



Building Structure Condition Assessment

How to Avoid Catastrophe

Joint ICRI/ACI Chapter Meeting
Thursday, November 17, 2022, Noon
The Whitley Hotel Buckhead

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

Presentation today provides general information.

For specific advice, consult a professional.

Innovative Engineering Inc.



- **Scott L. Weiland PE SE**
 - **BSCCE 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

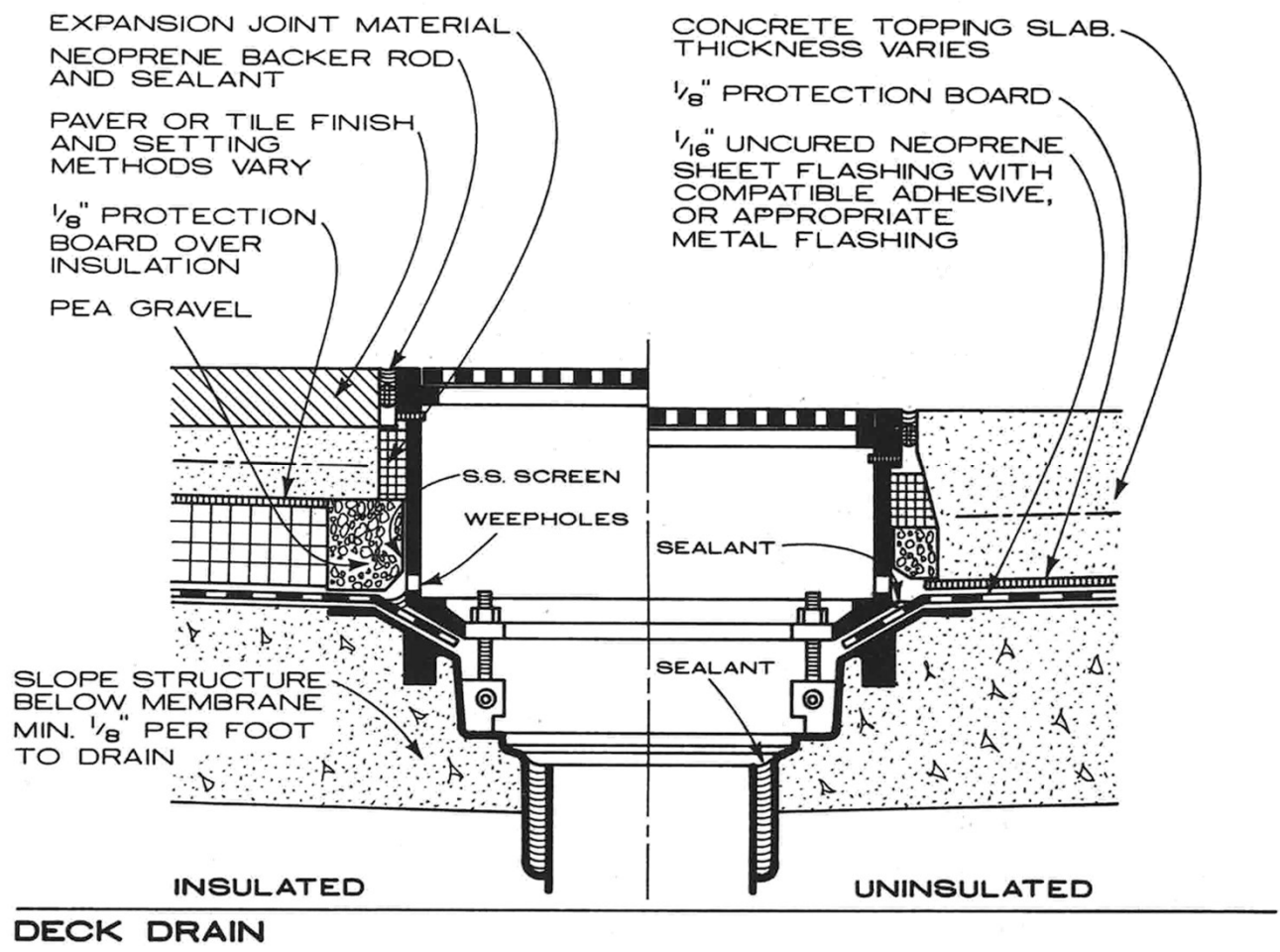
- Built 1981
- 12 Story, 136 Units
- Cast-In-Place Concrete
- Plaza Slab
- Below Grade Level Parking Garage
- 2018 Report
- 40 Year Recertification Underway



