“Defying Gravity . . . and Other Important Stuff”

MAINE BUILDING OFFICIALS AND INSPECTORS

Wednesday, October 26, 2022

Part 1: Combustible Construction

Goal

Address both building official and fire service concerns about construction materials and techniques to prevent building collapse. It covers *the International Building Code* construction type classifications, natural and technological threats to structural stability and how to identify structural threats in new and existing construction.

All You Need to Know

The Law of Gravitation

- “Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.” -- *Sir Isaac Newton*, 1687

The Second Law of Motion

- “Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.” -- *Sir Isaac Newton*, 1687

In other words . . .

- “If you build it, it can fall,”
- “Once it starts, you can’t stop it, and,”
- “Gravity always wins.”

Objectives

You will be able to:

- describe the influence of “forces” and “loads” on construction.
- identify four types of “engineered wood.”
- define “ordinary” construction.
- explain the difference between balloon and platform construction
- identify the key components of non-combustible and fire resistive construction
- identify potential indicators of building collapse related to construction types

The Bad News

Fire fighter deaths and injuries in single family dwelling structural collapse are increasing

Not just under fire conditions

875 on-duty fatalities since 2011
- 31 or 5.66% due to structural collapse
- 18 (58%) were multiple-fatality events

“The building is your enemy. Know your enemy.”

– Frank Brannigan

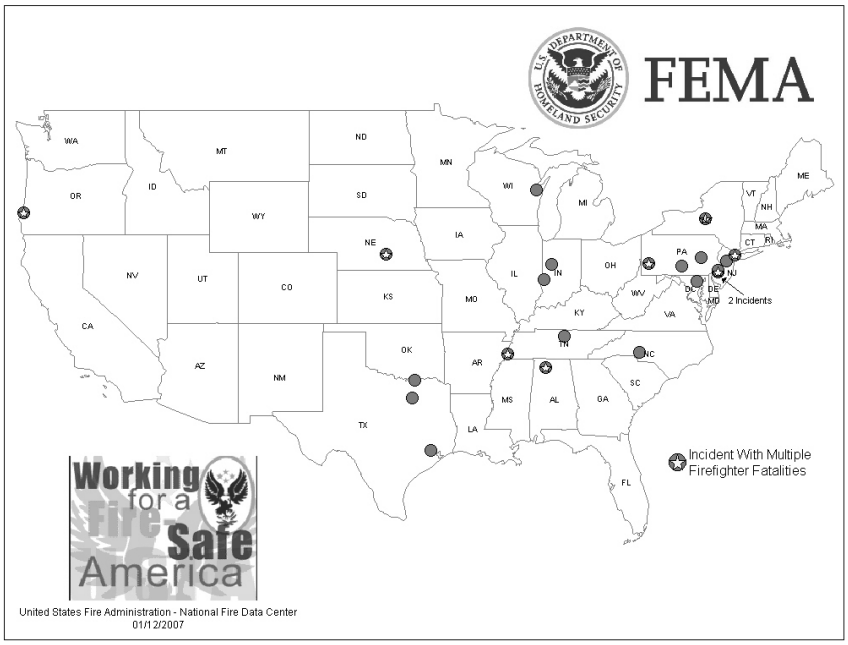
Recent Incidents

Fairhill, Pennsylvania
- Post-fire building collapse
- June 18, 2022
- 51- year-old male dead
- Five injured and transported

Baltimore, Maryland
- Rowhouse floor collapse
- January 25, 2022
- Three dead
- One on life-support

Frederick, Maryland
- Floor collapse in single family dwelling
- August 8, 2021
- 42 year-old male

York, Pennsylvania
- Wall collapse during overhaul
- March 23, 2018
- Two dead
- Two injured



The Good News

Modern building codes address a broad range of risks

- IBC §101.3 ". . . Reasonable level of safety to fire fighters and emergency responders in emergency operations.

"Everyone Goes Home"

Building and fire inspectors cannot catch every hazard

- You, and <u>you alone</u>, are responsible for your own safety
- "www.EveryoneGoesHome.com"

- Knowing how buildings are erected – and how they fail – may save your life

"The solution is a change in tactics. Fire fighters can no longer rush pell-mell into burning structures. Progressive fire departments will make the changes after analyzing the problem. Others will learn as the result of disasters and lawsuits" – Frank Brannigan

Mull This . . .

How long does the fire department have before collapse will occur in the building?

- Can you tell me when the fire started?
- Can you tell me where?
- Is the construction "protected" or "unprotected"?
- Are the fire protection systems and features operating?
- Has the building been maintained?

IBC Construction Classes

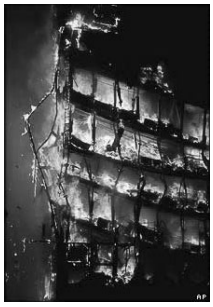
Building code describes five construction types

I	Non-combustible and fire resistive
II	Non-combustible
III	Non-combustible exterior walls, combustible framing
IV	Heavy timber
V	Combustible wood frame

Construction Classes

Type I

- All non-combustible materials
- Predominantly steel and concrete
- "Fire resistive" construction



Windsor Building
Madrid
February 12, 2005

Grenfell Tower
London
June 14, 2017

Type I

Construction Classes

Type II
- All non-combustible materials
- Predominantly steel
- May have little or no fire resistance

Type II

Construction Classes

Type III
- "Ordinary" construction
- Masonry exterior walls
  - Concrete, CMU, brick
- Wood frame structure and roof

"After the first brick hits you, the rest of the building really doesn't matter."

– Frank Brannigan

Type III

Construction Classes

Type IV
- Heavy timber
- Employs wood mass to obtain "slow burning" characteristics

Construction Classes

Type IVA-IVB-IVC

- Mass Timber/CLT
- Employs wood mass to obtain “slow burning” characteristics
- May include fire-resistant coverings
- Must be sprinklered
- Non-combustible shafts

Construction Categories

Type V

- Traditionally, “wood frame”
- Any material permitted by code
- Includes much “engineered wood”

Type V

Fire Resistance Ratings

Influence maximum height and “allowable” areas

- “Greater” fire resistance allows larger buildings

“Protected” or “Unprotected”

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A	B	A	B	HT	A	B
Structural frame Including columns, girders, trusses	3	2	1	0	1	0	HT	1	0
Bearing walls									
Exterior	3	2	1	0	2	2	2	1	0
Interior	3	2	1	0	1	0	1/HT	1	0
Nonbearing walls and partitions									
Exterior	See Exterior Wall/Separation Distance Table								
Interior									
Floor construction Including supporting beams and joists	2	2	1	0	1	0	HT	1	0
Roof construction Including supporting beams and joists	1½	1	1	0	1	0	HT	1	0

How Fire Resistance is Achieved

Encasement

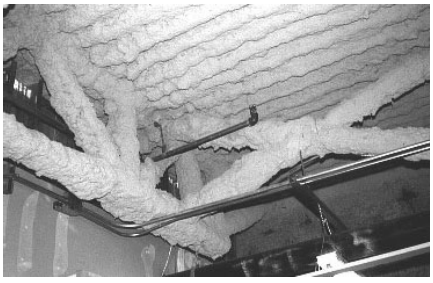
- Concrete
- Gypsum wallboard

So-called “Fireproofing”

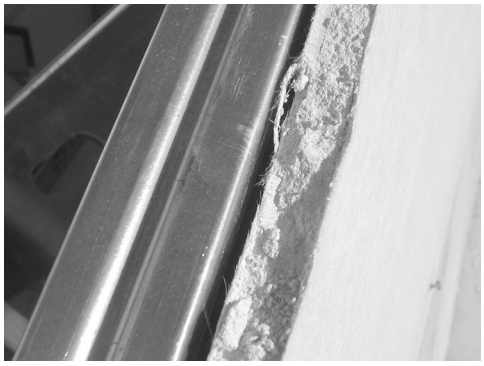
- Spray-on
- Intumescent mastic

Automatic sprinklers

- Substitute for “one-hour” rated construction



Encasement



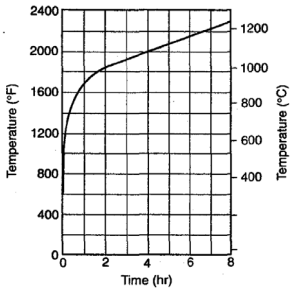
Hourly Ratings

Spray-on

Hourly Fire Ratings

DO NOT rely on them
- Comparison purposes only
- Not absolute values

"Standard Time-Temperature Curve"
- ASTM E119
- Developed in 1918
- Up to four hours
- Walls, floors, ceilings indepedently
  - Not connections!



Note: The following are the points that determine the curve.

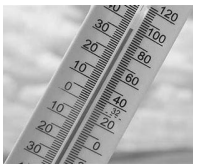
1000°F (538°C).....at 5 minutes
1300°F (704°C).....at 10 minutes
1550°F (843°C).....at 30 minutes
1700°F (927°C).....at 1 hour
1850°F (1010°C).....at 2 hours
2000°F (1093°C).....at 4 hours
2300°F (1260°C).....at 8 hours or over

Connections

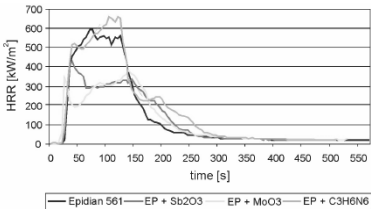
Connections

Temperature vs. HRR

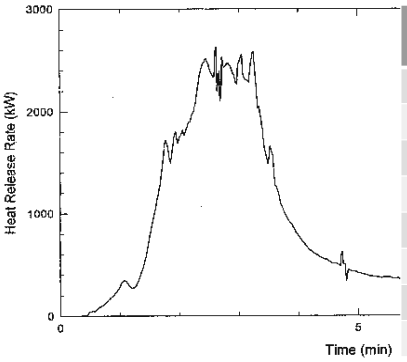
Temperature measures heat output
- Fahrenheit
- Celsius
- Typical housefire: up to 2000°F (1093°C)



Heat Release Rate (HRR) measures energy output
- Btu/min
- kW/m^2

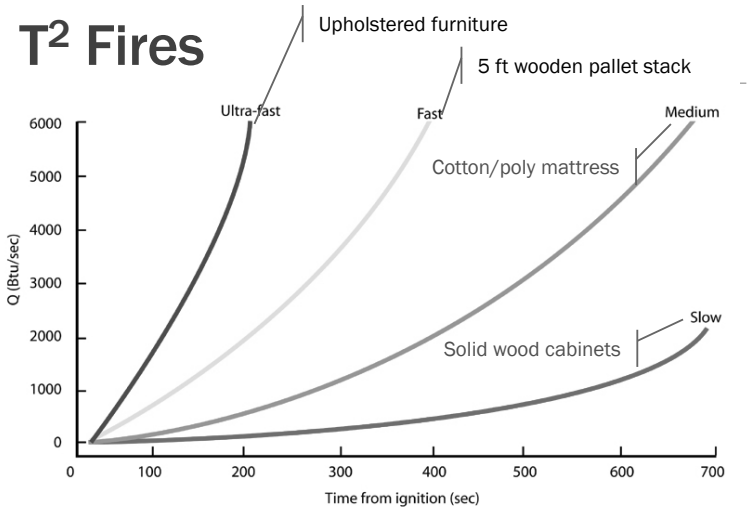


Peak HRR



Fuel	Peak HRR (kW)
Small wastebasket	4-50
TV sets	120-1500+
Plastic trash	120-350
Cotton easy chair	290-370
Gasoline pool	400
Polyurethane easy chair	1350-1990
Polyurethane sofa	3120
Wardrobe – wood construction	1900-6400

T^2 Fires



Pop Quiz

A building that has masonry exterior walls, and a wood frame interior is Type __or _____ construction.

