The ACI 562 Code

How does it affect your concrete repair project?

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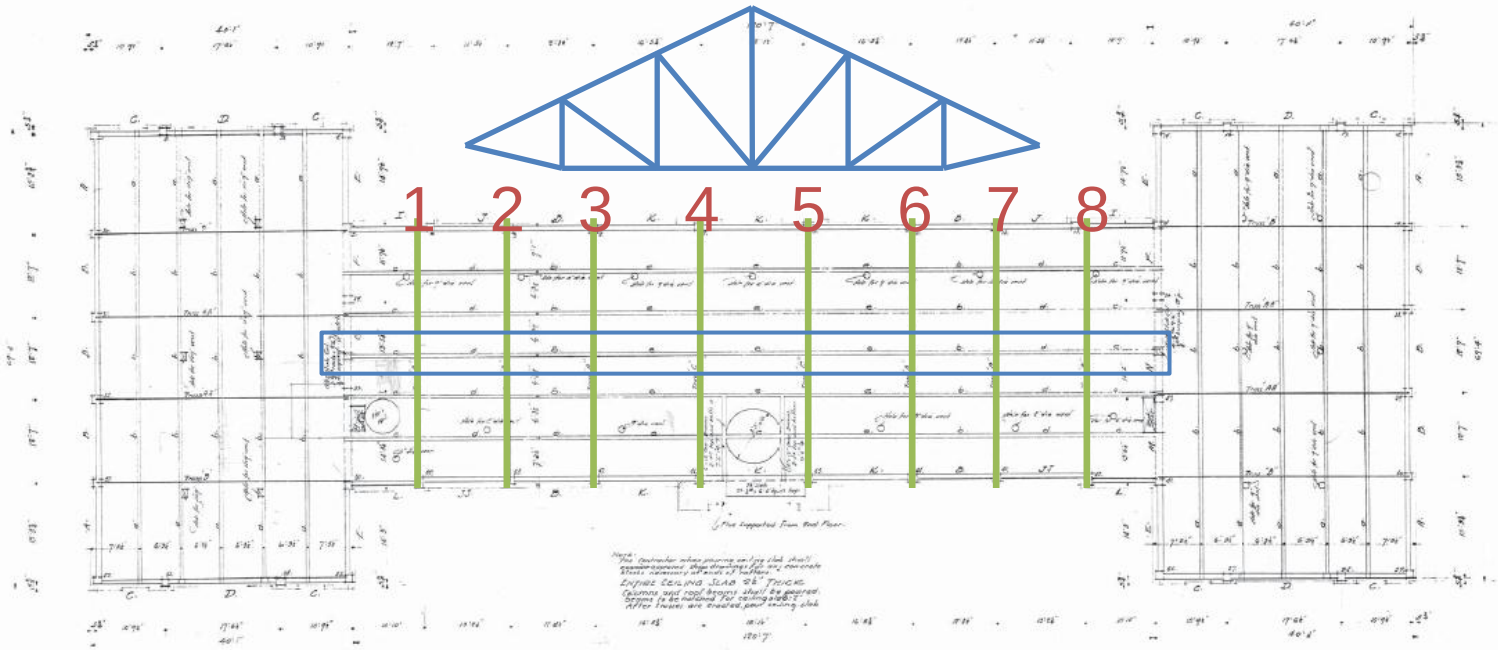
INTERNATIONAL CONCRETE REPAIR INSTITUTE
INFRASTRUCTURE REPAIR
ICRI 2014 SPRING CONVENTION, MARCH 19-21, 2014

Historic Structure

Air Force Base Academic Building

Project Background

- Built in the 1930s
- New HVAC system installed October 2011



CEILING FRAMING PLAN
Scale 1/4"=1'0"

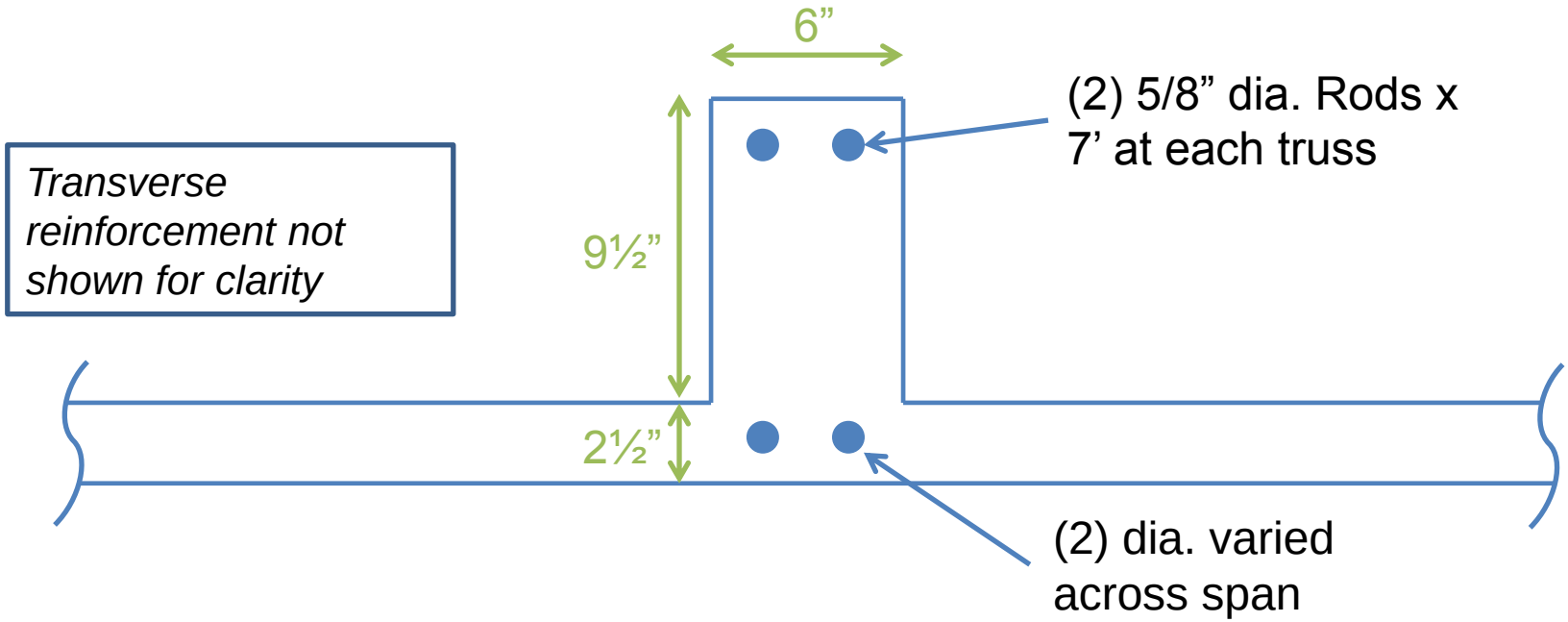
DETAIL OF CEILING CONSTRUCTION
Scale 1/2"=1'0"

W.E. SIMPSON CO.
CONSULTING ENGINEERS INC.
San Antonio, Texas
By:

