WJE

SOLUTIONS FOR THE BUILT WORLD

Structural Building Assessments

www.wje.com

WJE | ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.

MCCFMA Fall Conference | November 2, 2023

Presented by: Chelsea Ames, AIA; Mark Chauvin, P.E.; Luke Malm, P.E.

WJE

Outline

Structural Failures
Structural Assessments
Architectural Assessments
Questions

WJE

Structural Failures

Mark Chauvin, P.E.
mchauvin@wje.com

Surfside, FL (June 24, 2021)

Davenport, IA (May 28, 2023)

Rochester, MN (June 2, 2023)

Mankato, MN (February 14, 2023)

Source of Structural Problems?

- Design
  - Errors
- Construction
  - Mistakes
  - Materials
- Deterioration
  - Materials
  - Neglect
- All of the above
- None of the above
  - Conditions ≠ Expectations


Design


All of the above


Deterioration


None of the above?

Is My Building Safe?

(It's complicated)

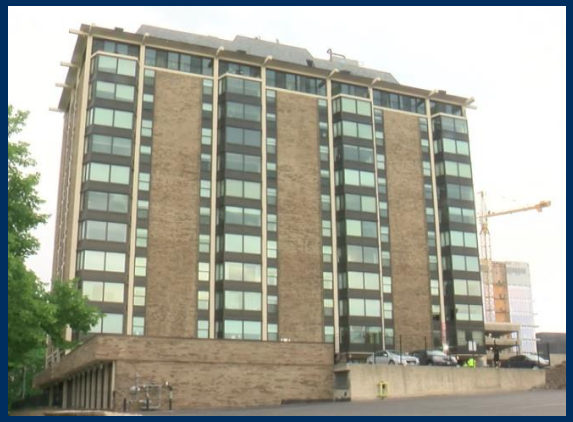
How Do **You** Define Safe?

- Safe is a relative term – what is the basis of comparison?
  - Not binary
- Building codes?
  - Maximum levels of acceptable risk ("safe enough")
    - Compliant with current code ≠ guarantee
  - Codes are legal (not engineering) documents
    - Does not meet code ≠ unsafe
  - Code provisions are arbitrary and change
    - "Safe" today ≠ "safe" tomorrow
  - Which code?
    - Applicable to construction? Current? Future codes?

What Level of Confidence Do **You** Need?

- Visual Inspection ($)
  - Focus on deterioration
    - Scope?
    - Limited to exposed + accessible
  - Little to no insight on design or construction

- Investigation ($$) – NDE, Cores, Openings
  - What is impetus?
  - Location specific… what is variability? (+ how much is enough?)
  - Little to no insight on adequacy of design
- Analysis ($$$)
  - Just members? Connections? Material properties?
- All of the above ($$$$$)
  - Higher confidence ≠ guarantee (don't know what you don't know)

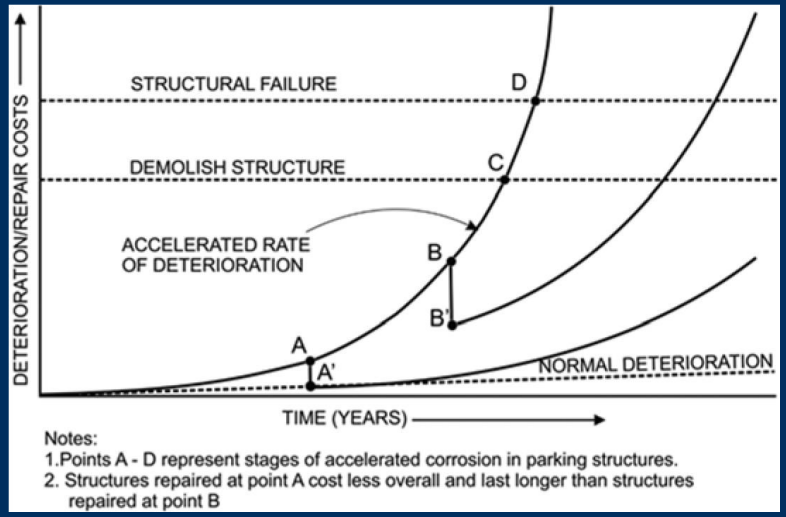


So…. what **can** we do?!?!

- Understand that structural problems exist + failures happen
  - Very low (but not zero) occurrence rate
- Issues at another building ≠ cause for concern about your buildings
  - Each problem/failure has a cause
  - First, understand it… then, does it apply? *(probably not)*
- If you don't know what you are looking for, how will you find it?

So…. what **can** we do?!?!

