*\*.

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## HIDDEN HAZARDS- OTHER METHODS

There are many other techniques and sources that can be used to identify hidden hazards. Here are some of them. Fault tree analysis (FTA) is a reliability and logic-based methodology. It is used for identifying and analyzing the events that would lead to an accident.

As you do a walk through, visits other similar facilities or read through standards, make a checklist. Use this checklist for you design.

Do a plan review. If you gut feeling tells you that something is unsafe, it probably is.

Read case studies on construction accidents. This might indicate how sequencing problems or human error may have created an unforeseen hazard.

Fatal Facts and NIOSH FACE reports usually provide background details on events that lead to a fatality which can provide other information

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## FATAL FACTS

The OSHA website has a catalog of “fatal facts” . These can be reviewed to become familiar with some of the things that occur in construction. Many of these might be called “Murphy’s Law”.

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## STEP #2 ASSESS RISK

Once the hazard(s) have been identified and a list is made, the next step is to identify the risk associated with each hazard. Risk is the product of the severity of an injury times the likelihood of an occurrence. There is no such thing as zero risk. A risk analysis will identify those hazards that need attention and those that may not. Also, a risk analysis will allow you to prioritize the hazards.

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## DfCS RISK ASSESSMENT-ESTIMATE INJURY SEVERITY

There are a number of methods to assess risk, some are qualitative and some are quantitative, some are relatively simple to implement and some are complicated and time-consuming. A very simple risk assessment is a qualitative analysis as follows. First, the injury severity is assessed as: severe, serious, moderate or slight

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## DfCS RISK ASSESSMENT-ESTIMATE PROBABILITY OF HAZARDOUS EVENT

Next the probability of occurrence is estimated, either high, medium, moderate or low.

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## DfCS RISK ASSESSMENT MATRIX

Once the severity and the probability have been estimated, this matrix can be used to assess the risk. The risk ranges from high to negligible. Design action ranges from intervention (high) to no action (negligible).

\*\*\*\*\*Now let’s pause again and do a couple of risk assessment exercises that are in your Appendix C.\*\*\*\*\*

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## STEP #3 APPLY HEIRARCHY OF CONTROLS

Once the risk has been determined, the design professional proceeds to eliminate the risk or reduce it to an acceptable level by using the I. The idea of designing out hazards dates back to the 1940’s. This design philosophy has been known as Design for Safety, Safety in Design. It has been used in general industry for many years and has recently been applied to construction hazards, hence, Designing for Construction Safety.

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## HIERARCHY OF CONTROLS

The design professional proceeds to eliminate the risk or reduce it to an acceptable level by designing out the hazard as the top priority, substituting a less hazardous method or material, followed by engineering controls such as safety devices or isolating the hazard, then administrative controls followed by personal protective equipment at the bottom of the priority list.

Warning systems such as back up alarms, beacon lights, and warning signs are vital in many situations, but really on administrative controls (training, reaction of workers) to be effective.

You will find that the most effective controls for safety will also have work quality benefits and cost savings in the long run.

In Designing for Construction Safety, we will be focusing on design out the hazard as top priority and providing safety devices as a second priority. Keeping in mind that DfCS is about designing permanent features into a building that make it safer to build and maintain. Warning devices, administrative procedures, and personal protective equipment do not fall into this category, unless there are design features that can make them easier to implement.

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## DfCS TEMPLATE

Here is a template that you can use for DfCS.

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## TOP TEN OSHA VIOLATIONS

While this whole process may seem over-welming at first. These are the top ten OSHA violations. Most of them could be influenced by design features. Let's start looking at some "low hanging" fruit. The top three violations related to falls in order can be lumped into fall protection, ladders, and scaffolds

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## 1926.501 FALL PROTECTION

Statistically, falls account for the greatest number of fatalities in the construction industry, roughly a third of all workplace fatalities. Fatal falls, slips, or trips took the lives of 699 workers in 2013. Falls to a lower level accounted for 574 (82 percent) of those fatalities. In 2013, the height of the fall was reported for 466 of the fatal falls to a lower level. Of those, about 1 in 4 occurred after a fall of 10 feet or less. Another one-fifth of the fatal falls occurred from falls of over 30 feet.

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## FATAL FALLS MOST OFTEN FROM

This data was taken from BLS 2010 statistics which is the last year that BLS coded fatal falls this way. This pie chart shows the statically breakdown of all fall injuries and fatalities. It provides a breakdown as to where the falls are occurring Even though the data is 2010 it provides useful information as to where falls are occurring. Ladders, roof edge, and scaffolds are the top three.

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## CONSIDER PARAPETS

Let's look at what can be done about falls from roof edge. We are following the Hierarchy of Controls: eliminate the hazard. A parapet wall that also functions as a perimeter guard can eliminate the need for temporary fall protection during construction and maintenance. As a designer, you would need to consider the additional snow loading that might be created with a parapet design.

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## SPECIFY WINDOW SILLS AT 42 INCHES

Here is another example of how certain design features can take the place of temporary guardrails. If window sills were specified at 42 inches plus or minus 3 inches, temporary guardrails would not be required during construction. Think of all the 2 x 4 (trees) that would be saved.

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## SKYLIGHTS

The problem with most skylights is that they cannot withstand the live load associated with a worker stepping on or fall on a skylight. Consider specifying skylights that can with stand the live impact loads or specify a guardrail or screen.

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## SKYLIGHTS

We can only guess what the worker on the right was doing before he fell through.

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## PERMANENT ROOF ANCHORS

Many falls occur because a worker does not have a safe place to tie off, and therefore does not bother to use fall protection, or ties off to a structure that is not structurally sound. Consider specifying permanent roof anchors so that workers will always have a safe place to tie off.

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## PERMANENT ROOF ANCHORS

This slide shows another example of permanent roof anchors that could be used for residential buildings as well. We've all seen residential roofers without fall protection, although that is changing. Permanent roof anchors will provide a safe place for the roofer on the right to tie off.

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## STAIRWAYS AND FLOOR OPENINGS

Unguarded floor openings, open side floors, and open side stairways are another source of falls. Many times, temporary guardrails are not put up. Consider specifying cast-in sockets. These sockets make it easy for contractor to install temporary guardrails during the construction phase. The sockets can be used for permanent guardrails later on, or just filled in. This photos shows cast in sockets on the open side of a stairway.

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## FLOOR OPENINGS/OPEN SIDED FLOORS

Here is another example of how a thoughtful design feature can make it easier to install temporary guardrails and can be used later for permanent wall systems. It is a better situation on the right where temporary guardrails are either not installed, or they are not structurally adequate.

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## FALLS THROUGH ROOF SURFACE

Many time construction materials are stored on a roof. Anticipate the weight and footprint of construction materials that may be stored on the roof and include that in dead loads.

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## FALLS THROUGH ROOF SURFACE

Consider adding a safe catwalk to your plans so that workers and future maintenance personnel will have a structurally sound and safe surface to walk on when working on the roof.

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## FALLS FROM OPEN SIDED FLOORS

Here is another idea where permanent design features can make it easier to install temporary fall protection systems. Specifying holes in columns at 42 inches and 21 inches above each floor slab makes it easier to install perimeter cables during construction.

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## REDUCE WORK AT ELEVATIONS

Less time spent at height means fewer fall accidents. The more that can be built on the ground then hoisted into place means less time working at height. Consider modular construction. This slide shows a roof system that was built on the ground then hoisted into place as opposed to the conventional method on the right where workers are at height, most likely without fall protection, sticking building the roof.

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## REDUCE WORK AT ELEVATIONS

Here is another example of how constructing segmented bridge sections on the ground then raising them into place can reduce time spent at height

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## 1926.1053 LADDERS

Next we'll discuss ladders. Falls from ladders occur because a worker used the wrong portable ladder, a defective portable ladder, or did not use the ladder properly. Consider permanent, safe stairways or fixed ladders so that the need to use a portable ladder is eliminated.

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## 1926.1053 LADDERS

Here is an example of the fixed ladder which eliminates the chance that a worker uses a portable ladder in an unsafe manner as the worker on the right.

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## 1926.451 SCAFFOLDING

Scaffold accidents occur because of improper access, lack of fall protection, or unsafe anchor points. Here are several ideas you can use. Gantry systems can be permanently installed so that scaffolds are not needed when, for example, servicing atriums and skylights. Davits can be installed so that there will always be a permanent suspension system whenever scaffolding is needed.

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## 1926.451 SCAFFOLDING

This photo says it all. Consider design features that eliminate the need for scaffolding, or, make it easier to use scaffolding.

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## 1926.121(b)(6) CONFINED SPACES

Now we will address some hazards from the 1926 regulations. 1926.21(b)(6) discusses precautions that should be taken when entering a confined or enclosed space. 1910.146 can be applied as a best practice regarding confined spaces. A confined space entry permit is an administrative procedure that is at the bottom of the hierarchy of controls priority list. The potential problem is that



someone does not use an entry permit, does not use it properly, or unexpected hazards arise that are not addressed by the permit. Try to avoid confined spaces whenever you can.

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## 1926.121 (b)(6) CONFINED SPACES

By eliminating the chance of human error in the implementation of the permit, a worker's life could be saved.

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## 1926.52 NOISE EXPOSURE

Construction sites are noisy places. Long term exposure to noise can lead to hearing loss. Noise on a construction site can also create other problems. Workers may not hear back up alarms or verbal instructions and warnings.

While noise control largely depends on personal protective equipment, there are some things that a designer can do. Here is an example of commercial sound panels that can help reduce noise levels. Sound barriers can also be constructed on the site using scrap materials.

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## 1926.52 NOISE EXPOSURE

Specify quiet pumps, generators, and compressors so that hearing protection would not be required.

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## 1926.52 NOISE EXPOSURE

These are some other things that a designer can specify on the drawings and specifications to help reduce noise levels. Design cast crack inducers in concrete to avoid the need to saw cut joints. Design cast-in anchors instead of drill and fix. Avoid vibro compacting. Detail mesh reinforcement to suit bay sizes, rather than cutting to fit on site. Specify non standard blocks to be cut off site under controlled conditions

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## 1926.55 FUMES

Specify water based primers, sealers and coatings that do not emit noxious fumes.

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## 1926.652 EXCAVATIONS

Trenching accidents occur because contractors don't bother to use shoring and trench boxes, or so not use them properly. In utility and other similar work, consider specifying trenchless technology. This eliminates the need for a worker to be down in the trench.

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## 1926.652 EXCAVATIONS

Why take the chance of a trench collapse if you don't need to!

