

Lessons Learned in Practice: Things they don't tell you about assessing and repairing concrete

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'Lessons Learned...'

is a sneaky way of saying – I get to ramble about a bunch of different things...

How many people are new to the concrete repair industry?

Within, say, last 5 years?



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Things take time



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Things cost money



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Things aren't always apparent



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It's always interesting



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Historical perspective is important

How many have been in the repair industry at least...

...1 year?

...since 2010?

...since 2000?

...since 1990?

...since 1980?

...since 1970?



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Looking Back to See Ahead...

Looking Back to See Ahead Using Historical Knowledge of Durability to Provide Clues for Concrete Repair

by David G. Tepke

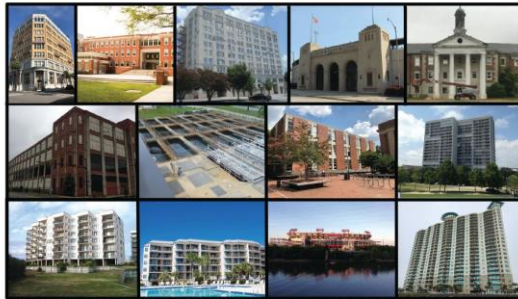


Fig. 1. Structures from the top row: 1910s; middle row: 1950s-70s; and bottom row: 1980s-2000s.

Jan/Feb 2023 Concrete Repair Bulletin

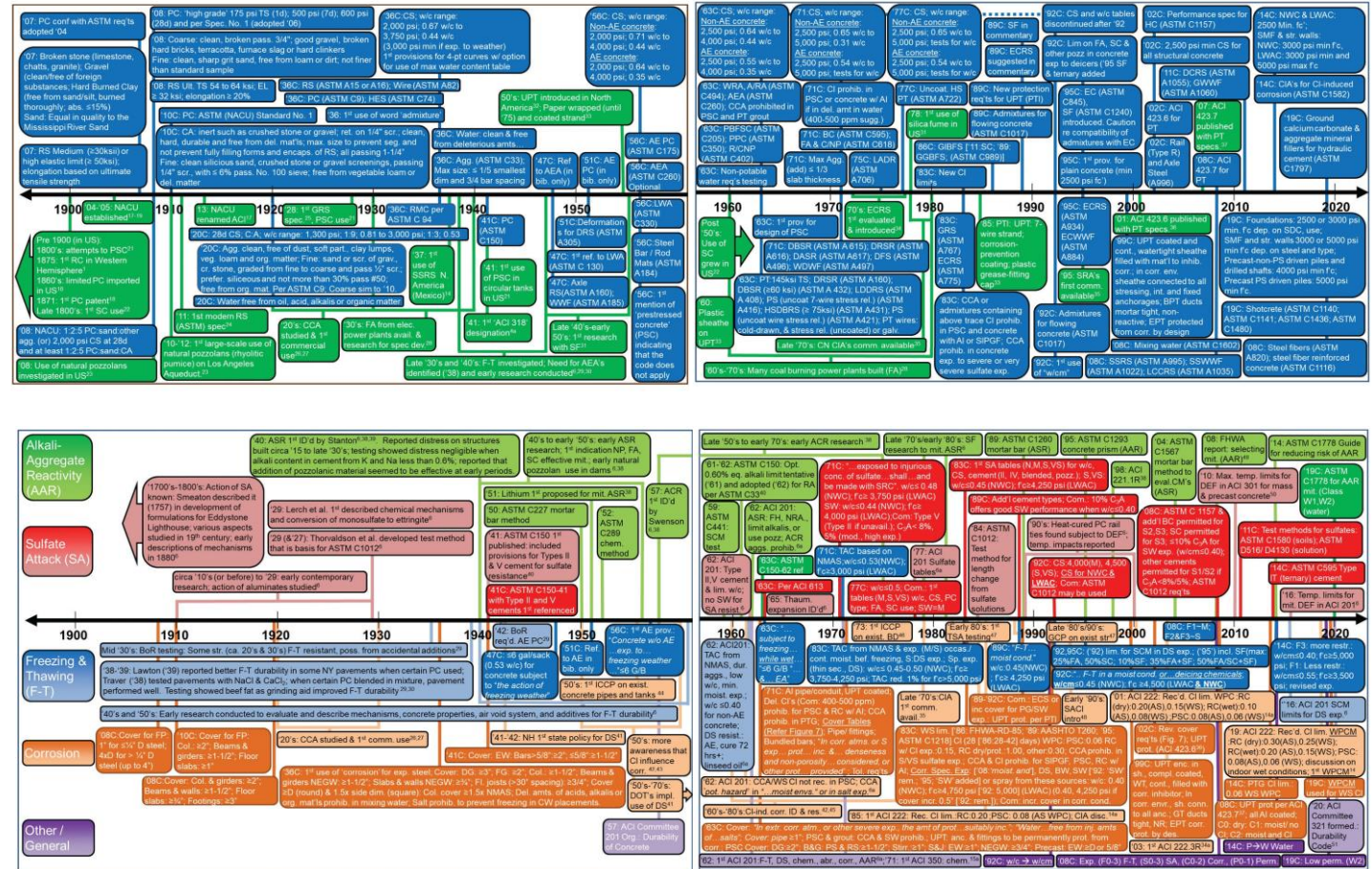
January/February 2023
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2023 ICRI PRESIDENT
PIERRE HÉBERT

CONCRETE REPAIR MATERIAL AND METHODS SELECTION



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The Industry Changes - Knowledge

	ACI Codes			ACI Committee Guides and Reports			
	318 - Building / Predecessors	350 - Sanitary / Environmental	562 - Repair	201 - Durability	222 - Corrosion	350 - Sanitary / Environmental	546 - Repair
1900-1910							
	Laws & Ord. (1907)						
1910-1920	NACU Standard No. 4 (1910)						
1920-1930	ACI Standard Specification 23 (1920)						
1930-1940		ACI 501-36					
1940-1950	ACI 318-41						
	ACI 318-47						

