



DETERMINING THE LOAD CAPACITY OF A STRUCTURE WHEN AS-BUILT DRAWINGS ARE UNAVAILABLE

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Introduction

In cases where a structural evaluation is to be performed, knowledge of member sizes, reinforcing details, and material properties is generally required. In cases where this information is not readily available through drawing document records, it should still be obtained. For most buildings, bridges, and structures governed by a building code or similar design standards, the process to establish load capacity typically needs approval of the governing official.

Question

How can the load capacity of a structure be determined when as-built structural drawings are not available?

Answer

In the absence of drawings, the engineer should develop and implement an investigation program involving visual inspection, material testing, nondestructive testing (NDT), and calculations to form a rational basis for determining the structural capacity. Engineers should rely on their knowledge, experience, and judgment to develop an approach that is valid and cost-effective. The following discussion is intended to assist engineers in developing such an approach.

Discussion

Derivation of load-carrying capacity and other critical behavioral characteristics requires the involvement of a structural engineer with strong experience in this field. Determining the structure's age may provide some idea of what the building code requirements were at the time of construction. Many historic reinforced concrete structures, however, were designed using systems that are no longer used and are not addressed in modern codes and design practices.

Structural configuration and reinforcement may be established using the general techniques described in ACI 364.1 (ACI Committee 364 2001) and ANSI/ASCE 11-90 (1994). Visual examination and physical measurements are made in conjunction with nondestructive examination and examination after removal of concrete (ACI Committee 364 2001; ANSI/ASCE 11-90 1994). Material properties (concrete and reinforcement strength) may be determined by physical testing (ACI Committee 228 2003, 2004). Reinforcement size and strength may also be determined through observation of mill imprinted markings on exposed bars (CRSI Manual of Standard Practice). Once the structural system, reinforcement, and material properties are known, the structural capacity may be determined through calculations. Research into the testing and design procedures for historic structural systems may provide valuable clues about reinforcement configuration and structural behavior (CRSI 1980 Manual of Standard Practice).

Visual examinations and physical measurements are suggested to define the overall structural system for resisting both gravity and lateral loads. Understanding the lateral load-resisting system is necessary to properly consider the structural effects of lateral loads on elements such as slabs, beams, columns, walls, and foundations.

Once the basic structural configuration is known, the actual layout of reinforcement may be determined. Where the depth of cover is less than 2 in. (50 mm), the size, spacing, and depth of the cover of reinforcement in typical structural members can usually be established using a pachometer. Pachometer surveys may be partially effective where the depth of cover ranges from 2 to 4 in. (50 to 100 mm). Pachometer surveys may be problematic in areas of congested reinforcement, such as columns and beams and at areas of metallic surface interference (for example, metallic conduits). Additional exploratory openings may be required, and other methods, such as x-ray or ground-penetrating radar surveys, may be necessary to determine internal reinforcing pattern arrangements. The pachometer survey results should be spot-checked by physical measurement of exposed reinforcement at exploratory openings.

Procedures are available to provide guidance on sampling and testing concrete (ASTM C39/39M, C42/C42M, C823/C823M) and reinforcing (ASTM A370). The reliability of material properties established by testing concrete cores and reinforcement samples is a function of the number of samples. The extent of sampling and testing is a matter of professional judgment, and may depend on the confidence level necessary and the consistency of the findings (ASTM E122; ACI 214R; ACI 214.4R). Core tests may be supplemented by other strength evaluation tests, such as rebound hammer tests and probe penetration tests. Mechanical reinforcement tests may be supplemented by in-place hardness tests and by metallurgical analysis of filings.

With the member sizes, patterns, and material properties known, calculations may be performed to establish the structure's load-carrying capacity. After computing the superimposed load capacity of one area or bay of a structure, it is recommended that similar analyses be performed on adjoining areas. Determining consistent load capacity results in separate areas of a structure may be considered a prudent method to confirm the overall analysis. If the member dimensions, reinforcing size and spacing, and material properties are well established by measurement and testing, then strength-reduction factors may be increased in accordance with the guidelines and within the limits identified in Chapter 20 of ACI 318. Professional judgment is important in this regard, especially where constraints have limited the extent of testing and on-site exploration.

Load testing (ACI 318; ACI 437R, 437.1R) is another tool for determining the load-carrying capacity of a member or structure. Load tests conducted in accordance with Chapter 20 of ACI 318 and ACI 437R may be used to verify the load capacity of a given structure. Load testing may reduce, but not completely eliminate, the need for investigative field work, material testing, and structural calculations. Determining the most efficient combination of investigative field work, material testing, structural calculations, load testing, or a combination of these depends on professional judgment and on an evaluation of the practical difficulties associated with each item. Each structure should be evaluated on a case-by-case basis.

As a final consideration, the capacity of the foundation system may need to be determined, especially in cases where the load capacity of an entire structure is being established. The foundation may need to be exposed and the soil-bearing capacity determined in the case of shallow foundations. Where deep foundations are used, some excavation may be required to determine the type of deep foundation, supplemented by other procedures such as NDT, coring, probing, load testing, or other means to reliably predict the foundation capacity. The original soil test boring records or a subsurface investigation report, if available, are valuable in establishing the likely foundation system employed in the building. Lacking this, an engineer's knowledge of subsurface conditions or records for adjacent buildings may aid in this aspect of the analysis. The strength of the superstructure members is independent of the foundation, but the capacity of the foundation may limit the load that can be applied to the superstructure members.

Summary

The load capacity of a structure can be determined when as-built drawings are unavailable. An engineering investigation involving visual inspection, material testing, and NDT provides a basis for rational calculations to determine the structural capacity.

Referenced standards and reports

The standards and reports listed below were the latest editions at the time this document was prepared. Because these documents are revised frequently, the reader is advised to contact the proper sponsoring group if it is desired to refer to the latest version.

American Concrete Institute

- 214R Evaluation of Strength Test Results of Concrete
- 214.4R Guide for Obtaining Cores and Interpreting Compressive Strength Results
- 228.1R In-Place Methods to Estimate Concrete Strength
- 228.2R Nondestructive Test Methods for Evaluation of Concrete in Structures
- 318/318M Building Code and Commentary
- 364.1R Guide for Evaluation of Concrete Structures before Rehabilitation
- 437R Strength Evaluation of Existing Concrete Buildings
- 437.1R Load Tests of Concrete Structures: Methods, Magnitude, Protocols, and Acceptance Criteria

ASTM International

- A370 Standard Test Methods and Definitions for Mechanical Testing of Steel Products
- C39/C39M Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
- C42/C42M Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete



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