



cvm



PIVOT



Load Testing – Changes in ACI 318-19

Integration and Coordination between Committees

by

Keith Kesner - Senior Project Manager, CVM Engineers

Aaron Larosche – Senior Engineer, Pivot Engineers

Paul Ziehl – Professor, University of South Carolina



Overview

- ACI 318-14 – Load Testing Requirements
- History of ACI Load Testing Requirements
- ACI 318-19 – Load Testing Requirements
 - What are the changes?
 - How did it happen?
- Where can we go?

ACI 318-14 – Load Testing

- Load – max. of three options
 - $1.15D + 1.5L + 0.4(L_r \text{ or } S \text{ or } R)$
 - $1.15D + 0.9L + 1.5(L_r \text{ or } S \text{ or } R)$
 - $1.3D$
- Load procedure
 - Monotonic – load applied in 4 increments
 - 24 hour hold for peak load
 - Measure peak deflection (Δ_{max}) at 24 hours
 - Measure residual deflection (Δ_r) after 24 hours
- Acceptance criteria
 - Do not break the structure
 - Max. deflection $\Delta_{max} \leq l^2 / 20,000 h$, or
 - Deflection recovery $\Delta_r \leq \Delta_{max} / 4$

An ACI Standard and Report

Building Code Requirements
for Structural Concrete
(ACI 318-14)

Commentary on
Building Code Requirements
for Structural Concrete
(ACI 318R-14)

Reported by ACI Committee 318

ACI 318-14

ACI Load Test History

- 1963 Acceptance Criteria

- Do not break the structure
- Max. deflection $\Delta_{max} \leq l^2/20,000 h$, or
- Deflection recovery $\Delta_r \leq \Delta_{max}/4$

- 1963 – 2014

- 51 years and 12 code cycles
- Minor changes in wording
- Minor changes in load intensity (approximately 85% of design load)
- Some discussion of shear added

202—Criteria for evaluation of load tests

(a) If the structure shows evident failure or fails to meet the following criteria, the changes needed to make the structure adequate for the rated capacity shall be made or a lower rating may be established.

1. If the maximum deflection, Δ , of a reinforced concrete beam, floor or roof exceeds $l^2/20,000t$, the recovery of deflection within 24 hr after the removal of the test load shall be at least 75 percent of the maximum deflection.

2. If the maximum deflection, Δ , is less than $l^2/20,000t$, the requirement on recovery of deflection in 1 may be waived.

3. In determining the limiting deflection for a cantilever, l shall be taken as twice the distance from the support to the end, and the deflection shall be adjusted for movement of the support.

4. Construction failing to show 75 percent recovery of the deflection may be retested. The second test loading shall not be made until at least 72 hr after removal of the test load for the first test. The structure shall show no evidence of failure in the retest, and the recovery of deflection caused by the second test load shall be at least 75 percent.

ACI Load Testing History

- Part of every ACI Code
 - 1936 (ACI 501-36T)
 - 1941 (first ACI 318)
- Acceptance criteria
 - Do not break the structure
 - Max. deflection = $\Delta_{max} \leq l^2 / 12,000 h$, Or
 - Deflection recovery = $\Delta_r \leq \Delta_{max} / 4$
- Deflection limit derivation
 - $\Delta = \frac{5wl^4}{384EI}$ $M = \frac{wl^2}{8}$ $\sigma = M/S$ $S = bh^2/6$
 - $E = 1,000f'_c$ $\sigma_c = 0.4f'_c$

202—Load Tests

(a) When a load test is required, the member or portion of the structure under consideration shall be subject to a superimposed load equal to one and one-half times the live load plus one-half of the dead load. This load shall be left in position for a period of twenty-four hours before removal. If, during the test, or upon removal of the load, the member or portion of the structure shows evident failure, such changes or modifications as are necessary to make the structure adequate for the rated capacity shall be made; or, where lawful, a lower rating shall be established. The structure shall be considered to have passed the test if the maximum deflection at the end of the twenty-four hour period does not exceed the value of D as given by the following:

