Evaluation of Existing Structures Using ACI 562

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Historic Structure

Air Force Base – Academic Center

Academic Building

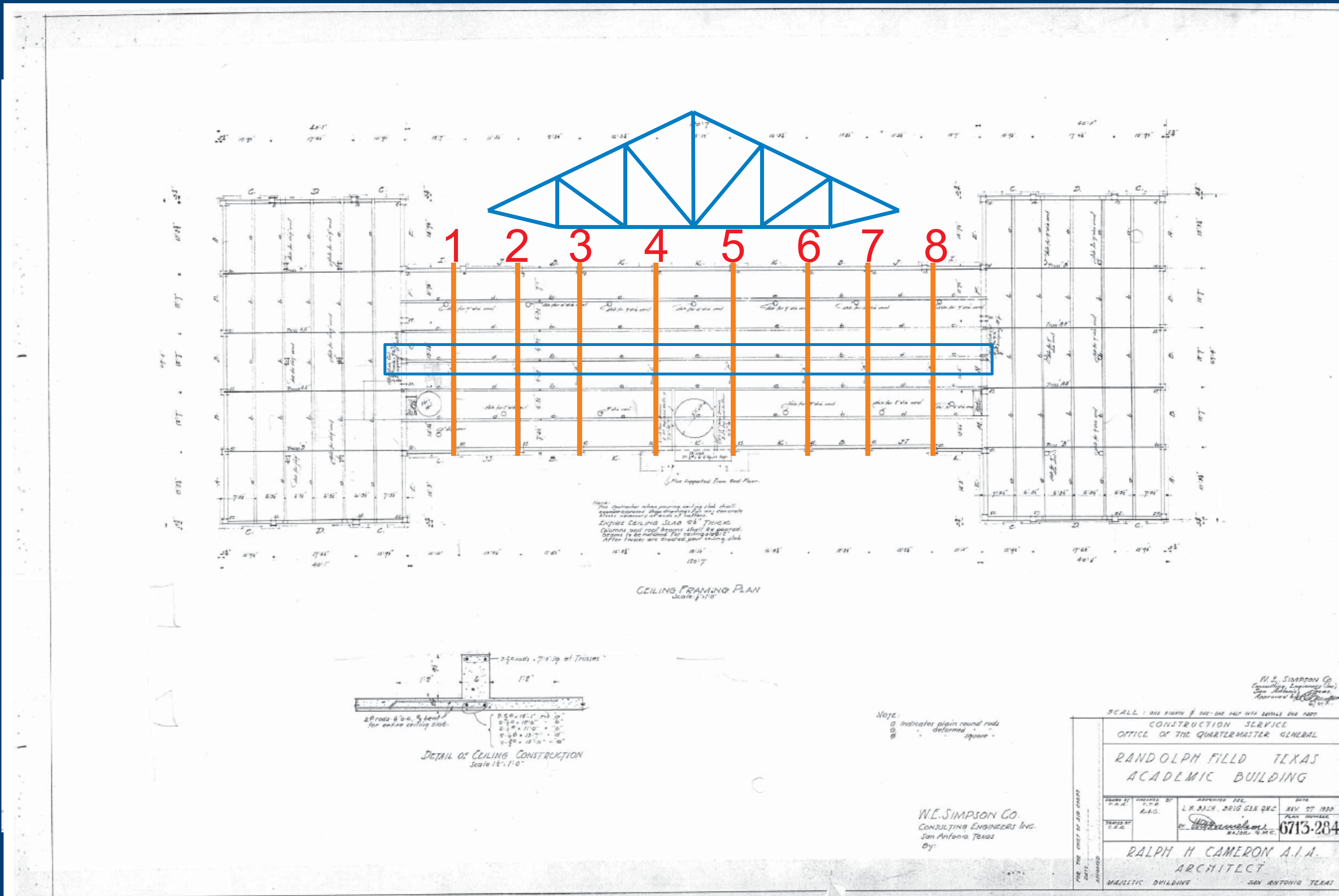
- Built in the 1930s
- New HVAC system

October 2011

Requirements for Structural Evaluation

- 6.1.1 - A structural evaluation shall comprise a structural assessment, structural analysis, or both.

- 6.1.2 – “A structural evaluation shall be performed if, during the preliminary evaluation, as described in Section 4.3, it is determined that an existing member, portions of a structure, or entire structure exhibit signs of deterioration, structural deficiency, …..”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CEILING FRAMING PLAN
DETAIL OF CEILING CONSTRUCTION
CONSTRUCTION SERVICE
OFFICE OF THE QUARTERMASTER GENERAL
RANDOLPH FIELD TEXAS
ACADEMIC BUILDING
6713-284
RALPH H. CAMERON A.I.A.
ARCHITECT
W.E. SIMPSON CO.
CONSULTING ENGINEERS INC.
San Antonio Texas

Visual Assessment

- **6.1.3** A structural evaluation shall be performed when there is a reason to question the design strength of the member or structure and insufficient information is available to determine if a member, portion, or all of the existing structure is <u>capable of supporting existing or new design loads.</u>

Structural Evaluation – Analysis

- 6.2.3 - If an analysis is required, the structural assessment shall document the requirements of 6.2.2 and (a) through (c).

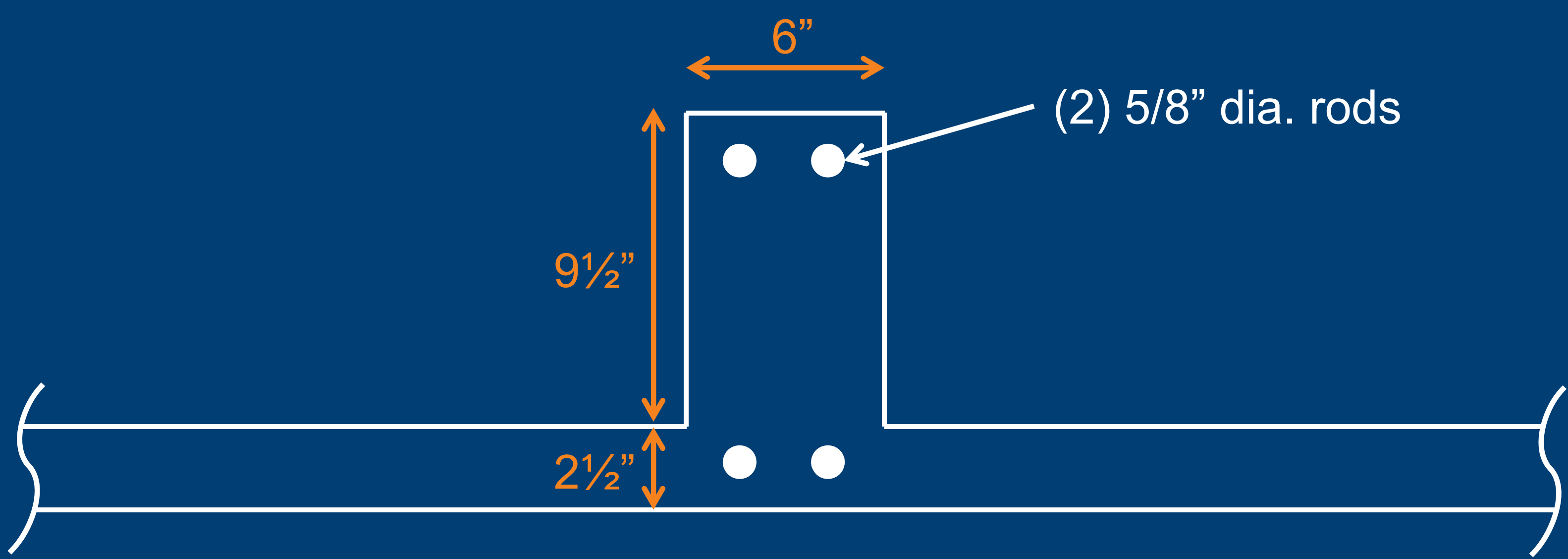
  (a) As-measured structural member section properties and dimensions.