Pop Quiz

A building that is constructed with the structural frame and bearings walls having at least a three-hour fire resistance rating is Type __ construction.

Pop Quiz

A building that is all combustible with no fire resistance rating is Type _____ construction.

Pop Quiz

A building that has all non-combustible structural elements is Type _____ construction.

Pop Quiz

A building that uses massive wooden structural elements to achieve fire resistance is Type _____ construction.

It's All About Physics

Compression
- Compresses materials

Tension
- Stretches materials

Inertia

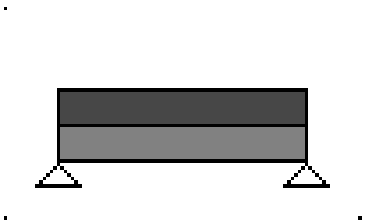
Brittleness & Ductility
- Breaks or bends

Shear
- Two opposite forces acting on a body

Bending or Moments
- A force acting on a body causing rotation

Compression

Downward force caused by mass (weight) applied to material
- Creates “deformation” by shortening or crushing



Tension

Horizontal forces in response to compression
- Deformation results in “elongation” or stretching

Inertia/Momentum

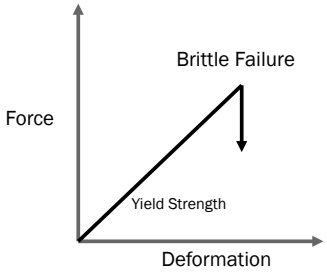
A body at rest stays at rest

A body in motion stays in motion

WTC 7 September 11, 2001

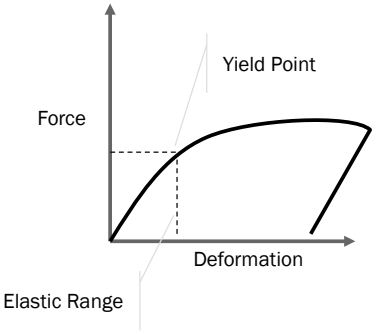
Brittleness

Catastrophic failure when yield strength is exceeded



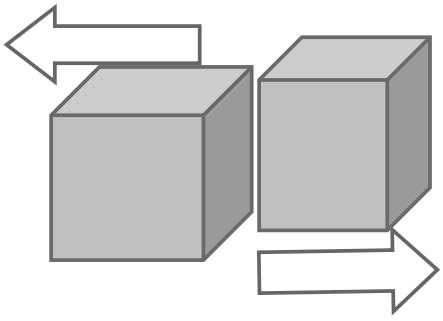
Ductility

Elastic range until yield point met, followed by unrecoverable strain failure



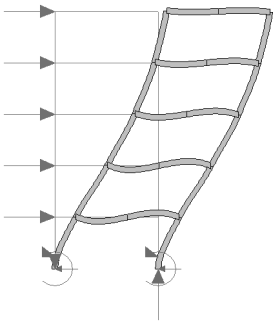
Shear

Oppositely moving lateral forces, resulting in tearing



Bending or Moments

Rotation, due to gravity, around a point



Pop Quiz

What force does this image represent?

Pop Quiz

- What force does this image represent?

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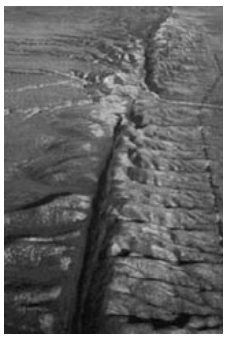


“Loads”

Forces acting on a structure

Loads

- Dead load
  - Weight of construction materials, permanent equipment, walls and fixed objects

Loads

- Live load
  - Temporary/transient
  - People
  - Snow
  - Fire protection water
  - Impact

Loads

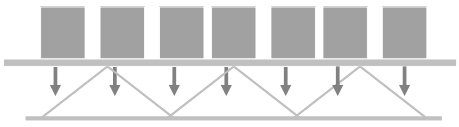
- Impact loads
  - Force caused by sudden load
  - Firefighter stepping onto roof
  - Falling, wind-borne, floating debris

Pop Quiz

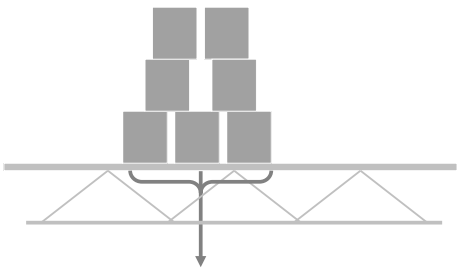
Two master streams are flowing 750 gpm and 1250 gpm, respectively. How long will it take add 100 extra tons of *live load* to the building?

Load Distribution

- Distributed/Uniform

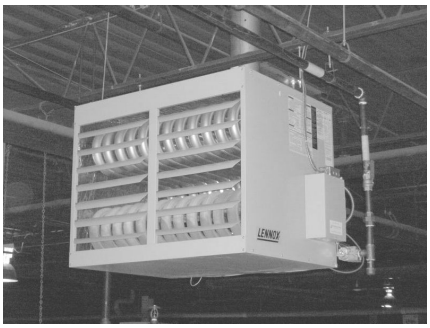


- Concentrated



Pop Quiz!

- This image is an example of a _____ load.



Pop Quiz

- This image is an example of a _____ load.

Pop Quiz

- This image is an example of a _____ load.

Pop Quiz

- This image is an example of a _____ load.

Reading Buildings

Knowing how buildings are erected – and how they fail – may save your life

Structural Frame

Transmits loads from where they occur to the ground

“Bearing” or “Nonbearing” Elements

Construction elements that transfer loads to ground

Bearing Construction

Construction feature that supports any load in addition to its own weight

- Wall
- Beam
  - Girder
- Column
- Truss
- Joist
- Roof/ceiling
- Floor/ceiling

Non-Bearing Construction

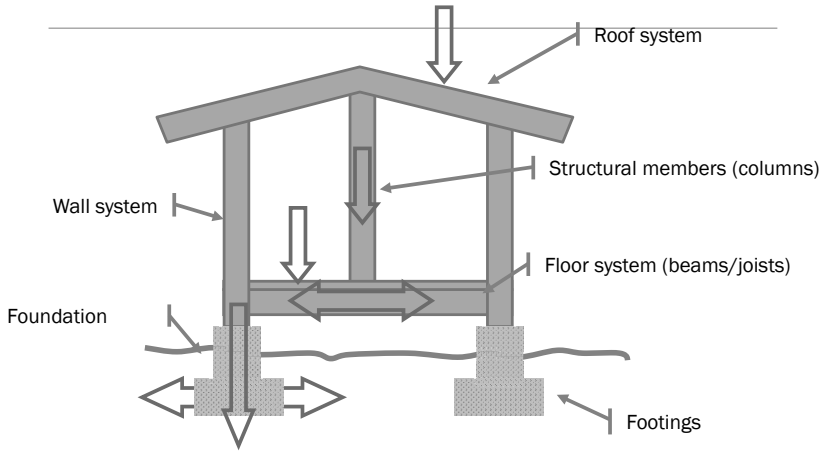
Wall supports no structural load

Construction feature that supports no load other than its own weight and moderate loads

- Wind
- Fabric canopies
- Window frames and glazing
- Curtain walls

The "Works"

Load Transfer



Structural Gravity Systems: Foundations

Footings
- Spread or continuous footings

Foundation walls

Piles
- Augured or drilled
- Friction or end-bearing

Pile caps

Structural Gravity Systems: Superstructure

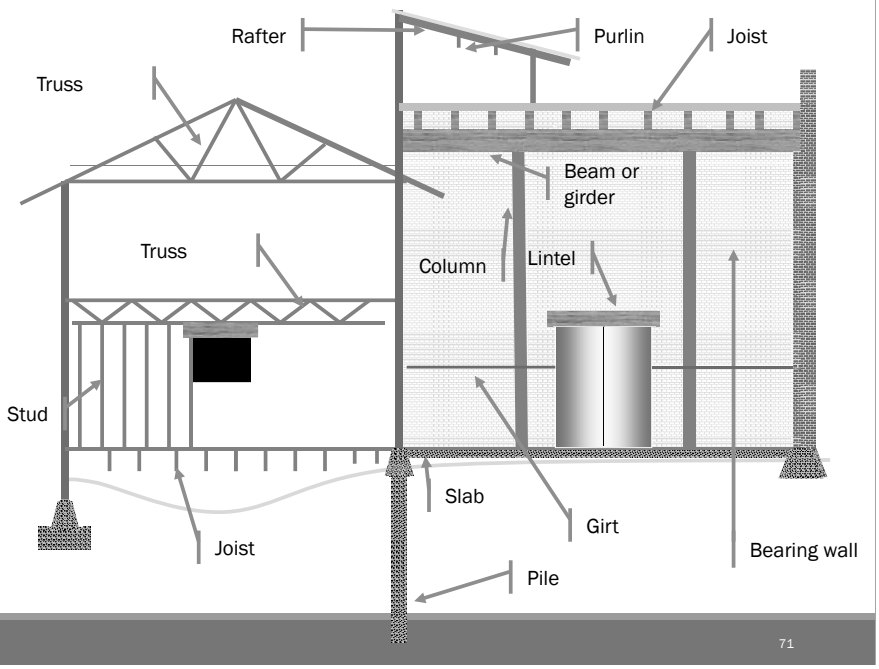
Beams, joists, rafters, purlins, girders