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References

	ACI Codes			ACI Committee Guides and Reports			
	318 - Building / Predecessors	350 - Sanitary / Environmental	562 - Repair	201 - Durability	222 - Corrosion	350 - Sanitary / Environmental	546 - Repair
1950-1960	ACI 318-51						
	ACI 318-56						
1960-1970	ACI 318-63			ACI 201 Report - JACI 59-57 (1962)			
1970-1980	ACI 318-71 ('73,'74,'75,'76s)					ACI 350 Report JACI 68-50 (1971)	
	ACI 318-77 ('80s)					ACI 350 Report JACI 74-26 (1977)	
1980-1990	ACI 318-83 ('86s)			ACI 201.2R-77		ACI 350 Report JACI 80-44 (1983)	
	ACI 318-89				ACI 222R-85		
1990-2000	ACI 318-89 (r92)			ACI 201.2R-92		ACI 350R-89	
	ACI 318-95				ACI 222R-96		ACI 546R-96
	ACI 318-99						
2000-2010	ACI 318-02	ACI 350-01		ACI 201.2R-01			
	ACI 318-05						
	ACI 318-08				ACI 222R-01		ACI 546R-04
2010-2020	ACI 318-11	ACI 350-06	ACI 562-13	ACI 201.2R-08			
	ACI 318-14		ACI 562-16				
			ACI 562-19	ACI 201.2R-16			
2020-present	ACI 318-19	ACI 350-20	ACI 562-21		ACI 222R-19		ACI 546R-14

Freezing and Thawing

- Benefits of air entrainment first identified in late 1930's
- First ACI 318 requirement for air entrainment for F-T in 1963
- First specific ACI 318 requirements for air content in 1971
- First ACI 318 limitations of SCM's for scaling resistance in 1992



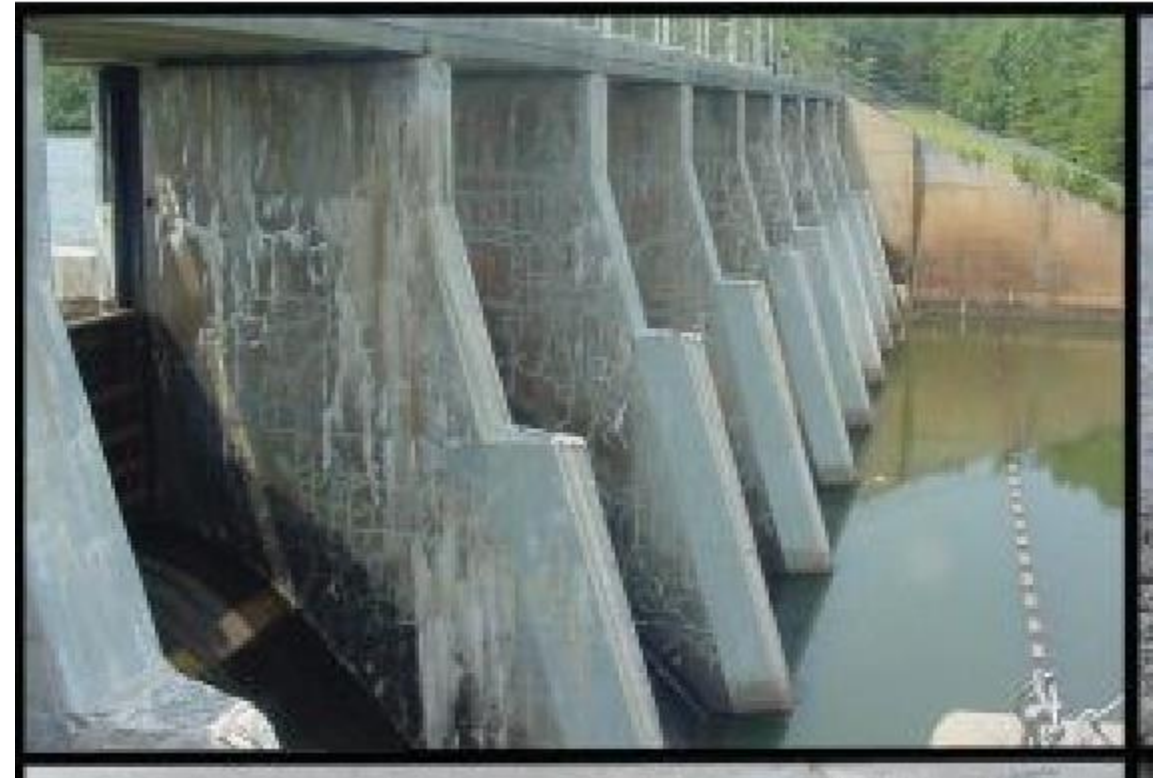
Sulfate Attack

- Known prior to 20th century
- First modern research 1910's – 1930's
- First ACI 318 provisions by reference to cement in 1941
- Advancement in provisions through late 20th and early 21st centuries
- DEF first identified in 1990's and provision included in ACI 301 in 2010



Alkali-Aggregate Reactivity

- First identified in late 1930's and reported in early 1940's
- First ACI 318 provisions by reference to ASTM C150 cement requirements in 1960's
- First inclusion into ACI 318 explicitly in 2019 through ref to ASTM C1778