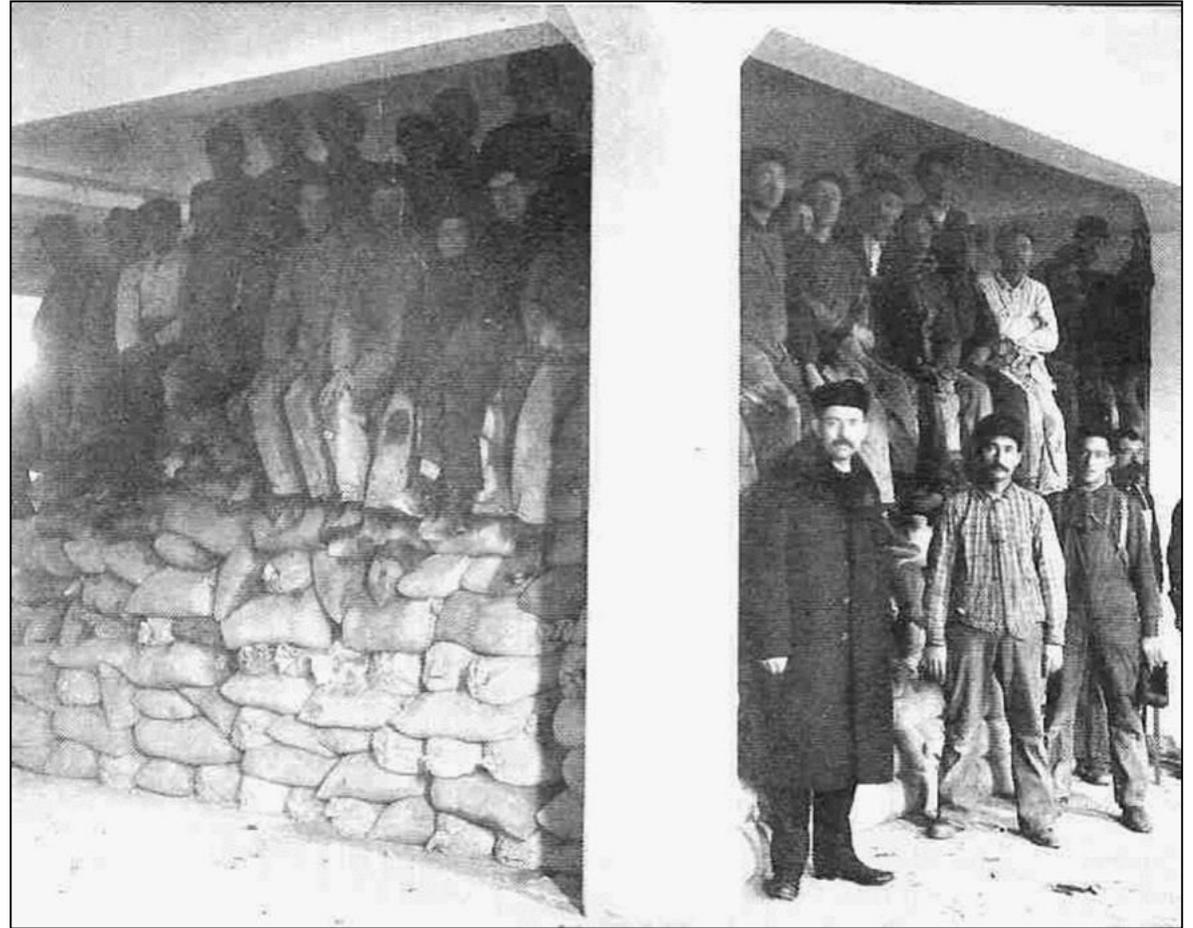
$$D = \frac{.001 L^3}{12t} \text{ in which } \dots \dots \dots (1)$$

L is the span, t is the total depth of the slab or beam and D is the maximum deflection—all expressed in the same units.

If the deflection exceeds the value of D as given in formula (1), the construction shall be considered to have passed the test if within twenty-four hours after the removal of the load the slabs or beams show a recovery of at least seventy-five per cent of the observed deflection.

Monotonic Test – ACI 318-14

- Nearly 100 years old
- Considers
 - Primarily flexural behavior
 - Essentially quasi-elastic behavior
 - Sustained load (24 period)
- Does not consider
 - Response of structure to load
 - Unloading behavior
 - Support conditions
 - Shear failure



Photograph courtesy of Chuck Larosche - WJE

ACI 437 – Strength Evaluation

- History of committee
 - ACI Committee 437 was formed in 1958 (was 337 prior).
 - Documents include Reports (437R-19 and 437.1-07) and a Code (437.2-13)
- Development of ACI 437.2-13
 - ACI 437.2-13 was an outcome of ACI 437.1-07 ‘Load Tests of Concrete Structures: Methods, Magnitudes, Protocols, and Acceptance Criteria’, which summarized load testing history and discussed cyclic load testing and associated acceptance criteria.
 - ACI 437.2-13 was developed to more formally introduce the cyclic method and to revisit some considerations related to the monotonic method.