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## 1926.756 BEAMS AND COLUMNS

A designer's expertise can be applied to making it easier and safer to erect structural steel. Avoid hanging connections. Safety seats (see arrow) make it easier to erect structural steel by eliminating the need for support for girders during the connection process

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## 1926.756 BEAMS AND COLUMNS

A steel frame might be designed so that it is stable and sound when everything is in place, but can be unsafe during the erection process. Why leave bracing up to a contractor that may not have the experience or structural background that an engineer has. Specify bracing on the bid documents so that the structure does not collapse mid-way through the erection process like on the right.

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## 1926.756 BEAMS AND COLUMNS

A composite beam might be fine when the concrete has cured, but is an entirely different animal during the construction phase. The concrete has little or no structural strength while it is curing, yet still has dead load. Consider how a non-composite beam and supporting steel members are loading during the construction and curing process.

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## 1926.756 BEAMS AND COLUMNS

Put the rebar details on the drawing so that there are no questions.

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## 1926.955 OVERHEAD POWER LINES

This was an actual accident whereby an engineer specified water monitoring wells under power lines. A worker was killed when his equipment came into contact with the power lines. Consider how a building or facility will be maintained. Do not specify ground water monitoring wells or other facilities near or under power lines.

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## SPRAINS, STRAINS, MATERIAL HANDLING

A designer's expertise can also be applied to sprains, strains, and material handling injuries. Consider specifying lightweight concrete whenever it is structurally feasible.

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## SPRAINS, STRAINS, MATERIAL HANDLING

Consider how a building or facility will be maintained. Which pump installation is easier to maintain? The one of the left which would require the worker to unbolt the pump through the congestion of piping while standing on a step ladder, or the one of the left which can be easily disconnected while standing on the floor.

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## OTHER BENEFITS OF DfCS

There are many other benefits of DfCS relating to life cycle costs. We will look at some examples of design features that make it easier and safer to maintain buildings and facilities. Positioning roof top equipment at least 15 feet back from the roof edge, or on the ground, will eliminate the need for fall protection whenever the equipment has to be serviced.

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## OTHER BENEFITS OF DfCS

Here is an example of roof ties that are easy to remove, and can be re-used in the future if scaffolding has to be erected to maintain the exterior.

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## OTHER BENEFITS OF DfCS

Hearing conservation programs can be costly to the end user, and could lead to hearing loss if not monitored properly. Consider specifying quiet equipment, or noise control in mechanical rooms so that hearing conservation program or personal protective equipment is not needed.

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## OTHER BENEFITS OF DfCS

If you specify "quiet" in the beginning, the owner will not have to do costly retrofitting later.

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## OTHER BENEFITS OF DfCS

Somewhere along the line, switchgear has to be maintained. Consider arc resistant switchgear which directs the arc energy directed away from personnel instead of at them.

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## OTHER BENEFITS OF DfCS

Maintaining electrical substations means electrical work permits, arc suits and the risks associated with entering an electrical cabinet. Smart substations eliminate all of this. The technician can make checks without entering the cabinet.

\*\*\*\*\*Before we do a wrap up, lets break up into three or four workgroups and work on some real life case studies that are in your Appendix C.\*\*\*\*\*

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## COURSE SUMMARY

Let's do a wrap up. These are the main points that we focused on. We identified the factors which contribute to construction injuries and fatalities. We covered how to analyze work sites for hazards. We discussed the hierarchy of controls for construction hazards. Finally we provided methodology and examples of how appropriate design features can eliminate or reduce the risk of an injury.

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## ALWAYS CONSIDER THE "BIG THREE"

While it may seem overwhelming and very complicated. Falls contribute to nearly 1/3 of all construction fatalities. Consider the "big three": scaffolds, fall, and ladders. Design buildings so that scaffolds are not need, or at least there are solid structures from which to suspends scaffolding when needed. Design the building so that fall protection is not needed. And lastly, design the building so that portable ladders are not needed.

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## OSHA RESOURCES

There is a wealth of information on the OSHA website. Appendix A in your course material has a lot of reference material from a number of sources.

## APPENDICES

- Appendix A - Reference Material
- Appendix B - NIOSH FACE Reports
- Appendix C - Work Group Exercises
- Appendix D - Sample Job Hazard Analysis Form
- Appendix E - Risk Assessment Matrix
- Appendix F - DfCS Template

- Appendix G - “What If” Analysis Template
- Appendix H - Design Solution Sheets

## APPENDIX A: REFERENCE MATERIAL

### 1. NIOSH Alerts

NIOSH has issued several Alerts concerning falls in construction, including:

1. Alert: Preventing Falls of Workers through Skylights and Roof and Floor Openings, NIOSH Publication No. 2004-156 (Aug. 2004). See <http://www.cdc.gov/niosh/docs/2004-156/>.
2. Alert: Preventing Injuries and Deaths From Falls During Construction and Maintenance of Telecommunication Towers, NIOSH Publication No. 2001-156 (July 2001). See <http://www.cdc.gov/niosh/2001156.html>.
3. Alert: Preventing Worker Injuries and Deaths Caused by Falls From Suspension Scaffolds, NIOSH Publication No. 92-108 (Aug. 1992). See <http://www.cdc.gov/niosh/92-108.html>.

### 2. Worker Health Chartbook (2004)

**Citation:** Worker Health Chartbook, 2004, NIOSH Publication No. 2004-146. See <http://www.cdc.gov/niosh/docs/chartbook/>.

**Summary:** The Chartbook is a descriptive epidemiologic reference on occupational morbidity and mortality in the United States. It includes a section on the construction trades. (See Chapter 4 at <http://www2a.cdc.gov/niosh-Chartbook/ch4/ch4-2.asp>.) This section includes detailed information on workplace fatalities and injuries/illnesses for the following trades: brickmasons, carpenters, drywall installers, electricians, ironworkers, laborers, operating engineers, painters, plumbers, roofers, truck drivers, and welders and cutters.

### 3. University of Tennessee Annual Analysis of Construction Fatalities

The Construction Industry Research and Policy Center at the University of Tennessee prepares annual reports entitled “An Analysis of Fatal Events in the Construction Industry.” The reports are funded by OSHA and use IMIS data supplied by OSHA. They analyze all OSHA-inspected fatal construction accidents, including fatalities in state plan states.

The reports are available at:

<http://bus.utk.edu/cirpc/Research/ConstructionFatalityReports.htm>

According to the report, falls have consistently been the leading cause of construction fatalities. In 2004, the study analyzed 785 fatalities. The following were the number and percentage of fatalities from various classifications of falls in 2004:

- Fall from/through roof: 109 fatalities (13.8% of construction fatalities)
- Fall from/with structure (other than roof): 63 fatalities (8.0%)
- Fall from/with ladder: 41 fatalities (5.2%)
- Fall through opening (other than roof): 26 fatalities (3.3%)
- Fall from/with scaffold: 24 fatalities (3.1%)
- Fall from/with platform or catwalk: 20 fatalities (2.3%)
- Fall from /with bucket (aerial lift/basket): 15 fatalities (1.9%)
- Fall, other or unknown: 3 fatalities (0.4)
- Fall from highway vehicle/construction equipment: 2 fatalities (0.3%)

These figures are similar to the averages for 1991-2003, which are:

- Fall from/through roof: 71.3 fatalities (11.3% of construction fatalities)
- Fall from/with structure (other than roof): 52.8 fatalities (8.4%)
- Fall from/with ladder: 25.8 fatalities (4.1%)
- Fall from/with scaffold: 21.2 fatalities (3.4%)
- Fall through opening (other than roof): 16.6 fatalities (2.6%)
- Fall from/with platform or catwalk: 14.4 fatalities (2.3%)
- Fall from /with bucket (aerial lift/basket): 13.2 fatalities (2.1%)
- Fall from highway vehicle/construction equipment: 5.4 fatalities (0.9%)
- Fall, other or unknown: 4.7 fatalities (0.7%)

## 4. National Association of Home Builders Study

**Citation:** Residential Construction Fall Fatality Study, NAHB, 1998.

**Data source:** OSHA IMIS database: all fatal falls in the construction industry from 1992 to 1995.

**Summary:** NAHB commissioned this study to determine whether a significant number of falls regulated under 29 CFR 1926, Subpart M occur in residential construction relative to non-residential construction or construction as a whole. The study found that of those fatal falls regulated under Subpart M, 22% occurred in residential construction. From 1992 to 1995, the fall fatality rate for residential construction was 7.8 per million workers, while for non-residential construction it was 19.8 per million workers. The study concluded that the risk of death from a fall regulated under Subpart M is significantly lower on residential sites compared with non-residential sites.

The report also includes breakdowns of fatalities by SIC code (residential and non-residential), fatalities by state, fall fatalities and single-family building permits by state, and employment in residential construction.

## 5. Center to Protect Workers' Rights

CPWR is the research, development, and training arm of the Building and Construction Trades Department, AFL-CIO. CPWR has done several studies related to construction falls, including the following.

Center to Protect Workers' Rights, "The Construction Chart Book, Third Edition (Sept. 2002). See <http://www.cpwr.com/chartbook.htm>.

McCann M, "Causes of Roofer Deaths" (1999). See <http://www.cpwr.com/pulications/krroofers.PDF>.

McCann M, Chowdhury R, "Deaths from Falls in Construction, 1997" (2000). See <http://www.cdc.gov/elcosh/docs/d0400/d000478/d000478.html>.

## 6. Journal Articles

The following are citations to selected journal articles that include statistics and other analysis on fall fatalities and injuries in construction.

Agnew J, Suruda AJ, "Age and fatal work-related falls," *Human Factors*, 35 (4): 731-6, 1993.

Becker P, Fullen M, Akladios M, Hobbs G, "Prevention of Construction Falls by Organizational Intervention," *Injury Prevention*, 7:i64-i67 (2001).

Bobick T, "Falls through roof and floor openings and surfaces, including skylights: 1992-2000, *Journal of Construction Engineering and Management*, 130 (6), 895-907 (2004).

Cattlege GH, Hendricks S, Stanevick R, "Fatal occupational falls in the U.S. construction industry, 1980-1989," *Accident Analysis & Prevention*, 28 (5): 647-54 (1996).

Derr J, Forst L, Chen HY, Conroy L, "Fatal falls in the US construction industry 1990 to 1999," *J Occup Environ Med.*, 43 (10): 853-60, 2001.

