SAFETY OF EXISTING STRUCTURES, WHAT DOES IT MEAN?

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Safety of existing structures

"Safety assessment" of existing structures

- Required by ordinances
- Requested by clients

What does safety mean?

What is reasonable?

Limitations of condition surveys

What provides hope for the future?

BACKGROUND - US DESIGN PRACTICE

New vs. existing structures

New structures

- IBC – general building code
  - ASCE 7 - loads
  - ACI 318 – concrete
  - AISC – steel

Existing structures

- IEBC – general existing building code
  - ACI 562 – concrete repair
  - AISC 500 – existing steel

SAFETY ASSESSMENT – ORDINANCES

Why?

Typically, in response to catastrophic events

NYC façade inspection (LL 11)

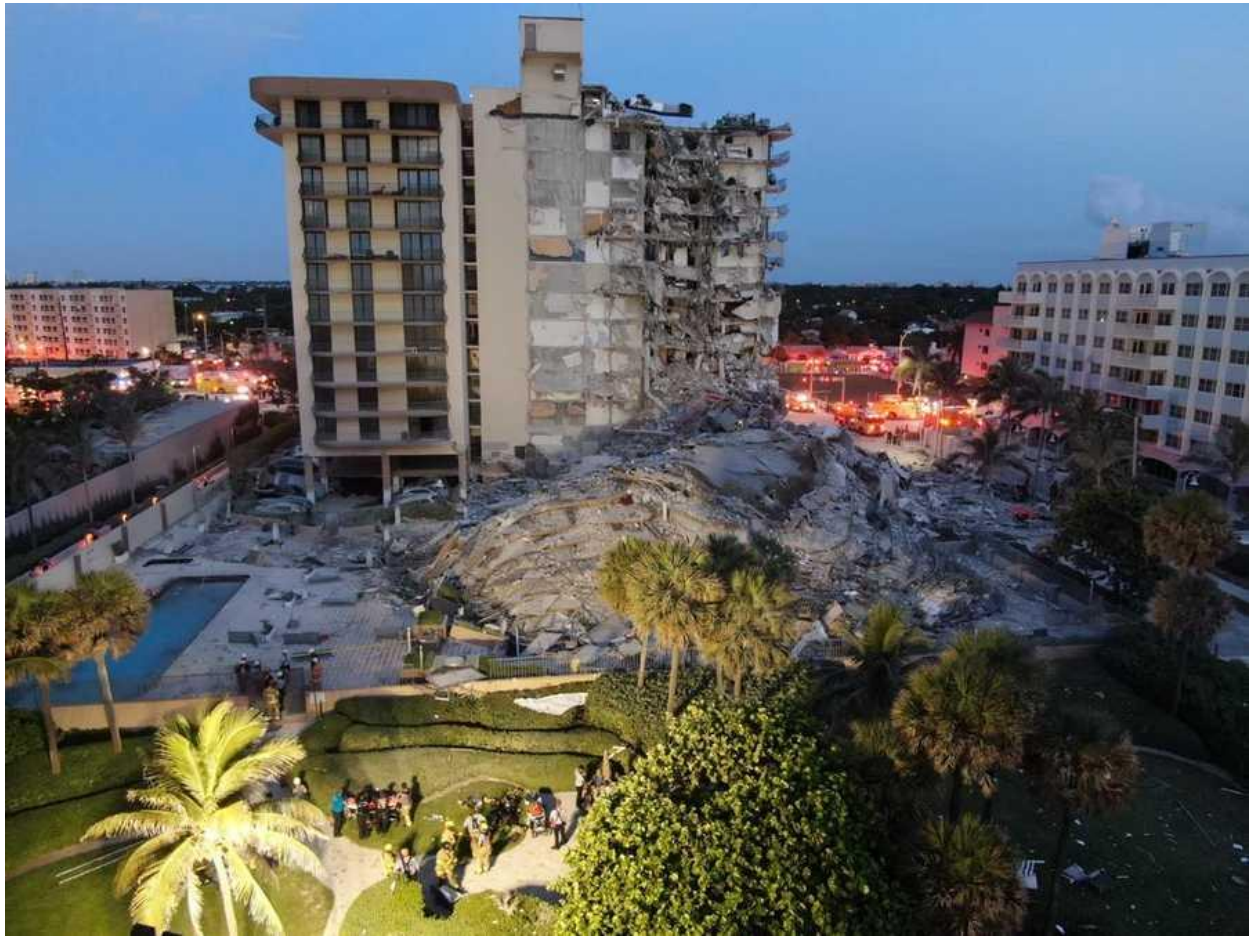
- 1981 falling debris

Florida milestone inspection

- 2021 Surfside collapse

New York parking structure inspection

- Rochester, NY collapses
- NYC – 57 Ann St.



Ordinance intent – protect the public

- Minimum requirements
  - Protect the public
  - Prevent unsafe conditions
  - Identify needed repairs
  - Recurrence of inspections
- Façade safety
- Parking garages
- Milestone inspections
  - Based on age of structure

EXAMPLES - ORDINANCES

Location and ordinance	Ordinance description							
	Façade	Structural	Occupancy/ Type	Age	Criteria	Frequency	Subject	Terminology
San Francisco, CA, Ord. 67-16	F		Type I, II, III, IV construction	Any	> 5 stories	Based on age for first survey, then every 5 years	100% walls, 100% balconies, 100% parapets	Risk of death or injury
State of Florida, Statute 553.71		S	Condominium cooperative	30 years, 25 years if within 3 miles of coast	—	10 years	Structural elements	Safe for continued use, substantial structural deterioration, structurally sound
Broward County, FL, Broward County Building Safety Inspection Program		S	Except 1- and 2-family and government or tribal buildings	40 years	≥ 3500 ft²	10 years	Structural elements	Structural failures
Dade County, FL, §8-11		S	Except 1- and 2-family and government or tribal buildings	40 years	≥ 2,000 ft²	10 years	Structural elements	Safe condition
Chicago, IL, Rules for the Maintenance of High-Rise Exterior Walls and Enclosures	F		All	Any	> 80 ft	2 years critical exam, every 4 years	50% walls, 100% cornices, 100% terracotta	Unsafe, imminently hazardous, safe with repair, safe condition
Boston, MA, Ord. 9.9-12	F		All	Any	> 70 ft	5 years	100% walls	Life-safety protection
Detroit, MI, Ord 15-88, § 9-1-35	F		All	Any	≥ 5 stories	5 years	100% cornices, 100% projections	—
St. Louis, MO, Ord. 68791	F		Any	Any	> 6 stories	5 years	100% walls	—