Ridge beams, headers, lintels

Columns, pilasters

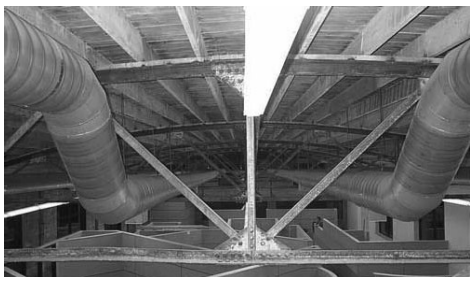
Trusses

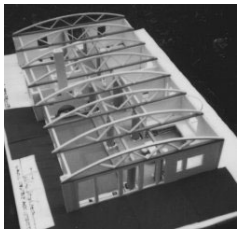
Bearing walls
- Wood or steel stud
- CIP concrete
- Reinforced and unreinforced masonry



A Word (or Two) on Trusses

Fire service has paid particular attention to truss behavior since July 1, 1988
- Hackensack, New Jersey Ford dealership: 5 fire fighters killed

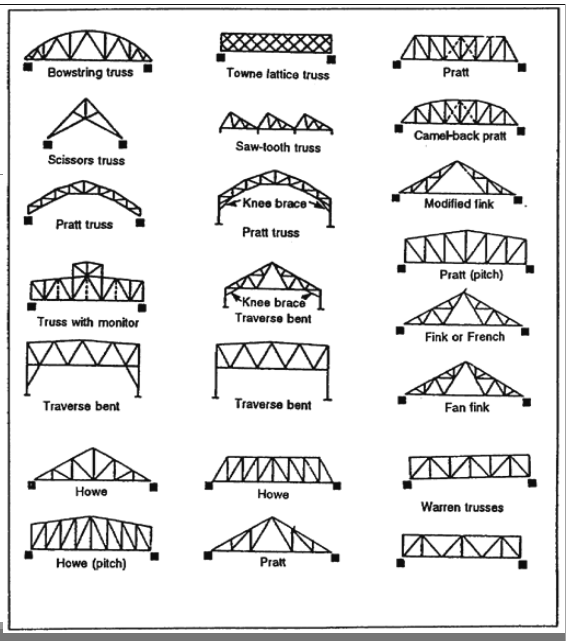




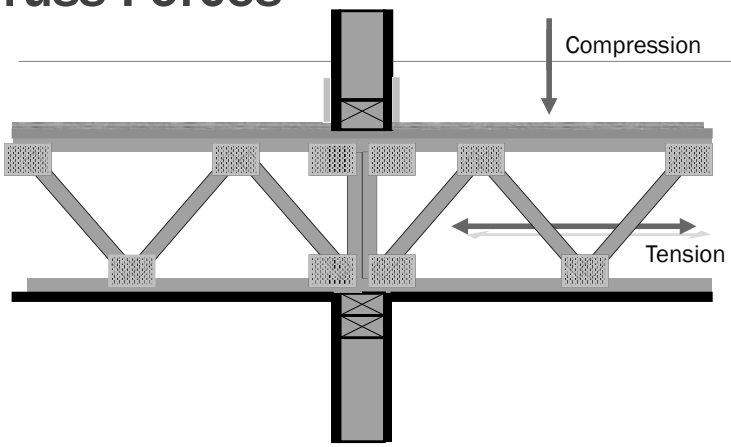
Trusses

A static structure consisting of straight slender members inter-connected at joints into triangular units

Truss Types

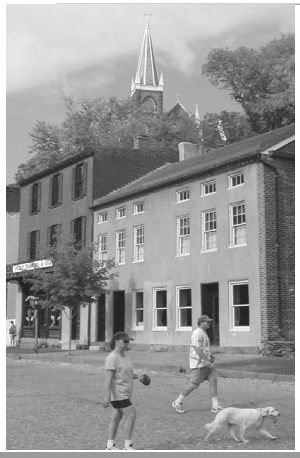


Truss Forces



Truss Failure: Fire

Masonry



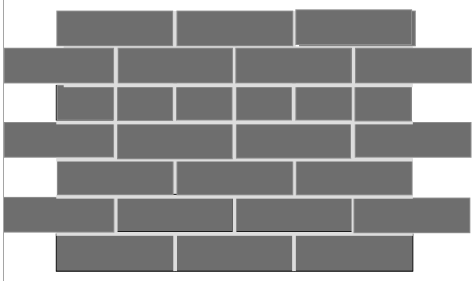
Brick, block, tile, concrete masonry unit (CMU)

May be reinforced or unreinforced

Assume <u>any</u> brick building built before 1930 is unreinforced

- Community redevelopment plans
- Remodeling efforts
- Post earthquake demand

Identifying Unreinforced Masonry



There is no reliable way

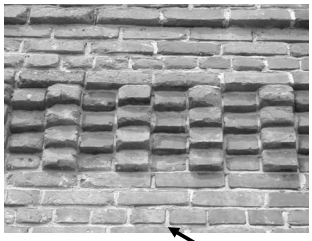
- Several wythes (thickness) of brick are used to support load
- Header course (King or stretcher row) every 5 or 6th course ties wythes

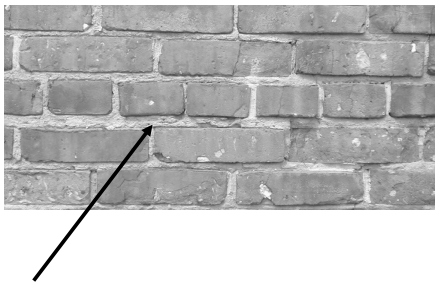
"Collapsing roofs often bring down masonry walls. Where a roof collapse is anticipated, fire fighters should be withdrawn beyond the wall collapse area." – Frank Brannigan

Unreinforced Masonry

May only be cosmetic for historic "authenticity"

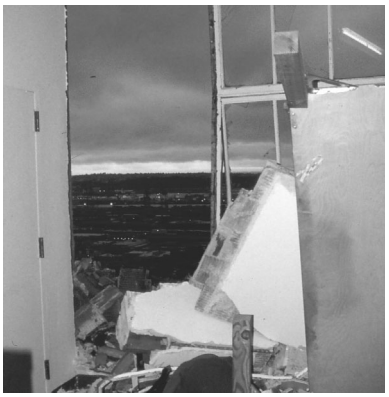
Assume all masonry walls are unreinforced!





King Row

Unreinforced Masonry



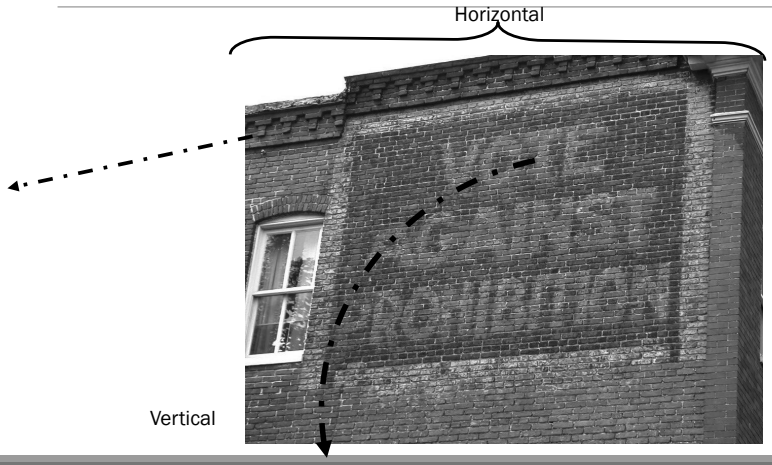
Collapse Zones

"Ordinary masonry, assuming no explosion or internal pressure, will fall within a distance of from the wall equal to <u>one-third its height</u>, but bricks may bounce or fall further." NFPA *Fire Protection Handbook,* 16th Edition

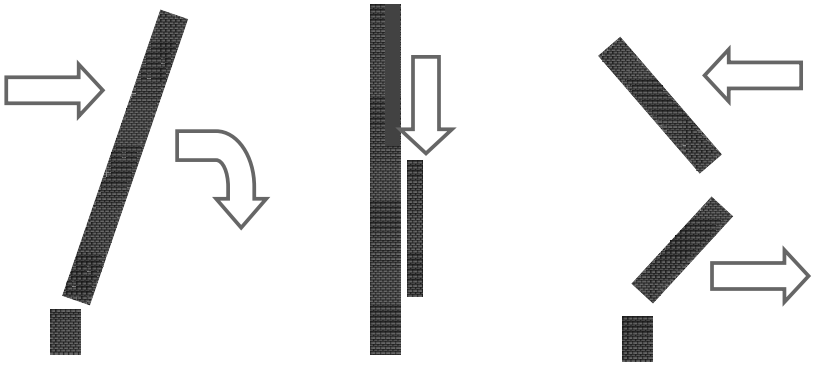
- Don't believe it!

"Fireground experience has shown this statement to be incorrect. It is a serious underestimation of the distance a wall may collapse" – Vincent Dunn

Collapse Modes

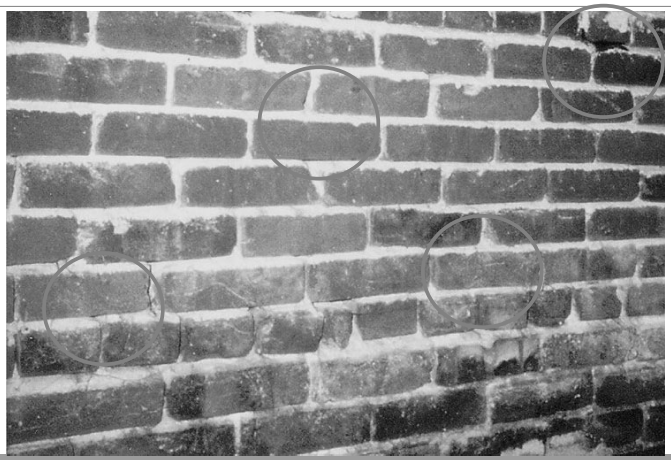


URM Collapse Modes



90° Angle | Curtain Wall | Inward/Outward

Deteriorated Mortar Joints



Lateral Force Damage

Reinforced Masonry Structures

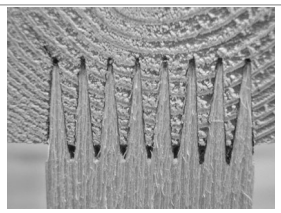
Known since 1755, not prevalent in US until 1930s

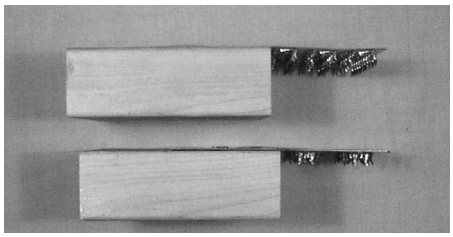
- Generally two brick wythes with grout-filled cavities
- Vertical and horizontal reinforcements are provided