Tycho K. Fredericks, Osama Abudayyeh, Sang D. Choi, Mike Wiersma, and Marcia Charles, "Occupational Injuries and Fatalities in the Roofing Contracting Industry," *J. Constr. Engrg. and Mgmt.*, 131 (11): 1233-40, 2005

Hsiao H, Simeonov P, "Preventing falls from roofs: A critical review," *Ergonomics*, 44 (5) 537-61, 2001.



Janicak, CA, "Fall-related deaths in the construction industry," *Journal of Safety Research*, 29 (1): 35-42, 1998

Lipscomb HJ, Glazner J, Bondy J, Lezotte D, Guarini K, "Analysis of Text From Injury Reports Improves Understanding of Construction Falls," *Journal of Occupational and Environmental Medicine*, 46(11): 1166-1173 (2004).

Lipscomb HJ, Li L, Dement J, "Work-related falls among union carpenters in Washington State before and after the Vertical Fall Arrest Standard," *American Journal of Industrial Medicine*, 44 (2): 157-65, 2003.

Nelson NA, Kaufman J, Kalat J, Silverstein B, "Falls in construction: Injury rates for OSHA-inspected employers before and after citation for violating the Washington State Fall Protection Standard," *American Journal of Industrial Medicine*, 31 (3): 296-302, 1997.

Rivara FP, Thompson DC, "Prevention of falls in the construction industry: evidence for program effectiveness," *American Journal of Preventive Medicine*, 18 (4 Suppl.): 23-6, 2000.

## 7. American National Standard Institute (ANSI)

ANSI A10.6-Safety Requirements for Demolition Operations

ANSI A10.8 Safety Requirements for Scaffolding

ANSI A10.13 Safety Requirements for Steel Erection

ANSI A14.2 Safety Requirements for Portable Ladders

ANSI A14.4 Job Made Wooden Ladders

ANSI A10.32-Fall Protection Systems for Construction and Demolition Operations.

ANSI A145.1 Recommended Practice for Concrete Formwork

ANSI Z49.1 Safety in Welding and Cutting

ANSI A1264.1-Safety Requirements for Workplace Floor and Wall Openings, Stairs & Railing Systems

ANSI D6.1 Manual on Uniform Traffic Control Devices

ANSI Z93.1 Fire Hazards in Oxygen Enriched Atmospheres

ANSI Z117.1 Safety Requirements for Confined Spaces

ANSI Z244.1 Lockout/Tagout of Energy Sources

## 8. American Society for Testing and Materials (ASTM)

ASTM 04.09 Wood Construction

ASTM D4532 Respirable Dust in Workplace Atmospheres

ASTM F802 Guide for Selection of Certain Walkway Surfaces When Considering Footwear

ASTM F1647 Standard Practice for Safe Walking Surfaces

ASTM O4.07 Building Seals and Sealants Traffic  
ASTM STP 1150 Fire Hazard and Fire Risk Assessment

## 9. National Fire Protection Association (NFPA)

NFPA Volume 13, 53M Fire Hazards in Oxygen Enriched Atmospheres  
NFPA 30 Flammable and Combustible Liquids  
NFPA 241 Safeguarding Construction, Alteration, and Demolition Operations  
NFPA 325M Fire Hazard Properties of Flammable Liquids, Gases & Volatile Solids  
NFPA 654 Prevention of Fire and Dust Explosions in the Chemical, Dye, Pharmaceutical, and Plastics Industries

## 10. OSHA

OSHA 1926.550 Cranes and derricks  
OSHA 1926.251 Rigging Material for Material Handling  
OSHA 1926.452 Scaffolds  
OSHA 1926.800 Underground Construction  
OSHA 1926.52 Occupational Noise Exposure  
OSHA 1918.95 Longshoring Operations in the Vicinity of Repair and Maintenance Work  
OSHA 1926.1050-1053 Stairways and Ladders  
OSHA 1926.650 Excavations

## 11. Hearing Loss

National Institute for Occupational Safety and Health (NIOSH) “Work-Related Hearing Loss.” Washington, DC: US Dept. of Health and Human Services.

<http://www.cdc.gov/niosh/hpworkrel.html>

<http://www.lhsfna.org/index.cfm?objectid=FE76D86F-D56F-E6FA-99A606116D8792FC>

“Construction Industry Noise Exposures Construction Workers” University of Washington, Department of Environmental and Occupational Health Services

Construction Noise Worker’s Compensation Board of BC, Engineering Section Report  
<http://www.elcosh.org/en/document/70/d000054/construction-noise%253A-exposure%252C-effects%252C-and-the-potential-for-remediation%253B-a-review-and-analysis.html>RCS Reference No: 0135-20

National Academy of Engineering Technology for a Quieter America report (2009)

NoiseCon(2009), AIHce(2010), NHCA (2011)

International Institute of Noise Control Engineering Buy-Quiet Symposium (Paris, 2011)

INCE Product Noise Technical Committee voluntary product noise labeling initiative

NIOSH (DART) construction sector programs

## 12. Fall Protection

*Guidelines: Roof Anchorages for Fall Arrest Systems.* Ontario Ministry of Labor  
ANSI/IWCA 1-14.1 Window Cleaning Safety Standard

[http://www.canaminternational.ws/www/v4/newslet.nsf/va\\_redir/joistv5n2?open](http://www.canaminternational.ws/www/v4/newslet.nsf/va_redir/joistv5n2?open)  
(H-frames)

American Society for Testing of Materials (ASTM) working group E06 WK 17797  
*“Working Group for the Specification of Human Impact Criteria, with Procedure for Testing and Rating Plastic-Glazed Unit Skylights and Related Products used on Commercial Walkable Roofs for Fall-Through Resistance*

NYC Title 27 Administrative Code Construction and Maintenance §[C26-503.4]  
27-334 Protective guards, 2004:  
[http://www.nyc.gov/html/dob/downloads/bldgs\\_code/bc27s5.pdf#page=5](http://www.nyc.gov/html/dob/downloads/bldgs_code/bc27s5.pdf#page=5)

Texas Department of Transportation Manual Notice 2006-1, Section 5, 2006:  
[http://onlinemanuals.txdot.gov/txdotmanuals/rlg/bridge\\_railing\\_for\\_pedestrians.htm#CHDEHHBF](http://onlinemanuals.txdot.gov/txdotmanuals/rlg/bridge_railing_for_pedestrians.htm#CHDEHHBF) at  
[http://onlinemanuals.txdot.gov/txdotmanuals/rlg/metal\\_and\\_concrete\\_railing.htm](http://onlinemanuals.txdot.gov/txdotmanuals/rlg/metal_and_concrete_railing.htm)

National Institute of Steel Detailing and Steel Erectors Association of America.  
*Detailing Guide for the Enhancement of Erection Safety.* 2001. [www.nisd.org](http://www.nisd.org) and [www.seaa.net](http://www.seaa.net).

ANSI ASC A14.3 American National Standard for Ladders-Fixed - Safety Requirements

ANSI/ASSE A1264.1 Safety Requirements for Workplace Walking/Working Surfaces and their Access; Workplace, Floor, Wall and Roof Openings; Stairs and Guardrails Systems

International Building Code (IBC), International Code Council, Inc.

National Safety Council Data Sheet: Fixed Ladders

National Institute for Occupational Safety and Health (NIOSH) conference  
*Prevention through Design—a new way of doing business: a report on the  
National Initiative* on August 22 – 24, 2011 at the Omni Shoreham in  
Washington, DC.

Fall Protection in Construction, OSHA Publication 3146, 1998 (Revised).

Fall Protection Hazard Awareness Guide, Construction Safety Council, 2000,  
[www.buidsafe.org](http://www.buidsafe.org).

Fall Protection Training in the Construction Industry, Associated General  
Contractors of America, OSHA 46C3-HT33, 2004, [www.agc.org](http://www.agc.org)

Fall Awareness in Construction Education and Training, The Construction  
Education Foundation of Associated Builders and contractors, Inc. 2003,  
[www.abc.org](http://www.abc.org).

Oregon OSHA Workshop Material, Introduction to Fall Protection.  
<http://www.cbs.state.or.us/external/osh/pdf/workshops/117w.pdf>

Tailgate Training for California Construction Workers, State Building and  
Construction Trades Council, Labors Occupational Health Program,  
University of California Berkeley, 2001.

### 13. Design for Construction Safety (DfCS)

<http://www.cdc.gov/niosh/topics/ptd/>

<http://www.designforconstructionsafety.org/index.shtml>

<http://www.safetyindesign.org.uk/design-guides>

## APPENDIX B NIOSH FACE REPORTS

([http://www2a.cdc.gov/NIOSH-FACE/state.asp?state=ALL&Incident\\_Year=ALL&Category2=0005&Submit=Submit](http://www2a.cdc.gov/NIOSH-FACE/state.asp?state=ALL&Incident_Year=ALL&Category2=0005&Submit=Submit))

Incident	State	Title
<u>2009-01</u>	NC	Hispanic worker dies after fall from step ladder while cleaning windows - North Carolina.
<u>2007-10</u>	CT	Seventeen year old female laborer falls from residential roof and dies nine days later - Connecticut.
<u>2007-06</u>	SC	Hispanic construction worker dies while operating ride-on roller/compactor - South Carolina.
<u>2007-01</u>	NC	Hispanic laborer dies after falling through a second story floor opening in a single family home under construction - North Carolina.
<u>2006-06</u>	TN	Laborer dies when a water truck drifts downhill and pins him against a retaining wall - Tennessee.
<u>2006-03</u>	VA	Laborer dies after being run over by a backing dump truck during a nighttime paving project - Virginia.
<u>2006-01</u>	NC	Hispanic carpenter's helper dies after crane boom fell on him during disassembly - North Carolina.
<u>2005-11</u>	NC	Construction worker dies after being run over by a bulldozer at a commercial construction site - North Carolina.

<u>2005-06</u>	NC	Hispanic worker dies after falling from a pile of construction debris in the bed of a trash-style body truck to a paved driveway below - North Carolina.
<u>2005-04</u>	NC	Hispanic laborer dies after footing collapse - North Carolina.
<u>2004-10</u>	NC	Hispanic flagger dies after being run over by a dump truck - North Carolina.
<u>2004-07</u>	NC	Chain saw operator dies after being struck by excavator bucket during site clearing - North Carolina.
<u>2004-06</u>	SC	Sixteen-year-old Hispanic youth dies after falling from a job-made elevated work platform during construction - South Carolina.
<u>2004-05</u>	OH	Four construction workers die after cantilever launching gantry collapses at bridge construction site - Ohio.
<u>2003-13</u>	SC	18-year-old dies after being entangled in a portable mortar mixer - South Carolina.
<u>2003-12</u>	SC	Hispanic pipe layer dies after being struck by excavator (track hoe) bucket on construction site - South Carolina.
<u>2003-07</u>	SC	Two Hispanic construction laborers (ages fifteen and sixteen) die after trench collapse - South Carolina.
<u>2003-05</u>	NC	Hispanic construction laborer dies and two coworkers are injured after falling 10 feet from an unsecured box on the forks of a forklift - North Carolina.

