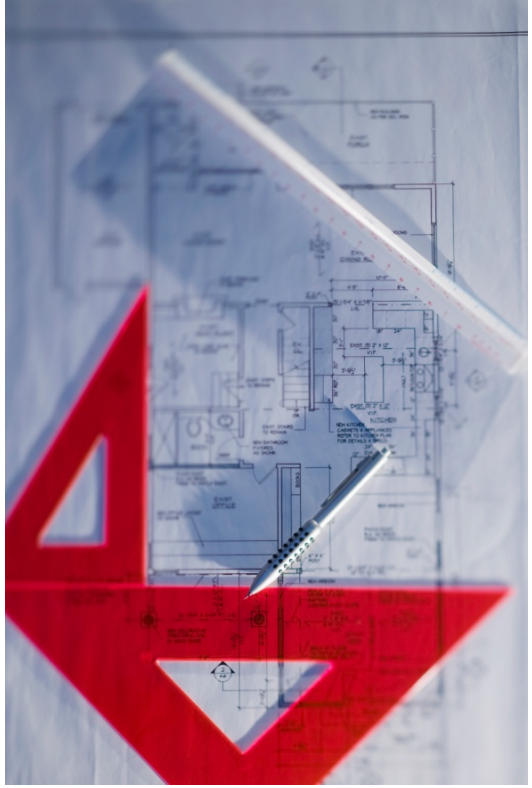

Photo courtesy of Thinkstock

PtD
Prevention through Design

Architectural Design and Construction

EDUCATION MODULE

Developed by Michael Behm , Ph.D.
Cory Boughton
East Carolina University

CDC Workplace Safety and Health
NIOSH

Guide for Instructors

Slides	Slide numbers	Approx. minutes
Introduction to Prevention through Design	5–28	45
Site Planning	29–34	10
Excavation	35–40	10
Building Elements	41–65	50
General Considerations	66–68	5
Building Decommissioning	69–71	5
Recap	72–73	5
References and Other Sources	74–88	—

Overview

- PtD concept
- Site planning
- Excavation
- Building elements
- General considerations
- Decommissioning

Photo courtesy of Thinkstock

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Learning Objectives

- Explain the Prevention through Design (PtD) concept.
- List reasons why project owners may wish to incorporate PtD in their projects.
- Identify workplace hazards and risks associated with design decisions and recommend design alternatives to alleviate or lessen those risks.

PtD™
Prevention through Design

Introduction to Prevention through Design

EDUCATION MODULE

Occupational Safety and Health

- Occupational Safety and Health Administration (OSHA) www.osha.gov
  - Part of the Department of Labor
  - Assures safe and healthful workplaces
  - Sets and enforces standards
  - Provides training, outreach, education, and assistance
  - State regulations possibly more stringent
- National Institute for Occupational Safety and Health (NIOSH) www.cdc.gov/niosh
  - Part of the Department of Health and Human Services, Centers for Disease Control and Prevention
  - Conducts research and makes recommendations for the prevention of work-related injury and illness

Construction Hazards

- Cuts
- Electrocution
- Falls
- Falling objects
- Heat/cold stress
- Musculoskeletal disease
- Tripping

[BLS 2006; Lipscomb et al. 2006]

Graphic courtesy of OSHA

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Construction Accidents in the United States

Construction is one of the most hazardous occupations. This industry accounts for

- 8% of the U.S. workforce, but 20% of fatalities
- About 1,100 deaths annually
- About 170,000 serious injuries annually

[CPWR 2008]

Photo courtesy of Thinkstock

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Design as a Risk Factor: Australian Study, 2000–2002

- Main finding: design contributes significantly to work-related serious injury
- 37% of workplace fatalities are due to design-related issues
- In another 14% of fatalities, design-related issues may have played a role

[Driscoll et al. 2008]

