



# NOW

## WE MOVE FORWARD

**BOMA 2022**

INTERNATIONAL CONFERENCE & EXPO  
Presented by BOMA International and BUILDINGS

JUNE 25-28 | NASHVILLE, TN

# Building Structure Condition Assessment

## How to Avoid Catastrophe

BOMA International Conference  
Monday, June 27, 2022, 2:45-3:45 PM  
Nashville, TN

# Learning Objectives

- **Building Structure Condition Assessment**

- Champlain Towers Collapse
- Structural Engineering 101
- Failure Mechanisms
  - Concrete, Masonry, Steel, & Wood
- Laws & Standards

**AIA**  
**Continuing**  
**Education**  
**Provider**

# Disclaimer

This presentation is intended to provide general information only regarding the subject matter covered. The contents of this presentation, written or auditory, are not to be considered a professional opinion nor a substitute for obtaining the advice and council of a licensed professional who specializes in this subject matter.



# Innovative Engineering, Inc.



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  - **BSCE University of Michigan**
  - **Graduate Studies:**
    - San Jose State University
    - Georgia Institute of Technology
  - **Level I sUAS Thermographer**
  - **BESI Building Envelope Certified Level 2**
  - **Haag Certified Inspector – Commercial Roofs**
  - **Author, Presenter, Educator**



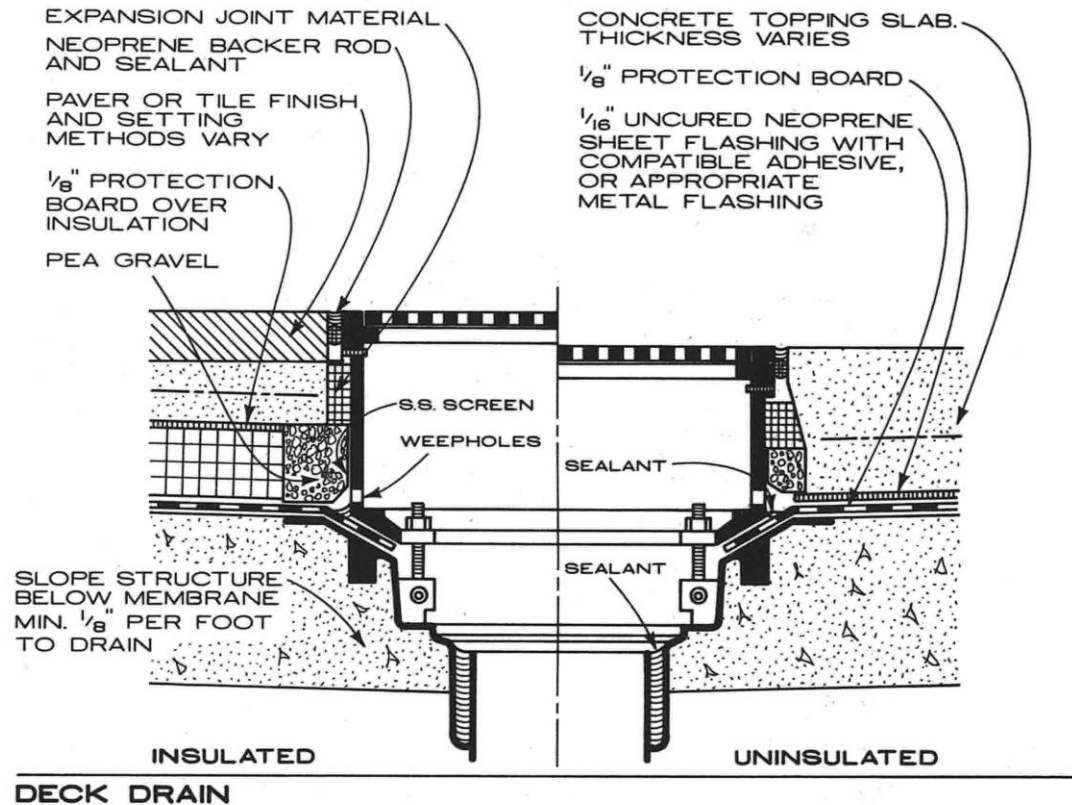
# Champlain Towers Collapse

- Built 1981
- 12 Story, 136 Units
- Cast-In-Place Concrete
- Plaza Slab
- Below Grade Level Parking Garage
- 2018 Report
- 40 Year Recertification Underway