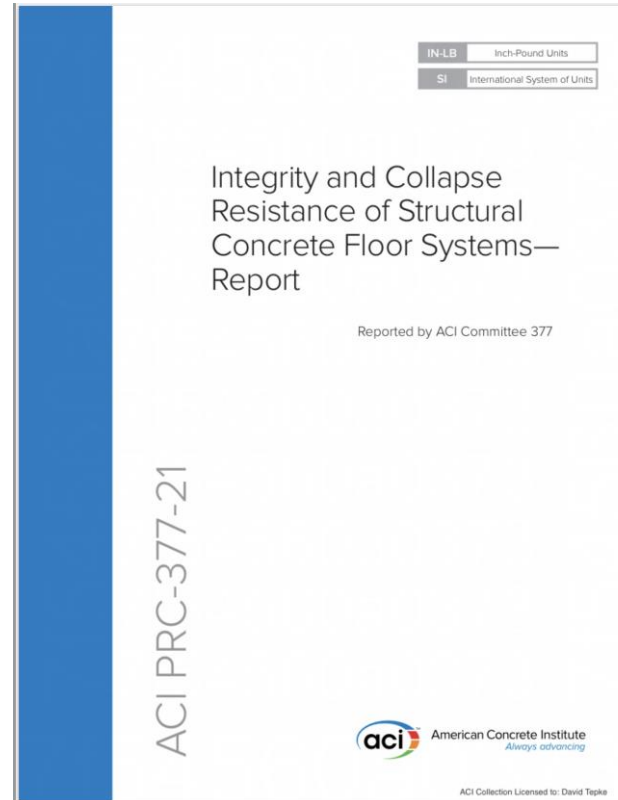


Corrosion

- Calcium chloride accelerator first commercially used in US in 1920's
- Not really considered a problem until better studied through 1960's – 1980's
- First ACI 318 chloride limits in new construction in 1983
- Post-tension protection evolution, especially between 1960's and late 1990's
- Refinements for addressing still occurring



Structural Integrity Provisions (ACI 318-89)



From ACI PRC 377 Fig 3.2.3.2a

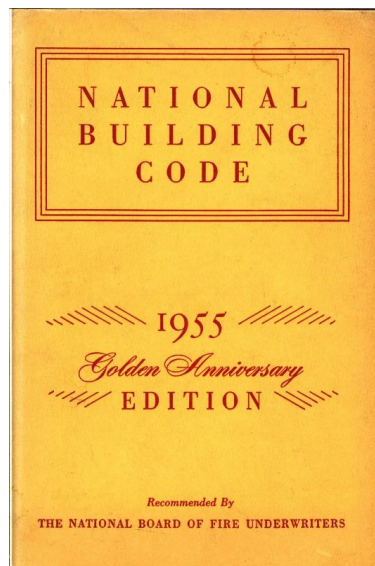
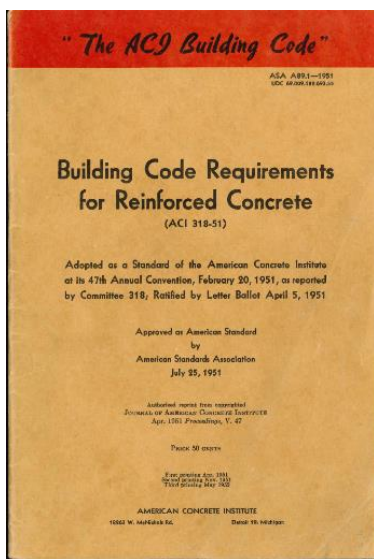
From ACI PRC 377 Fig 3.3.2.1

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Jurisdictional Codes Lag Industry Knowledge

An idea → Research/Development → Publication/Product → Consensus Guide → Industry Standard Code → Jurisdictional Code → Refinement and Revision Towards Progress



City of Charleston
Department of Public Service
Inspections Division

Building Code Adoption

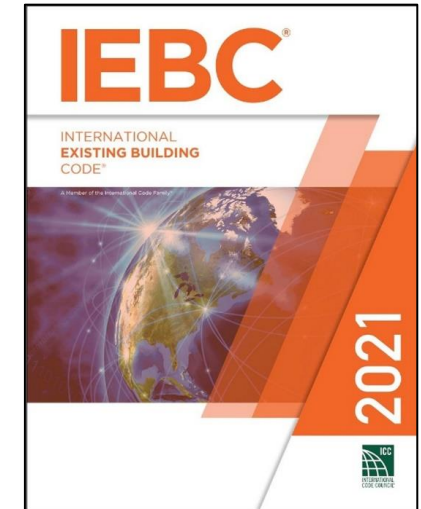
- | | |
|------|--|
| 1895 | Chapter XIII, Section 482 of City Ordinances |
| 1929 | Section 684 of City Code, National Board of Fire Underwriters, in addition to requirements prescribed by City Ordinance. |
| 1952 | Section 9-13, Adopted National Building Code, 1949 Edition |
| 1964 | Section 10-14, Adopted National Building Code, 1955 Edition |
| 1975 | Section 10-18, Adopted National Building Code, 1967 Edition |

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Concept of Reasonable Safety in Buildings

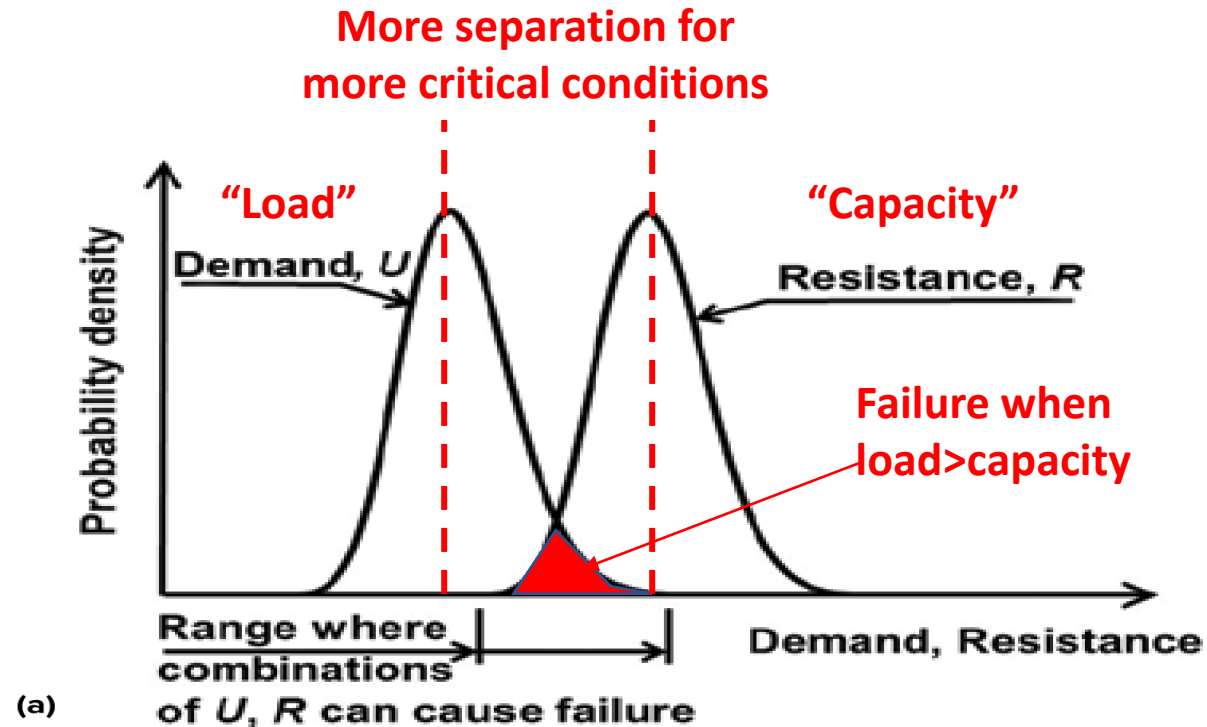
- Safety, dangerous, hazardous are relative terms
- Certification of unqualified safety can be impractical
- Judgement and inherent uncertainties are nearly always characteristic
- Meaning: Engineer vs. the Public
- Concept of 'reasonable safety' in codes
 - New structures and existing