Table from Kesner, et al., Concrete International, Nov. 2023

ORDINANCE DETAILS – LL126

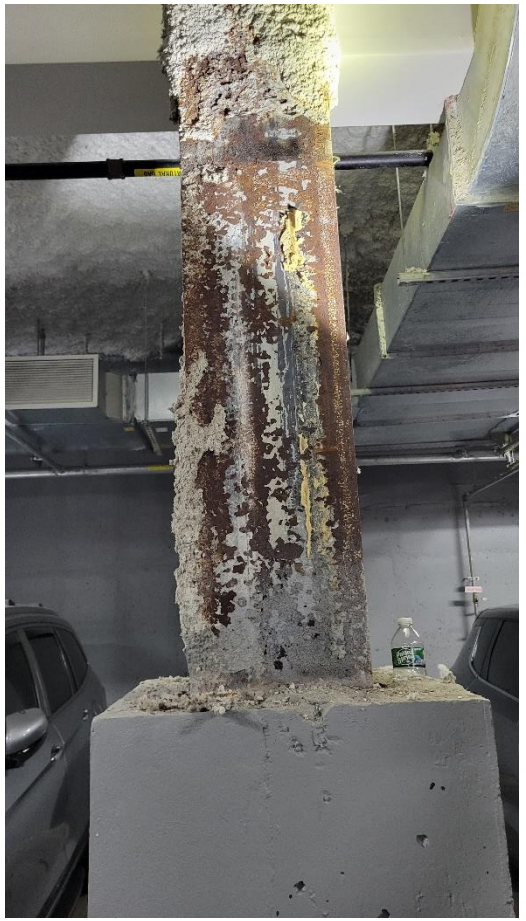
NYC Parking Structures

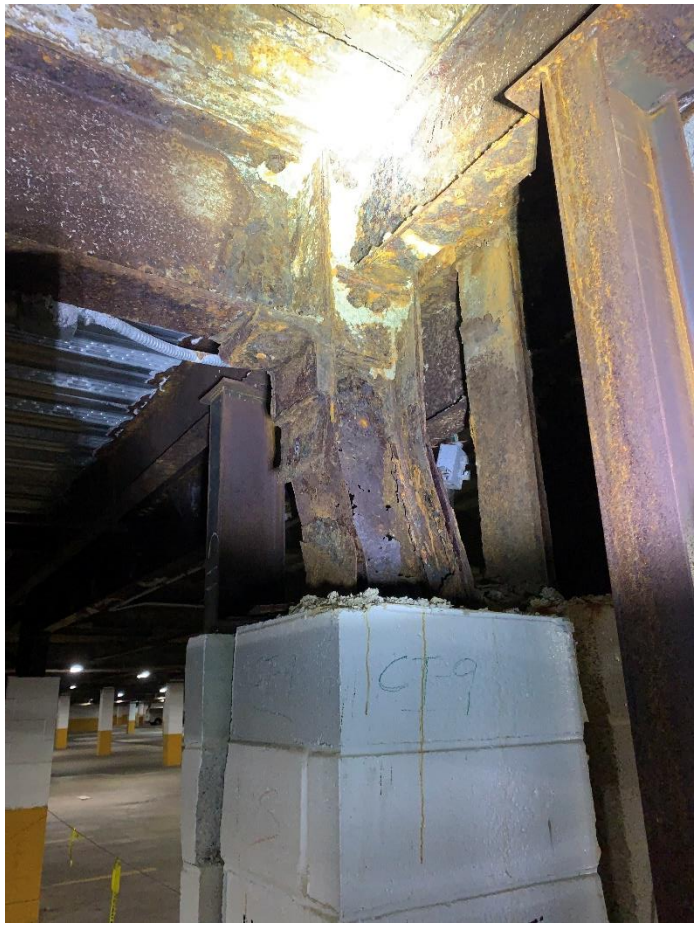
6-year inspection cycle, with

- Annual visual survey
- Unsafe, SREM, Safe
- Report unsafe conditions
- Performed by a QPSI

Survey Requirements

- 10% tactile survey of all elements
- Immediate report of unsafe conditions
- Follow up on SREM