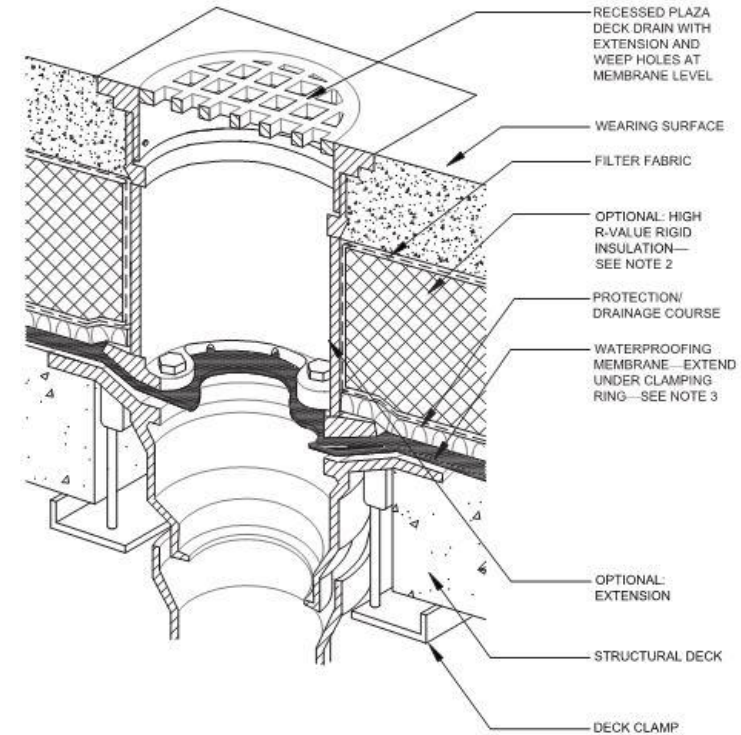




# Plaza Slabs – Protected Membranes

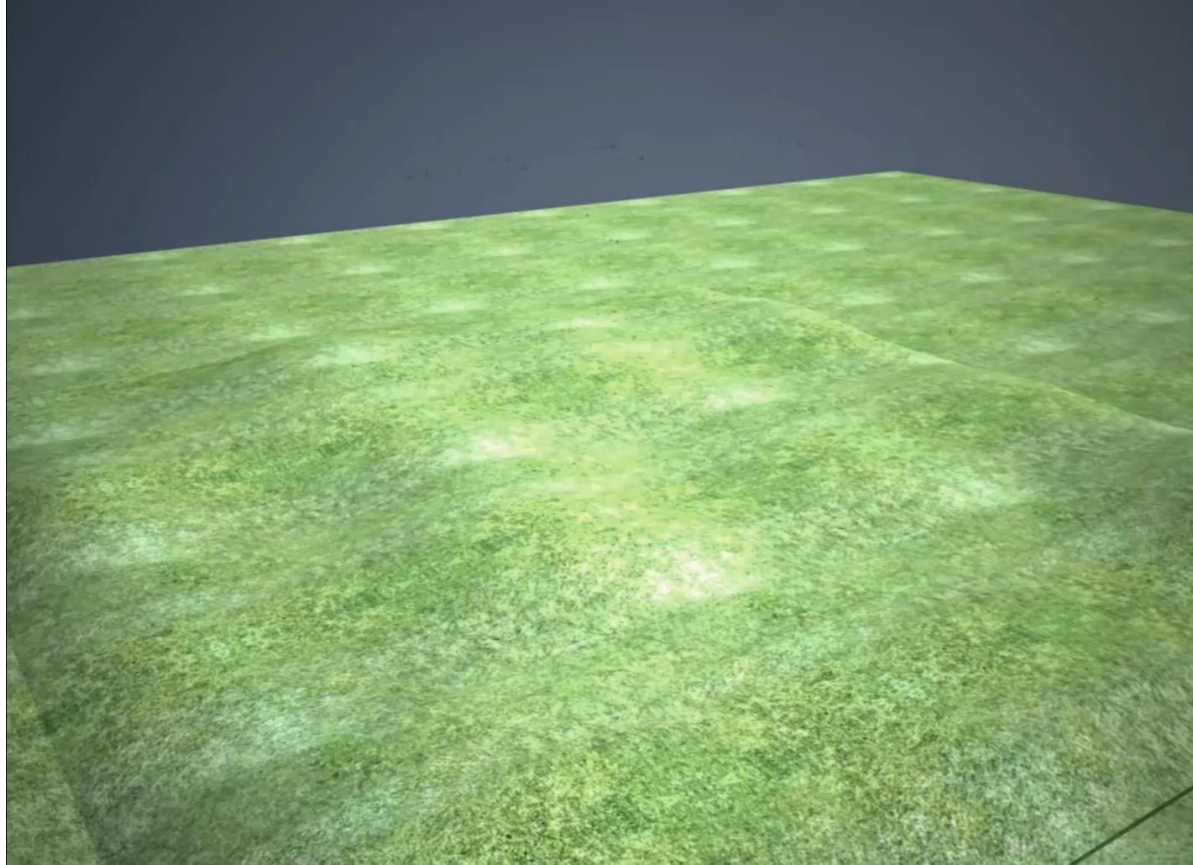


Ref.: 1981 Architectural Graphics  
Standards



Ref.: NRCA Detail WP-24

# Building Structure - Definitions



Credit: James Burke

- **Foundations**
- **Columns**
- **Beams**
- **Slabs**

# Building Structure - Columns

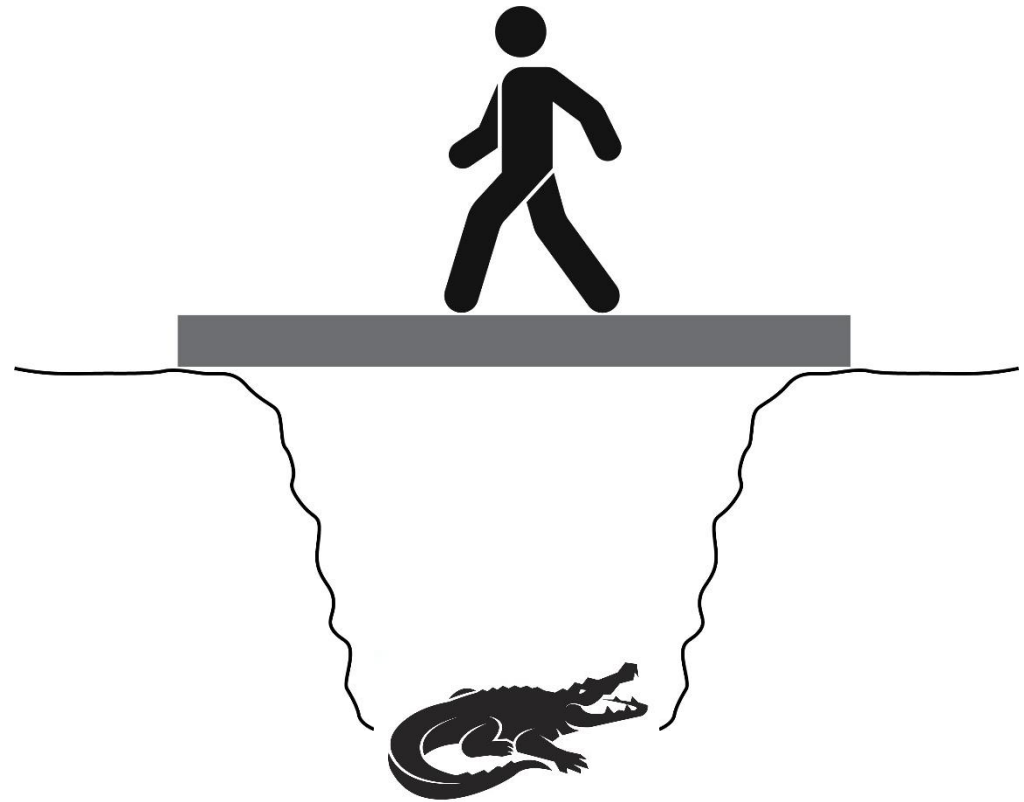
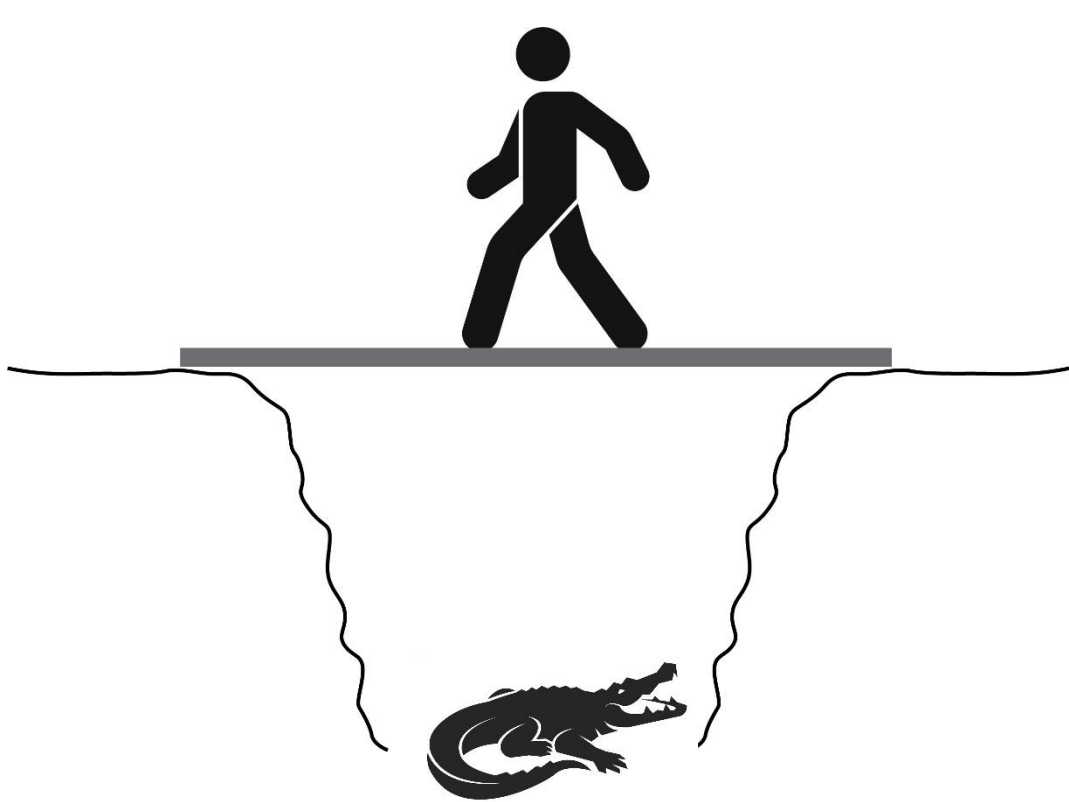
- **Failure Modes**

- Stress
  - Pure Compression
  - Combined Stresses
  - Shear
  - Lack of Confinement
  - Torsion
- Buckling

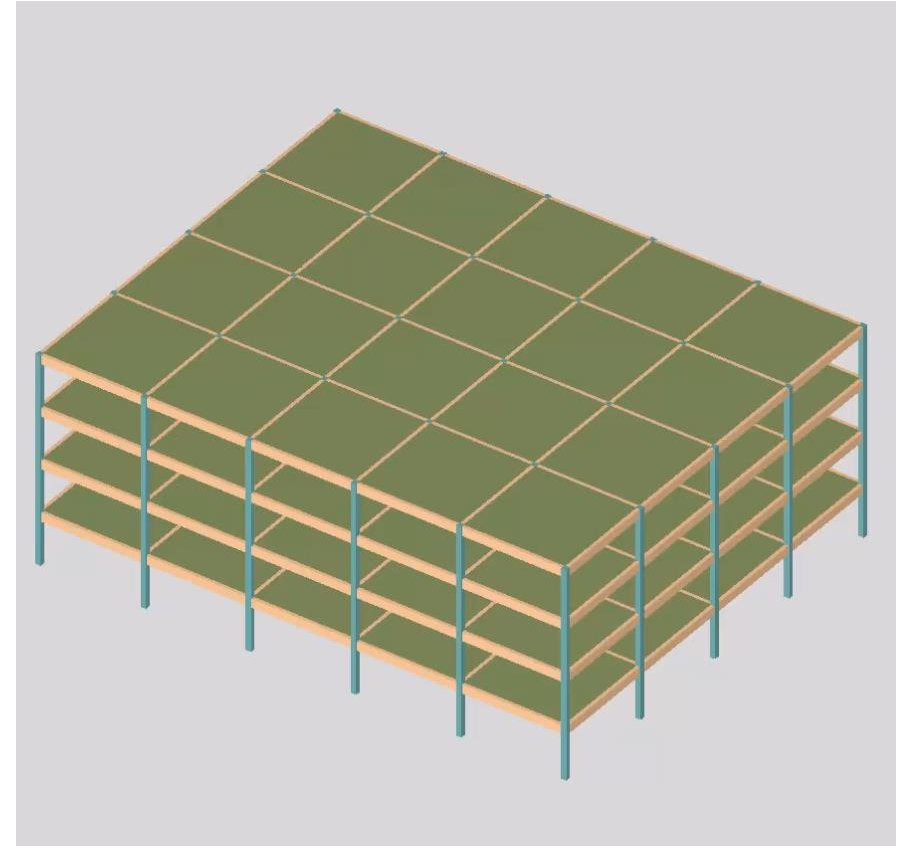
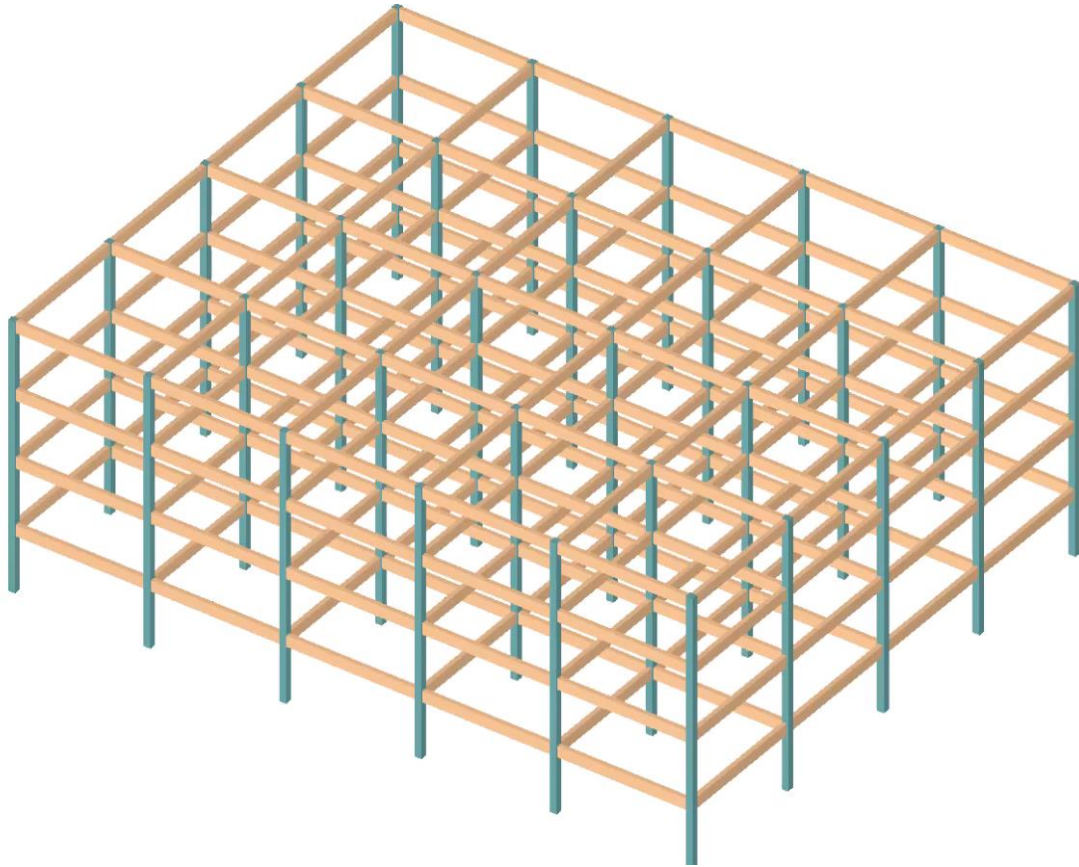




# Building Structure – Beams and Slabs



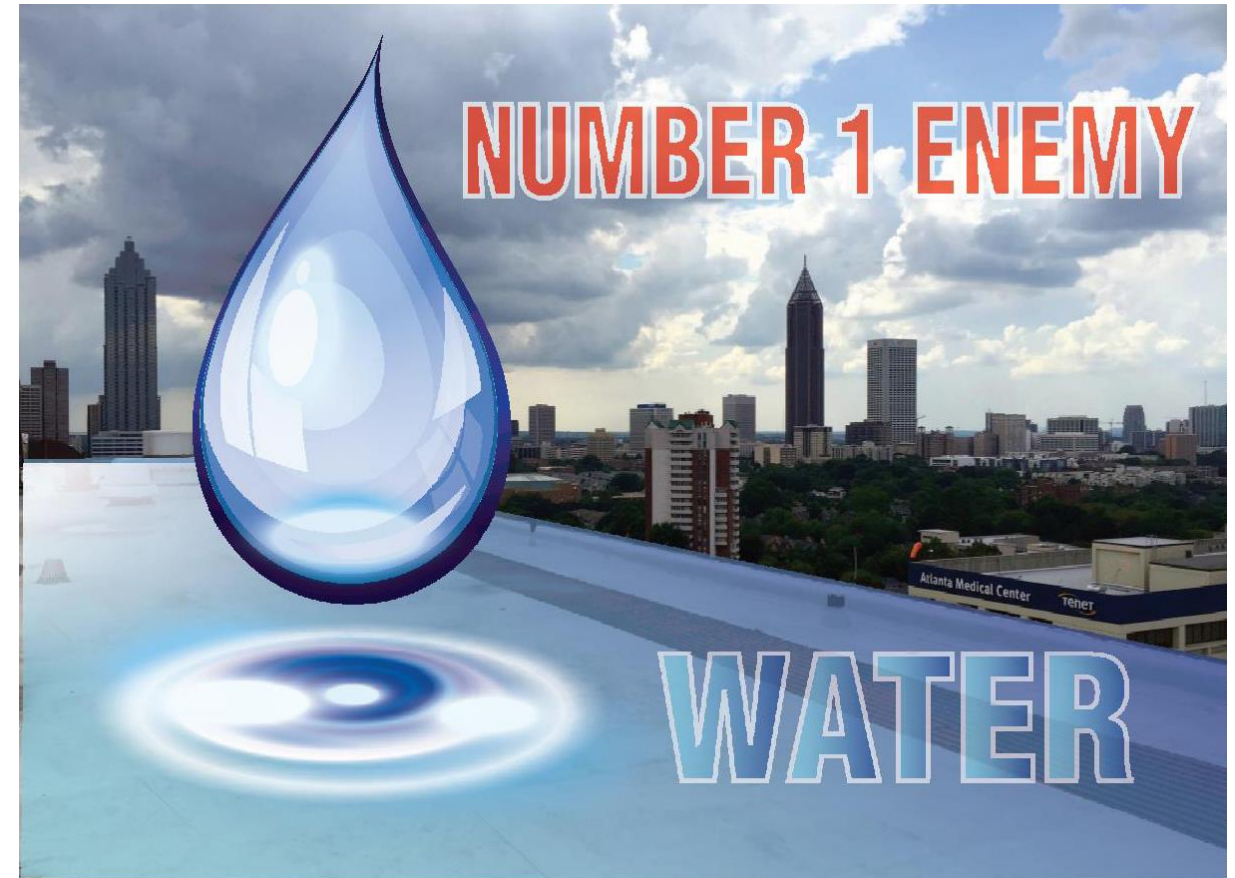
# Building Structure – Progressive Collapse