- If no specific concerns:
  - Do you need to do anything?
- If specific concerns (or required/desired):
  - Phased approach
    - Dig deeper if/as warranted
  - Condition assessments are sensible starting point
    - Identify visible/obvious issues
    - BUT must understand the limitations/applicability



WJE

Structural Assessments

Luke Malm, P.E.
lmalm@wje.com

Structural Assessment

- WHY?
  - Observed movement
  - Equipment not working
  - Someone heard a pop
  - Falling material
  - Prepurchase
  - Change of occupancy
  - Fire/collision

Structural Assessment

History and Background

- Interviews
- Document review
- Renovation history
- Maintenance history

TIMING

Site visits – Visual

- From ground
- Drone
- Aerial observations

Sampling and Testing

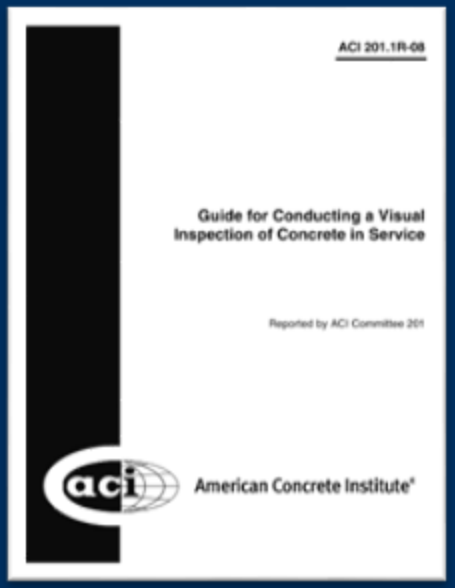
- Laboratory studies
- Non-destructive testing
- Destructive or full scale load testing

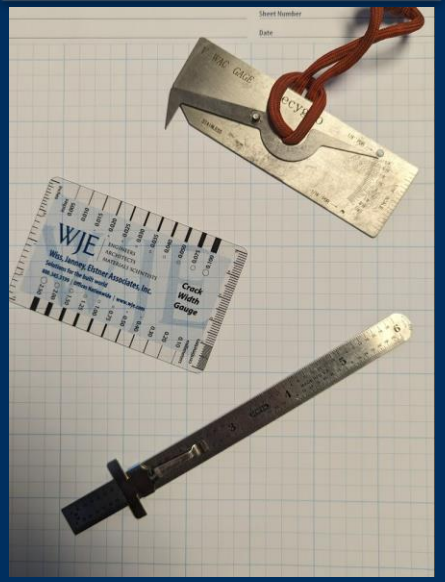
Structural Analysis

- Simple hand calcs
- 3-d modeling
- Non-linear FEM

Structural Assessment - Visual

- Eyes are our most valuable and versatile tools
  - Concrete cracks, spalls, staining
  - Steel/aluminum distortion, weld porosity
  - Wood staining, moisture, visible decay
- Proper terminology
- Basic measurements
  - Crack width, direction, tapered
  - Porosity density
  - Distortion of steel or aluminum
  - Section loss
- Limited to only the surface

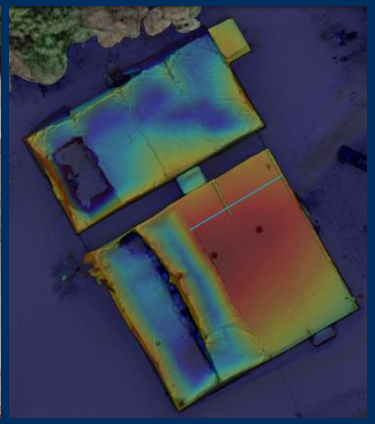




Structural Assessment - Drones

- Great camera on a long stick
- More powerful when teamed with photogrammetry

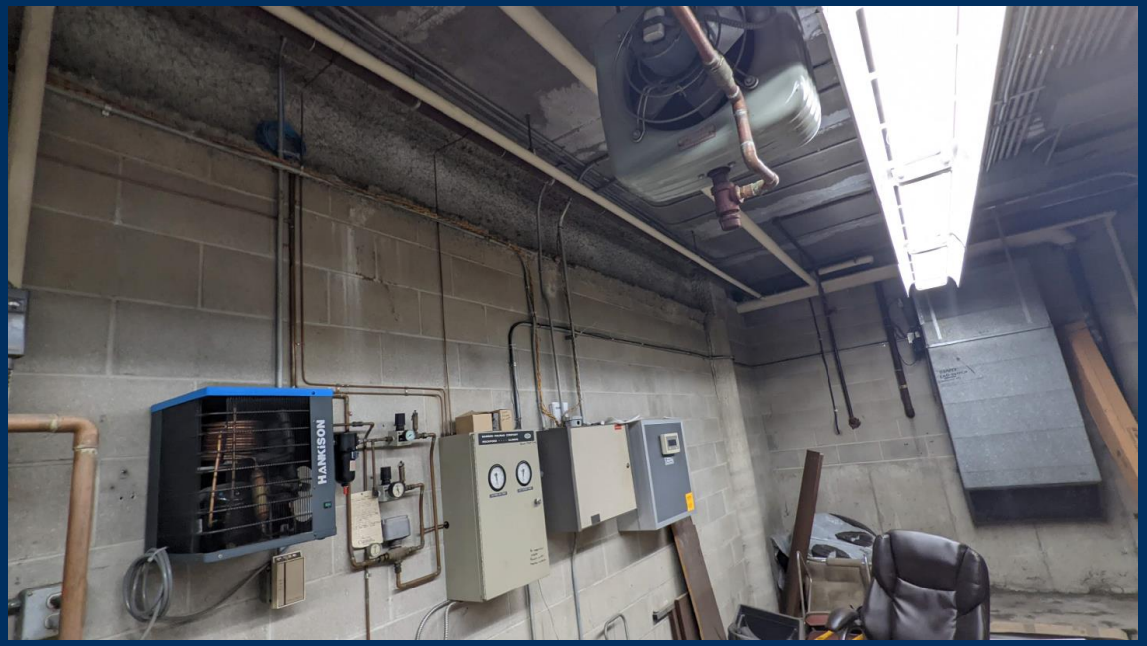
Structural Assessment – Drones and Photogrammetry