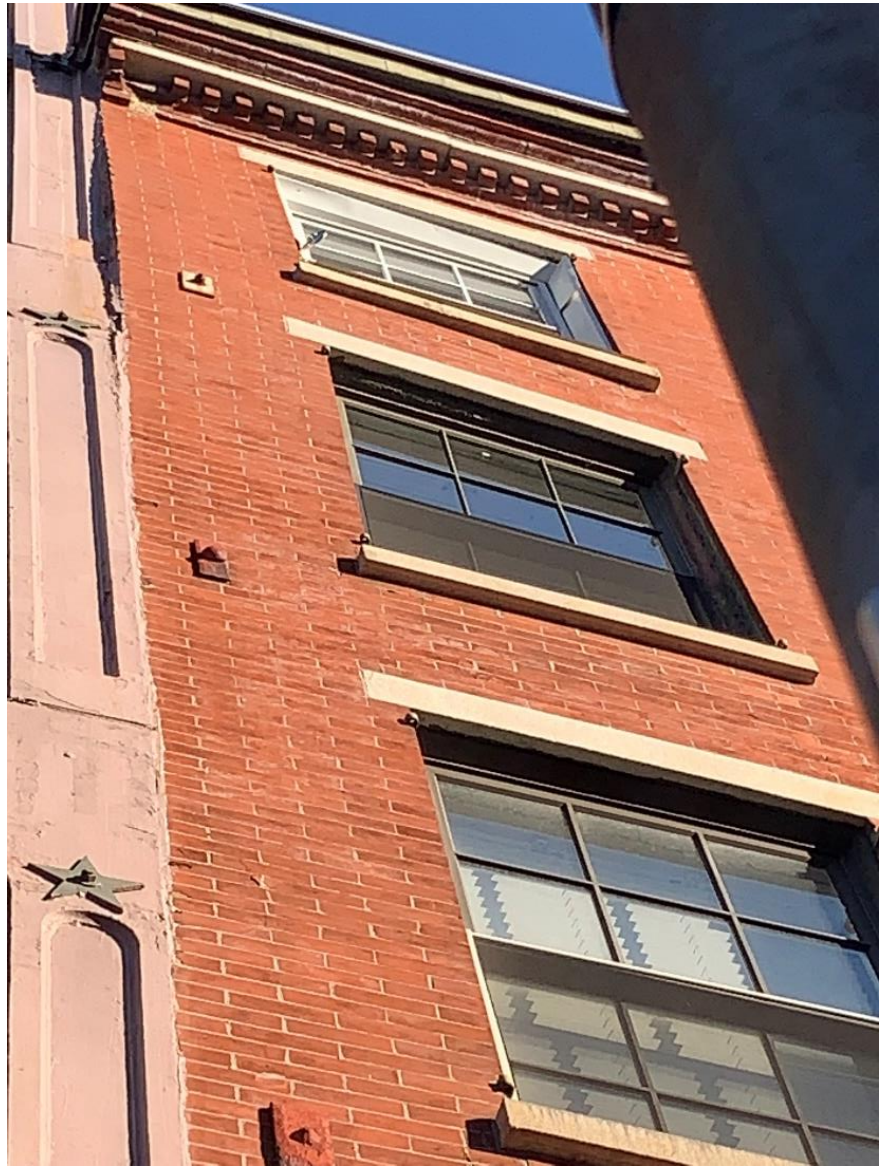
Performance requirements

Design professionals shall ensure existing structures are:

- “Safe”
- “Secure”
- “Structurally sound”
- “Maintained free of defects”

Fundamental question:

- Is this possible?
- What is reasonable?



CONCEPT OF STRUCTURAL SAFETY – IS IT ABSOLUTE?

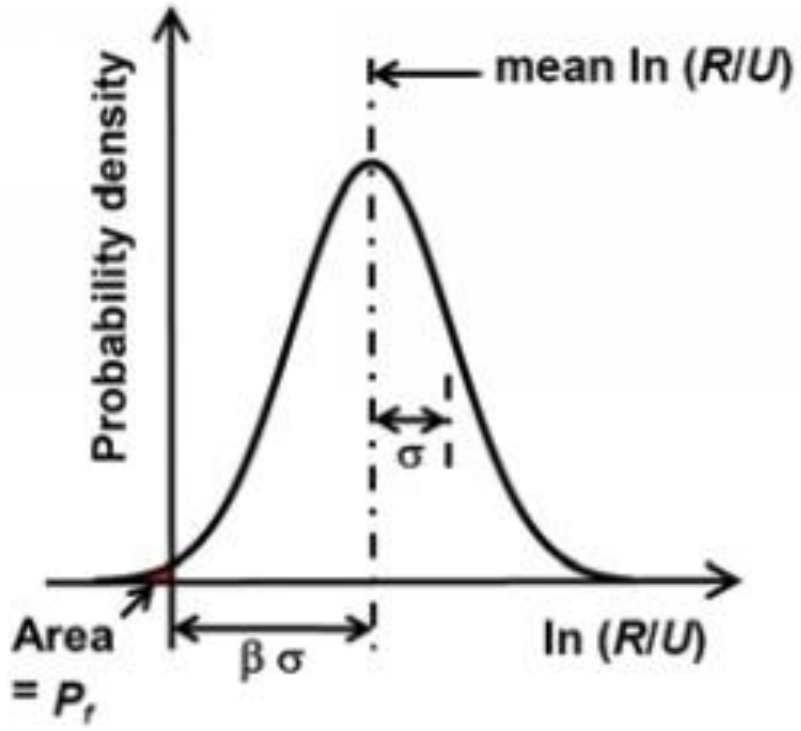
Absolute vs. design

Absolute safety

- Zero probability of failure

Design code safety

- Calibrated to a statistical probability of failure
- Function of:
  - Importance of structure
  - Failure mechanism
  - Statistically based loads
  - Statistically based material strength



Stevens, et al. Concrete International V. xx No. x

CONCEPT OF STRUCTURAL SAFETY – IS IT ABSOLUTE?