<u>2003-01</u>	VA	Part-time laborer pinned between scissor lift work platform railing and doorway header - Virginia.
<u>2002-11</u>	NC	Hispanic construction laborer dies after portable silo collapse - North Carolina.
<u>2002-08</u>	TN	Hispanic dump-truck driver dies after being caught between frame and dump body of off-road truck while performing routine lubrication - Tennessee.
<u>2002-03</u>	NC	Construction laborer dies after being run over and crushed by a grader at a road construction site - North Carolina.
<u>2001-10</u>	IN	Seventeen-year-old part-time road construction laborer dies after being run over by a water truck - Indiana.
<u>2001-07</u>	AL	Fourteen-year-old laborer dies after falling through a skylight - Alabama.
<u>2001-04</u>	FL	Fifteen-year-old laborer dies after falling through a skylight - Florida.
<u>2001-02</u>	NS	State department of transportation highway maintenance worker dies after being struck by a car while installing reflectors on a guardrail.
<u>2001-01</u>	NC	State Department of Transportation worker (Laborer) dies after being struck by motor vehicle - North Carolina.
<u>2000-20</u>	NC	Twenty-nine-year-old asphalt compactor operator dies from crushing injuries received during machine rollover - North Carolina.

<u>2000-16</u>	AL	A 16-year-old died after falling 27 feet at a residential construction site - Alabama.
<u>2000-12</u>	OH	Carpenter dies after being struck by uncontrolled concrete bucket when crane tips over - Ohio.
<u>2000-10</u>	NC	Construction laborer dies after being pinned between the bucket of a mini-excavator and an air compressor - North Carolina.
<u>2000-07</u>	NC	Three tower painters die after falling 1,200 feet when riding the hoist line - North Carolina.
<u>2000-05</u>	PA	Truck driver dies after the off-highway truck he was operating rolled over an embankment and came to rest on its top - Pennsylvania.
<u>2000-03</u>	MI	Youth laborer dies in trench collapse - Michigan.
<u>2000-02</u>	WI	Flagger struck from behind and killed by a truck intruding into a highway construction work zone - Wisconsin.



## **APPENDIX C: WORK GROUP EXERCISES**

### Risk Assessment Work Group Exercise #1

You have determined through a hazard analysis that roofers are exposed to a fall hazard of twelve feet. The project is expected to last 2 days.

What is the injury severity?

What is the probability of an occurrence over the 2 days?

What is the risk?

Is the risk acceptable?

### Risk Assessment Work Group Exercise #2

HVAC workers will have to handle sheet metal. You have determined that they will be exposed to a laceration hazard from handling the sheet metal that you specified.

What is the injury severity?

What is the probability of an occurrence?

What is the risk?

Is the risk acceptable?

Is the risk acceptable if the workers are required to wear gloves?

### Risk Assessment Work Group Exercise #3

You have specified heavy weight concrete block for a project. Workers must carry the block a distance to where they will be used.

What is the injury severity?

What is the probability of a back injury?

What is the risk?

Is the risk acceptable?

### “What If” Analysis Group Exercise #1

You are preparing renovation plans for an old, existing building. Nothing is known about the building and there are no “as-built” plans.

Who do you want to be on your “What If” analysis team?

What are the potential hazards that workers may encounter during this project?

“What If” Analysis Group Exercise #2

You are designing equipment that will be used to cool computer equipment. You set out to identify the hazards that could arise.

Who do you want on your “What If” analysis team?

How could the equipment fail? What are the consequences of a failure?

“What If” Analysis Group Exercise #3

You are designing a sprinkler system for an addition to a building. The design includes a new supply piping from the existing underground supply to the building. There are several shutoff valves in the current system. You not sure, but there could be a jockey pump somewhere in the current system. You want to identify the possible hazards to workers that will be following your plans.

Who do you want on your “What If” analysis team?

What are the possible hazards that could arise from connecting the new underground piping from the existing supply pipe to where it will connect to the new sprinkler system?

Work Group Case Study #1

A construction worker penetrated an embedded electrical conduit containing an energized 120-volt line while hand drilling into a concrete beam to install pipe hanger inserts. The conduit was 1 inch from the surface.

What could have been done from a design standpoint to prevent this accident?

### Work Group Case Study #2

Plant utility worker was fatally injured while performing clean-up duties at a raw coal reclaim area. Victim either fell through a 56" x 80" opening in a platform or entered through a coal feeder opening



What could have been done from a design standpoint to prevent this accident?

### Work Group Case Study #3

A 20-year-old male drywall mechanic (the victim) died after falling about 10 feet from an open-sided second floor landing and striking his head on a concrete floor. The victim was working alone sanding a ceiling constructed of sheetrock. The victim was operating a sander and apparently unaware of his position in relation to the open-sided floor. The victim fell about 10-feet, hitting the concrete floor face first.

What could have been done from a design standpoint to prevent this accident?

### Work Group Case #4

A 60-year-old physical plant director for a state university fell 120 feet to his death. The victim was using the roof of the campus library as an observation point to inspect campus facilities for wind damage. High wind conditions with gusts to 30 miles per hour existed at the time of the incident. Campus employees routinely used the library roof as an observation point because it was the highest structure on campus and allowed an unobstructed view of the entire campus. The victim was apparently walking around the perimeter of the roof when he tripped on a utility vent pipe located near the low parapet of the roof.

What could have been done from a design standpoint to prevent this accident?

## APPENDIX D: SAMPLE JOB HAZARD ANALYSIS FORM

Job Title:	Job Location:	Analyst	Date
Task #	Task Description:		
Hazard Type:	Hazard Description:		
Consequence:	Hazard Controls:		
Rational or Comment:			

## APPENDIX E RISK ASSESSMENT MATRIX

Probability	Severity			
	<u>Severe</u>	<u>Serious</u>	<u>Moderate</u>	<u>Slight</u>
<u>High</u>	High	High	Medium	Low
<u>Medium</u>	High	Medium	Low	Low
<u>Moderate</u>	Medium	Low	Low	Negligible
<u>Low</u>	Low	Low	Negligible	Negligible

## APPENDIX F DfCS TEMPLATE

Hazard	Significant		Practical to Eliminate		Practical to Isolate		All Practical Steps to Minimize		Controls Required
	Yes	No	Yes	No	Yes	No	Yes	No	

## APPENDIX G “WHAT IF” ANALYSIS TEMPLATE

What if?	Answer	Likelihood	Consequences	Recommendations



## **APPENDIX H DESIGN SOLUTION SHEETS**

This Appendix contains thirteen (13) DFCS solutions. The design solutions are categorized by design category (site, envelope, interior, roof) and the nature of the hazard.

**CONSTRUCTION WORKPLACE DESIGN SOLUTION #1**  
**DESIGN CATEGORY: SITE**  
**HAZARD: FALLS FROM NON-MOVING VEHICLES**  
**DESIGN SOLUTION: PROVIDE SAFE ACCESS FOR**  
**LOADING AND UNLOADING TRUCKS**

This design solution reduces the risk of serious falls from non-moving vehicles. When a truck is on the road, it is controlled by DOT regulations. However, when vehicles are stopped for loading and unloading, or when a trailer is used for storage, the truck bed or trailer is in effect a working/walking surface. While OSHA 1926 excludes trucks and trailers from the agencies definition of "working/walking surface" thereby exempting these areas from fall protection requirements, workers are injured or killed in falls from non-moving vehicles. The same safety precautions that apply to open sided floors six feet above a lower level would also apply in preventing fall injuries during loading and unloading of trucks. Falls from non-moving vehicles can result in death or serious injury – about 21 fatalities per year [BLS, 2009] are reported.

**SOLUTION**

The bed of the truck or trailer should have a safe access, such as a stairway with railings, and guardrails around all open sides of the truck bed or platforms. Designers working with contractors can provide safe designs for access stairways, railings, and guardrails for loading and unloading trucks on a construction site, or when a trailer is used for storage. Permanent or movable stairway/platform/guardrail systems can be designed for loading and unloading areas of permanent buildings and structures.



The above two photos show how movable platforms with guardrails can be used around the open sides of a truck bed when loading and unloading trucks

The photo at the right shows a stairway and platform for accessing a trailer.



## **BACKGROUND INFORMATION**

### Applicable US Safety Regulations

#### OSHA Construction standards

1926.501(b)(1) Unprotected sides and edge. Each employee on a walking/working surface (horizontal and vertical surface) with an unprotected side or edge which is 6 feet or more above a lower level shall be protected from falling by the use of guardrails systems, safety net systems, or personal fall arrest systems.

1926.502(b)(1) Top edge height of top rails, or equivalent guardrail system members shall be 42 inches plus or minus 3 inches above the walking/working level.

1926.502(b)(2) Midrails, screens, mesh, intermediate vertical members, or equivalent intermediate structural members shall be installed between the top edge of the guardrail system and the walking/working surface when there is no wall or parapet wall at least 21 inches high.

1926.502(b)(3) Guardrail systems shall be capable of withstanding, without failure, a force of 200 pounds applied within 2 inches of the top edge, in any outward or downward direction, at any point along the top edge.

1926.1052(a)(2) Stairs shall be installed between 30 deg. and 50 deg. from horizontal.

1926.1052(c)(1) Stairways having four or more risers or rising more than 30 inches (76 cm), whichever is less, shall be equipped with:

1926.1052(c)(1)(i) At least one handrail; and

1926.1052(c)(1)(ii) One stair rail system along each unprotected side or edge

**CONSTRUCTION SAFETY DESIGN SOLUTION #2**  
**DESIGN CATEGORY: INTERIOR/EXTERIOR**  
**HAZARD: FALLS FROM FLOOR OPENINGS**  
**DESIGN SOLUTION: INSTALL GUARDRAILS**

This design solution reduces the risk of serious falls from floor openings during the construction and maintenance activities during the life of a building. Falls from floor openings can result in death or serious injury – about 6 fatalities per year [BLS, 2009] are reported.