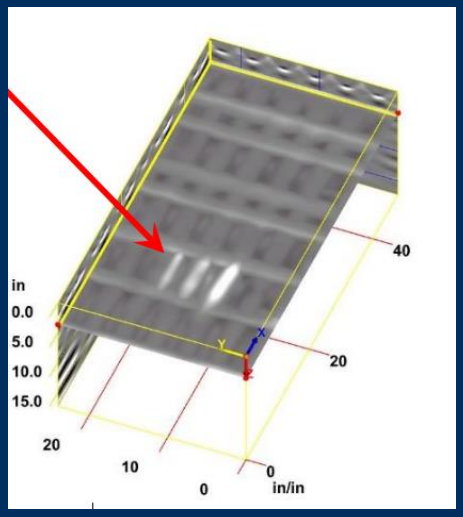
Structural Assessments – Inspection Openings

Elevator shafts, mechanical rooms, pipe penetrations frequently provide direct view of the structure.

Limited window into the structure



Structural Assessment – Non-Destructive Testing



It can be used to zoom in or zoom out of a problem.

Needs verification.

Hammer sounding and chain dragging. Wood and concrete. Wood preservatives only penetrate to shallow depth allowing for internal decay.

GPR – Can be used to broaden the results of an inspection opening to determine slab thickness, rebar placement, presence of voids. Subject to variations in concrete materials. Proper antenna for what you're looking at (higher frequency is shallower with greater resolution).

UT – Can be used for determining remaining thickness. Spot only and requires a clean surface. Can identify subsurface defects, but extensive training is required and still often needs a test block.

...AND MANY MORE

Factors	Method						
	Remote visual inspection	*Resistance drilling*	*Infrared thermography*	*Stress waves*	*Visual grading*	*Digital radioscopy*	*Moisture measurement*
Measure moisture content			Limited				Yes
Locate deterioration	Limited	Yes	Limited	Limited		Yes	
Quantify deterioration	Limited	Yes		Limited		Limited	
Assess strength				Limited	Estimate		
Determine modulus of elasticity				Estimate	Estimate		
Identify hidden construction details	Yes	Limited	Limited			Yes	
Locate and assess fasteners						Yes	

	Surface Cracking	Internal Cracking	Delamination	Internal Voids	Corrosion	Reinforcement Cover & Location	In-place Strength	In-place Density	Surface Damage	Element Thickness	Uniformity	Structural Capacity
Visual	G	N	N	N	F	N	N	N	G	N/G	F	P
Sounding	N	N	G	G	N	N	N	N	N	N	F	N
Surface rebound	N	N	P	P	N	N	P	P	F	N	G	N
Windsor probe	N	N	P	P	N	N	G	F	F	N	G	P
Cover meter	N	N	N	N	N	G	N	N	N	P	F	N
Half-cell potential	N	N	N	N	F	N	N	N	N	N	F	N
Linear Polarization	N	N	N	N	G	N	N	N	N	N	F	N
UPV	P	G	G	G	N	P	F	F	G	P	G	N
Impact-echo	N	G	G	G	N	P	F	N	P	G	F	N
Impulse response	N	P	P	F	N	N	P	N	N	F	G	F
GPR	N	F	F	G	N	G	N	N	N	G	G	N
Radiography	G	G	N	G	P	G	N	P	N	P	G	N

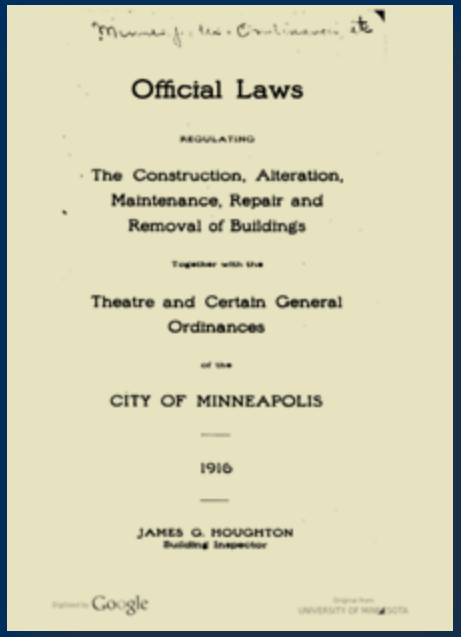
G = GOOD F = FAIR P = POOR N = not applicable

