



**IFMA WORLD
WORKPLACE**

SEPTEMBER 28-30, 2022
MUSIC CITY CENTER | NASHVILLE, TENNESSEE, USA

Building Structure Condition Assessment

How to Avoid Catastrophe

IFMA World Workplace 2022

Friday, September 30, 2022, 9:15 – 10:15 AM

Music City Center, Nashville, Tennessee



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Learning Objectives

- **Building Structure Condition Assessment**

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

**CEU Code:
BV29OFR**

**AIA
Continuing
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Disclaimer

Presentation today provides general information.

For specific advice, consult a professional.



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Innovative Engineering, Inc.

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





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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





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Building Science – Plaza Slabs

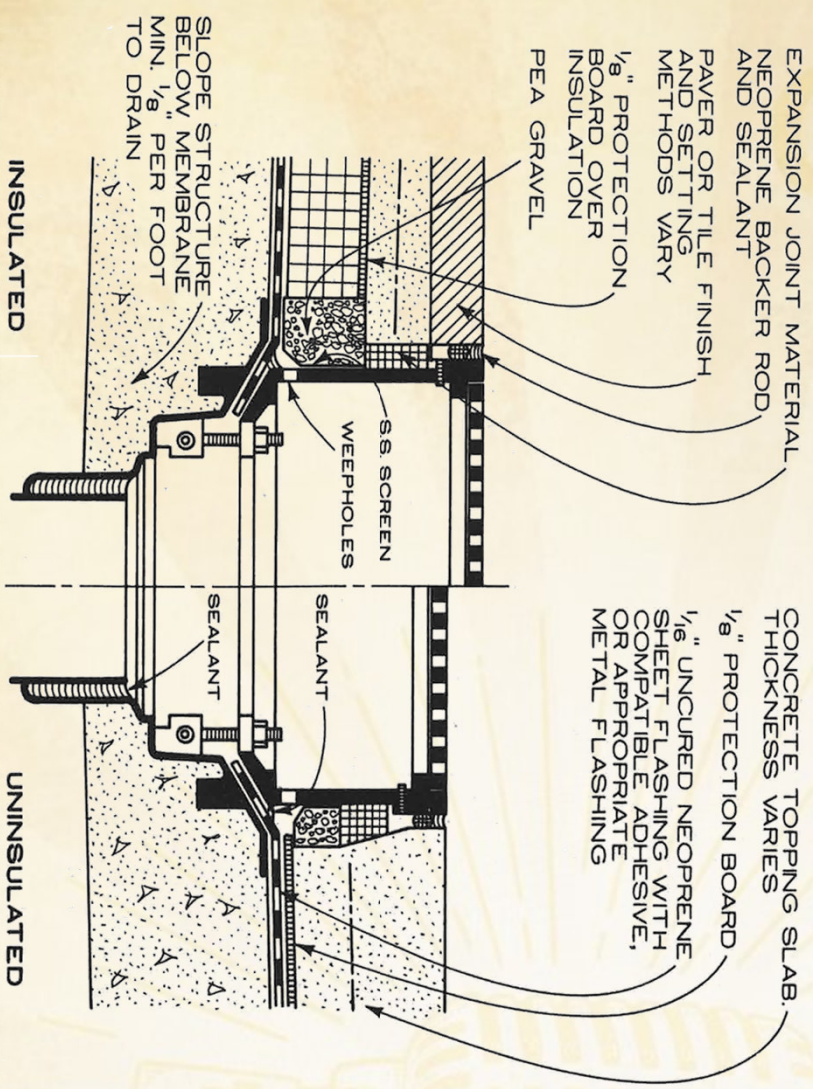




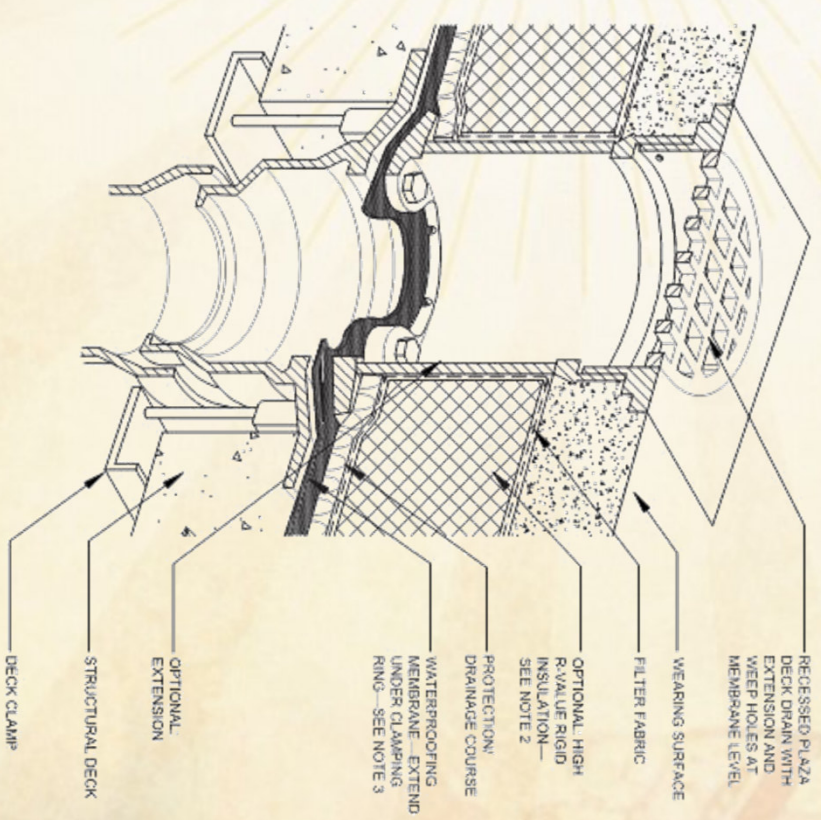
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Plaza Slabs – Protected Membranes



Ref.: 1981 Architectural Graphics Standards



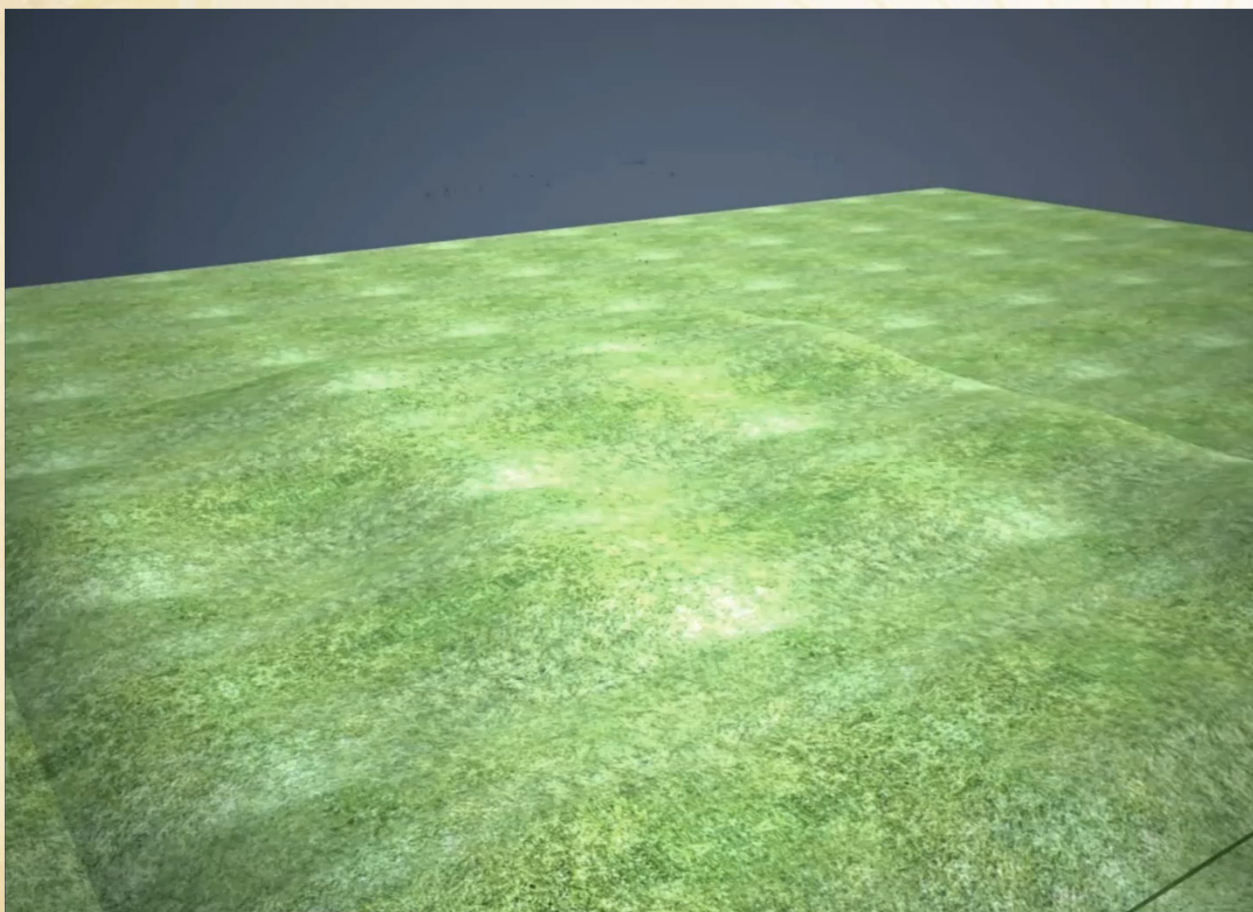
Ref.: NRCA Detail WP-24



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Building Structure - Definitions