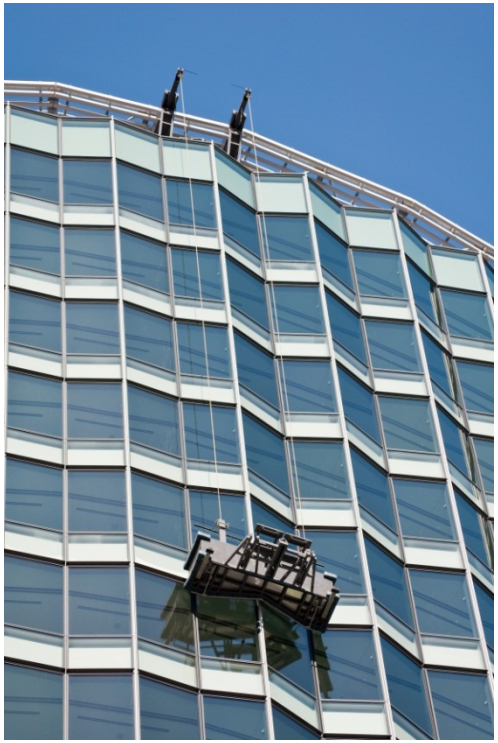

Photo courtesy of Thinkstock

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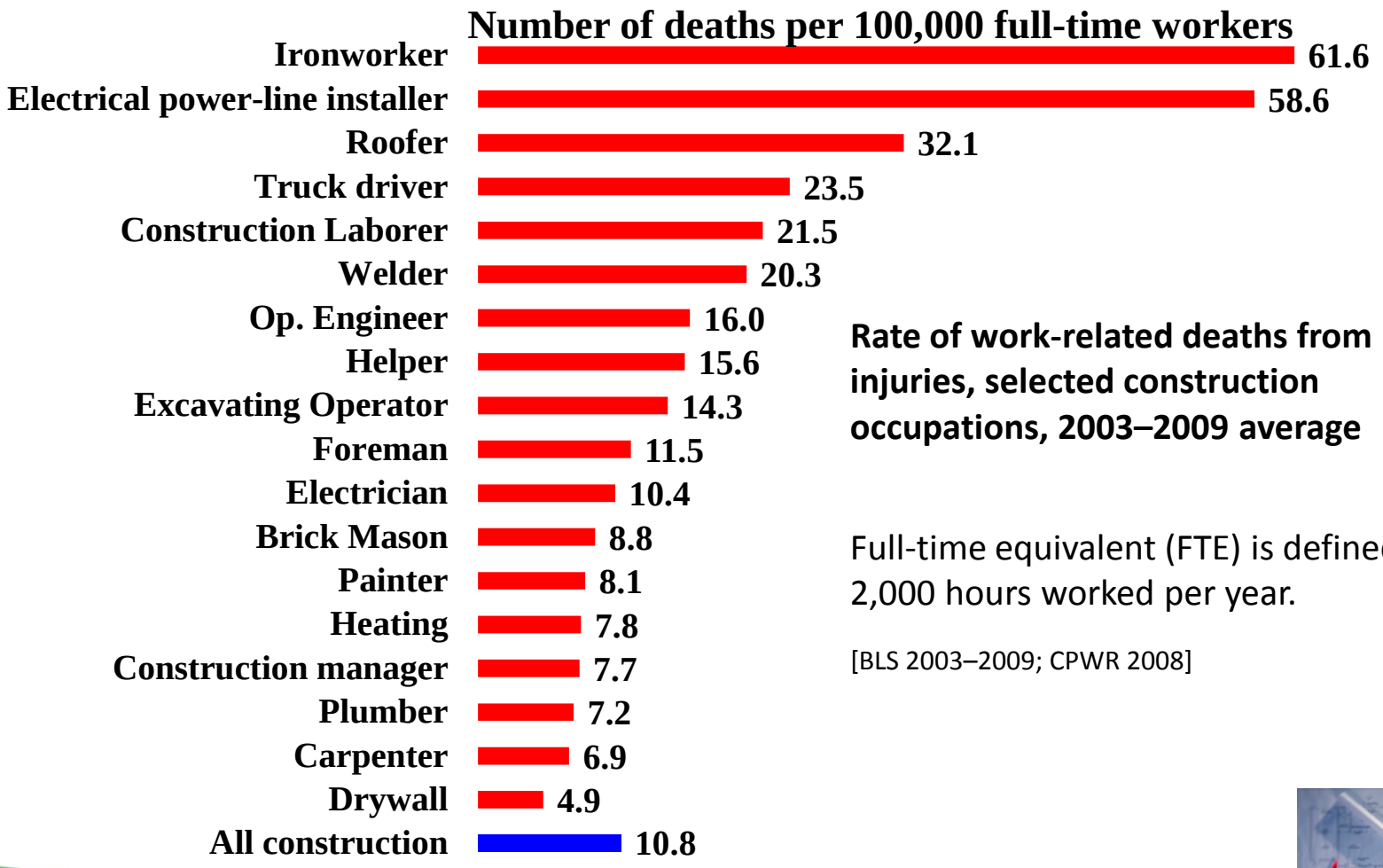
Accidents Linked to Design

- 22% of 226 injuries that occurred from 2000 to 2002 in Oregon, Washington, and California were linked partly to design [Behm 2005]
- 42% of 224 fatalities in U.S. between 1990 and 2003 were linked to design [Behm 2005]
- In Europe, a 1991 study concluded that 60% of fatal accidents resulted in part from decisions made before site work began [European Foundation for the Improvement of Living and Working Conditions 1991]
- 63% of all fatalities and injuries could be attributed to design decisions or lack of planning [CHAIR safety in design tool 2001]

Falls

- Number one cause of construction fatalities
  - in 2010, 35% of 751 deaths
    www.bls.gov/news.release/cfoi.t02.htm
- Common situations include making connections, walking on beams or near openings such as floors or windows
- Fall protection is required at height of 6 feet above a surface [29 CFR 1926.760].
- Common causes: slippery surfaces, unexpected vibrations, misalignment, and unexpected loads

Death from Injury



Rate of work-related deaths from injuries, selected construction occupations, 2003–2009 average

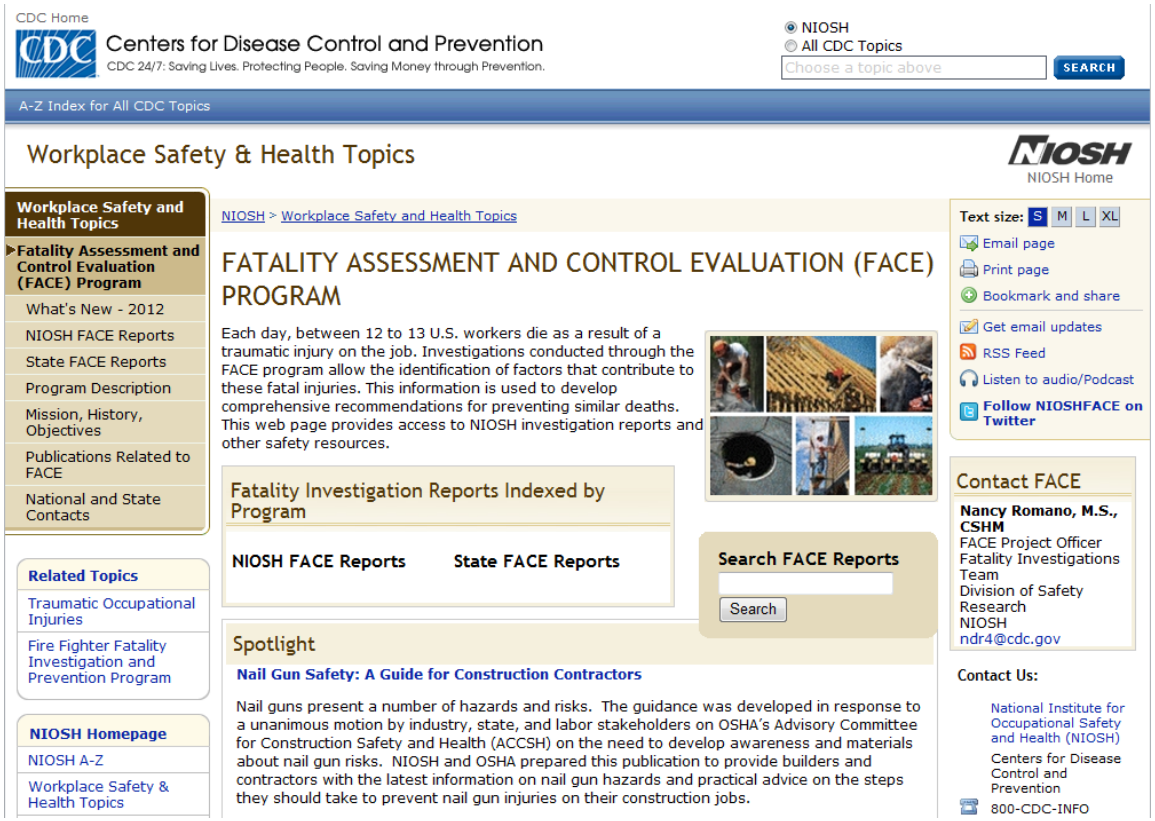
Full-time equivalent (FTE) is defined as 2,000 hours worked per year.

