Architectural Design and Construction

EDUCATION MODULE

Developed by Michael Behm, Ph.D.
Cory Boughton
East Carolina University
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<tr>
<th>Slides</th>
<th>Slide numbers</th>
<th>Approx. minutes</th>
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<td>Introduction to Prevention through Design</td>
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<td>45</td>
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<td>Site Planning</td>
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<td>Excavation</td>
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<td>General Considerations</td>
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<td>74–88</td>
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</table>
Overview

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

Photo courtesy of Thinkstock
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.
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]
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]

- 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]
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

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Number of deaths per 100,000 full-time workers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ironworker</td>
<td>61.6</td>
</tr>
<tr>
<td>Electrical power-line installer</td>
<td>58.6</td>
</tr>
<tr>
<td>Roofer</td>
<td>32.1</td>
</tr>
<tr>
<td>Truck driver</td>
<td>23.5</td>
</tr>
<tr>
<td>Construction Laborer</td>
<td>21.5</td>
</tr>
<tr>
<td>Welder</td>
<td>20.3</td>
</tr>
<tr>
<td>Op. Engineer</td>
<td>16.0</td>
</tr>
<tr>
<td>Helper</td>
<td>15.6</td>
</tr>
<tr>
<td>Excavating Operator</td>
<td>14.3</td>
</tr>
<tr>
<td>Foreman</td>
<td>11.5</td>
</tr>
<tr>
<td>Electrician</td>
<td>10.4</td>
</tr>
<tr>
<td>Brick Mason</td>
<td>8.8</td>
</tr>
<tr>
<td>Painter</td>
<td>8.1</td>
</tr>
<tr>
<td>Heating</td>
<td>7.8</td>
</tr>
<tr>
<td>Construction manager</td>
<td>7.7</td>
</tr>
<tr>
<td>Plumber</td>
<td>7.2</td>
</tr>
<tr>
<td>Carpenter</td>
<td>6.9</td>
</tr>
<tr>
<td>Drywall</td>
<td>4.9</td>
</tr>
<tr>
<td>All construction</td>
<td>10.8</td>
</tr>
</tbody>
</table>

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]
# Fatality Assessment and Control Evaluation (FACE) Program

Each day, between 12 to 13 U.S. workers die as a result of a traumatic injury on the job. Investigations conducted through the FACE program allow the identification of factors that contribute to these fatal injuries. This information is used to develop comprehensive recommendations for preventing similar deaths. This web page provides access to NIOSH investigation reports and other safety resources.

## Fatality Investigation Reports Indexed by Program

<table>
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<tr>
<th>NIOSH FACE Reports</th>
<th>State FACE Reports</th>
</tr>
</thead>
</table>

## Spotlight

**Nail Gun Safety: A Guide for Construction Contractors**

Nail guns present a number of hazards and risks. The guidance was developed in response to a unanimous motion by industry, state, and labor stakeholders on OSHA’s Advisory Committee for Construction Safety and Health (AC2OSH) on the need to develop awareness and materials about nail gun risks. NIOSH and OSHA prepared this publication to provide builders and contractors with the latest information on nail gun hazards and practical advice on the steps they should take to prevent nail gun injuries on their construction jobs.
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

**BEST**

- **ELIMINATION**
  - Design it out

- **SUBSTITUTION**
  - Use something else

**ENGINEERING CONTROLS**
- Isolation and guarding

**ADMINISTRATIVE CONTROLS**
- Training and work scheduling

**PERSONAL PROTECTIVE EQUIPMENT**
- Last resort

**Control effectiveness**

**Business value**
Personal Protective Equipment (PPE)

• Last line of defense against injury

• Examples:
  – Hard hats
  – Steel-toed boots
  – Safety glasses
  – Gloves
  – Harnesses

OSHA [www.osha.gov/Publications/osha3151.html](http://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

PtD Process

- 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

Issue for construction
## Integrating Occupational Safety and Health with the Design Process

<table>
<thead>
<tr>
<th>Stage</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual design</td>
<td>Establish occupational safety and health goals, identify occupational hazards</td>
</tr>
<tr>
<td>Preliminary design</td>
<td>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.</td>
</tr>
<tr>
<td>Detailed design</td>
<td>Select controls; conduct process hazard reviews</td>
</tr>
<tr>
<td>Procurement</td>
<td>Develop equipment specifications and include in procurements; develop “checks and tests” for factory acceptance testing and commissioning</td>
</tr>
<tr>
<td>Construction</td>
<td>Ensure construction site safety and contractor safety</td>
</tr>
<tr>
<td>Commissioning</td>
<td>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</td>
</tr>
<tr>
<td>Start up and occupancy</td>
<td>Educate; manage changes; modify SOPs</td>
</tr>
</tbody>
</table>
Safety Payoff During Design

[Adapted from Szymborski 1997]

- Conceptual design: Ability to influence safety is high, but project schedule is low.
- Detailed design: Ability to influence safety decreases as project schedule progresses.
- Procurement and Construction: Ability to influence safety is low, project schedule is high.
- Start-up: Ability to influence safety is low, project schedule is highest.
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
Designer Tools

- Checklists for construction safety [Main and Ward 1992]
- Construction safety tools from the UK or Australia
  - Construction Hazard Assessment Implication Review (CHAIR) [NOHSC 2001]
Example Checklist

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

[Checklist courtesy of John Gambatese]
Why Prevention through Design?