A 20-year-old male drywall mechanic (the victim) died after falling about 10 feet from an open-sided second floor landing and striking his head on a concrete floor. The victim was working alone sanding a ceiling constructed of sheetrock. The victim was operating a sander and apparently unaware of his position in relation to the open-sided floor. The victim fell about 10-feet, hitting the concrete floor face first. A temporary or permanent guardrail system along the open-sides of the floor would have prevented this tragedy.

**SOLUTION**

Designers should specify guardrail systems around floor openings except at the entrance to stairways. Designers should work with contractors to install permanent guardrails as soon as possible in the construction process so that workers will not be exposed to fall hazards.

Cast-in sockets can be specified around floor openings. The sockets make it easy for contractors to install temporary guardrails during the construction phase. The sockets can then be used for permanent railings or filled in.



This photo shows cast sockets along the open side of a stairway. The sockets make it convenient to install temporary or permanent guardrails.



This photo shows guardrails installed along an opening. Installing guardrails early on in the construction process can eliminate the risk of a fall through an opening.

## **BACKGROUND INFORMATION**

### Applicable US Safety Regulations

#### OSHA Construction standards

1926.501(b)(1) Unprotected sides and edge. Each employee on a walking/working surface (horizontal and vertical surface) with an unprotected side or edge which is 6 feet or more above a lower level shall be protected from falling by the use of guardrails systems, safety net systems, or personal fall arrest systems.

1926.502(b)(1) Top edge height of top rails, or equivalent guardrail system members shall be 42 inches plus or minus 3 inches above the walking/working level.

1926.502(b)(2) Midrails, screens, mesh, intermediate vertical members, or equivalent intermediate structural members shall be installed between the top edge of the guardrail system and the walking/working surface when there is no wall or parapet wall at least 21 inches high.

1926.502(b)(3) Guardrail systems shall be capable of withstanding, without failure, a force of 200 pounds applied within 2 inches of the top edge, in any outward or downward direction, at any point along the top edge.

#### OSHA General Industry standards

1910.23 (a) Protection for floor openings. (1) every stairway floor opening shall be guarded by a standard railing constructed in accordance with paragraph (e) of this section. The railing shall be provided on all exposed sides (except at the entrance to stairway). For infrequently used stairways where traffic across the openings prevent the use of fixed standard railing (as when located in aisle spaces, etc.) the guard shall consist of a hinged floor opening cover of standard strength and construction and removable standard railings on all exposed sides (except at the entrance to stairway).

## **OTHER CONSIDERATIONS**

- Consider specifying perimeter beams around floor openings. The beams would provide a convenient tie off point for workers during construction.
- Consider adding drawing notes to plans specifying that floor openings and holes should be protected with either a secured cover or guardrail.



# CONSTRUCTION SAFETY DESIGN SOLUTION #3

## DESIGN CATEGORY: ROOF

### HAZARD: FALLS FROM ROOF EDGE

### DESIGN SOLUTION: MINIMIZE NEED TO GO ONTO ROOF OR NEAR ROOF EDGE

This design solution reduces the risk of serious falls from a roof edge during the construction and maintenance activities during the life of a building. Falls from roof edge can result in death or serious injury – about 47 fatalities per year [BLS , 2008] are reported.

#### SOLUTION

Designers should try to minimize the need to go onto a roof and/or near the edge of a roof. Mechanical equipment should be placed at ground level whenever possible. This eliminates the need to go onto the roof during installation and routine maintenance. Roof vents, mechanical equipment, and communication equipment should be located at least 15 feet back from the roof edge to provide an additional safety factor. The 15 foot distance reduces the risk of a fall when servicing equipment. Specify permanent guardrails when equipment must be closer to the roof edge. Specify multiple roof anchors to provide convenient tie off points when workers must be near the roof edge.



This photo shows equipment located on a roof. Positioning equipment at least 15 feet back from the roof edge will reduce the risk of falling when installing and servicing the equipment



This photo shows permanent roof anchors. Specifying multiple roof anchors will provide convenient tie off points when working near the edge of the roof.

#### BACKGROUND INFORMATION

##### Applicable US Safety Regulations

OSHA Construction standards

1926.501(b)(1) Unprotected sides and edge. Each employee on a walking/working surface (horizontal and vertical surface) with an unprotected side or edge which is 6 feet or more above a lower level shall be protected from falling by the use of guardrails systems, safety net systems, or personal fall arrest systems.

1926.502(b)(1) Top edge height of top rails, or equivalent guardrail system members shall be 42 inches plus or minus 3 inches above the walking/working level.

1926.502(b)(2) Midrails, screens, mesh, intermediate vertical members, or equivalent intermediate structural members shall be installed between the top edge of the guardrail system and the walking/working surface when there is no wall or parapet wall at least 21 inches high.

1926.502(b)(3) Guardrail systems shall be capable of withstanding, without failure, a force of 200 pounds applied within 2 inches of the top edge, in any outward or downward direction, at any point along the top edge.

1926.502(d)(15) Anchorages used for attachment of personal fall arrest equipment shall be independent of any anchorage being used to support or suspend platforms and capable of supporting at least 5,000 pounds per employee attached, or shall be designed, installed, and used as follows:

- (i) as part of a complete personal fall arrest system which maintains a safety factor of at least two; and
- (ii) under the supervision of a qualified person

1926.502(f) Warning line systems. Warning line systems and their use shall comply with the following provisions:

(1) The warning line shall be erected around all side of the roof work area.

- (i) When mechanical equipment is not being used, the warning line shall be erected not less than 6 feet from the roof edge.
- (ii) When mechanical equipment is being used, the warning line shall be erected not less than 6 feet from the roof edge which is parallel to the direction of mechanical equipment operation, and not less than 10 feet from the roof edge which is perpendicular to the direction of the mechanical equipment operation.

### **OTHER CONSIDERATIONS**

- Try to specify roof materials that do not require frequent inspections
- Position gutters so that they can be cleaned using cherry pickers or other safe access areas
- Specify durable seals at roof penetrations to minimize the need for reactive maintenance
- Consider designing roof parapets, at least 39 inches high, to serve as permanent guardrails along the roof edge. Additional snow load on the roof structure should be considered when considering parapets.

### **LIFE CYCLE SOLUTION BENEFITS**

- Eliminating the need to go onto a roof and/or near a roof edge can reduce maintenance costs during the life cycle of the building since fall protection or warnings lines would not be needed.

**CONSTRUCTION SAFETY DESIGN SOLUTION #4**  
**DESIGN CATEGORY: ENVELOPE/INTERIOR**  
**HAZARDS: FALLS FROM STRUCTURAL STEEL**  
**DESIGN SOLUTION: BEAM COLUMNS**

This design solution reduces the risk of serious falls from structural steel during the construction of a building. Falls from structural steel can result in death or serious injury – about 36 fatalities per year [BLS, 2008] are reported.

**SOLUTION**

Designers can specify features that make it safer and easier to erect structural steel. For example, hanging connections should be avoided. Safety seats at column connections would eliminate this by providing support for girders during the connection process.

Perimeter safety cables should be installed as soon as the metal decking has been installed. Specifying holes in columns at 42 inches plus or minus 3 inches and 21 inches above each floor slab make it easy to install cable or wire perimeter cables.



Specify holes in columns at 21 and 42 inches above the floor slab. This design feature makes it easy to install cable or wire perimeter cables.



Design safety seats (see arrow) at column connections. The safety seats eliminate hanging connections making the connection process easier.



## **BACKGROUND INFORMATION**

### Applicable US Safety Regulations

#### OSHA Construction standards

1926.760(a)(1) Except as provided by paragraph (a)(3) of this section, each employee engaged in a steel erection activity who is on a walking/working surface with an unprotected side or edge more than 15 feet above a lower level shall be protected from fall hazards by guardrail systems, safety net systems, personal fall arrest systems, positioning device systems or fall restraint systems.

1926.760(a)(2) On multi-story structures, perimeter safety cables shall be installed at the final interior and exterior perimeters of the floors as soon as the metal decking has been installed.

1926.760 (3) Perimeter safety cables shall meet the criteria for guardrail systems in 1926.502.

### Other Applicable Design Guidelines:

National Institute of Steel Detailing and Steel Erectors Association of America. *Detailing Guide for the Enhancement of Erection Safety*. 2001. [www.nisd.org](http://www.nisd.org) and [www.seaa.net](http://www.seaa.net).

## **OTHER CONSIDERATIONS**

- Shop welded connections should be specified whenever possible instead of bolts or field welds to avoid dangerous positions during erection.
- For bolted beam connections, provide an extra hole into which a spud wrench or other object can be inserted to provide continual support for the beam during installation of the bolts
- Be familiar with the physical constraints for making connections. Try to avoid tight spaces and provide ample room for tools used in making connections.

**CONSTRUCTION SAFETY DESIGN SOLUTION #5**  
**DESIGN CATEGORY: ROOF**  
**HAZARD: FALL FROM ROOF**  
**DESIGN SOLUTION: ROOF ANCHORS**

This design solution reduces the risk of serious falls from roofs during the construction and maintenance activities over the life of a building. Falls from roofs result in about 121 fatalities per year [BLS, 2008] Permanent anchors provide a convenient, safe place to tie off when personal fall arrest systems are needed. They also reduce the chance a worker will not use a personal fall arrest system because there is no approved place to anchor, or the worker connects to something that may not be structurally sound or certified by a registered Professional Engineer (PE).

**SOLUTION**

Planning the construction and future maintenance of a building can identify areas where permanent anchors should be installed. There are many vendors that design and install roof anchors. Anchors should be capable of sustaining a load of at least 5000 pounds without fracture or failure in the most adverse loading direction. The potential for material degradation due to environmental factors such as temperature, salt, and humidity should be considered.

There are many different methods of securing an anchor to a structure in order to meet the load requirements. Through-bolting with a backup plate is the preferred installation method. An H-frame can be designed and installed between bar joints when installing roof anchors to bar joists. Once installed it is generally the responsibility of the building owner to inspect and maintain roof anchors to ensure their continued reliable performance.



Figure 1 Planning the construction and future maintenance of a building can identify areas where permanent anchors should be installed.



Figure 2 Residential roofing has a high incidence of falls. Residential roof anchors properly installed provides a place for workers to anchor to during future maintenance.