Credit: James Burke

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

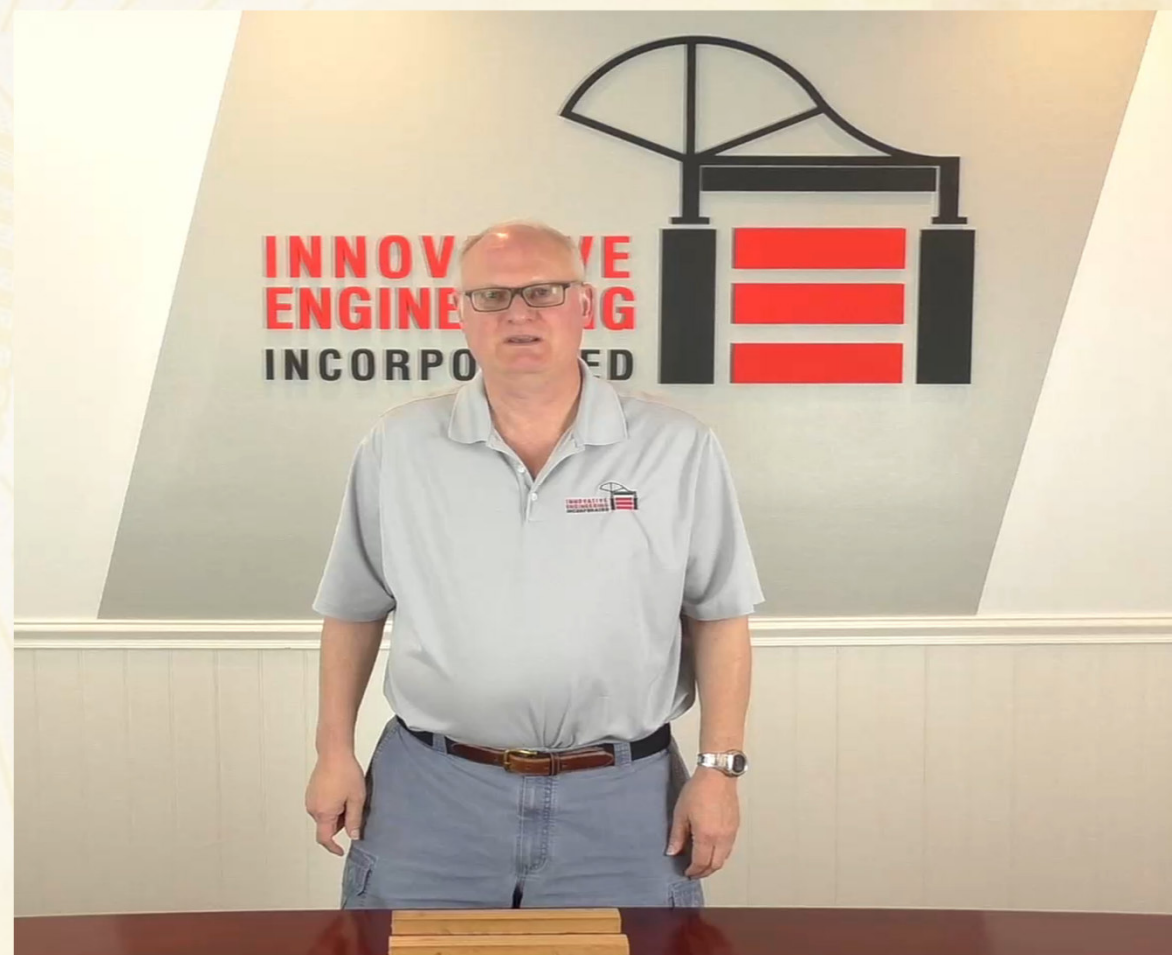


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Building Structure - Columns

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

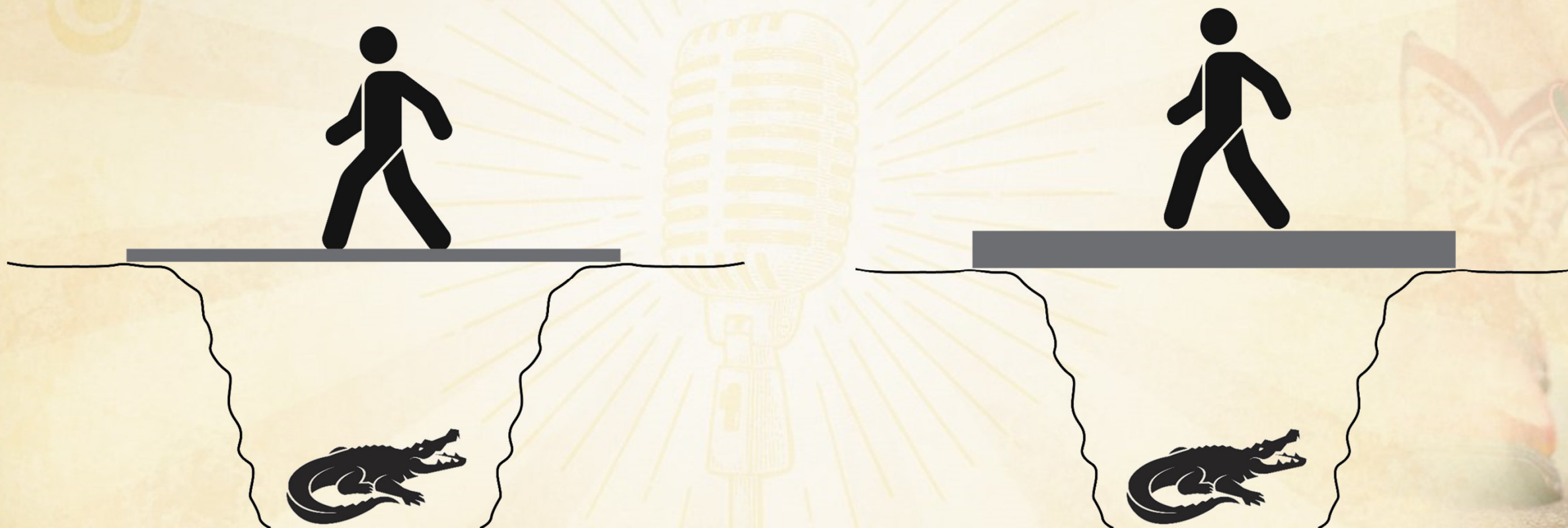




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Building Structure – Beams and Slabs

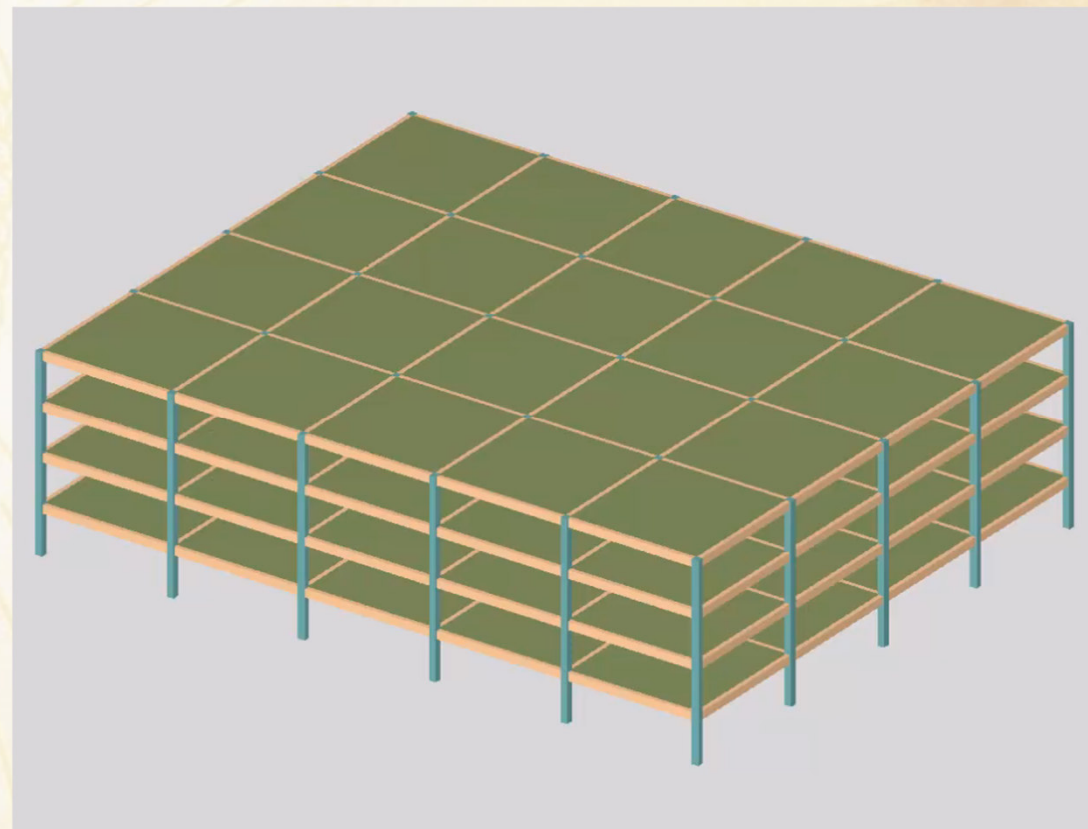
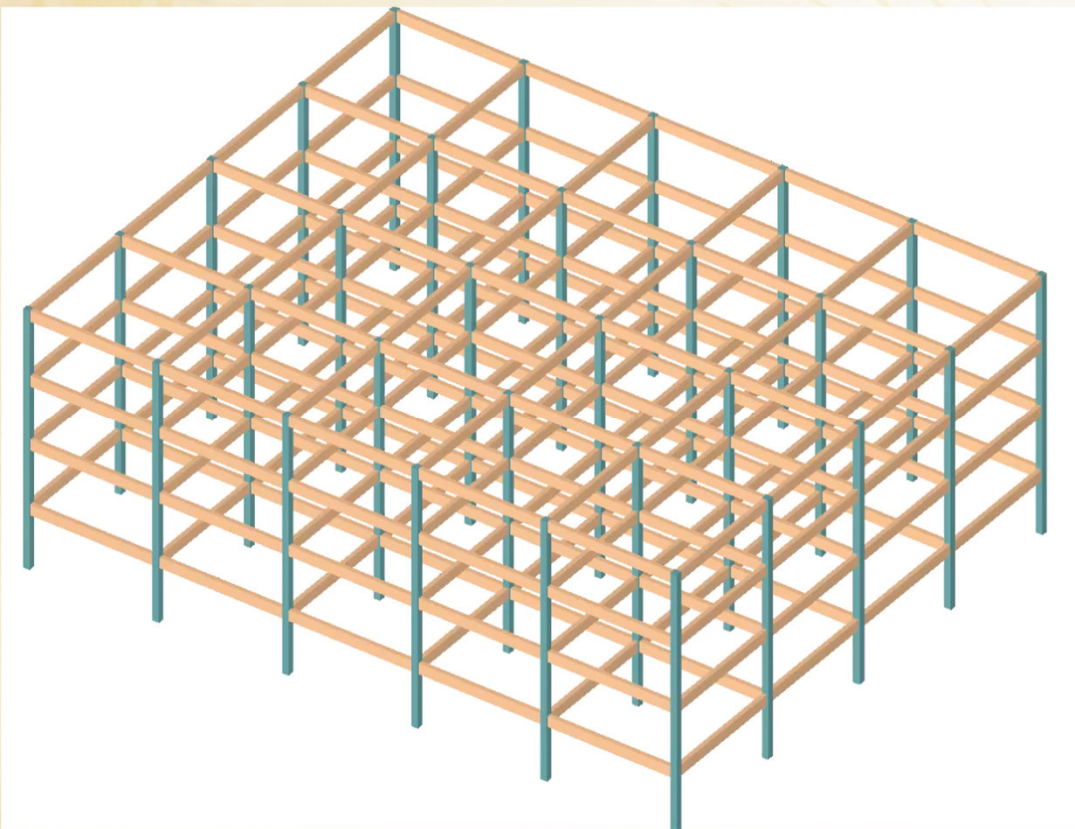