- Ethical reasons
- Construction dangers
- Design-related safety issues
- Financial and non-financial benefits
- Practical benefits
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](http://www.nspe.org/ethics/index.html)
ASCE  [www.asce.org/content.aspx?id=7231](http://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
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
ARCHITECTURAL DESIGN AND CONSTRUCTION

Site Planning
Site Location and Access

- Materials
- Workers
- Equipment
- Pedestrians
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

Center the Load

Photo courtesy of Thinkstock
Inspect Chokers Prior to Lift

Photo courtesy of Thinkstock
ARCHITECTURAL DESIGN AND CONSTRUCTION

Excavations
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
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.

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]
ARCHITECTURAL DESIGN AND CONSTRUCTION

Building Elements
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]
Roof Hazards

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

Photo courtesy of T.J. Lyons
Methods to Reduce Roof Hazards

• Use parapets as guardrails
• Guardrail systems
• Anchor points
• Lifeline systems
• Prefabrication
The parapet will serve as adequate fall protection if it is at least 39” high.

Photo courtesy of Mike Behm
Railings Prevent Falls

Photo courtesy of Thinkstock
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
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
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

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
Unguarded Flat Skylight

Laborer Dies From Fall Through Skylight While Shoveling Snow on Roof

www.cdc.gov/niosh/face/stateface/wi/99WI002.html
Skylight with Guard Cage

Photo courtesy of Plasteco
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
Sketch of Rooftop

Not to scale

Skylights N=12

HVAC units

8m

Sketch courtesy of Mike Behm
Green Roofs

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

[ Luckett 2010]
## Green Roof Safety Design

[Weiler and Scholtz-Barth 2009]

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

Garden rooftop patio with railings to prevent falls

Photo courtesy of Thinkstock
Unsafe Vegetated Roof

Photo courtesy of Mike Behm
Installing Rails for Solar Panels

How could this man work safer?
Windows and Atria

How would you wash these windows or replace a broken pane?
Unsafe Window Maintenance
Safe access for cleaning and maintenance of the facility should be considered during the design phase.
ARCHITECTURAL DESIGN AND CONSTRUCTION

General Considerations
Material Handling

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

Photo courtesy of Thinkstock
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?

This worker wears protection against finish hazards.

Photo courtesy of Thinkstock
ARCHITECTURAL DESIGN AND CONSTRUCTION

Building Decommissioning
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
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/
References

References


References


• CHAIR safety in design tool [2001]. New South Wales, Australia: NSW WorkCover.

References


References


References


References


• NIOSH Fatality Assessment and Control Evaluation (FACE) Program [1991]. Construction Laborer is Electrocuted When Crane Boom Contacts Overhead 7200-volt Power line in Kentucky. FACE9121 www.cdc.gov/niosh/face/In-house/full9121.html.
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• NIOSH Fatality Assessment and Control Evaluation (FACE) Program [1996]. Electrician dies following a 60-foot fall through a roof—Virginia. FACE 9605 [website](http://www.cdc.gov/niosh/face/In-house/full9605.html).
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• NIOSH Fatality Assessment and Control Evaluation (FACE) Program [2009]. An electrical worker dies when he falls through a skylight while installing solar panels on the roof of a warehouse. California case report no. 09CA003 [www.cdc.gov/niosh/face/stateface/ca/09ca003.html].

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  www.hse.gov.uk/guidance/index.htm

• National Society of Professional Engineers [NSPE]
  www.nspe.org/ethics

• NIOSH Fatality Assessment and Control Evaluation Program
  www.cdc.gov/niosh/face

• NIOSH Prevention through Design program Web sites:
  www.cdc.gov/niosh/topics/PtD
  www.cdc.gov/niosh/programs/PtDesign
Other Sources

- OSHA home page
- OSHA Anchorage Standard 29 CFR 1926.502(d)(15)
- OSHA comprehensive crane standard
- OSHA crane regulation text is available at [www.osha.gov/cranes-derricks/index.html](http://www.osha.gov/cranes-derricks/index.html)
Other Sources

• A press release for the crane standard can be found: www.advancedsafetyhealth.com/blog/index.php/category/cranes

• OSHA PPE publications
  – www.osha.gov/Publications/osha3151.html
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