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Safety in Design



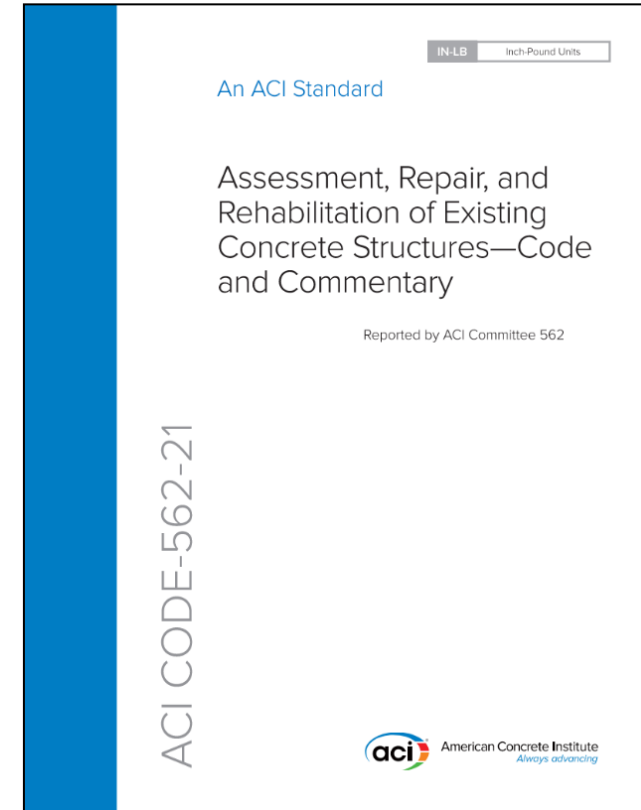
Figures from Bartlett, et al 2019, though concept was pre-established

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ACI 562 – Concrete Repair Code

- Potentially Dangerous
 - Meet def for dangerous or unsafe
 - Unstable
 - Falling hazards
 - Demand-to-capacity ratio exceeding 1.5
 - Potentially hazardous resistance for seismic events
 - Low margin of safety against collapse



Jurisdictional Requirements / Certifications

- Ordinances
- Language?
 - Safe?
 - Secure?
 - Free of deterioration?
 - Free of defects?
- Language needs to be selected to be useful to owners and public, but accurately convey issues

Concerning Conditions: Obvious and More Definitive

- Tripping hazards
- Overhead spalling hazards
- Conditions where demand (load) and capacity (strength) can be determined with reasonable certainty



Dangerous or Unsafe: May Not Be So Obvious or Definitive

- Loads
 - Actual
 - Extraordinary events
 - Changes in future
- Constraints
 - Hidden areas
 - Previous repairs
 - Ability to accurately model
 - Interpretation
 - Documentation



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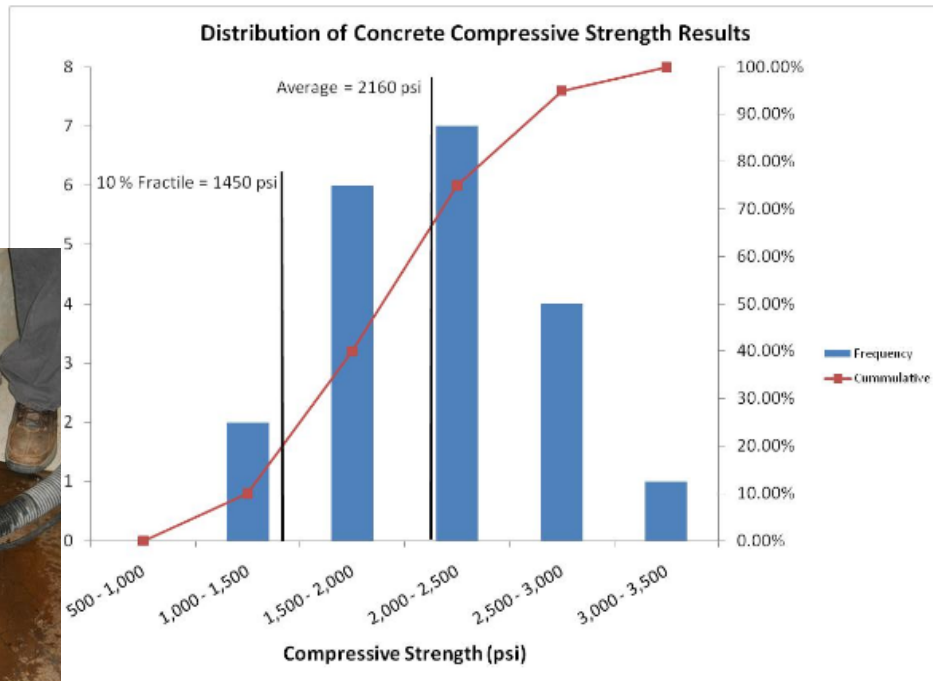
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Dangerous or Unsafe: May Not Be So Obvious or Definitive