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Building Structure – Progressive Collapse



ASI Extreme Loading

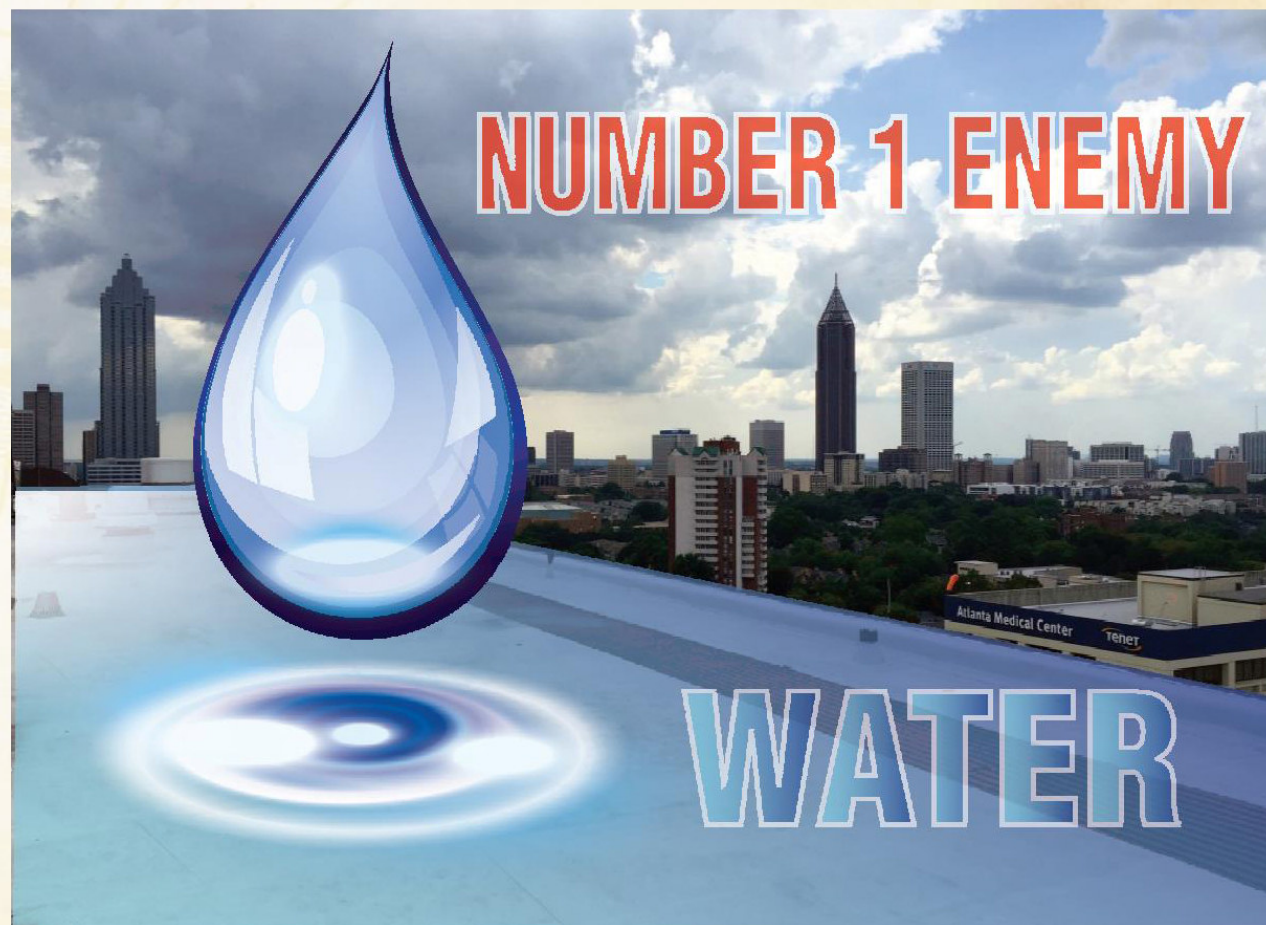


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Building Science – Sources of Deterioration