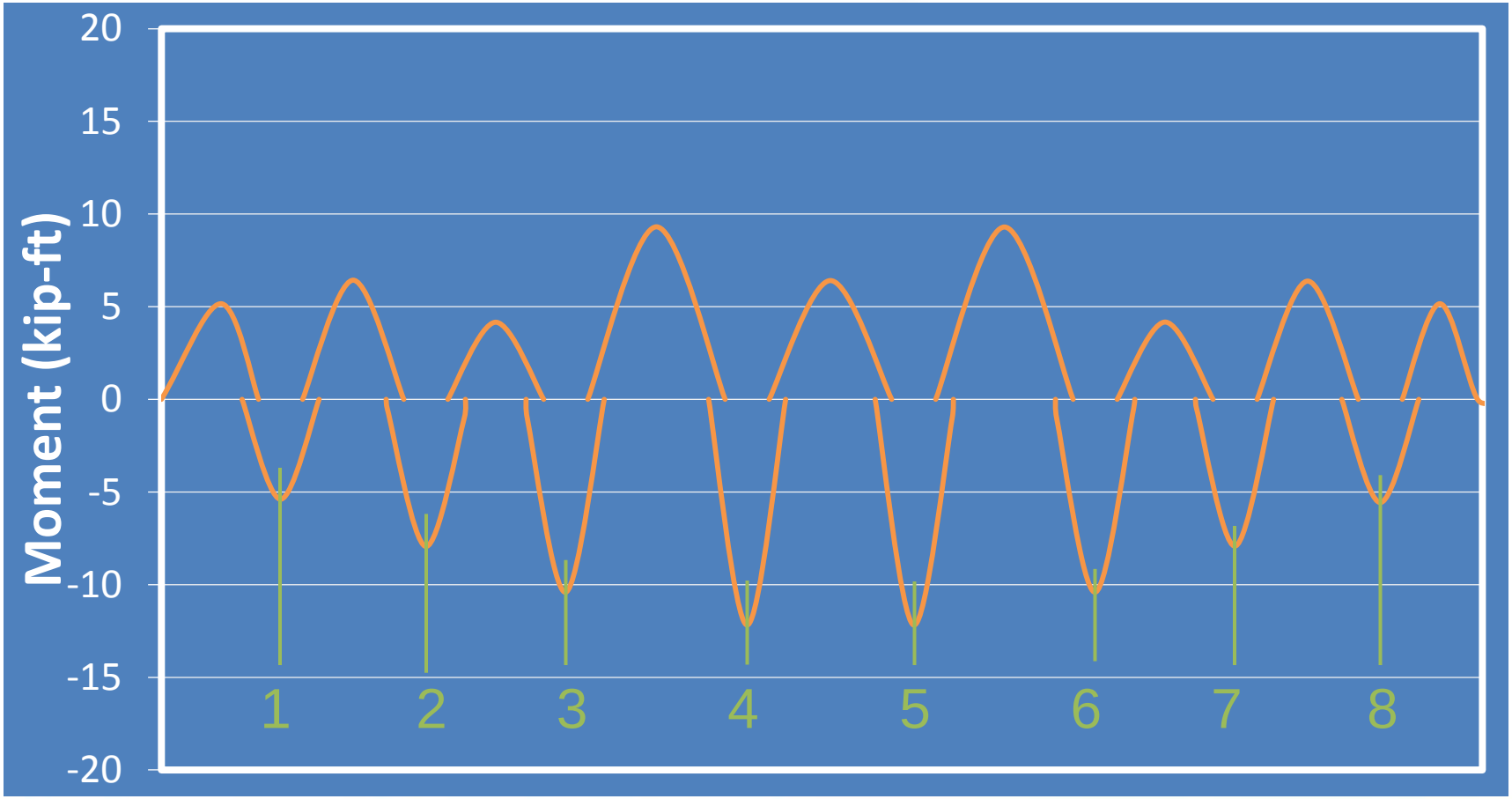
CONSTRUCTION SERVICE
OFFICE OF THE QUARTERMASTER GENERAL
RANDOLPH FIELD TEXAS
ACADEMIC BUILDING
RALPH H CAMERON A.I.A.
ARCHITECT
MAJESTIC BUILDING SAN ANTONIO TEXAS

Cross Section

- Inverted tee



Structural Analysis – Original Loading



Chapter 6 – Default Strength

- Material properties (*reference §6.3.3*)
  - Concrete (Table 6.3.1a)

Time frame	Footings	Beams	Slabs	Columns	Walls
1900-1919	1000 psi	2000 psi	1500 psi	1500 psi	1000 psi
1920-1949	1500 psi	2000 psi	2000 psi	2000 psi	2000 psi
1950-1969	2500 psi	3000 psi	3000 psi	3000 psi	2500 psi
1970-present	3000 psi	3000 psi	3000 psi	3000 psi	3000 psi

Chapter 6 – Default Strength

- Material properties (*reference §6.3.3*)
  - Steel (Table 6.3.1b)

Time frame	Grade	33	40	50	60	65	70	75
	$F_{y,min}$ (ksi)	33	40	50	60	65	70	70
	$F_{t,min}$ (ksi)	55	70	80	90	75	80	100
1911-1959		X	X	X	—	X	—	—
1959-1966		X	X	X	X	X	X	X
1966-1972		—	X	X	X	X	X	—
1972-1974		—	X	X	X	X	X	—
1974-1987		—	X	X	X	X	X	—
1987-present		—	X	X	X	X	X	—

Calculated Capacity – Historic Values

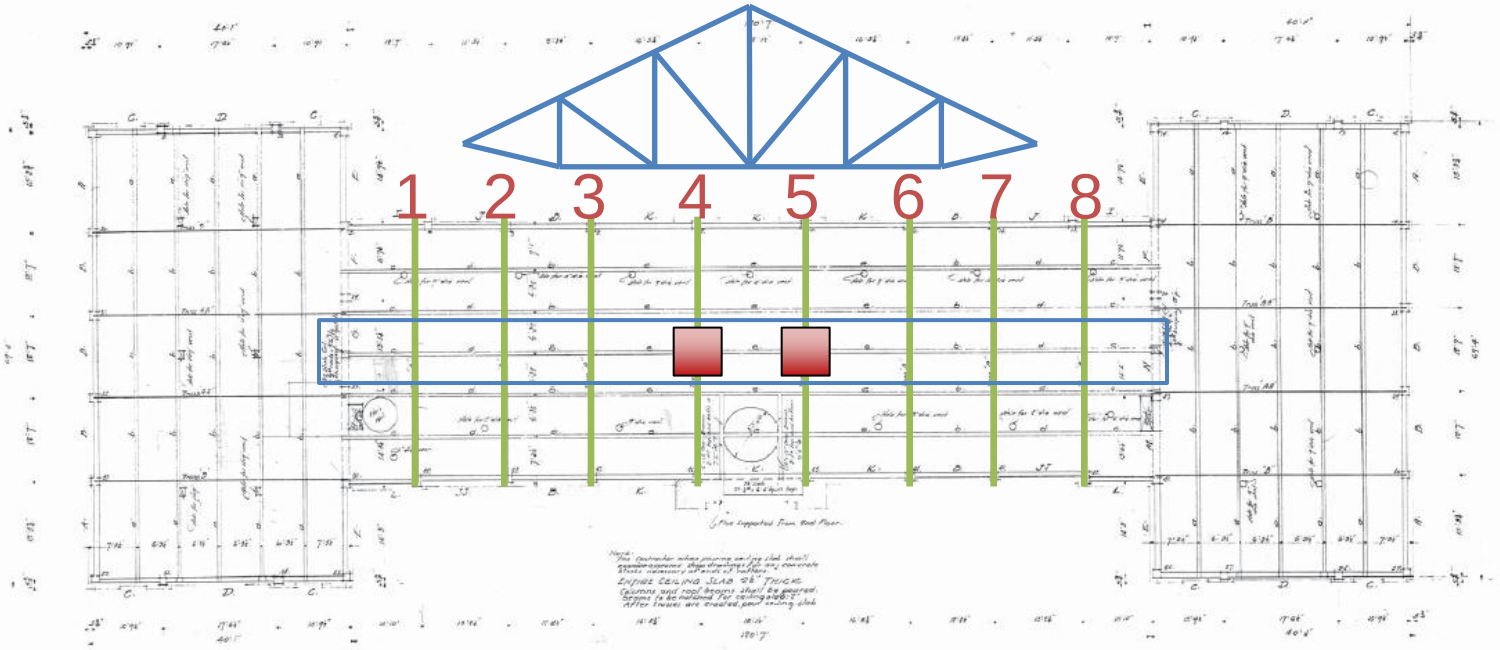
- Flexural strength
  - Concrete: 2,000 psi
  - Steel: 33 ksi
  - Demand: -13 kip-ft