[BLS 2003–2009; CPWR 2008]

Architecture

Fatality Assessment and Control Evaluation

NIOSH FACE Program www.cdc.gov/niosh/face

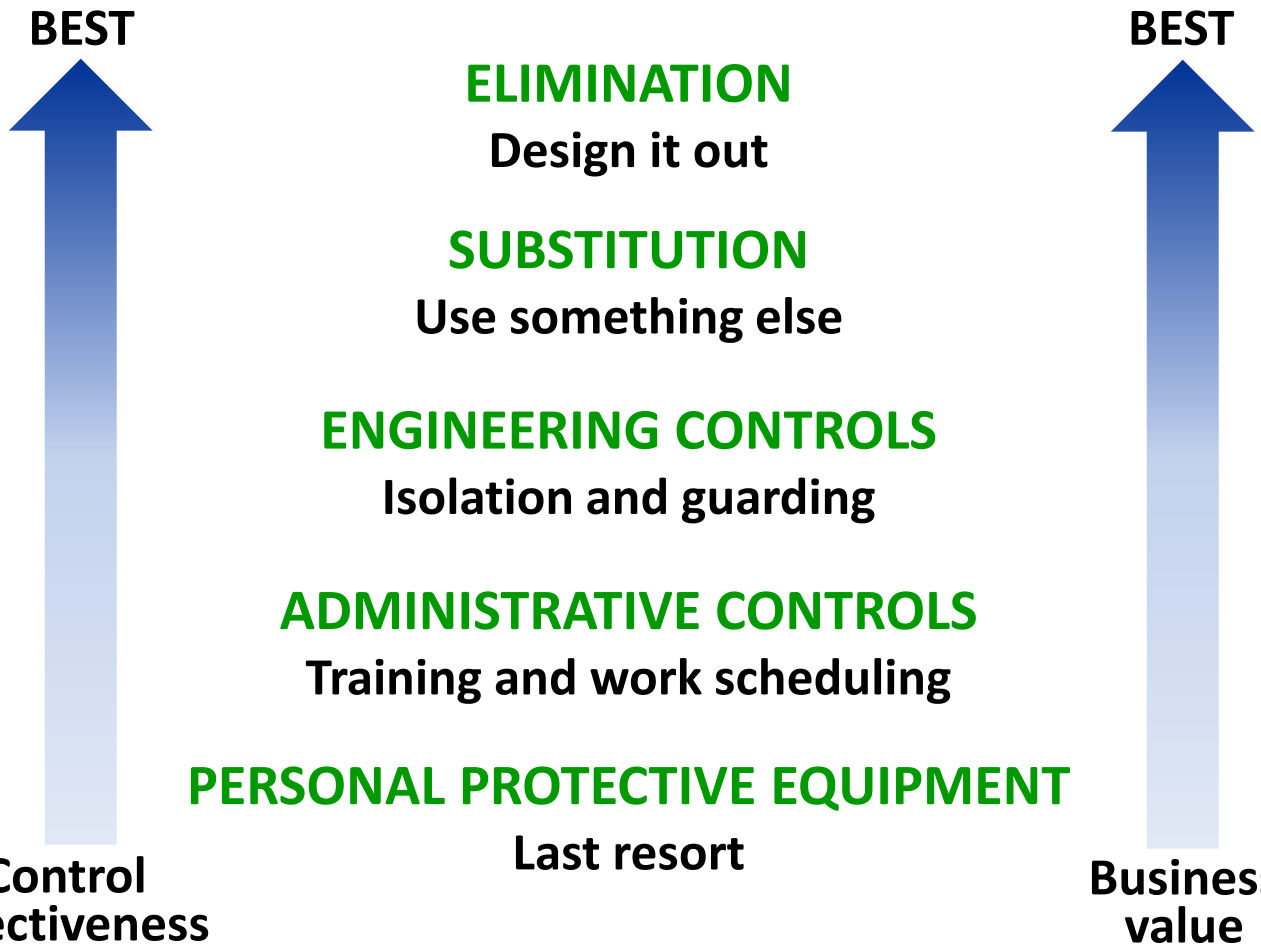


What is Prevention through Design?

Eliminating or reducing work-related hazards and illness and minimizing risks associated with

- Construction
- Manufacturing
- Maintenance
- Use, reuse, and disposal of facilities, materials, and equipment

Hierarchy of Controls per ANSI/AIHA Z10-2005



Personal Protective Equipment (PPE)

- Last line of defense against injury
- Examples:
  - Hard hats
  - Steel-toed boots
  - Safety glasses
  - Gloves
  - Harnesses

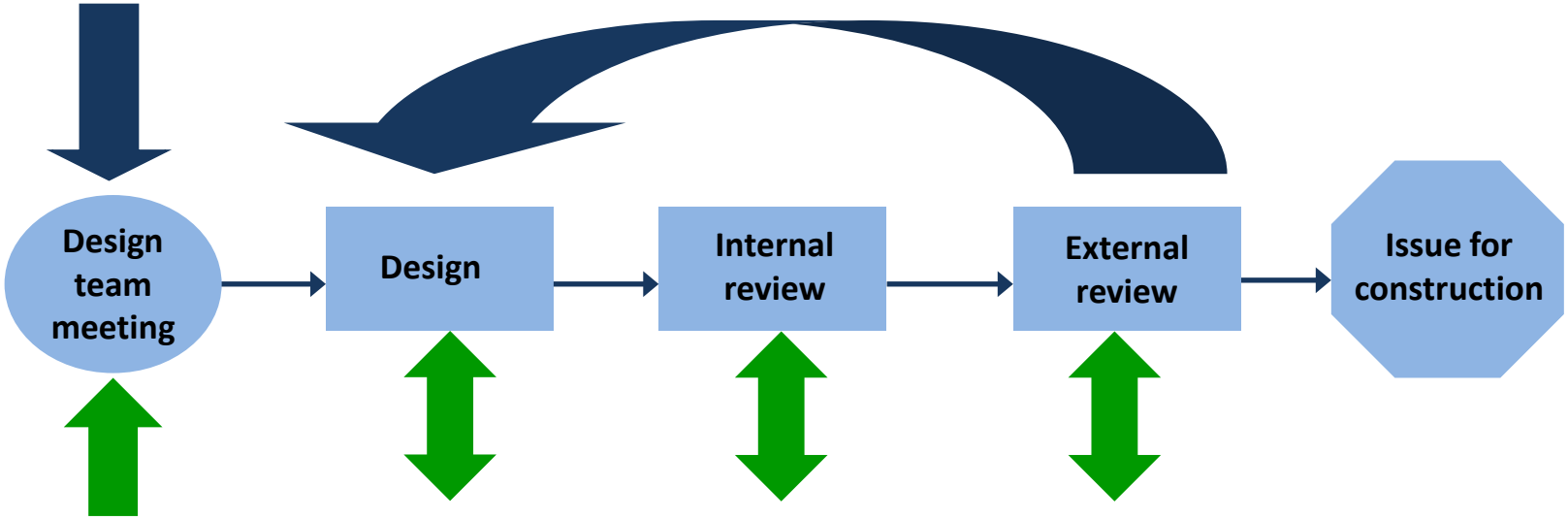
Photo courtesy of Thinkstock

OSHA www.osha.gov/Publications/osha3151.html

PtD Process

[Hecker et al. 2005]