- Structural system
 - Redundancy
 - Area of influence
 - Failure mechanism and ductility
 - Lateral stability
 - Stiffness and load shedding
 - Impact of damage on adjacent areas



Dangerous or Unsafe: May Not Be So Obvious or Definitive



• Material Performance

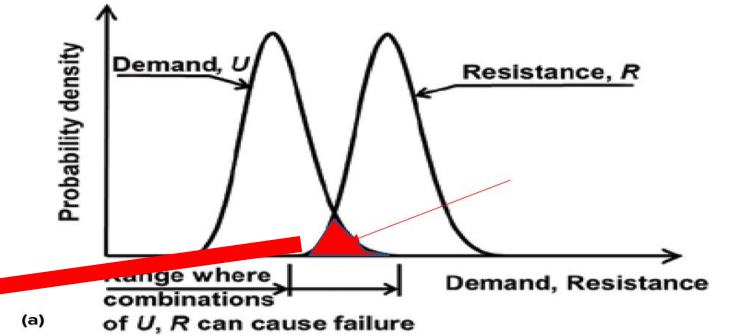
- In-place dimensions and properties
- Inherent defects
- Composite action / development length
- Corrosion
- Material damage / deterioration
- Rate of deterioration
- Variability
- Local vs. global

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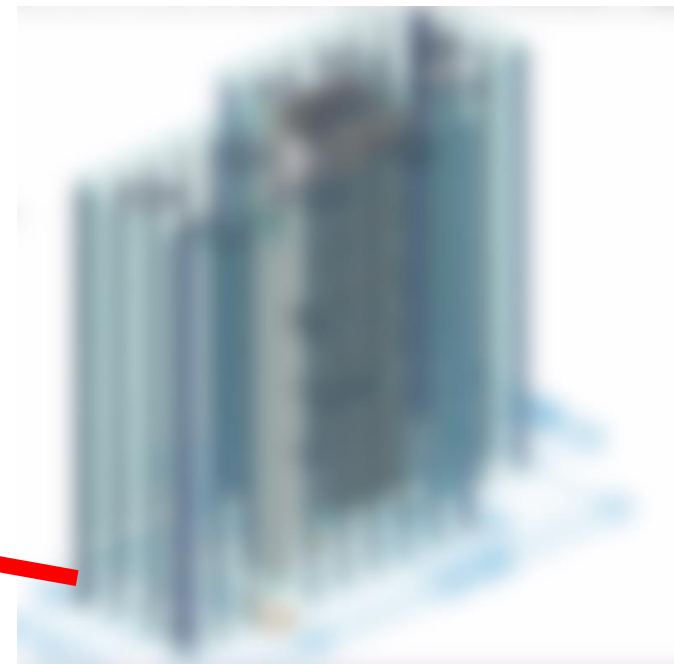
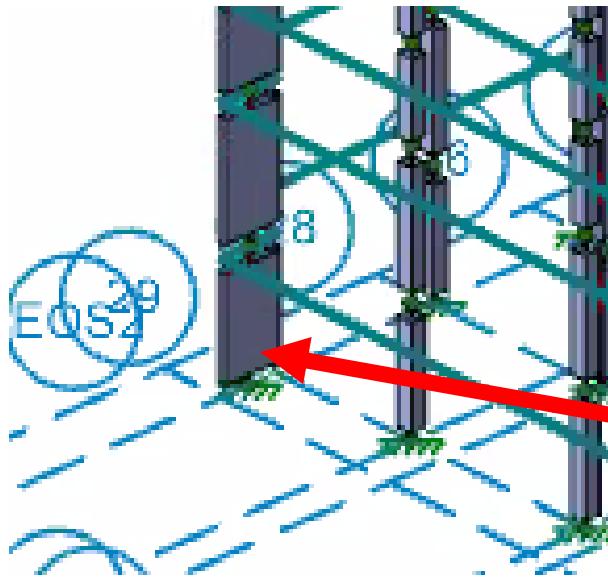
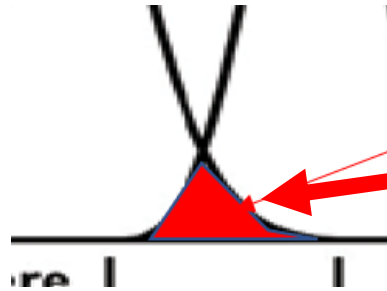
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Safety: Global vs. Local