    Φ: 0.9 (evaluation)

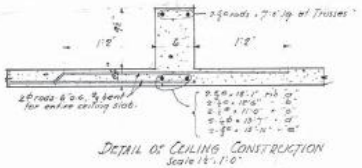
    Capacity: -16.0 kip-ft

    D/C: 0.81

Beam okay



CEILING FRAMING PLAN
Scale 1/4"=1'0"



DETAIL OF CEILING CONSTRUCTION
Scale 1½"=1'0"

Note:
G. Indicates plain round rods
D. " deformed "
S. " square "

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CONSULTING ENGINEERS INC.
San Antonio, Texas
By:

W. E. Simpson Co.
Consulting Engineers (Inc.)
San Antonio, Texas
Approved

SCALE: ONE EIGHTH & ONE-HALF WITH DOUBLE ONE FOOT

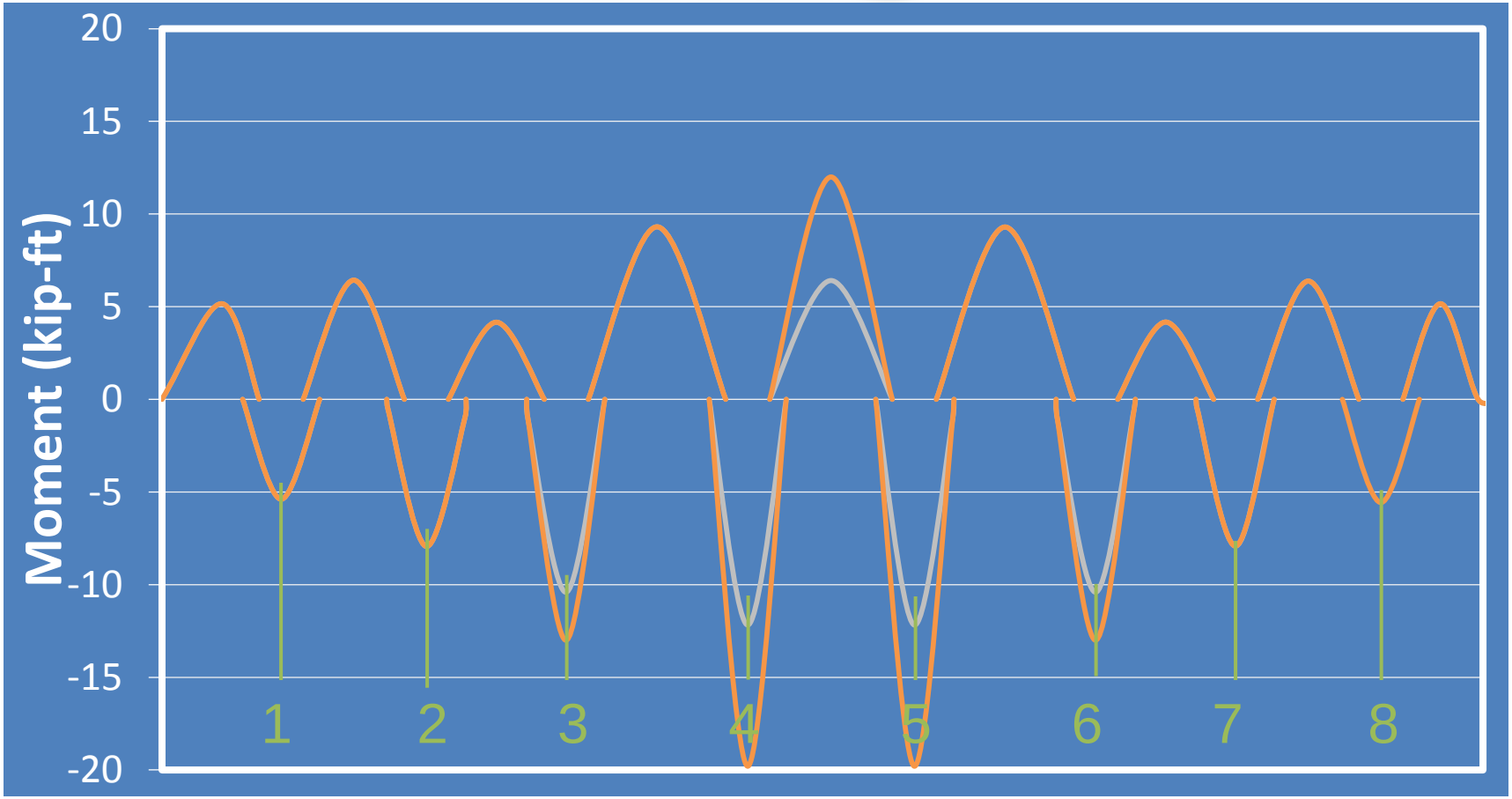
CONSTRUCTION SERVICE
OFFICE OF THE QUARTERMASTER GENERAL

RANDOLPH FIELD TEXAS
ACADEMIC BUILDING

DRAWN BY H.A.A.	CHECKED BY L.T.B. A.A.C.	APPROVED FOR L.H. BACH, BRIG GEN QMC BY [signature] MAJOR, Q.M.C.	DATE NOV. 27 1939
TRACED BY C.E.A.			PLAN NUMBER 6715-284

RALPH H CAMERON A.I.A.
ARCHITECT
MAJESTIC BUILDING SAN ANTONIO TEXAS

Structural Analysis – Revised Loading



Calculated Capacity – Historic Values

- Flexural strength
  - Concrete: 2,000 psi
  - Steel: 33 ksi
  - Demand: -19.8 kip-ft
    - Φ: 0.9 (evaluation)
    - Capacity: -16.0 kip-ft
    - D/C: 1.24

Strengthen beam

Determine Material Strength (Testing)

Reference Section 6.4

- Concrete cores
  - $n = 8$
  - $\bar{f}_c = 6{,}200$ psi, $V = 0.15$
  - §6.4.3-equivalent specified concrete strength

$$f_{ceq} = 0.9\bar{f}_c\left[1 - 1.28\sqrt{\frac{(k_c V)^2}{n} + 0.0015}\right]$$

$$f_{ceq} = 5{,}100 \text{ psi}$$

- Measured dimensions of beam

Determine Material Strength (Testing)

- Steel coupons
  - $n = 8$
  - $\bar{f_y} = 40{,}000 \text{ psi}, V = 0.05$
- §6.4.6-equivalent specified yield strength (reinf.)
  - $f_{yeq} = (\bar{f_y} - 3500)e^{-1.3k_sV}$
  - $f_{yeq} = 33{,}217 \text{ psi}$
- Measured locations of bars

Calculated Capacity – Tested Values

- Flexural strength
  - Concrete: 5,100 psi
  - Steel: 33 ksi
  - Demand: -19.8 kip-ft