ACI 437.2-13 – Standard for Load Testing of Existing Structures

- Test Procedures
 - Monotonic – old school
 - Cyclic – new school
- Test load magnitude
 - Full live load
 - More rational dead load
 - $1.0D_w + 1.1D_s + 1.6L + 0.5(L_r \text{ or } S \text{ or } R)$
 - $1.0D_w + 1.1D_s + 1.0L + 1.6(L_r \text{ or } S \text{ or } R)$
 - $1.3(D_w + D_s)$
- Acceptance criteria
 - Includes $l/180$ deflection limit
- Developed for use with ACI 562-13

ACI 437.2-13

Code Requirements for Load Testing
of Existing Concrete Structures
(ACI 437.2-13) and Commentary

An ACI Standard

Reported by ACI Committee 437



American Concrete Institute®

ACI 437.2-13 – Standard for Load Testing of Existing Structures

- Acceptance criteria - monotonic
 - Do not break the structure
 - Deflection recovery = $\Delta_r \leq \Delta_{max} / 4$
 - Max. deflection = $\Delta_{max} \leq l / 2,000$, or 0.05”
 - Deflection limit – $l / 180$
- Acceptance criteria - cyclic
 - Function of response of structure
 - Deviation from linear elastic behavior
- Adopted into ACI 562-13