## **BACKGROUND INFORMATION**

### Applicable US Safety Regulations

#### OSHA Construction standards

1926.502(d)(15) Anchorages used for the attachment of personal fall arrest equipment shall be independent of any anchorage being used to support or suspend platforms and capable of supporting at least 5,000 pounds per employee attached, or shall be designed, installed, and used as follows:

- (i) as part of a complete personal fall arrest system which maintains a safety factor of at least two;  
and
- (ii) under the supervision of a qualified person

### Other applicable standards and guidelines

*Guidelines: Roof Anchorages for Fall Arrest Systems.* Ontario Ministry of Labor

ANSI/IWCA 1-14.1 Window Cleaning Safety Standard

[http://www.canaminternational.ws/www/v4/newslet.nsf/va\\_redir/joistv5n2?open](http://www.canaminternational.ws/www/v4/newslet.nsf/va_redir/joistv5n2?open) (H-frames)

## **OTHER CONSIDERATIONS**

- Roof anchors should be inspected by a qualified person on an annual basis. The report of this inspection should be included in the building's logbook and distributed to contractors prior to starting work.
- Anchors should be re-certified when there is re-roofing or renovating, or at periods not to exceed 10 years. The report of this inspection shall be included in the building's logbook.
- If the structural integrity of a roof anchor becomes suspect at any time, a test procedure shall be performed under the approval of a registered Professional Engineer (PE).
- Post installation testing should include applying a minimum static load equal to half the maximum capacity of the anchor in the most adverse loading direction that the load might be applied.. For example, an anchor designed for a 5000 pound ultimate load should be tested at 2500 pounds.

## **LIFE CYCLE SOLUTION BENEFITS**

- A well thought out plan for roof anchors can be beneficial during maintenance because workers will have a structurally sound, certified, convenient place to tie off . The proper purpose of the anchor must be provided for contractors and workers. Any other use must be approved by the owner's representative.

**CONSTRUCTION SAFETY DESIGN SOLUTION #6**  
**DESIGN CATEGORY: ROOF/INTERIOR**  
**HAZARD: FALL FROM LADDERS**  
**DESIGN SOLUTION: SPECIFY FIXED LADDERS OR**  
**STAIRWAYS**

Fixed ladders are used to access an upper level landing or a roof. Overall, falls from ladders is the number one cause of fatalities 129 fatalities per year [BLS, 2010]. Portable ladders can be hazardous when placed improperly, not secured, or used inappropriately. This fixed ladder design solution reduces the risk of serious falls from unstable ladders during maintenance activities or when accessing a roof, platform, mezzanine, or upper level of a building.

**SOLUTION**

Designers can contribute to reducing falls from ladders by specifying fixed ladders or stairways whenever possible. This would eliminate the need for a portable ladder when accessing a roof, work platform, mezzanine, or upper level. The chance that a worker may use a defective ladder, an improper ladder, or not use the ladder properly is eliminated. Many building codes require a stairway or alternating tread device for roof access in commercial buildings.



Fixed ladders should be specified to access a work platform, mezzanine, upper level, or roof. Ladder climbing devices can be rail or cable systems outdoors and SRL's indoors. A cage is not a positive fall stopping device although it does some positive reassurance. A ladder climbing device should be designed to provide positive stopping of a fall from a fixed ladder in a short distance.



Industrial stairs are preferred to access a work platform, mezzanine, upper level or roof. Alternating tread devices can be specified if space is limited.

Design details on industrial stairs can be found in OSHA 1910.24 and ANSI/ASSE A1264.1. Details for fixed ladders can be found in OSHA 1910.27, 1926.1050-1053 and ANSI ASC A14.3. An important feature of all ladder designs is provision of 7” space behind rungs for proper foot placement. Hands should use horizontal rungs or grab bars for reliability in case of a fall.

## **BACKGROUND INFORMATION**

### **Applicable US Safety Regulations**

OSHA General Industry standards for industrial stairs see 1910.24

[http://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=9696](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9696)

OSHA General Industry standards for fixed ladders see 1910.27

[http://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=9719](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9719)

#### Other Applicable Standards and Publications:

ANSI ASC A14.3 American National Standard for Ladders-Fixed - Safety Requirements

ANSI/ASSE A1264.1 Safety Requirements for Workplace Walking/Working Surfaces and their Access; Workplace, Floor, Wall and Roof Openings; Stairs and Guardrails Systems

International Building Code (IBC), International Code Council, Inc.

National Safety Council Data Sheet: Fixed Ladders

Handhold coupling: Ph.D. thesis of Justin Young, University of Michigan December 2010

## **OTHER CONSIDERATIONS**

Design professionals and contractors should work to coordinate the installation of fixed ladders for structures, and preferably stairways as early as possible in the construction process. This would provide safer means of access for estimators in electric, plumbing, tile work, to each floor level rather than using portable ladders, job-made ladders, or other means.



# CONSTRUCTION SAFETY DESIGN SOLUTION #7

## DESIGN CATEGORY: ROOF

### HAZARD: FALLS FROM ROOF OPENING

### DESIGN SOLUTION: SPECIFY ROOF HATCH SAFETY SYSTEM

This design solution protects against the serious risk of falls through roof hatches. The roof hatch constitutes a floor or roof opening which should be protected. A climber can also fall if there are no graspable handholds to use when transitioning from the ladder or stairway to the roof. In 2008, 19 workers died as a result of falling through a roof surface (BLS).

#### SOLUTION

The use of 42 inch high guardrails around the open sides of the roof hatch reduces the risk of falling through the hatchway opening. Additionally, hatch access grab bars can be built or added, and access made with an integral swing gate which opens away from the ladder opening. Grab bars should extend 42 inches above the roof level to allow the climber to confidently step onto the roof and to the side. Consideration should be given when mounting a hatch on an outside wall without a 42 inch high parapet. Consider relocating hatches on an inside wall for structural support or a guardrail added for protection at the roof edge.

For new roof hatches, the answer is to specify the roof hatch safety system as soon as possible. The new hatches can provide for a standing access either out onto the roof or into the opening which fits the human condition and walking posture in work situations such as access to and from roofs. Existing hatches can be retrofitted in the same way.



This photo shows a guardrail, swing gate, and grab bars



This photo shows horizontal grab bars

#### BACKGROUND INFORMATION

##### Applicable US Safety Regulations

OSHA General Industry standards:

1910.23(a). Ladderway roof and floor opening to be guarded.

1910.23(a)(3)(i). Hinged floor opening cover.

Design for Construction Safety

1910.23(a)(2)(ii). Removable railing.

1910.23(a)(8). Cover of standard strength (200 lbs).

OSHA Construction regulations:

1926.502(a)(13). Guardrails, swing gates, offset railings to avoid walking into floor openings.

1926.502(i). Covers used for laying over holes in floors, roofs, etc. must meet 200 lbs strength.

1926.1053(a)(24). Side rails shall extend 42” above the landing served by the ladder.

1926.1053(a)(27). Horizontal grab bars spaced by continuation of rung spacings, or vertical grab bars shall have the same lateral spacing as the side rails\*.

## **OTHER CONSIDERATIONS**

- Roof hatches should be installed into roof openings as soon as possible and the roof hatch lid kept closed unless an access is made.
- Roof hatch locks should be compatible with balance and stability such as using an offset platform or rest platform. ANSI A14.3-2008 Section 9.2.1.
- Roof hatch ladder rung centers should be coated with skid resistant material having a wet friction coefficient of 0.5 minimum.
- Roof hatch ladders should be checked for structural strength sufficient for attachment of retractable lifelines for safer access up the ladder and providing a back-up to stability while opening the hatch lock.
- Roof hatch location on interior building walls for support. IBC 2009 Section: 1009.13.2.
- ANSI A14.3-2008 Section 5.3.4.3 requires additional handholds for safety while accessing hatch openings including grab bars that can be grasped.
- Research conducted by the University of Michigan Center for Ergonomics indicates that free falling arrest is most successful and reliable when holding horizontal handholds and that free falling with vertical handholds is not successful in arresting falls. See article referenced below.

## **LIFE CYCLE SOLUTION BENEFITS**

A safe roof hatch system will make it safer to access the roof for maintenance during the life cycle of the building

## **ADDITIONAL INFORMATION SOURCES**

University of Michigan Center for Ergonomics, Ann Arbor, MI: Researchers have performed several studies investigating the ability of workers to climb and hold onto various designs of handholds, rungs, and rails. See October 2009 article in the journal *Human Factors*: “Hand/handhold coupling: effect of handle shape, orientation, and friction on breakaway strength,” by Justin Young, Charles Woolley, Tom Armstrong and James Ashton-Miller. Additional articles are forthcoming.

**CONSTRUCTION SAFETY DESIGN SOLUTION #8**  
**DESIGN CATEGORY: ROOF**  
**HAZARD: FALLS THROUGH SKYLIGHT**  
**DESIGN SOLUTION: SPECIFY NON-FRAGILE**

This design solution protects against the risk of serious falls through skylights during construction, maintenance, and demolition activities over the life of a building. Falls through skylights can result in death or serious injury – from 13 to 23 fatalities a year occurred between 2006 and 2010 (BLS, 2010). Skylight use, also called daylighting, is increasingly associated with green design and energy conservation measures.

A 51- year-old roofer died from injuries sustained after falling 30 feet through a skylight. The roofer was part of a crew removing tar and gravel built-up roofing. He positioned a wheelbarrow full of gravel alongside a skylight while he talked to one of the company managers. As he turned to resume work, he fell through the skylight onto the concrete floor.

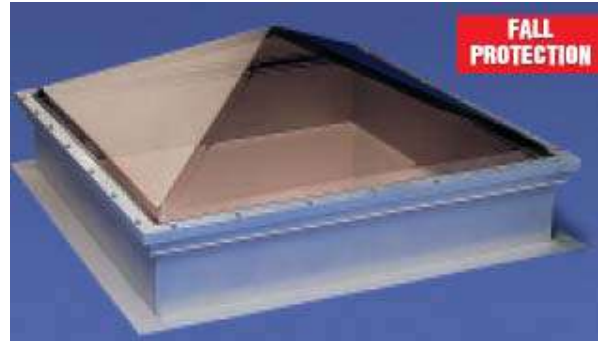
Guardrails or skylight screens would have prevented this terrible tragedy.

**SOLUTION:**

For new skylight installations, use best available criteria to specify products that can withstand the live load associated with a construction or maintenance worker inadvertently stepping on or falling on a skylight. An alternative approach is to specify that guards or screens designed to handle these loads be attached over each skylight, or that a guardrail be provided around the perimeter of the skylight installation. Existing fragile skylight installations can be upgraded by installing screens or guards. Screens are recommended for plastic dome skylights and light transmitting panels as they can degrade over time.



This photo shows a skylight guard



This photo shows a non-fragile skylight model

**BACKGROUND INFORMATION**

**Applicable US Safety and Health regulations**

OSHA General Industry standards (apply to completed buildings):

1910.23(a)(4) – Every skylight floor opening and hole shall be guarded by a standard skylight screen or a fixed standard railing on all exposed sides.