  (b) The presence and effect of any alterations to the structural system.

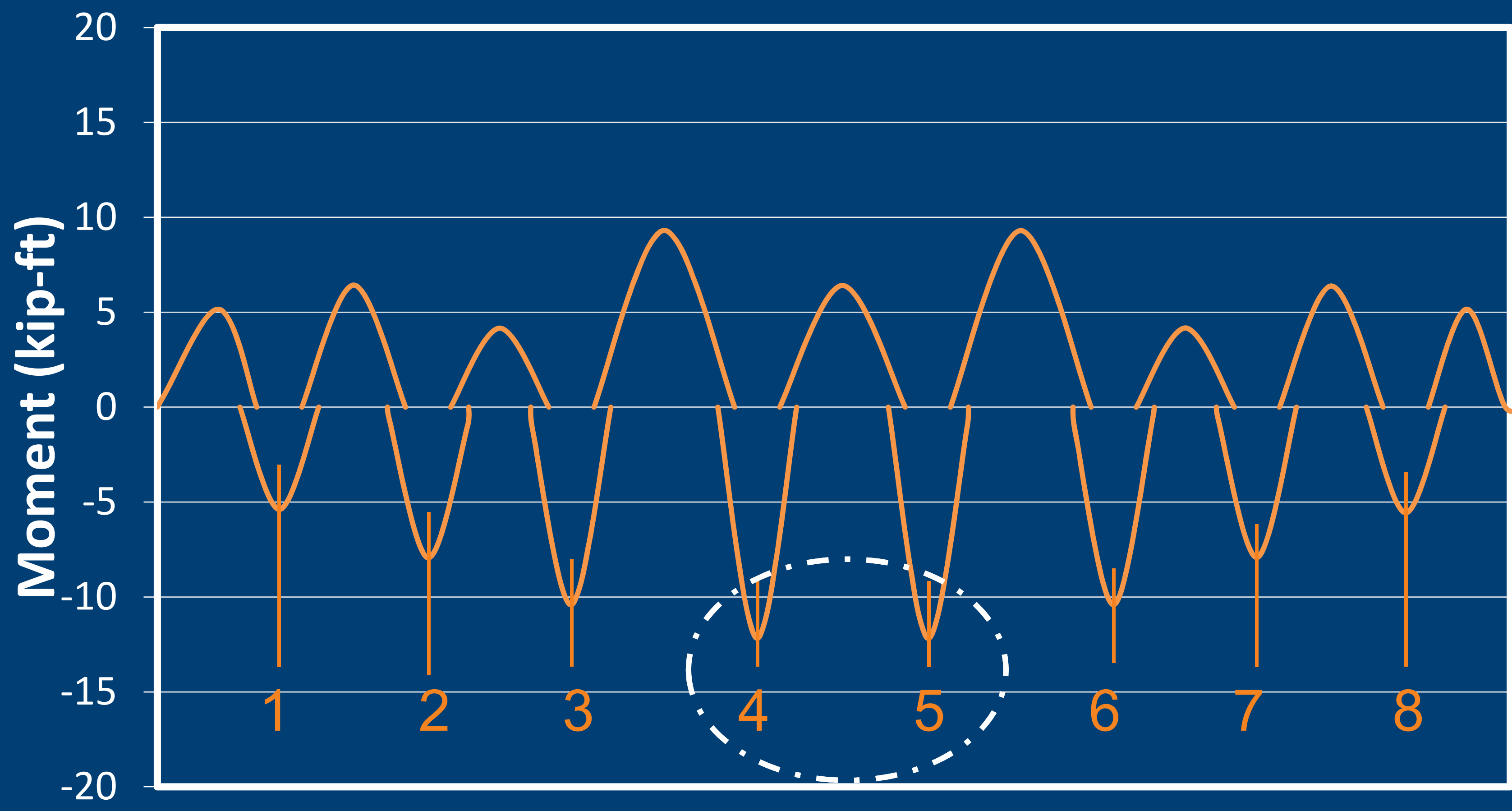
  (c) Loads, occupancy, or usage different from the original design.

Cross Section

- Inverted tee



Structural Analysis – Original Loading



Chapter 6 – Default Strength

- Material properties

  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

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

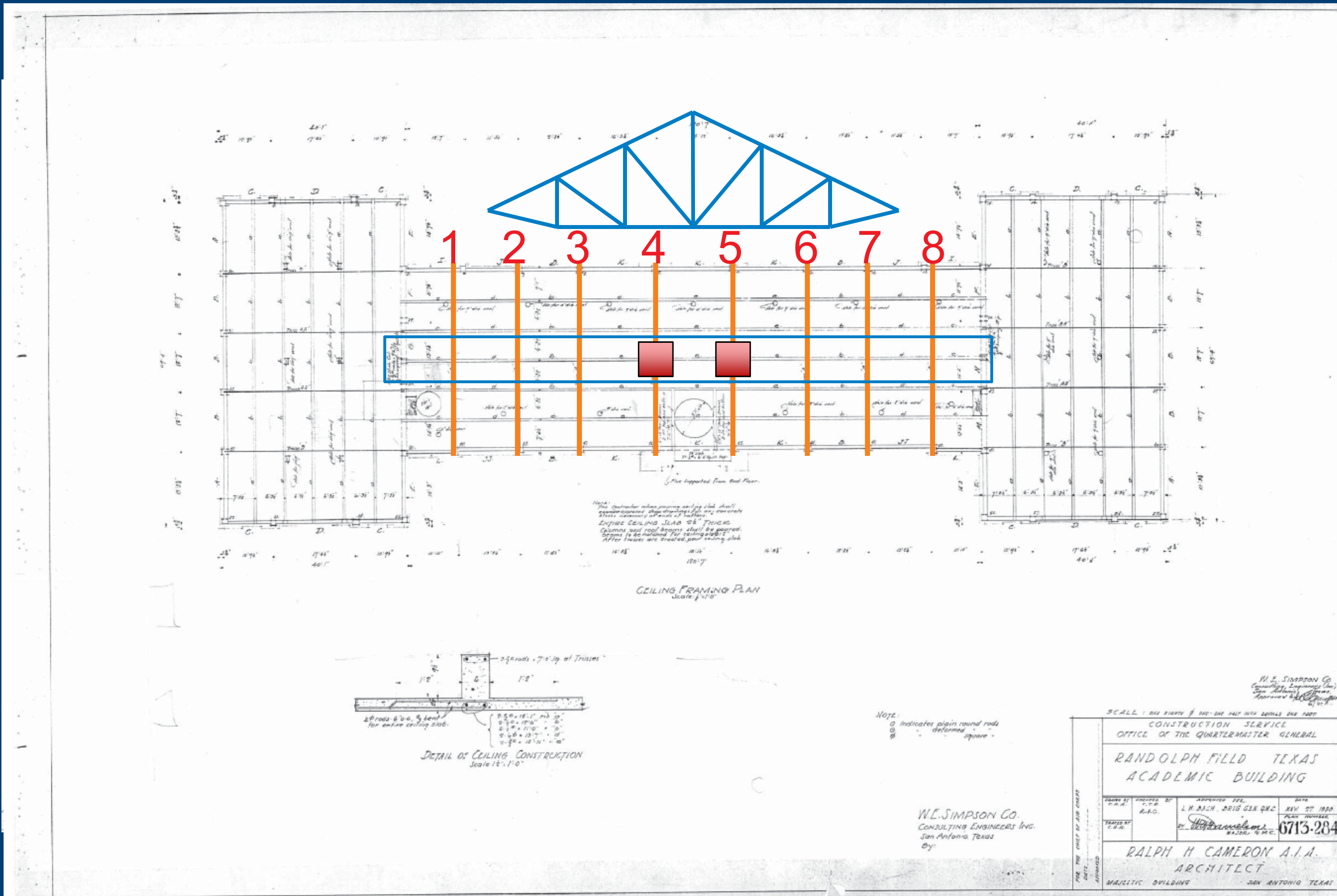
  Demand: -13 kip-ft

  Φ: 0.9 (evaluation)