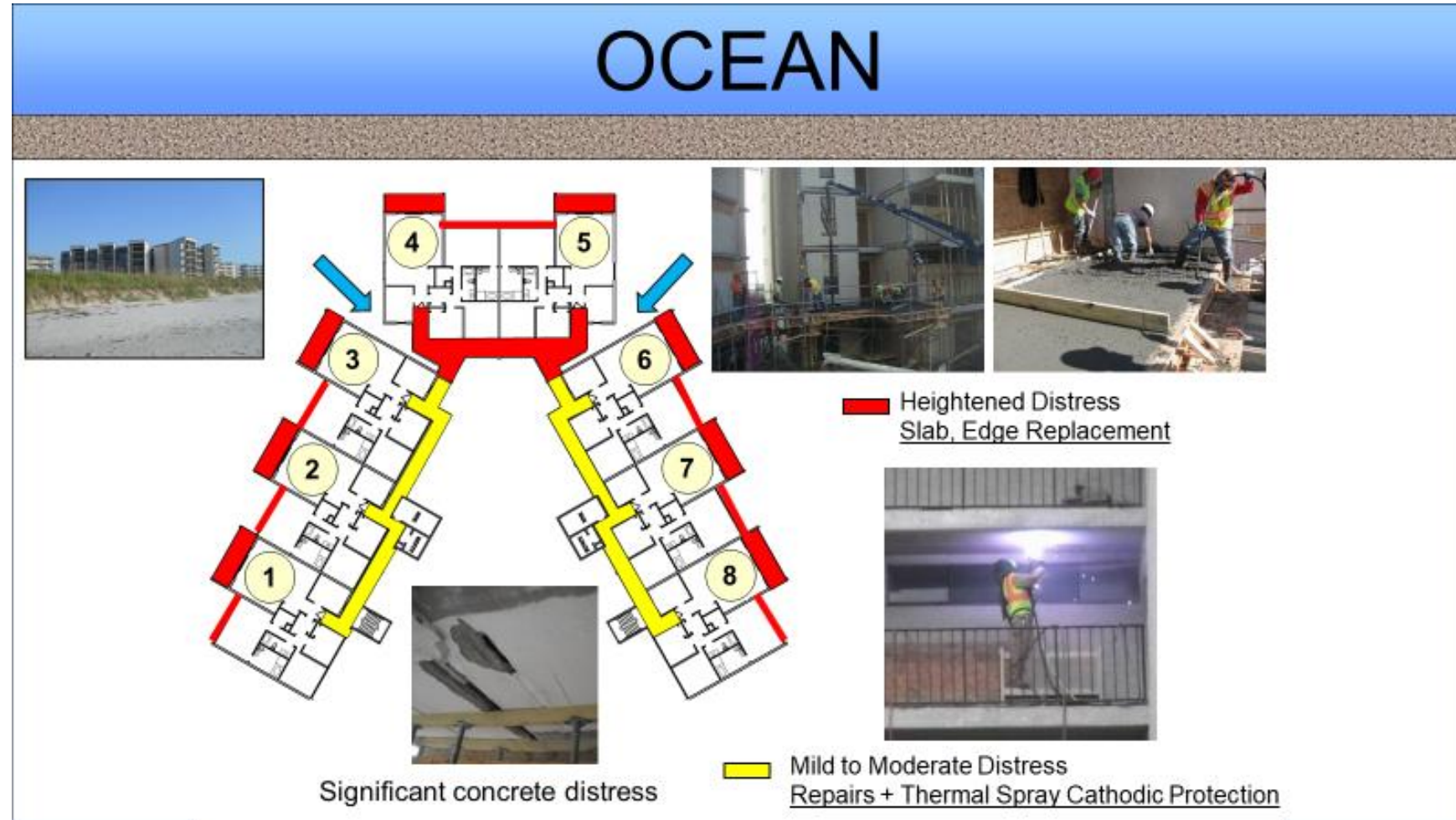
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Spatial and Local Considerations of Corrosion

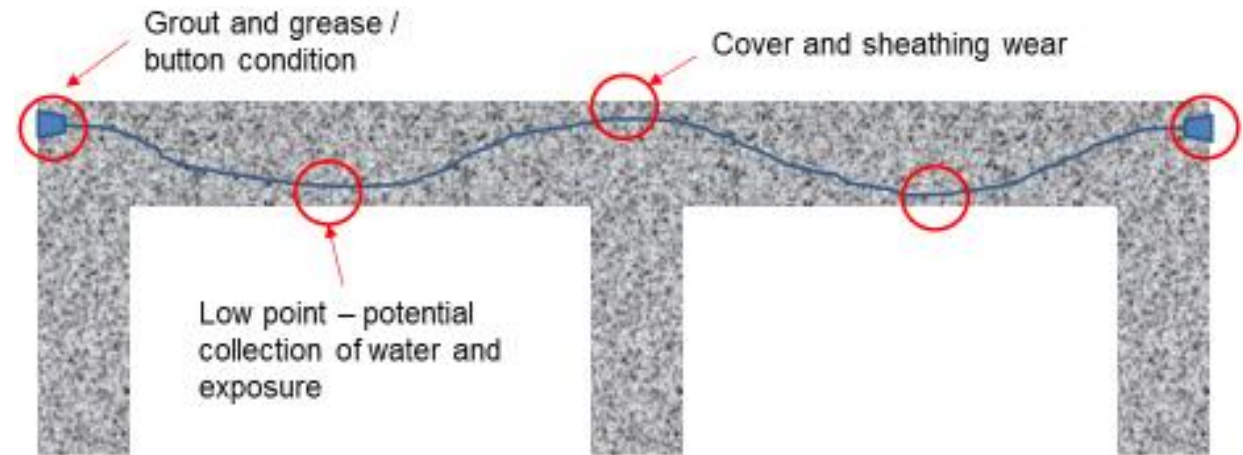


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Spatial and Local Considerations of Corrosion

Post-Tensioned Steel



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Corrosion is not just an outdoor concern...

Is the Inside of Your Structure Safe from Corrosion?

by David G. Tepke and O. Burkan Isgor



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...and not just in indoor 'corrosive' conditions



A detour if you will indulge me...



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“Engineering is an Art and a Science”