- Establish PtD expectations
- Include construction and operation perspective
- Identify PtD process and tools



- **Owner**
- **Architect**
- **Project Manager**
- **Health & Safety Professional**

- **Trade contractor**
- **Health & Safety review**

- **Quality Assurance/ Quality Control**
- **Health & Safety review**
- **Value Engineering review**

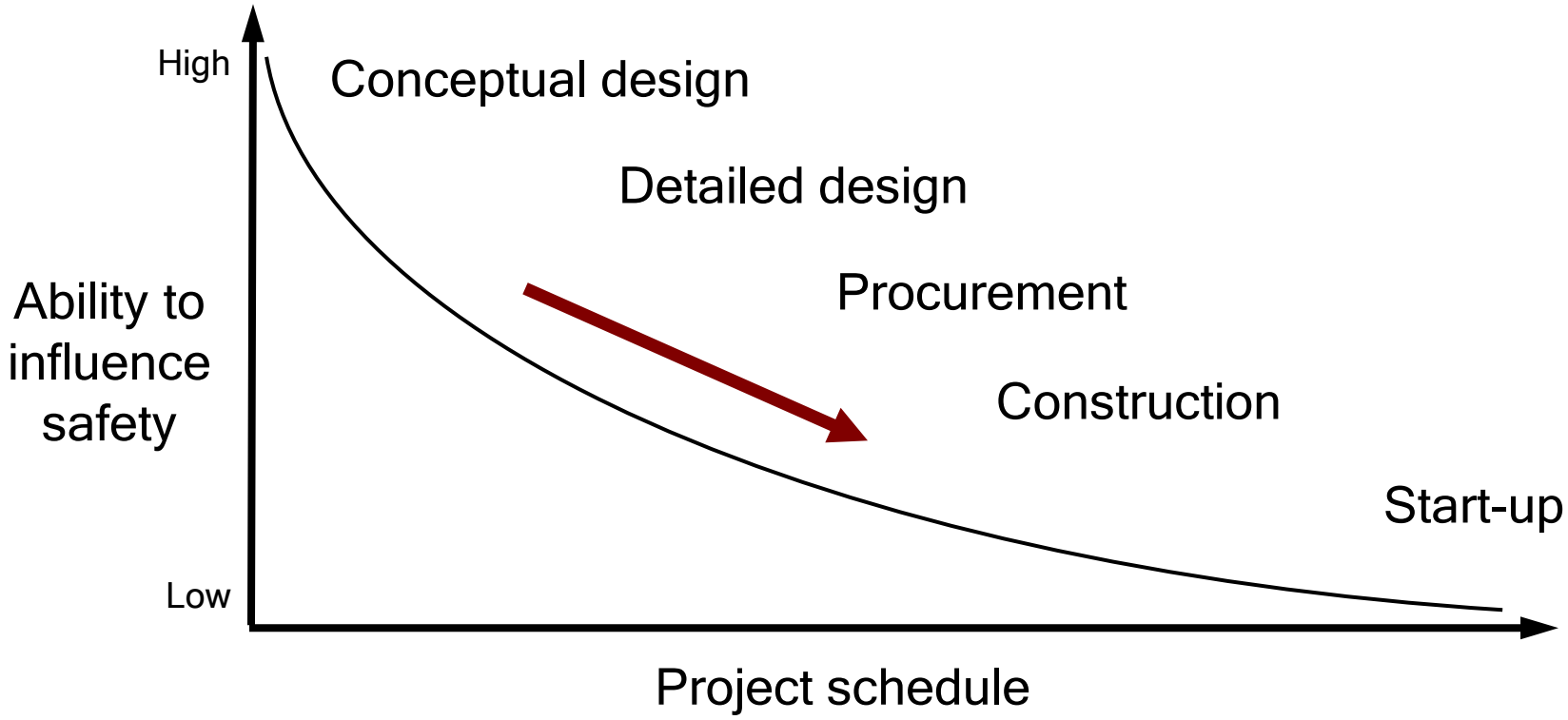
- **Focused Health & Safety review**
- **Owner review**

Integrating Occupational Safety and Health with the Design Process

Stage	Activities
Conceptual design	Establish occupational safety and health goals, identify occupational hazards
Preliminary design	Eliminate hazards, if possible; substitute less hazardous agents/processes; establish risk minimization targets for remaining hazards; assess risk; and develop risk control alternatives. Write contract specifications.
Detailed design	Select controls; conduct process hazard reviews
Procurement	Develop equipment specifications and include in procurements; develop “checks and tests” for factory acceptance testing and commissioning
Construction	Ensure construction site safety and contractor safety
Commissioning	Conduct “checks and tests,” including factory acceptance; pre–start up safety reviews; development of standard operating procedures (SOPs); risk/exposure assessment; and management of residual risks
Start up and occupancy	Educate; manage changes; modify SOPs

Safety Payoff During Design

[Adapted from Szymberski 1997]



Architecture

PtD Process Tasks

[Adapted from Toole 2005; Hinze and Wiegand 1992]

- Perform a hazard analysis
- Incorporate safety into the design documents
- Make a CAD model for member labeling and erection sequencing

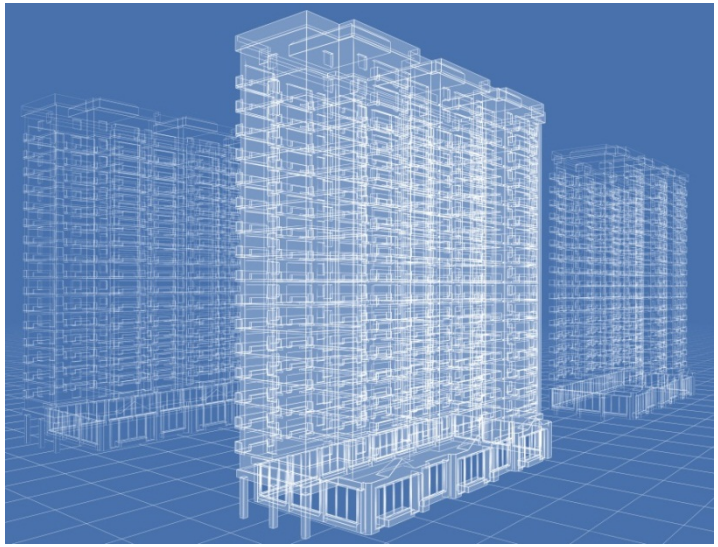


Photo courtesy of Thinkstock

Architecture

Designer Tools

- Checklists for construction safety [Main and Ward 1992]
- Design for construction safety toolbox [Gambatese et al. 1997]
- Construction safety tools from the UK or Australia
  - Construction Hazard Assessment Implication Review (CHAIR) [NOHSC 2001]