Wood: Light Frame

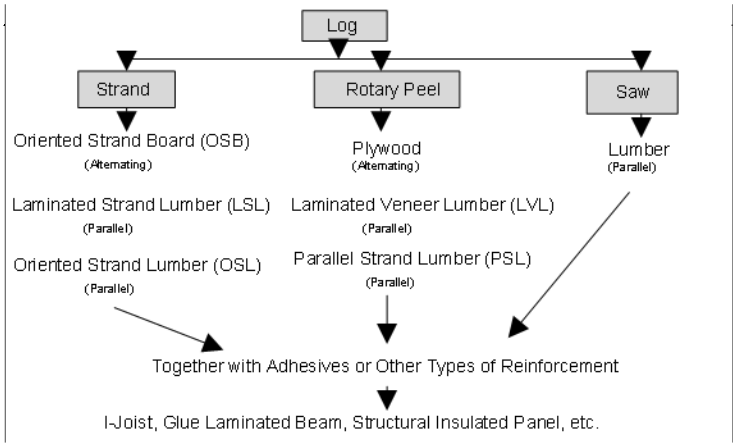
"Fire fighters operating on, in, or under burning wooden structures are in a hazardous situation."
– Frank Brannigan

“New” Wood



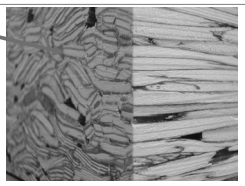
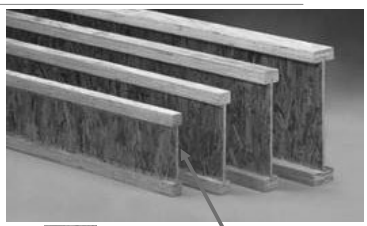



Engineered Wood Products

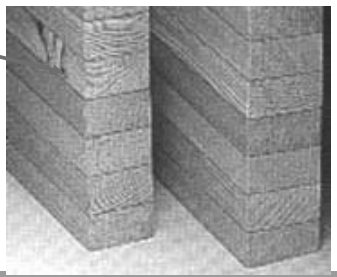


Engineered Wood Products

Parallel Strand Lumber

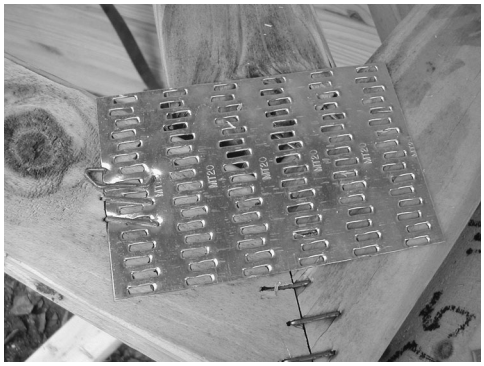
Glu-Lam




Truss Joist®

Nailer or “Gusset” Plates

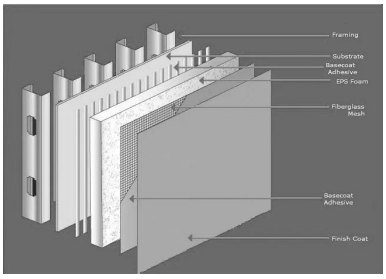
- Plates do not pull out due to fire, but joist sagging can cause failure



Engineered Wood Products

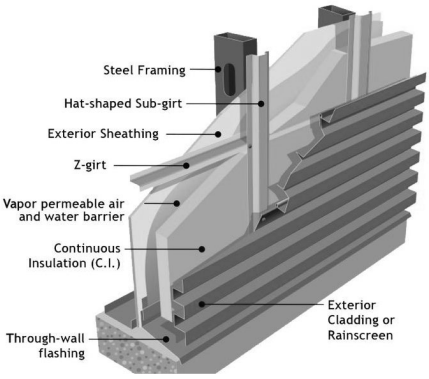
“SIPS and EIFS”

Structural insulated panels
- Used in wall and roof construction
- Expanded polystyrene foam
  - Group A plastics



“MCMS”

Metal-clad Material Systems

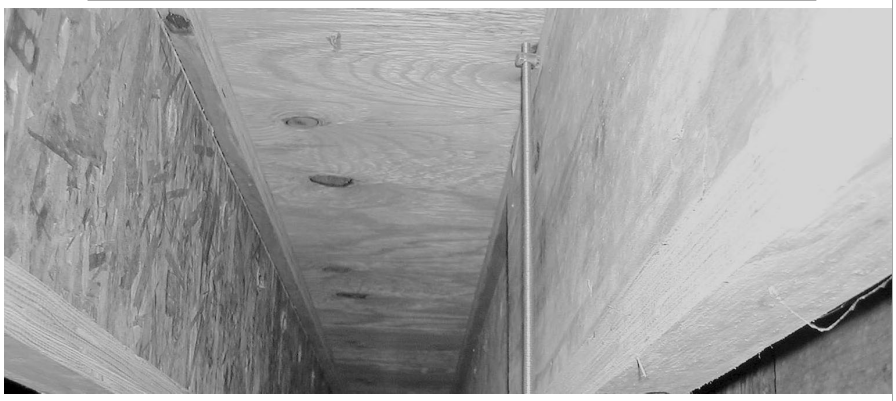


Fire, Framing and Collapse

Case Study: Lightweight Construction Baltimore County, Maryland

Laminated Plate with Hangers

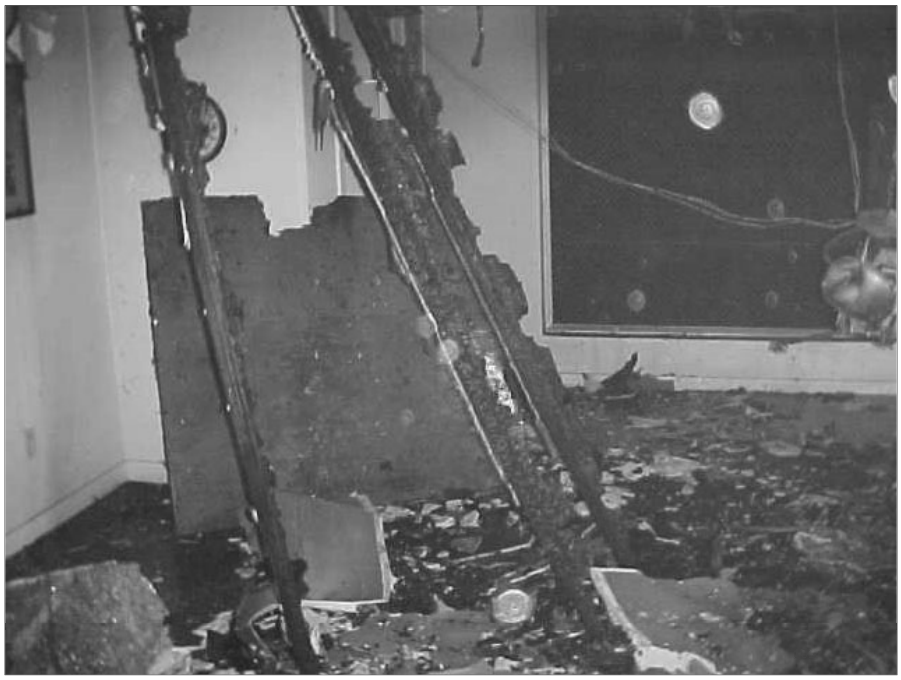
Wood joists and Wood Panel Sub-floor (Exposed)



Basement Fire

Call “Mayday”

Two fire fighters down



IRC §R501.3: Fire Protective Membrane

"Floor assemblies, not required elsewhere in this code to be fire-resistance rated, shall be provided with a 1/2-inch gypsum wallboard membrane, 5/8-incl wood structural panel membrane, or equivalent on the underside of the floor framing member."

§R302.13

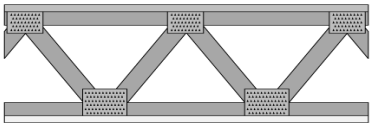
Penetrations or opening for ducts, vents, electrical outlets, lighting devices, luminaires, wires, speakers, drainage, piping and similar openings of penetrations shall be permitted.

Fire Protective Membrane

Protect light-weight floor systems in unfinished basements by attaching a membrane to the bottom of joists:

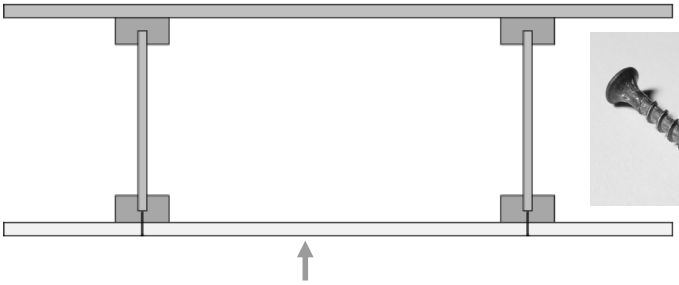
- 1/2-inch gypsum wallboard (GWB),
- 5/8-inch wood structural panel (plywood, oriented-strand board [OSB] or composites), or
- Equivalent.

Cold-Formed Steel



Floor Trusses

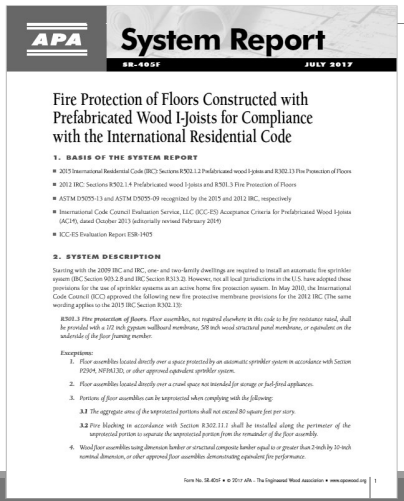
Fire Protective Membrane



Protect light-weight floor systems in unfinished basements by attaching a membrane to the bottom of joists.