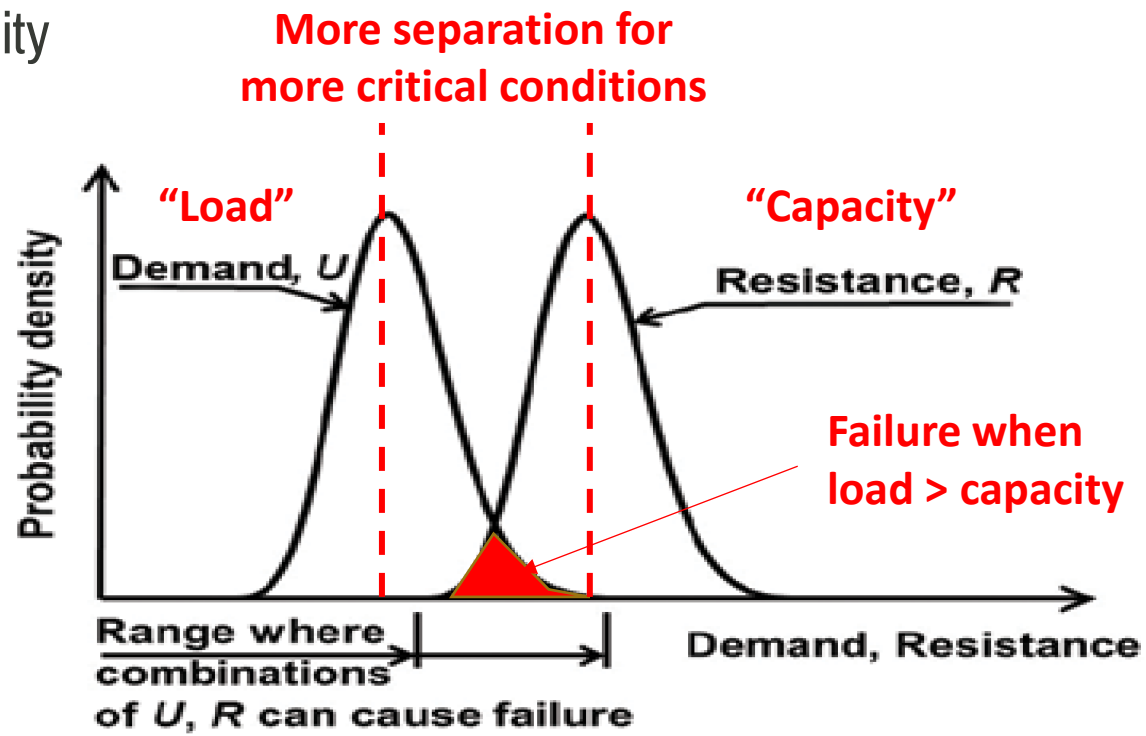
New Design

Even new / compliant structures have some probability of failure

Design for failure and ductility

More separation (safety) for:

- More critical components
- More variable or unsure conditions
- Less ductile failures (i.e. shear)
- Less redundant failure mechanisms
- More unpredictable loads



Figures from Bartlett, et al 2019, though concept was pre-established

NEW VS. EXISTING STRUCTURES

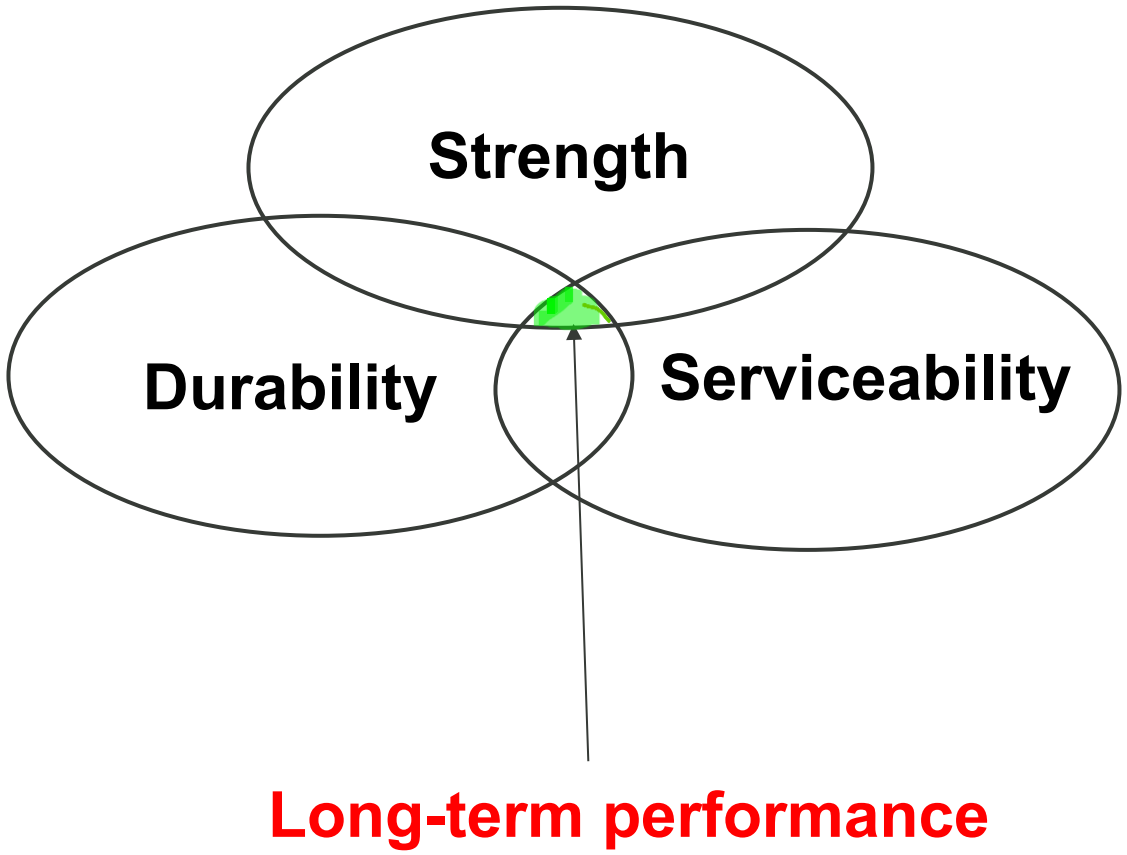
Differences?

Imperfect construction

Long-term exposure

- Starts during construction
- Does not stop

Limited maintenance



Reasonable Safety

2021 IBC Section 101.3 – Purpose

“ …to establish the minimum requirements to provide a reasonable level of safety, health, and general welfare through structural strength, means of egress, stability, ……providing reasonable level life safety….”

So, what is a reasonable level of safety?

How can we evaluate reasonable safety?

WHAT CAN WE DO? LIMITATIONS?