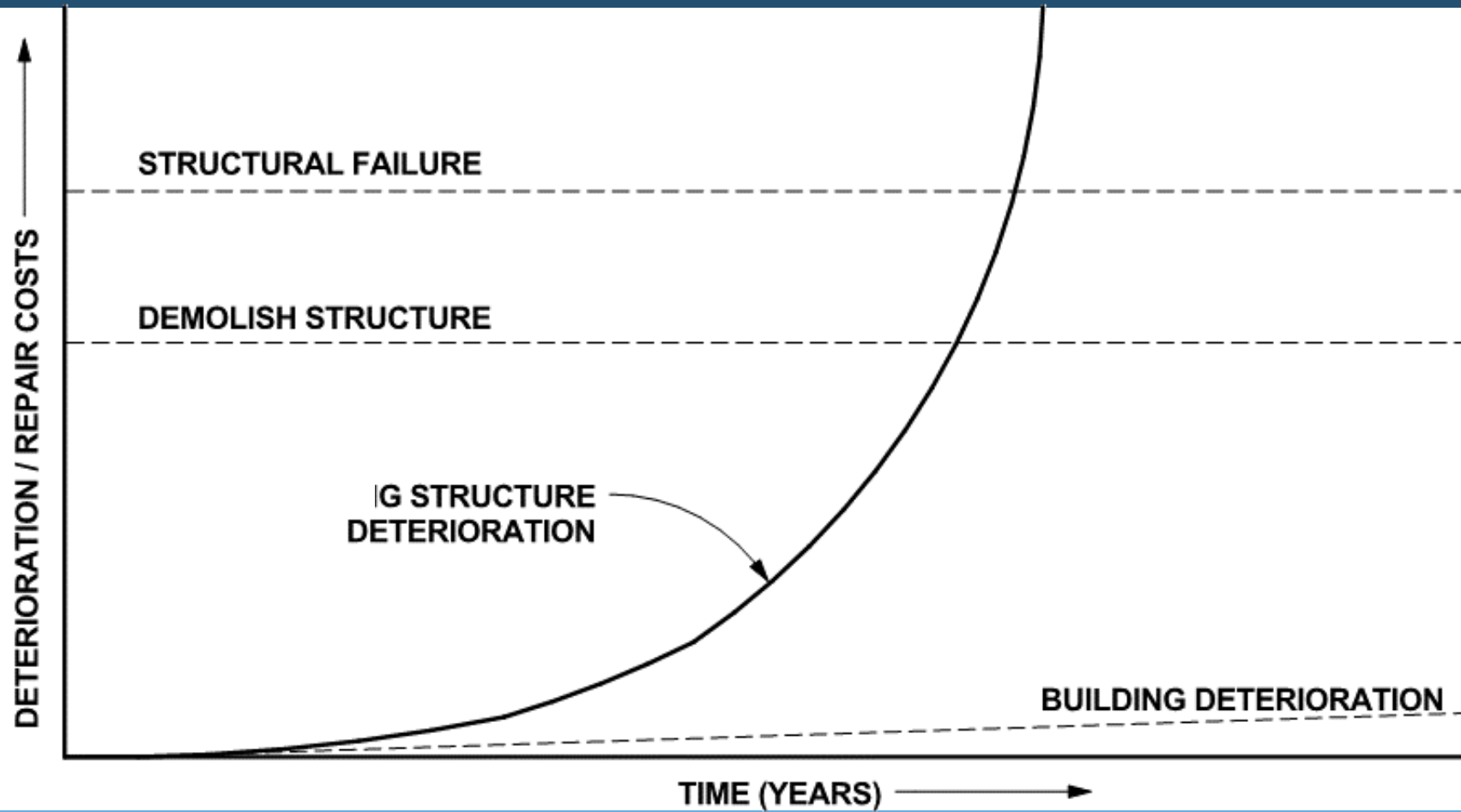
ASI Extreme Loading

# Building Science – Sources of Deterioration

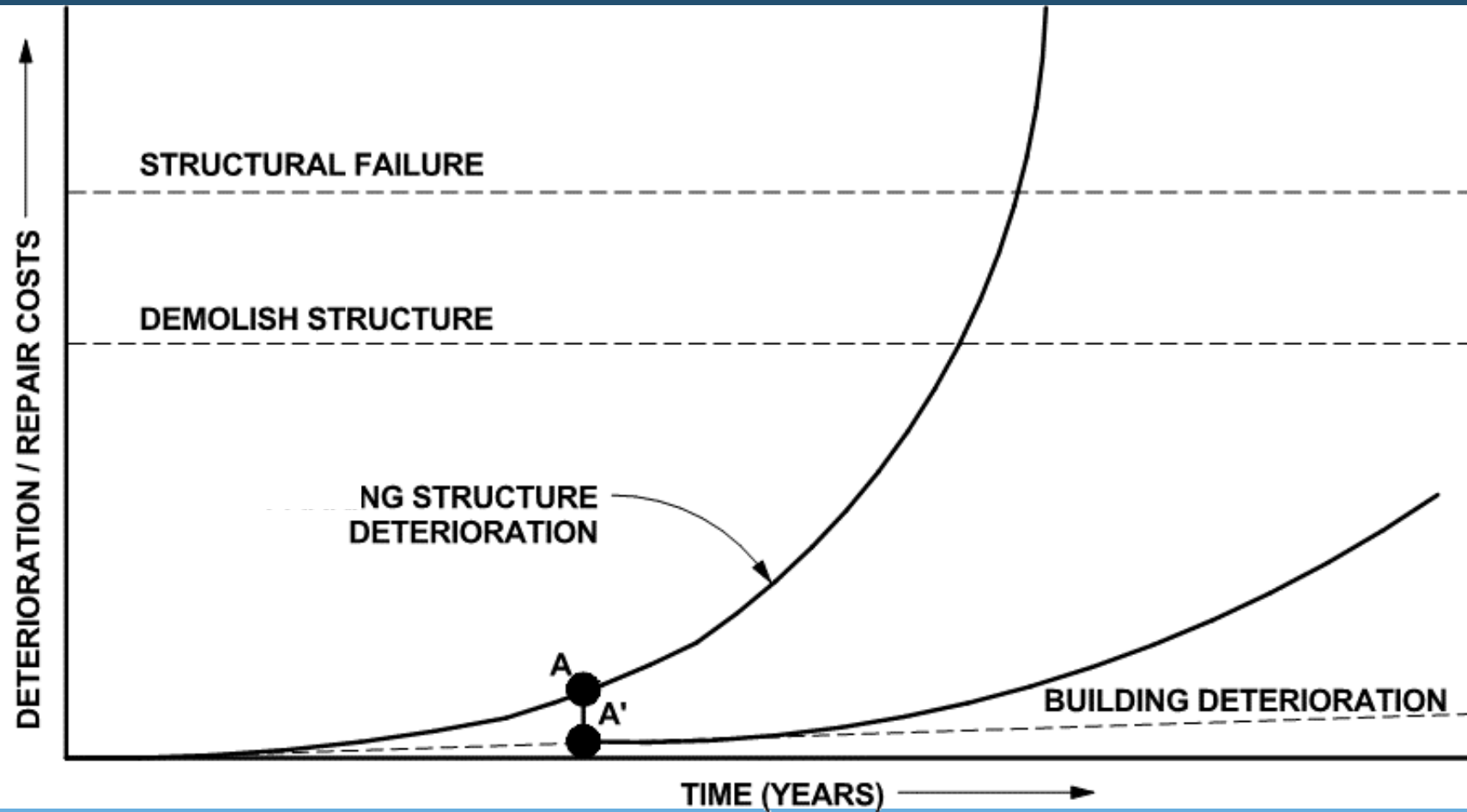
- Water Damage
  - Mold
  - Corrosion
  - Rot
  - Termites & Insects
- Movement of Materials
  - Thermal
  - Moisture
  - Elastic Deformation
  - Creep
- Other
  - Impact Damage
  - Lightning Strike
  - Overload
  - Wind, Earthquake, Flood