    Φ: 1.0 (evaluation) Reference 5.4.1

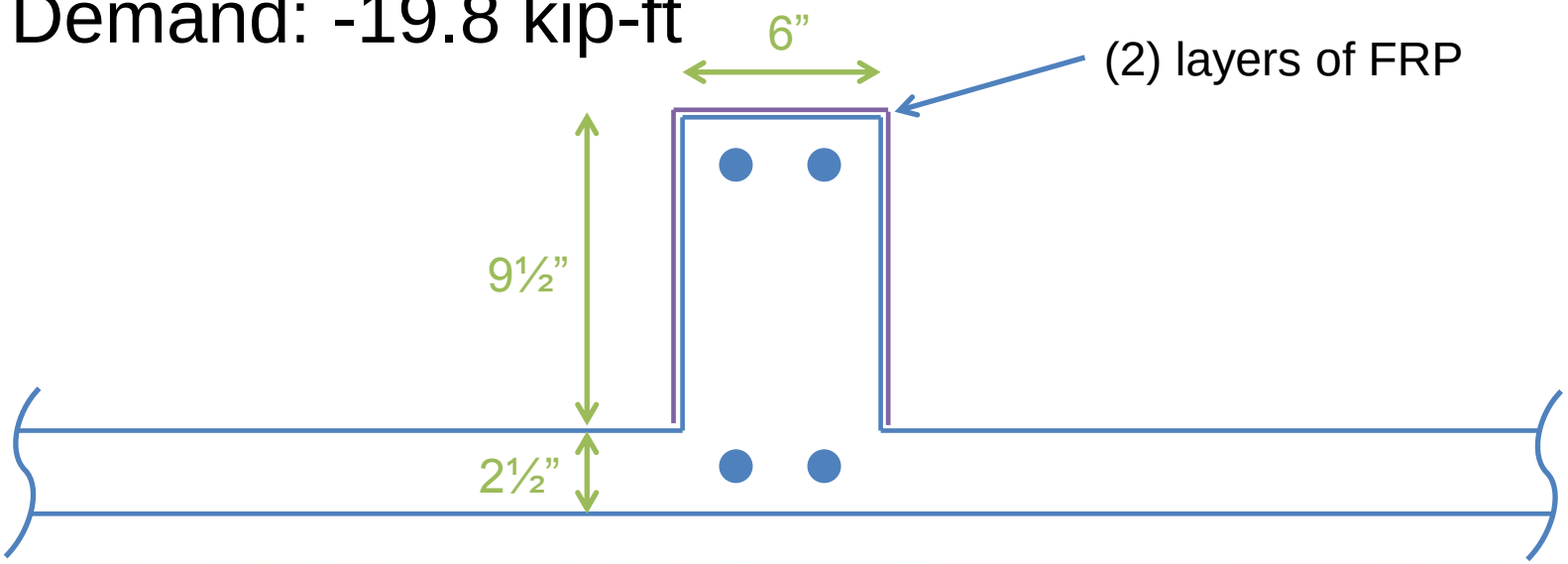
    Capacity: -18.1 kip-ft

    D/C: 1.09

Strengthen beam

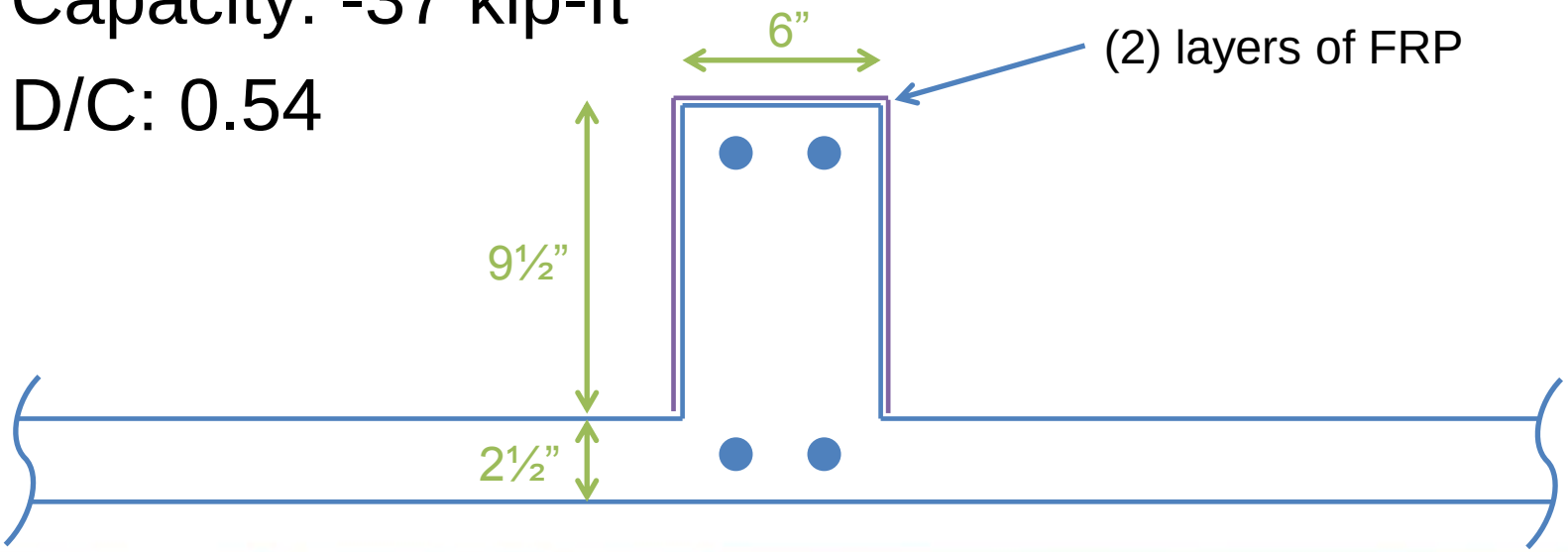
Repair

- Flexural strength
  - Concrete: 5,100 psi
  - Steel: 33 ksi
  - Demand: -19.8 kip-ft



Repair

- Flexural strength
  - Φ: 0.9 (design)
  - Demand: -19.8 kip-ft
  - Capacity: -37 kip-ft
  - D/C: 0.54



Key Concepts

- Evaluation based on historic values
  - Quick check (ballpark)
  - Evaluate element with standard ϕ-factors
- Evaluation based on material testing
  - More refined analysis
  - Evaluate element with modified ϕ-factors (lower variability because material properties are known)