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

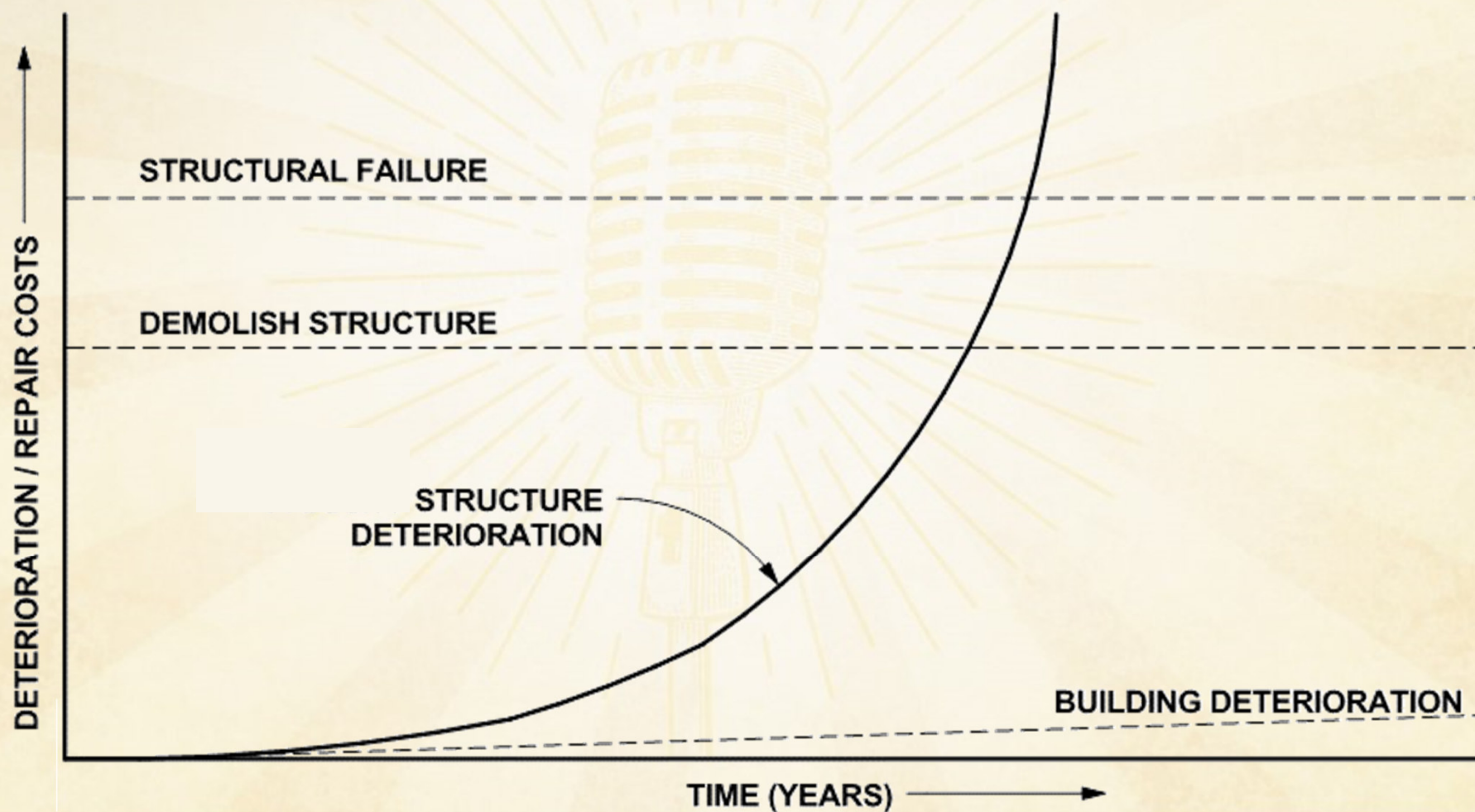




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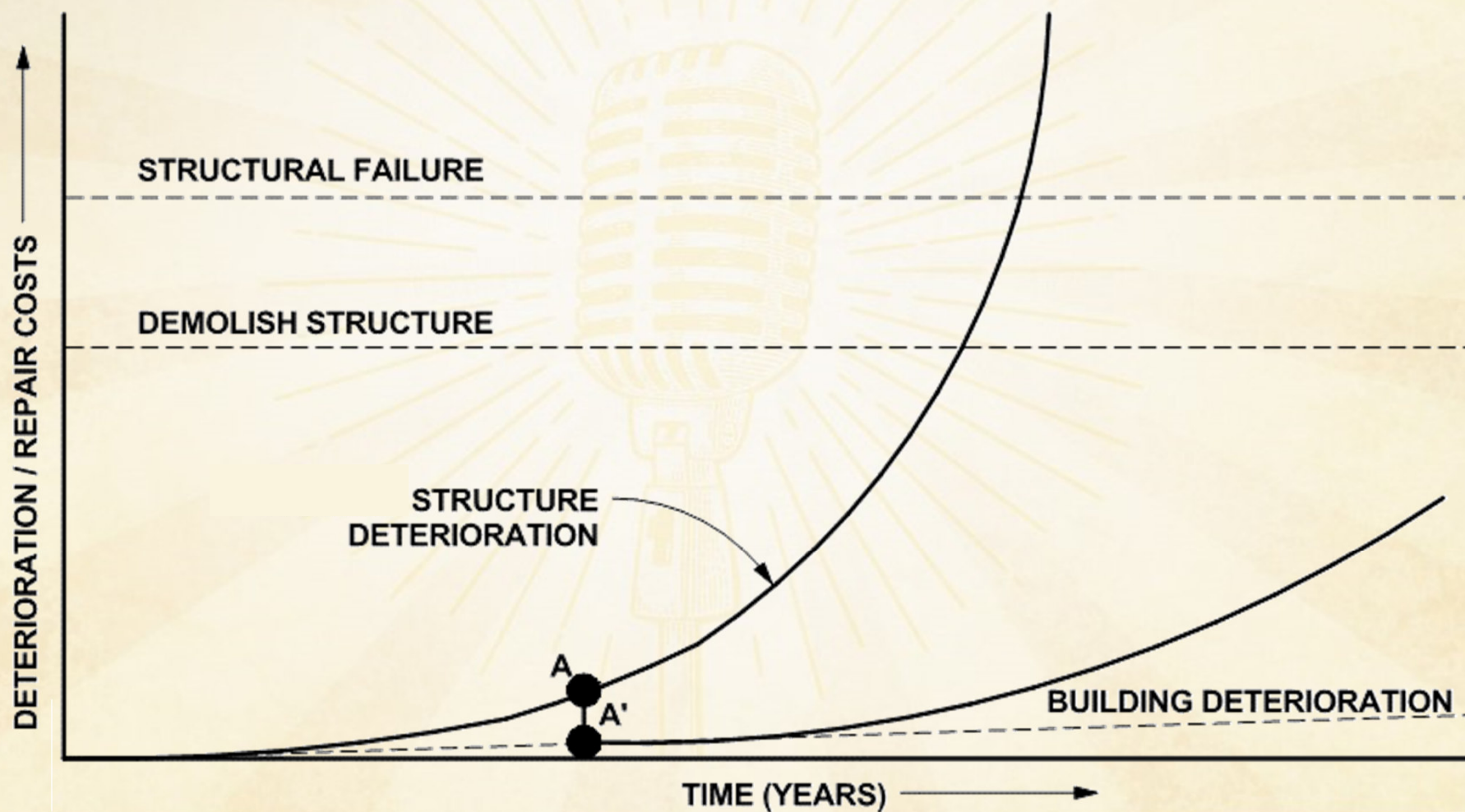
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Deferred Maintenance Cost Curve





Deferred Maintenance Cost Curve

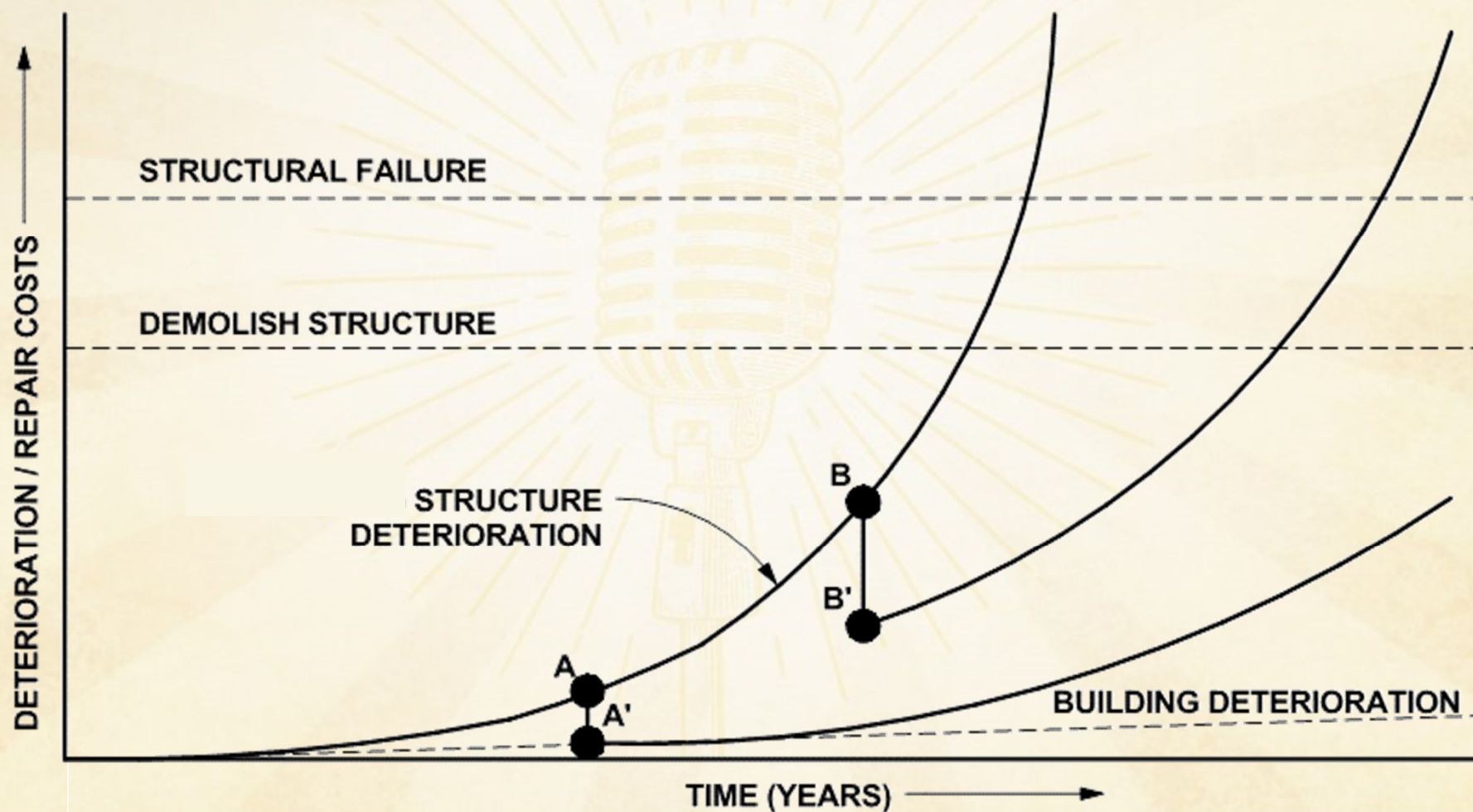




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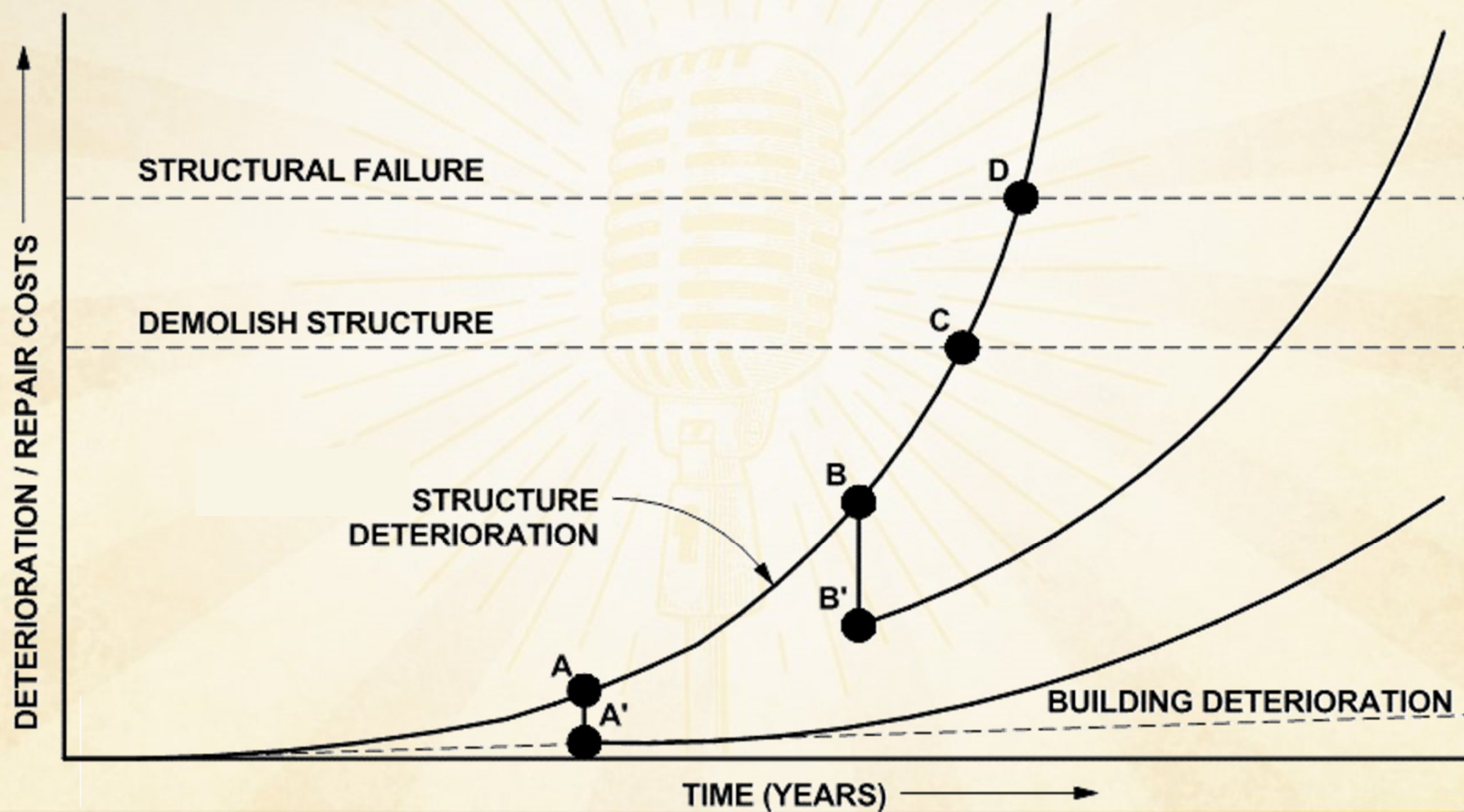
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Deferred Maintenance Cost Curve





Deferred Maintenance Cost Curve





Reinforced Concrete

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





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Reinforced Concrete - Strength