ACI 437.2-13

**Code Requirements for Load Testing
of Existing Concrete Structures
(ACI 437.2-13) and Commentary**

An ACI Standard

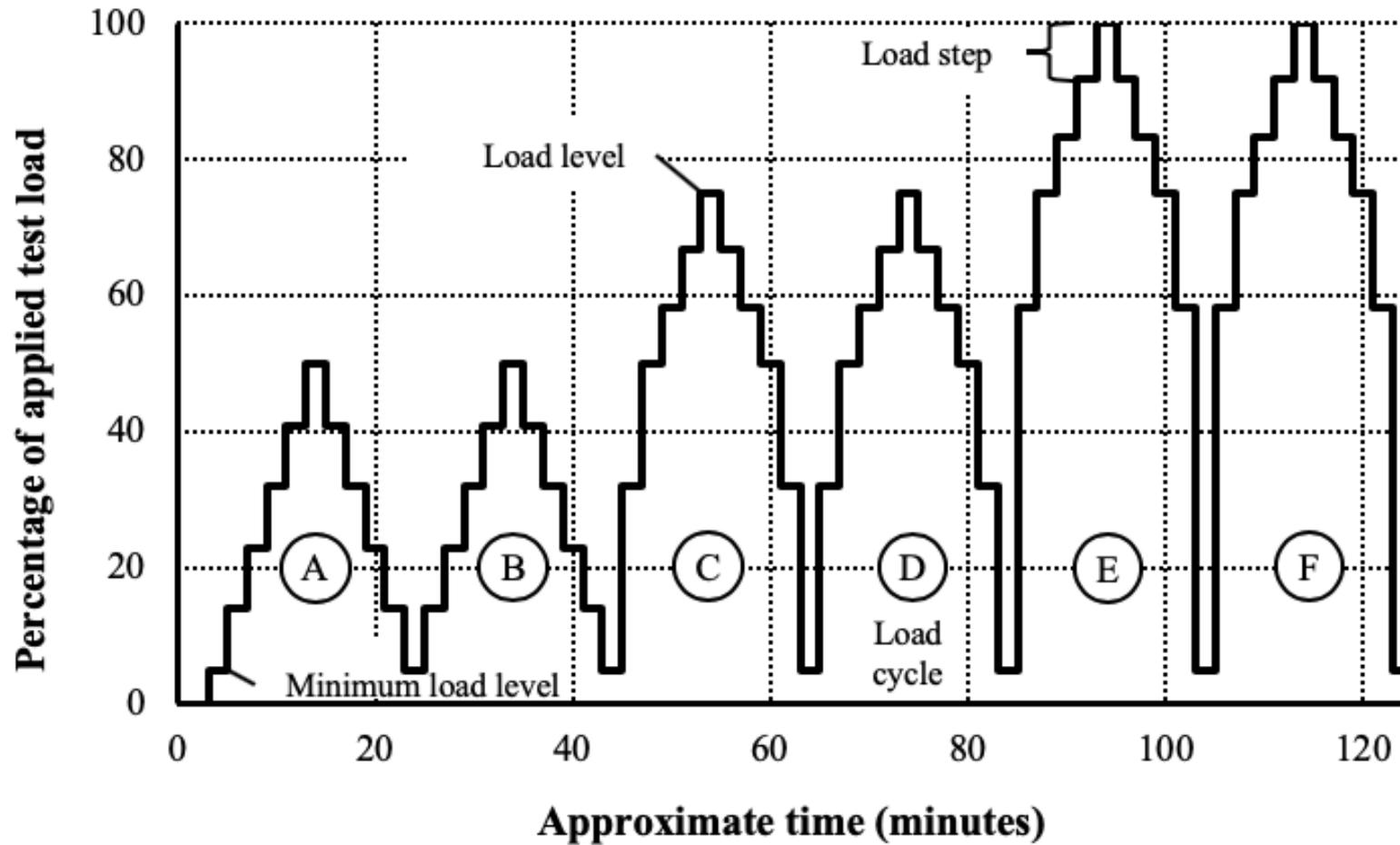
Reported by ACI Committee 437



American Concrete Institute®

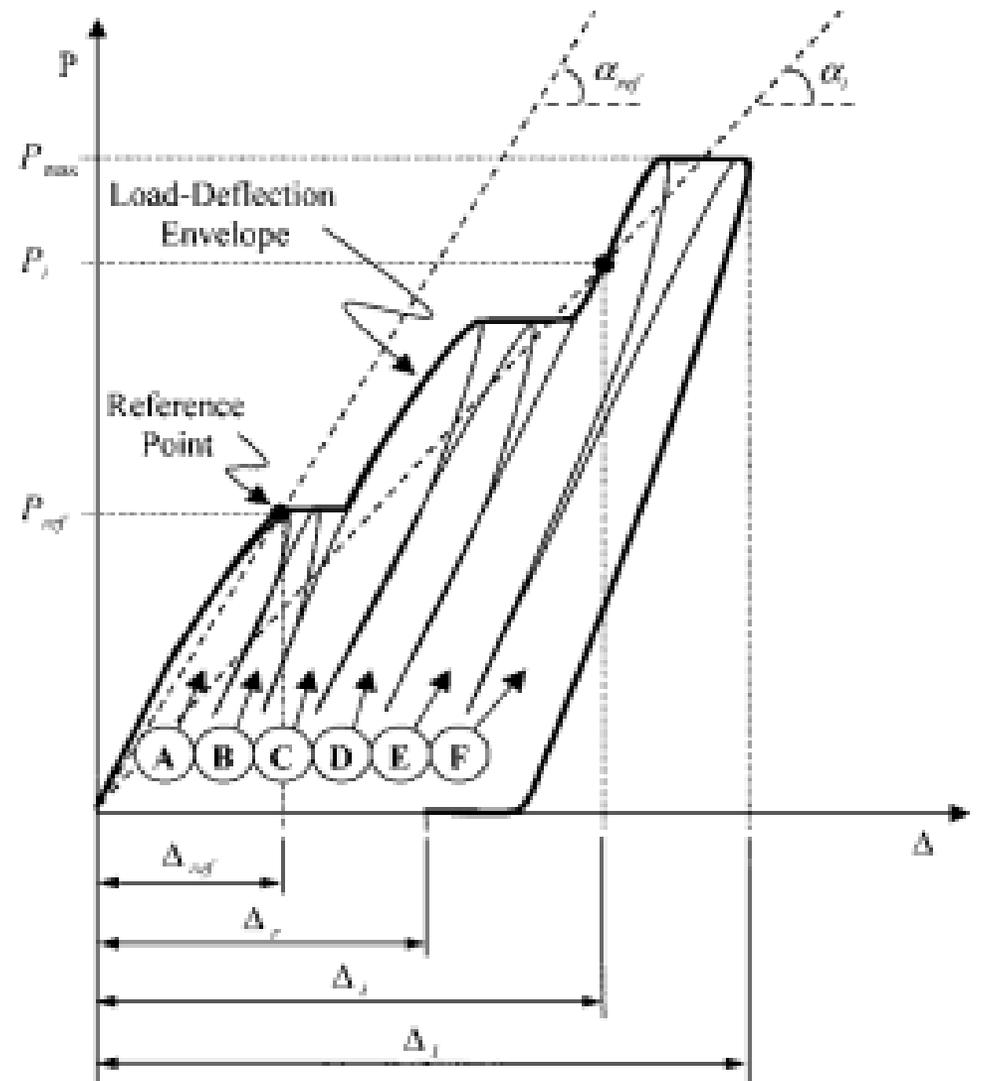
Cyclic Testing Protocol

- Repeated cycles of loading / unloading



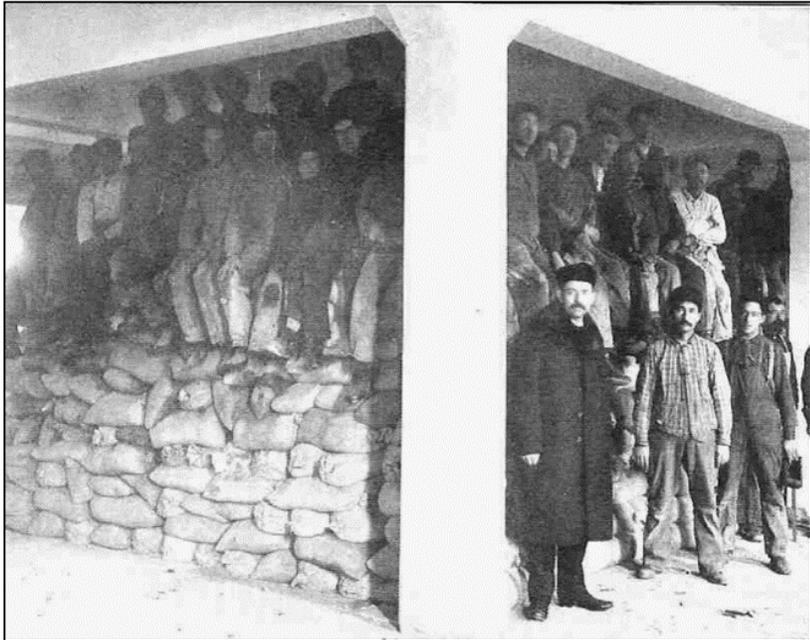
Cyclic Testing – Acceptance Criteria

- Load-deflection response
 - Multiple load cycles
 - 3 criteria to be satisfied
- Deviation from linearity index
 - Change (increase in α)
 - Measure of damage
- Permanency ratio
 - Residual Δ / Peak Δ at each load cycle
- Overall residual deflection



Cycle Testing - Advantages

- Time – full load test in a day
- More rational look at behavior
- Modern equipment



Photograph courtesy of Chuck Larosche - WJE



2013 / 2014 – What Happened?

- 562-13 – Load testing by reference to ACI 437.2
 - Cyclic testing is allowed
- 318-14 - Monotonic testing only
- Public comments indicate a major problem
- One organization – two load test methods
 - Houston, we have a problem, or
 - **Opportunity for collaboration**

ACI 318-19 – Chapter 27

- Start work in Fall 2014
 - Key goal – unification / consistency
- Committees involved
 - ACI 318-C
 - ACI 437
 - ACI 562
- End result – changes in ACI 318-19
 - Unified TLM with ACI 437.2