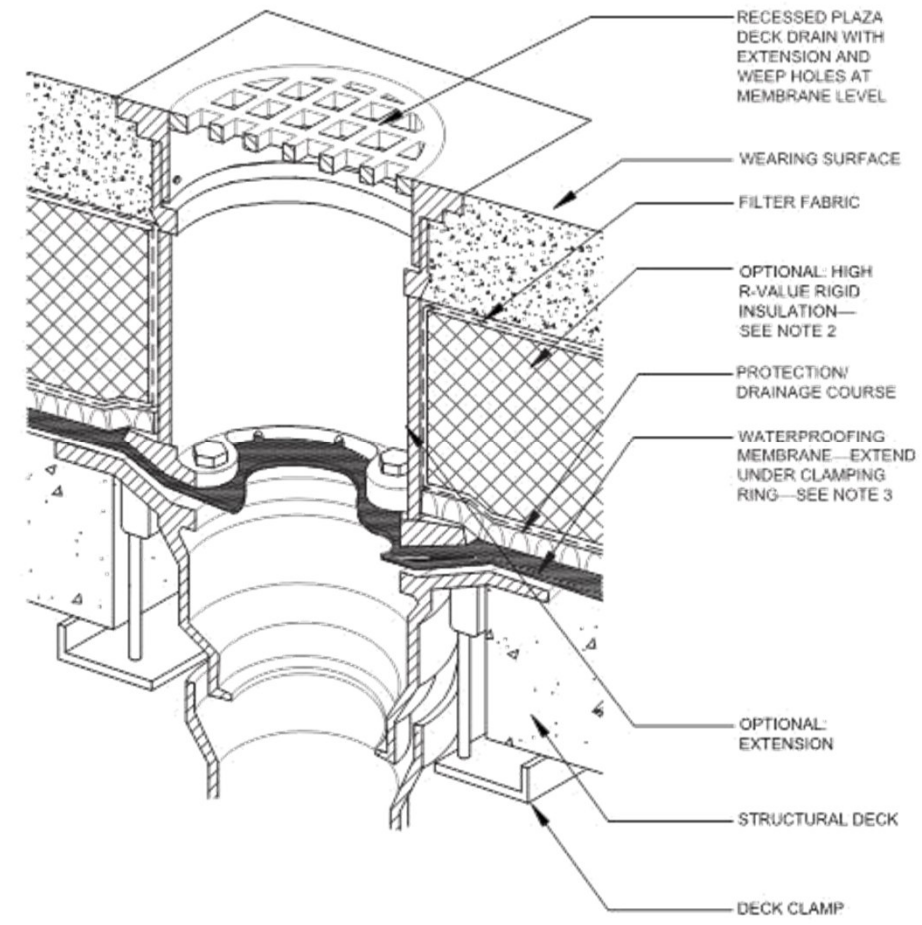
Building Science – Plaza Slabs



Plaza Slabs – Protected Membrane

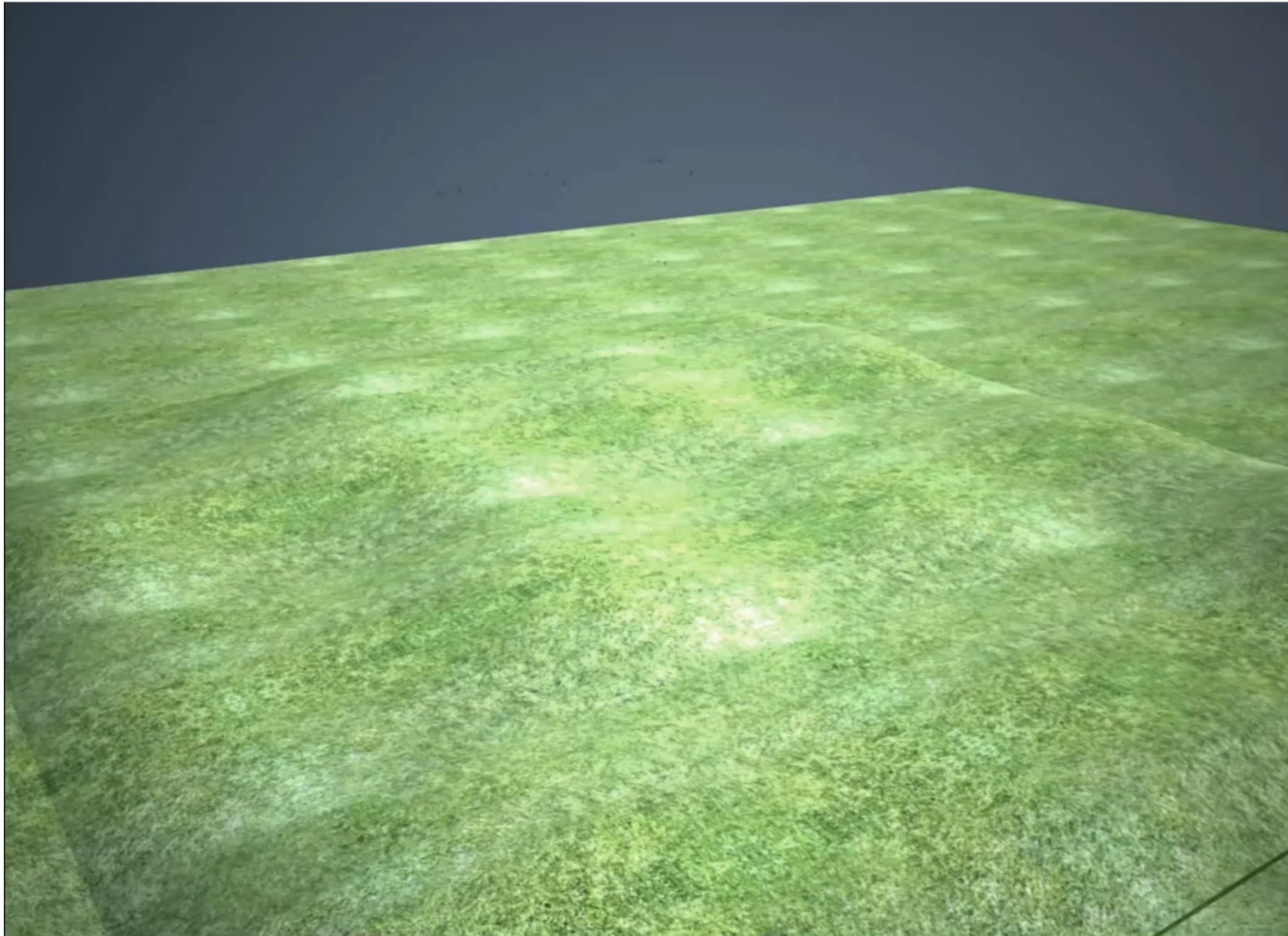


Ref.: 1981 Architectural Graphics Standards



Ref.: NRCA Detail WP-24

Building Structure - Definitions

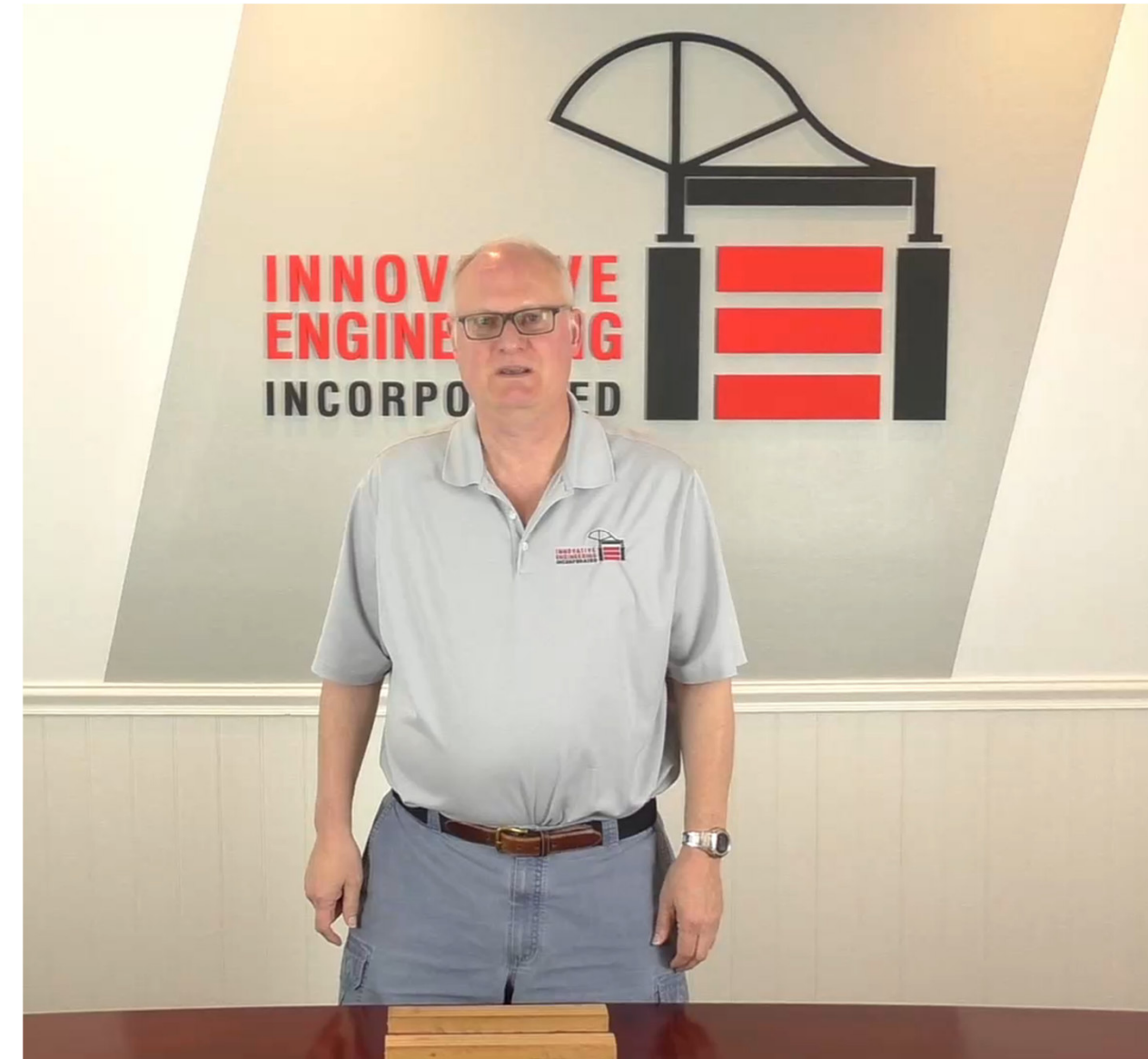


Credit: James Burke

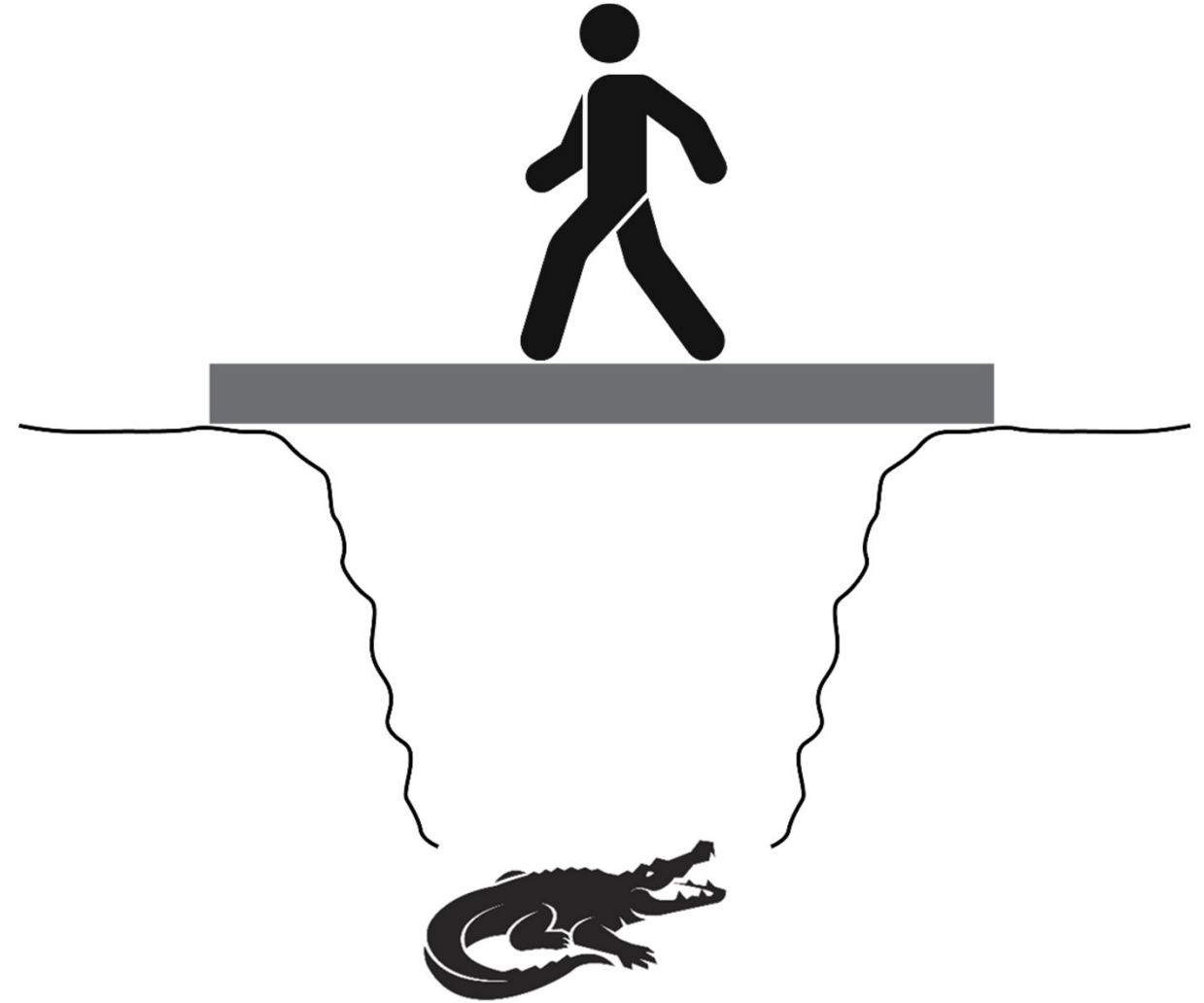
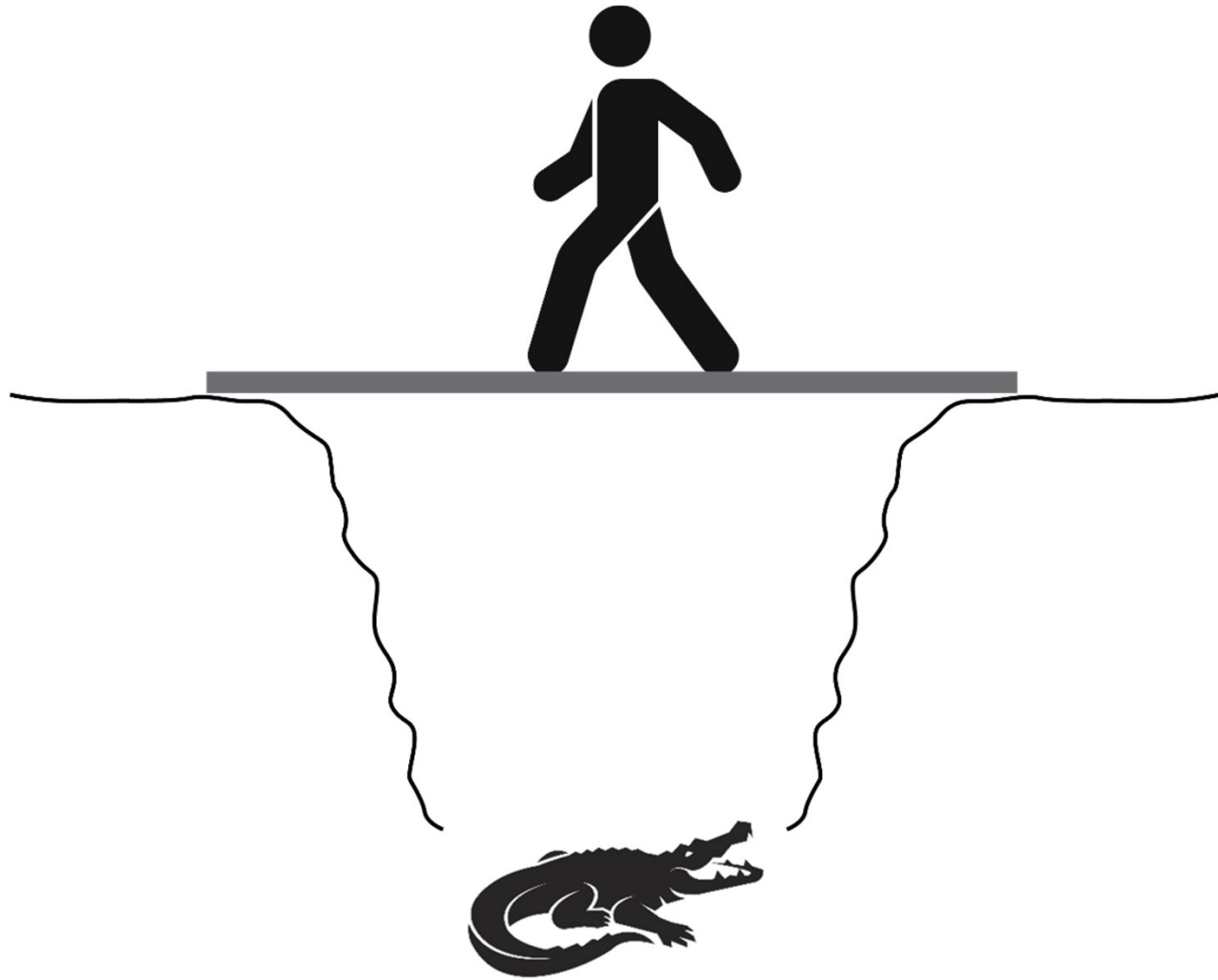
- **Foundations**
- **Columns**
- **Beams**
- **Slabs**