  Capacity: -16.0 kip-ft

  D/C: 0.81

Beam okay



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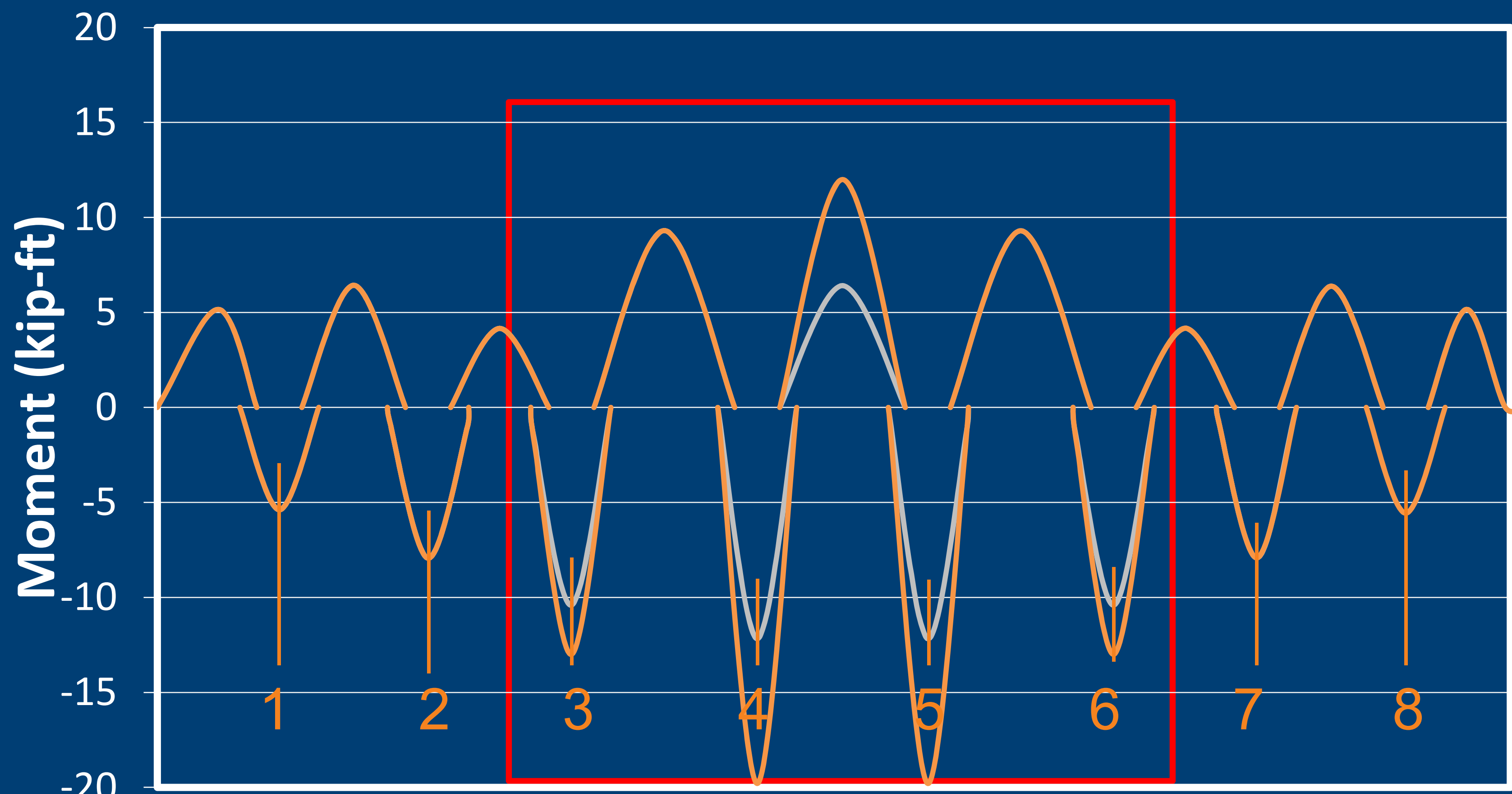
Structural Analysis – Revised Loading



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)

- Concrete cores

$$n = 8$$

$$\bar{f}_c = 6{,}200 \text{ psi}, V = 0.15$$

- § 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

$$n = 4$$
$$\bar{f}_y = 40{,}000 \text{ psi}, V = 0.05$$

- § 6.4.6-equivalent specified yield strength (reinf.)

$$f_{yeq} = (\bar{f}_y - 3500)e^{-1.3k_s V}$$
$$f_{yeq} = 33{,}217 \text{ psi}$$

- 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)