Type	Volumetric	Characterization	Length & Width	Depth	Permanent Record
VT	No	Yes	Yes	No	Photo
PT	No	Yes	Yes	No	Photo
MT	No	Yes	Yes	No	Photo
ET	possible	possible	possible	possible	Yes
UT	Yes	Yes	subsurface	Yes	Auto
RT	Yes	Yes	Yes	possible	Yes
HT	Yes	n.a.	n.a.	n.a.	Yes
AE	Yes	possible	No	No	Yes
FMR	No	Yes	n.a.	n.a.	Yes

What we don’t have

Structural Assessment - Initiation

Structural Assessment – Code Review



Official Laws

REGULATING

The Construction, Alteration, Maintenance, Repair and Removal of Buildings

Together with the

Theatre and Certain General Ordinances

of the

CITY OF MINNEAPOLIS

1916

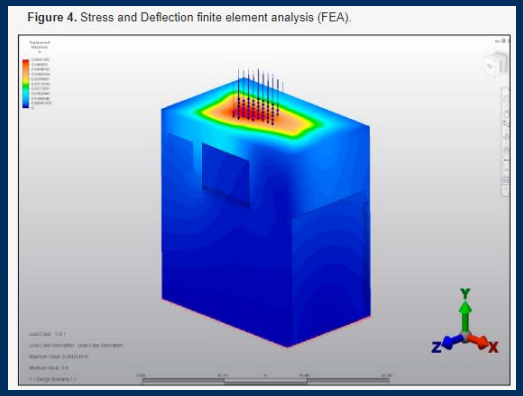
JAMES G. HOUGHTON
Building Inspector

Live load of 20 psf?
Roof load of 50 psf?
Drifting load?

1916

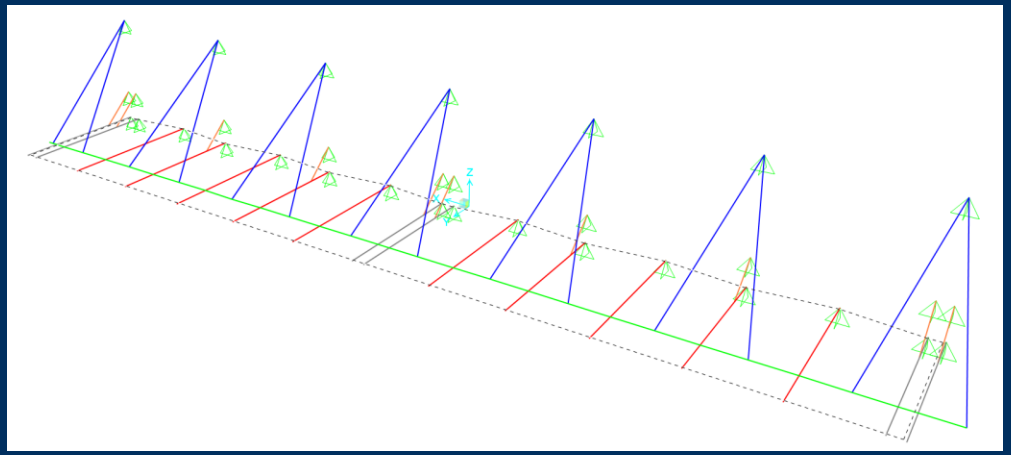
2010

Structural Assessment - Analysis



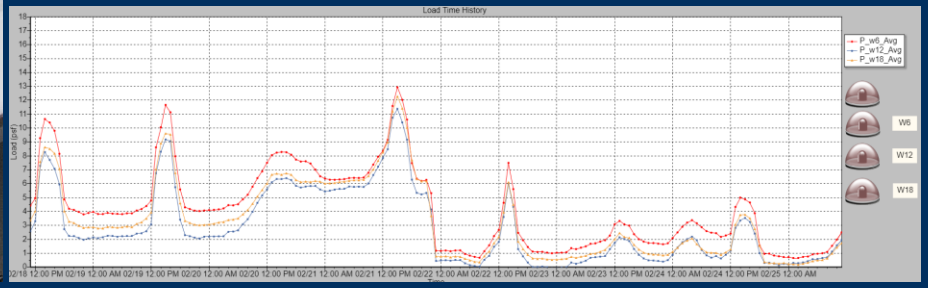
Analysis is only as good as your information!

We had good information.