Building Structure - Columns

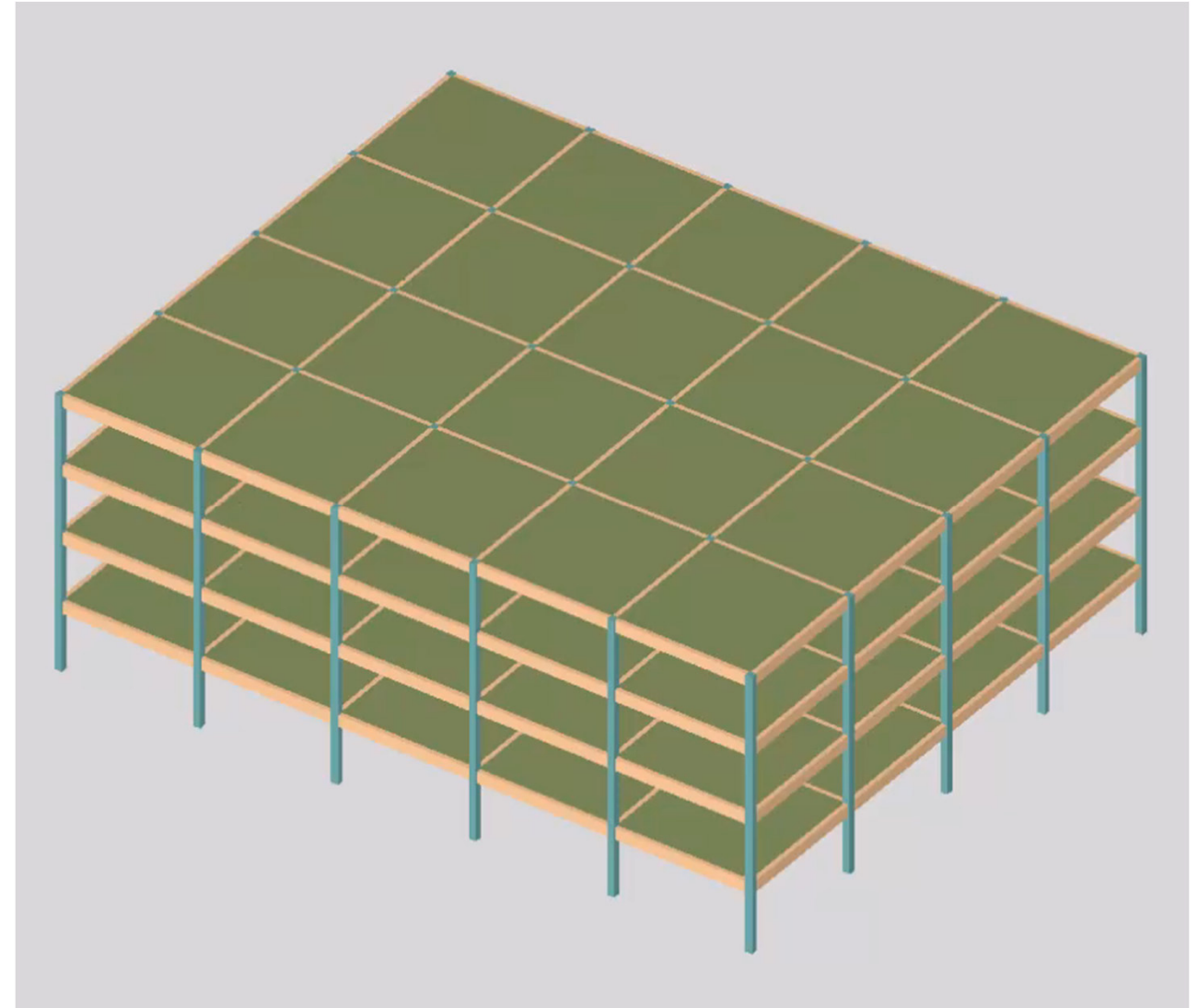
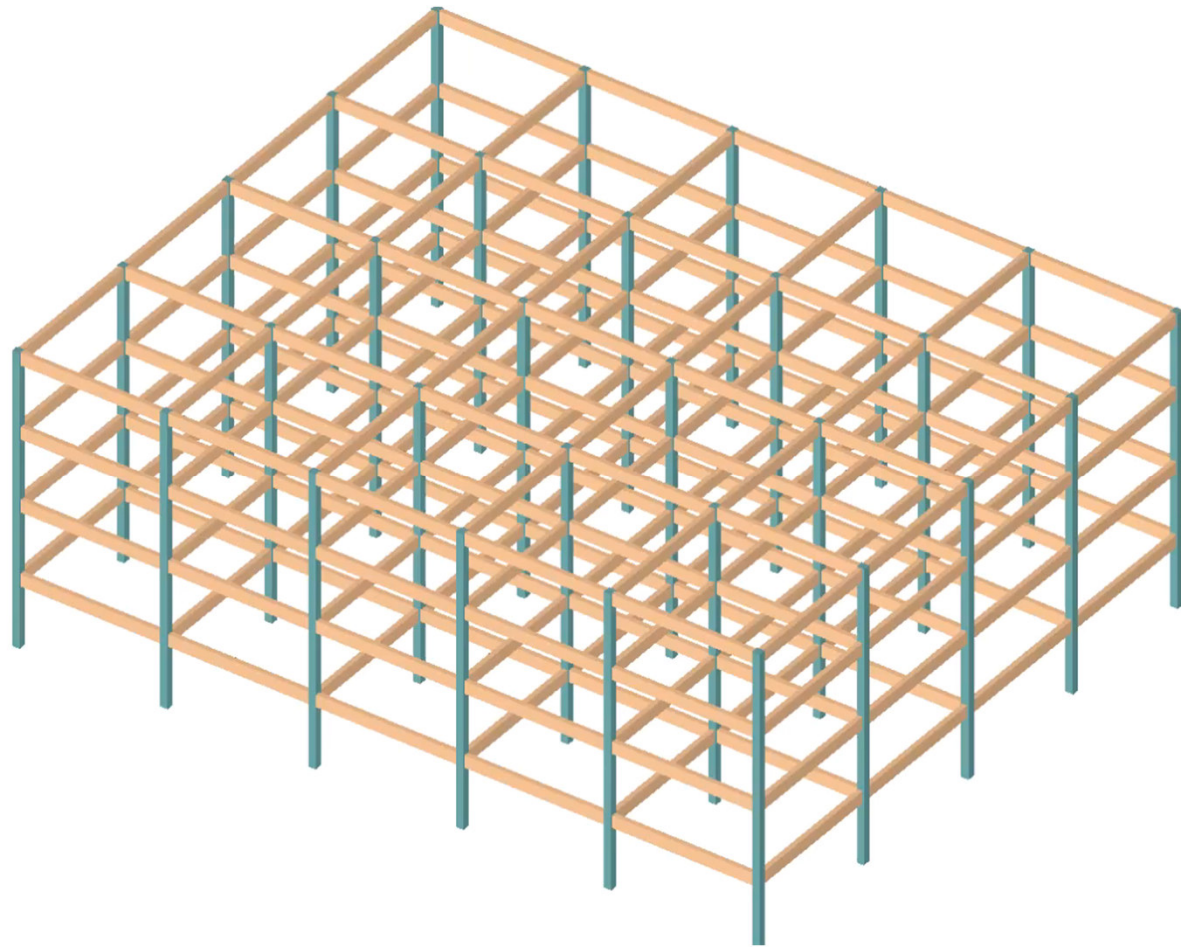
- **Failure Modes**
 - Stress
 - Pure Compression
 - Combined Stresses
 - Shear
 - Lack of Confinement
 - Torsion
 - Buckling



Building Structure – Beams & Slabs



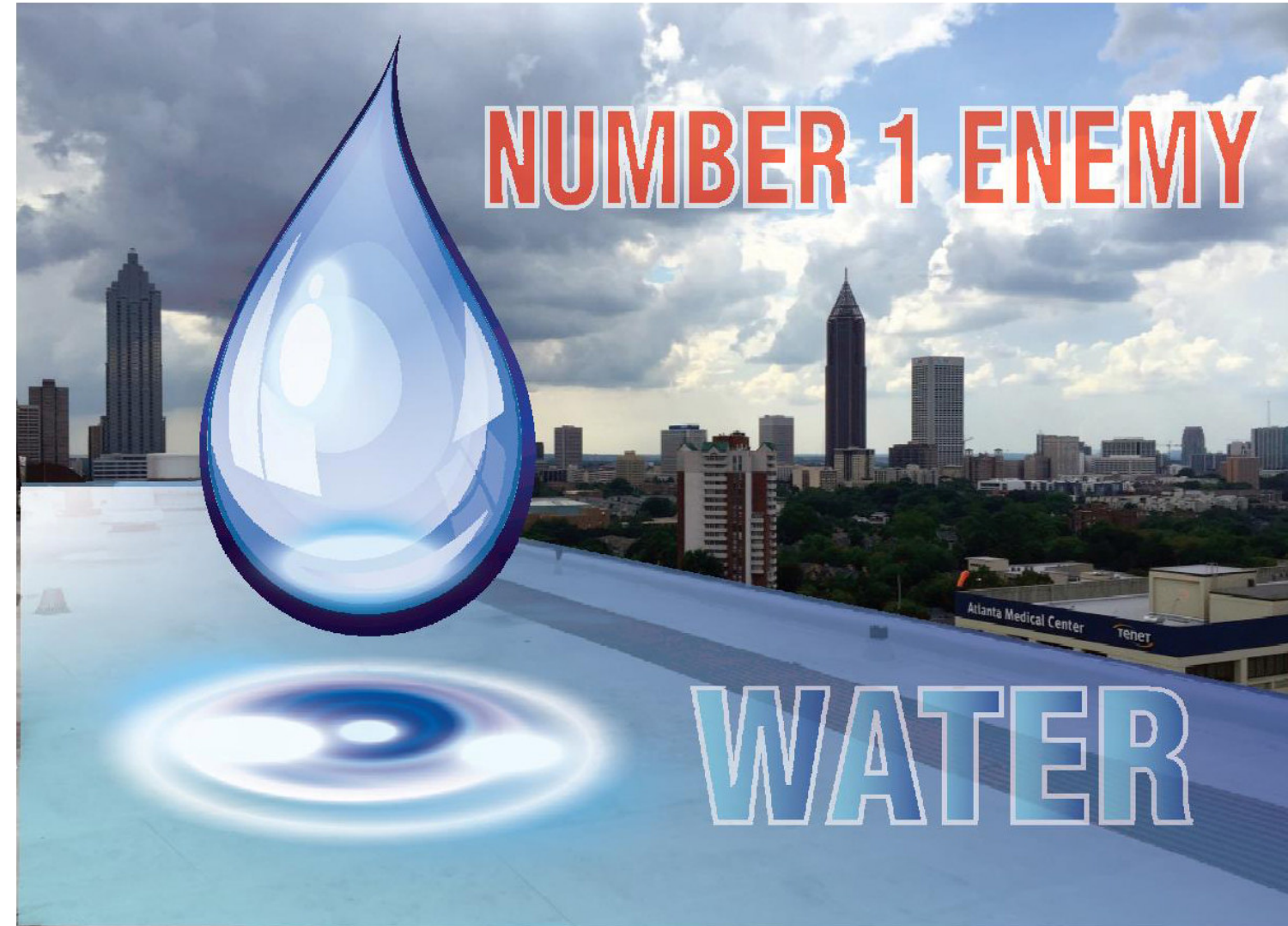
Building Structure – Progressive Collapse