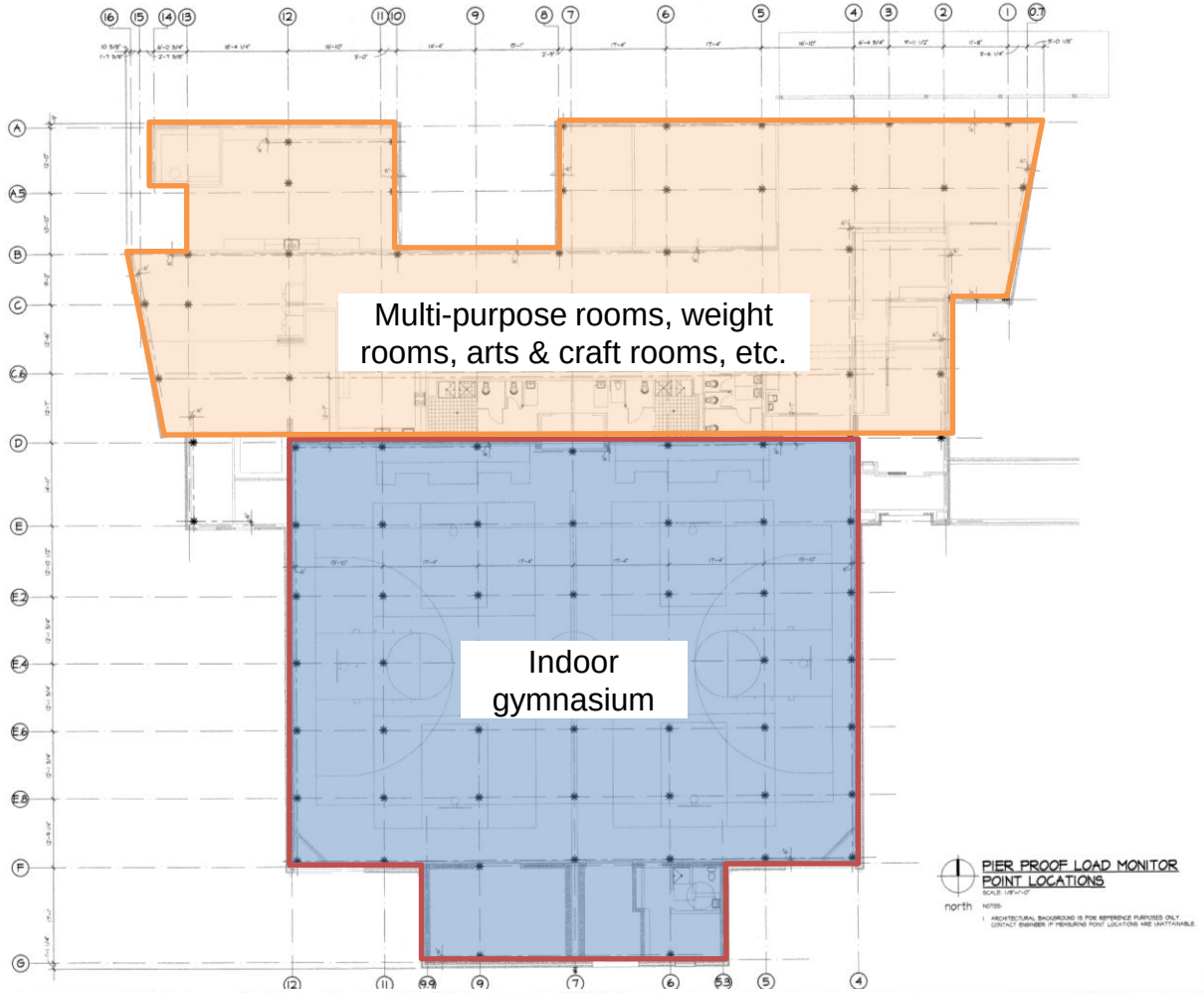
Key Concepts

- Repair design consistent with relevant standards (ACI 318, ACI 440.2R, etc.)
  - Use standard ϕ-factors (because material properties will be unknown with repair work)

New Structure

Turner-Roberts Recreation Center

Zoning of Structure



Problems at Turner-Roberts

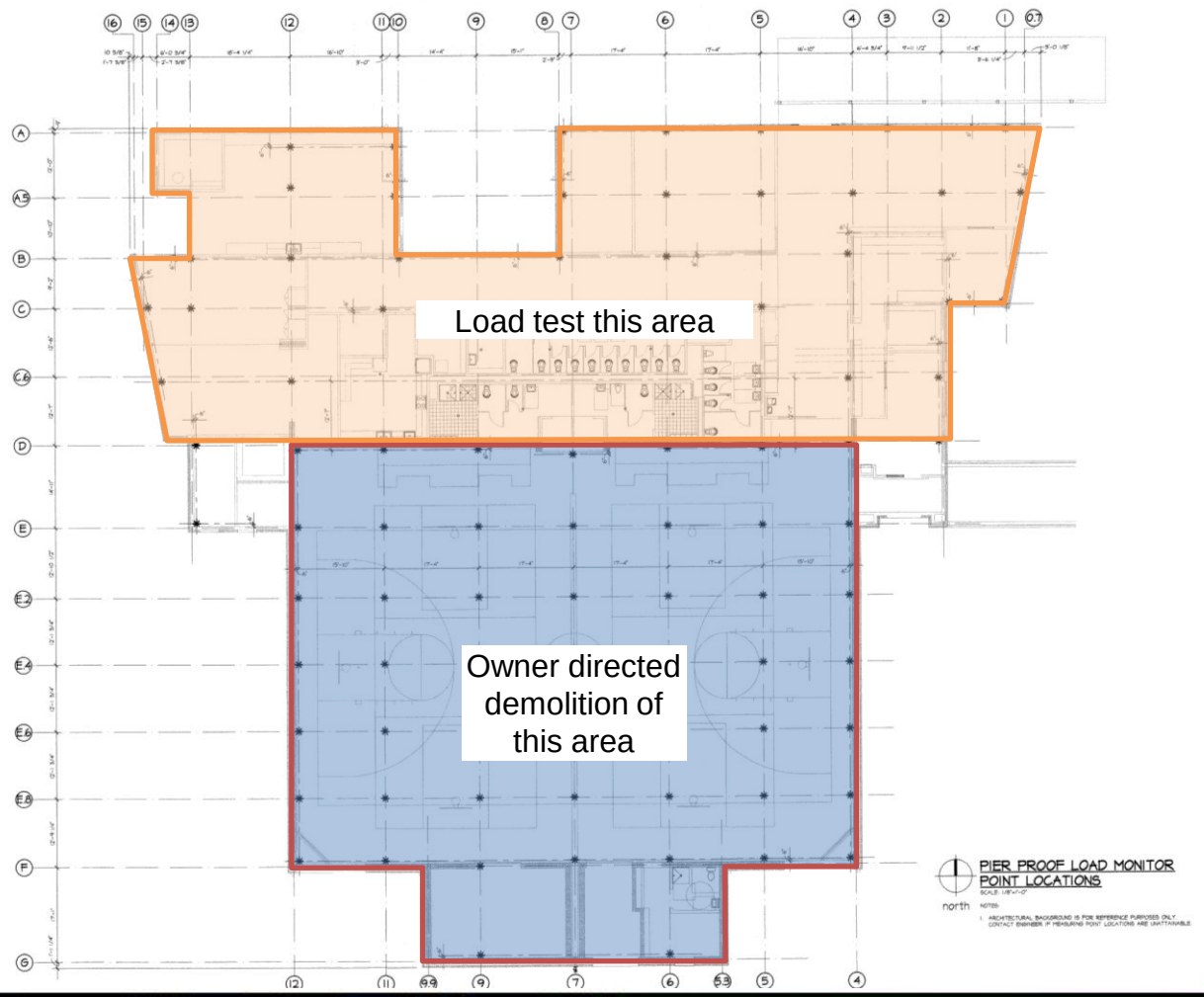
- Problems identified in 2009
- Issues
  - Hairline cracks in structure
  - Carton void form filled
  - Expansion clays
  - Construction errors
- Center closed July 2011

Evaluate structure

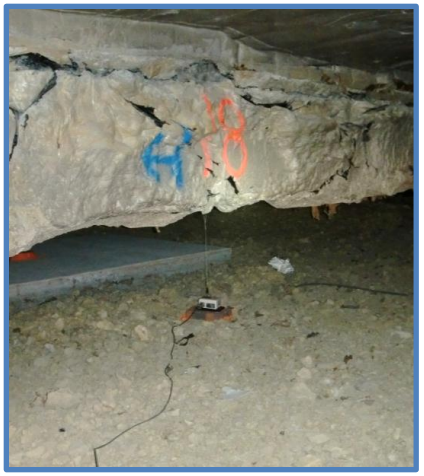
Evaluation Approaches for Existing Structures

- Analytical (sectional analysis based on construction drawings)
- Experimental (load test)
  - Reference Section 6.8