Structural Assessment – Instrumentation

- Rational determination of limits
- Validation of results
- Planning for response



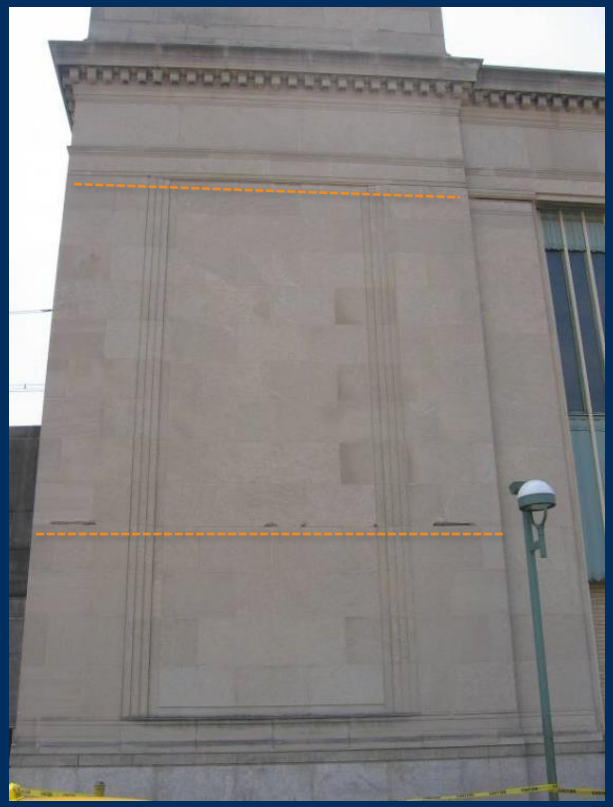
WJE

Architectural Assessments

Chelsea Ames, AIA
cames@wje.com

Architectural (Building Enclosure) vs. Structural Assessments

- Enclosures = Facade = "Face"…
  - Components of the enclosure are exposed by definition
  - Concealed conditions may exist
  - There are structural aspects to all facades (e.g., shelf angles, lateral anchors, etc.)
  - Deterioration of facade can affect structure, both at macro and micro scales
- Building superstructure is often concealed… facades and building interiors can provide clues



Architectural Assessments

WHEN?

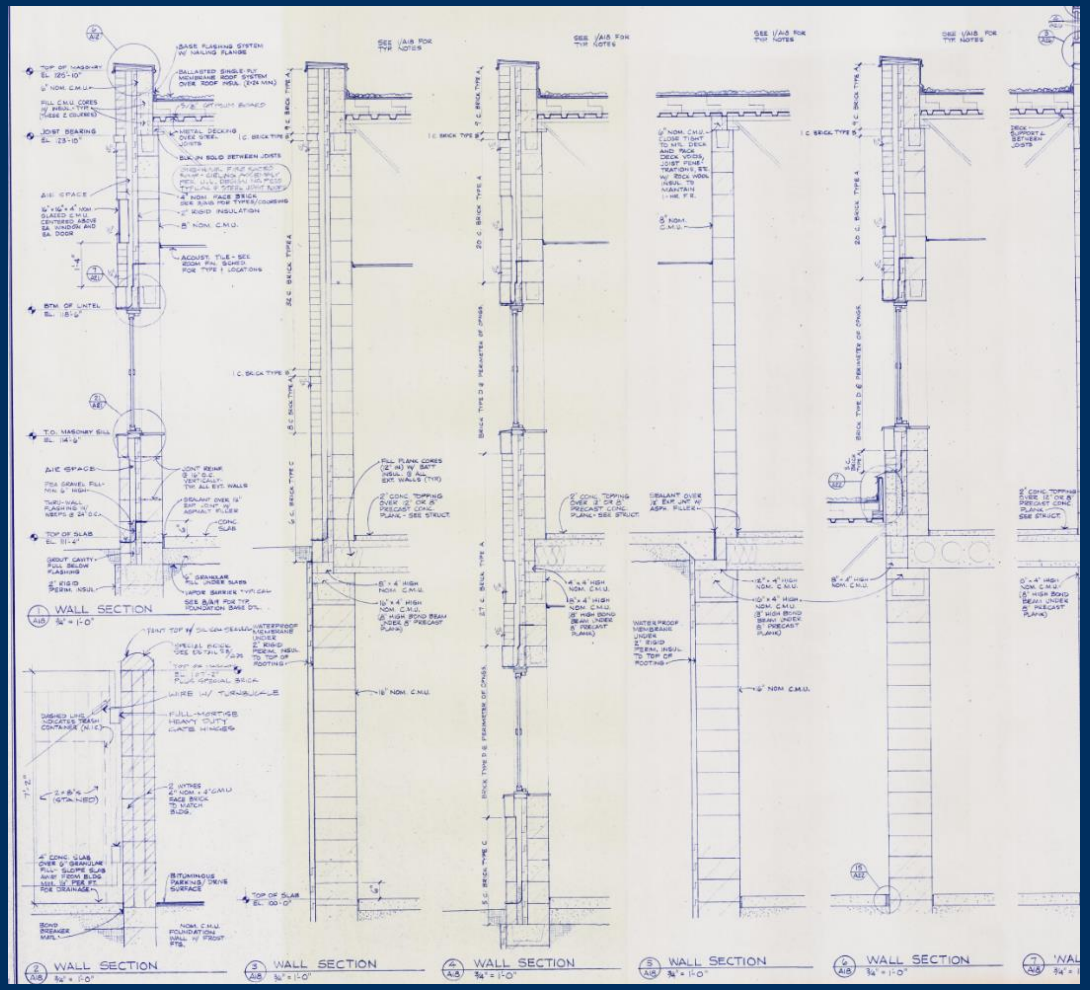
- Prepurchase
- Routine
- Issue response
- Planned project

WHY?

