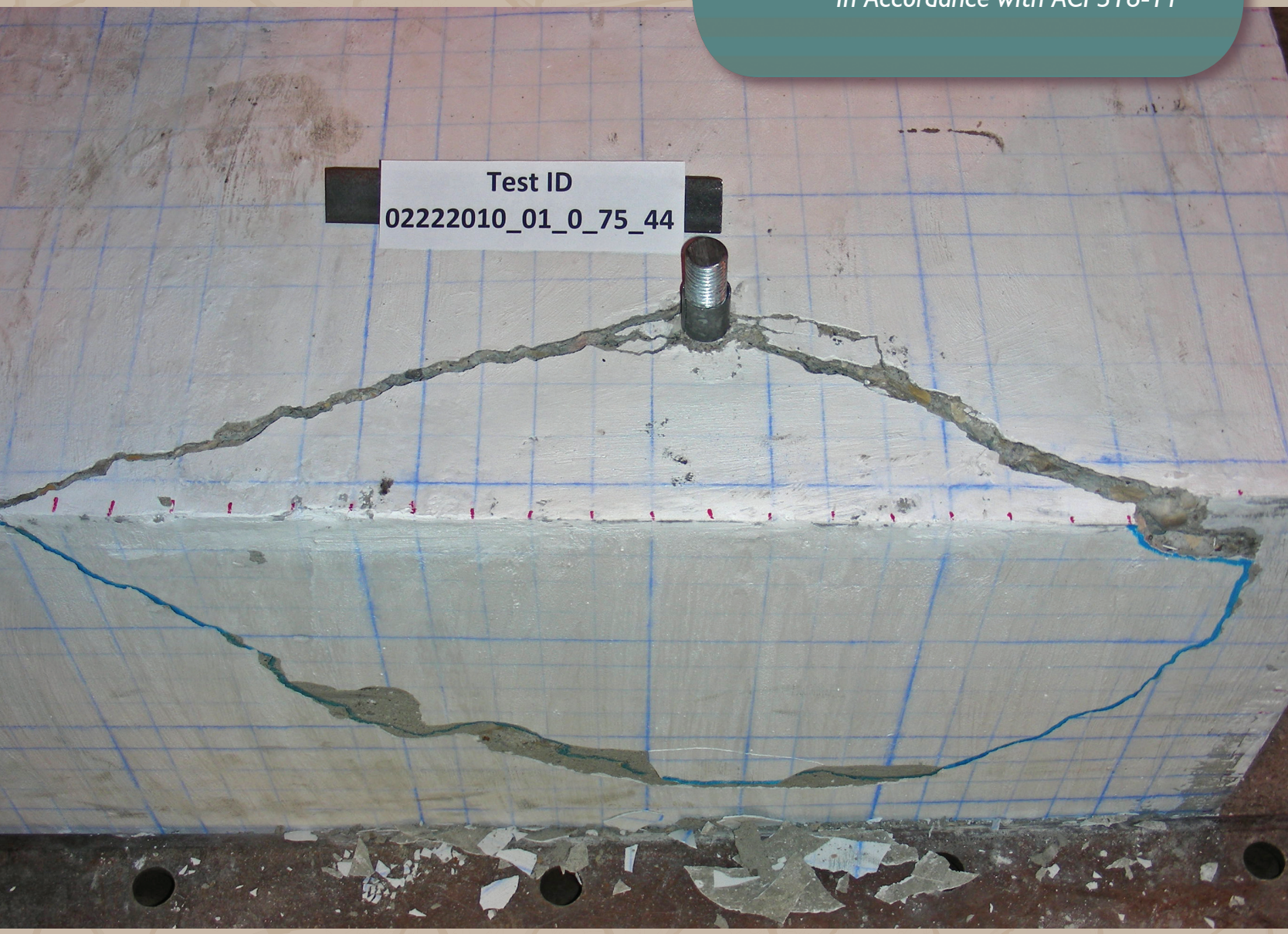
The Reinforced Concrete Design Manual

In Accordance with ACI 318-11



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THE REINFORCED CONCRETE DESIGN MANUAL

in Accordance with ACI 318M-11

Anchoring to concrete

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FOREWORD

The *Reinforced Concrete Design Manual* [SP-17M(11)] is intended to provide guidance and assistance to professionals engaged in the design of cast-in-place reinforced concrete structures.

The first *Reinforced Concrete Design Manual* (formerly titled *ACI Design Handbook*) was developed in accordance with the design provisions of 1963 ACI 318 Building Code by ACI Committee 340, Design Aids for Building Codes, whose mission was to develop handbook editions in accordance with the ACI 318 Building Code. That committee published revised editions of the handbook in accordance with the 1971, 1977, 1983, and 1995 ACI 318 Building Codes. Many individuals and members of ACI Committee 340 contributed to the earlier editions of the handbook, which remains the basis for the current *Reinforced Concrete Design Manual*. Their contributions, as well as the administrative and technical assistance from ACI staff, are acknowledged. This earlier handbook format was a collection of design aids and illustrative examples, generated in the pre-calculator era. Many of these earlier design aids intended to carry out relatively simple design calculations were eliminated in the SP-17M(09) edition. Explanatory text was added to each chapter, while maintaining relevant design aids and illustrative examples.