Example Checklist

Item	Description
1.0	**Structural Framing**
1.1	Space slab and mat foundation top reinforcing steel at no more than 6 inches on center each way to provide a safe walking surface.
1.2	Design floor perimeter beams and beams above floor openings to support lanyards.
1.3	Design steel columns with holes at 21 and 42 inches above the floor level to support guardrail cables.
2.0	**Accessibility**
2.1	Provide adequate access to all valves and controls.
2.2	Orient equipment and controls so that they do not obstruct walkways and work areas.
2.3	Locate shutoff valves and switches in sight of the equipment which they control.
2.4	Provide adequate head room for access to equipment, electrical panels, and storage areas.
2.5	Design welded connections such that the weld locations can be safely accessed.

[Checklist courtesy of John Gambatese]

Why Prevention through Design?

- Ethical reasons
- Construction dangers
- Design-related safety issues
- Financial and non-financial benefits
- Practical benefits

Photo courtesy of Thinkstock

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Ethical Reasons for PtD

- National Society of Professional Engineers' Code of Ethics:

  "Engineers shall hold paramount the safety, health, and welfare of the public…"

- American Society of Civil Engineers' Code of Ethics:

  "Engineers shall recognize that the lives, safety, health and welfare of the general public are dependent upon engineering decisions…"

NSPE www.nspe.org/ethics/index.html

ASCE www.asce.org/content.aspx?id=7231

PtD Applies to Constructability

- How reasonable is the design?
  - Cost
  - Duration
  - Quality
  - Safety

Photo courtesy of the Cincinnati Museum Center www.cincymuseum.org

Architecture

Business Value of PtD

- Anticipate worker exposures—be proactive
- Align health and safety goals with business goals
- Modify designs to reduce/eliminate workplace hazards in

Facilities	Equipment
Tools	Processes
Products	Work flows

→ Improve business profitability!

AIHA www.ihvalue.org

Benefits of PtD

- Reduced site hazards and thus fewer injuries
- Reduced workers' compensation insurance costs
- Increased productivity
- Fewer delays due to accidents
- Increased designer-constructor collaboration
- Reduced absenteeism
- Improved morale
- Reduced employee turnover

Industries Use PtD Successfully

- Construction companies
- Computer and communications corporations
- Design-build contractors
- Electrical power providers
- Engineering consulting firms
- Oil and gas industries
- Water utilities

And many others

PtD
Prevention through Design

ARCHITECTURAL DESIGN AND CONSTRUCTION

Site Planning

CDC Workplace Safety and Health
NIOSH

Site Location and Access

- Materials
- Workers
- Equipment
- Pedestrians

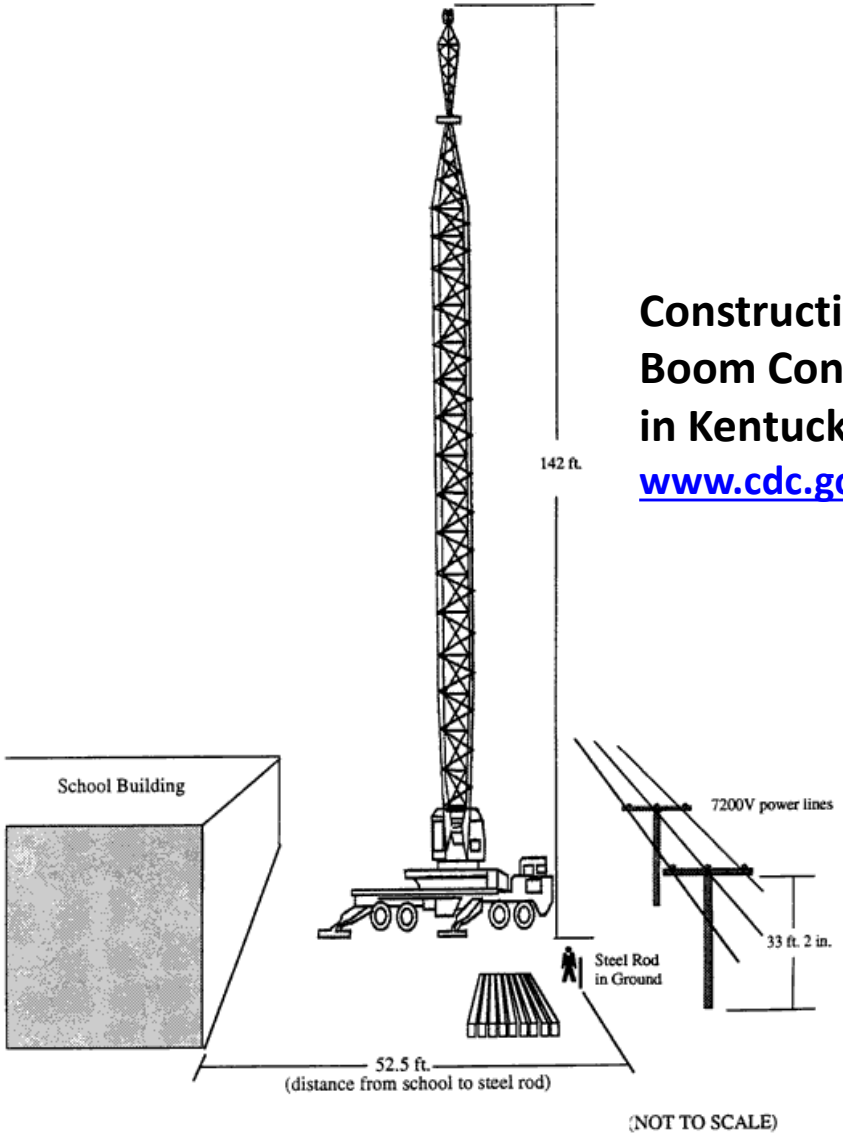
Photo courtesy of Thinkstock

Architecture

Prefabrication

- Prefabrication and preassembly will likely increase worker safety [Haas 2000]
- Prefabrication reduces work at height [CIRIA 2004]
- Prefabrication may reduce cold/heat stress
- Prefabrication increases heavy lifting; possible access and transportation issues
  - Managing risks is the key

Site Activities



Construction Laborer is Electrocuted When Crane Boom Contacts Overhead 7200-volt Power line in Kentucky

www.cdc.gov/niosh/face/In-house/full9121.html

Cranes and Derricks

- Carefully plan erection and disassembly
- Site layout affects crane maneuverability
- Show site utilities on plans
- Comply with OSHA standards

Photo courtesy of Walter Heckel

OSHA comprehensive crane standard: www.osha.gov/FedReg_osha_pdf/FED20100809.pdf
Regulation text: www.osha.gov/cranes-derricks/index.html

Center the Load

Photo courtesy of Thinkstock

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Inspect Chokers Prior to Lift

Photo courtesy of Thinkstock

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PtD
Prevention through Design

ARCHITECTURAL DESIGN AND CONSTRUCTION

Excavations

CDC Workplace Safety and Health
NIOSH

Excavation

- U.S. Bureau of Labor Statistics (BLS) data show that 271 workers died in trenching or excavation cave-ins from 2000 through 2006 [BLS 2003-2009]
- Project designers have a role to play in excavation safety.