Condition Surveys

Typically:

- Visual in nature
- Include tactile component
- Minimum extent by ordinance

Goals:

- Identify unsafe conditions
- Identify necessary repairs
- Ideally – plan for maintenance

Limited in nature

LIMITATIONS: BUILDINGS AND THEIR EVALUATION

Issues

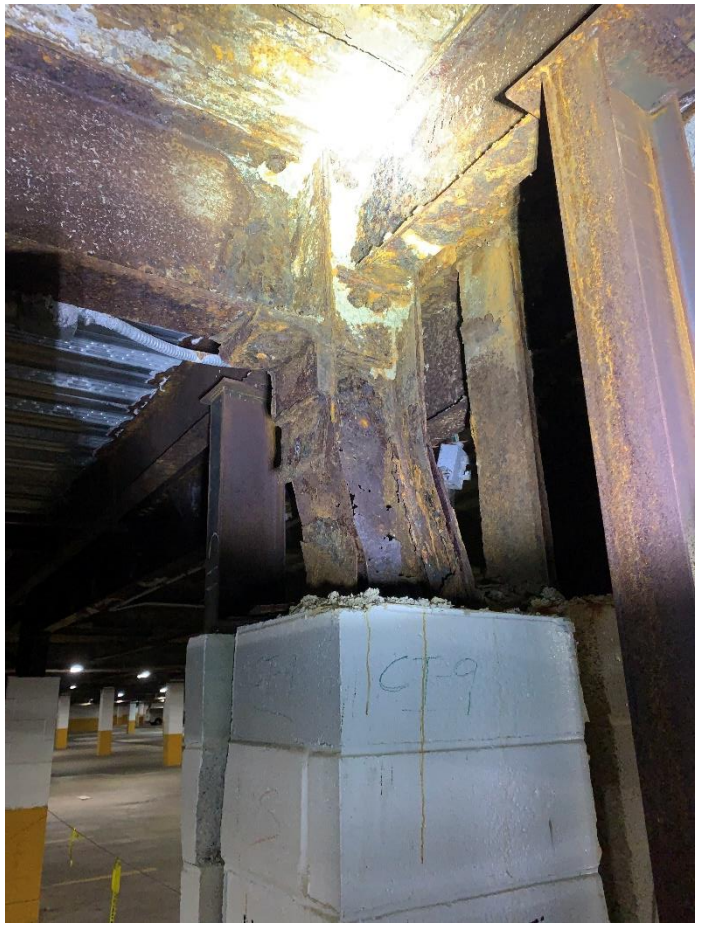
Access

Available documentation

Accuracy of available information

Codes – lagging indicator of knowledge

Knowledge gap



LIMITATIONS

Access

What can we see?

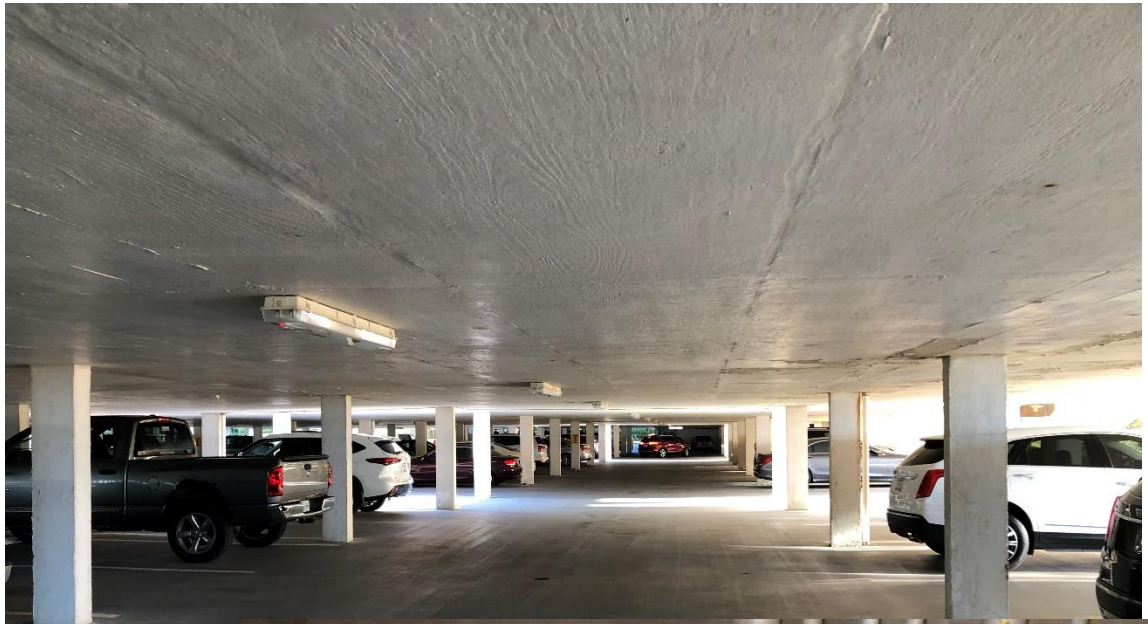
- Usually not much

How are we limited by access methods

- Swing stage
- Ladders

What percentage is enough?

- 10% tactile survey of elements?
- One drop per 60 feet of façade?
- Tactile survey of all structural members?