1910.23(e)(8) - Skylight screens shall be of such construction and mounting that they are capable of withstanding a load of **at least 200 pounds** applied perpendicularly at any one area on the screen. They shall also be of such construction and mounting that under ordinary loads or impacts, they will not deflect downward sufficiently to break the glass below them. The construction shall be of grillwork with openings not more than 4 inches long or of slatwork with openings not more than 2 inches wide with length unrestricted. (emphasis added)

OSHA Construction standards (apply to buildings under construction):

1926.501(b)(4)(i) - Each employee on walking/working surfaces shall be protected from falling through holes (including skylights) more than 6 feet (1.8 m) above lower levels, by personal fall arrest systems, covers, or guardrail systems erected around such holes.

1926.502(i)(2) ...[C]overs shall be capable of supporting, without failure, **at least twice the weight of employees, equipment, and materials** that may be imposed on the cover at any one time. (emphasis added)

*(NOTE: If the skylight itself meets the cover criteria in 1926.502(i)(2), OSHA will treat the skylight itself as a cover. OSHA does not explicitly specify the type of load (static vs. dynamic) to be imposed for the twice-the-weight requirement.)*

#### Other information

American Society for Testing of Materials (ASTM) working group E06 WK 17797 “*Working Group for the Specification of Human Impact Criteria, with Procedure for Testing and Rating Plastic-Glazed Unit Skylights and Related Products used on Commercial Walkable Roofs for Fall-Through Resistance*” has been formed to develop procedures and criteria for fall through resistance. ASTM Fall Protection Test Standard Development Work Group (E06.51.25 WK17797) has been charged with developing a skylight fall protection test standard.

#### **EXAMPLES OF PRODUCT OR USE:**

The American Architectural Manufacturers Association (<http://www.aamanet.org>) includes skylight information and links to other groups and manufacturers. Several skylight manufacturers offer models engineered to resist impacts exceeding the OSHA criteria (e.g., to 1200 foot pounds).

#### **OTHER CONSIDERATIONS**

- Non-fragile skylights may have secondary design benefits related to snow loads, wind loads, and hail resistance.
- Additional construction safety measures are needed during skylight installation to guard against falls through the hole created for the skylight.
- Signs to notify and warn building occupants and maintenance personnel about skylight locations and other roof-related hazards should be posted at roof entry points.
- Heat and smoke vents are normally smaller than skylights and are designed to open automatically in fire situations to vent smoke and heat. Skylight-type precautions may be warranted for larger diameter smoke vents.

#### **LIFE CYCLE SOLUTION BENEFITS**

Designing a skylight that can withstand the live load of a person falling on it or that has a guard or screen will eliminate the need for safety precautions when maintenance is done on the roof during the life cycle of the building. Safe skylights can also be a positive feature when considering garden roof tops.

## ADDITIONAL INFORMATION SOURCES

- NIOSH, 2004. Preventing Falls of Workers through Skylights and Roof and Floor Openings:  
<http://www.cdc.gov/niosh/docs/2004-156/>
- BLS, 2008 (As cited in *Should an Impact Resistance Standard Cover All Skylights?* US Glass Network News:  
<http://www.usgnn.com/newsSkylight20080430.htm>)
- NIOSH, 2003. Roofer's Family Member Helping at Work Site Dies After Falling Through Skylight:  
<http://www.cdc.gov/niosh/face/stateface/or/03or001.html>
- NIOSH, 2006. Truck Driver Killed After Falling Through Unprotected Skylight:  
<http://www.cdc.gov/niosh/face/stateface/mi/06mi006.html>
- FM Global, 2006. Approval Standard for Skylights: <http://www.fmglobal.com/assets/pdf/fmapprovals/4431.pdf>
- AAMA Skylight Council Position Paper on Fall Protection, 2008:  
[http://www.aamanet.org/upload/Skylight\\_Council\\_Position\\_Paper\\_rev\\_Dec\\_08.pdf](http://www.aamanet.org/upload/Skylight_Council_Position_Paper_rev_Dec_08.pdf)

**CONSTRUCTION SAFETY DESIGN SOLUTION #9**  
**DESIGN CATEGORY: ROOF**  
**HAZARD: FALLS FROM ROOF EDGE**  
**DESIGN SOLUTION: SPECIFY SUFFICIENT WALL HEIGHT TO  
ALLOW PARAPETS TO FUNCTION AS FALL PREVENTION**  
**HAZARD: FALLS**

This design solution protects against the risk of serious falls from roofs or platforms during construction, maintenance, and demolition activities over the life of a building. Falls from roofs can result in serious death or injury - there were 161 fatal falls from roofs reported in 2007 [BLS, 2009]. A parapet is a low wall or railing used to protect the edge of a platform or roof. Parapets are not used on every building, but where they are used they can be designed to provide fall protection. Parapet/guardrail combinations are also commonly used on bridges.

**SOLUTION:**

Specify parapet wall heights to be at least 39 inches high and strong enough to support 200 pounds. This allows the parapet wall to function as an effective barrier against falls. The International Building Code requires that parapet walls be at least 30 inches high (IBC 704.11.1) for fire spread, but this height is insufficient to meet regulatory requirements and insufficient to function as an effective perimeter guard against falls.

A parapet that can function as a perimeter guard also eliminates the need to provide temporary fall protection for construction and maintenance activities on the roof thus reducing total costs over the building life cycle.



This photo shows a parapet wall around the roof edge



This photo shows a parapet wall installed on a bridge

## **BACKGROUND INFORMATION**

### Applicable US Safety and Health Regulations

#### OSHA Construction standards

1926.501(b)(1) “Unprotected sides and edges.” Each employee on a walking/working surface (horizontal and vertical surface) with an unprotected side or edge which is 6 feet (1.8 m) or more above a lower level shall be protected from falling by the use of guardrail systems, safety net systems, or personal fall arrest systems. Unprotected sides and edges is defined as meaning any side or edge (except at entrances to points of access) of a walking/working surface, e.g., floor, roof, ramp, or runway where there is no wall or guardrail system at least 39 inches (1.0 m) high.

#### Other information

Various local building codes may address parapet design and height. For example, since 1968 buildings in New York City more than twenty-two feet in height with roofs flatter than twenty degrees have been required to be provided with a parapet not less than three feet six inches (42 inches) high, or be provided with a 42 inch railing or fence, or combination [§[C26-503.4] 27-334 Protective guards].

Various state codes may also address guardrail and parapet heights for highway bridges. For example, the Texas Department of Transportation specifies a 42 inch guardrail (24 inch parapet with 18 inch guardrail) for bridge railings for pedestrians [Manual Notice 2006-1, Section 5]

#### **AVAILABLE EXAMPLES OF PRODUCT OR USE:**

No specific parapet products were found as they are commonly constructed as part of the building. There may be combination parapet and guardrail products available for bridges.

#### **OTHER CONSIDERATIONS**

- Parapet design must also consider other potential uses. For example, some parapets may be designed to support window-washing scaffolds or for use as an anchorage with personal fall arrest systems.
- Parapets must be maintained over the life of the building. Older parapets may need bracing.
- A parapet wall may change the snow or pond loading on a roof. The designer should take this into account when considering a parapet roof as additional structural framing may be required.

#### **LIFE CYCLE SOLUTION BENEFITS**

A parapet can also eliminate the need to provide temporary fall protection during maintenance activities on the roof thus reducing total costs over the building life cycle. A parapet roof can also be an important feature when considering garden roofs.

#### **ADDITIONAL INFORMATION SOURCES**

- BLS, 2009. Table 1. Fatal occupational injuries by event or exposure, 2006-2007:  
<http://stats.bls.gov/news.release/cfoi.t01.htm>
- NIOSH, 1991. University Employee is Fatally Injured in 120-foot Fall from Roof:  
<http://www.cdc.gov/niosh/face/stateface/co/91co020.html>
- NIOSH, 1993. Roofing Estimator Dies After Falling 14 Feet From The Roof of a Shopping Center Strip Mall:  
<http://www.cdc.gov/niosh/face/stateface/nj/93nj094.html>

- NYC Title 27 Administrative Code Construction and Maintenance §[C26-503.4] 27-334 Protective guards, 2004: [http://www.nyc.gov/html/dob/downloads/bldgs\\_code/bc27s5.pdf#page=5](http://www.nyc.gov/html/dob/downloads/bldgs_code/bc27s5.pdf#page=5)
- Texas Department of Transportation Manual Notice 2006-1, Section 5, 2006: [http://onlinemanuals.txdot.gov/txdotmanuals/rlg/bridge\\_railing\\_for\\_pedestrians.htm#CHDEHBBF](http://onlinemanuals.txdot.gov/txdotmanuals/rlg/bridge_railing_for_pedestrians.htm#CHDEHBBF) at [http://onlinemanuals.txdot.gov/txdotmanuals/rlg/metal\\_and\\_concrete\\_railing.htm](http://onlinemanuals.txdot.gov/txdotmanuals/rlg/metal_and_concrete_railing.htm)

**CONSTRUCTION SAFTY DESIGN SOLUTION #10**  
**DESIGN CATEGORY: ROOF/ENVELOPE**  
**HAZARD : FALLS FROM HEIGHT**  
**DESIGN SOLUTION:PRE-FABRICATION AND**  
**ASSEMBLY AT GROUND LEVEL TO REDUCE**  
**OVERALL TIME EXPOSURE AT HEIGHT**

This design solution reduces the risk of serious falls from a height during the construction and maintenance during the life of a building. Falls from height can result in death or serious injury – about 22 fatalities per year [BLS , 2008] are reported.

**SOLUTION**

This design solution reduces the total exposure to falls from heights by a factor of greater than 70% when installing the large duct and attachments typical to coal plant air quality projects by pre-fabricating and assembling the duct sections on the ground.

The duct goes through an assembly line set-up where insulation and insulation covering is installed from a scaffold inside a large tent. The duct then has catwalks, permanent lighting, handrails and miscellaneous attachments installed while at ground level. When the duct is lifted into place very little high work is then required to join the sections. The scaffolding is much safer and able to be easily maintained inside the tent than if the scaffold had to be built from the ground up to insulate the duct if it was installed without insulation. The permanent lighting, handrails, cable trays installed at ground level greatly reduce the exposure to heights that would be required otherwise.



Figure 1-This photo shows the C Section of duct going into the tent.



Figure 2 – This photo shows work inside the tent.