- Understand systems & potential service life
- Maintenance
- Water leakage
- Air leakage
  - Condensation?
  - Energy concerns?
- Cladding deterioration
- Observed distress
- Aesthetic concerns
- Many other reasons…

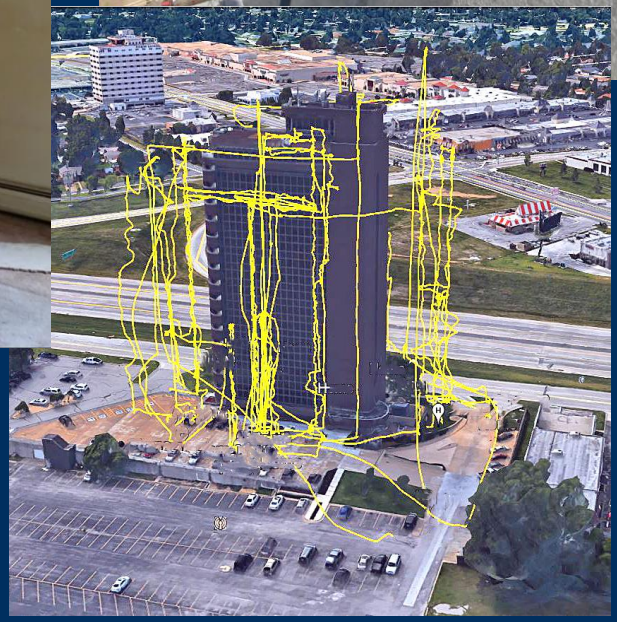
Building Enclosure Assessment Tasks

- Document review
- Interviews
- Visual Assessment
- Hands-on assessment
- Field Testing
- Inspection Openings
- Laboratory Testing



Building Enclosure Assessment Tasks

- Document review
- Interviews
- Visual Assessment
- Hands-on assessment
- Field Testing
- Inspection Openings
- Laboratory Testing

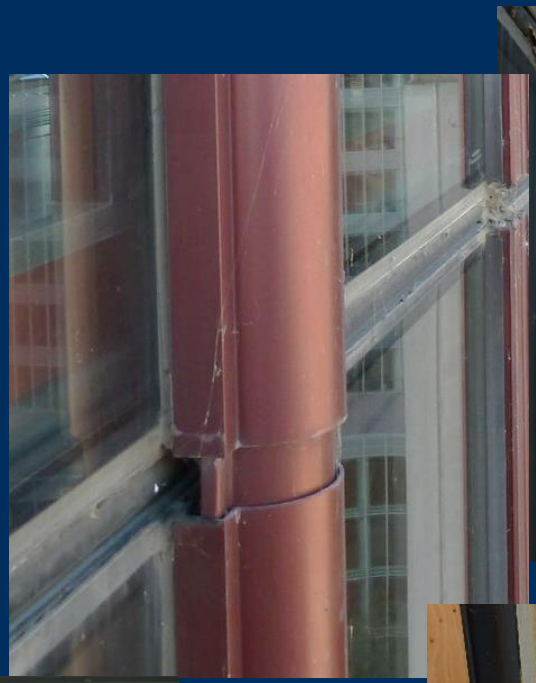


Building Enclosure Assessment Tasks

- Document review
- Interviews
- Visual Assessment
- Hands-on assessment
- Field Testing
- Inspection Openings
- Laboratory Testing

Building Enclosure Assessment Tasks

- Document review
- Interviews
- Visual Assessment
- Hands-on assessment
- Field Testing
- Inspection Openings
- Laboratory Testing



Building Enclosure Assessment Tasks

- Document review
- Interviews
- Visual Assessment
- Hands-on assessment
- Field Testing
- Inspection Openings
- Laboratory Testing

Building Enclosure Assessments

What are you trying to determine?

- Symptoms:
  - Erosion
  - Spalling
  - Cracking
  - Efflorescence
  - Displacement
  - Staining
- Causes:
  - Water management
  - Corrosion
  - Freeze-thaw cycling
  - Thermal hysteresis
  - Loss of lateral anchorage
  - Impact
  - Unaccommodated stress

Building Enclosure Assessments

What are you trying to determine?

- Symptoms:
  - Erosion
  - Spalling
  - Cracking
  - Efflorescence
  - Displacement
  - Staining
- Causes:
  - Water management
  - Corrosion
  - Freeze-thaw cycling
  - Thermal hysteresis
  - Loss of lateral anchorage
  - Impact
  - Unaccommodated stress

It is often more than meets the eye.
Expertise matters.

Building Enclosure Assessments

What are you trying to determine?