LIMITATIONS

Documentation

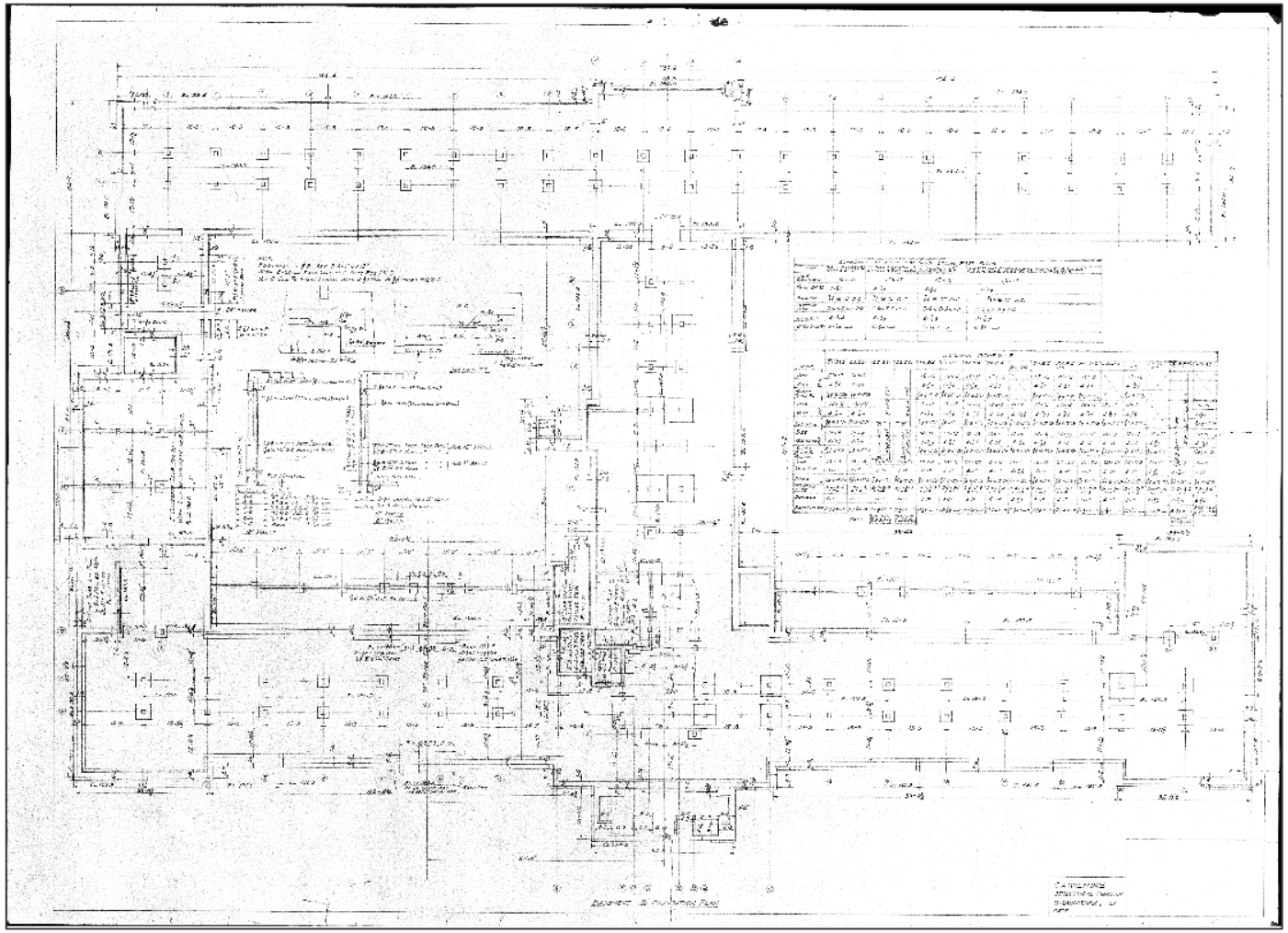
Documents from original construction

- Are they accurate or complete?

Repair or maintenance documents

- What is available?

Prior condition assessment reports



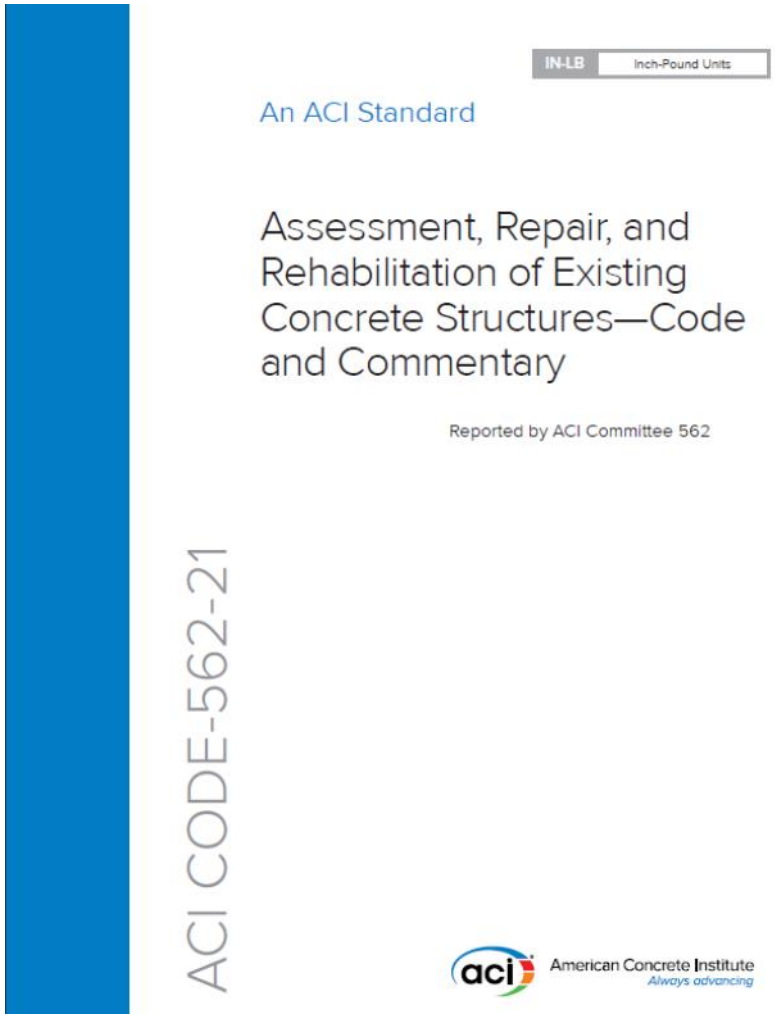
Lagging indicators

ACI 562 – Concrete Repair Code

- 2013 – First edition
- 2018 – First statewide adoptions (OH and HI)
- 2024 – Reference in IEBC

Air entrainment

- Original research – 1930s
- First ACI 318 requirement 1963



Older structures and “Younger” Engineers

Limited knowledge of existing structures

- Rarely taught

Potentially vulnerable structures

- Flat plates
- Structural integrity provisions
    - Added to ACI 318 in ~1989
- Early PT structures
    - Limited ductility