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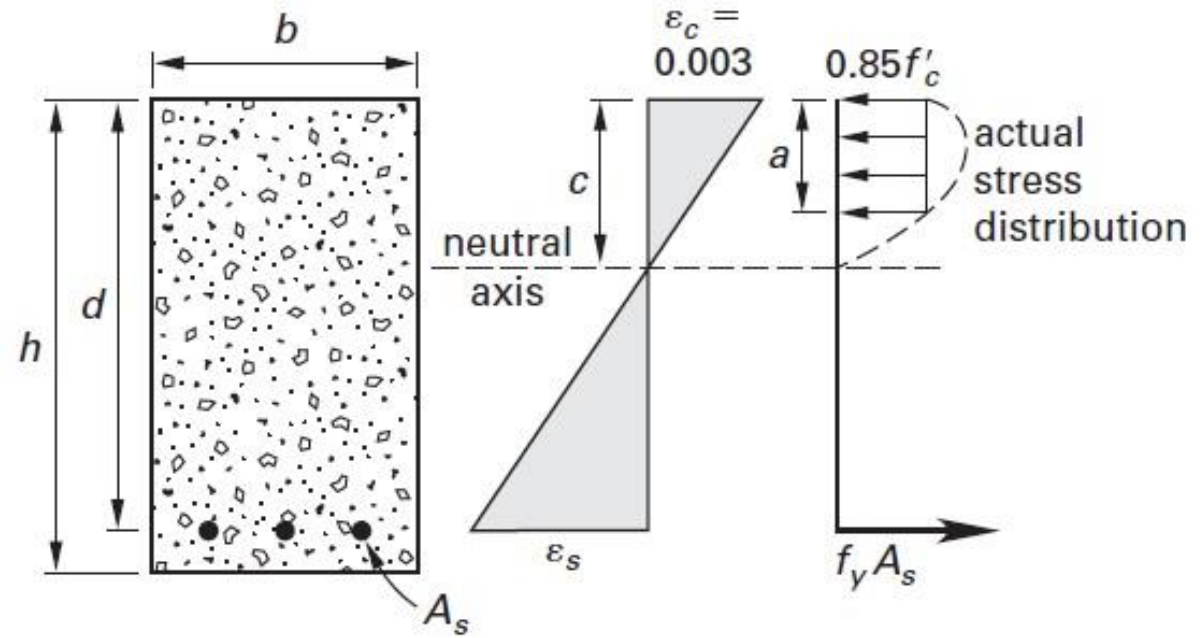
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Art



www.wikipedia.com

Science



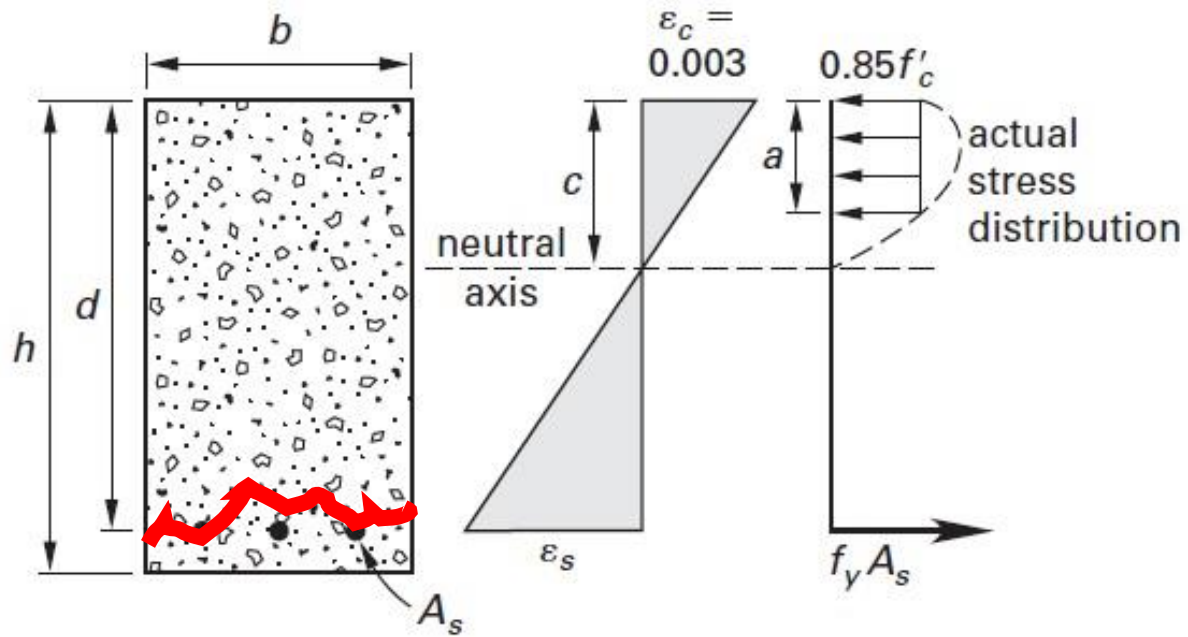
www.civilengineeringbibleikipedia.com

“Structural Investigation and Repair are like abstract art and that type of science that makes you feel really dumb sometimes”



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What do you think?



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Columns



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Beams



Joists



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Load Testing



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Repairs need to make new things fit together with old things but without changing things too much



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Be careful in assuming a repair or condition is 'non-structural'



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Don't assume typical details apply