Mini Case Study 1

- 1910s mass masonry facade with direct-applied stucco
- Stucco distress including bowing, cracking
- Contractor retained to remove stucco, requesting architectural consulting to review underlying conditions
- Is this an architectural problem? Or a structural one?

Mini Case Study 1

Mini Case Study 1

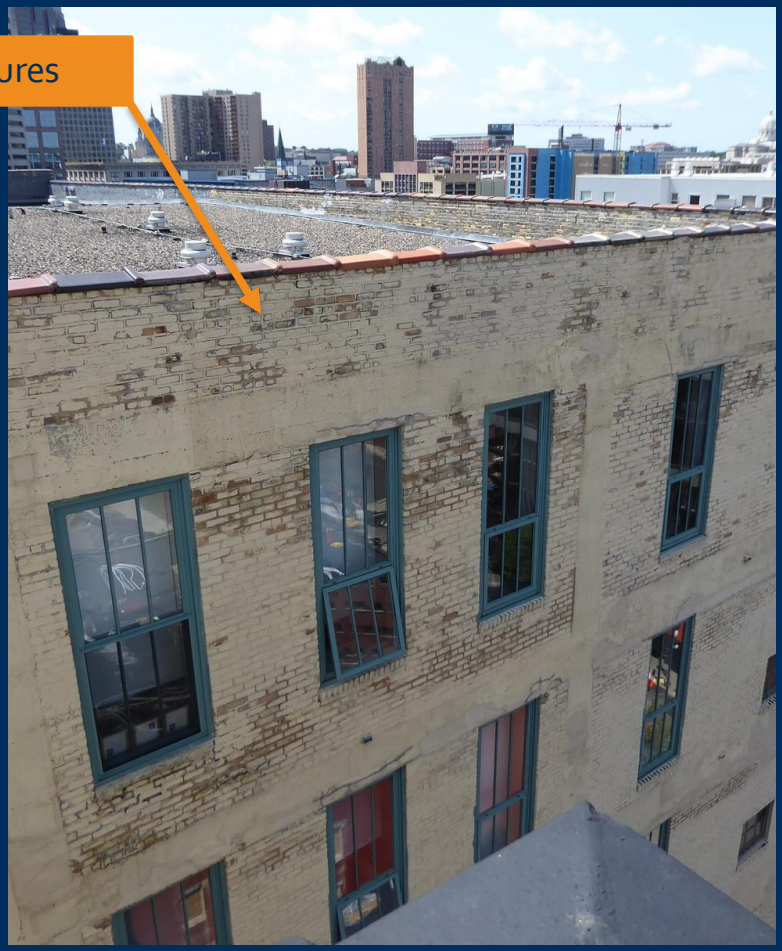
Mini Case Study 1: Architectural or Structural?

- BOTH!
- Mass masonry wall is both architectural and structural
- Scope of repairs include:
  - Interior shoring
  - 100% replacement outer wythe
  - ~50% replacement middle wythe
  - 100% lintel replacement
  - Repointing
  - Window replacement
  - Concrete repairs

Mini Case Study 2

- 1911 expressed reinforced concrete frame with brick infill
- Originally a dry good warehouse, converted to multi-family residential
- Brick and concrete frame feature architectural coating
- Owner interested in replacing the failed coatings
- Is this an architectural problem? Or a structural one?