The 2012 edition of the *Reinforced Concrete Design Manual* [SP-17M(11)] was developed in accordance with the design provisions of ACI 318M-11, and is consistent with the format of SP-17M(09). Chapters 1 through 6 were developed by individual authors, as indicated on the first page of those chapters, and updated to the content of ACI 318M-11 as needed. Those authors were members of the former ACI Committee 340. SP-17M(09) was reviewed and approved by ACI's Technical Activities Committee (TAC).

Three new chapters were developed by ACI staff engineers under the auspices of TAC for SP-17M(11): Chapter 7 (Deflection); Chapter 8 (Strut-and-Tie Model); and Chapter 9 (Anchoring to Concrete). To provide immediate oversight and guidance for this project, TAC appointed three content editors: Ronald Janowiak, Michael Kreger, and Antonio Nanni. Their reviews and suggestions improved this publication and are appreciated. TAC also appreciates the comments provided by Ronald Cook, Catherine French, Gary Klein, and John Silva for Chapters 8 and 9.

SP-17M(11) is published in two volumes: Chapters 1 through 8 are published in Volume 1 and Chapter 9 is published in Volume 2.

Khaled Nahlawi
Managing Editor

On the cover:

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THE REINFORCED CONCRETE DESIGN MANUAL

in Accordance with ACI 318M-11

Volume 2

Editors: Ronald Janowiak, Michael Kreger, and Antonio Nanni

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CHAPTER 9—ANCHORING TO CONCRETE

9.1—Introduction

Steel anchors, either cast in concrete or post-installed in hardened concrete, are used to transfer shear and tension forces to a concrete member. Cast-in anchors are usually headed studs, headed bolts, hooked bolts, or threaded rods with nuts. Post-installed anchors include undercut, expansion, and adhesive anchors. Appendix D of ACI 318M is used for the design of anchors in concrete for two main applications: (a) connections between structural members; and (b) attachments of nonstructural, safety-related elements to a structural member.

Cast-in anchors are placed into the formwork before concrete placement.

Advantages are:

- Anchors may be accurately placed with respect to reinforcing bars
- Many anchor sizes, configurations, and lengths are possible

Disadvantages are:

- Anchors that are not adequately held in place may shift from their intended location during the placement of concrete
- Anchors may be affected by poor concrete consolidation
- Anchors cannot be moved after concrete is placed
- Anchors in walls and the bottom of slabs require penetrations in the formwork.

Post-installed anchors are installed into drilled holes after concrete has hardened. Post-installed anchors transmit loads to the concrete by friction, bearing, bond, or a combination of these mechanisms.

Advantages are:

- Anchors may be accurately placed with respect to attached components
- Avoids formwork penetrations

Disadvantages are:

- Anchor location with respect to reinforcing bars is usually uncertain, and drilling anchor holes may damage reinforcement
- Post-installed anchors generally have lesser design strength than cast-in anchors with equal embedment depth and diameter
- Inspection requirements for post-installed anchors may be greater than for cast-in anchors.

9.2—Materials

Anchor design strength is influenced by both the steel anchor characteristics (yield strength, ductility, diameter, embedment length) and the member's specified concrete strength.

All types of steels are allowed, but there is approximately 10 to 15% design strength reduction for using less ductile steel. Anchor steel is considered ductile if the tensile elongation as measured in accordance with ASTM F606 is at least 14% with a reduction in area of at least 30%. Some steels, such as A307 bolts and A615 reinforcing bars, are deemed to meet this requirement without testing. A restriction on the maximum ratio of tensile strength to yield strength is imposed to prevent yielding of anchors at service load levels (see D.5.1.2). If the anchor resists significant seismic forces, other restrictions—for example, on the ratio of tensile ultimate to yield strength—may apply (see D.3.3.4.3).

Table 9(a)—Depth limits for post-installed adhesive anchors, mm

d_a	6	10	12	16	22	24
Min $4d_a$	25	40	50	65	90	100
Max $20d_a$	125	190	250	315	440	500

Cast-in anchors do not have embedment depth limits, but post-installed adhesive anchor embedment depths are limited to $4d_a \le h_{ef} \le 20d_a$ (see Table 9(a)).

For anchor diameters larger than 100 mm, testing is required.

Post-installed mechanical anchors and post-installed adhesive anchors are qualified by testing in accordance with ACI 355.2[1] and ACI 355.4[2], respectively.

For calculation purposes, the concrete strength f'_c cannot exceed 70 MPa for cast-in anchors or 55 MPa for post-installed anchors. For concrete compressive strengths beyond these limits, testing is required. There is a reduction factor λ_a for lightweight concrete.

9.3—Design assumptions

ACI 318M Appendix D assumptions to calculate anchor forces include:

1. Loads are applied through a base plate to individual anchors
2. Anchor reactions are usually calculated by either (a) or (b):
   (a) elastic analysis by varying the anchor reactions linearly with distance from axis of rotation
   (b) inelastic analysis by force redistribution among ductile anchors
3. Friction between the base plate and the concrete is ignored
4. Anchor tension strength is unaffected by the presence of an adjacent compression field

ACI 318M Appendix D design assumptions include:

5. Cracked concrete members have sufficient reinforcement to restrain cracking to acceptable widths under design loads
6. Anchors in a group are of a similar type, size, and depth
7. In buildings subject to earthquake forces, anchors are not located in plastic hinge zones

To evaluate a preliminary design, consider:

1. The location of anchors relative to each other, to the base plate edges, and to the edge of concrete
2. The anchor type (cast-in, mechanical post-installed, adhesive)