Wet Conditions Increase Risk

Photos courtesy of Thinkstock

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Excavation Court Case

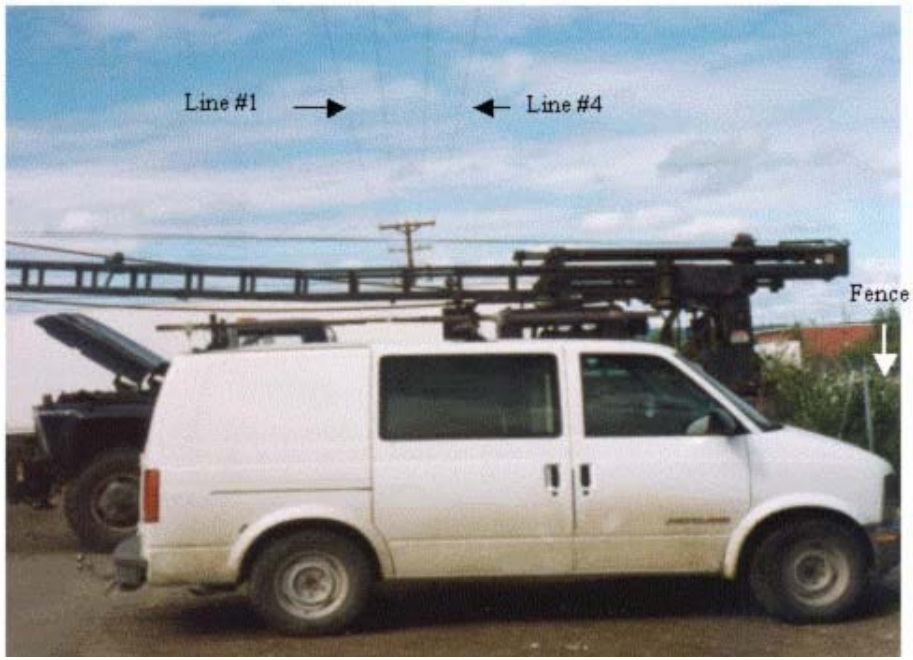
- Supreme Court of Mississippi
  - The heirs of a construction worker sued the project architects and others.
  - The worker and two others were killed when the walls of a ditch being excavated for a sewer line caved in, burying and smothering them.

Wanda M. Jones vs. James Reeves Construction,
93-CA-01139-SCT 9/20/1993 caselaw.findlaw.com/ms-supreme-court/1046041.html

Driller's Helper Electrocuted

Safety tips to live by:

1. Watch for overhead dangers
2. Be aware of your surroundings
3. Know the machine capacity
4. Always secure loads
5. Drive safely
6. Be safe and smart



Alaska FACE Investigation 99AK019 www.cdc.gov/niosh/face/stateface/ak/99ak019.html

PtD
Prevention through Design

ARCHITECTURAL DESIGN AND CONSTRUCTION

Building Elements

CDC Workplace Safety and Health
NIOSH

Roofs

- Falls are the leading cause of fatal injuries and the second most common cause of nonfatal injuries in construction.
- In 2005, falls caused
  - 396 (32%) of 1,243 work-related deaths from injuries
  - 36,360 nonfatal injuries (23% were “lost time” accidents)
- One-third of the fatal falls were from roof edges or through holes [BLS 2003-2009]

Architecture

Roof Hazards

- Access
- Fall from height
- Falling objects
- Heat/cold stress
- Material handling
- Structural collapse

Photo courtesy of T.J. Lyons

Architecture

Methods to Reduce Roof Hazards

- Use parapets as guardrails
- Guardrail systems
- Anchor points
- Lifeline systems
- Prefabrication

Photo courtesy of T.J. Lyons

Architecture

Parapets

The parapet will serve as adequate fall protection if it is at least 39” high.

Photo courtesy of Mike Behm

Architecture

Railings Prevent Falls

Photo courtesy of Thinkstock

Architecture

Anchor Points

- Part of the facility
- Use during construction and maintenance
- OSHA standard regarding anchorages can be found in 29 CFR 1926.502(d)(15)

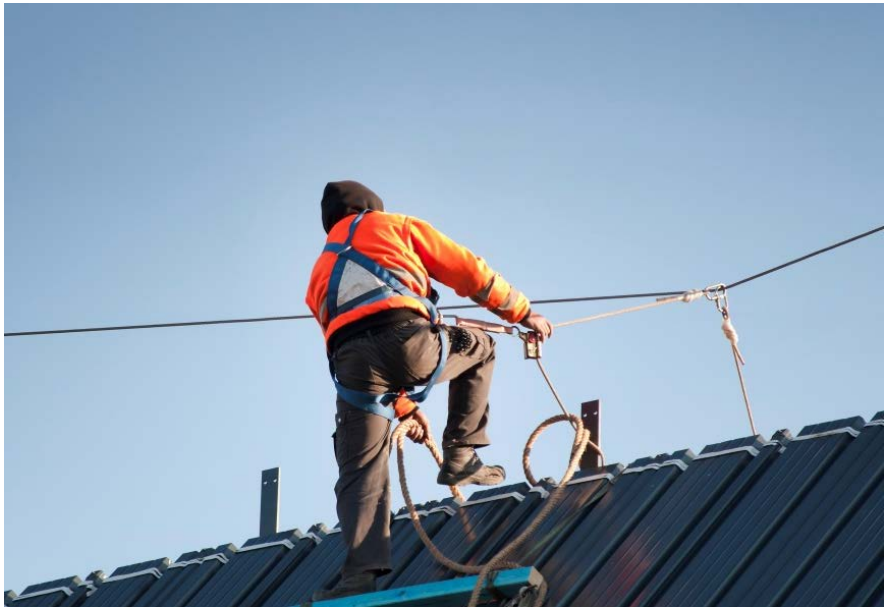


Photo courtesy of Thinkstock

Is this safe?