The Unforeseen is the Foreseen



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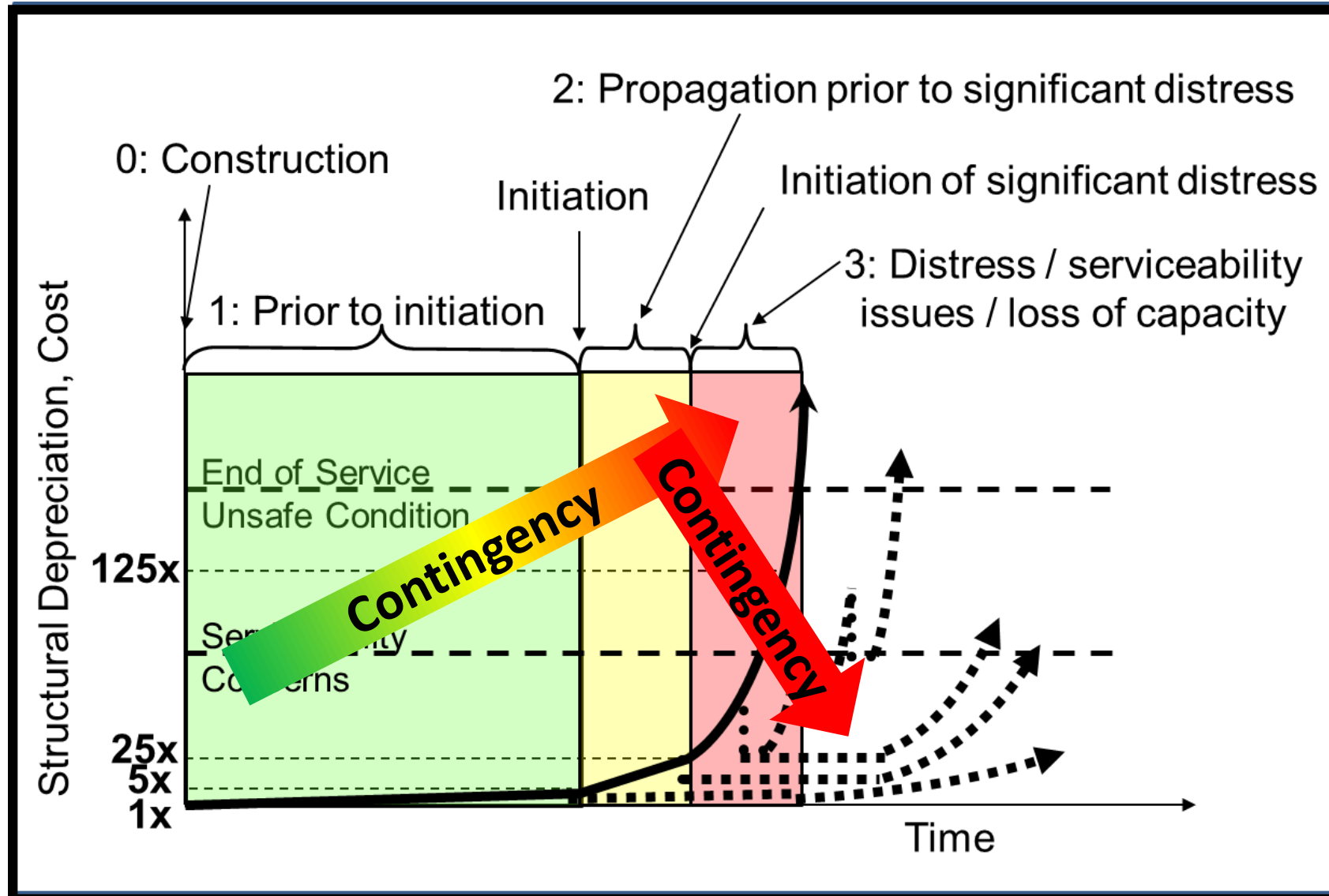
Delaminations and distress can be hidden



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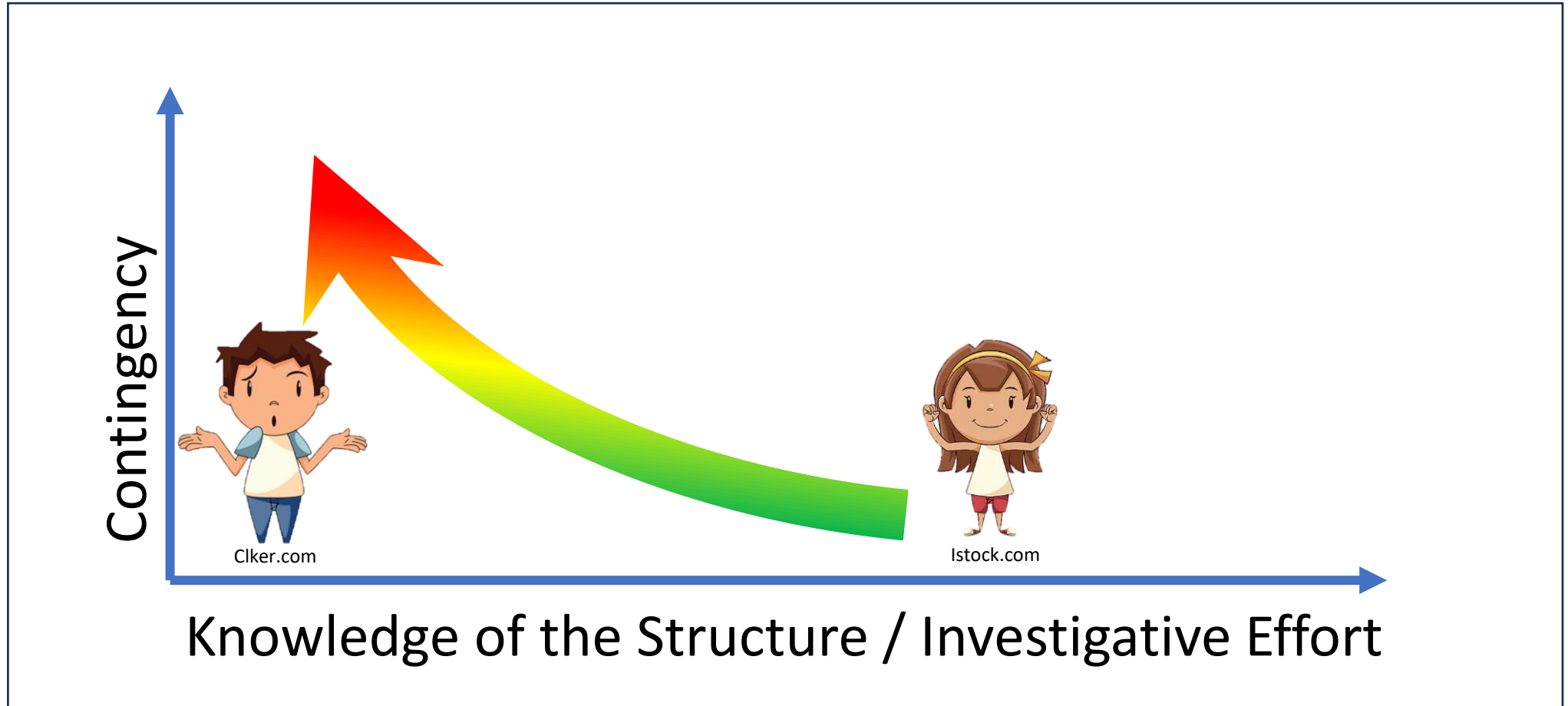
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Contingency



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Contingency



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But when in doubt, put a contingency on the contingency



The industry is always changing with challenges, keeping things interesting



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