1 1/4-inch Type W drywall screws up to 12 inches on center

Fire Protective Membrane Requirements



APA **System Report**

SR-405F JULY 2017

Fire Protection of Floors Constructed with Prefabricated Wood I-Joists for Compliance with the International Residential Code

1. BASIS OF THE SYSTEM REPORT

- 2015 International Residential Code (IRC): Sections R501.3.2 Prefabricated wood I-joists and R302.13 Fire Protection of Floors
- 2012 IRC: Sections R502.1.9 Prefabricated wood I-joists and R501.3 Fire Protection of Floors
- ASTM D5055-13 and ASTM D5055-09 recognized by the 2015 and 2012 IRC, respectively
- International Code Council Evaluation Service, LLC (ICC-ES) Acceptance Criteria for Prefabricated Wood I-joists (AC14), dated October 2013 (editorially revised February 2014)
- ICC-ES Evaluation Report ESR-1405

2. SYSTEM DESCRIPTION

Starting with the 2009 IRC and IRC, one- and two-family dwellings are required to install an automatic fire sprinkler system (IRC Section 903.2.8 and IRC Section R313.2). However, not all local jurisdictions in the U.S. have adopted these provisions for the use of sprinkler systems as an active home fire protection system. In May 2010, the International Code Council (ICC) approved the following new fire protective membrane provisions for the 2012 IRC. (The same wording applies to the 2015 IRC Section R302.13):

R501.3 Fire protection of floors. Floor assemblies, not required elsewhere in this code to be fire resistance rated, shall be provided with a 1/2 inch gypsum wallboard membrane, 5/8 inch wood structural panel membrane, or equivalent on the underside of the floor framing member.

Exceptions:

1. *Floor assemblies located directly over a space protected by an automatic sprinkler system in accordance with Section P2904, NFPA13D, or other approved equivalent sprinkler system.*
2. *Floor assemblies located directly over a crawl space not intended for storage or fuel-fired appliances.*
3. *Portions of floor assemblies can be unprotected when complying with the following:*
   - *3.1 The aggregate area of the unprotected portions shall not exceed 80 square feet per story.*
   - *3.2 Fire blocking in accordance with Section R302.11.1 shall be installed along the perimeter of the unprotected portion to separate the unprotected portion from the remainder of the floor assembly.*
4. *Wood floor assemblies using dimension lumber or structural composite lumber equal to or greater than 2-inch by 10-inch nominal dimension, or other approved floor assemblies demonstrating equivalent fire performance.*

Form No. SR-405F • © 2017 APA – The Engineered Wood Association • www.apawood.org | 1

- ESR-1405

APA's ICC-ES® report for I-joist assemblies with equivalent fire performance

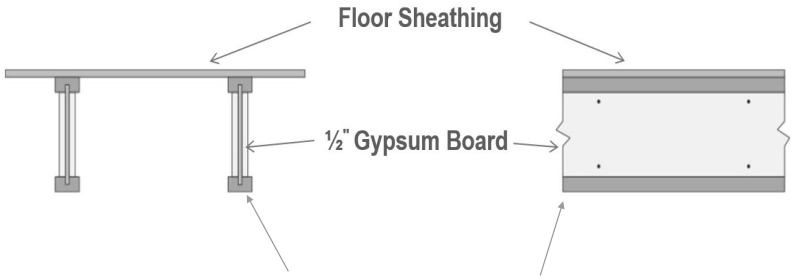
- APA Systems Report SR-405

Prescriptive assemblies for fire protection of wood I-joist floors

(Available at: www.apawood.org)

Fire Protective Membrane (Options)

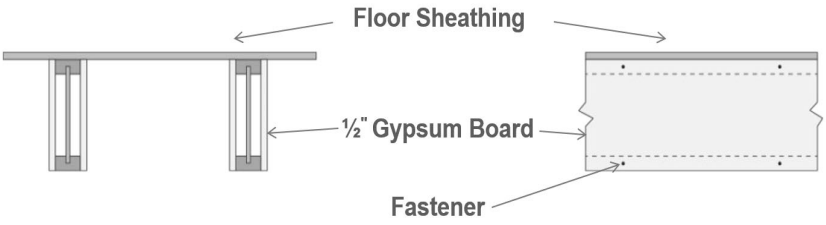
Web attachment of Gypsum Board (FP-02)



Minimum flange size:
1 - 1/2 inches x 2 inches

Fire Protective Membrane (Options)

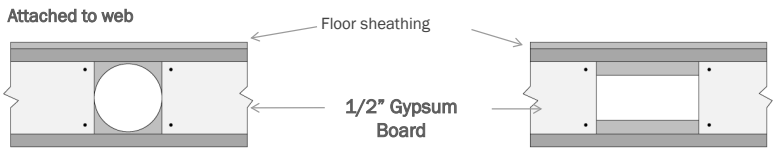
Flange Attachment of Gypsum Board (FP-03)

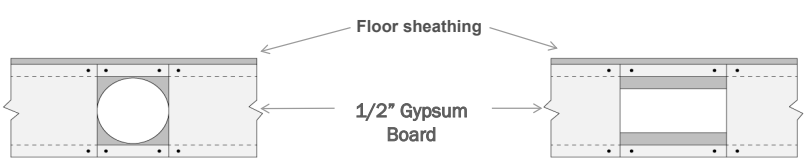


For smaller flanged I-joists
(min. 1-1/8 inches x 1-3/4 inches)

Fire Protective Membrane (Options)

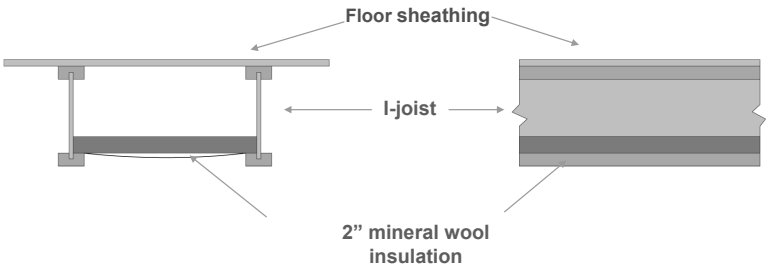
Web Attachment of Gypsum Board – Hole protection





Fire Protective Membrane (Options)

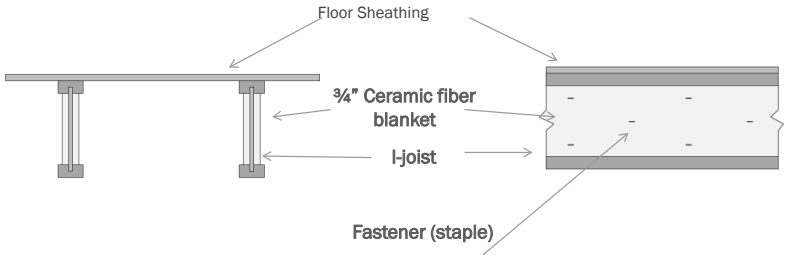
Mineral Wool Insulation (FP-04)



Minimum flange size:
1-1/8 inches thick x 1-3/4 inches wide

Fire Protective Membrane (Options)

Proprietary Ceramic Fiber Blanket Insulation (FP-05)

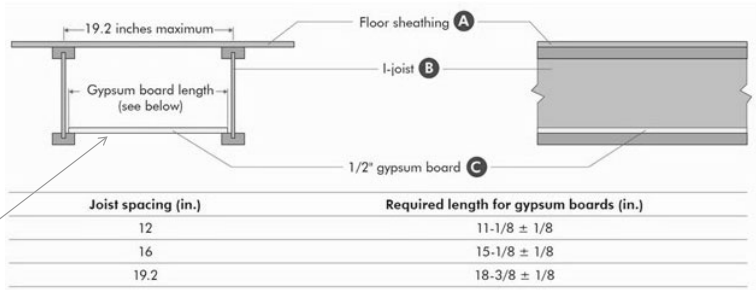


Minimum flange size:
1 1/2 inches thick x 2 1/3 inches wide

Fire Protective Membrane (Options)

Drop-in 1/2-inches Gypsum Board –

Joists spaced up to 19.2" on center (FP-06: 07/2017)



Joist spacing (in.)	Required length for gypsum boards (in.)
12	11-1/8 ± 1/8
16	15-1/8 ± 1/8
19.2	18-3/8 ± 1/8

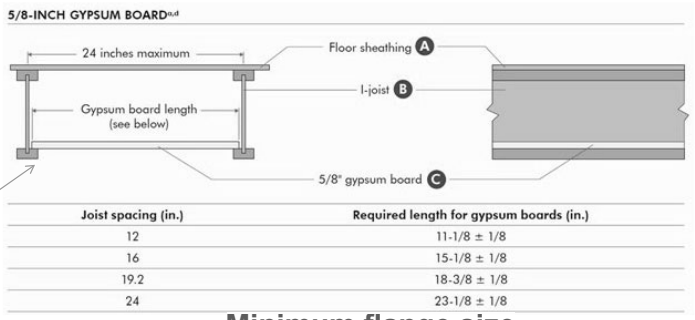
1/2-inch Gypsum board

Minimum flange size:
1 1/8 x 2 inches

Fire Protective Membrane (Options)

Drop-in 5/8-inches Gypsum Board

Joists spaced up to 24" on center (FP-07: 07/2017)



Joist spaced (in.)	Required length for gypsum boards (in.)
12	11-1/8 ± 1/8
16	15-1/8 ± 1/8
19.2	18-3/8 ± 1/8
24	23-1/8 ± 1/8

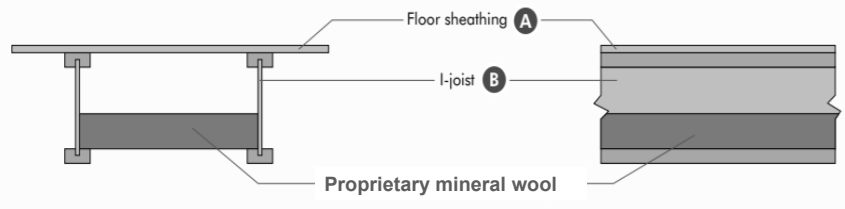
5/8-inch Gypsum board

Minimum flange size
1 1/8 x 2.0 inches

Fire Protective Membrane (Options)

Drop-in 3-inches proprietary mineral wool

Joists spaced up to 24" on center (FP-09: 07/2017)



Minimum flange size:
1 1/8 x 2 inches

Fire Protective Membrane (Options)

Fire Protective Coatings

- Factory installed protection and coatings
  - Must meet ICC-ES® Acceptance Criteria AC14
  - Look for evaluation report statement that the joist meets IRC® requirements for membrane protection
  - Availability?