Figure 3- Insulated before raising into place

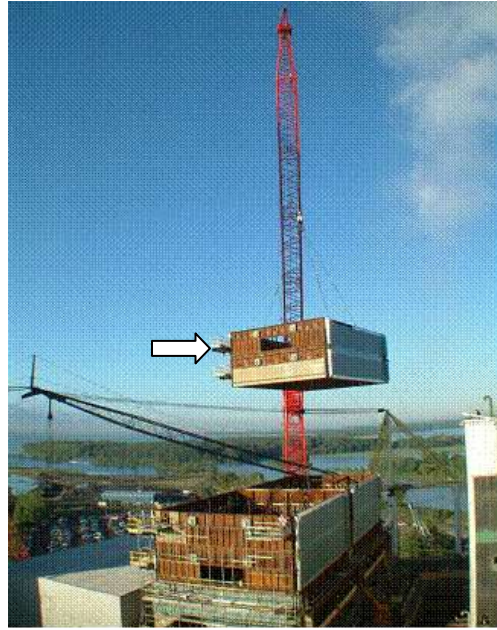


Figure 4 - Different piece, but see the permanent catwalk on left side installed before lift.

## BACKGROUND INFORMATION

### Applicable US Safety Regulations

1926.501 Duty to have fall protection

Link: [http://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=10757](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10757)

## OTHER CONSIDERATIONS

The method is appropriate for many situations in heavy construction. In addition to prefabricating fall prevention measures eliminating much of the need the need for fall protection, productivity is greatly enhanced by installing components at ground level. Working at heights is not only more hazardous, but is also slower than working at ground level. When the guardrails, cable trays, lights or other components are installed with the duct on the ground, if some elevated work is required it's usually brief and performed from an aerial lift which is inherently safer than working from a scaffold 100 or more feet in the air.

## LIFE CYCLE SOLUTION BENEFITS

By installing permanent catwalks, guardrails, and handrails future maintenance costs are reduce since personal fall protection would not be needed and the units would be more assessable.

**CONSTRUCTION SAFETY DESIGN SOLUTION #11**  
**DESIGN CATEGORY: ENVELOPE/INTERIOR**  
**HAZARDS: FALLS FROM STRUCTURAL STEEL**  
**DESIGN SOLUTION: CONSIDER ACTUAL CONSTRUCTION**  
**LOADS**

This design solution reduces the risk of serious falls from structural steel during the construction of a building. Falls from structural steel can result in death or serious injury – about 36 fatalities per year [BLS, 2008] are reported. Not included in these statistics are injuries and fatalities that have results from structure failures because the design professional did not consider actual construction loads in the structural design. The actual loads during construction could be higher than the building code requirement.

**SOLUTION**

Building codes requires sizing structural members based on the dead load of the construction materials and the live load resulting from occupancy. However, structural failures have occurred because the designer did not consider the actual construction loads or processes. For example, Figure 1 below shows a typical composite beam construction. The steel beam is proportioned based upon composite action. But, during construction the structure does not act like a composite structure. Designers should consider how the structure behaves during construction as well as the when it is complete. The weight of construction vehicles, pallets of bricks, lumber and other materials should be considered in addition to the building code requirements when sizing structural members.

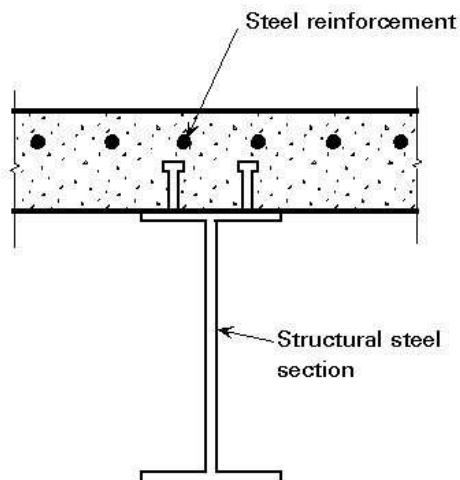


Figure1 Typical Composite Construction



Figure 2 Structural collapse from weight of equipment



## **BACKGROUND INFORMATION**

### US Building Codes

See for example, International Building Code, International Code Council

### Other Applicable Design Guidelines:

National Institute of Steel Detailing and Steel Erectors Association of America. *Detailing Guide for the Enhancement of Erection Safety*. 2001. [www.nisd.org](http://www.nisd.org) and [www.seaa.net](http://www.seaa.net).

## **OTHER CONSIDERATIONS**

- Avoid exterior slender columns
- Show reinforcement details on drawings

**CONSTRUCTION SAFETY DESIGN SOLUTION #12**  
**DESIGN CATEGORY: SITE**  
**HAZARD: FALLS DUE TO SCAFFOLD COLLAPSE**  
**DESIGN SOLUTION: DESIGN PERMANENT FEATURES INTO THE BUILDING THAT MAKE IT EASIER AND SAFER TO USE SCAFFOLDING**

This design solution reduces the risk of serious falls due to scaffold collapse. Scaffolding is a temporary structure used to support workers and material during the construction, repair, or maintenance of buildings and structures. Design professionals generally do not concern themselves with scaffolding, thinking it is the responsibility of the contractor(s). Falls from scaffolding ranks second in the number of construction fatalities due to falls, about 46 each year (BLS, 2009). A percentage of these falls are due to scaffold collapse. In August of 2009, a 42-year-old construction worker at a Brooklyn apartment building plunged four stories to his death when a scaffold suddenly collapsed.

**SOLUTION**

Designers should consider permanent features that will make it easier and safer to erect scaffolding. For example, scaffold needs to be laterally supported to resist wind and other lateral loads. An important element of the scaffold system is the building tie which connects the scaffold to the structure. Permanent building ties such as the one shown in the figure below not only can be reused if scaffolding is needed in the future, but is stronger than relying on the strength of day old veneer. A metal bracket is permanently connected to a concrete floor deck or steel. An eye bolt threads into the bracket to provide a building tie. The tie is easily removed by simply unthreaded the eye bolt and can be reused in the future.

Davits can be installed around the perimeter of the roof to provide a permanent suspension system for self powered platforms and single man cages. Davit sockets can be recessed below the pavers and the davits can be bolted in place only when needed. Monorail systems can be installed along the building profile. These systems can be used to suspend work platforms and be aesthetically pleasing at the same time. Gantry systems can be designed to maintain atriums and skylights



Figure 1 This photo shows how building ties can be designed so that they are easier to remove and can be reused.



Figure 2 This photo shows how davits can be installed to provide a permanent suspension system.



Figure 3 This photo shows how monorail systems can be installed along a building profile. They can be used to suspend work platforms.



Figure 4 Gantry systems can be designed to maintain atriums and skylights.

## **BACKGROUND INFORMATION**

OSHA 1926 Subpart L-Scaffolds

[http://www.osha.gov/pls/oshaweb/owadisp.show\\_document?p\\_table=STANDARDS&p\\_id=10916](http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10916)

ANSI/ASSE A10.8 Safety Requirements for Scaffolding

Scaffold and Access Industry Association SAIA <http://www.saiaonline.org/AboutSIA>

N.C. Department of Labor Occupational Safety and Health Division

<http://www.nclabor.com/osha/etta/indguide/ig38.pdf>

## **OTHER CONSIDERATIONS**

- When it is not possible to provide tying points or other permanent features, allow sufficient room in the design so that outriggers or buttresses can be used to secure the scaffold.
- Try to provide as much information regarding material weights to the contractor. This will make it easier for the contractor to control the load on the scaffold system.
- Consider potential scaffold loads when designing parapet walls and structural steel.
- Consider designing permanent tie back anchors that can be used to secure building maintenance systems and boatswain chairs. The anchors can be wall mounted, flush, or “U” mounted, and can be designed to reduce architectural visibility.

## **LIFE CYCLE SOLUTION BENEFITS**

Permanent, reusable tying points and other building features provide a life cycle benefit because they can be used when scaffolding is needed for future repairs and maintenance.

**CONSTRUCTION SAFETY DESIGN SOLUTION #13**  
**DESIGN CATEGORY: SITE**  
**HAZARD: FALLS FROM STATIONARY FLATBED TRAILERS**  
**DESIGN SOLUTION: TRANSPORTABLE ANCHOR POSTS**

This design solution reduces the risk of serious falls from stationary flatbed trailers. When a truck is on the road, it is controlled by DOT regulations. However, when vehicles are stopped for loading and unloading the flatbed trailer is in effect a working/walking surface. While OSHA 1926 excludes trucks and trailers from the agencies definition of "working/walking surface" thereby exempting these areas from fall protection requirements, using the same safety precautions that apply to open sided floors six feet above a lower level to loading and unloading of flatbed trailers makes sense. Many truck drivers and ironworkers unloading the steel have been seriously injured falling from flatbeds while removing tiedown straps and misstepping or being hit by swinging suspended steel. Falls backwards from the deck usually result in severe head injury. BLS data shows that in 2010 76 workers were killed and 9,330 workers suffered a day away from work injury as a result of falling from a nonmoving vehicle. In that same year, 1,190 workers suffered a day away from work injury as a result of jumping from nonmoving vehicles.

**SOLUTION**

This solution alternative reduces 5-8' fall hazards from stationary flatbed trailers when delivering steel shapes (beams and girders) to construction sites. Transportable anchor posts positioned at each end of the trailer enable harness access with fall protection as demo shows. The centering of the anchorage point is achieved by sliding under the trailer using the appropriate sized wheels for the environment allowing fork lift access. However if the site crane is removing the steel then the equipment can be moved over slightly to avoid collision.



The photo to the left shows anchor posts with harness access being used by workers to unload steel from a flatbed trailer.

**BACKGROUND INFORMATION**

Fall protection for unloading trailers at construction sites should comply with 1926.501(b)(15) and 502(d)(15/16).

ANSI A10.32-2004 equipment requirements including anchorage strength will be satisfied by this arrangement as will ANSI Z359.1-2007.

### **OTHER CONSIDERATIONS**

Other designs besides that shown are wheeled to suit the terrain and transported by pick up in collapsed form. The hoists can be manual to lift the rail. The SRL's run on the small steel I-beam by trolley to remain overhead for ironworker access. The SRL is pulled down by a tag line which is stuffed in a pocket after the SRL snaphook is attached to their harness back D-ring. Specification: approx 3600 lbs, height 18 ft.

### **LIFE CYCLE SOLUTION BENEFITS**

This solution is a simple procedure for many work sites and can be set up quickly. The application should be reliable for many years with sturdily built equipment.

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This material is for training purposes only.

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