10 % of Compression

Compression

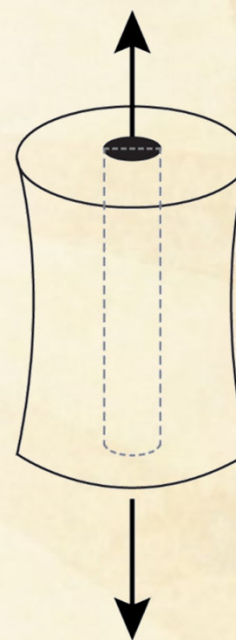


Tension



Add Reinforcing

Tension

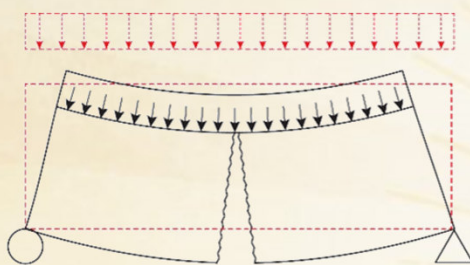




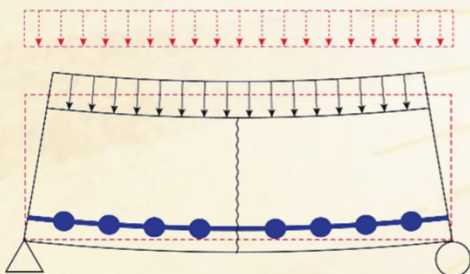
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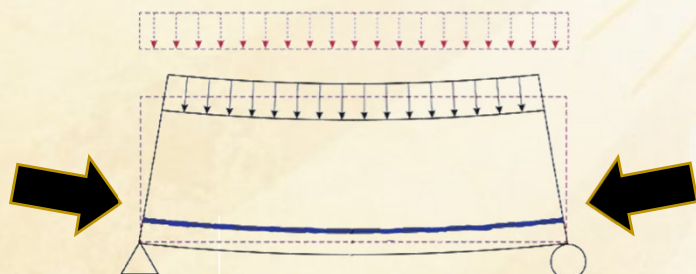
Reinforced Concrete – Simple Span Beam



Plain Concrete



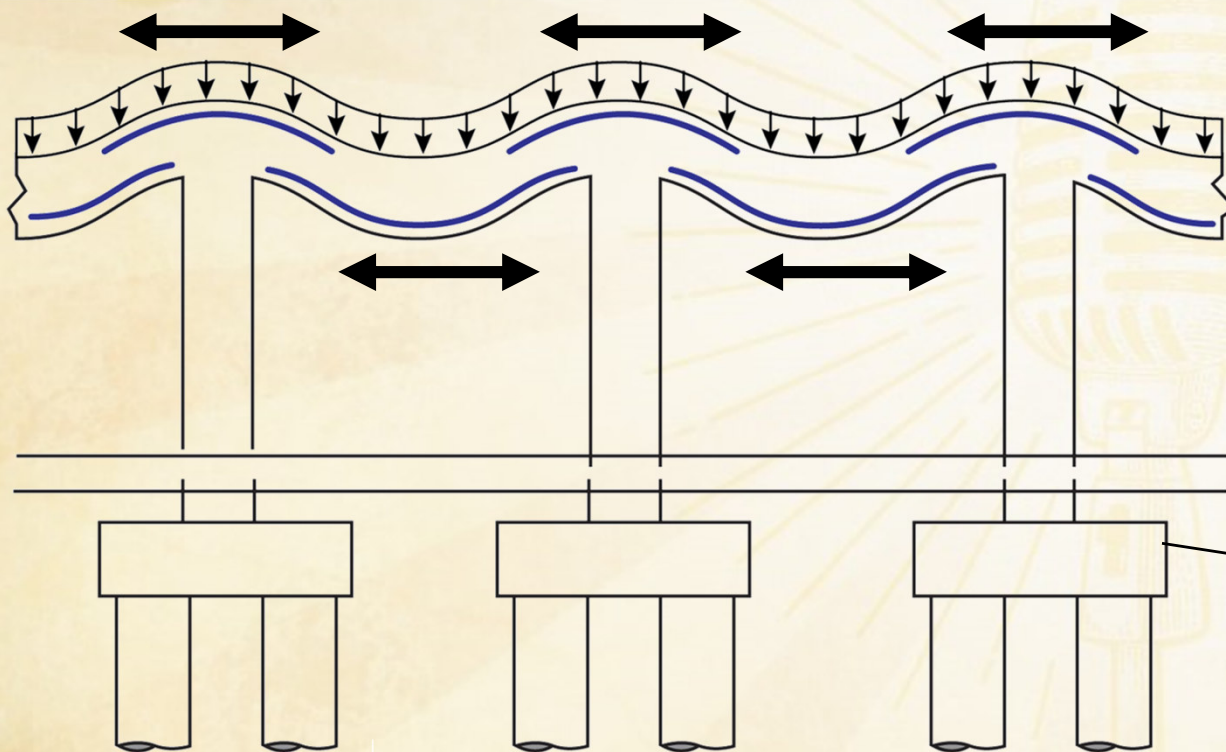
Reinforced Concrete



Prestressed Concrete



Reinforced Concrete – Multi-Span Beam/Slab



- Tension
 - Top over Columns
 - Bottom between Columns

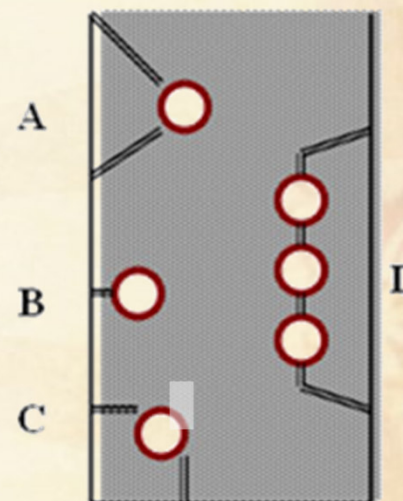
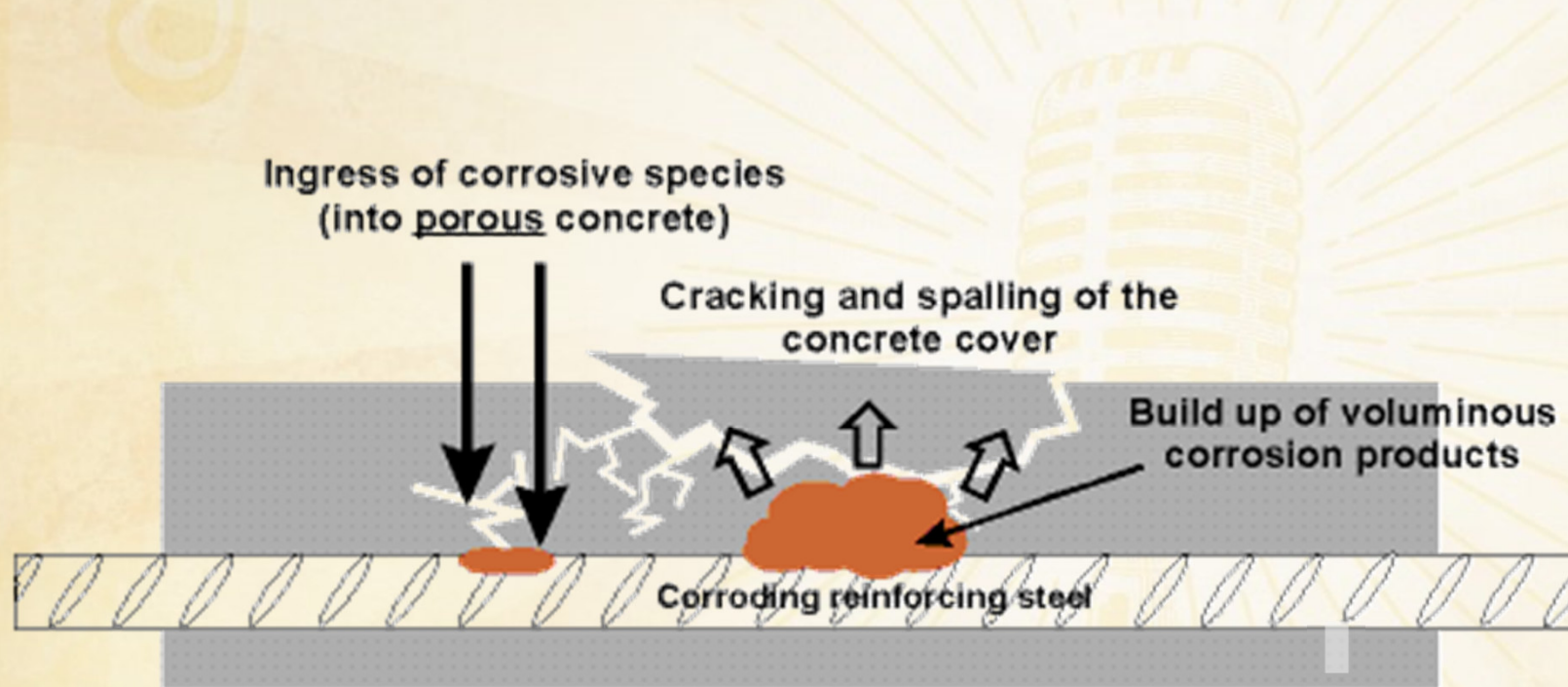
Foundation



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Reinforced Concrete - Corrosion



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



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Reinforced Concrete – Spall & Delamination



Spall



Delamination



Section Loss



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Reinforced Concrete - Sounding



Sounding Technology Inc.