# Deferred Maintenance Cost Curve

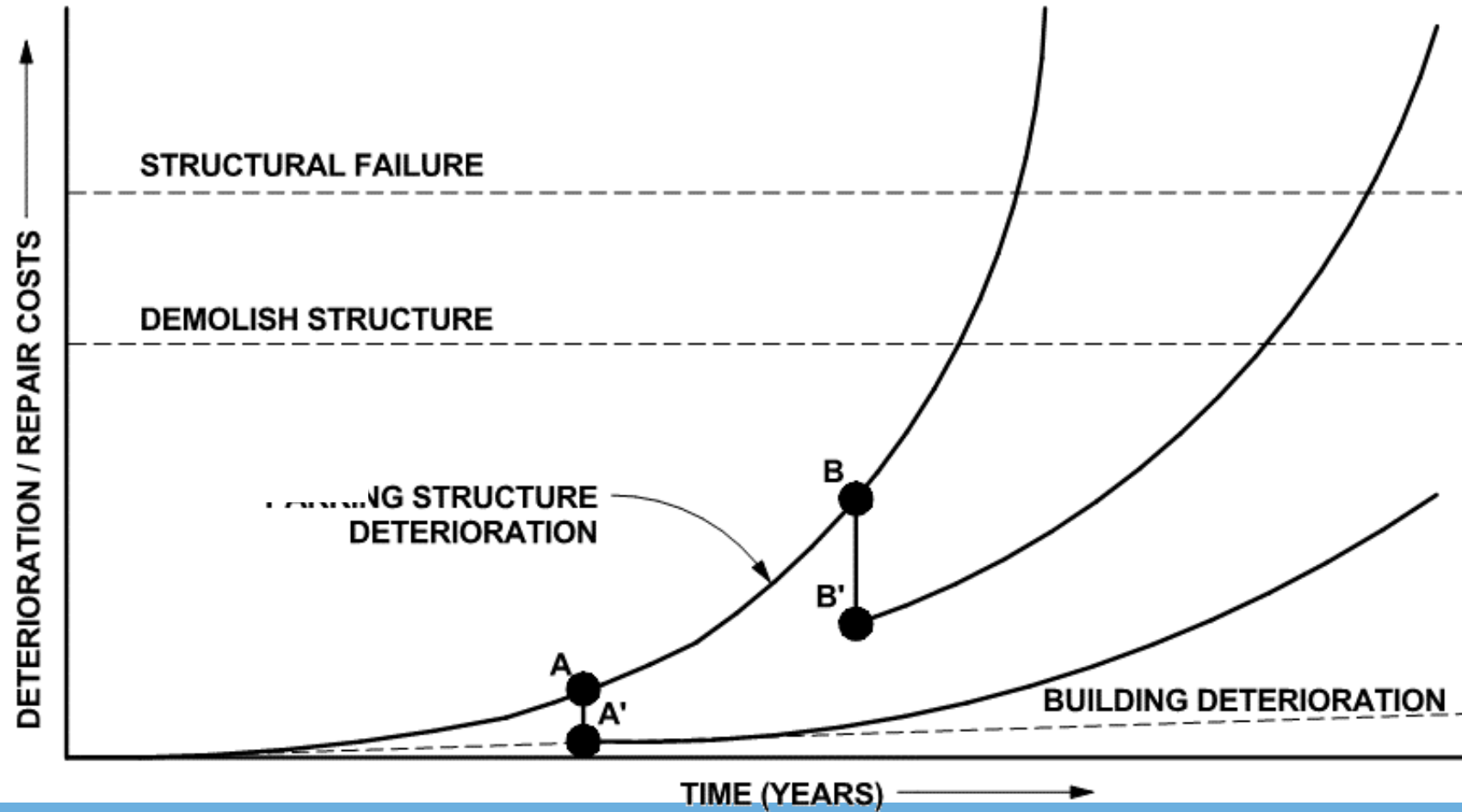


# Deferred Maintenance Cost Curve

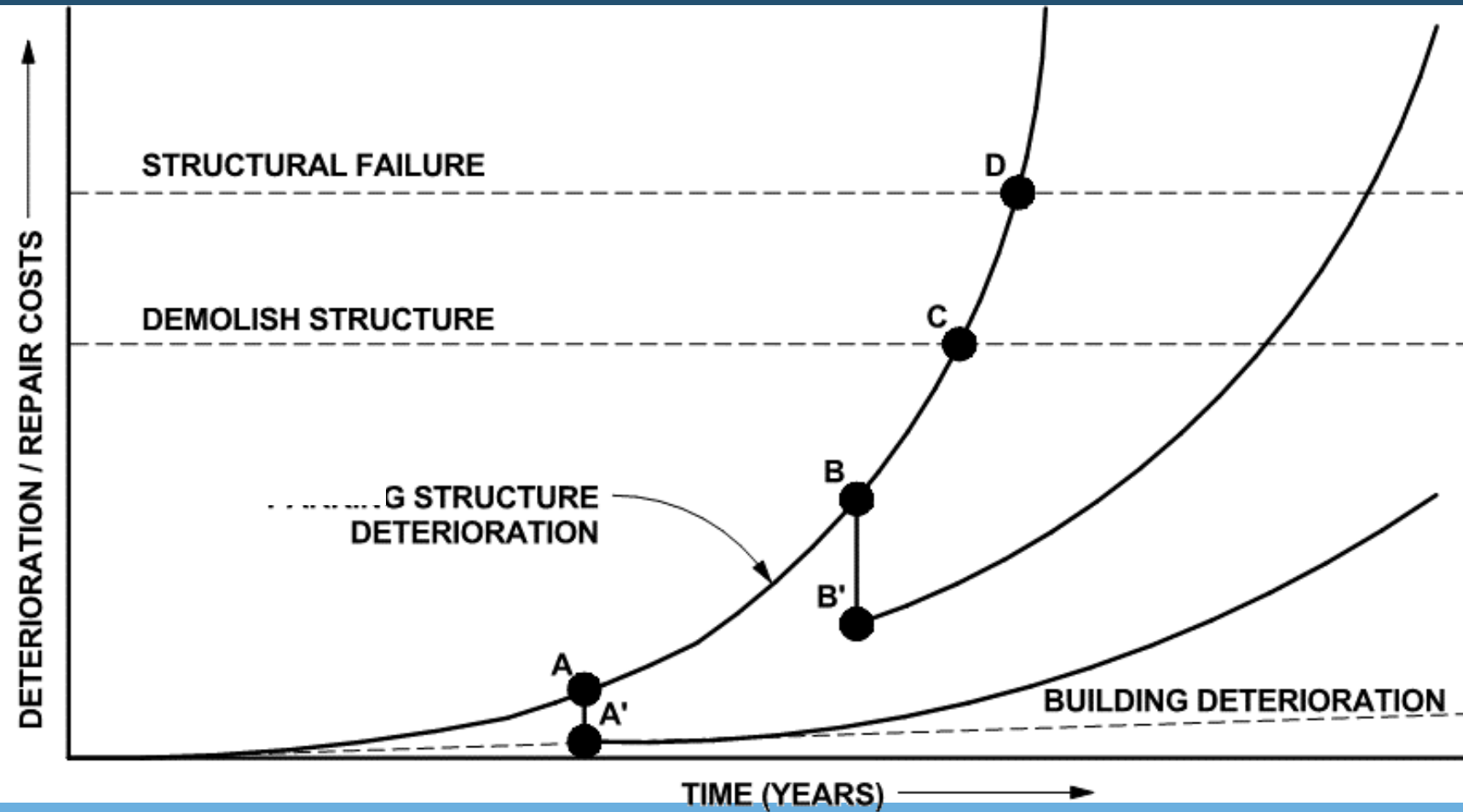




# Deferred Maintenance Cost Curve



# Deferred Maintenance Cost Curve



# Reinforced Concrete

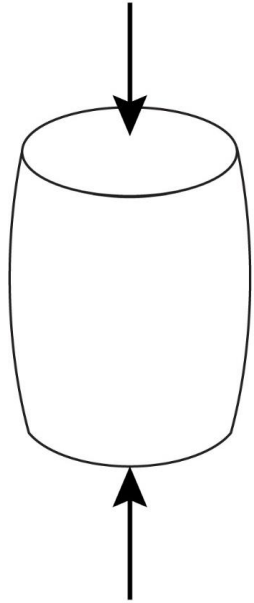
- Moisture
  - Corrosion
  - Freeze-Thaw
  - Osmosis
- Cracking



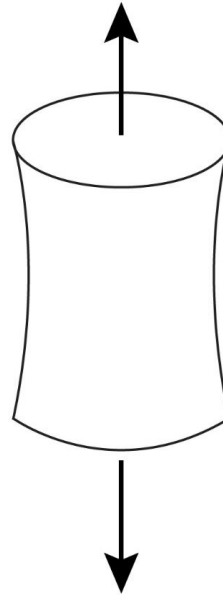
# Reinforced Concrete - Strength

10 % of Compression

Compression

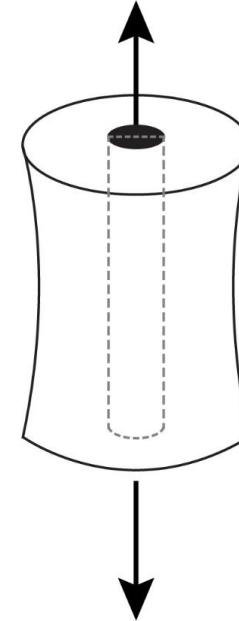


Tension

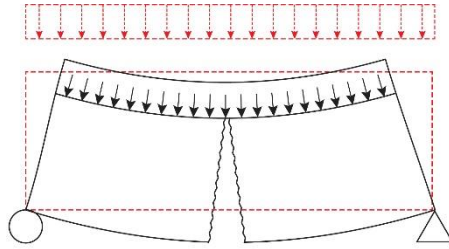


Add Reinforcing

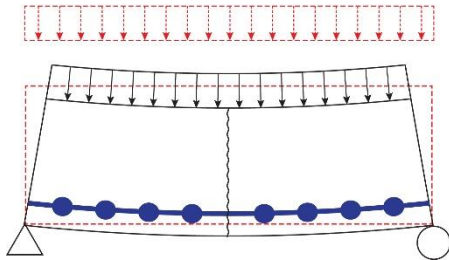
Tension



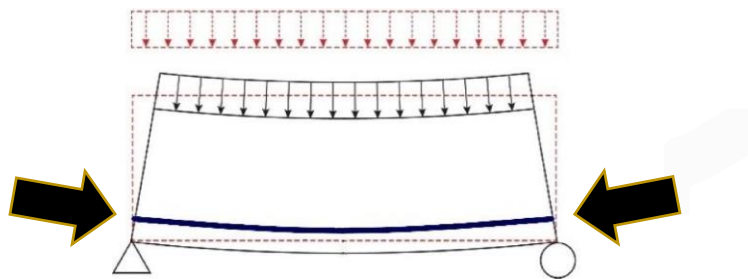
# Reinforced Concrete – Simple Span Beam