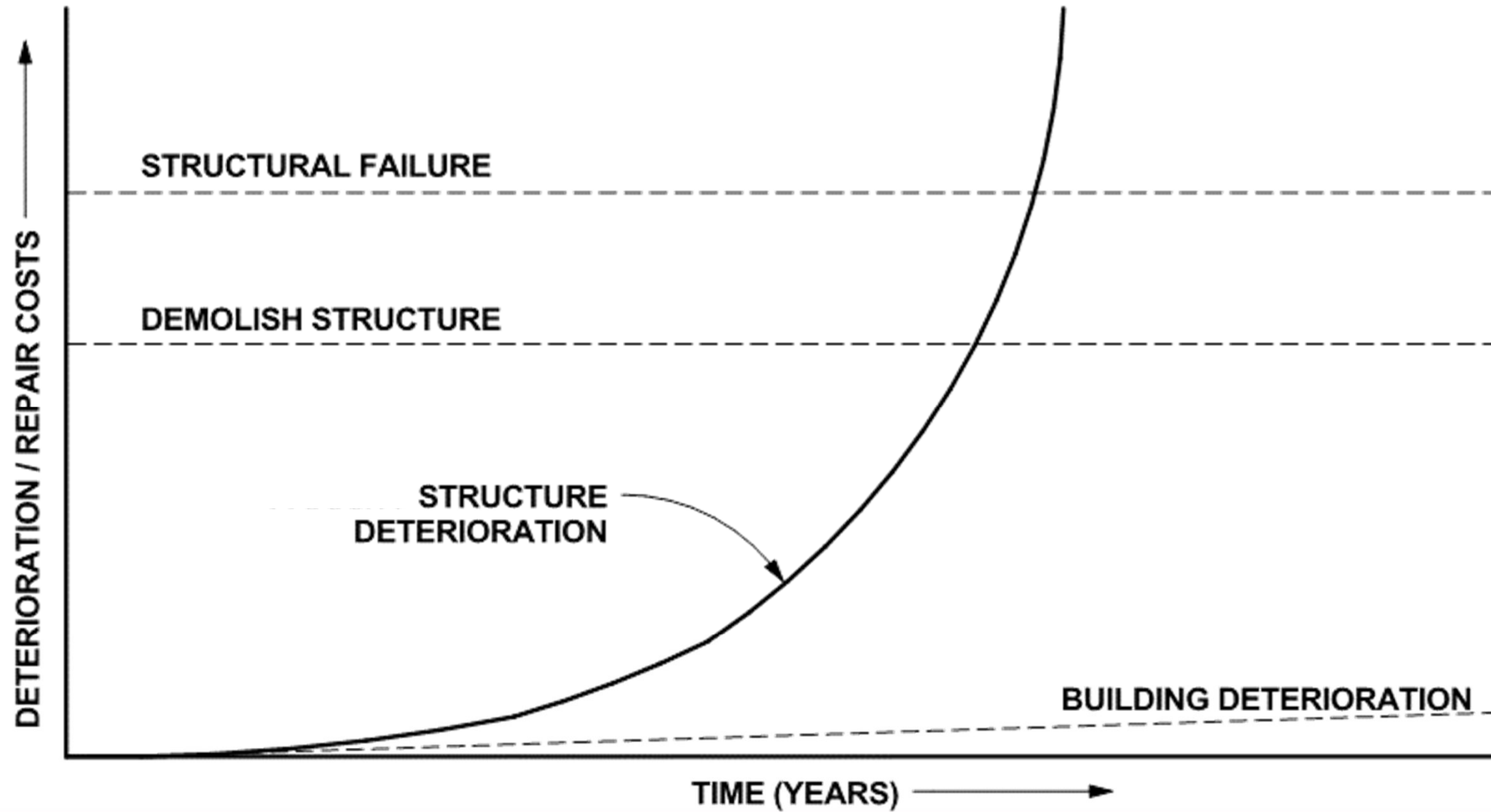
ASI Extreme Loading

Building Science – Sources of Deterioration

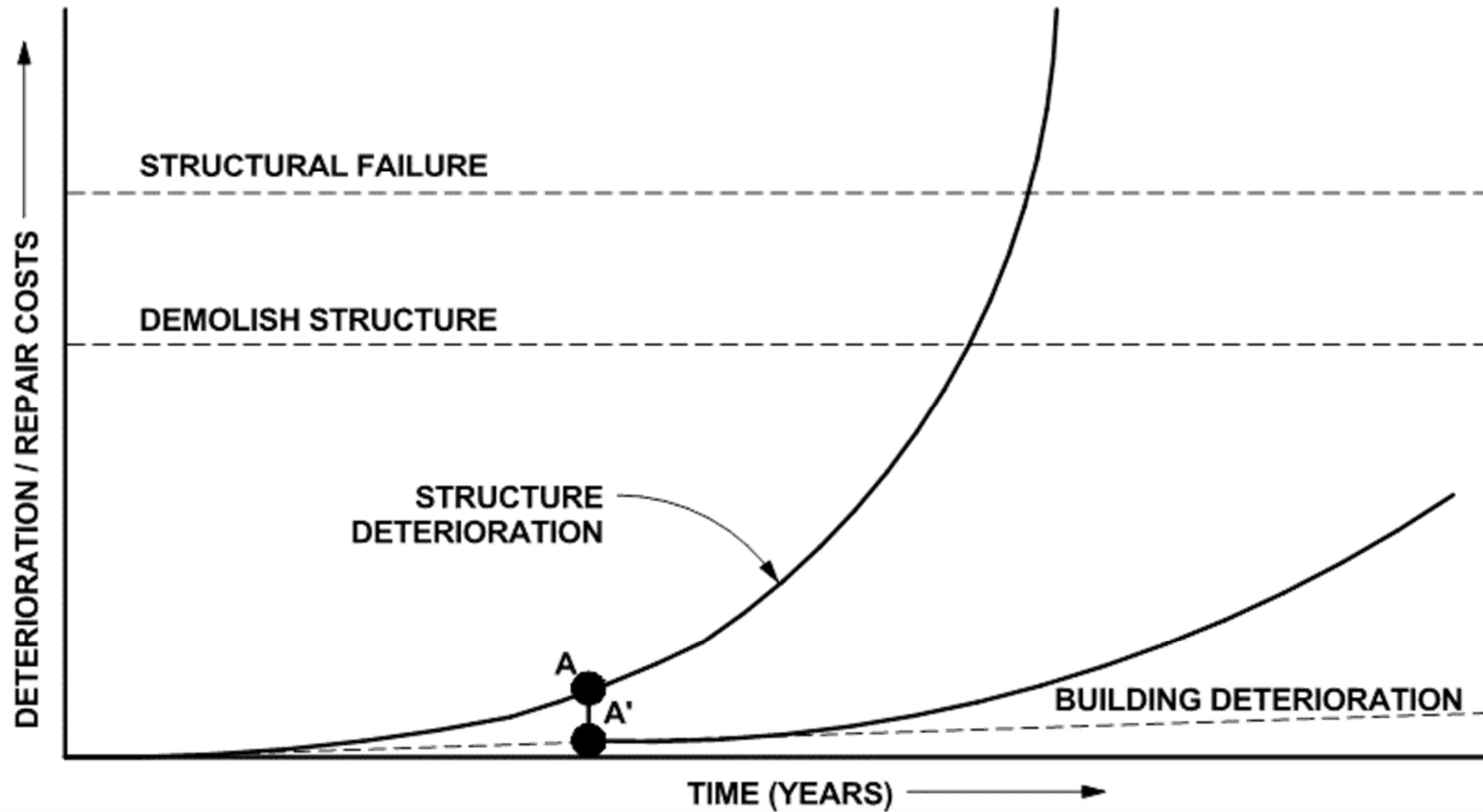
- **Water Damage**
 - Mold
 - Corrosion
 - Rot
 - Termites & Insects
- **Movement of Materials**
 - Thermal
 - Moisture
 - Elastic Deformation
 - Creep
- **Other**
 - Impact Damage
 - Dynamic Loads
 - Lightning Strike
 - Overload
 - Wind, Earthquake, Flood
 - UV Exposure