  Capacity: -18.1 kip-ft

  D/C: 1.09

Strengthen beam

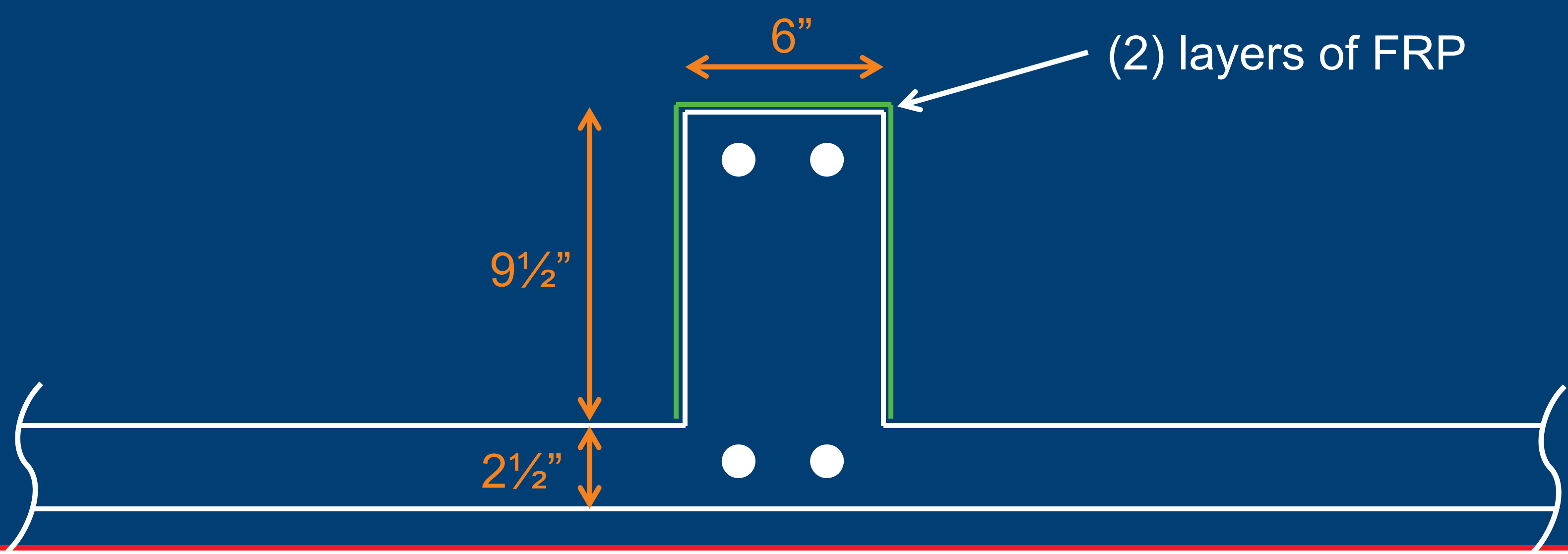
Repair

- Flexural strength

  Concrete: 5,100 psi

  Steel: 33 ksi

  Demand: -19.8 kip-ft



Repair

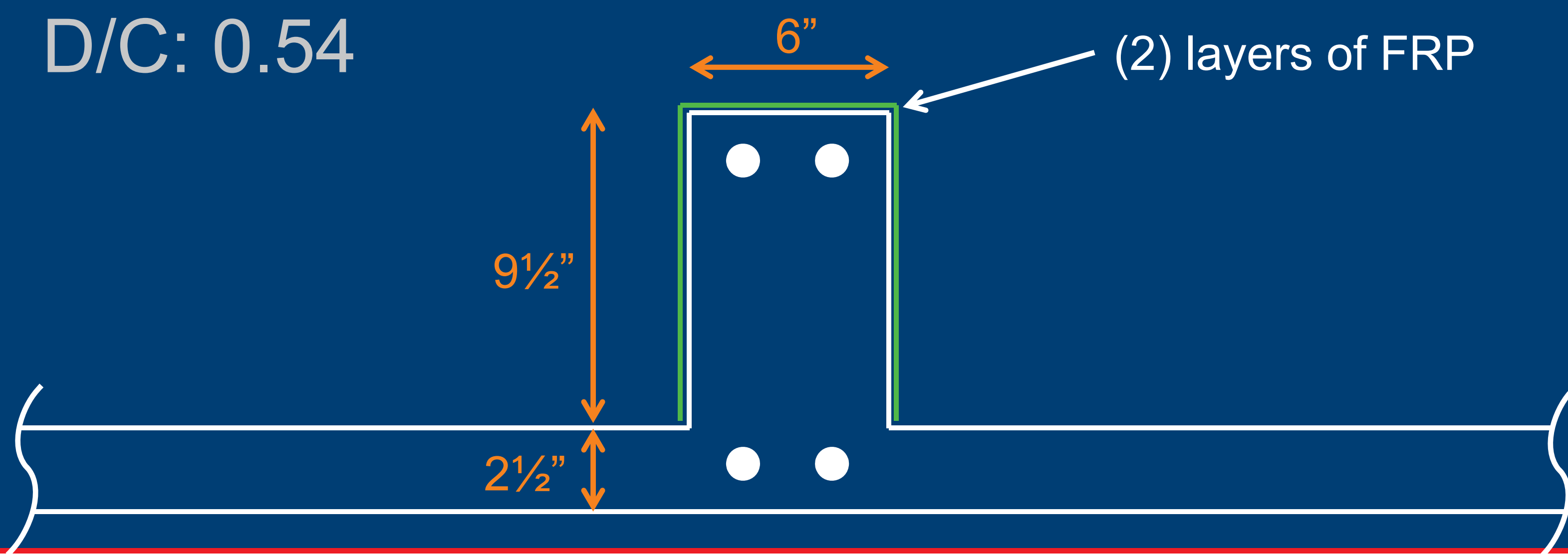
- Flexural strength

  Φ: 0.9 (design)

  Demand: -19.8 kip-ft

  Capacity: -37 kip-ft

  D/C: 0.54



External Reinforcing Systems

- **5.5.1** For repairs achieved with unprotected external reinforcing systems, the required strength *U* of a structure without repair shall be at least equal to the effects of factored loads in Eq. (5.5.1).

$$U_{ex} \;{}^{3}\; 1.2D + 0.5L + A_k + 0.2S \qquad (5.5.1)$$

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.)

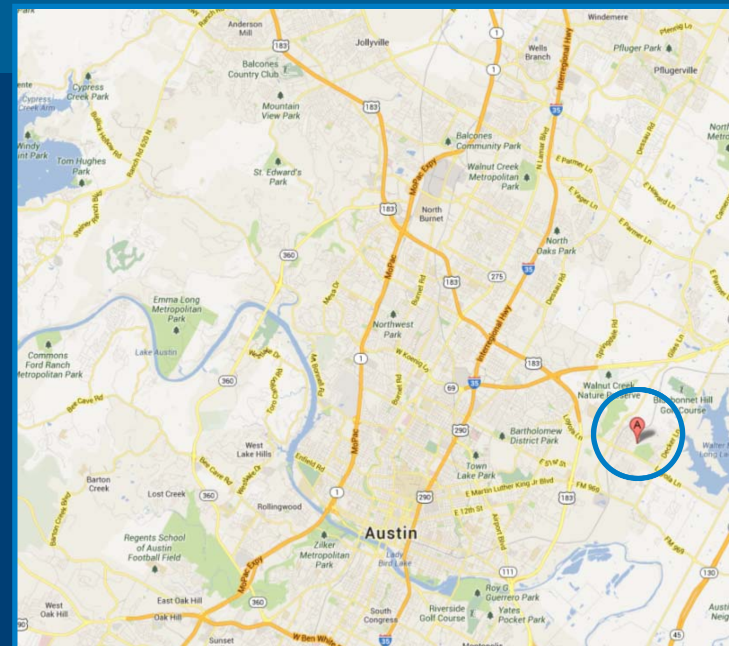
  Use standard ϕ-factors (because material properties will be unknown with repair work)