Plain Concrete



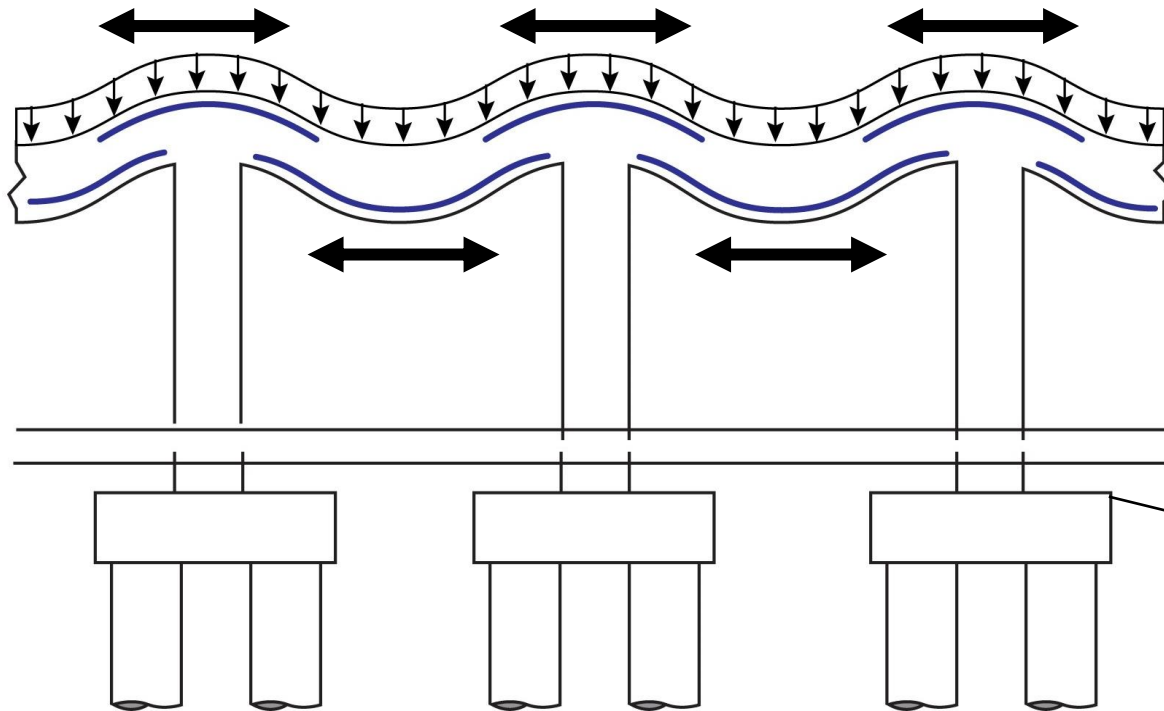
Reinforced Concrete



Prestressed Concrete



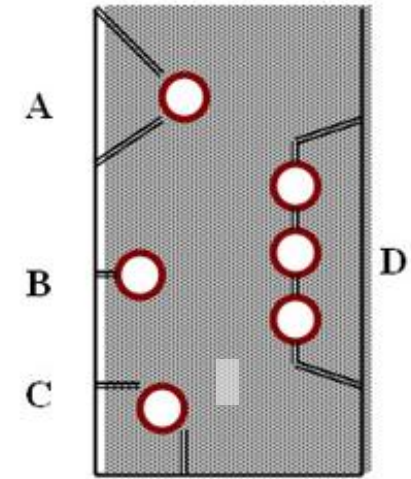
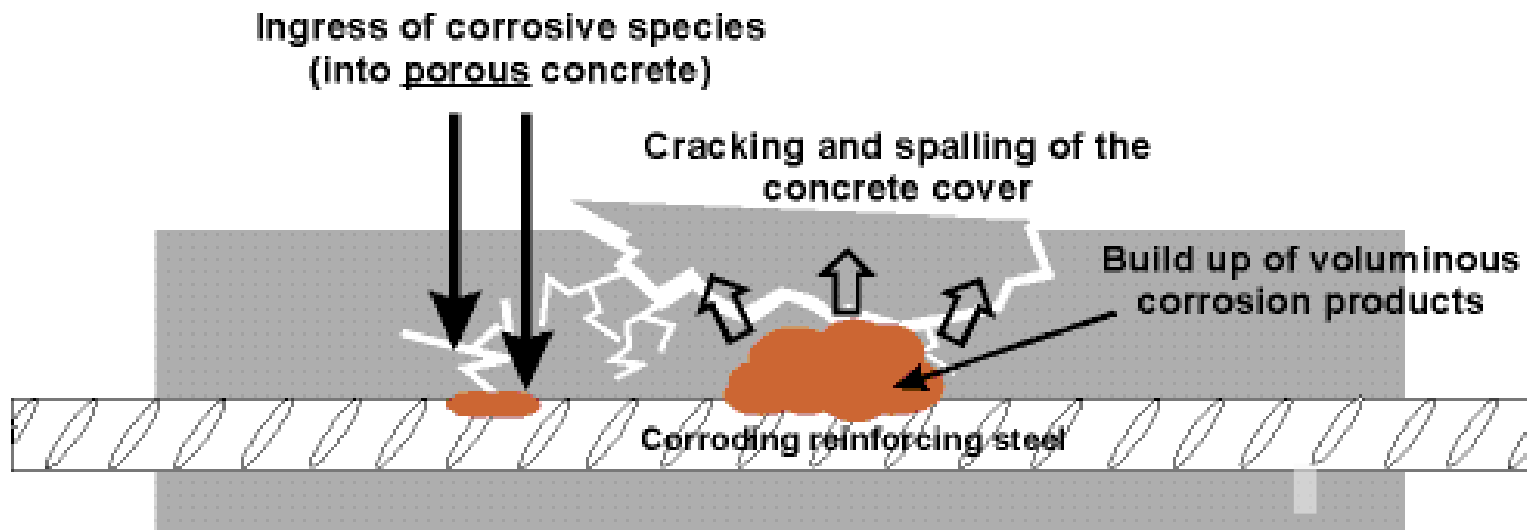
# Reinforced Concrete – Multi-Span Beam/Slab



- Tension
  - Top over Columns
  - Bottom between Columns

Foundation

# Reinforced Concrete - Corrosion



- A: Spall
- B: Crack
- C: Corner Spall
- D: Delamination

# Reinforced Concrete - Spall & Delamination



Spall



Delamination



Section Loss

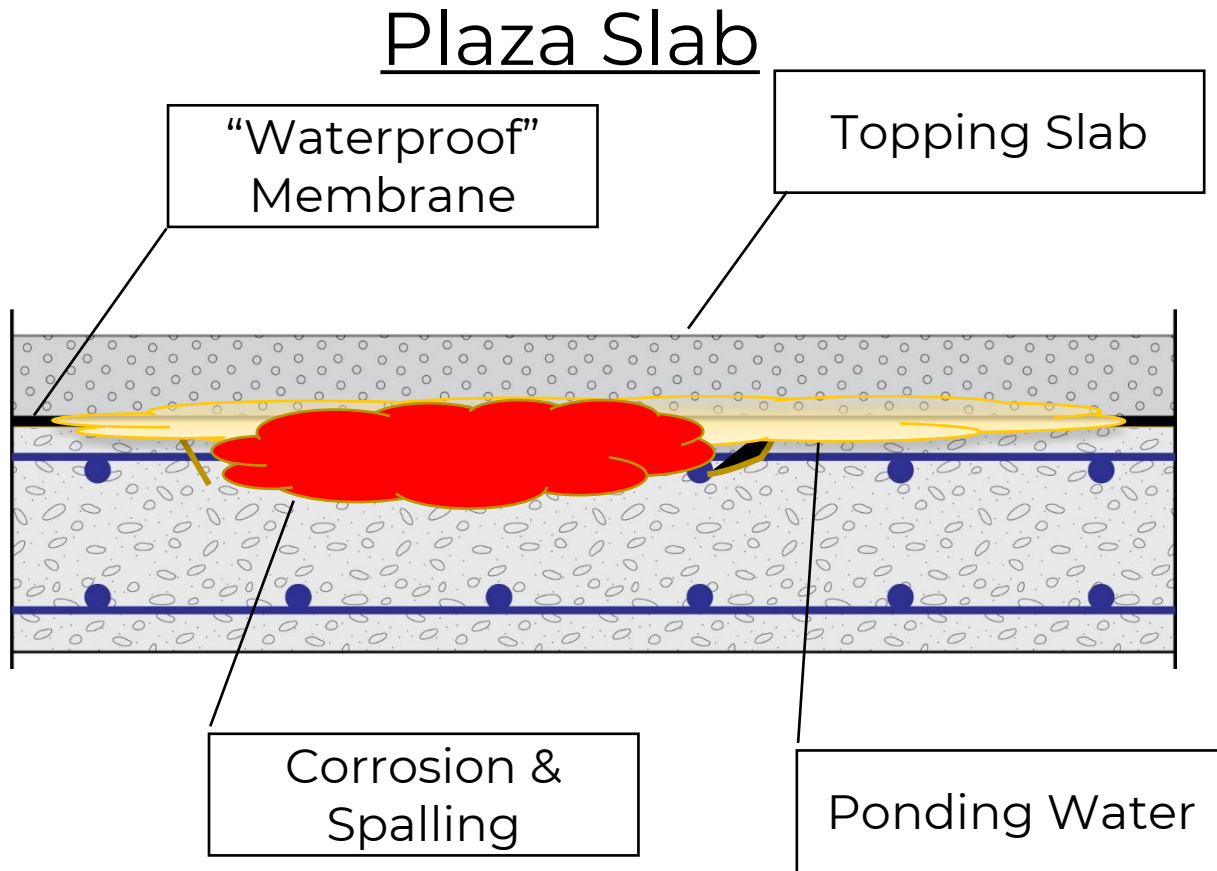


# Reinforced Concrete - Sounding



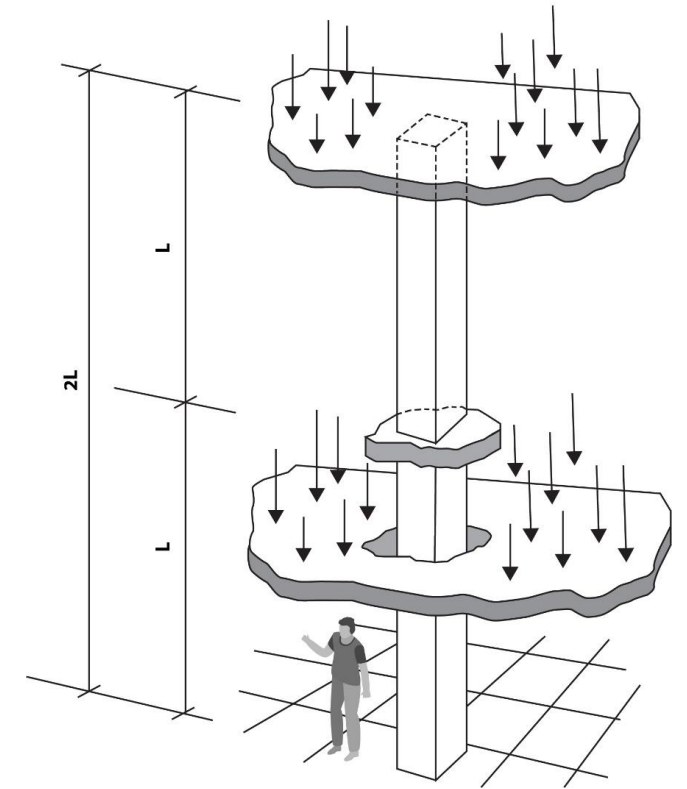
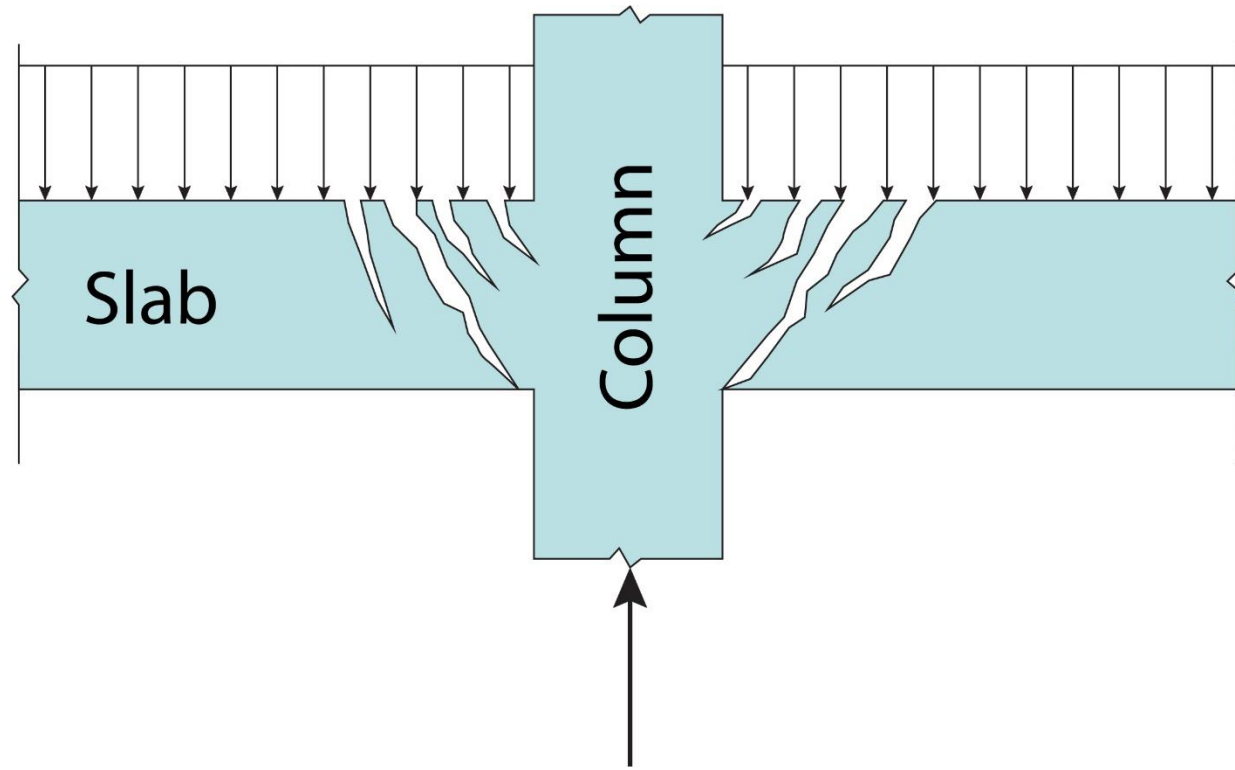
Sounding Technology Inc.