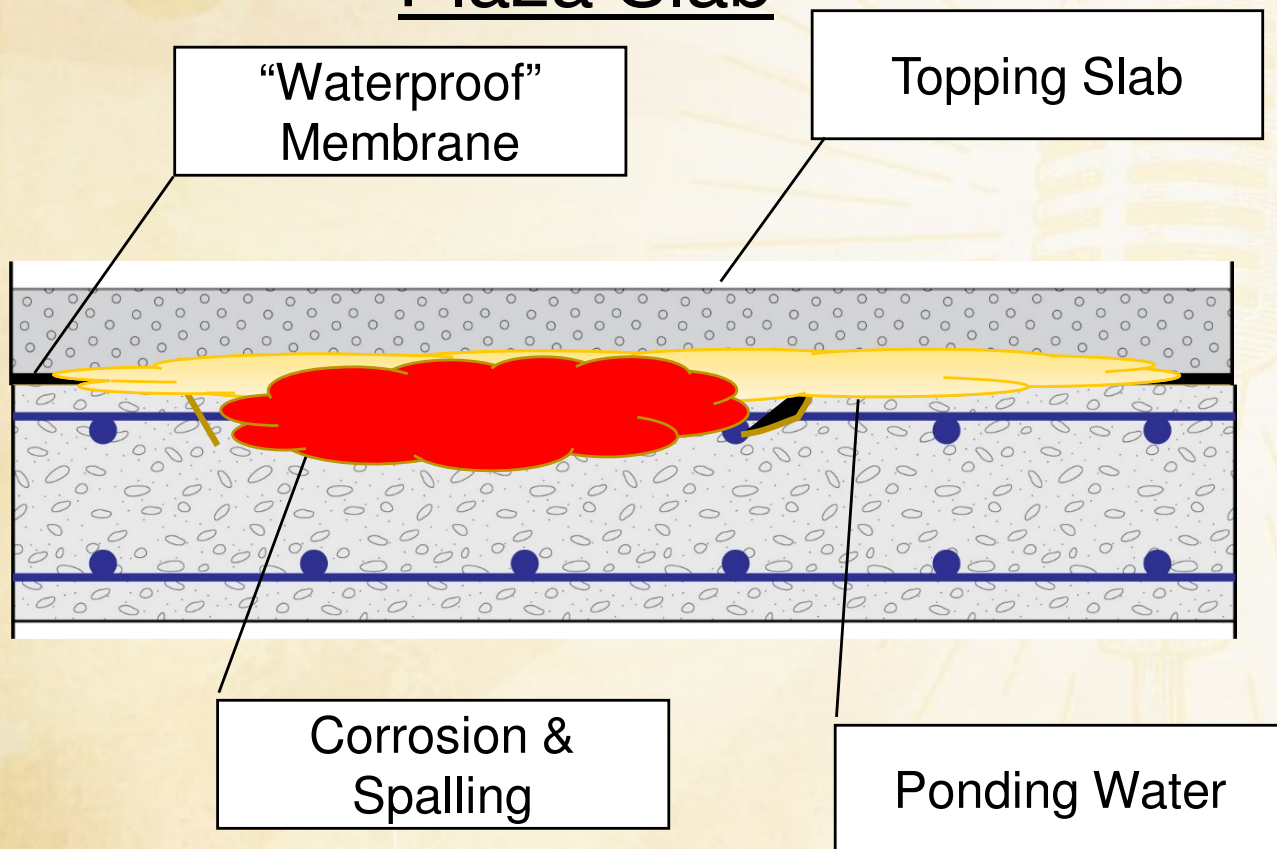


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Reinforced Concrete – Impulse Echo

Plaza Slab

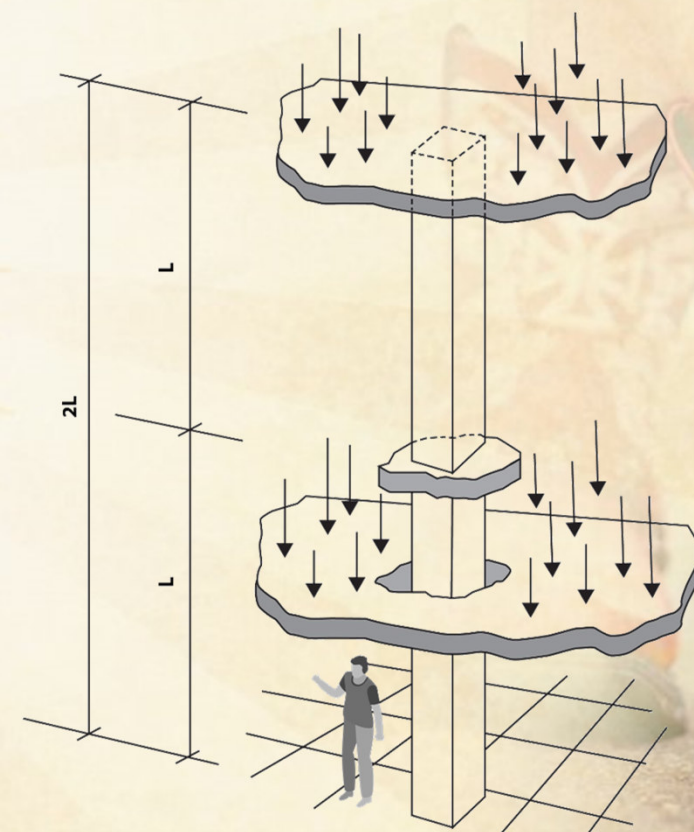
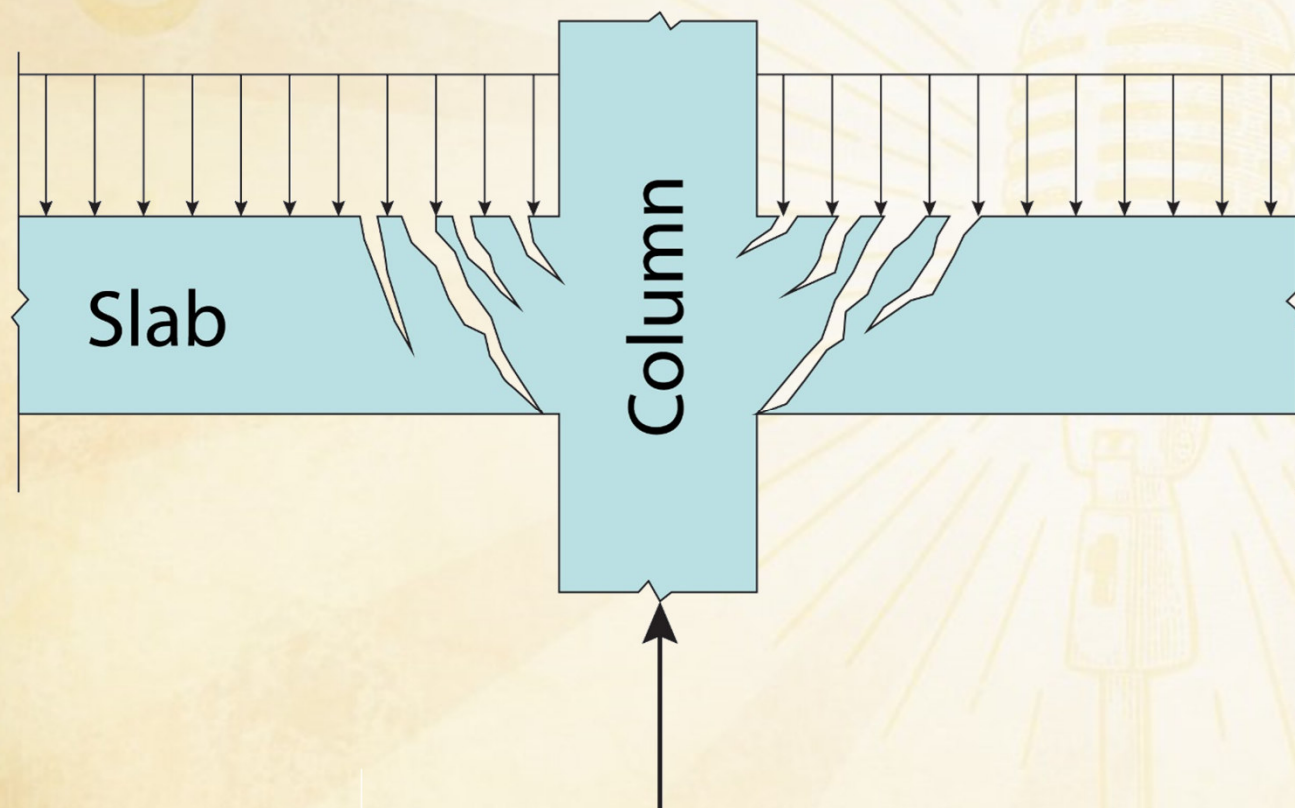




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Champlain Towers Collapse – Punching Shear





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Reinforced Concrete - Cracks



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



Cracks that Leak $< .035''$



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Reinforced Concrete – Crack Repair (Route & Seal)



Crack Chasing



Crack Sealant



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Reinforced Concrete – Crack Repair (Epoxy Injection)



Cracks \geq .035"



Inflatable Injection Port

Photos by Engineered Restorations Inc.



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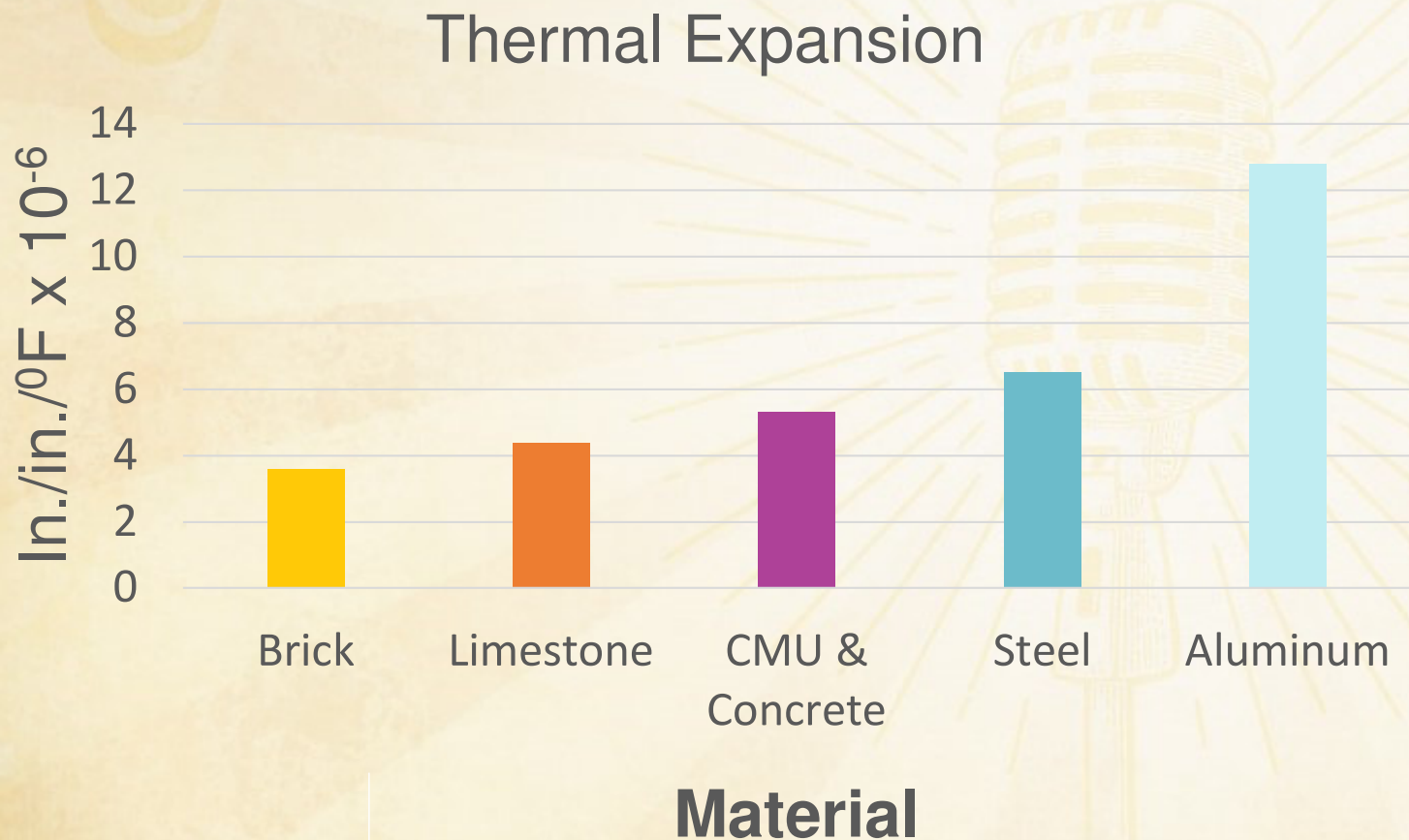
Masonry