Chloride limitations

- Added to ACI 318 in 1983
- Corrosion susceptibility

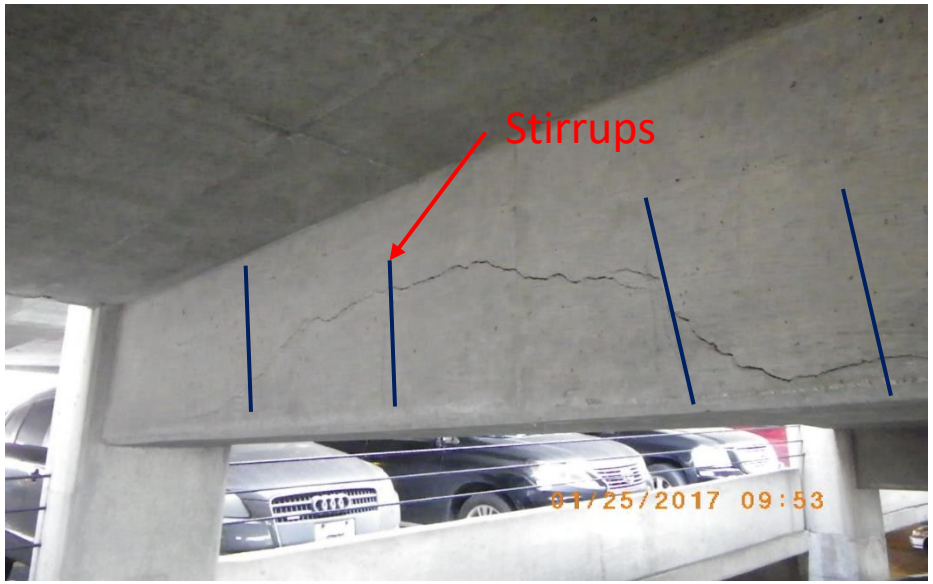
SUBJECTIVITY OF ASSESSMENTS

All concrete structures crack

When is additional examination warranted?

- Is the cracking pattern consistent with “expected” behavior?
- Are the crack widths and spacing consistent with “expected behavior?

“Normal” cracking



Inconsistent behavior

SUBJECTIVITY OF ASSESSMENTS

Concrete spalling?

When is it unsafe?

- Consequences of failure?
- Can it be removed?

IMPROVED ASSESSMENTS

New technologies

Lidar and photogrammetry

Building information modeling

Structural health monitoring

Drone surveys

Industrial rope access

TECHNOLOGY TO IMPROVE SAFETY ASSESSMENTS

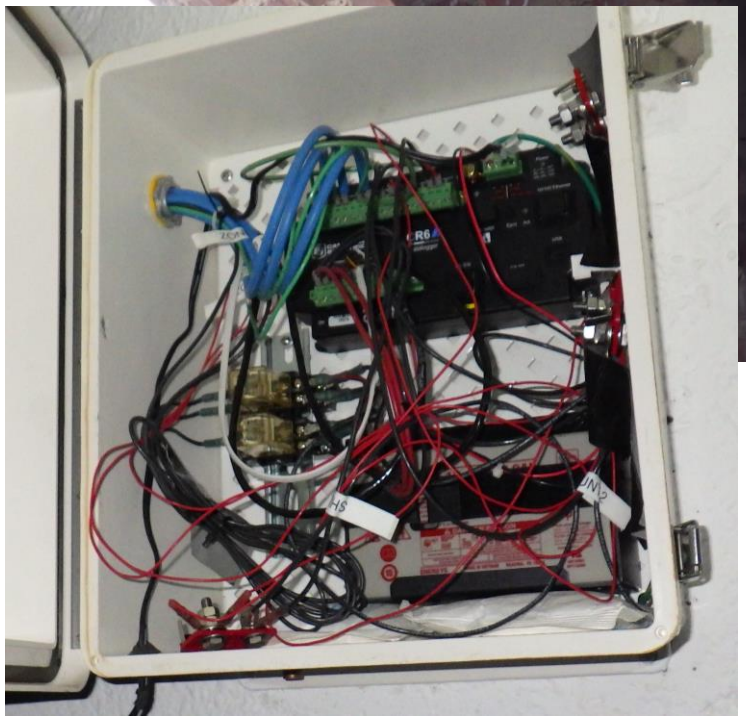
Structural Health Monitoring (SHM)

Continual monitoring of performance

- Displacements
- Internal conditions (temp., RH, etc.)
- Corrosion activity
- Strains