Photo courtesy of Thinkstock

Architecture

Walkways on Roof

Fragile roofing poses hazards to workers who need rooftop access

Electrician Dies Following a 60-foot Fall Through a Roof—Virginia, FACE 9605
www.cdc.gov/niosh/face/In-house/full9605.html

Walkway guardrails designed as a barrier from fragile materials

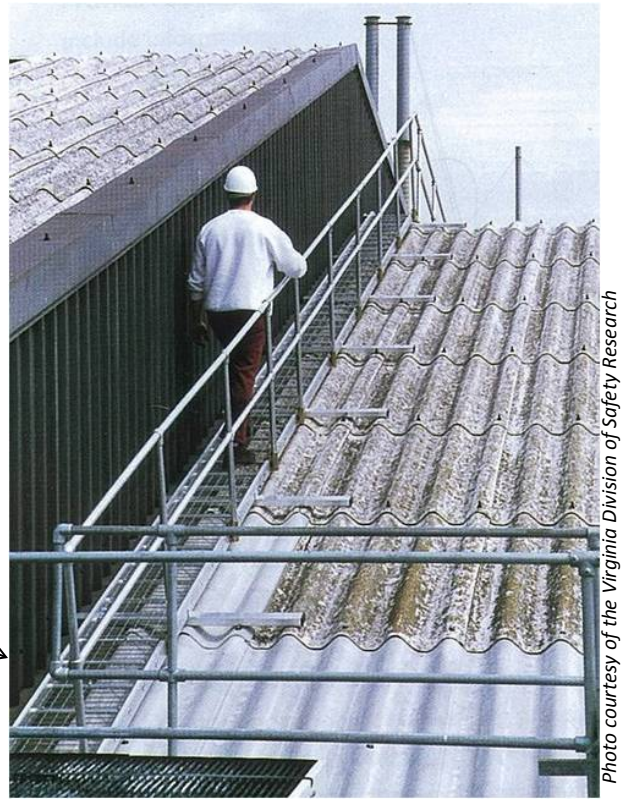


Photo courtesy of the Virginia Division of Safety Research

Architecture

United Kingdom CDM Case

The UK Construction Design and Management (CDM) regulations were discussed in the Overview module.

Construction Industry Research and Information Association (CIRIA) [2004]. CDM regulations: work sector guidance for designers. 2nd Ed. London: CIRIA.

Architect fined after health and safety lapse causes death
www.bdonline.co.uk/30-july-2010/20050.issue

Skylights

In 2003, worker deaths included these falls:

- 23 through skylights
- 11 through existing roof openings
- 24 through existing floor openings

Most of these deaths occurred in the construction industry.
[BLS 2003–2009]

Fatality During Skylight Installation

Photo courtesy of the California Department of Public Health

An Electrical Worker Dies When He Falls Through a Skylight While Installing Solar Panels on the Roof of a Warehouse www.cdc.gov/niosh/face/stateface/ca/09ca003.html

Architecture

Unguarded Flat Skylight

Photo courtesy of the Wisconsin Department of Public Health

Laborer Dies From Fall Through Skylight While Shoveling Snow on Roof

www.cdc.gov/niosh/face/stateface/wi/99WI002.html

Architecture

Skylight with Guard Cage

Photo courtesy of Plasteco

Architecture

AC Unit Maintenance

- 2000
  - Renovation, addition to existing building
  - 12 existing skylights were located on lower roof
  - Several existing AC units located on lower roof
  - New AC units located on raised roof
  - One towards the edge of the raised roof
  - Roof is split level, ~8 meters
- 2002
  - Contractor hired to service air conditioning units

AC Unit Maintenance

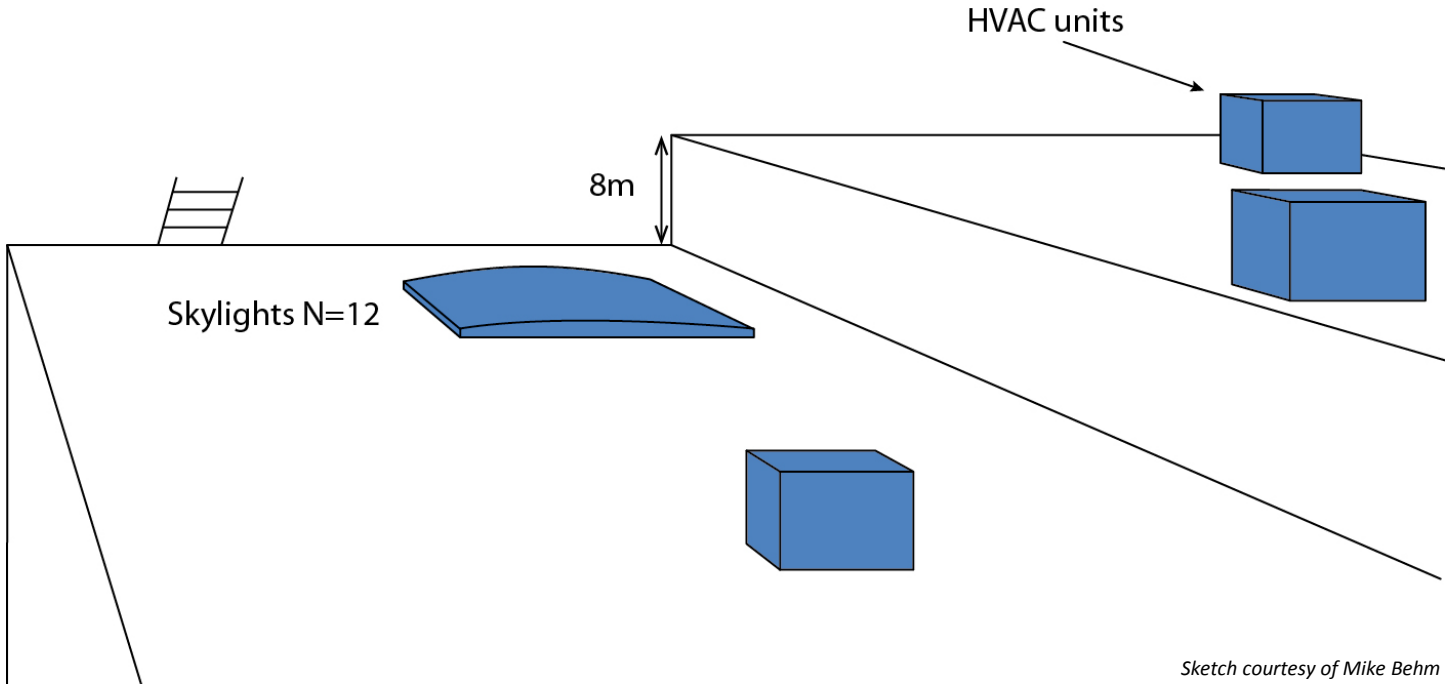
Consider:

1. Comparison with Mississippi case
2. Judgment against architect
3. Could this judgment happen in the U.S.?
4. Was the risk foreseeable?
5. Was the ruling fair?