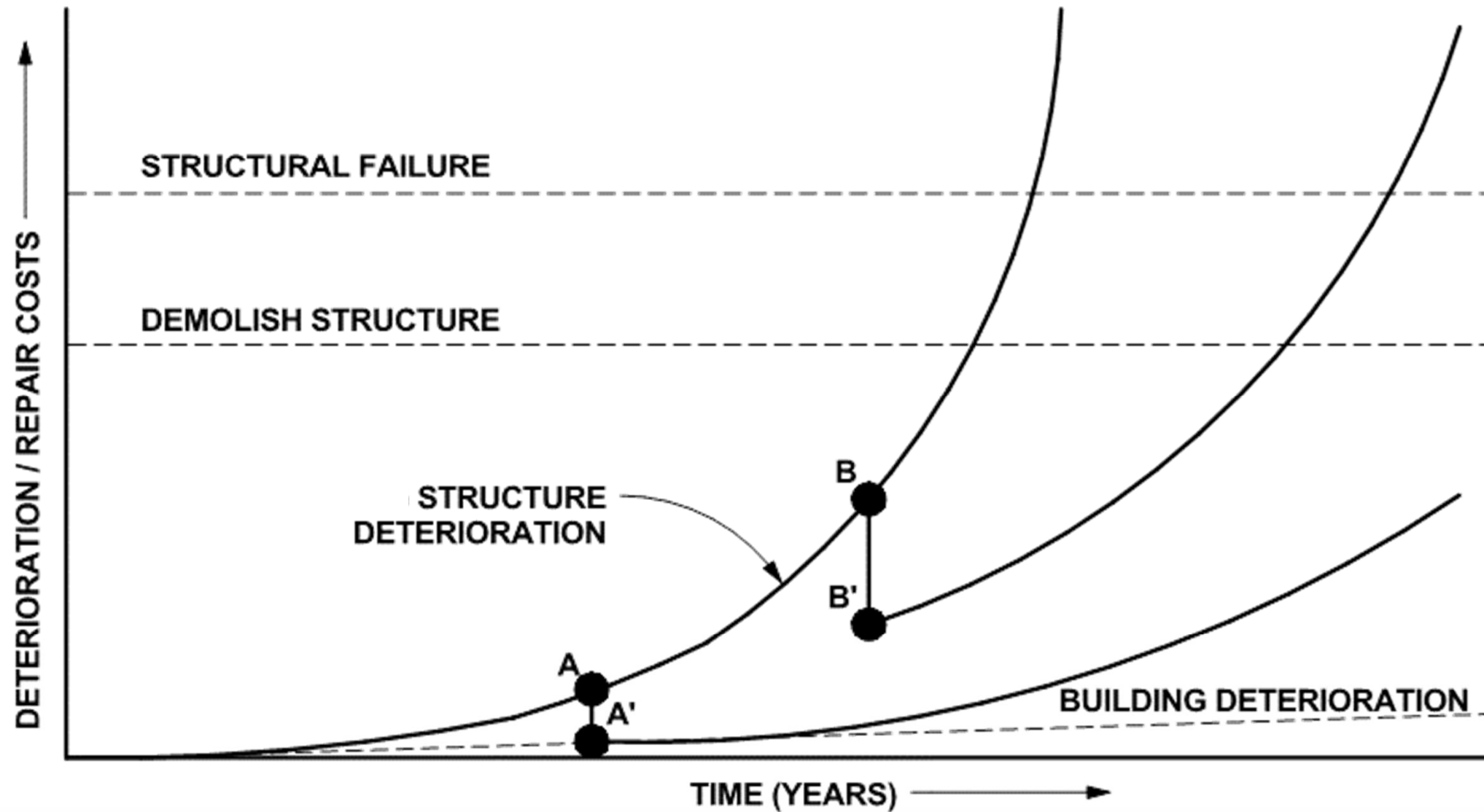
Deferred Maintenance Cost Curve



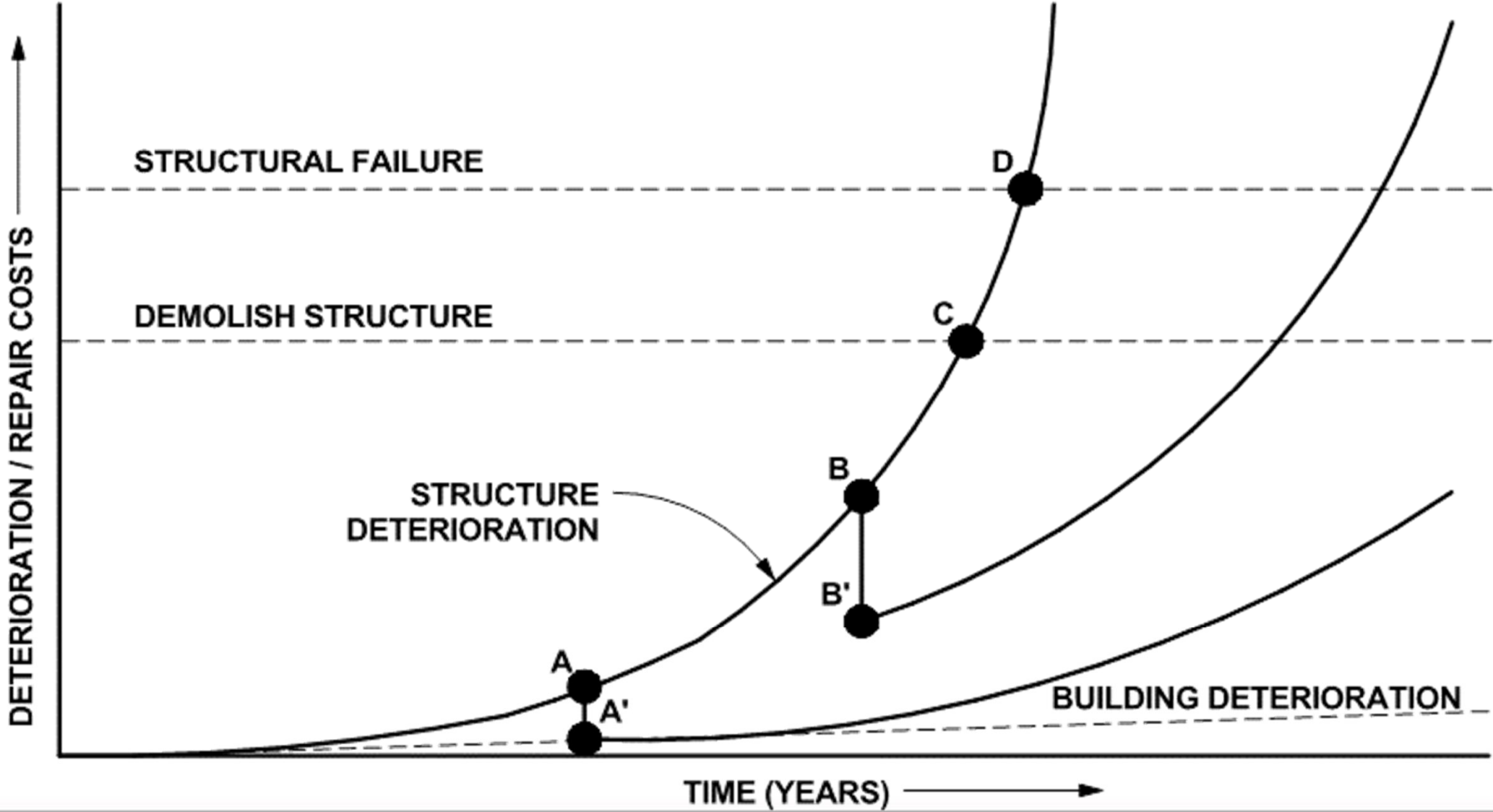
Deferred Maintenance Cost Curve



Deferred Maintenance Cost Curve



Deferred Maintenance Cost Curve



Reinforced Concrete - Deterioration

- **Moisture**
 - Corrosion
 - Freeze-Thaw
 - Sub-Efflorescence
- **Cracking**

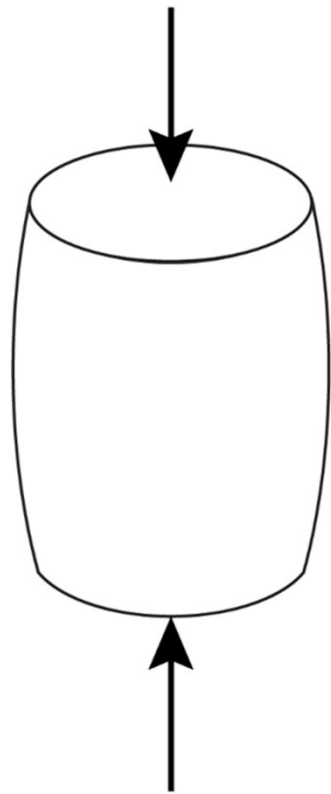


Reinforced Concrete

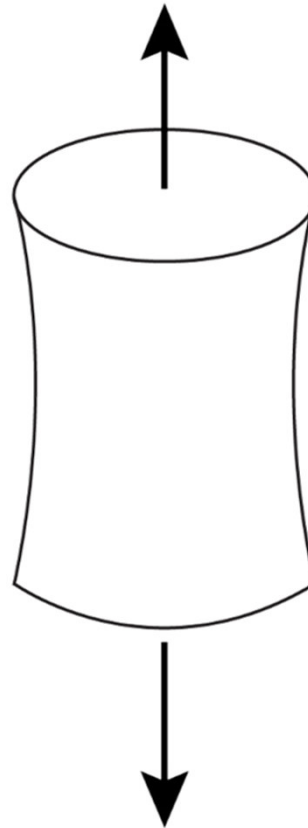
10 % of Compression

Add Reinforcing

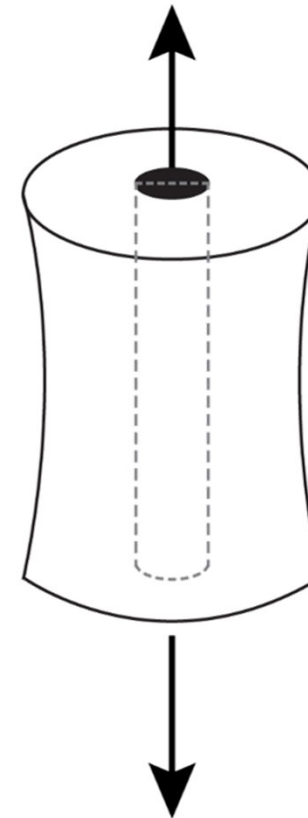
Compression



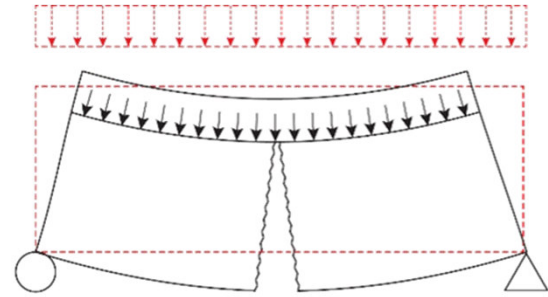
Tension



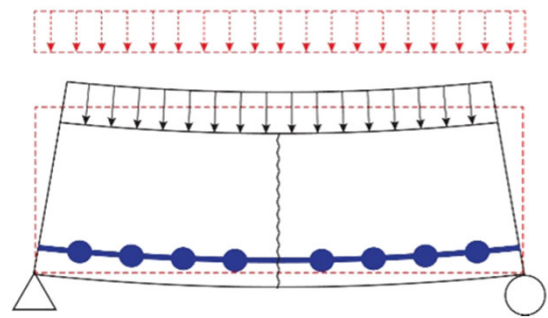
Tension



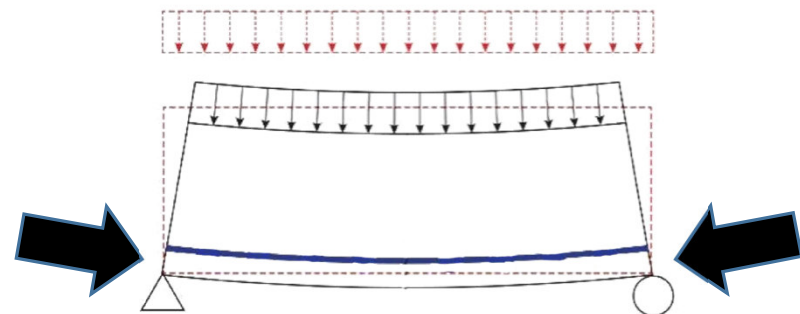
Reinforced Concrete – Simple Span Beam/Slab



Plain Concrete

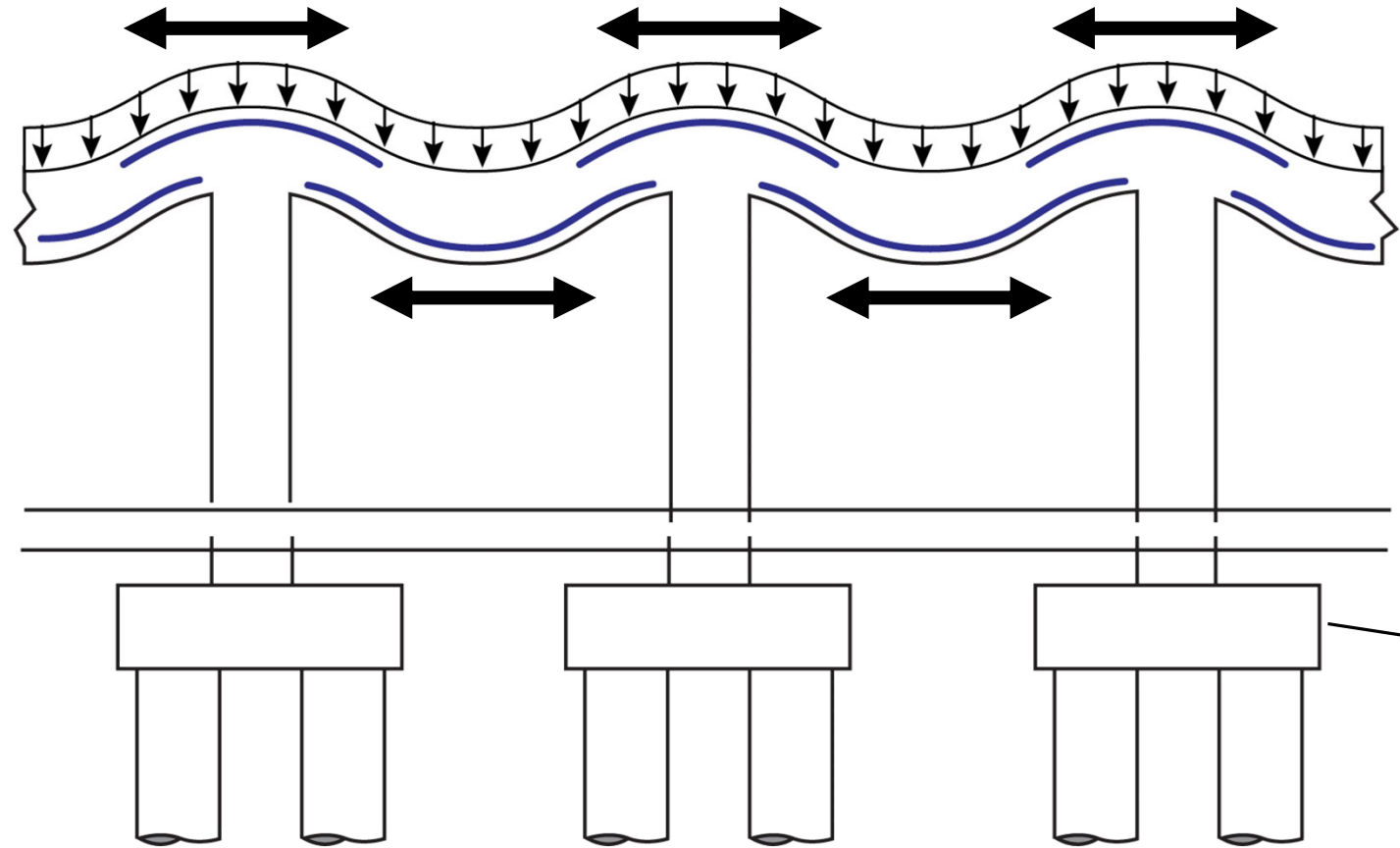


Reinforced Concrete



Prestressed Concrete

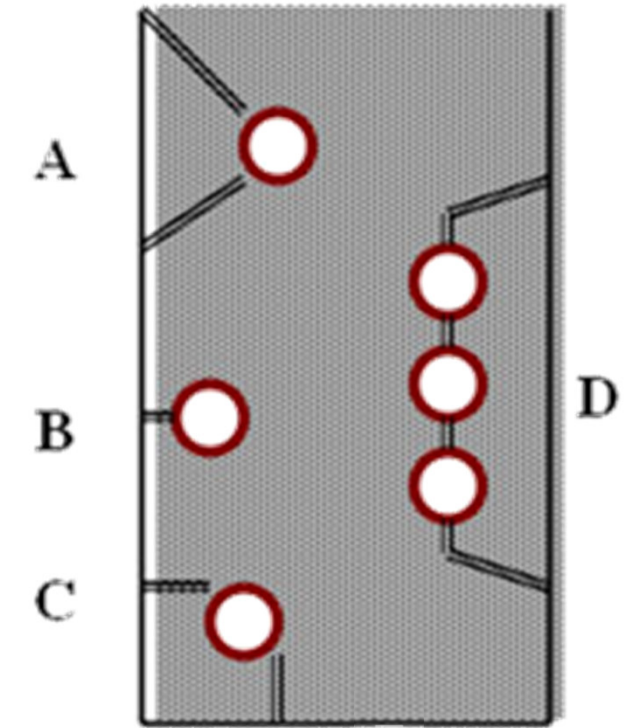
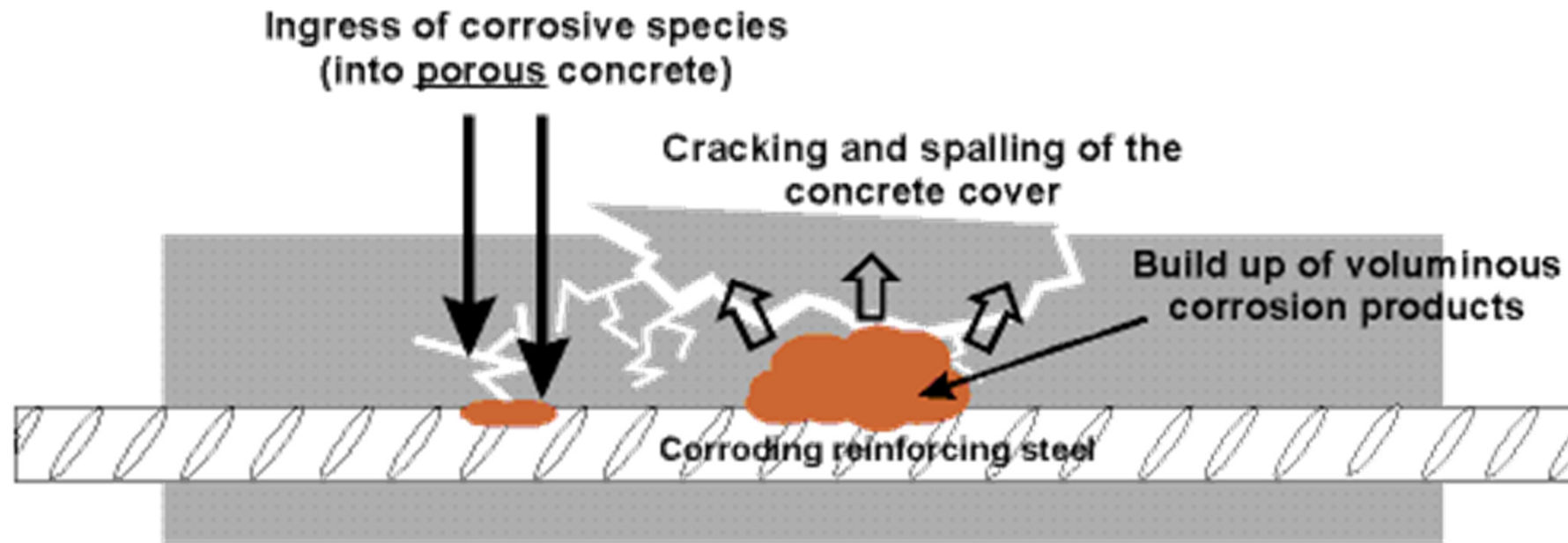
Reinforced Concrete – Multi-Span Beam/Slab