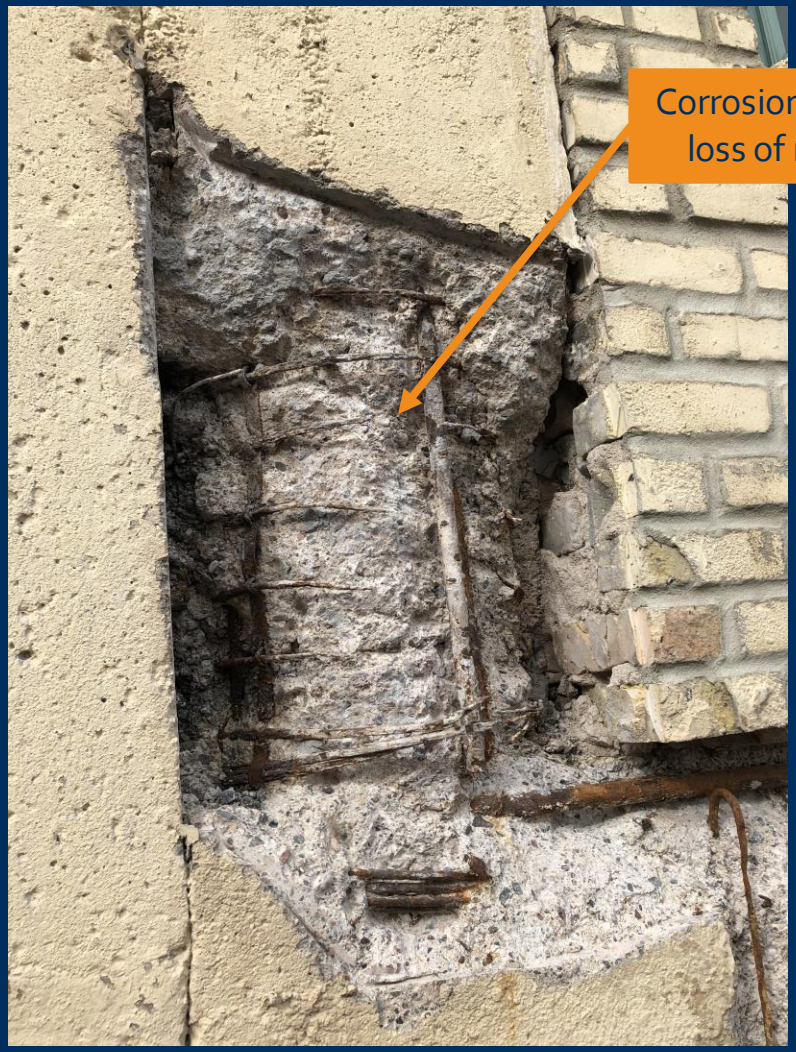
Mini Case Study 2

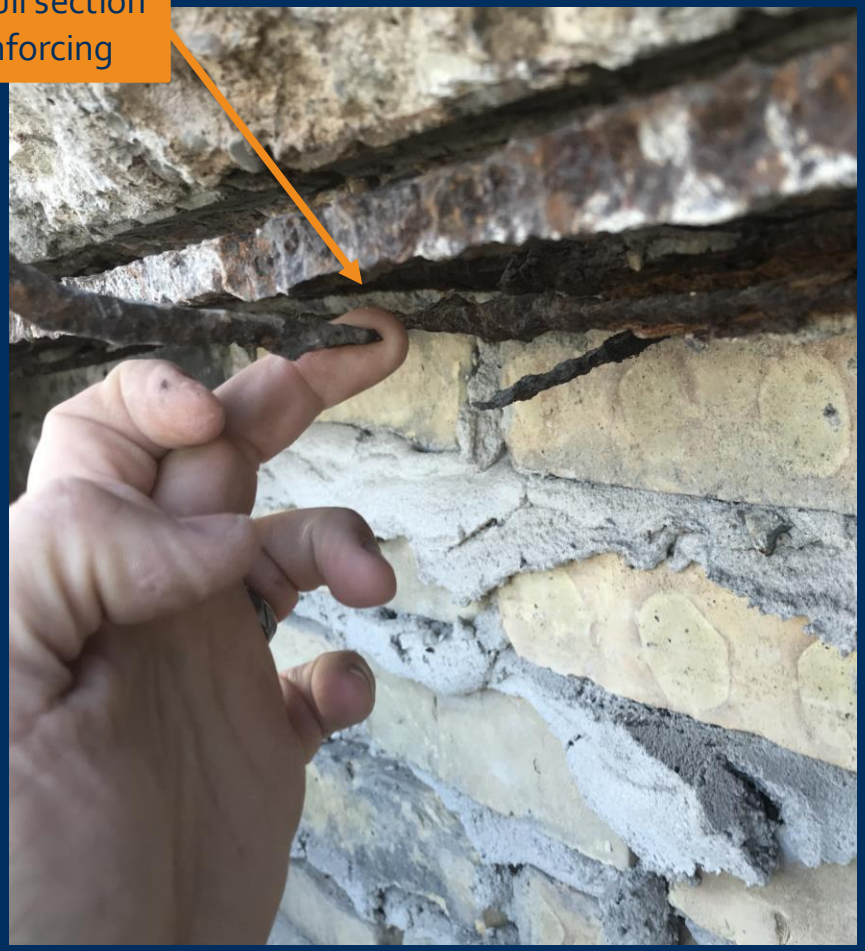


Mini Case Study 2

Mini Case Study 2

Mini Case Study 2





Corrosion, full section loss of reinforcing

Mini Case Study 2: Architectural or Structural?

- BOTH!
- Robust structure, even so…
- Scope of repairs included:
  - Brick repointing and limited replacement
  - 100% parapet reconstruction
  - Sealant replacement
  - Concrete patching
  - Supplemental steel reinforcing
  - Coatings

Summary

- Structures can fail for a wide variety of reasons
- There is no single guaranteed approach to "catch" a failure before it happens
- Assessments can help identify problems and patterns
- Architectural (building enclosure) and structural condition assessments are often intertwined

WJE

SOLUTIONS FOR THE BUILT WORLD

Questions?

Chelsea Ames, AIA
cames@wje.com

Mark Chauvin, P.E.
mchauvin@wje.com

Luke Malm, P.E.
lmalm@wje.com

Please visit WJE.com/Knowledge for more webinars and articles by WJE engineers, architects, and materials scientists, including:

- Champlain Towers South (Surfside, FL) Collapse Investigation
- WJE Primer: Reacting Rationally to Unexpected Structural Failures
- Current Code and Repair of Damaged Buildings

Thank you!