 - Unified monotonic acceptance criteria with 437.2
 - L / 180 may be waived
 - Cyclic testing allowed
- **Massive change after 56 years**

IN-LB Inch-Pound Units

An ACI Standard

Building Code Requirements
for Structural Concrete
(ACI 318-19)

Commentary on
Building Code Requirements
for Structural Concrete
(ACI 318R-19)

Reported by ACI Committee 318

ACI 318-19

 American Concrete Institute
Always advancing

Licensed to: Keith Keener

How did this Happen?

- ACI TAC
 - Guidance - figure it out
- Work primarily in ACI 318-C
- Three options – balloted in 318-C over 4 years
 - Adopt ACI 437.2 by reference
 - Does not work ACI 562 issue
 - Incorporate all of ACI 437.2 into ACI 318
 - Too much new text / lack of coordination
 - Modify ACI 318 to capture key parts of ACI 437.2
 - Unify TLM with ACI 437.2
 - Unity monotonic acceptance criteria
 - Allow cyclic testing by reference to ACI 437.2
- **Third option approved by ACI 318**

Where do we go next?

- ACI Committees
 - 437 – revising 437.2
 - 318 / 318-C – new cycle starting
 - 562 – new cycle starting
- Ideally keep working together
 - Updated ACI 437.2
 - Adopted by reference into ACI 318-25 and 562-25

Acknowledgements

- ACI 318
 - Jack Moehle - Chair
- ACI 318-C Members
 - JoAnn Browning - Chair
- ACI 437 Members
 - Chuck Larosche
 - Jeff West
 - John Fraunhoffer



CVM



PIVOT



Thank You

Questions?