ACI 550.3M-13

(metric)

Design Specification for Unbonded Post-Tensioned Precast Concrete Special Moment Frames Satisfying ACI 374.1 (ACI 550.3M-13) and Commentary

An ACI Standard

Reported by Joint ACI-ASCE Committee 550

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American Concrete Institute
38800 Country Club Drive
Farmington Hills, MI 48331
U.S.A.
Phone: 248-848-3700
Fax: 248-848-3701

www.concrete.org

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Subcommittee Members
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Suzanne Dow Nakaki

This Standard defines requirements that may be used to design special hybrid moment frames composed of discretely jointed precast concrete beams post-tensioned to concrete columns. After a major earthquake, these hybrid moment frames should exhibit minimal damage in beam-column regions and negligible permanent displacements. Hybrid moment frames do not satisfy the prescriptive requirements of Chapter 21 of ACI 318M-11 for frames of monolithic construction. According to 21.1.1.8 of ACI 318M-11, their acceptance requires demonstration by experimental evidence and analysis that the frames have strength and toughness equal to or exceeding those provided by comparable monolithic reinforced concrete frames that satisfy the prescriptive requirements of Chapter 21. This Standard describes the requirements that the licensed design professional may use to demonstrate, through analysis, that such frames have strength and toughness at least equal to those of comparable monolithic frames. This Standard is a revision of the ACI T1.2 Standard.

In this Standard, consistent with the format of ACI 318M, the word "Section" is not included before a reference to a section of ACI 318M. To more clearly designate a section of this Standard, however, the word "Section" is used before any reference to a section of this Standard. Consistent with the format of ASCE/SEI 7, the word "Section" is also included before a reference to a section of ASCE/SEI 7.

Keywords: drift ratio; earthquake-resistant design; energy dissipation; moment frame; post-tensioning; precast concrete; prestressed concrete; test module; toughness.

CONTENTS

ACI 550.3M-13 supersedes T1.2-03, was adopted August 8, 2013, and was published January 2014.

CODE

CHAPTER 1—GENERAL

1.1—Introduction

For regions of high seismicity, 21.1.1.8 of ACI 318M-11 permits the use of structural systems that do not meet the prescriptive requirements of Chapter 21 if certain experimental evidence and analysis are provided. The intent of ACI 374.1 is to define the minimum evidence required when attempting to validate the use of weak-beam, strong-column special moment frames in accordance with 21.1.1.8 of ACI 318M-11.

Before acceptance testing can be undertaken, ACI 374.1 requires that a design procedure be developed for prototype moment frames having the generic form for which acceptance is sought, and that procedure be used to proportion the test modules. ACI 550.3-13 defines the requirements to be used for one specific type of moment frame that does not fully satisfy the prescriptive requirements of Chapter 21 of ACI 318M-11. This moment frame has been validated for use in regions of high seismicity under ACI 374.1 and ACI 318M. The moment frame uses precast concrete beams that are post-tensioned to precast or cast-in-place concrete columns. The columns are continuous through the joints and the beams each span a single bay. This Standard describes the frame as hybrid because it combines post-tensioned and precast concrete construction and combines the use of deformed reinforcement that is designed to yield with unbonded post-tensioning tendons that are designed to remain essentially elastic during the design basis earthquake (DBE).

In this specific type of hybrid frame, the post-tensioning tendons are unbonded. Horizontal reinforcing bars grouted in ducts located in the columns and in the top and bottom of the beams, and described in this Standard as energy-dissipating reinforcement, provide additional continuity between the beams and the columns, and additional moment strength to the beams. Those bars dissipate energy as they yield alternately in tension and compression during an earthquake.

A key feature of this system is that the grouted bars are deliberately debonded for a short distance in the beam adjacent to the beam-column interface to reduce the high cyclic strains that would otherwise occur at that location. Consequently, during an earthquake, the beams and columns displace essentially as rigid bodies with deformations occurring primarily at the beam-column interface as the beam rocks against the column.

A second key feature is that post-tensioning allows the columns to be built without the permanent corbels normally found in precast concrete construction. The post-tensioning has two purposes. First, the friction induced by the post-tensioning transfers vertical shears at the interface between beam and column for both gravity and lateral loadings. Second, with the post-tensioning deliberately designed to remain essentially elastic during the DBE, the post-tensioning forces the moment frame to return to its undeformed position following the DBE.

COMMENTARY

R1—INTRODUCTION AND SCOPE

R1.1—Introduction

Laboratory studies (Stone et al. 1995; Hawkins and Ishizuka 1988; Priestley 1996; Priestley and MacRae 1994; Palmieri et al. 1996; Nakaki et al. 1999; Priestley et al. 1999; Day 1999) have shown that precast or prestressed concrete moment frames can provide safety and serviceability levels, during and after an earthquake, that meet or exceed performance levels required by 21.1.1.8 of ACI 318M-11. To achieve such performance levels, the precast or prestressed concrete moment frames should be carefully proportioned and detailed. This Standard is based on the studies reported by Stone et al. (1995), Hawkins and Ishizuka (1988), Priestley and MacRae (1994), Priestley (1996), Nakaki et al. (1999), Priestley et al. (1999), and Day (1999). It contains the minimum requirements for ensuring that one type of precast and prestressed concrete moment frame can sustain a series of oscillations into the inelastic range of response without critical decay in strength or excessive story drifts. Further, that frame should show only minimal or no damage in beam-column joint regions and no permanent displacements after the oscillations cease.

A typical interior frame for this seismic-force-resisting system is illustrated in Fig. R1.1. Details for a vertical longitudinal section of the beam as it passes through the column are shown in Fig. R1.1(b), and details for cross sections of the beam at the column face (Section B) and on the centerline of the column (Section C) are shown in Fig. R1.1(c). The frame is composed of multistory columns to which single-bay precast concrete beams are connected. Except for possible yielding at the column bases, the interfaces between the precast beams and the continuous columns are the only locations where yielding of the reinforcement (nonlinear action location) occurs in the frame during a major earthquake. Crossing each interface are three deliberately debonded reinforcement elements: post-tensioned strands that extend the full length of the frame in the direction of its plane; and top and bottom deformed bar energy-dissipating reinforcement that is anchored by grouting in ducts preformed in the beam and column. The length over which the energy-dissipating reinforcement is debonded in the beam adjacent to the connection is selected deliberately to provide the desired design level of overall performance. Cheok et al. (1996) describes the development of a rational basis for the design procedures for a frame with equal strength for the top and bottom partially debonded energy-dissipating reinforcement and central post-tensioning tendons that remain elastic during a major earthquake. Stanton and Nakaki (2002) describe design guidelines for the same frame system using an iterative step-by-step procedure and displacement-based design procedures. Hawileh et al. (2006) provide nondimensional, noniterative, simplified design procedures for that same system for either displacement-based or force-based design procedures. Where force-based design procedures are used, ASCE/SEI