An ACI Standard

Code Requirements for the Design of Precast Concrete Diaphragms for Earthquake Motions (ACI 550.5M-18) and Commentary

Reported by Joint ACI-ASCE Committee 550

ACI 550.5M-18

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This standard describes code requirements for the design of precast concrete diaphragms subject to earthquake motions where used under the design provisions of ASCE/SEI 7-16 Section 12.10.3 and ACI 318M. The response of precast concrete diaphragms under earthquake motions depends primarily on the strength, stiffness, and deformation capacities of the connectors and the reinforcement at joints between the precast concrete members. The seismic forces specified in ASCE/SEI 7 for the design of precast concrete diaphragms, their chords, and collectors in structures assigned to Seismic Design Category (SDC) C, D, E, or F are tied to force reduction factors specified in ASCE/SEI 7-16 Chapter 12, and to the shear overstrength provided by the connections and the reinforcement at joints specified in ASCE/SEI 7-16 Chapter 14. The shear overstrength depends on the design methodology, elastic or ductile, used for the diaphragm and targets elastic response for the maximum considered earthquake for shear connections regardless of the design option selected. The design option that can be used depends on the assigned design category and on the span and aspect ratio of the diaphragm. The selection of the design option is associated with minimum requirements for the tensile deformation capacity of the connections and the reinforcement at joints.

Keywords: connections; diaphragms; earthquake-resistant structures; precast concrete; seismic design.

ACI 550.5M-18 was adopted August 13, 2018, and published September 2018.

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CHAPTER 1—GENERAL

1.1—Introduction

1.1.1 Consistent with ACI 318M requirements for analysis, this standard specifies expected performance and design requirements for precast concrete diaphragms subject to earthquake loading. This standard is meant to replace the design procedure for precast concrete diaphragms for structures assigned to Seismic Design Category (SDC) C, D, E, or F that was developed and accepted for use by ASCE/SEI 7-16 in Section 14.2.4. The procedure described herein and that of ASCE/SEI 7-16 supplement the provisions of Chapter 18 of ACI 318M-14 and do not supplant them.

1.1.2 The procedure described herein may also be used for precast concrete diaphragms in structures assigned to SDC B.

R1—GENERAL

R1.1—Introduction

Precast concrete diaphragms are extensively used for parking structures and residential and commercial buildings. Those diaphragms frequently consist of large precast, prestressed concrete members such as double-tee (DT) or hollow-core (HC) members. Double-tee members are connected to one another through discrete mechanical connections or by reinforcement that crosses the joint between members. Industry practice is to use these DT diaphragms in an untopped condition in buildings assigned to SDC A and B, and in a topped condition in buildings assigned to SDC C, D, E, or F. Hollow-core members are primarily used in an untopped condition in buildings assigned to SDC A and B.

Design requirements for precast concrete diaphragms are covered by the general provisions of ACI 318M. However, unless a precast concrete diaphragm includes a topping that meets all the prescriptive requirements for diaphragms in Chapter 18 of ACI 318M-14, the precast concrete diaphragm cannot be designed directly using that chapter. For DT diaphragms made composite with a topping or without a topping, structural integrity and force transfer within the diaphragm are provided by the discrete web and chord connections that join the individual precast concrete members. If a precast concrete diaphragm made composite with a topping or without a topping is to provide a structural system with an earthquake loading performance equal to or exceeding that of a comparable cast-in-place concrete diaphragm, accurate knowledge of the strength, stiffness, and deformability of the individual connections used in the diaphragm is needed. Results from tests on individual connections in accordance with ACI Standard 550.4M-18 are needed to obtain the information on stiffness, shear strength, tensile strength, and tensile deformation capacity required for the design of connections and reinforcement at joints for precast concrete diaphragms satisfying the lateral load performance requirements of this standard, Section 12.10.3 of ASCE/SEI 7-16, and Chapter 18 of ACI 318M-14.

Post-earthquake reconnaissance following the 1994 Northridge earthquake (Iverson and Hawkins 1994) revealed that when precast concrete diaphragms with topping of 75 mm or less were subjected to significant earthquake motions, the topping was likely to crack along the edges of the precast concrete members. Consequently, reinforcement crossing the edges was susceptible to damage and the degree of susceptibility increased as the aspect ratio for the diaphragm increased and as the larger dimension of the diaphragm between seismic-force-resisting vertical elements increased.

Those observations on the behavior of large precast concrete diaphragms resulted in a comprehensive research study (Fleischman 2014) to develop better design models for precast concrete diaphragms and comprehensive studies of the strength and deformation capacity of diaphragm connections. In the improved design methodology resulting from that research, the choice of connection type is tied to the tension deformations and shear overstrength needed in the diaphragm to achieve the required design performance.

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Where connections with limited deformation capacity are used, the earthquake design forces need to be higher than for ductile connections. The choice of the appropriate overstrength that should be used in diaphragm design requires detailed knowledge of the strength and deformation capacities of the diaphragm connections for the differing combinations of force and deformation experienced by the connections.

1.2—Scope

1.2.1 This standard shall apply to precast concrete diaphragms and collectors that are part of the seismic-force-resisting system in structures assigned to SDC C, D, E, or F. It is permissible to use this standard for the design of the same elements in structures assigned to SDC B.

1.2.2 This standard shall apply to precast concrete diaphragms, including a) through c):

a) Diaphragms that consist of a cast-in-place composite topping slab with a thickness of less than 75 mm on precast concrete members

b) Diaphragms that comprise precast concrete members with end strips formed by either a cast-in-place composite topping or edge beams

c) Diaphragms of interconnected precast concrete members without cast-in-place concrete topping.

1.3—Structural drawings

Structural drawings for precast concrete diaphragms shall show all features of the members into which the connectors or reinforcement at joints are cast that are essential to the intended seismic performance of the diaphragms and all details of the connections or reinforcement at joints essential for attainment of that intended performance.

Essential details shall include:

a) The anchorage of the connectors and reinforcement at joints into the precast concrete member

b) The procedures and materials by which the connection between connectors in adjacent members shall be made and the tolerances that are acceptable

c) Supplemental reinforcement that shall be included in the precast concrete members to ensure that the performance of the member under earthquake loading does not materially affect the measured response of the connections between members

d) The methods to be used to ensure composite action, as specified in the design, between topping and precast concrete member

e) The connection of the collectors and the adjacent precast concrete members to the vertical elements of the seismic-force-resisting system

f) The quality control and special inspection procedures governing placement of connectors and completion of connections

R1.3—Structural drawings

Reinforcement details in the vicinity of the connectors and the means and procedures by which the connections between the precast concrete members are completed affect the performance of the connection. Details should be specified completely, including tolerances, and fully documented on the structural drawings for the diaphragm.