# Reinforced Concrete – Impulse Echo

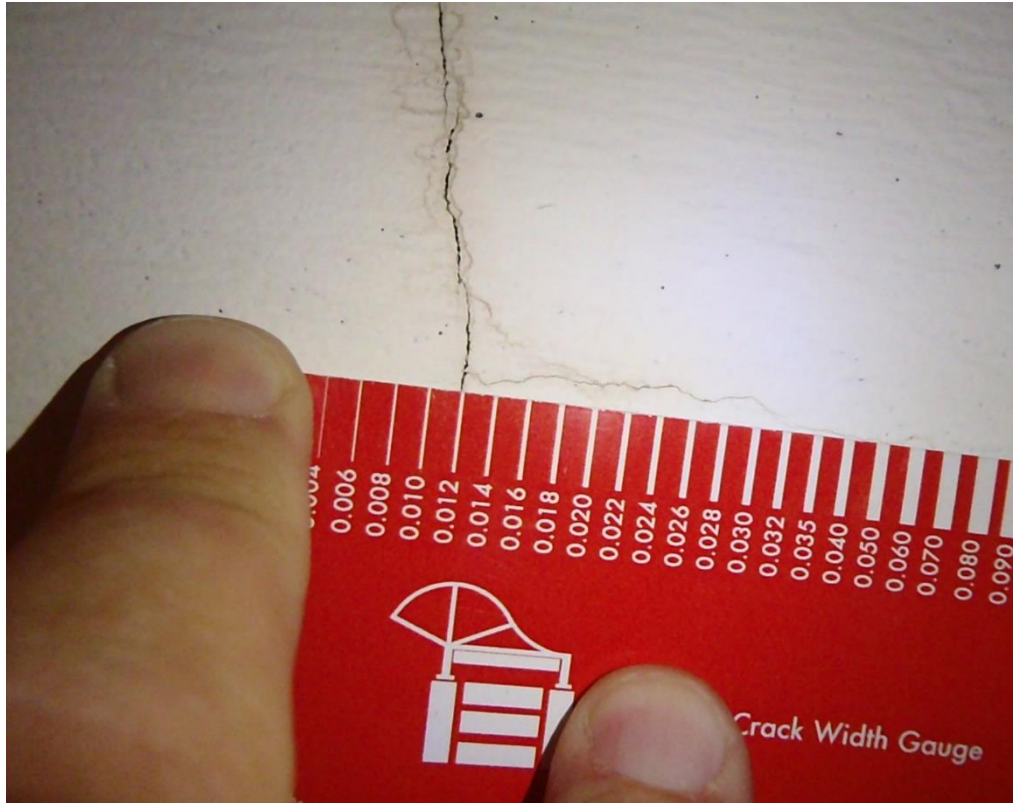




# Champlain Towers Collapse – Punching Shear



# Reinforced Concrete - Cracks



$.013'' \leq \text{Cracks} < .035''$



Cracks that Leak  $< .035''$

# Reinforced Concrete – Crack Repair (Route & Seal)



Crack Chasing



Crack Sealant



# Reinforced Concrete – Crack Repair (Epoxy Injection)



Cracks  $\geq .035''$



Inflatable Injection Port

Photos by Engineered Restorations Inc.

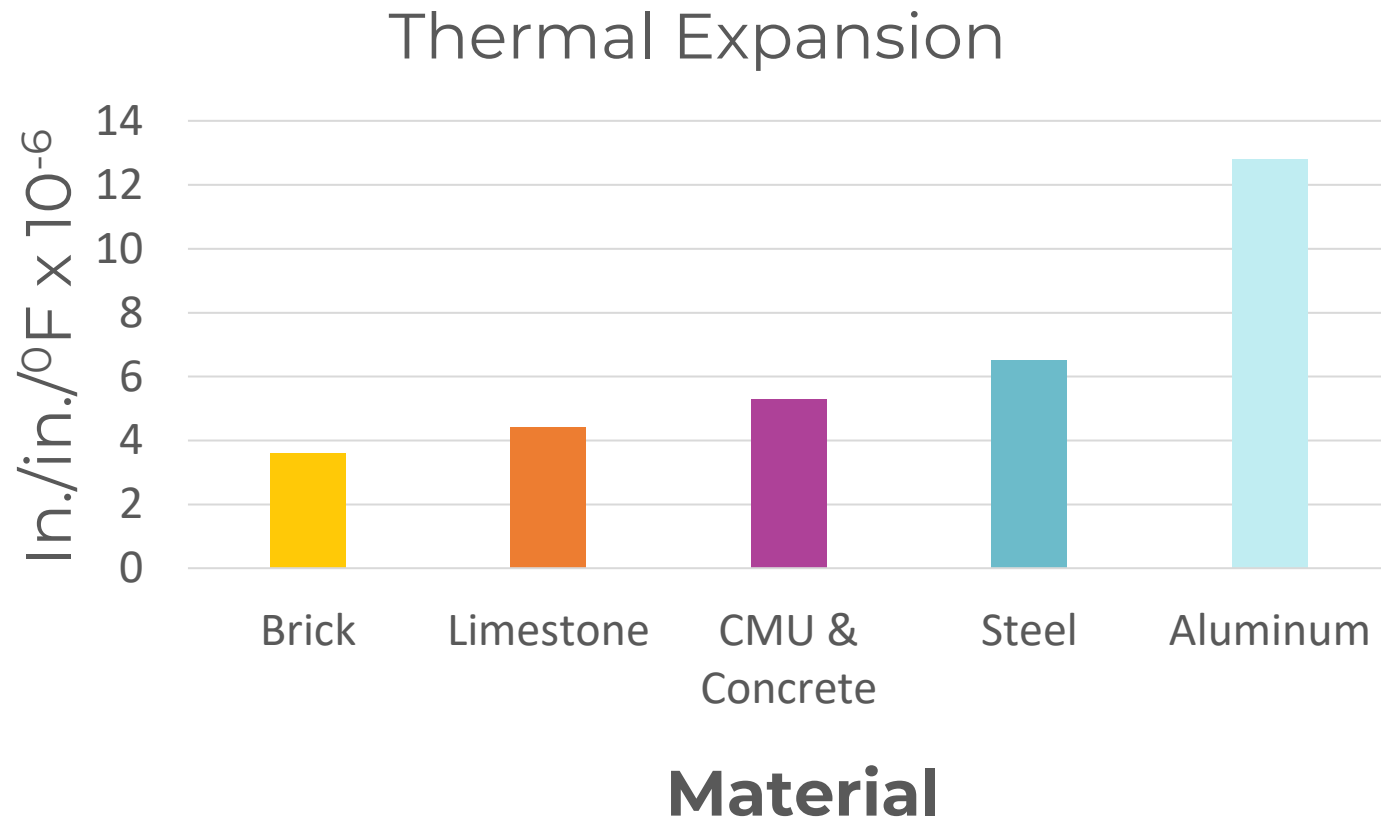


# Masonry

- Thermal Expansion/Contraction
- Moisture
  - Expansion/Contraction
  - Corrosion
  - Freeze-Thaw
  - Osmosis
- Cracking



# Facade - Thermal Expansion



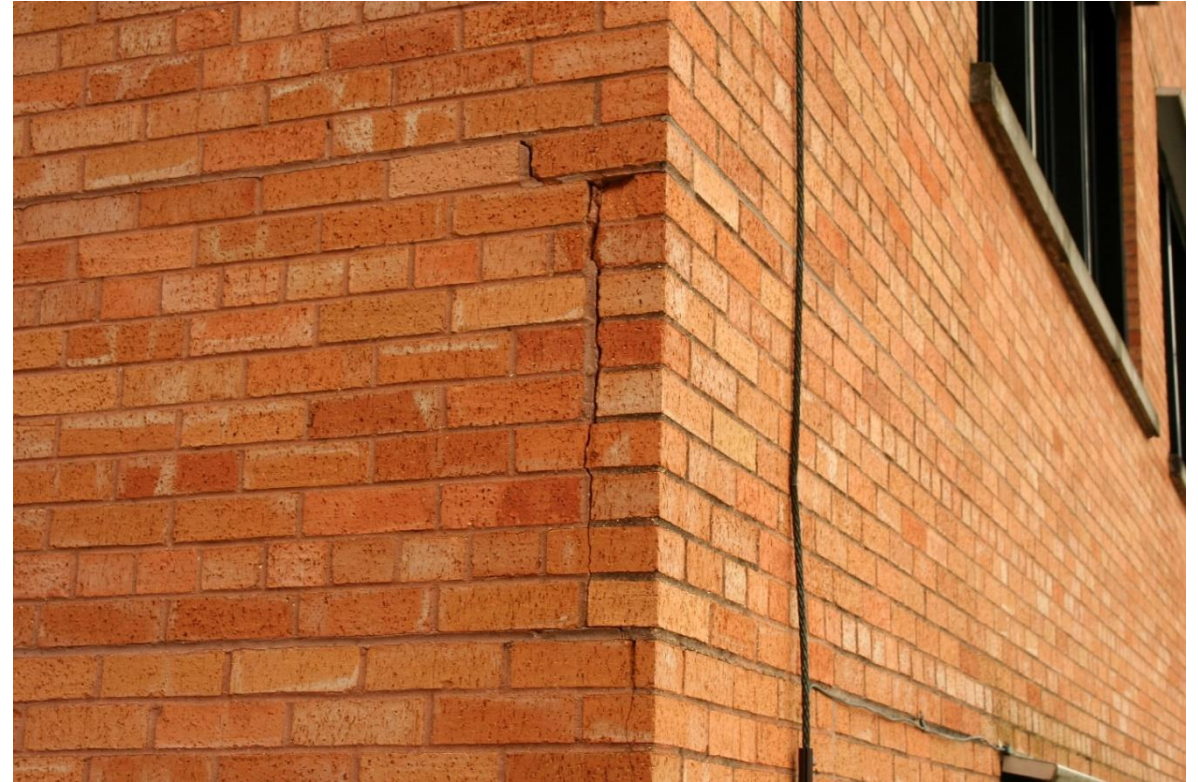
Coefficients of Thermal Expansion	
Material	in./in./°F x 10 <sup>-6</sup>
<b>Wood</b>	
Pine (parallel to grain)	3.0
Pine (perpendicular to grain)	19.0
<b>Masonry</b>	
Brick	3.6
Limestone	4.4
Granite	4.7
Concrete Masonry Unit (CMU)	5.2
Marble	7.3
<b>Concrete</b>	
Concrete (Normal Weight)	5.5
<b>Metals</b>	
Steel	6.5
Copper	9.3
Aluminum	12.8
<b>Finishes</b>	
Glass	5.0
Gypsum Plaster, Sand	7.0
Gypsum Board	9.0