Data-based prediction of performance

- Maintenance planning
- Need for repairs



Repaired stadium

Long-term protection of repairs

- Urethane coating
- Galvanic anodes

Monitoring – 5 stadium sections

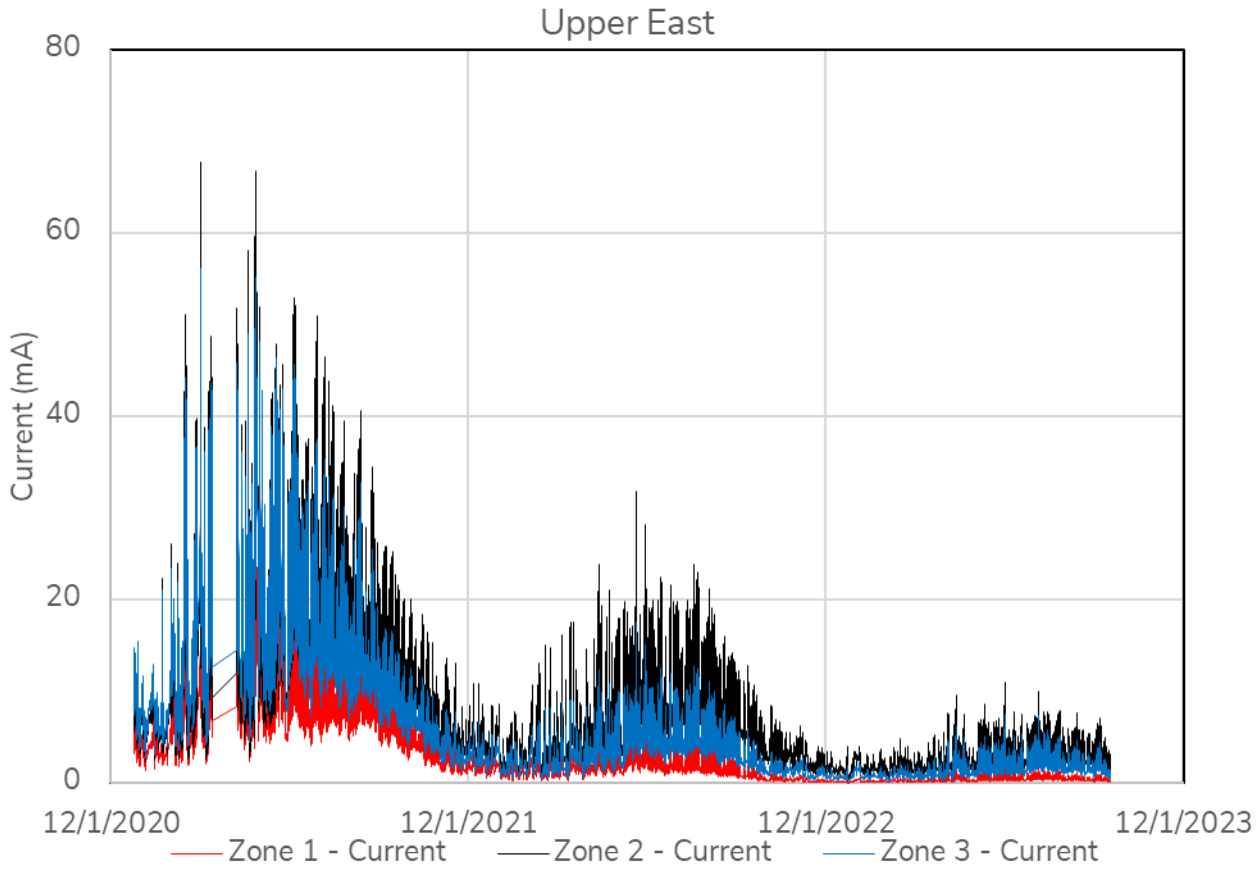
- Internal RH / temperature
- Current generated by anodes

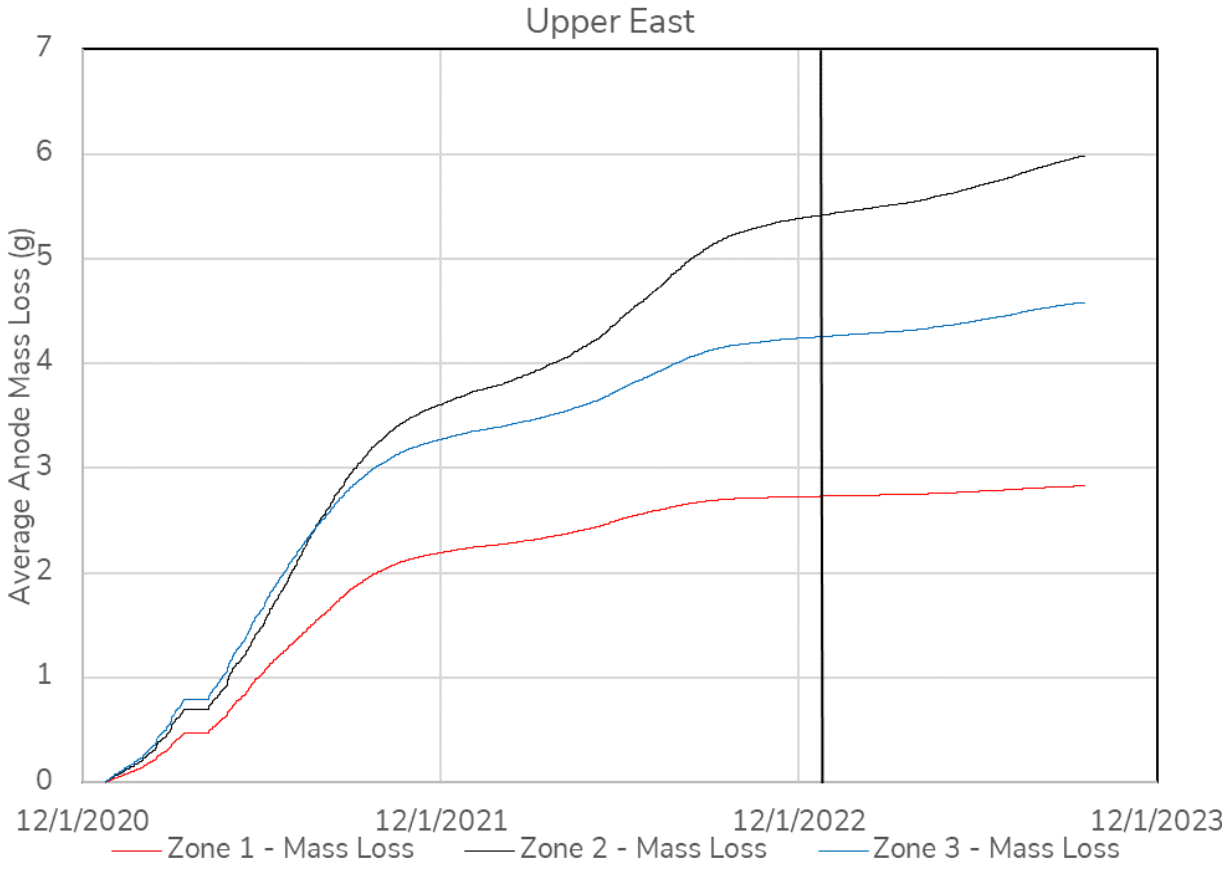
Results – use to plan future maintenance

- Coating degradation
- Anode consumption

STRUCTURAL HEALTH MONITORING

Results





AN APPROACH TO REASONABLE SAFETY

Considerations

Learn about the structure

Apply the latest technology

Use the latest techniques

Explain limitations of assessment

REASONABLE SAFETY

Safety is a relative term that requires qualification

…in comparison to…

…with respect to…

…in terms of…

…under the conditions of…

…with a probability of failure of…

…in accordance with…

…for a period of…3 seconds? …200 years?

Certification of safety is impractical where hidden conditions and variable materials and loads are prevalent

QUESTIONS?