Iannello v. BAE Automation and Electrical Services Pty Ltd & Ors
www.austlii.edu.au/au/cases/vic/VSC/2008/544.html

Sketch of Rooftop

Not to scale



Sketch courtesy of Mike Behm

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Green Roofs

- Green (vegetated) roofs becoming popular in United States
- Present new hazards for landscapers and maintenance crews

[Luckett 2010]

Photo courtesy of Carol Clinton

Green Roof Safety Design

[Weiler and Scholtz-Barth 2009]

Issues	Design Ideas
Access for people, tools, materials	Fixed stairs inside, designated walkways
Ergonomics	Allow adequate space to work. Include on-site storage for tools, fertilizers, etc.
Falls at building edge	Parapets, lifelines, anchorage systems
Falls in roof openings	Guard skylights and other roof openings
Fire, wind uplift	Vegetation-free zones
Maintenance	Plant-selection strategies
Rooftop machinery hazards	Machinery guards

Safe Roof Garden

Garden rooftop patio with railings to prevent falls

Photo courtesy of Thinkstock

Architecture

Unsafe Vegetated Roof

Photo courtesy of Mike Behm

Architecture

Installing Rails for Solar Panels

How could this man work safer?

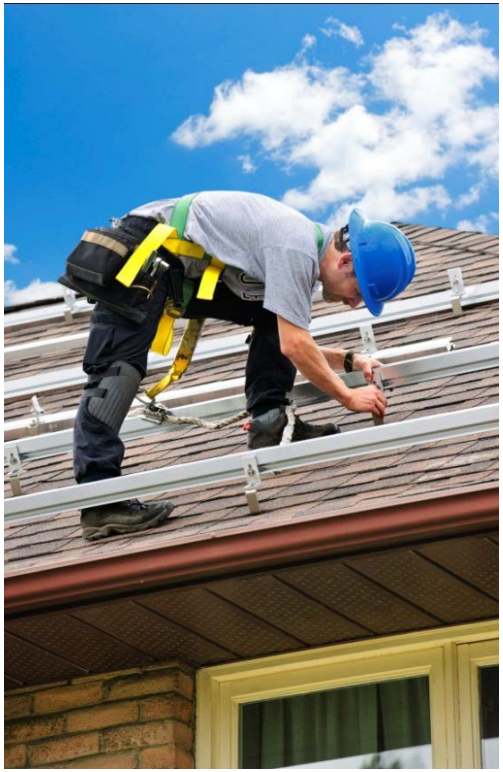

Photo courtesy of Thinkstock

Architecture

Windows and Atria

How would you wash these windows or replace a broken pane?

Photo courtesy of Thinkstock

Unsafe Window Maintenance

Photo courtesy of Thinkstock

Architecture

Window Access System

Safe access for cleaning and maintenance of the facility should be considered during the design phase.

Photo courtesy of Thinkstock

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PtD
Prevention through Design

ARCHITECTURAL DESIGN AND CONSTRUCTION

General Considerations

CDC Workplace Safety and Health
NIOSH

Material Handling

Heavy blocks are a significant musculoskeletal hazard, causing many injuries, but are an easy design issue to resolve.

Photo courtesy of Thinkstock

Architecture

Surface Coatings and Finishes

- Why apply?
- Must be sprayed?
- Materials compatible?
- Working space?
- Ventilation?
- Pretreat materials?
- Handling issues?
- Access issues?
- Is there a need for respiratory protection?

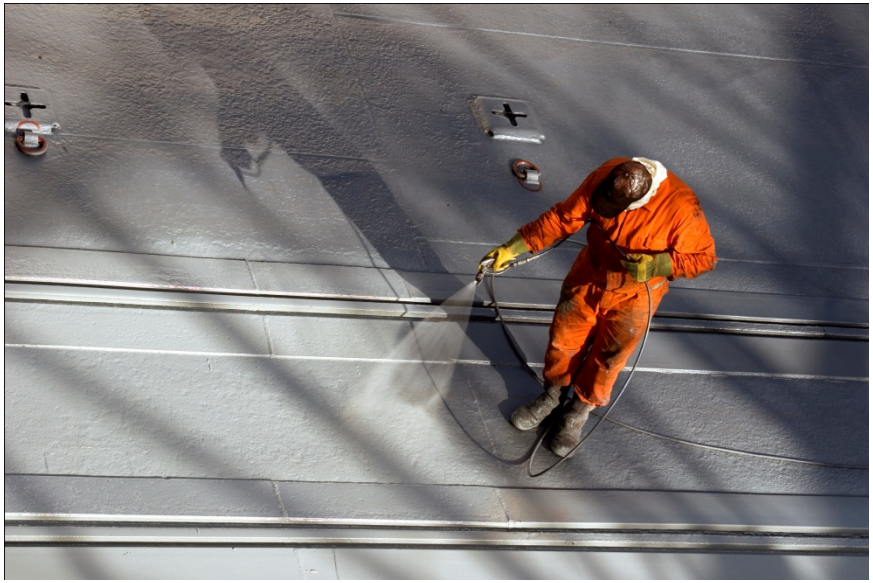

Photo courtesy of Thinkstock

This worker wears protection against finish hazards.

Architecture

ARCHITECTURAL DESIGN AND CONTRUCTION

Building Decommissioning

Demolition

Photo courtesy of Thinkstock

Architecture

Refurbishment

During remodeling, minimize risks to

- Eyes: Safety glasses
- Skin: Long sleeves, pants, shoes and socks
- Hands: Gloves
- Ears: Earplugs
- Head: Hardhat
- Nose & Mouth: Face mask
- Lungs: Exhaust fan

Photo courtesy of Thinkstock

Architecture

Recap

- **Prevention through Design (PtD)** is an emerging process for saving lives, time, and money and for protecting workers' health.
- PtD is the smart thing to do and the right thing to do.
- Although site safety is the contractor's responsibility, the designer has the ethical duty to create drawings with good constructability.
- There are tools and examples to facilitate PtD.

Help make the workplace safer…

Include *Prevention through Design* concepts in your projects.

For more information, please contact the National Institute for Occupational Safety and Health (NIOSH) at

Telephone: (513) 533–8302
E-mail: preventionthroughdesign@cdc.gov

Visit these NIOSH Prevention through Design Web sites:

www.cdc.gov/niosh/topics/PtD/

www.cdc.gov/niosh/programs/PtDesign/

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Architecture

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