- **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

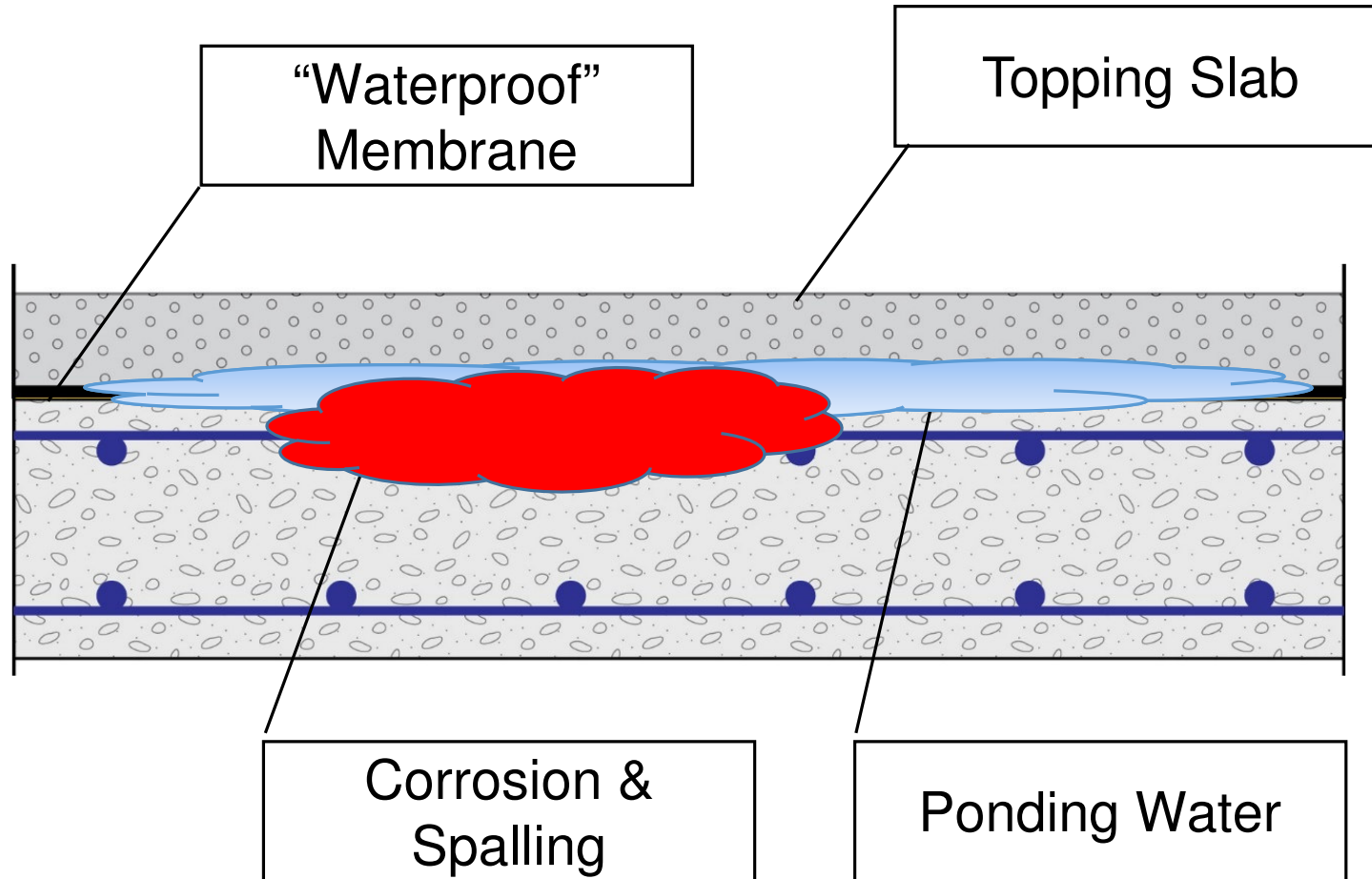
Reinforced Concrete - Sounding



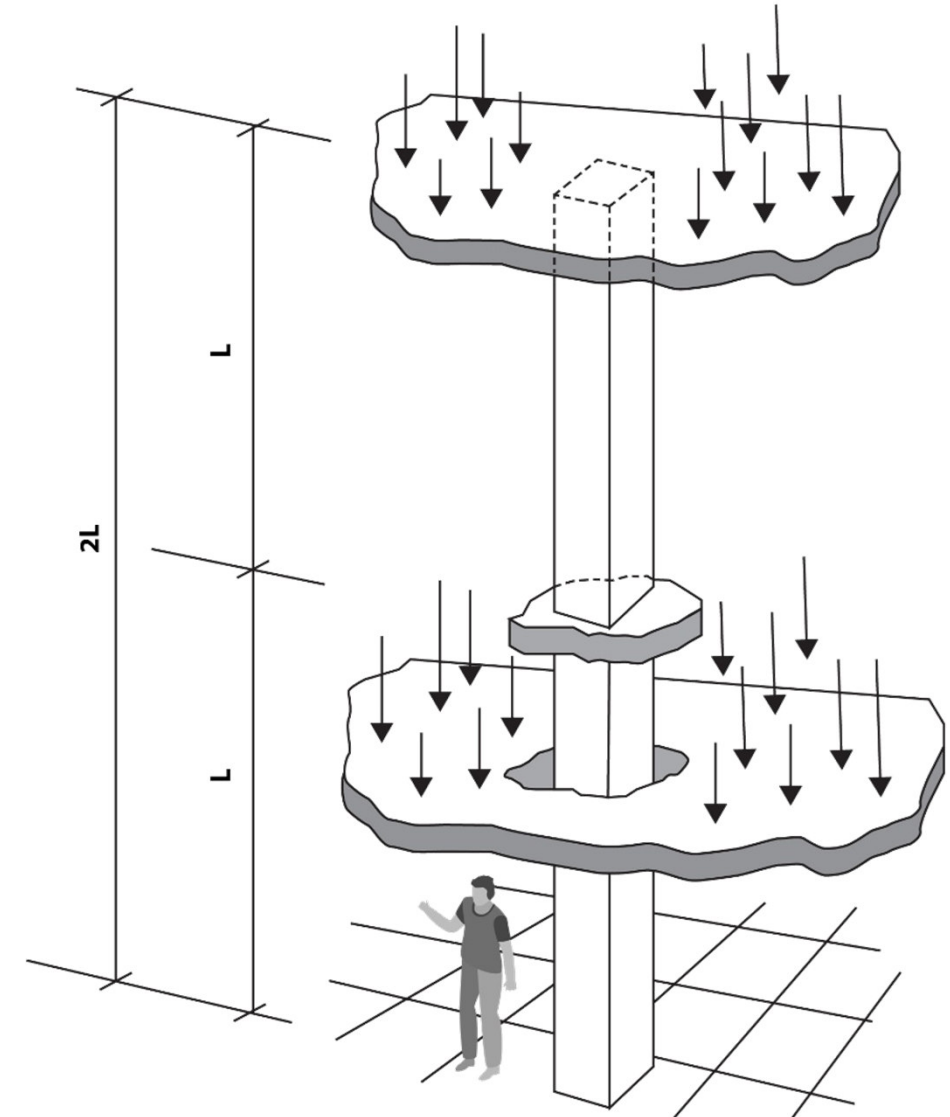
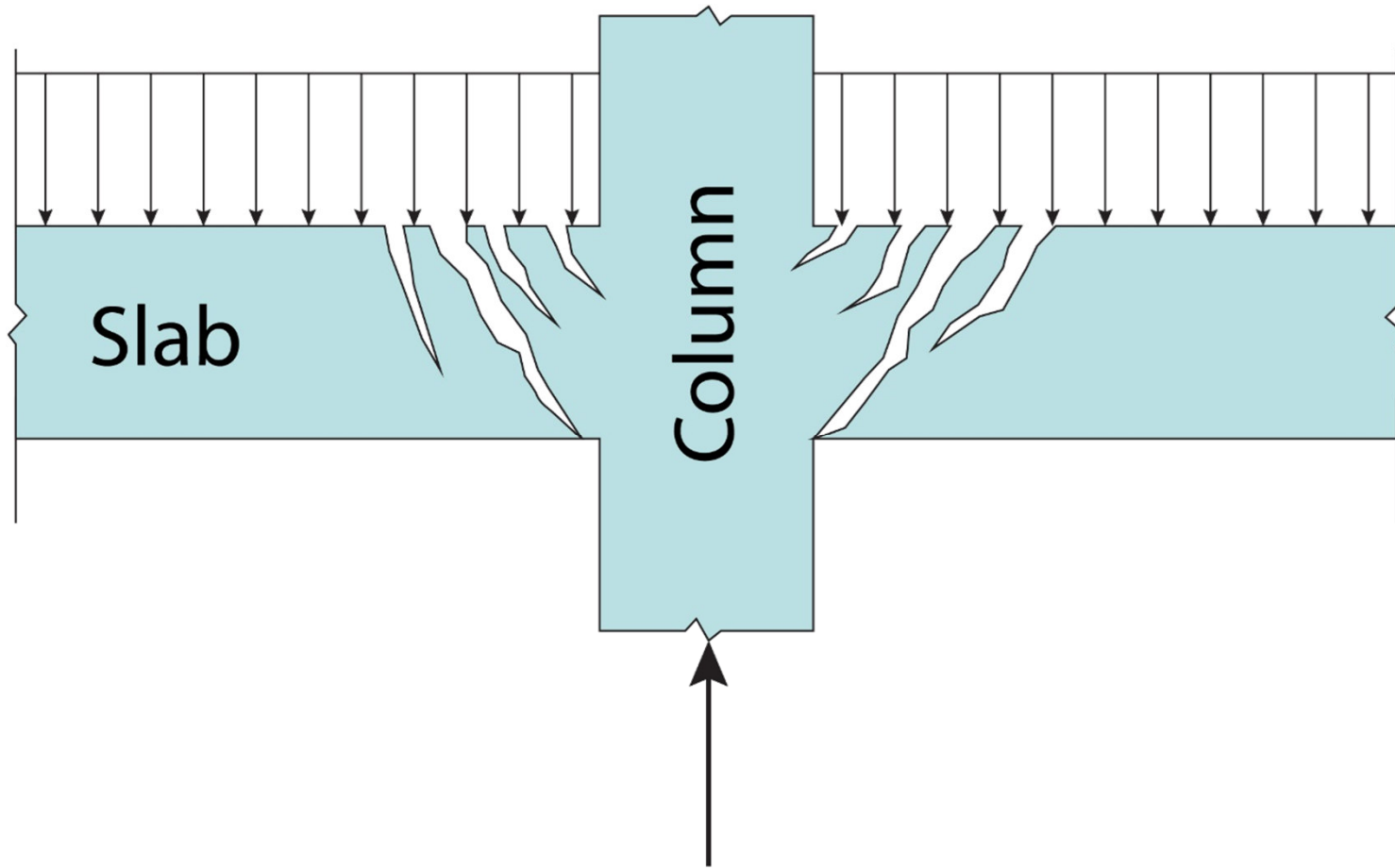
Sounding Technology Inc.

Reinforced Concrete – Impulse Echo

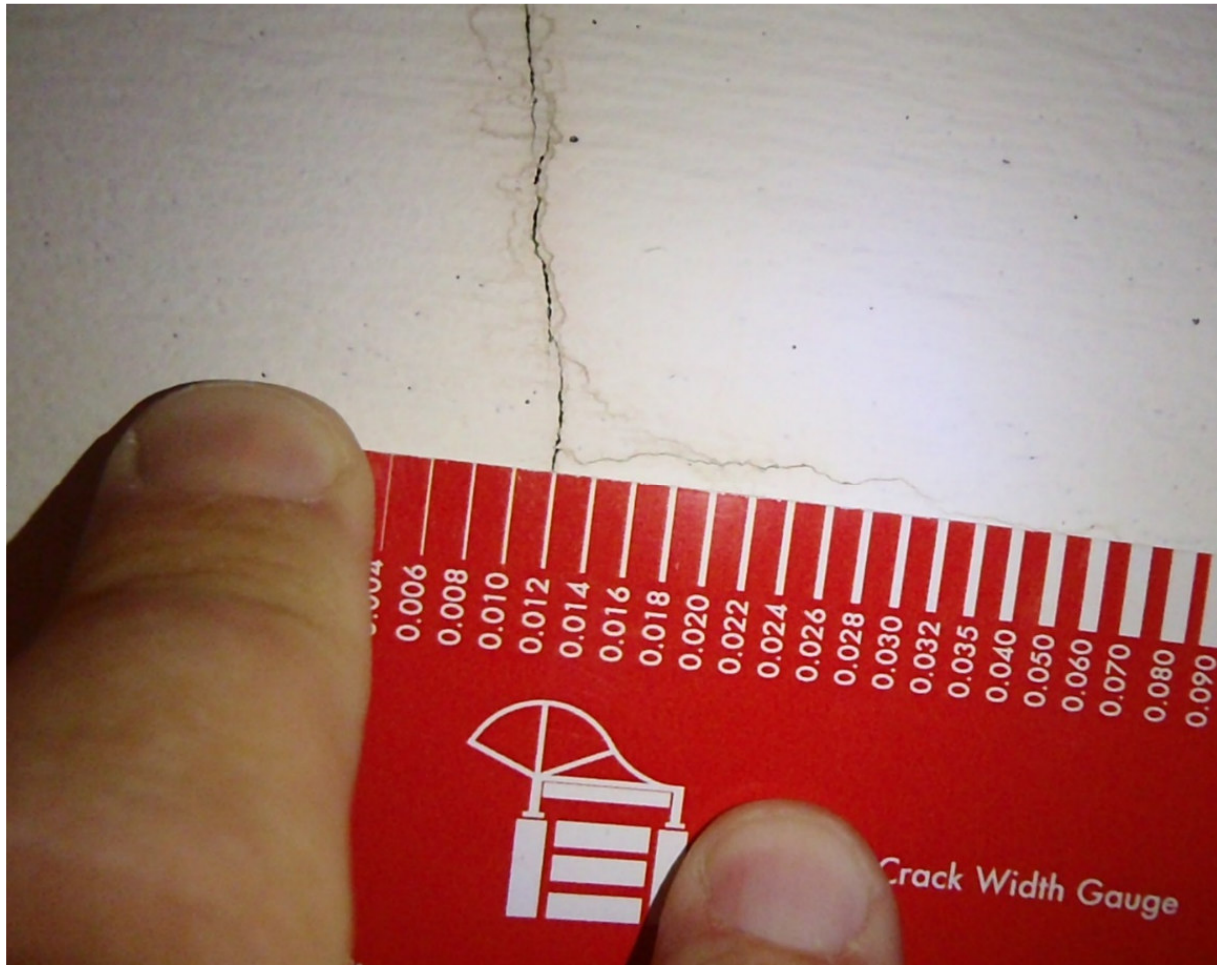
Plaza Slab



Reinforced Concrete – 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.