Fire Protective Membrane (Options)

Fire Protective Coatings

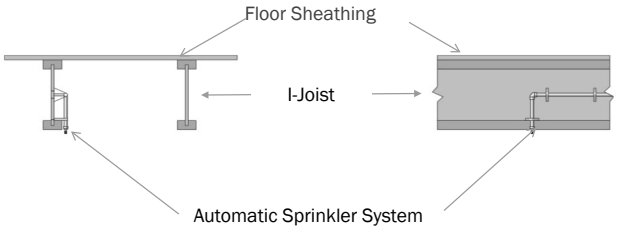
- Field-applied coatings
  - Outside the scope of ICC-ES Acceptance Criteria (AC14)
  - Certify I-joist structural and fire performance with coating company or their agency
  - Review evaluation reports and application instructions with the Authority Having Jurisdiction (AHJ) or code official
  - Recommend having documented justification for acceptance

Fire Protective Membrane (Exceptions)

Exceptions –

Gypsum board or wood structural panel not required

1. Over space protected by an automatic sprinkler system



Framing Methods

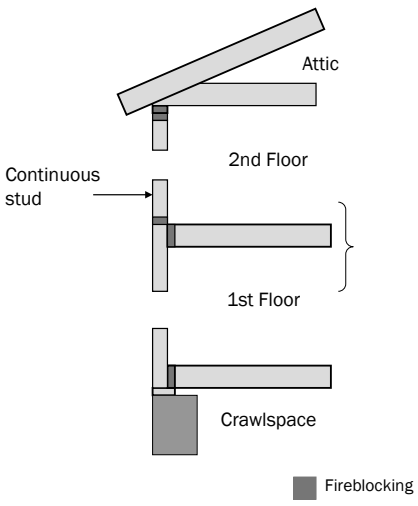
Balloon or “Western” Platform

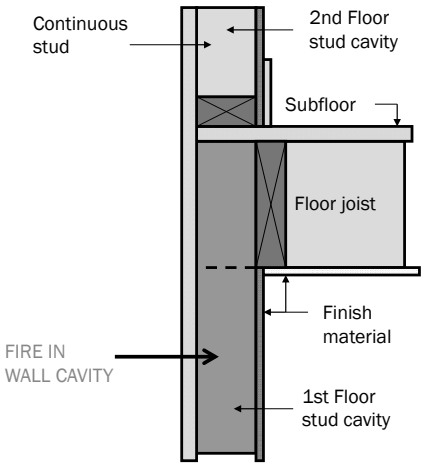
Balloon Frame

Typical pre-1940's method

- Lack of fireblocking can lead to chimney effect.

"Fire burning in balloon frame walls destroys the structural integrity of the building. Collapse is a serious threat." – Frank Brannigan





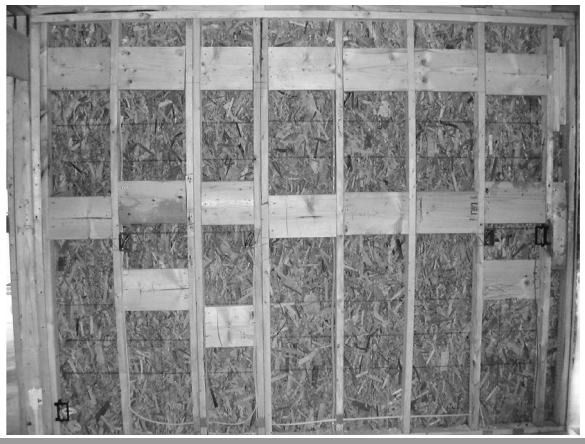
Current Method

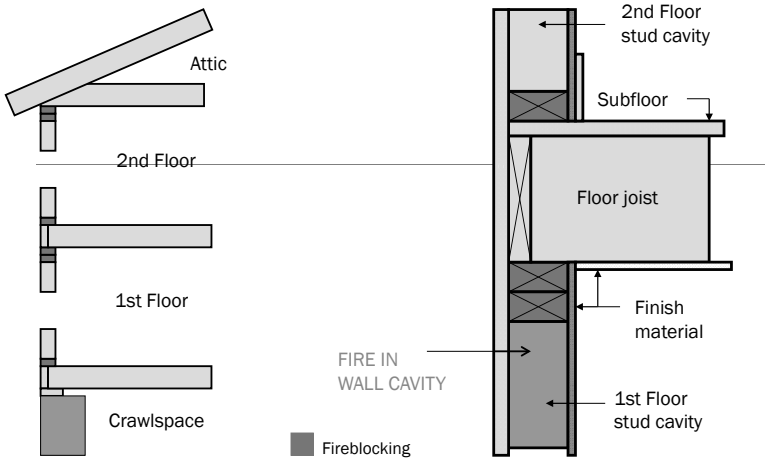
Platform frame

- Offers protection due to nature of framing.
- Fire block continuity is important.
  - Draftstopping

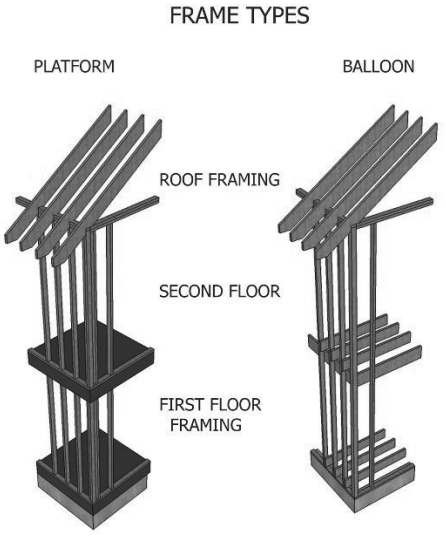
Would You Accept?

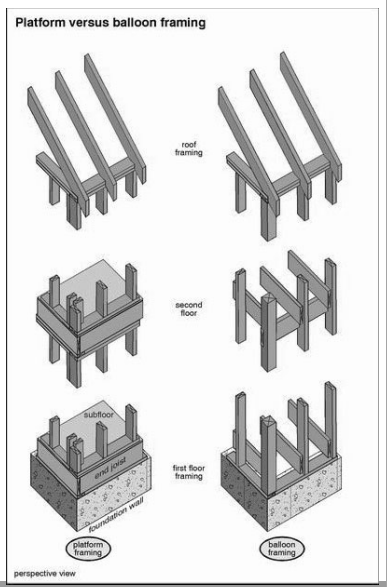
Why or why not?





"In a fire in a combustible structure, it is best to assume that no firestopping was installed. Then, any surprise will be pleasant rather than unpleasant." – Frank Brannigan





Conventional Wooden Framing

Not structurally "engineered"

Based on construction experience

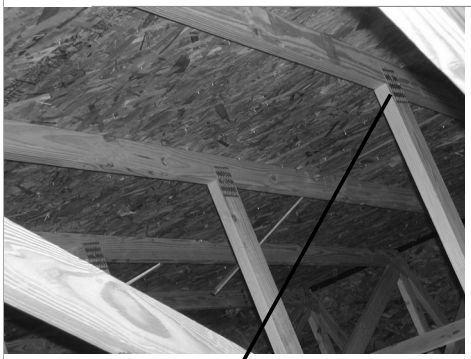
- "We've always done it this way."

Combustible Fuels

Engineered Wood

Fire Resistance Not Required

Lightweight Trusses



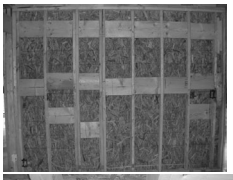
3/8-inch nailer plates or "gussets"

"Simpson" ties

Concealed Spaces

Attic

Kitchen Cabinets



Kitchen Soffit

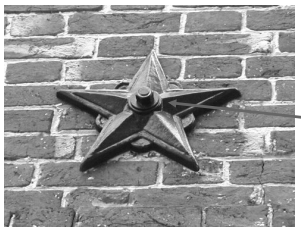
Fire Channels

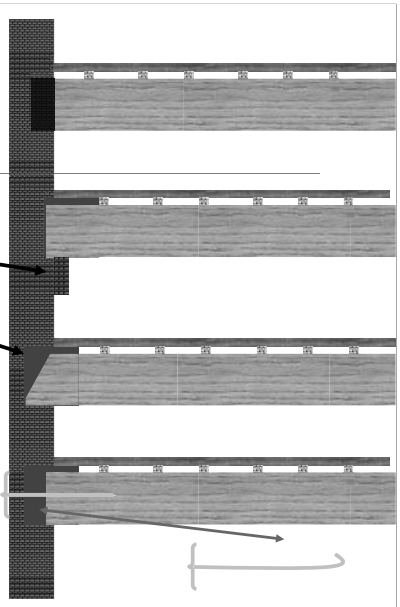
Platform Construction

Collapse Hazards

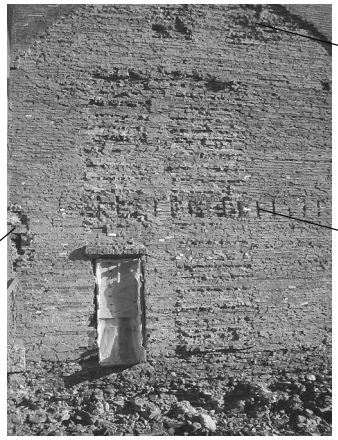
Wooden girders
- Restrained
- Corbels
- Fire cuts

Reinforcements
- Stars, “S”, circles





“The Mother of All Risks”



Gross deterioration

Missing brick

Exposed joists

Wood floor joists embedded in wall
(Once restrained by brick veneer)

Unreinforced masonry

“Defying Gravity . . . and Other Important Stuff”

PART 2: NON-COMBUSTIBLE AND FIRE RESISTIVE

Wednesday, October 26, 2022

Refresher Quiz

- This image is an example of a _____ load.

Refresher Quiz

- This image is an example of a _____ load.

Refresher Quiz

- This image is an example of a _____ load.