New Structure

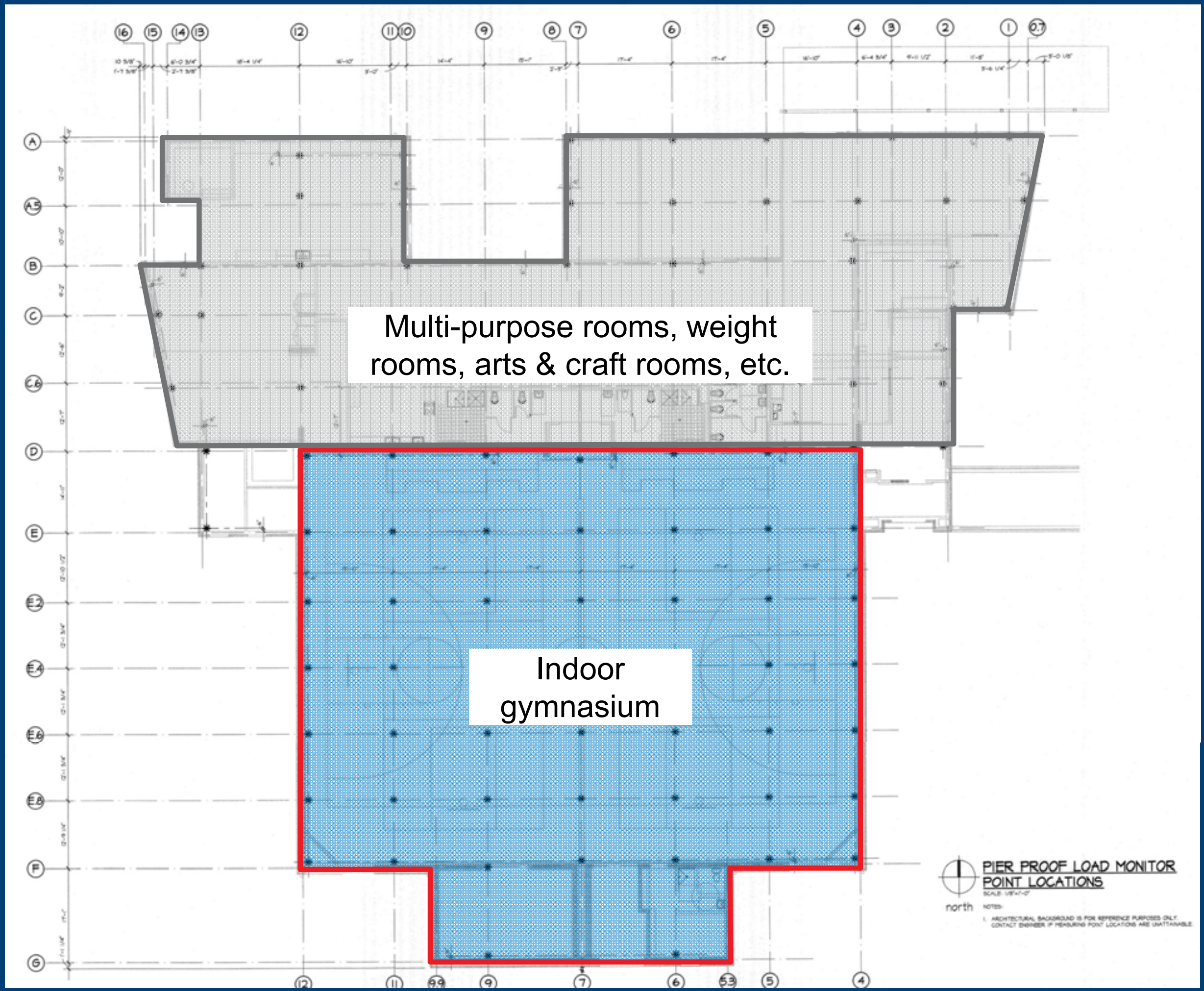
Turner-Roberts Recreation Center

Project Background

- Construction in 2008
- 7,700 sf joint-use facility
- Reinforced-concrete beams, drilled piers, and steel joist roof
- Indoor gymnasium, multi-purpose rooms, weight room, and other rooms