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





Façade – 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



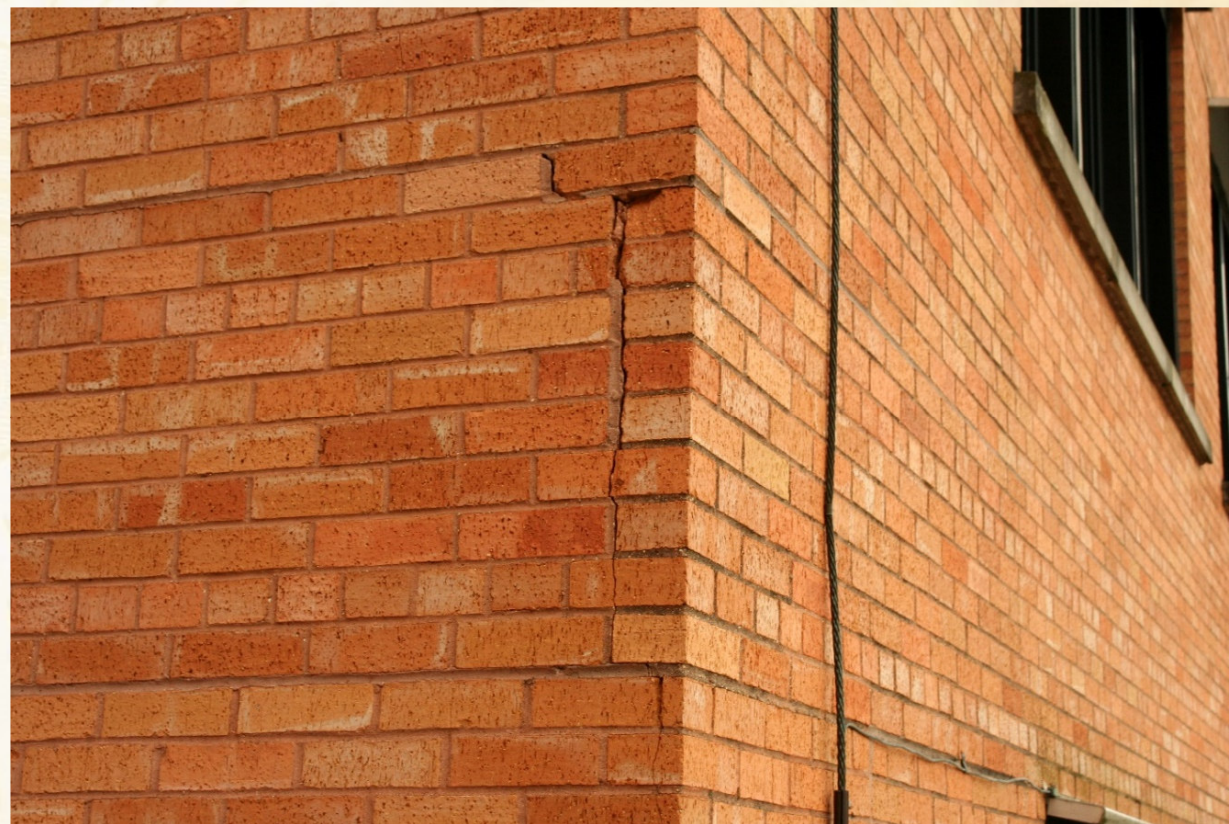
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Façade – Thermal Expansion



No Expansion Joints



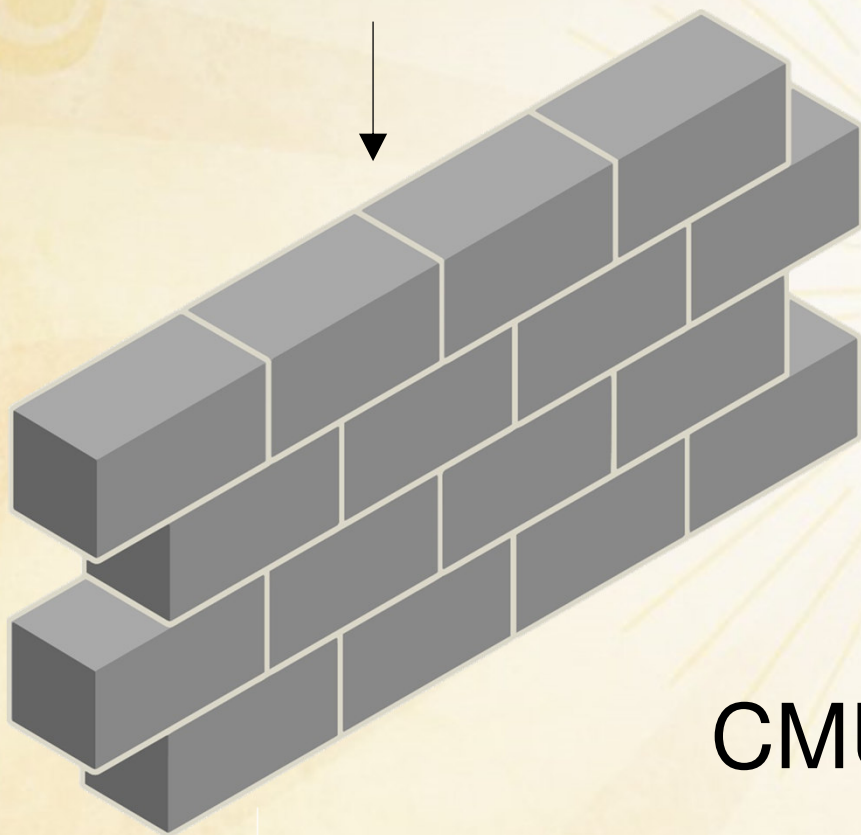
Creates Hinge at Corner



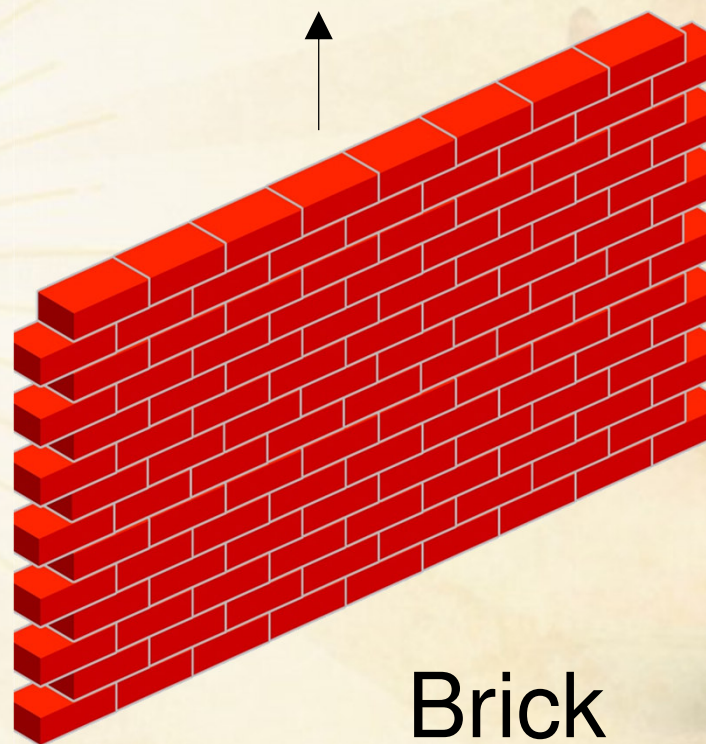
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Façade – Moisture Expansion/Shrinkage



CMU



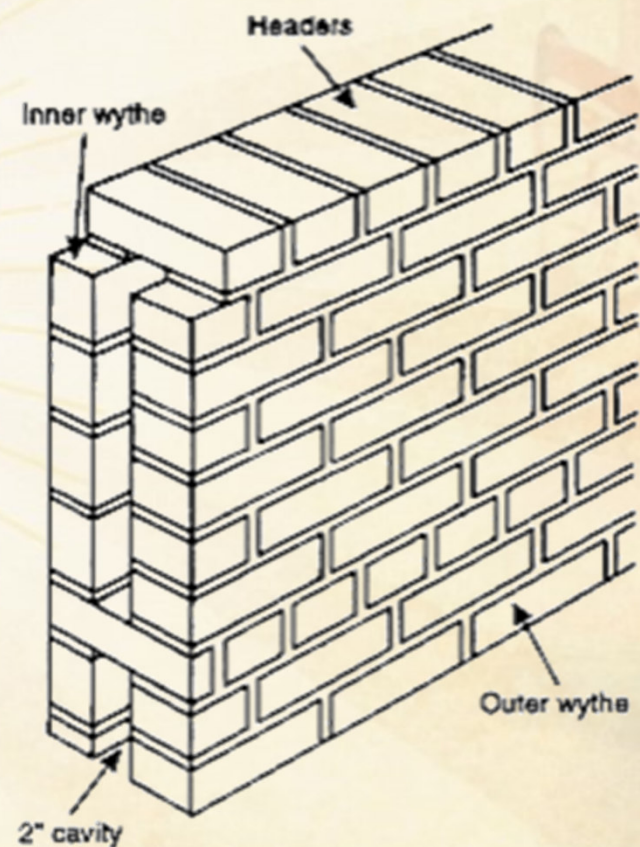
Brick



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Façade – Moisture/Thermal Expansion/Contraction





