IN-LB	Inch-Pound Units
SI	International System of Units

Report on Deflection of Nonprestressed Concrete Structures

Reported by ACI Committee 435

ACI 435R-20

American Concrete Institute
Always advancing

American Concrete Institute
Always advancing

First Printing
November 2020
ISBN: 978-1-64195-128-9

Report on Deflection of Nonprestressed Concrete Structures

The technical committees responsible for ACI committee reports and standards strive to avoid ambiguities, omissions, and errors in these documents. In spite of these efforts, the users of ACI documents occasionally find information or requirements that may be subject to more than one interpretation or may be incomplete or incorrect. Users who have suggestions for the improvement of ACI documents are requested to contact ACI via the errata website at http://concrete.org/Publications/DocumentErrata.aspx. Proper use of this document includes periodically checking for errata for the most up-to-date revisions.

ACI committee documents are intended for the use of individuals who are competent to evaluate the significance and limitations of its content and recommendations and who will accept responsibility for the application of the material it contains. Individuals who use this publication in any way assume all risk and accept total responsibility for the application and use of this information.

All information in this publication is provided "as is" without warranty of any kind, either express or implied, including but not limited to, the implied warranties of merchantability, fitness for a particular purpose or non-infringement.

ACI and its members disclaim liability for damages of any kind, including any special, indirect, incidental, or consequential damages, including without limitation, lost revenues or lost profits, which may result from the use of this publication.

It is the responsibility of the user of this document to establish health and safety practices appropriate to the specific circumstances involved with its use. ACI does not make any representations with regard to health and safety issues and the use of this document. The user must determine the applicability of all regulatory limitations before applying the document and must comply with all applicable laws and regulations, including but not limited to, United States Occupational Safety and Health Administration (OSHA) health and safety standards.

Participation by governmental representatives in the work of the American Concrete Institute and in the development of Institute standards does not constitute governmental endorsement of ACI or the standards that it develops.

Order information: ACI documents are available in print, by download, through electronic subscription, or reprint and may be obtained by contacting ACI.

Most ACI standards and committee reports are gathered together in the annually revised the ACI Collection of Concrete Codes, Specifications, and Practices.

American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
Phone: +1.248.848.3700
Fax: +1.248.848.3701

www.concrete.org

ACI 435R-20

Report on Deflection of Nonprestressed Concrete Structures

Reported by ACI Committee 435

Eric S. Musselman, Chair

Dylan Freytag, Secretary

Peter H. Bischoff
Allan P. Bommer
Flora A. Calabrese
Eamonn F. Connolly
Norbert J. Delatte
Mamdouh M. El-Badry
Amin Ghali
Mayrai Gindy
Shawn P. Gross
Young Hak Lee
Adam S. Lubell
Faris A. Malhas
Michael C. Mota
Hani H. Nassif
Edward G. Nawy
Debrethann R. Orsak
Maria A. Polak
Mahmoud M. Reda Taha
Andrew Scanlon
Richard H. Scott

Consulting Members

Alex Aswad
Finley A. Charney
Satyendra Ghosh
Peter Lenkei
Bernard L. Meyers
Vilas S. Mujumdar
Himat T. Solanki
Susanto Teng

This report presents a consolidated treatment of initial and time-dependent deflection of nonprestressed reinforced concrete members such as simple and continuous beams and one-way and two-way slab systems. It presents the current state of practice of deflection prediction as well as analytical methods for computer use in deflection estimation. Topics include material properties, deflection of reinforced concrete one-way flexural members, deflection of two-way slab systems, and reducing deflection of concrete members.

Keywords: camber; cracking; creep; curvature; deflection; modulus of rupture; moments of inertia; serviceability; shrinkage; time-dependent deflection.

CONTENTS

ACI 435R-20 supersedes ACI 435R-95(03) and became effective November 2020.

CHAPTER 1—INTRODUCTION AND SCOPE

1.1—Introduction

Design for serviceability is central to the work of structural engineers and code-writing bodies. It is also essential to users of the designed structures. Increased use of high-strength concrete and higher-strength reinforcing bars, coupled with more detailed computer-aided designs, has resulted in lighter and more material-efficient and, thus, more flexible structural members and systems. This in turn has necessitated better prediction and control of short-term and long-term behavior of concrete structures at service loads.

This report presents a consolidated treatment of initial and time-dependent deflection of nonprestressed reinforced concrete members such as simple and continuous beams and one- and two-way slab systems. It presents current engineering practice in design for control of deformation and deflection of concrete members and includes methods presented in ACI 318 plus selected other approaches suitable for computer-based use in deflection computation. Design examples are given at the end of one- and two-way framing chapters showing how to evaluate deflection and, thus, control it through adequate design for serviceability. The content of the report as well as the step-by-step examples are intended to familiarize practitioners with the current methods for estimating deflections in buildings as well as analytical methods suitable for computer-based application. The examples apply ACI 318 requirements and a recommended alternative approach with a lower cracking moment (to account for shrinkage restraint). Methods for predicting initial and time-dependent deflections of prestressed concrete are not addressed in this document, although prestressing can be an effective tool for controlling both short- and long-term deflections.

1.2—Scope

The principal causes of deflections taken into account in this report are those due to elastic deformation, flexural cracking, creep, shrinkage, and temperature effects. This document is composed of two introductory chapters and four main chapters that provide information on calculating and controlling deflections of members constructed using reinforced concrete. The organization of the report is:

a) **Chapter 1—Introduction and Scope** provides background information on the document.

b) **Chapter 2—Notation and Definitions** provides a listing of the notation used throughout the document.

c) **Chapter 3—Material Properties** discusses material properties that affect deflections.

d) **Chapter 4—Deflection of Reinforced Concrete One-Way Flexural Members** discusses behavior of uncracked and cracked members, and time-dependent effects. It also includes the relevant code procedures and expressions for deflection computation in reinforced concrete beams. Numerical examples are included to illustrate the standard calculation methods for simply supported and continuous concrete beams.

e) **Chapter 5—Deflection of Two-Way Slab Systems** covers the deflection behavior of reinforced two-way-action slabs and plates. This chapter gives an overview of classical and other methods of deflection estimation, such as the crossing beam analogy and the finite element method for immediate deflection computation. It also discusses approaches for determining the minimum thickness requirements for two-way slabs and plates and gives a detailed computational example for evaluating the long-term deflection of a two-way reinforced concrete slab. The chapter emphasizes the uncertainties inherent in estimating deflections of two-way slab systems.

f) **Chapter 6—Reducing Deflection of Concrete Members** gives practical and remedial guidelines for improving and controlling the deflection of reinforced concrete members, hence enhancing their overall long-term serviceability.

It should be emphasized that the magnitude of actual deflection in concrete structural members, particularly in buildings, which are the emphasis and the intent of this report, can only be estimated with limited accuracy. This is because of the large variability in the properties of the constituent materials of these members, the quality control exercised in their construction, and the construction methods used. Therefore, for practical considerations, the computed deflection values in the illustrative examples at the end of each chapter should be interpreted with this in mind.

In summary, this single document gives design engineers the key tools for estimating, and thereby controlling through design, the expected deflection in nonprestressed reinforced concrete building structures. The material presented and the design examples will help to enhance serviceability when