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Code Requirements For Load Testing Of Existing Concrete Structures And Commentary

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PROVISIONAL STANDARD

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ACI Committee 437 - Strength Evaluation of Concrete Structures

**CODE REQUIREMENTS FOR LOAD TESTING OF EXISTING
CONCRETE STRUCTURES AND COMMENTARY**

REPORTED BY ACI COMMITTEE 437

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This standard provides requirements for test load magnitudes, test protocols, and acceptance criteria for conducting a load test as a means of evaluating the safety and serviceability of concrete structural members and systems for existing buildings. A load test may be conducted as part of a structural evaluation to determine whether an existing building requires repair and rehabilitation, or to verify the adequacy of repair and rehabilitation measures applied to an existing building, or both. The standard contains provisions for both a cyclic load test and a monotonic load test procedure.

Keywords: acceptance criteria; cyclic loading; load test; monotonic loading; test load magnitude;
test protocol

CHAPTER 1—GENERAL

1.1—Scope

1.1.1 The scope, purpose, applicability, limitations, interpretation principles, and units of measure of “ACI Code Requirements and Commentary for Load Testing of Existing Concrete Structures,” hereafter referred to as the “Code” are defined in this Chapter.

1.1.2 The “General Building Code” refers to the building code adopted in each jurisdiction. This Code supplements and is part of the General Building Code through reference.

1.1.3 The requirements of this Code shall govern for the evaluation of safety and serviceability of members in existing concrete structures by load testing, except as modified by the General Building Code.

1.1.4 In jurisdictions without a General Building Code, this Code provides minimum acceptable requirements for the evaluation of safety and serviceability of existing concrete structures by load testing.

1.1.5 The requirements of this Code shall apply to reinforced concrete with prestressed or non-prestressed reinforcement, or both.

1.1.6 Procedures and requirements provided in this Code are not applicable to existing structures having concretes with compressive strengths above 8000 psi unless permitted by the licensed design professional.

1.2 — Purpose

1.2.1 The purpose of this Code is to establish the minimum requirements for the test load magnitudes, load test procedures, and acceptance criteria applied to existing concrete structures as part of an evaluation of safety and serviceability to determine whether an existing structure requires repair and rehabilitation, to verify the adequacy of repair and rehabilitation measures applied to an existing structure, or to provide for public health and safety.

1.2.2 The purpose of this Code is to establish minimum requirements for the strength evaluation of concrete structures to provide for public health and safety through structural safety and serviceability.

1.2.3 Load tests shall be conducted according to load test procedures as described in Chapter 5.

1.2.2 All references in this Code to the “licensed design professional” shall be understood to mean persons who are licensed to practice structural design in the jurisdiction where this Code is being used. The licensed design professional for a project is responsible for and in-charge of the evaluation of safety and serviceability.

1.2.3 A licensed design professional must possess sound engineering knowledge and experience, and exercise judgment when interpreting and applying this Code.

1.3—Limitations

1.3.1 This Code does not apply to foundations, slabs-on-ground, structures whose responses are dominated by in-plane actions, or structures having unusual design concepts as determined by the licensed design professional.

1.3.2 This Code shall not be used for product development testing where load testing is used for quality control or approval of mass-produced members.

1.3.3 Testing for resistance to fatigue, wind, and seismic loads is outside the scope of this Code.

1.3.4 Load testing to determine design strength or load carrying capacity is outside the scope of this Code.

1.4 — Interpretation

1.4.1 The principles of interpretation in 1.4 shall apply to this Code as a whole unless otherwise explicitly stated.

1.4.2 This Code consists of the following components: the text in each chapter; headings; figures and footnotes to and figures. The commentary provides helpful information to the user but it is not part of this Code, does not provide binding requirements, and cannot be used to create a conflict with or ambiguity in the requirements of this Code.

1.4.3 This Code shall be interpreted in a manner that harmonizes and avoids conflict between its provisions. The more specific provision shall govern over general provisions.

1.4.4 This Code shall be interpreted and applied to give effect to the plain meaning of the words and terms used. Specific definitions of words and terms in this Code shall be used where provided and applicable, regardless of whether other materials, standards, or resources outside of this Code would provide a different definition.

1.4.5 Unless stated otherwise, this Code shall use the following words or terms as specified here:

- (a) The words “must” and “shall” are mandatory;
- (b) “And” indicates that all of the connected items, conditions, requirements, or events shall apply;
- (c) “Or” indicates that the connected items, conditions, requirements, or events shall apply singularly or in any combination as determined by the licensed design professional.