Demolition of Structure



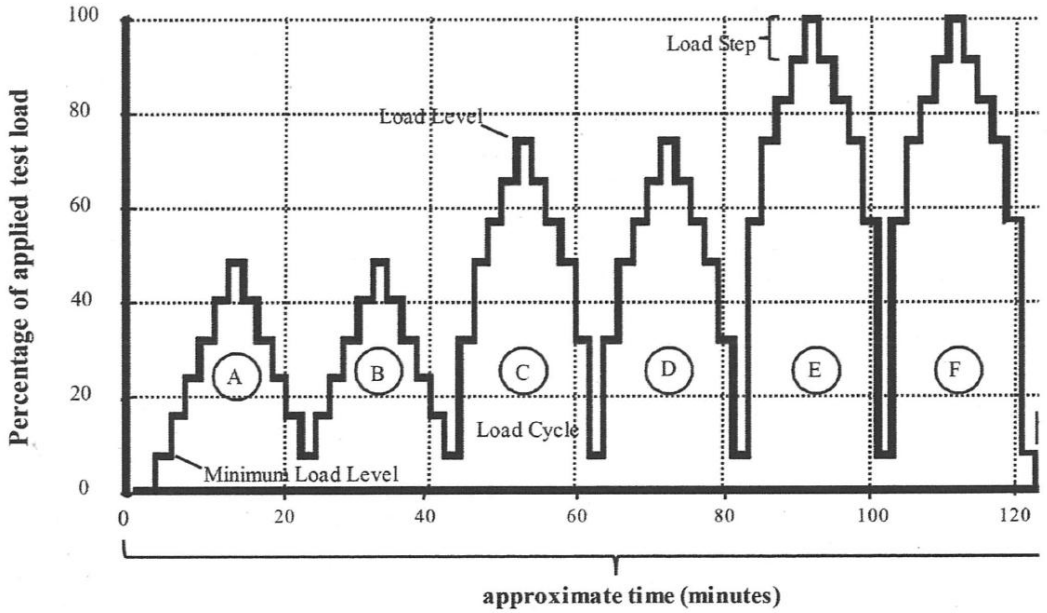
Load Test Procedures (ACI 437.2-13)



- Monotonic
  - Apply load in four equal increments and measure response
  - Hold load for 24 hours
  - Measure response and unload load
  - Measure final response
- Acceptance criteria
  - Evidence of failure
  - Maximum and residual deflections

Load Test Procedures

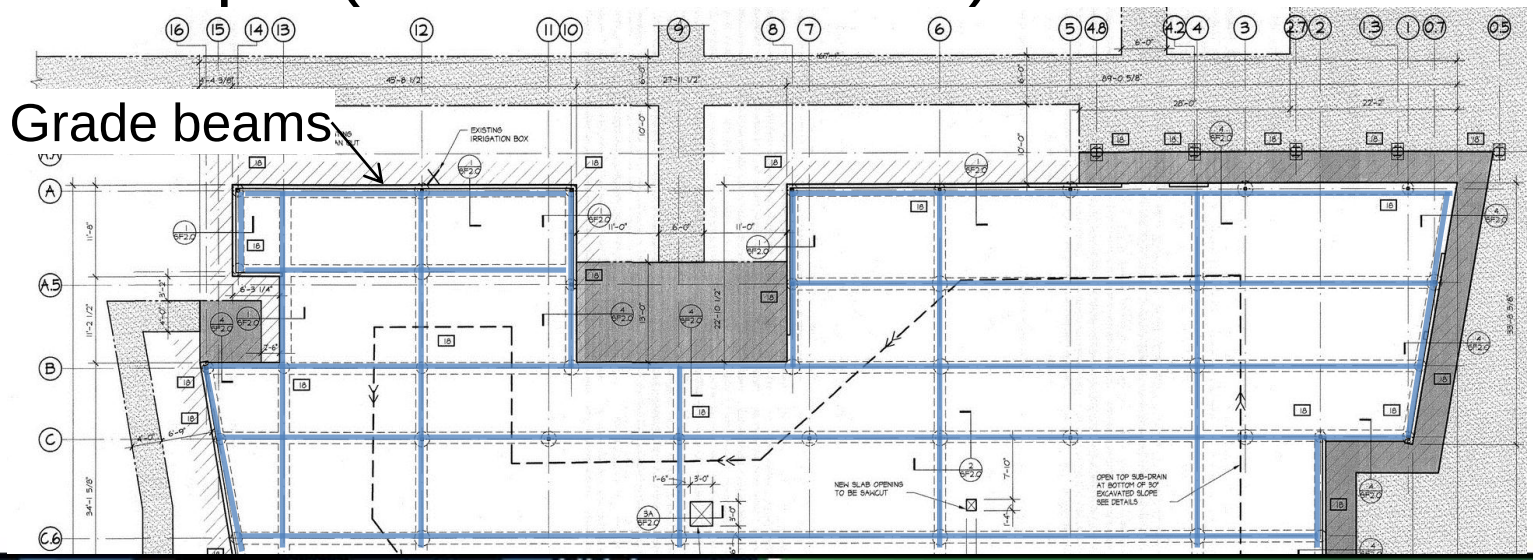
- Cyclic



- Acceptance criteria
  - Evidence of failure
  - Deviation from linearity and permanency ratio

Monotonic Load Test

- Performed phased approach
- Test Load Magnitude (TLM)
  - $TLM = 1.0 \times D_W + 1.1 \times D_S + 1.6 \times L$
  - Superimposed load (ATL)
    - 166 psf (32 inches of water)