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Façade – Moisture/Thermal Expansion/Contraction





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Façade – Corrosion Expansion





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Façade – Moisture Damage





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Masonry – Creep & Settlement





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Masonry – Unauthorized Openings



- Penetrations:
 - Through Load Bearing Walls



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Steel Framing - Deterioration

- Moisture
 - Rust
- Fatigue
- Modified or Damaged Members





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Steel Framing Corrosion

- Surface Rust
- Section Loss
 - Flange
 - Web





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Steel Framing Corrosion

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





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Steel Framing - Fatigue





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Steel Framing – Altered or Damaged members





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Wood Framing - Deterioration

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





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Wood Framing – Moisture Meter



Moisture Content > 30% =
Serious Decay



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Wood Framing – Termite Infestation



Mud Tubes





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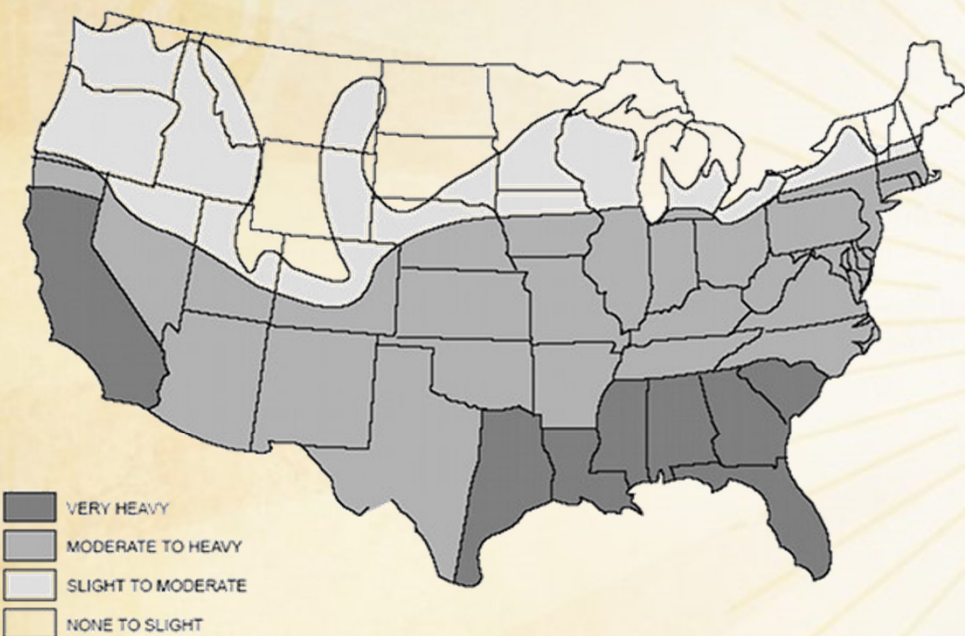
Wood Framing – Termite Infestation

- 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



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Wood Framing – Modified Members



Image: Russ LaBlanc





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Structural Condition Assessment - Why

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





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International Property Maintenance Code (IPMC)

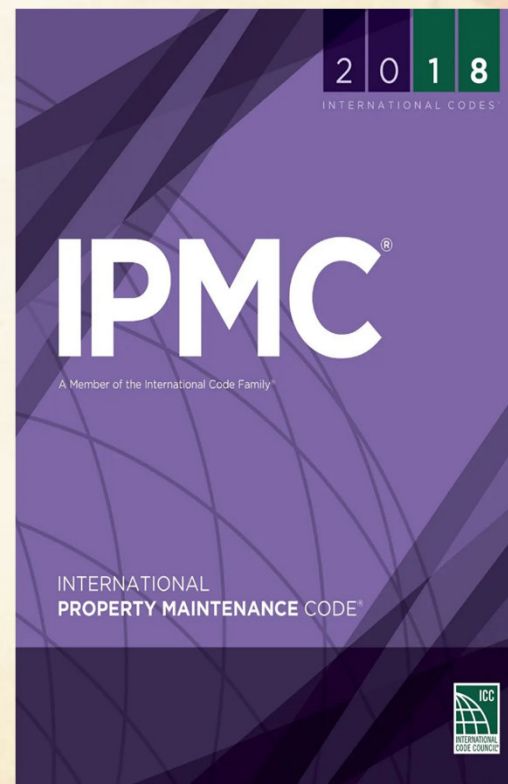
SECTION 304 EXTERIOR STRUCTURE

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!

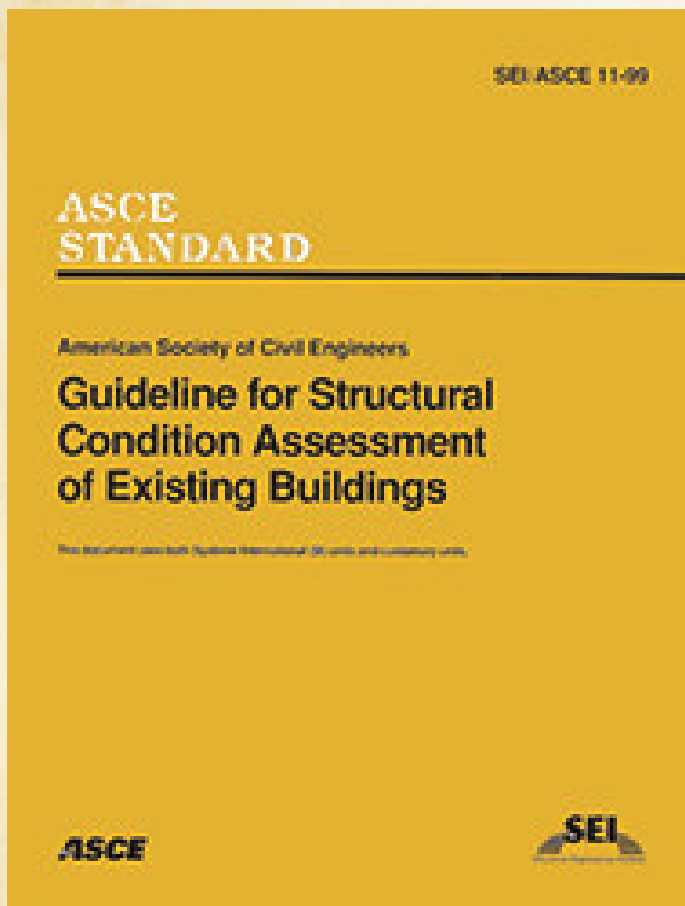




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ASCE Standard SEI/ASCE 11-99



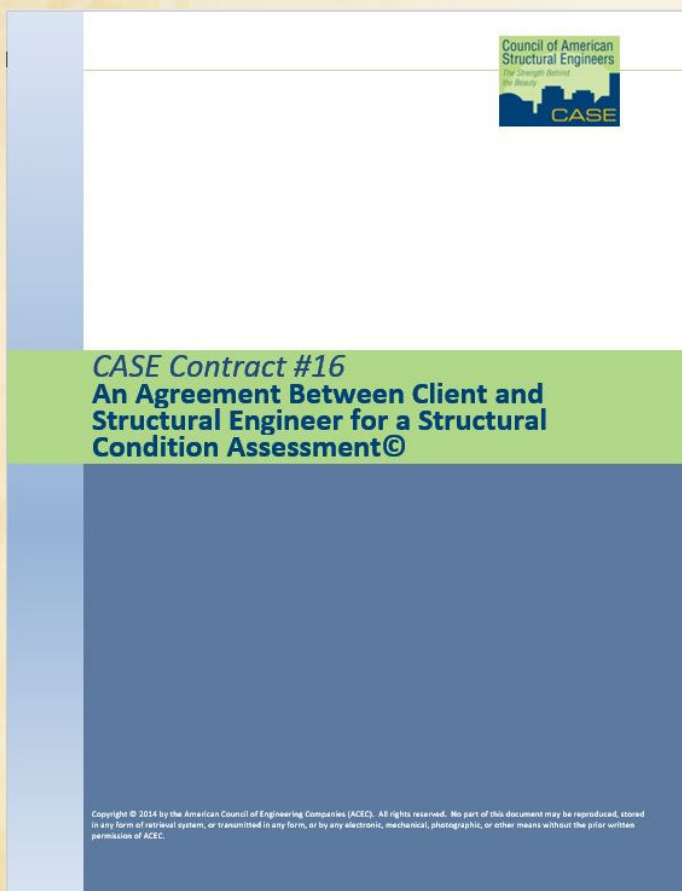
- **Assessment**
 - Preliminary
 - Detailed
- **Materials**
 - Concrete
 - Masonry
 - Metals
 - Wood
- **Procedures**
- **Reporting**



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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**



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Inspection Checklist



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



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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)



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Learning Objectives

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

**AIA
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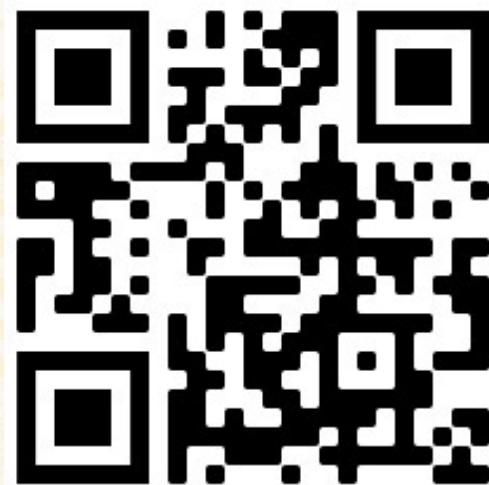


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Questions?

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