# Façade – Thermal Expansion

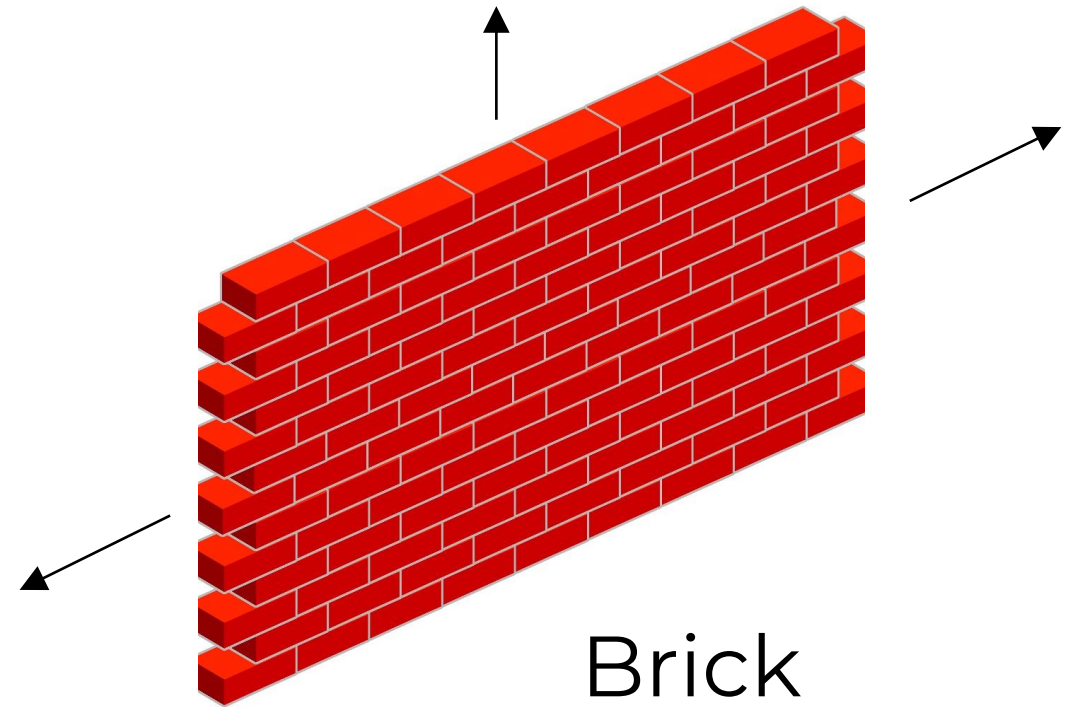
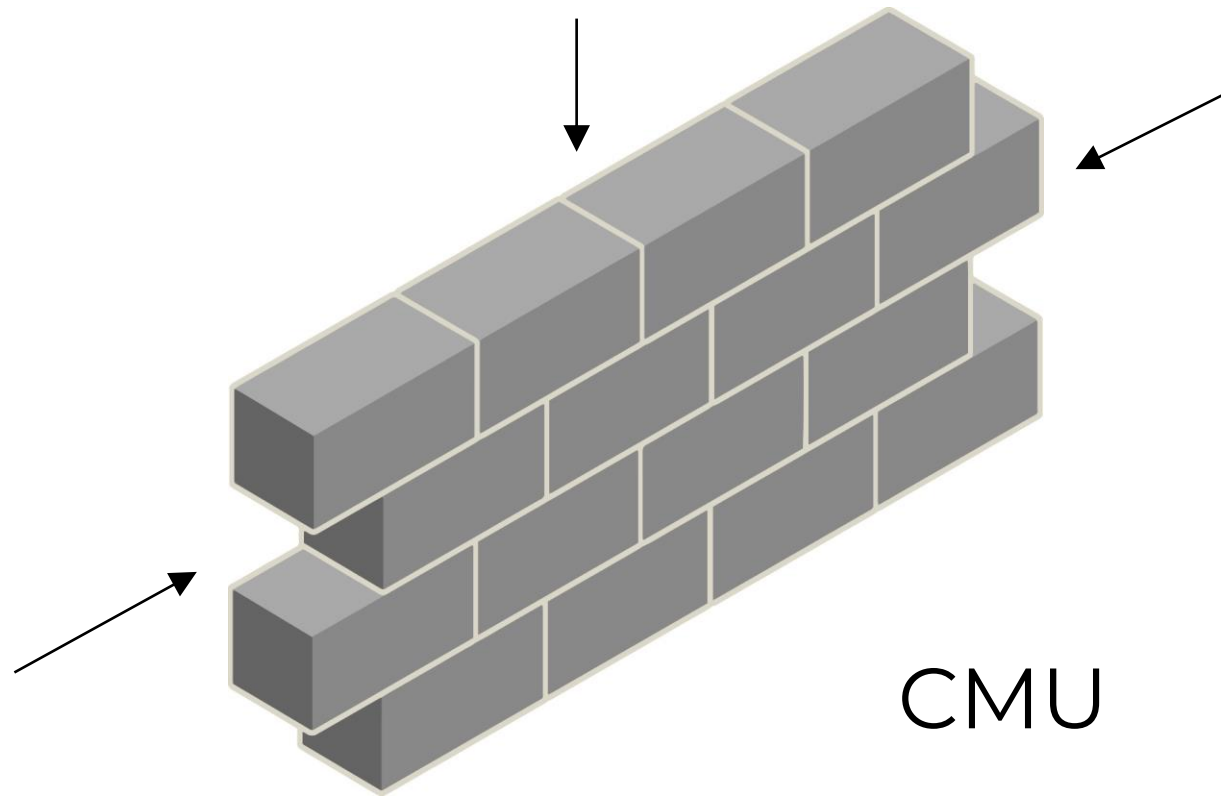


No Expansion Joints



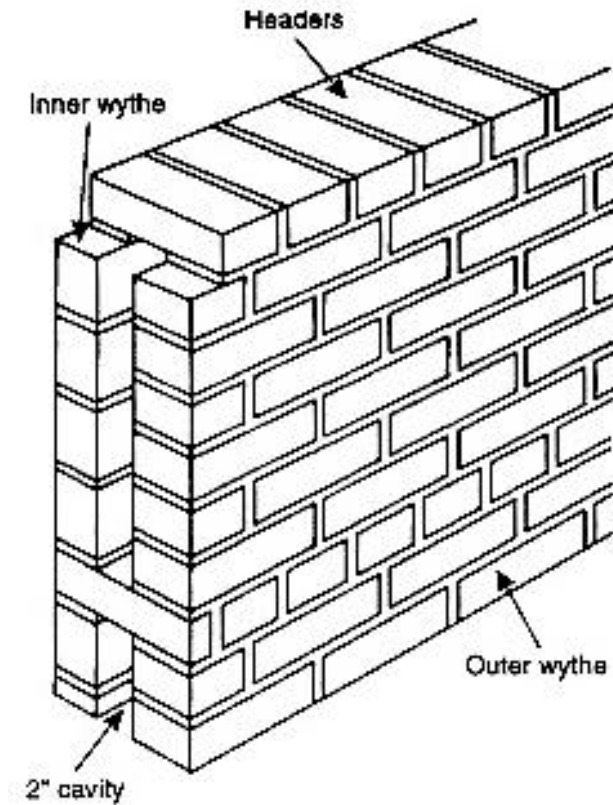
Creates Hinge at Corner

# Facade - Moisture Expansion/Shrinkage





# Façade – Moisture/Thermal Expansion/Contraction



# Façade – Moisture & Thermal Expansion/Contraction





# Façade – Corrosion Expansion



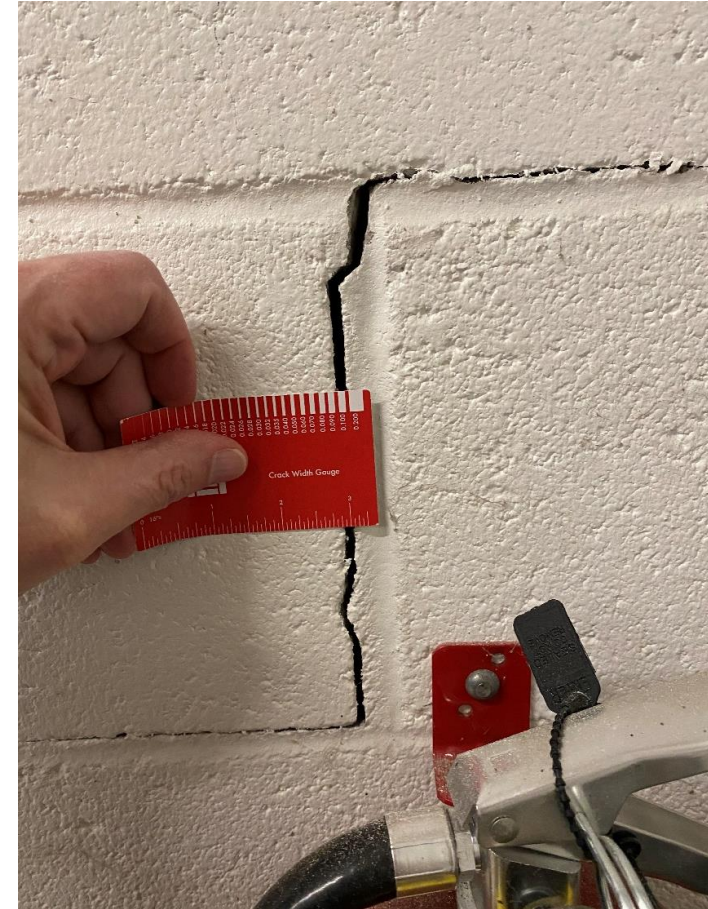


# Façade – Moisture Damage





# Masonry – Creep & Settlement



# Masonry – Unauthorized Openings



- Penetrations:
  - Through Load Bearing Walls

# Steel Framing - Deterioration

- Moisture
  - Rust
- Fatigue
- Modified or Damaged Members





# Steel Framing Corrosion

- Surface Rust
- Section Loss
  - Flange
  - Web





# Steel Framing - Corrosion

- Rust Expands:
  - 5 to 6 Times Original Volume
- Often Looks Worse Than It Is
- Scrape Rust
- Measure with Caliper



# Steel Framing - Fatigue





# Steel Framing – Altered or Damaged Members





# Wood Framing - Deterioration

- Moisture
  - Rot
  - Insect Infestation
- Checks & Splits
- Missing or Modified Members