Refresher: The "Works"

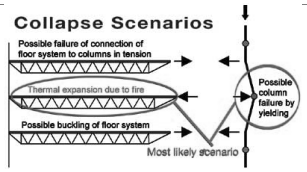
Trusses

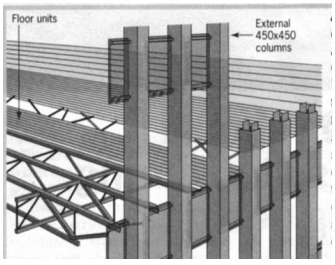
A static structure consisting of straight slender members inter-connected at joints into triangular units

Truss Failure: Snow

Truss Failure: Snow

Truss Failure: WTC





Key Features by Construction Material

Concrete
- Strong in compression
- Weak in tension

Steel
- Strong in tension
- Weak in compression

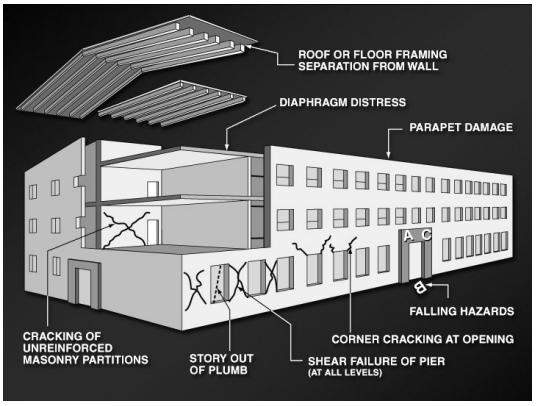
Masonry
- Brittle
- Potentially unstable
  - Reinforced or unreinforced

Concrete Shear Wall Structures

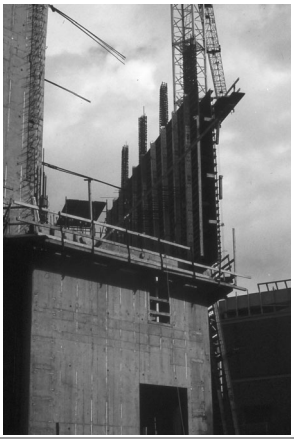
Cast-in-place concrete shear walls

- Shear walls can be located on the exterior or in the interior building core
- Lack of ductility reinforcement causes concrete spalling may result in collapse
- Code change enacted in 1976 added ductility requirements

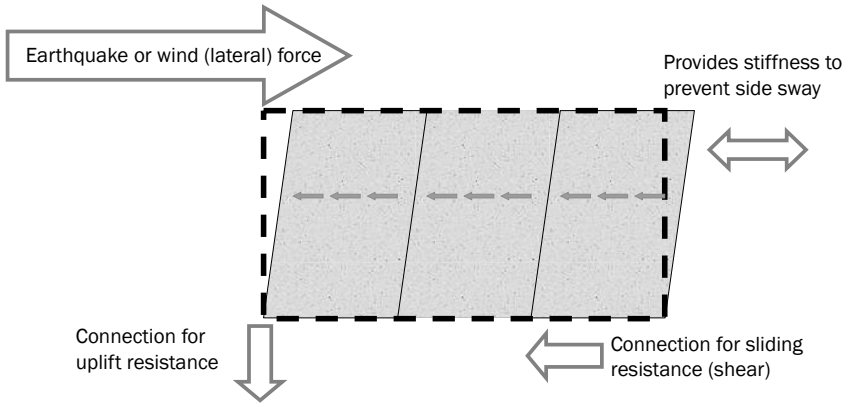
Concrete Shear Wall Structures



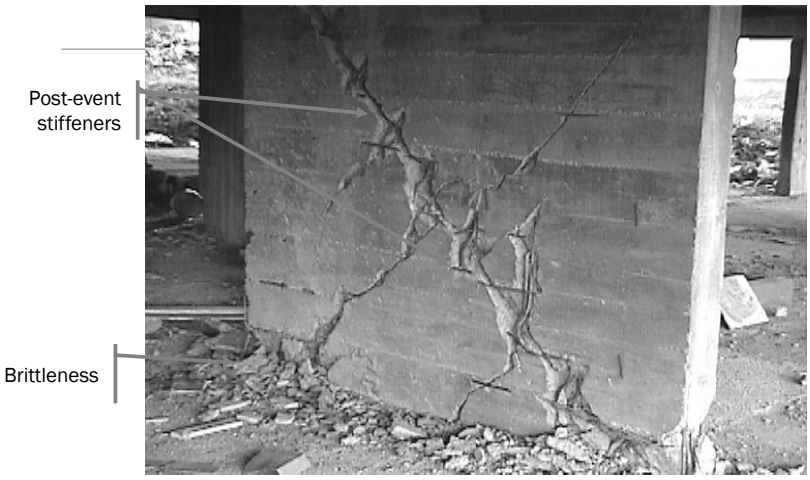
Concrete Shear Wall Structures



Shear Wall Functions

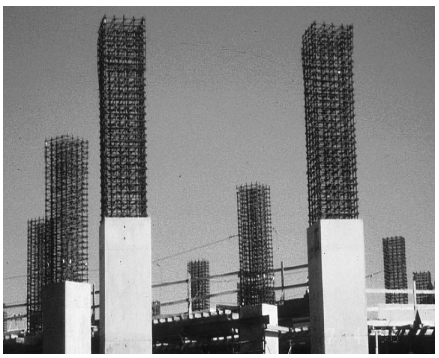


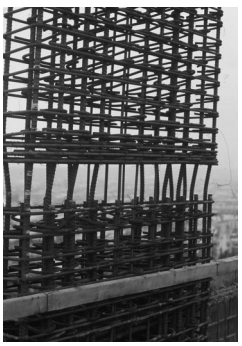
Unreinforced Masonry Shear Wall



Concrete-Ductile Moment Frame

Resists rotation around connections



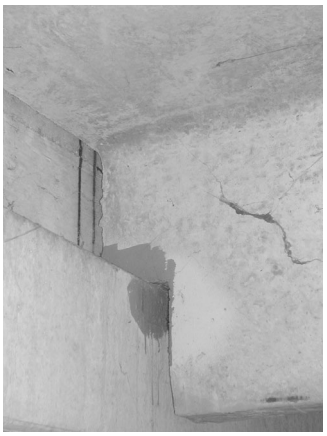


Non-Ductile Concrete Frame

Pre-Cast Concrete Structures

Poured-in-Place (Monolithic)

Pre-stressed and Post-tensioned

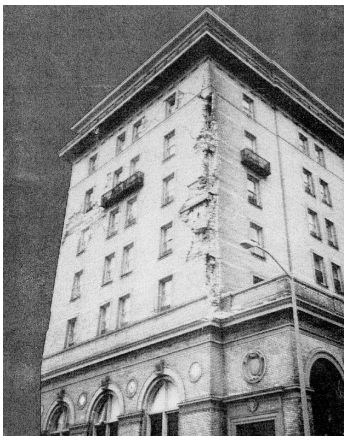


Concrete or Steel Frame with URM Infill

Concrete or steel frames are not ductile moment frames

- Unreinforced masonry (URM) walls are the only means of lateral support
- URM walls can be on the exterior or interior
- URM walls are damaged during cyclic forces due to lack of reinforcement

Concrete or Steel Frames with URM Infill



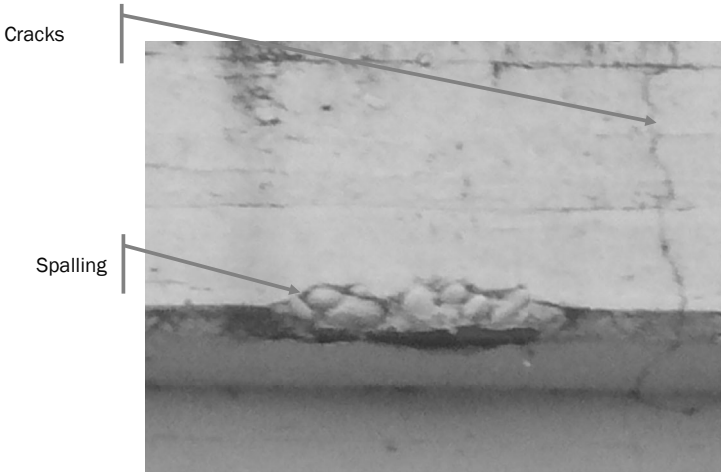
Quick Case Study

Looking at buildings in detail.

Unreinforced Masonry (URM)

Concrete Frame

Dead Loads

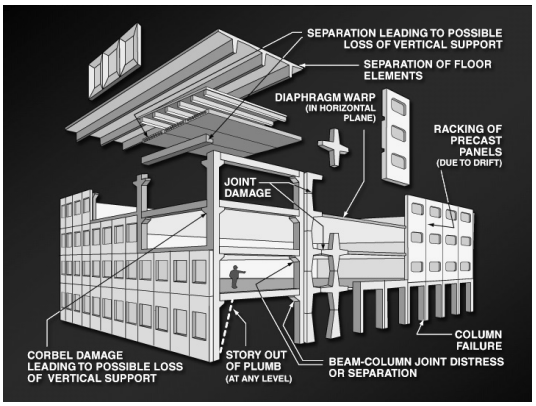

Cracks
Spalling

Pre-Cast Concrete Structures

Concrete elements are manufactured and brought to job site for assembly

- Include hollow core, single or double T sections, wall panels, column & beam sections
- Box or moment frame structures
- Connections are very important
- Connections can be damaged by water penetration

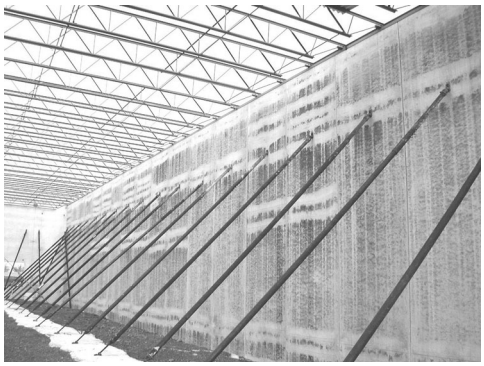
Pre-Cast Concrete Structures



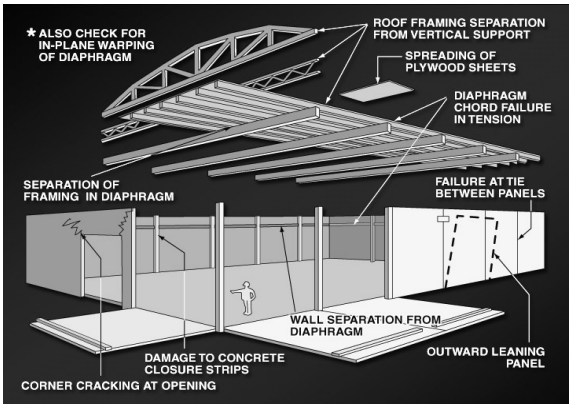
Tilt-Up Concrete Structures

Concrete tilt-up walls are formed and constructed on site on top of the floor slab

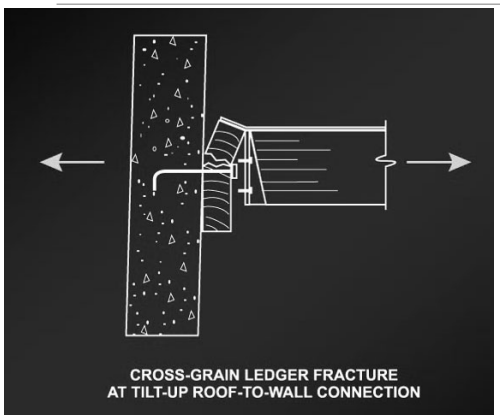
- Reinforcement and embedment plates are included in the concrete forms
- Walls are tilted-up in place and welded at the joints
- Tilt-up structures are box structures
- Connections are very important