1.4.6 In any case in which one or more provisions of this Code are declared by a court or tribunal to be invalid, that ruling shall not affect the validity of the remaining provisions of this Code,

which are severable. The ruling of a court or tribunal shall be effective only in that court's jurisdiction and shall not affect the content or interpretation of this Code in other jurisdictions.

1.5—Units

Values in this Code are stated in inch-pound units..

COMMENTARY

R1.1.3 The determination of situations where a load test is required is outside the scope of this Code. Furthermore, this Code does not address procedures for analytical strength evaluations, condition evaluation of existing structures, or assessment of structural deterioration and its consequences. The licensed design professional should advise owner and parties participating in the load testing of a structure of the potential for damage or even failure of the portions of the structure to be load tested in accordance with the procedures of this Code. See 5.1-Safety for provisions relating to safety and shoring.

R1.1.6 Experience is lacking in the application of the procedures and requirements in this Code to structures having high-strength concrete (concrete compressive strengths over 8000 psi). Structures with high-strength concrete may exhibit a more linear response as the structure approaches its capacity and may experience a more brittle failure in comparison to structures with strengths less than 8000 psi..

R1.3.1 The procedures and requirements in this Code have been developed and applied to structural members subjected to gravity loads and where the structural response is dominated by flexure, such as typical elements of the gravity load-carrying system in a building. This Code is not applicable to structures where the response involves significant in-plane or membrane action, where soil-structure interaction is present, or in situations where the structural behavior is not

typical of building structural elements. Structures where the response may be inappropriate for use with the requirements of this Code include shells, arches, bins and silos, blast-resistant structures, and chimneys.

R1.3.4 The procedures and requirements of this Code are not intended to provide any indication of the strength or load-carrying capacity of a member or structure at failure. The term “design strength” refers to the strength of a member or cross section as used in the context of the basic requirement for strength design, expressed as “design strength” $\geq$ “required strength” (based on factored load combinations of the governing Building Code). The design strength is calculated in accordance with the provisions and assumptions of the strength design method of the governing Building Code and multiplied by the appropriate strength reduction factor, ϕ .

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

$D =$ total dead load: $D_w + D_s$, or related internal moments or forces

$D_s =$ superimposed dead load, or related internal moments or forces

$D_w =$ load due to self-weight of the concrete structural system

$F =$ loads due to weight and pressure of fluids with well-defined densities and controllable maximum heights, or related internal moments or forces

$I_{DL} =$ deviation from linearity index

$I_{pr} =$ permanency ratio index

$I_{Pi} =$ permanency index for the i^{th} cycle at specified load level of a cyclic load test

$I_{P(i+1)} =$ permanency index for the $(i+1)^{\text{th}}$ cycle at specified load level of a cyclic load test

- L = live load due to use and occupancy of the building not including environmental load and superimposed dead load, or related internal moments or forces
- L_r = roof live load produced during maintenance by workers, equipment, and materials or during life of structure by moveable objects such as planters and people, or related internal moments or forces
- l_t = span of member under load test and taken as the smaller of: (a) distance between centers of supports, and (b) clear distance between supports plus thickness h of member; for a cantilever it shall be taken as twice the distance from face of support to cantilever end, in.
- P_i = applied load corresponding to point i in load-deflection envelope in a cyclic load test, used for computation of α_i in I_{DL} acceptance criterion (see Fig. 6.3.1), lbs.
- P_{max} = applied load corresponding to 100 percent of test load magnitude, lbs.
- P_{min} = minimum load to be maintained during a cyclic load test, lbs.
- P_{ref} = reference load corresponding to the peak load of the first cycle (reference point) in a cyclic load test, used for computation of α_{ref} in I_{DL} acceptance criterion (see Fig. 6.3.1), lbs.
- R = rain load, or related internal moments and forces
- S = snow load, or related internal moments or forces
- α_i = slope of secant line of point i in load-deflection envelope, where secant line passes through origin and point of interest, i , in a cyclic load test (see Fig. 6.3.1), degrees
- α_{ref} = slope of reference secant line in load-deflection envelope, where reference secant line passes through origin and peak load of the first cycle (reference point) in a cyclic load test (see Fig. 6.3.1), degrees