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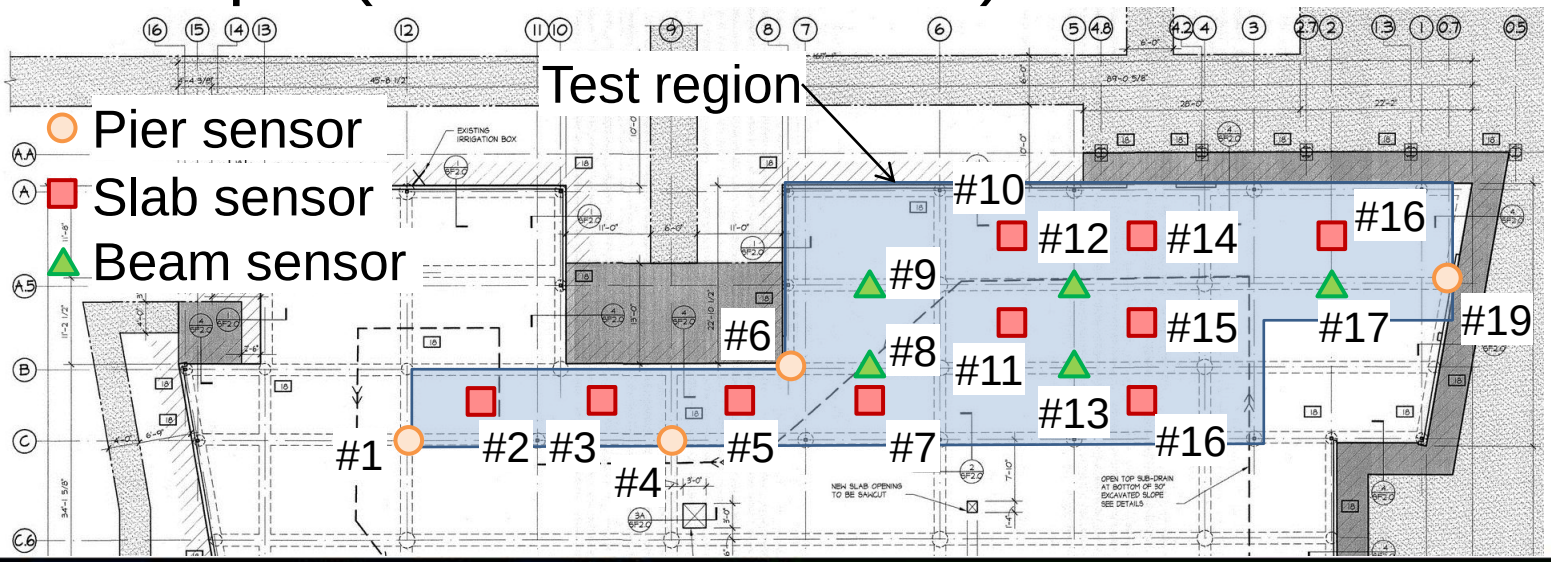
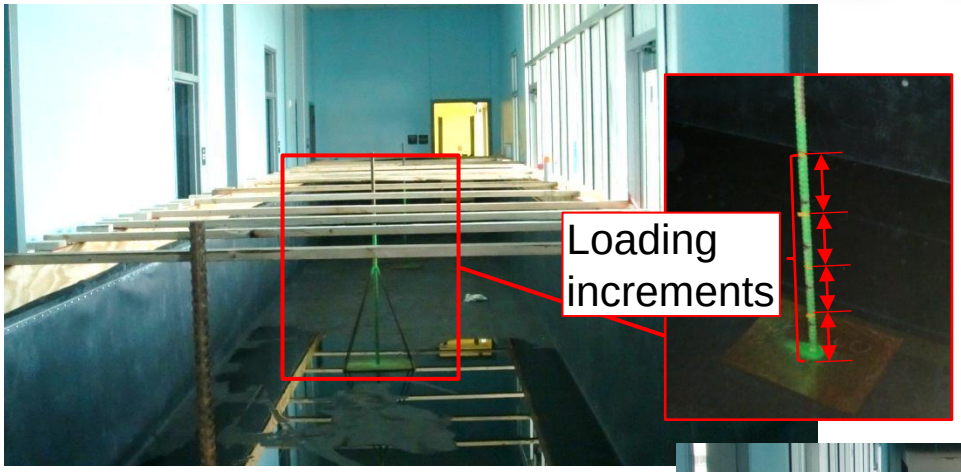
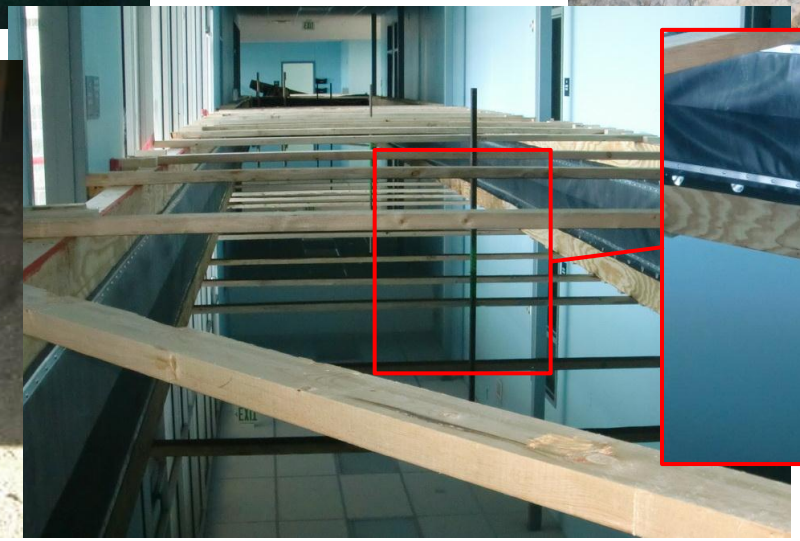
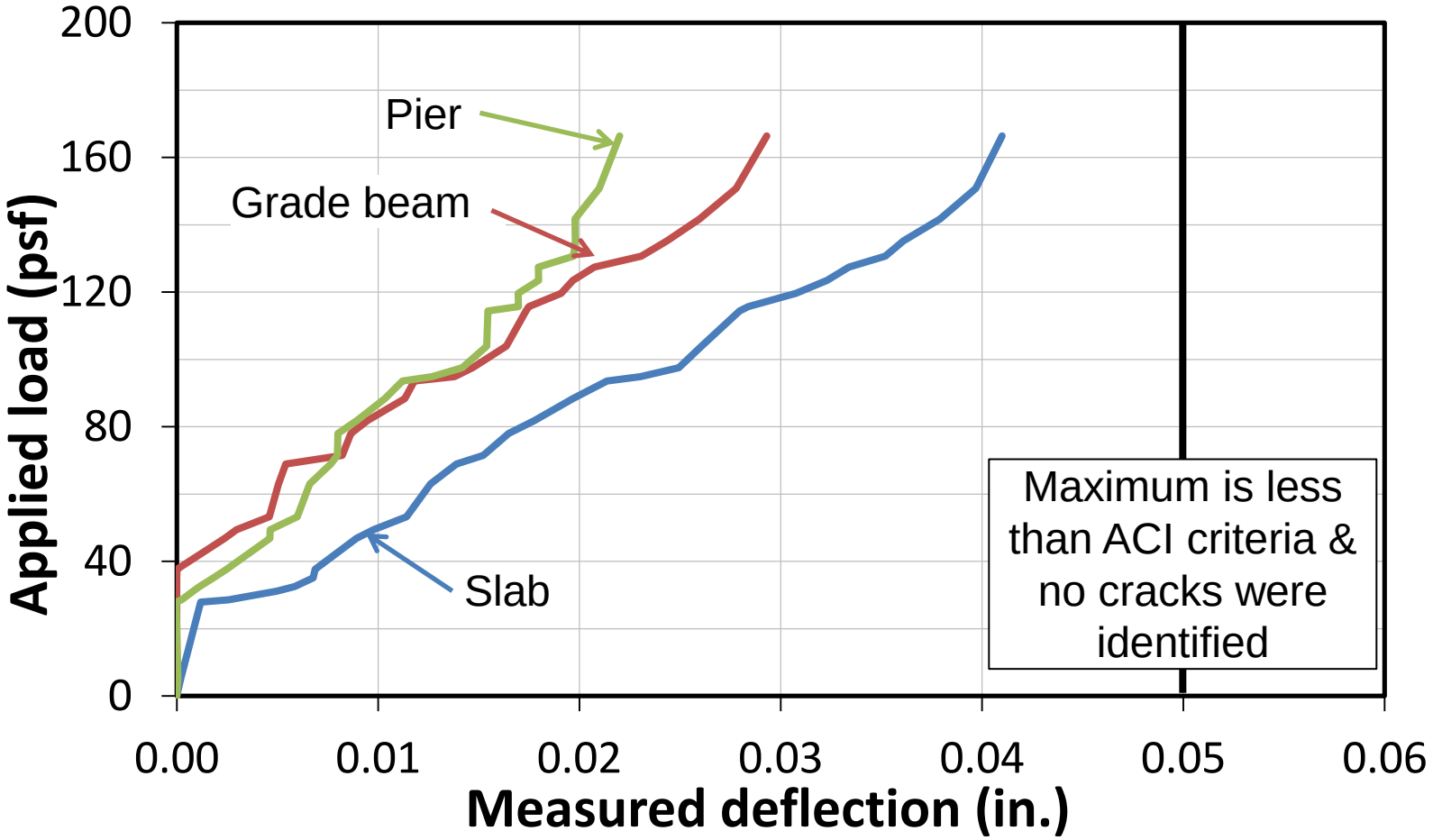