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

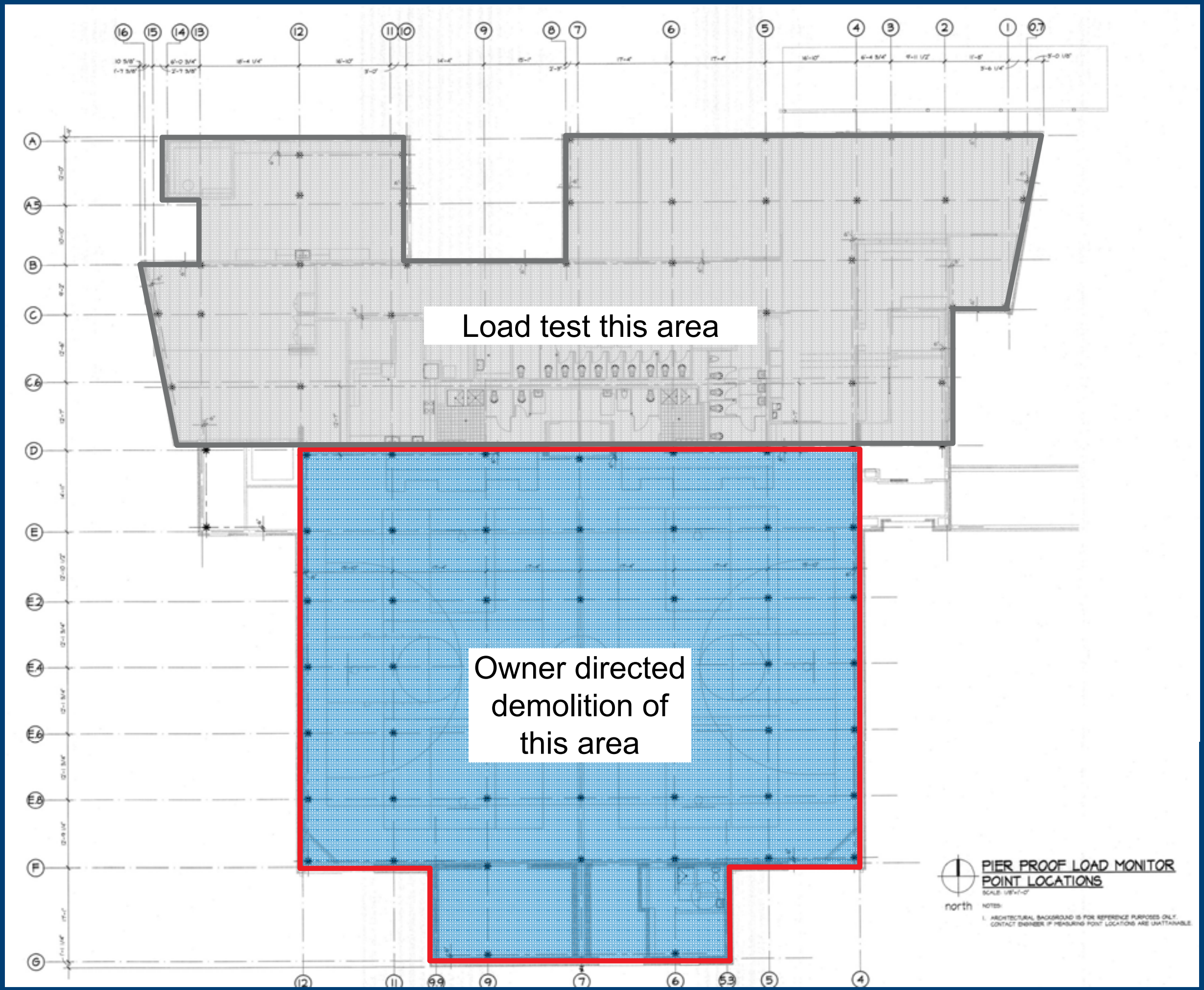
Evaluate structure

Evaluation Approaches for Existing Structures

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

ACI 437

Demolition of Structure

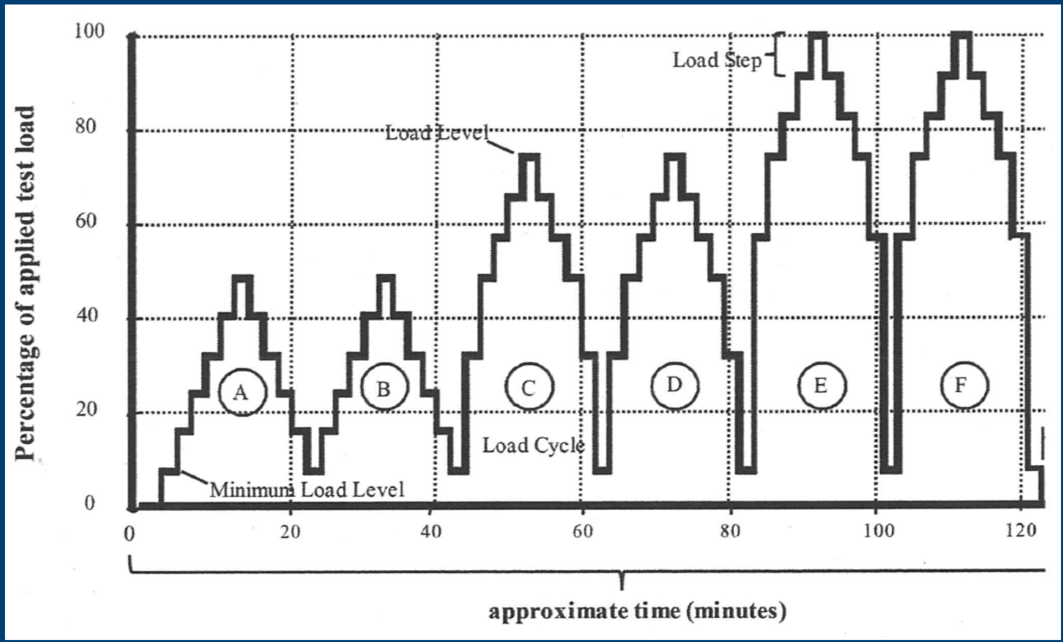


562 Load Test Procedures – Two Types

- 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

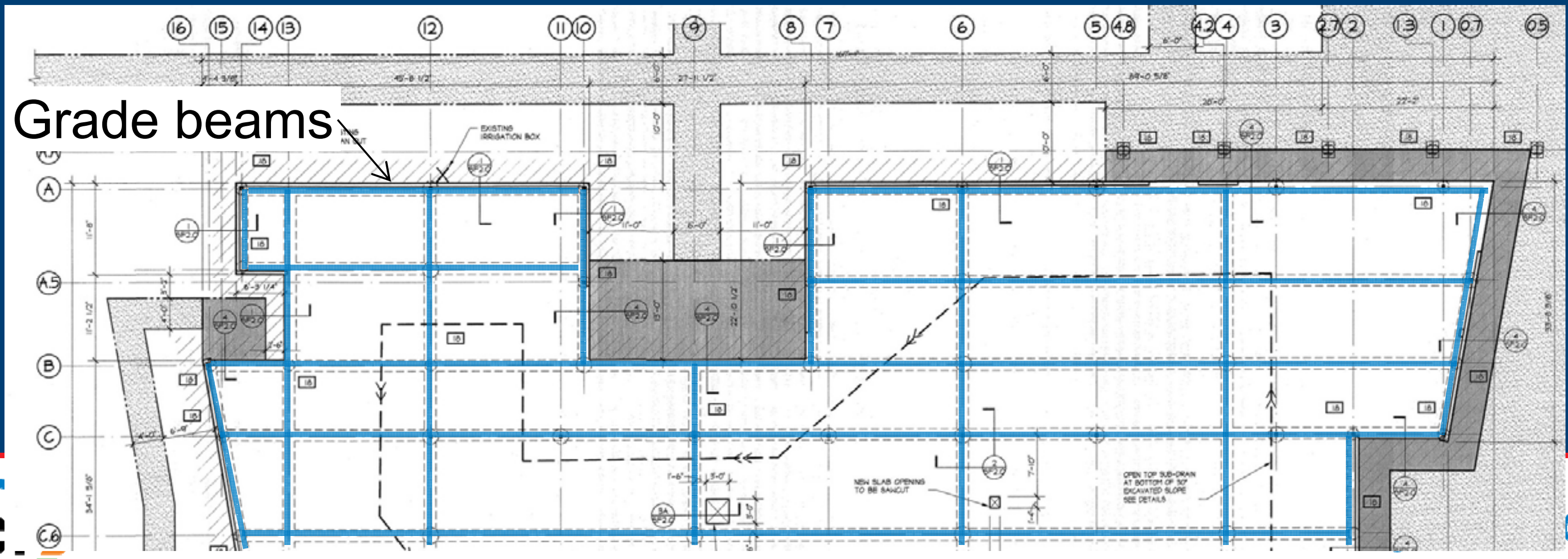
Monotonic Load Test

- 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)



Monotonic Load Test

- Performed phased approach
- Test Load Magnitude (TLM)

