



DETERMINING THE LOAD CAPACITY OF A STRUCTURE WHEN STRUCTURAL DRAWINGS ARE UNAVAILABLE—TECHNOTE

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Introduction

When a structural evaluation to determine capacity is to be performed, knowledge of member sizes, reinforcing details, and material properties is required. In cases where this information is not readily available through drawing document records, it needs to be obtained through in-place measurements and sampling.

Question

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

Answer

In the absence of structural drawings, the licensed design professional (LDP) should develop and implement an investigation program involving a combination of approaches that may include visual inspection, material testing, load testing, nondestructive testing (NDT), exploratory openings, and calculations to form a rational basis for determining the structural capacity. LDPs 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 LDPs in developing such an approach. It should be noted that, in cases where structural drawings are available, the methods described in the following can be used to confirm the conformance of the as-built construction to the available drawings.

Discussion

Determination of the structure's age may provide some idea of what the building code requirements, typical material properties, and structural systems were at the time of construction. Many historic reinforced concrete structures, however, were designed using proprietary systems that are no longer used. Therefore, the involvement of a structural engineer with experience in evaluating structures of the same nature as the one being addressed (type of structure/construction and structural layout, for example) can be beneficial when determining the load-carrying capacity and other critical behavioral characteristics of a structure.

Structural configuration

The structural configuration and reinforcement layout may be established using the general techniques described in [ACI 364.1R](#) and [ASCE/SEI 11](#). Visual examination, physical measurements, and nondestructive testing (NDT) are performed on in-place members and followed up with more detailed observations and measurements after the removal of concrete in selected areas ([ACI 364.1R](#); [ASCE/SEI 11](#)). Concrete material characteristics and properties may be obtained using concrete core samples extracted from the existing structure, as described in [ACI 214.4R](#). NDT methods, as described in [ACI 228.1R](#), can be used to gather data from larger areas of the structure once a valid correlation is established between the nondestructive test results and concrete strength test results. Reinforcement size and strength may be verified through observation of mill imprinted markings on exposed reinforcing steel ([CRSI 2001](#)) or physical measurements and testing performed on samples. Once the structural system, reinforcement, and material properties have been determined, the structural capacity may be evaluated through analytical structural modeling and calculations. Research into the testing and design procedures for historic structural systems may provide valuable information about reinforcement configuration and structural behavior ([CRSI 2018](#)). Valuable reference documents are available to support this type of analysis. For instance, a summary of historical material properties potentially suitable for use in the determi-

nation of the load-carrying capacity of a concrete structure is provided in [ACI 562](#). Additionally, [CRSI \(2010\)](#) summarizes the types of reinforcing bars and mesh, reinforcement layouts, and reinforcing material properties that were used back to the early 1900s.

Care should be taken to collect relevant information that will allow the LDP 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.

Reinforcement layout

Once the basic structural configuration is known, the actual layout of reinforcement may be determined using a combination of destructive and nondestructive methods. It should be noted that the development and splice lengths required by previous codes may be less than the current code requirements. Therefore, determination of the development and splice lengths used in the design and construction of the structure is necessary for the determination of the structure's load capacity. Development and splice length requirements have changed over time; refer to prior versions of [ACI 315R](#) for older detailing requirements that may coincide with the vintage of the building being evaluated.

Particular attention should also be given to areas of potentially atypical detailing, such as joints, member connections, and boundary elements. In typical structural members where the concrete cover thickness is less than 2 in. (50 mm), the reinforcement spacing and depth can usually be evaluated using a pachometer. In the cover range from 2 to 4 in. (50 to 100 mm), pachometer surveys may be partially effective. Ground-penetrating radar (GPR) can be used to determine the spacing and depth of reinforcement that is located further inside concrete members and beyond the range of a pachometer. Nondestructive surveys using either a pachometer or GPR may be problematic in areas of congested reinforcement, such as columns and beams, and other areas subject to metallic interference (for example, metallic conduits). GPR, however, is typically more effective than a pachometer at identifying individual reinforcing elements in congested areas of reinforcement. Estimation of the reinforcing bar size(s) is not very reliable, either with the pachometer or GPR. By using multiple measurement methods, however, bar diameter can generally be estimated to within two adjacent bar sizes ([ACI 228.2R](#)). The exploratory openings may be required to more reliably determine the internal reinforcement bar size(s) and layout. The LDP should then calibrate and validate the NDT data using physical measurement of exposed reinforcement at exploratory openings.

Material properties

Procedures are available to provide guidance on on-site sampling and laboratory testing of concrete ([ASTM C42/C42M](#); [ASTM C823/C823M](#)) and reinforcement ([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 in-place strength evaluation tests, such as rebound hammer tests and probe penetration tests. It should be noted, however, that these methods only measure physical properties of the concrete that have some relationship to strength, but do not provide a direct measurement of the concrete strength. It is essential to find the correlation between the data yielded with these test methods and the concrete compressive strength data determined on core samples ([ACI 228.1R](#)). Mechanical reinforcement tests may be supplemented by in-place hardness tests and by metallurgical analysis of filings.

Load-carrying capacity

After obtaining the necessary information on the structural configuration, member dimensions, reinforcement layout, and material properties, calculations may be performed to establish the structure's load-carrying capacity. While performing structural analysis and evaluation, it is important to consider all relevant factors such as deformations, lateral drift, duration of loads, shrinkage and creep, and reactions imparted to the supporting foundations.

In general, it is important to consider the effects of pattern loading when determining the superimposed load capacity of a structure. Analyzing separate areas of the structure assumed to have been designed for similar loads and then comparing the calculated load capacity results for consistency is a judicious approach for validating the overall analysis. Therefore, after computing the superimposed load capacity of one area or bay of a structure, it is recommended that similar calculations be performed on adjoining areas. If the member dimensions, reinforcing size and spacing, and material properties have been established reliably by measurement and testing, then strength-reduction factors may be increased in accordance with the guidelines and within the