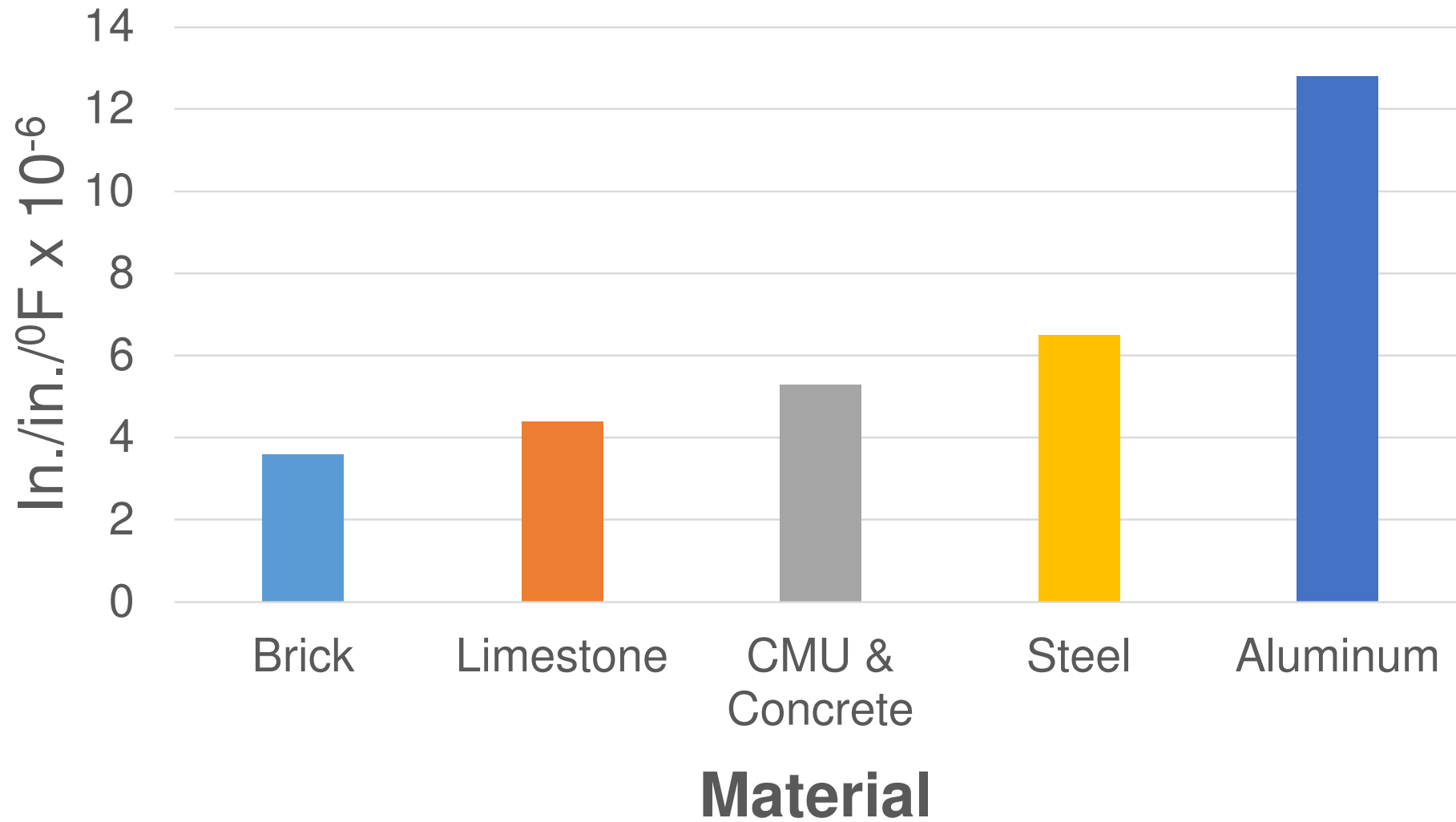
Masonry - Deterioration

- **Thermal Expansion/Contraction**
- **Moisture**
 - Expansion/Contraction
 - Corrosion
 - Freeze-Thaw
 - Sub-efflorescence
- **Cracking**