# Wood Framing – Moisture Meter



Moisture Content > 30% =  
Serious Decay



# Wood Framing – Termite Infestation



Mud Tubes



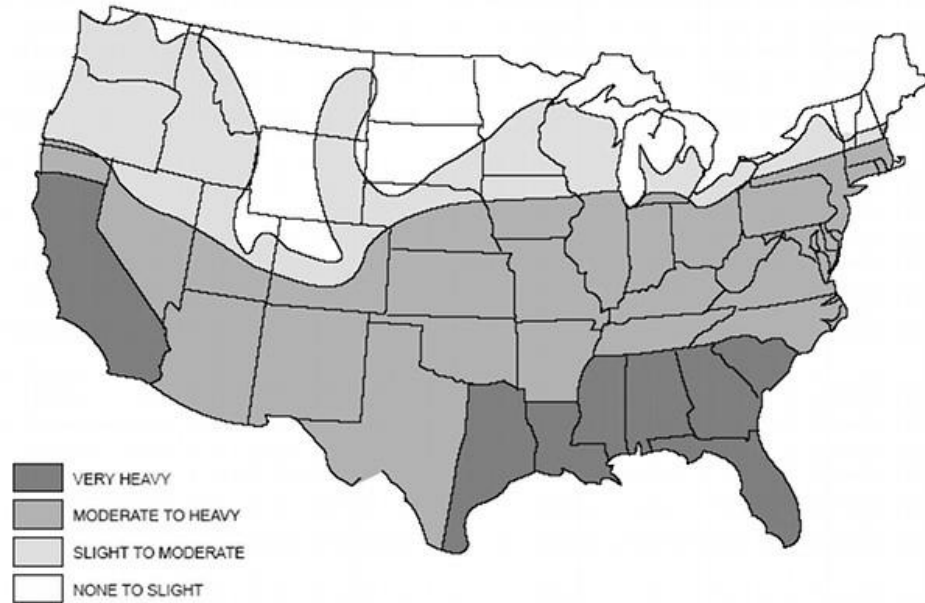


# Wood Framing – Termite Infestation

- Galleries
- Parallel to Growth Rings
- May not be visible
  - Thick lumber
  - Pressure Treated lumber



# Wood Framing – Termite Infestation Probability



Note: Lines defining areas are approximate only. Local conditions may be more or less severe than indicated by the region classification.

FIGURE R301.2(6)  
TERMITE INFESTATION PROBABILITY MAP  
2000 INTERNATIONAL RESIDENTIAL CODE™

- Exist in all states except Alaska
- Live in a Colony (nest) in the Ground below the Frost Line
- Dark, Damp Environment
- Soldiers are ¼" Long and Whitish Crème in Color
- Can Penetrate 1/32" Openings.
- Travel in Shelter (Mud) Tubes to Shelter from Light

# Wood Framing – Modified Members



Image: Russ LaBlanc





# Structural Condition Assessment - Why

- Legal
- Deterioration
- Transfer of Ownership
- Change of Occupancy
- Renovation, Rehabilitation, and Restoration
- Strengthening or Hardening
- Damage
- Signs of Distress



# International Property Maintenance Code (IPMC)

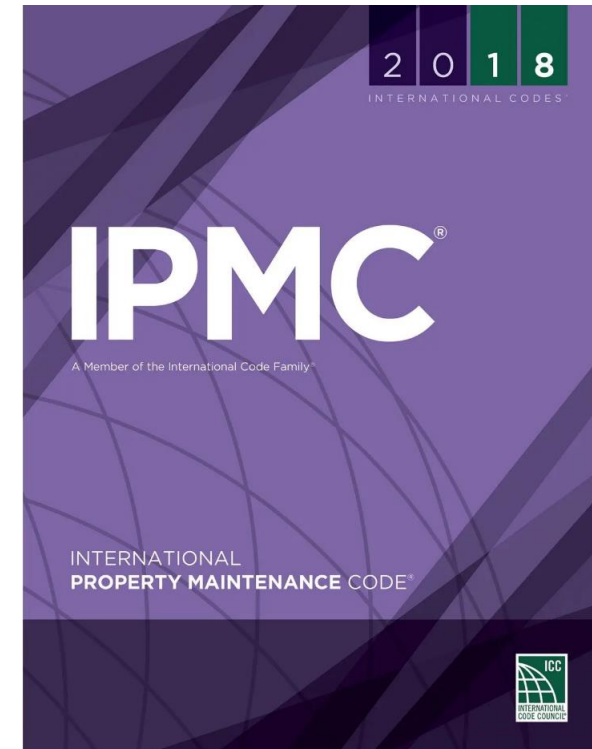
## SECTION 304 EXTERIOR STRUCTURE

**304.1 General.** The exterior of a structure shall be maintained in good repair, structurally sound and sanitary so as not to pose a threat to the public health, safety or welfare.

## SECTION 305 INTERIOR STRUCTURE

**305.1 General.** The interior of a structure and equipment therein shall be maintained in good repair, structurally sound and in a sanitary condition. *Occupants* shall keep that part of the structure which they occupy or control in a clean and sanitary condition. Every *owner* of a structure containing a *rooming house, housekeeping units, a hotel, a dormitory, two or more dwelling units* or two or more nonresidential occupancies, shall maintain, in a clean and sanitary condition, the shared or public areas of the structure and *exterior property*.

It's the Law!



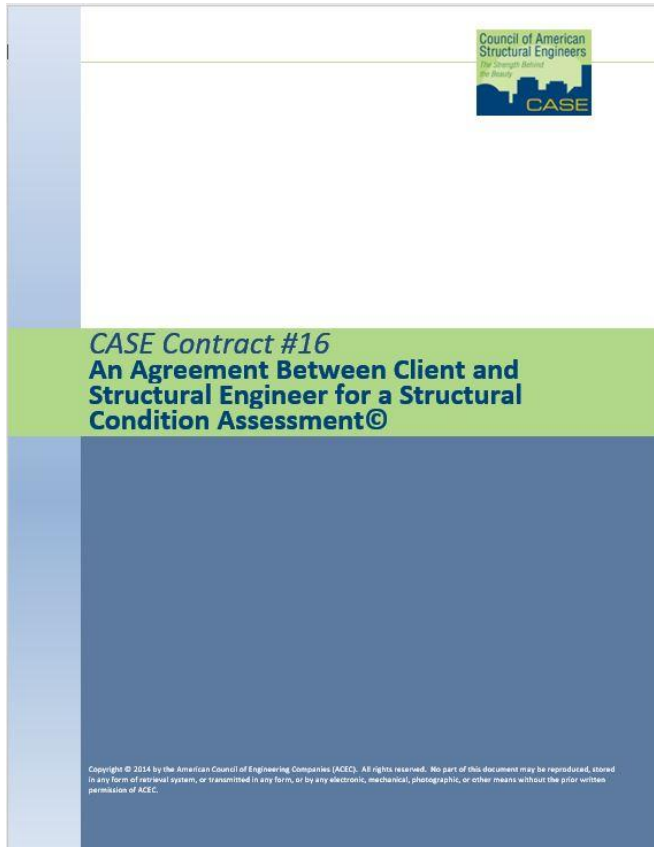
# ASCE Standard SEI/ASCE 11-99



- **Assessment**
  - Preliminary
  - Detailed
- **Materials**
  - Concrete
  - Masonry
  - Metals
  - Wood
- **Procedures**
- **Reporting**

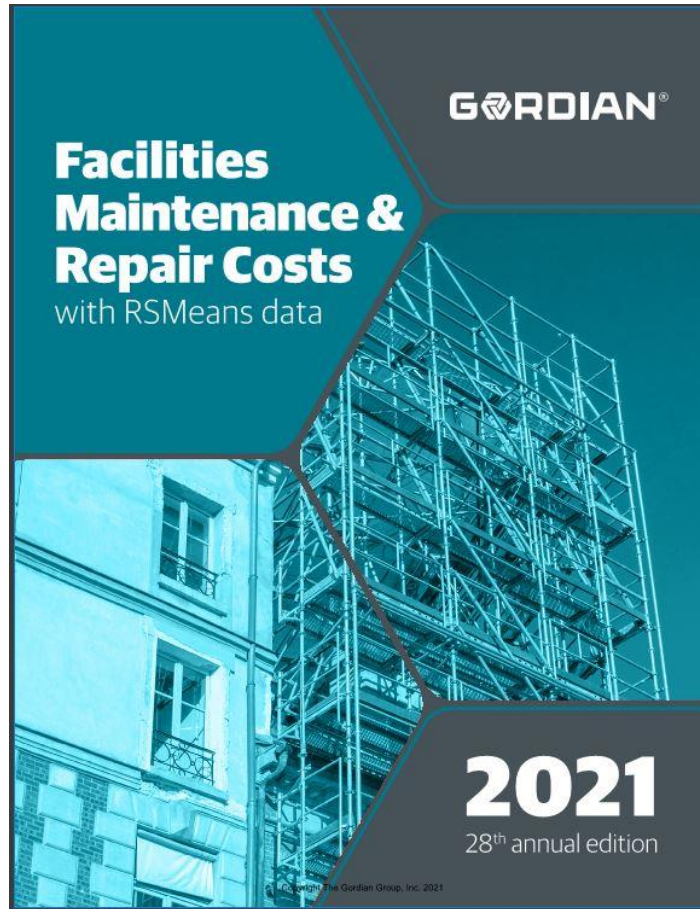


# CASE Contract #16 – Structural Condition Assessment



- **Document Review**
- **Visual Inspection**
  - Gravity Load path
  - Lateral Load path
- **Roof & Below Grade for Water Infiltration**
- **Façade Inspection**
- **Report**

# Inspection Checklist



- **Sitework**
- **Safety**
- **Foundations**
- **Basement**
- **Superstructures**
- **Exterior Closure**
- **Roofing**
- **Partitions & Doors**
- **Walls, Floors, Ceilings & Finishes**
- **Conveying**
- **Plumbing**
- **HVAC**
- **Electrical**

# Suggested Frequency of Inspection

- **Roof, Plaza & Below Grade Waterproofing**

- Biannual
  - Fall Before Winter
  - Spring After Winter
  - After Storm
  - After Work on Roof

- **Façade & Structural Systems**

- Self Inspection: Annual
- Professional Inspection: Every 5 Years

- **Other Systems**

- Annual Organized Self Inspection



# Life Expectancy – Dependent on Install & Exposure

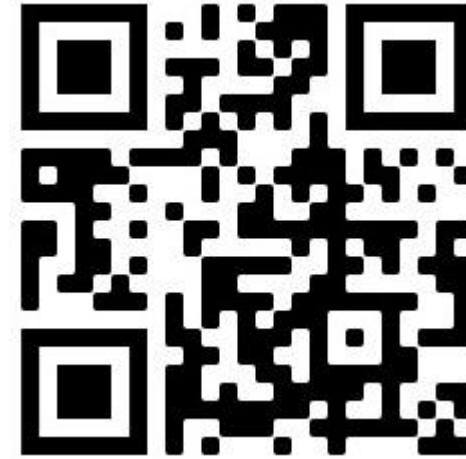
- **Building – 50 Years**
- **Roofing**
  - Metal – 25 Years
  - BUR & SBS Mod-Bit – 17 Years
  - APP Mod-Bit, EPDM, PVC – 14 Years
  - TPO – 13 Years
  - Polyurethane Foam – 12 Years
- **Sealants – 10 to 20 Years**
  - Silicone
  - Polyurethane
- **Traffic Bearing Membrane:**
  - 5 to 20 years
- **Below Grade Waterproofing:**
  - 50 Years (Modern)
- **Protected Waterproof Membrane:**
  - 50 Years (Modern)

# Learning Objectives

- **Building Structure Inspection**
  - Champlain Towers Collapse
  - Structural Engineering 101
  - Failure Mechanisms
    - Concrete, Masonry, Steel, & Wood
  - Laws & Standards

# Questions?

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