Load Test

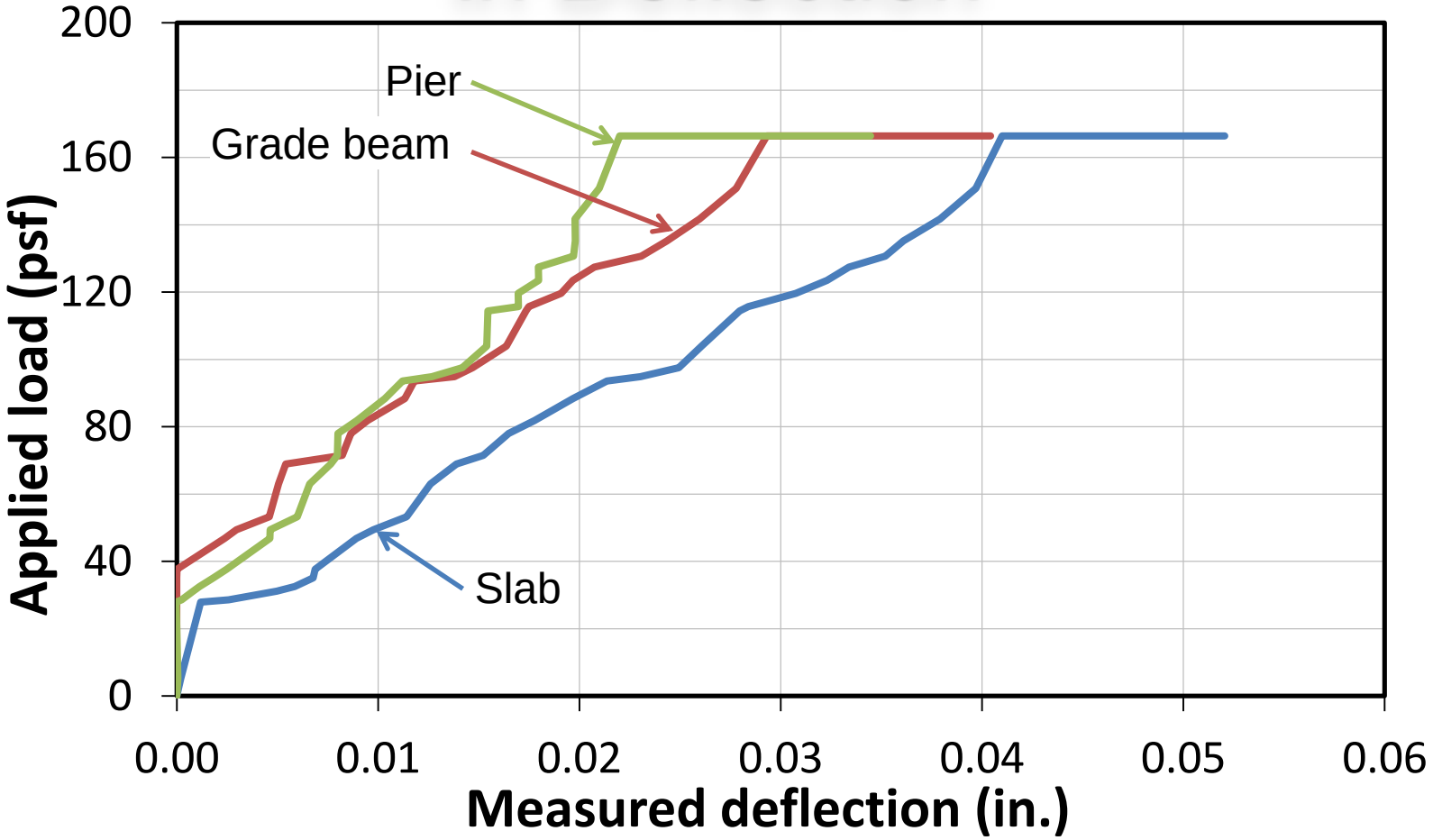




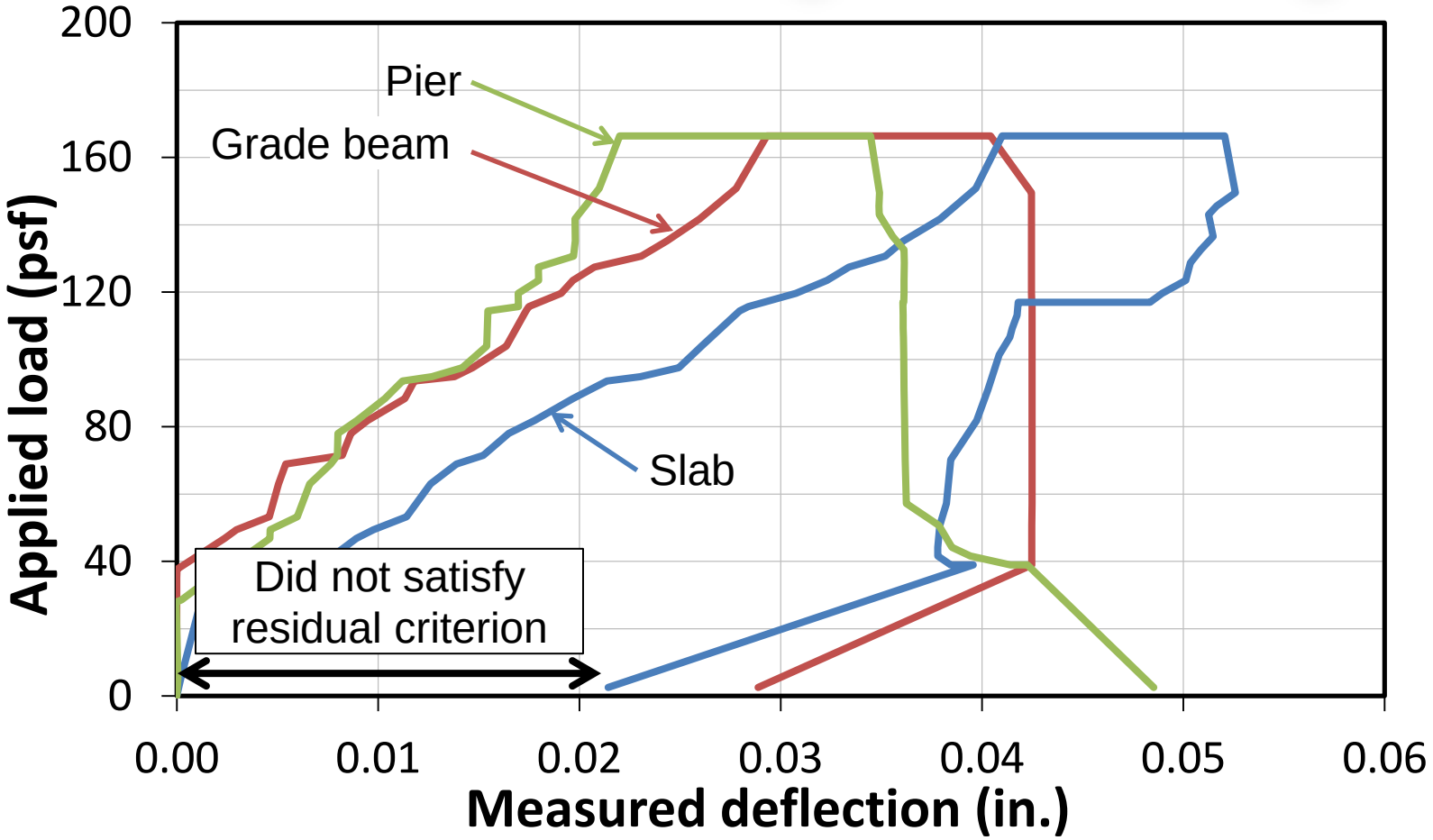
Behavior During Loading - Linear



Behavior After 24 Hour – Increase in Deflection



Behavior During Unloading



Key Concepts

- Monotonic testing is essentially a proof test
  - Slower to perform (24-hr hold)
  - Generally easy to apply uniform load (water, sand, etc.)
  - Criteria is based on deflections
- Cyclic testing is more of a performance standard
  - Faster to perform with hydraulics (no 24-hr hold)
  - Can be difficult to perform (hydraulics need to react against something)
  - Criteria is based on stiffness

Thank you

For the most up-to-date information, please visit the American Concrete Institute at

www.concrete.org