Masonry – Thermal Expansion/Contraction

Thermal Expansion



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

Masonry – Thermal Expansion/Contraction

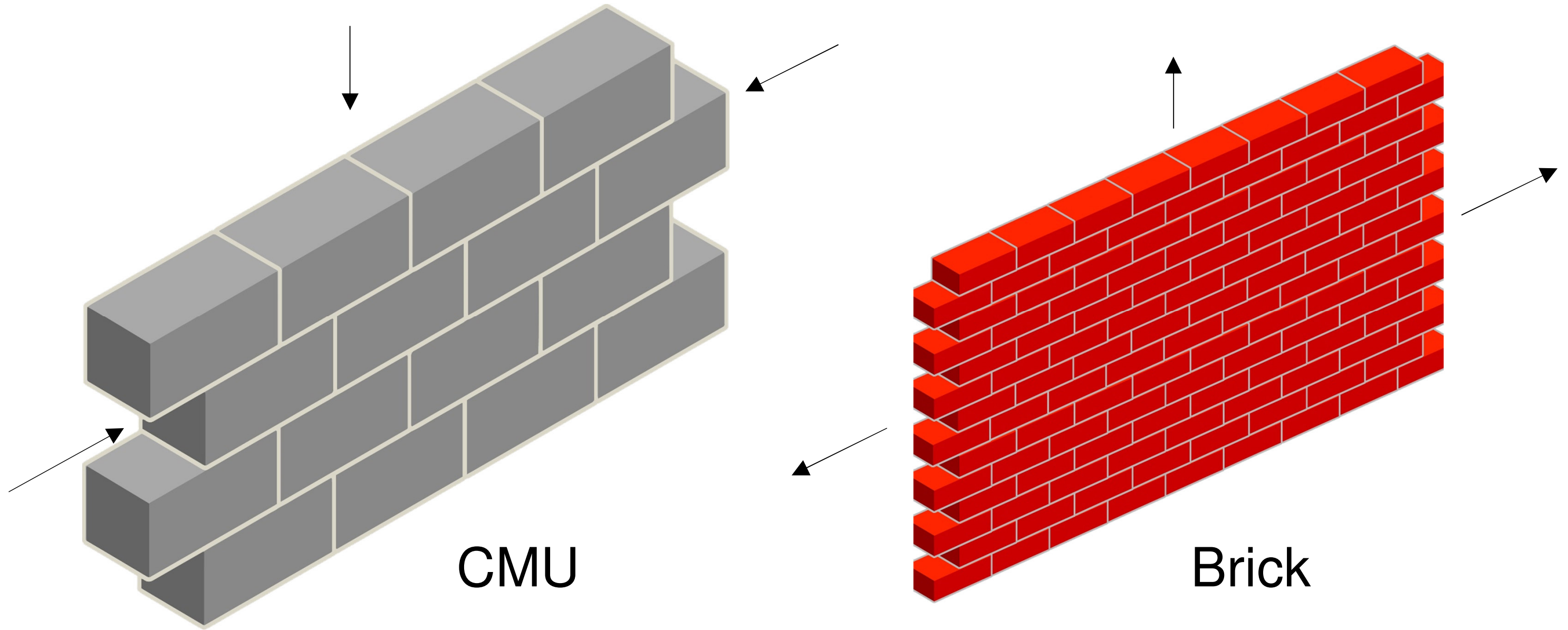


No Expansion Joints

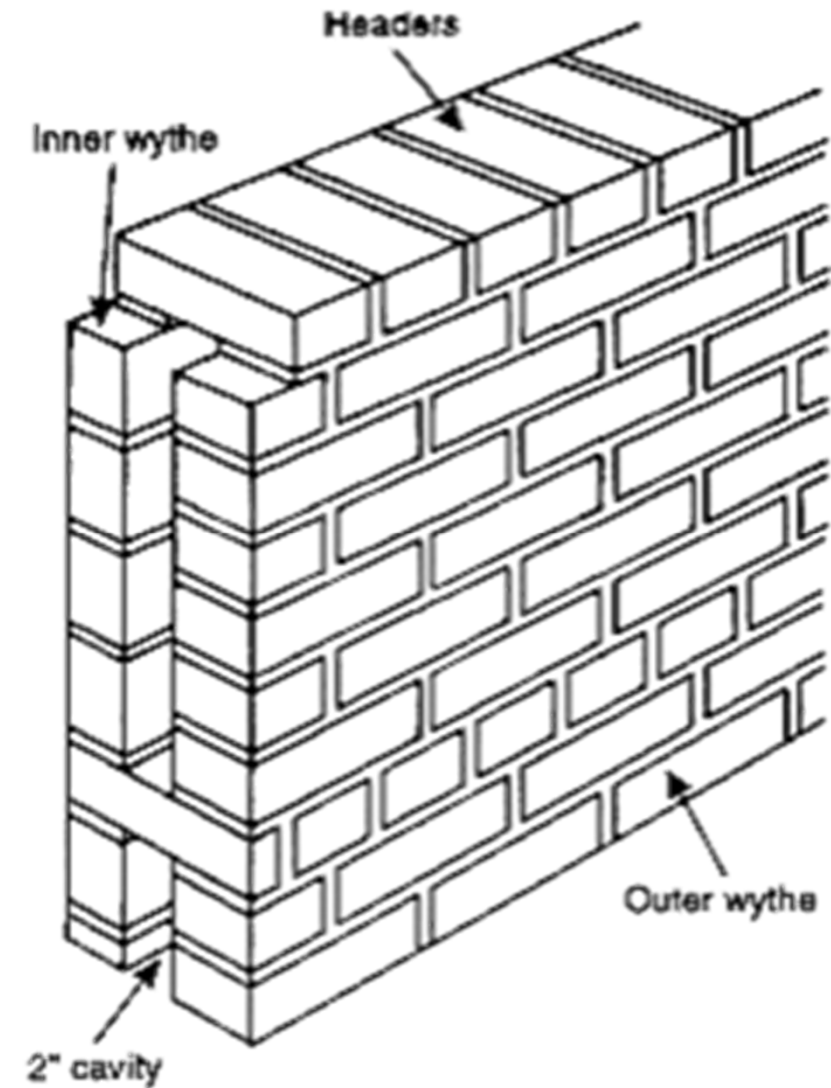


Creates Hinge at Corner

Masonry – Moisture Expansion/Contraction



Masonry – Thermal/Moisture Expansion/Contraction



Masonry – Thermal/Moisture Expansion/Contraction



Masonry – Corrosion Expansion



Masonry – Moisture Damage



Masonry – Creep & Settlement



Masonry – Unauthorized Openings



- **Penetrations:**
 - Through Load Bearing Walls

Structural Steel - Deterioration

- **Moisture**
- **Rust**
- **Fatigue**
- **Modified or Damaged Members**



Structural Steel - Corrosion

- **Surface Rust**
- **Section Loss**
- **Flange**
- **Web**



Structural Steel - Corrosion

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



Structural Steel - Fatigue



Structural Steel – Altered/Damaged Members



Wood Framing - Deterioration

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



Wood Framing - Moisture



Moisture Content $> 30\%$ =
Serious Decay

Wood Framing – Termite Infestation



Mud Tubes

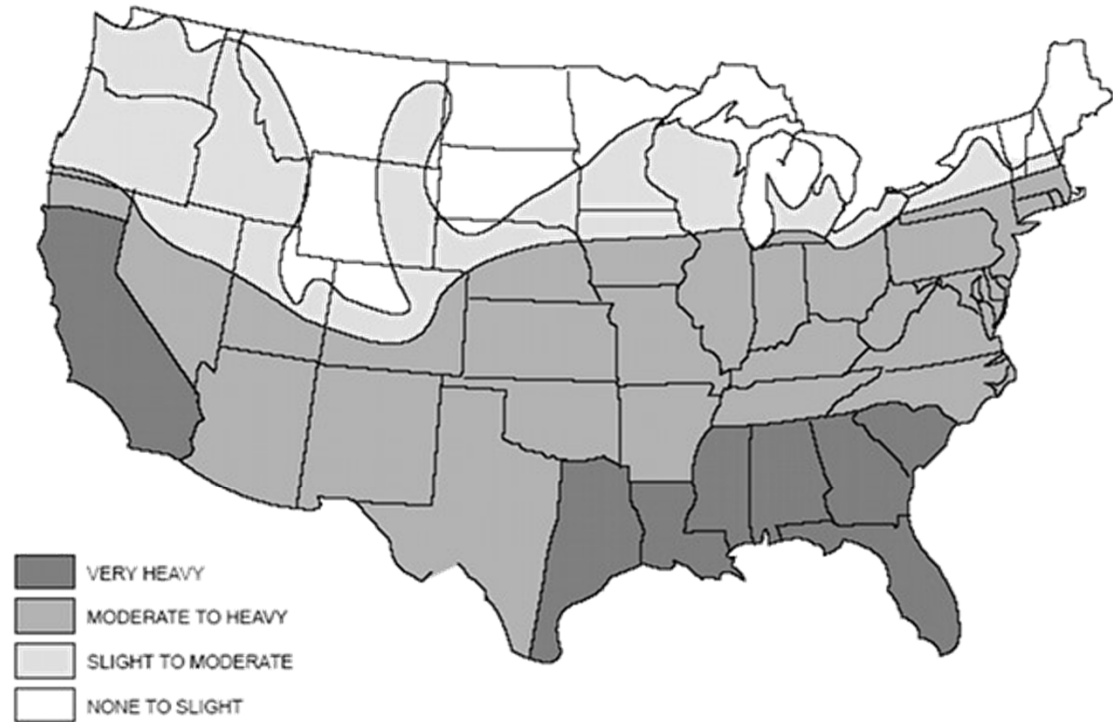


Wood Framing – Termite Infestation

- **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 1/4" 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



Laws & Standards – Why Condition Assessment

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



Laws & Standards – Int’l Property Maintenance Code

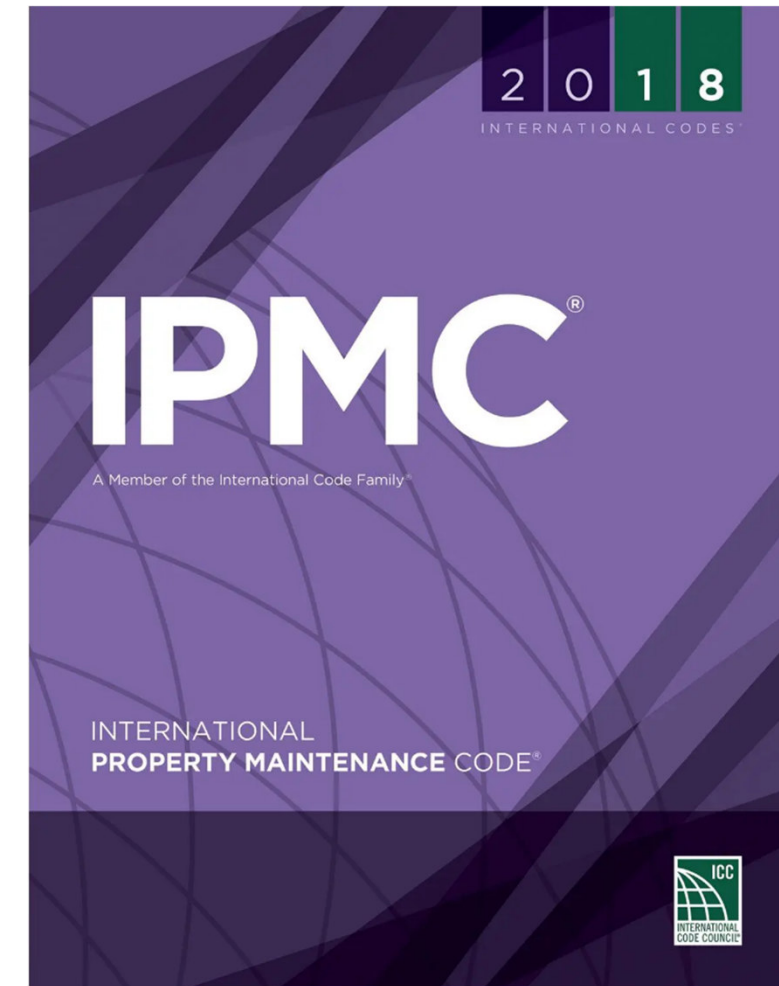
SECTION 304 EXTERIOR STRUCTURE

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.

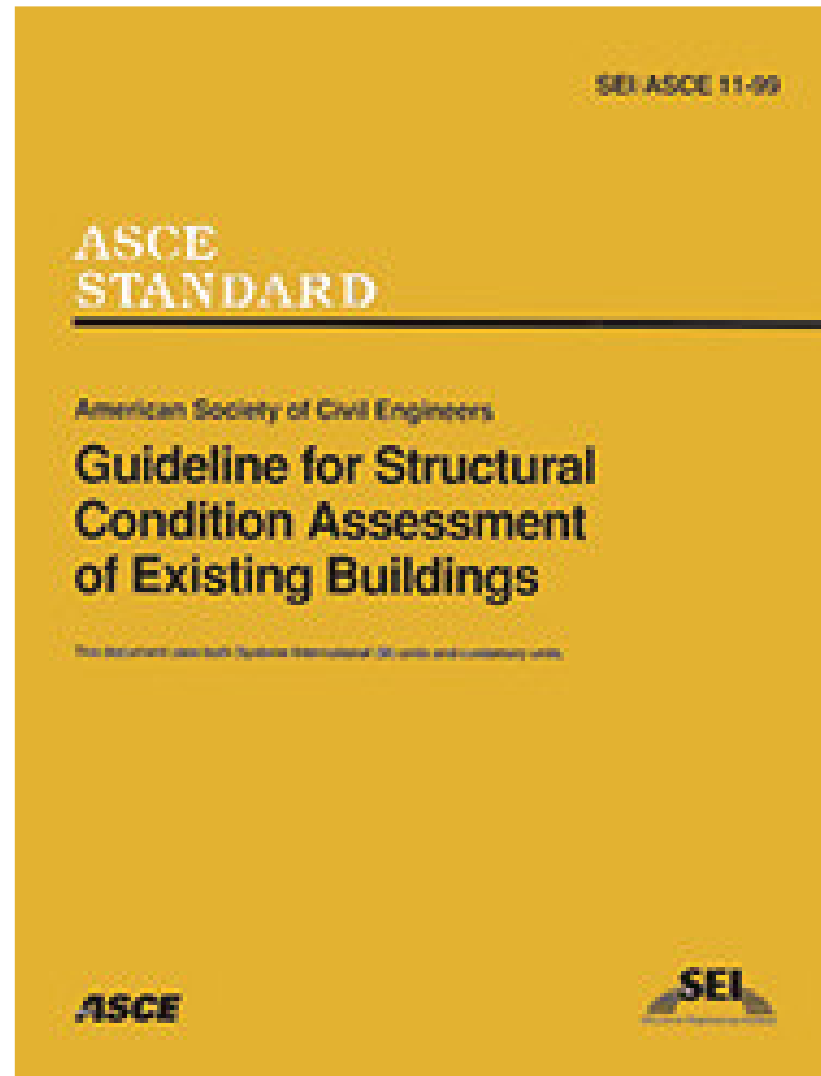
SECTION 305 INTERIOR STRUCTURE

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!

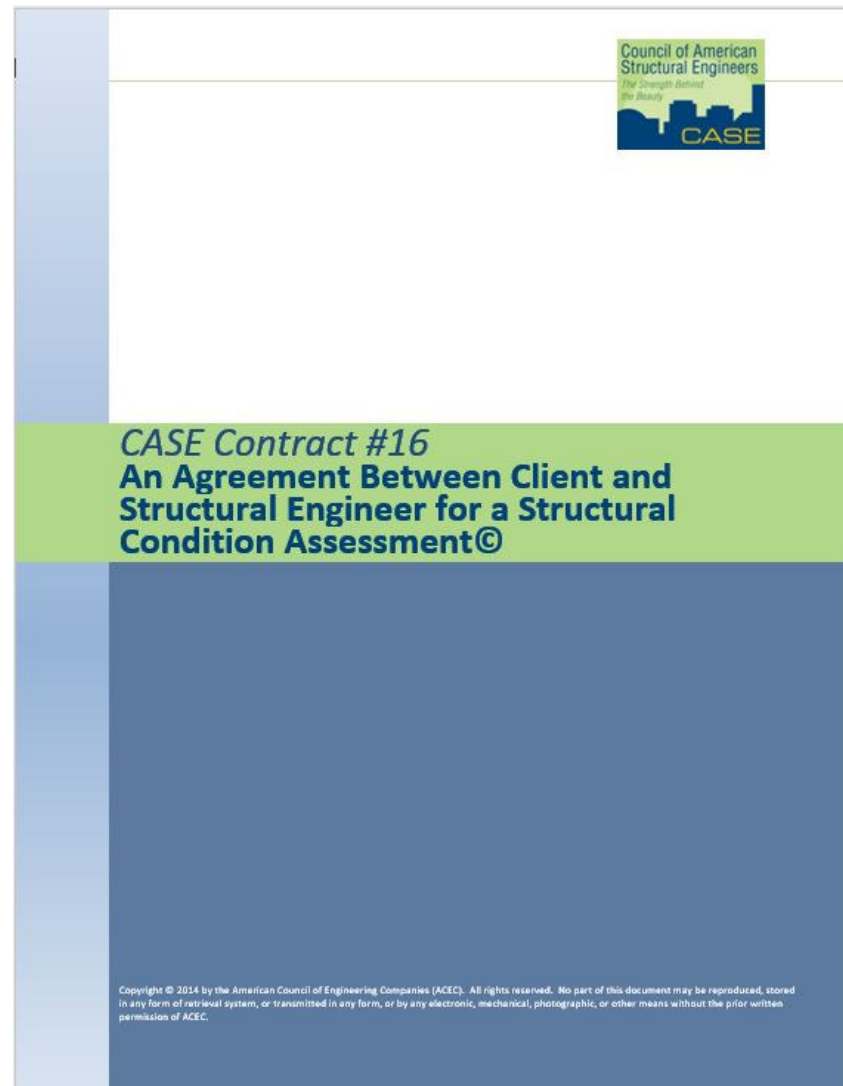


Laws & Standards – ASCE Std. SEI/ASCE 11-99



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

Laws & Standards – CASE Contract #16



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

Laws & Standards – Inspection Checklist



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

Laws & Standards – 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

Laws & Standards – Life Expectancy

- **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)

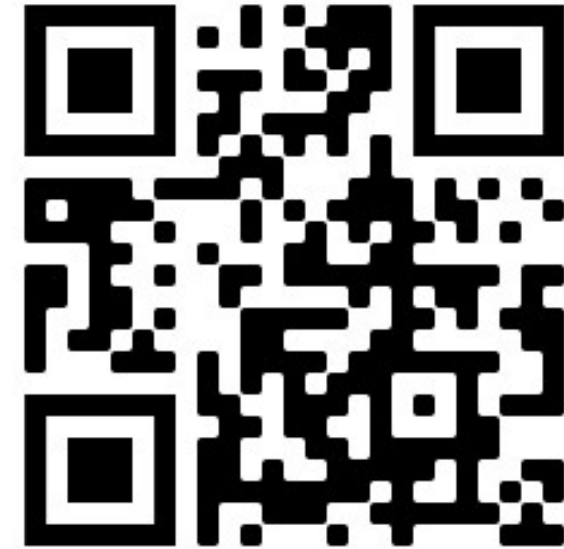
Learning Objectives

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

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Questions

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