- Δ_i = measured deflection corresponding to point i in load-deflection envelope in a cyclic load test, used for computation of α_i in I_{DL} acceptance criterion, (see Fig. 6.3.1), in.
- Δ_l = maximum measured deflection (cyclic or monotonic load test), (see Fig. 6.3.1), in.
- Δ_{l2} = maximum deflection measured during a retest relative to the position of the structure at the beginning of the retest, in.
- Δ_r = residual deflection measured after the 24-hour recovery period following complete removal of the load at the completion of the load test, (see Fig. 6.3.1), in.
- Δ_{rrt} = permanent or residual deflection measured after the 24-hour recovery period following complete removal of the load at the completion of the repeat load test. Residual deflection during the repeat test is relative to the position of the structure at the beginning of the repeat test, in.
- Δ_{ref} = measured reference deflection corresponding to the peak load of the first cycle (reference point) in a cyclic load test, used for computation of α_{ref} in I_{DL} acceptance criterion (see Fig. 6.3.1), in.
- $\Delta_{\max}^1$ = measured maximum deflection at the end of the i^{th} cycle at a given load level of a cyclic load test (see Fig. 6.3.2), in.
- Δ_r^1 = measured residual deflection after unloading to the minimum load, $P_{\min}$, (see Fig. 6.3.2) at the completion of the i^{th} cycle at a given load level of a cyclic load test (see Fig. 6.3.2), in.
- $\Delta_{\max}^2$ = measured maximum deflection at the end of the $(i+1)^{\text{th}}$ cycle at a given load level of a cyclic load test (see Fig. 6.3.2), in.

Δ_r^2 = measured residual deflection after unloading to the minimum load, P_{min} , (see Fig. 6.3.2) at the completion of the $(i+1)^{th}$ cycle at a given load level of a cyclic load test (see Fig. 6.3.2), in.

2.2—Definitions

acceptance criteria—a set of explicit and quantitative rules to establish whether or not a structure (or a portion of it) passes a load test.

dead load (D), total—total load due to self-weight including superimposed loads.

dead load (D_w), self-weight—load due to self-weight of the concrete structural system only.

Unless documentation or tests are available to define the density of concrete used in the structure, the density of normal weight reinforced concrete shall be taken as 150 lb/ft³.

dead load (D_s), superimposed—load due to weight of construction materials other than self-weight of the structural system that are already incorporated into the building or will be incorporated in the future.

failure—when referred to the performance of a structure (or a portion of it) under load test, it indicates that one or more acceptance criteria are not met.

licensed design professional—an engineer or architect who is licensed to practice structural design as defined by the statutory requirements of the professional licensing laws of a state or jurisdiction; or the architect or engineer, licensed as described, who is responsible for the structural design of a particular project.

load-deflection envelope—the curve enclosing the points on a plot of applied load versus measured deflection from a cyclic load test (refer to Fig. 6.3.1). Only those loads that are greater than or equal to any previously applied load cycle are included.

load level—maximum load attained during a loading cycle in a cyclic load test or an intermediate load before the full test load magnitude is applied in a monotonic load test.

load step—load increment applied during a loading cycle to reach the load level for that cycle or the load decrement during the unloading portion of the cycle.

load test, cyclic—application of test load magnitude using a defined set of increasing, repeated load cycles and then maintaining the test load magnitude for at least 24 hours.

load test, monotonic—application of test load magnitude in at least four approximately equal steps and then maintaining the test load magnitude for at least 24 hours.

reference point—the point on a plot of applied cyclic load versus measured deflection corresponding to the peak load of the first load cycle (refer to Fig. 6.3.1).

reference secant line—the line passing through the origin of a plot of applied cyclic load versus measured deflection and the reference point (refer to Fig. 6.3.1).

strip or patch test load—a test load distributed over a limited portion of the tributary area of the structure or member to be tested and typically applied by means of hydraulic jacks.

test load magnitude (TLM)—total load to be used in conjunction with acceptance criteria in this Code to determine whether or not a structure, or a portion of it, passes a load test.

COMMENTARY

R2.2—Definitions

dead load (D), total—a distinction is made between dead load due to self-weight and superimposed dead loads in this Code. The total dead load D includes both dead load due to self-weight and superimposed dead loads; that is, $D = D_w + D_s$.

dead load (D_s), superimposed—this includes, but is not limited to, walls, roofs, ceilings, stairways, built-in partitions, finishes, cladding and other similarly incorporated architectural and