Tilt-Up Concrete Structures

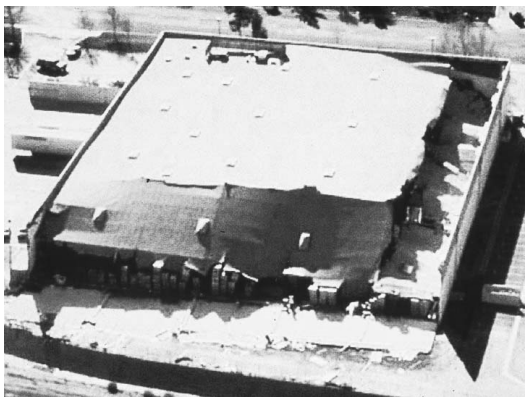


Tilt-Up Concrete Structures



Tilt-Up Concrete Structures

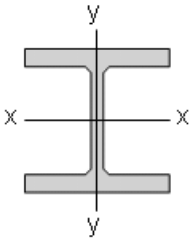
Tilt-Up Concrete Structures



Steel Moment Frame

Frames are usually constructed from wide flange sections

- Fire resistive structures (protected)
- Relies on the frame (beam-column) connection for lateral support
  - Welded or bolted connections
  - Stiffener plates



"W14 x 53"

Structural Steel Characteristics

Modulus of elasticity

- Ability to distort and restore
- 29 million psi

Softening temperature

- 752°F to 1292°F depending upon carbon content

Coefficient of expansion

- 0.00000645in/in/deg
- At 1000°F, an exposed 50-foot beam elongates almost 4 inches
- If restrained, may cause outward building expansion

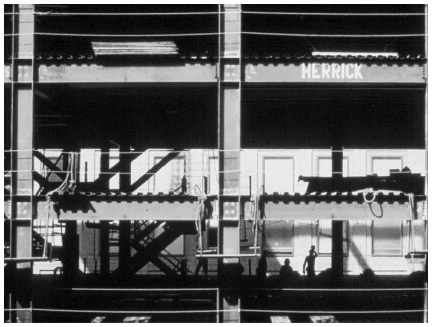
Yield point

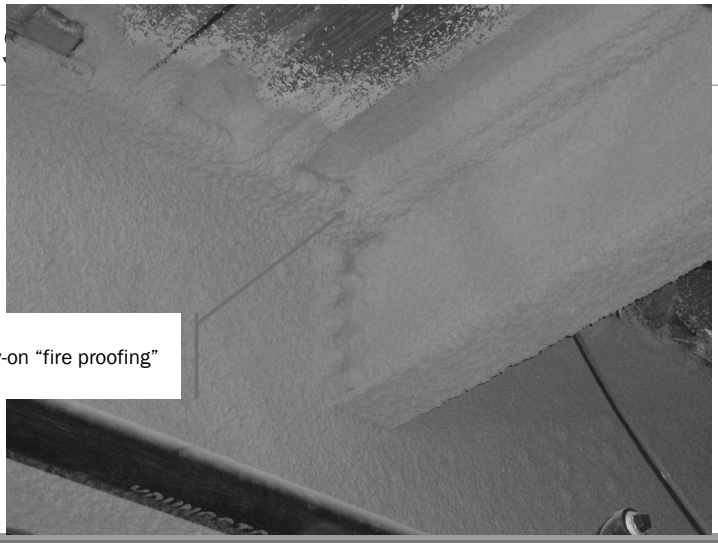
- Approximately 1300°F

Moment-Resisting Frames

Moment or rigid frames
- Concrete frames
- Steel frames

Moment connections
- Concrete ductile connections
- Welding
- Bolting
- Stiffener plates





Spray-on “fire proofing”

Steel Moment Frame

“Space” Frame

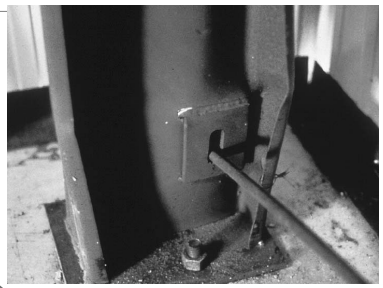
Light Steel Frame

Prefabricated light metal construction

- Generally employed in non-rated structures (unprotected)
- Lateral support by:
  - Bracing in the longitudinal direction
  - Moment frames in the transverse direction
- Braces & frames are left unprotected (without fire-proofing)
- System connections are very important

“Cooling of unprotected structural steel may well be the most important operation of a fire department at certain fires where unprotected steel structural members are being heated.” – Frank Brannigan

Light Steel Frame (Frederick Co. 26)



Column

Beam

Purlin

Light

Potential Collapse Warning Signs

Looking at the details

Collapse Indicators

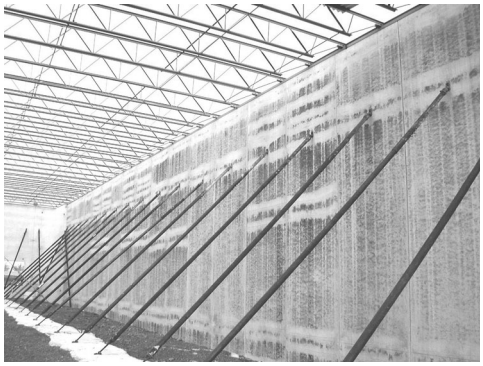
Connections usually the weakest spot

Masonry unit construction

- URM
- Poor quality brick
  - Clinkers
- Sand lime mortar

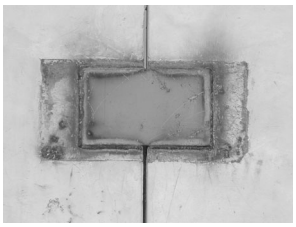
"Look at the connections and consider the effect of fire on them. For instance, do not be impressed by the slow-burning three-foot-deep laminated wood beam. It is often supported on an unprotected steel column." – Frank Brannigan

Collapse Threats



Braced walls

Heat-weakened weld plates



Collapse Threats

Cracks
- Spalling

Arches

Tiles

Holes in walls

Steel lintels

Collapse “Watch-Outs”

Trusses

Balconies/canopies
- Especially cantilevers

Hanging signs

Suspended loads

Excessive live loads

Collapse “Watch-Outs”

Deterioration

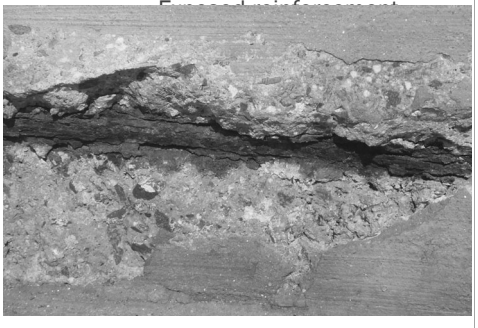
Distortion

Warning Signs

Damaged fire protection

Warning Signs

Champlain Towers South
Surfside, Florida
June 24, 2021
98 dead



Structural Fire Fighting: Rules of Engagement*

Risk Acceptability

- No building or property is worth a fire fighter's life.
- All interior fire fighting involves inherent risk.
- Some risk is acceptable, in a measured and controlled manner, when lives can be saved.
- No level of risk is acceptable when there is no potential to protect lives or property.
- Fire fighters shall not be committed to interior or offensive fire fighting abandoned, derelict or dangerous buildings.

* With credit to the International Association of Fire Chiefs

Structural Fire Fighting: Rules of Engagement

Risk Assessment

- "I am responsible for my own safety."
- All feasible measures shall be taken to limit or avoid risks through regular pre-incident planning and on-scene risk assessment by a qualified person.
- It is the Incident Commander's responsibility to evaluate risk in every situation.
- Risk assessment is a continuous process through the incident duration.
- If conditions change, and risk increases, change control objectives, strategy and tactics.
- No building or property is worth a fire fighter's life!

Building Construction Final Group Quiz

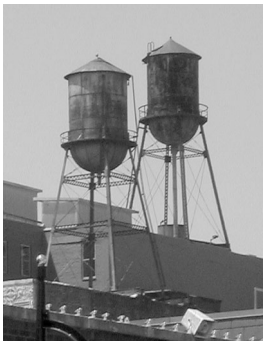
What are the potential failure points in this photograph?

Building Construction Final Quiz

What are the potential failure points in this photograph?

Building Construction Final Quiz

What are the potential failure points in this photograph?



Building Construction Final Quiz

What is the potential failure point in this photograph?

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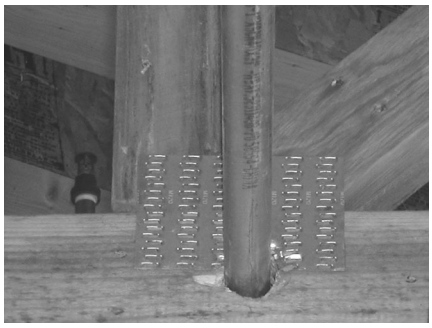


Building Construction Final Quiz

What is the potential failure point in this photograph?

Building Construction Final Quiz

What building code construction type does this image represent?

- IA
- IIB
- IIIB
- VA

Building Construction Final Quiz

What is the potential failure point in this photograph?

Building Construction Final Quiz

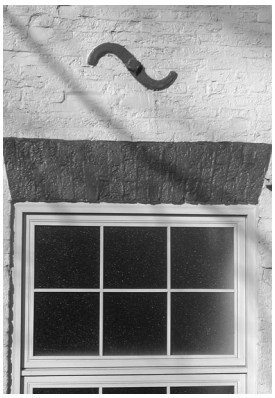
What are the potential failure points in this photograph?

Building Construction Final Quiz

What is the potential failure point in this photograph?

Building Construction Final Quiz

What are the potential failure indicators in this photograph?



Building Construction Final Quiz

What building code construction type does this image represent?

IA

IIB

IIIB

VA

Building Construction Final Quiz

What type of load is this rooftop cooling unit?

Building Construction Final Quiz

What type of steel frame does this photograph represent?

Building Construction Final Quiz

What are the potential failure modes in these pictures?

Building Construction Final Quiz

Depending upon carbon content, structural steel may soften at about _____°F and fail at about _____°F ?

Building Construction Final Quiz

All masonry buildings constructed before 1930 are unreinforced masonry. True or False?

Summary

You should be able to:

- describe the influence of “forces” and “loads” on construction.
- identify four types of “engineered wood.”
- define “ordinary” construction.
- explain the difference between balloon and platform construction
- identify the key components of non-combustible and fire resistive construction
- identify potential indicators of building collapse related to construction types

Questions??