  $TLM = 1.0 \times D_W + 1.1 \times D_S + 1.6 \times L$
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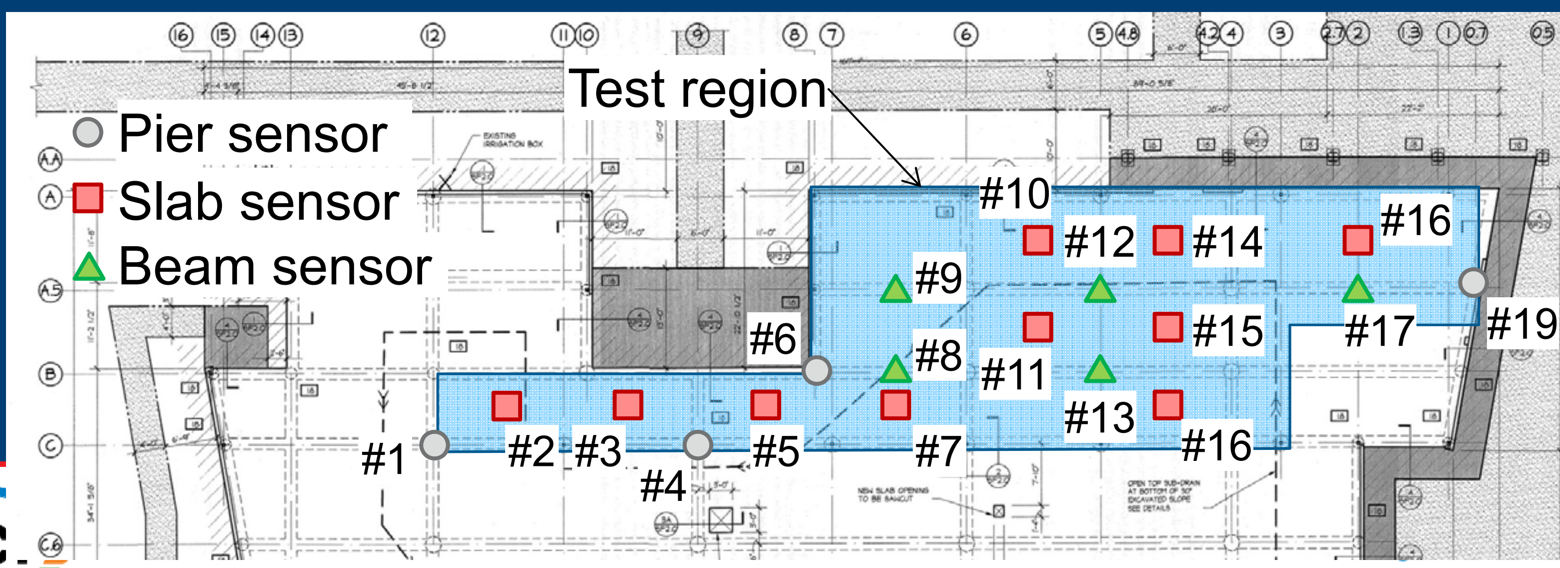
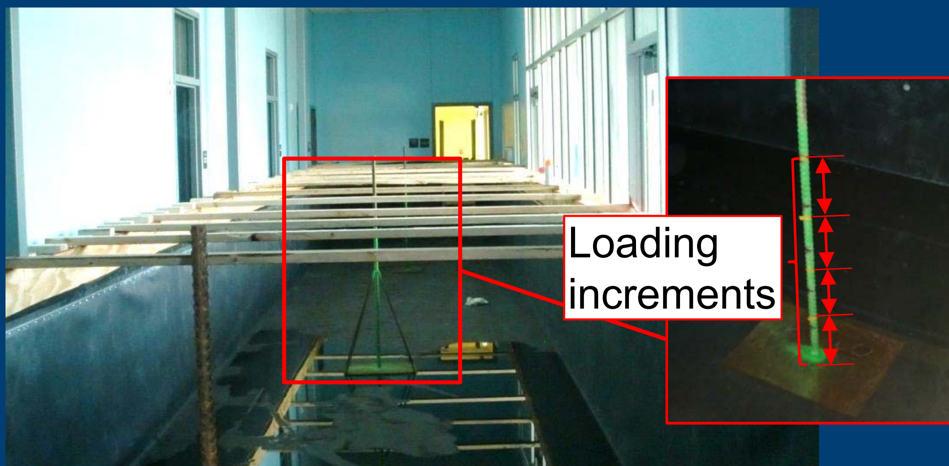
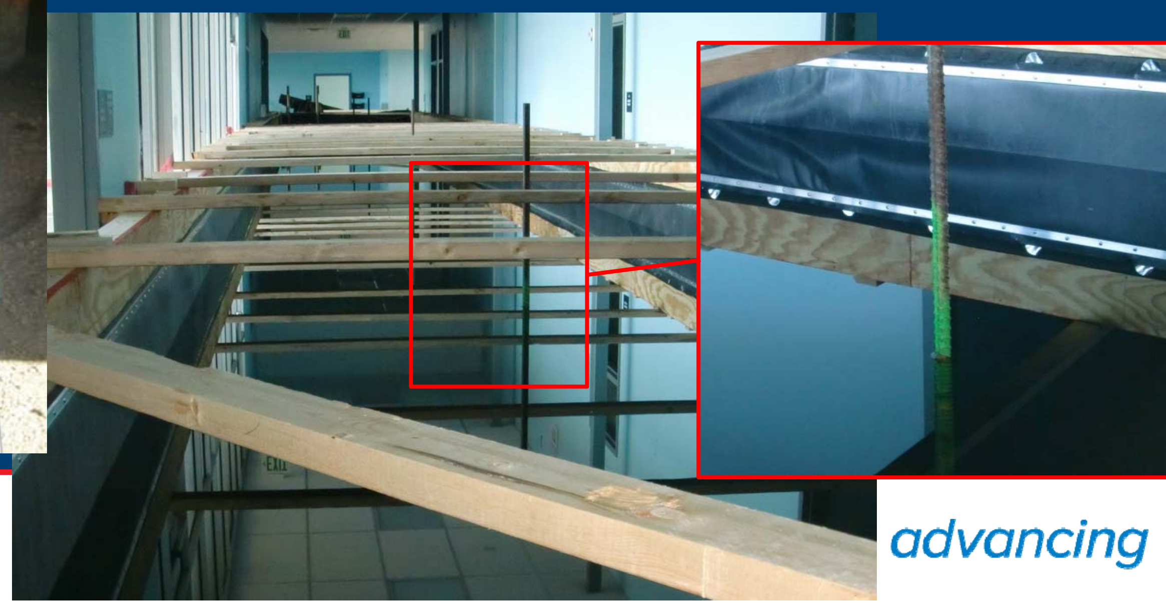
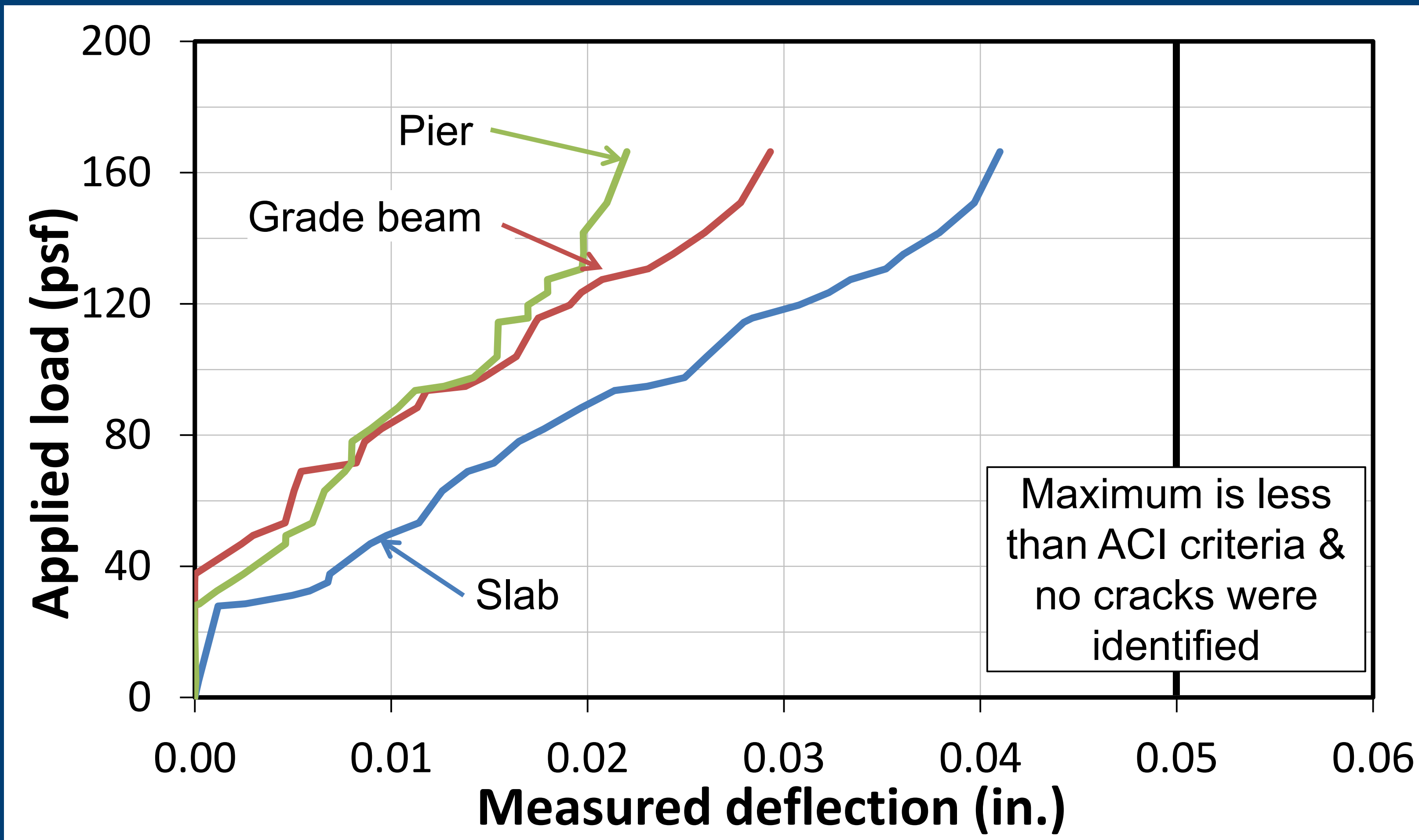


Load Test

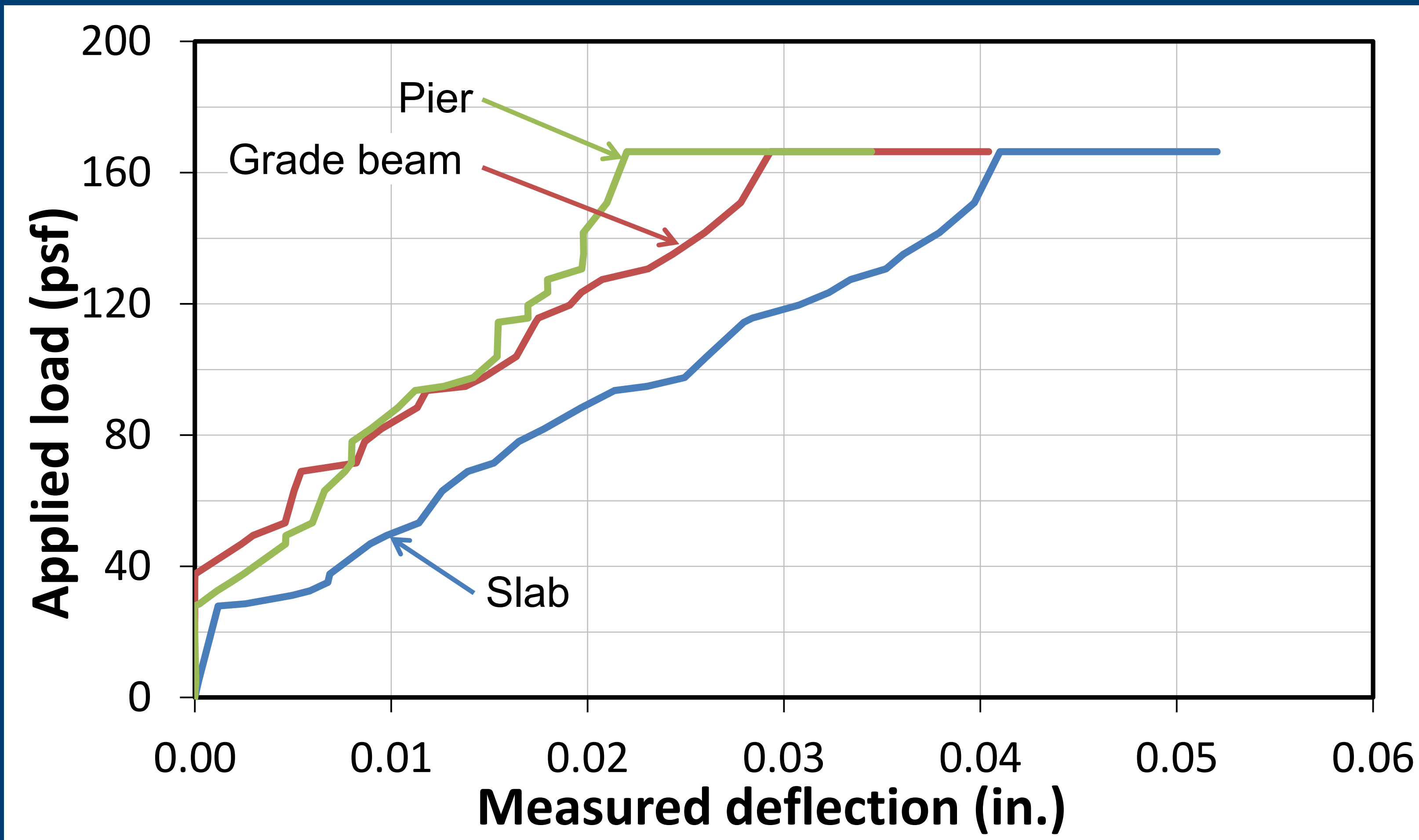




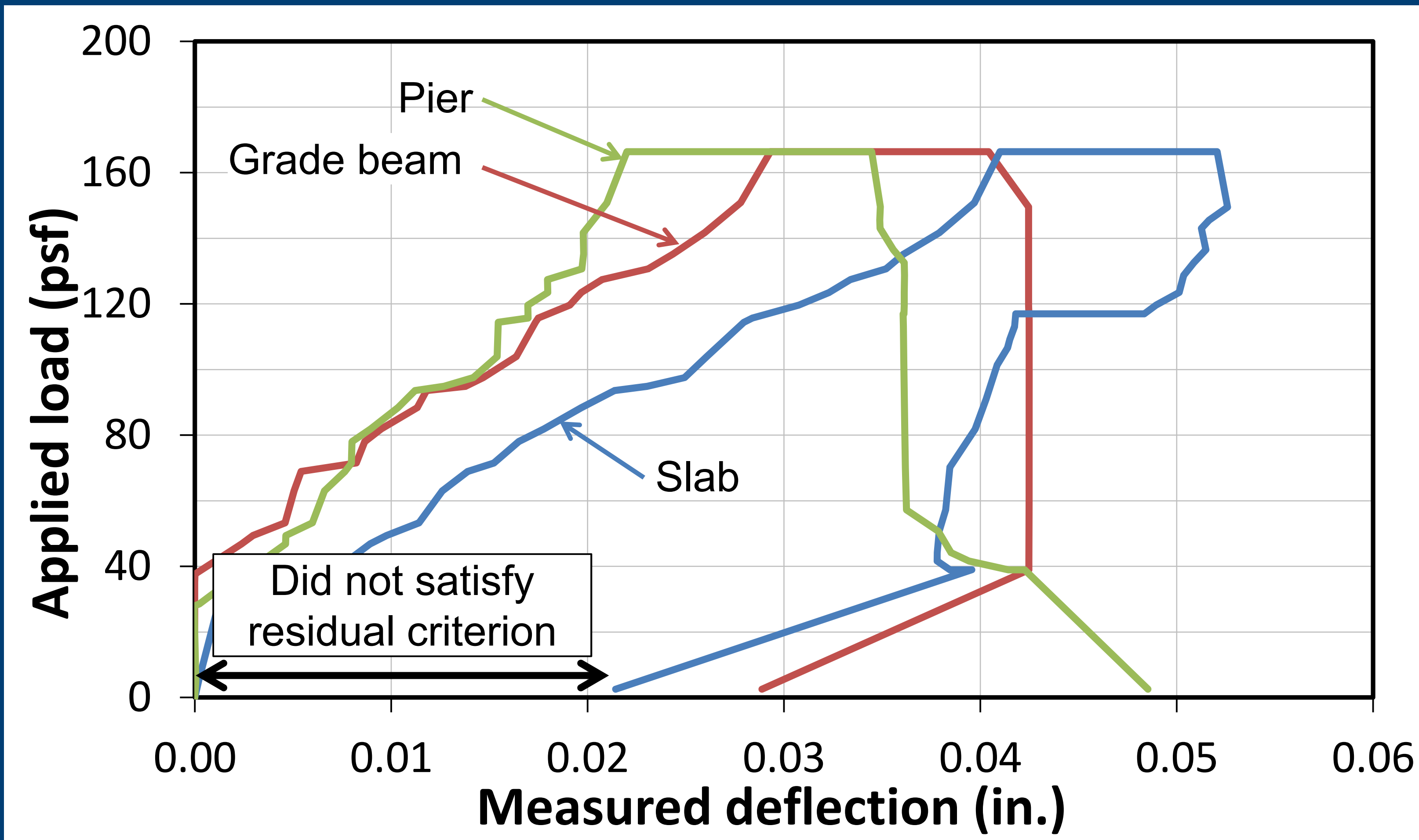
Behavior During Loading - Linear



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 perform (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