ACI 423.3R-17

Recommendations for Concrete Members Prestressed with Single-Strand Unbonded Tendons

Reported by Joint ACI-ASCE Committee 423

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This report provides information for the design of flexural concrete members in buildings post-tensioned with single-strand unbonded tendons. The report is intended to complement the commentary in ACI 318 and to provide suggestions for revisions and additions to ACI 318. Consideration is given to design for gravity and lateral loads, determination of fire endurance, design for seismic forces, and design for catastrophic loading. Recommendations concerning details and properties of tendons, protection against corrosion, and construction procedures are presented.

Keywords: concrete slabs; cracking; fire resistance; joints; punching shear; unbonded post-tensioning.

CONTENTS

ACI 423.3R-17 supersedes ACI 423.3R-05 and was adopted and published July 2017.

CHAPTER 1—INTRODUCTION

1.1—General

Since the publication of previous ACI 423.3R reports, many of their recommendations have been incorporated into ACI 318. All references to ACI 318 refer to ACI 318-14 unless specifically noted. The recommendations in this report have been prepared to provide a comprehensive guide for design, materials, and construction for concrete members prestressed with single-strand unbonded tendons. Suggested revisions and additions to ACI 318 are also included in this report. Mandatory language used in this report reflects requirements in ACI 318.

1.2—Objective

This report presents recommendations for design, materials, and construction for concrete structures prestressed with unbonded tendons that are commensurate with the strength, serviceability, and safety requirements of ACI 318. Practitioners should use their judgment when applying the recommendations of this report. This report is not intended for reference in a specification or a code.

1.3—Scope

Recommendations pertinent to design with single-strand unbonded tendons considered in this report include the design of slabs, beams, and continuous members; details and properties of tendons and anchors; and protection from corrosion during construction and throughout the life of the structure.

The recommendations in this report are not intended for unbonded construction stages of elements using bonded tendons; for multistrand unbonded tendons used as external tendons; for members subject to direct tension, such as tiebacks, cable stays, arch ties, or circumferential tendons for containment structures; or for ground-supported post-tensioned slabs for light residential construction.

CHAPTER 2—NOTATION AND DEFINITIONS

2.1—Notation

A_b = net bearing plate area, in.^{2} (mm^2)
A_b' = maximum area of the portion of the concrete anchorage surface that is geometrically similar to and concentric with the area of the anchorage, in.^{2} (mm^2)
A_c' = cross-sectional area of the slab, perpendicular to the slab edge, between the center of the exterior span and the slab edge, in.^{2} (mm^2)
A_{cf} = larger of gross cross-sectional areas of the slab-beam strips of the two orthogonal equivalent frames intersecting at the column, in.^{2} (mm^2)
A_{ps} = area of prestressed longitudinal tension reinforcement, in.^{2} (mm^2)
$A_{s\,min}$ = minimum bonded reinforcement in negative moment areas of two-way systems
b = width of compression face of member, in. (mm)
b_f = total flange width
b_n = effective overhang flange width for normal forces, in. (mm)
b_o = perimeter of critical section for two-way shear in slabs, in. (mm)
b_w = effective flange width for normal forces at post-tension anchor, in. (mm)
d_p = distance from extreme compression fiber to centroid of prestressing reinforcement, in. (mm)
E_s = modulus of elasticity of prestressing reinforcement, psi (MPa)
f_{ci}' = strength of concrete at time of initial prestress, psi (MPa)
f_{cp} = permissible concrete compressive stress, psi (MPa)
f_{pc} = compressive stress in concrete, after allowance for all prestress losses, at centroid of cross section resisting externally applied loads or at junction of web and flange where the centroid lies within the flange, psi (MPa); in a composite member, f_{pc} is the resultant compressive stress at centroid of composite section, or at junction of web and flange where the centroid lies within the flange, due to both prestress and moments resisted by precast member acting alone, psi (MPa)

f_{ps} = stress in prestressing reinforcement at nominal flexural strength, psi (MPa)
$f_{ps\theta}$ = stress in post-tensioned tendons at nominal strength at high temperatures, psi (MPa)
f_{pu} = specified tensile strength of prestressing reinforcement, psi (MPa)
$f_{pu\theta}$ = tensile strength of tendons at high temperatures, psi (MPa)
f_{se} = effective stress in prestressing reinforcement, after allowance for all prestress losses, psi (MPa)
f_y = specified yield stress of reinforcement, psi (MPa)
h = slab thickness, in. (mm)
L = span length of beam or one-way slab; clear projection of cantilever, in. (mm)
ℓ = length of tendon, in. (mm)
M = total applied static moment (unfactored), lb-in. (kN-m)
M_{tq}^+ = retained midspan moment, lb-in. (kN-m)
$M_{t1\theta}^-$ = retained negative moment capacity at Column 1, lb-in. (N-m)
$M_{t2\theta}^-$ = retained negative moment capacity at Column 2, lb-in. (N-m)
N_c = resultant tensile force acting on the portion of the concrete cross section that is subjected to tensile stresses due to the combined effects of service loads and effective prestress, lb (N)
P = average force in the prestressing reinforcement, lb (N)
V_p = vertical component of effective prestress forces crossing the critical section
v_c = stress corresponding to nominal two-way shear strength provided by concrete, psi (MPa)
v_{cw} = nominal shear stress provided by concrete where diagonal cracking results from high principal tensile stress in web, lb (N)
w = uniformly distributed load, plf (kN/m)
α_s = constant used to calculate V_c in slabs, lb (MPa)
Δ_ℓ = tendon elongation, in. (mm)
ϕ = strength reduction factor
λ = modification factor to reflect the reduced mechanical properties of lightweight concrete
ρ_p = ratio of A_{ps} to bd_p

2.2—Definitions

ACI provides a comprehensive list of definitions through an online resource, "ACI Concrete Terminology," https://www.concrete.org/store/productdetail.aspx?ItemID=CT16. Definitions provided herein complement that source.

encapsulated tendon—a tendon that is completely enclosed in a watertight covering from end to end, including anchorages, sheathing, post-tensioning coating, sleeves, and an encapsulation cap over the strand tail at each end.

post-tensioning coating—material between prestressing reinforcement and sheathing used to protect against corrosion and reduce friction.

prestressing reinforcement—strand, wire, or bar tensioned to impart forces to the concrete.

sheathing—material encasing prestressing reinforcement to prevent bonding of the prestressing reinforcement with the surrounding concrete, to provide corrosion protection, and to contain the corrosion-inhibiting coating.

CHAPTER 3—MEMBER DESIGN

3.1—General

The design provisions of ACI 318 apply to the contents of this chapter, but some recommendations are offered that complement those of ACI 318. Significant changes were made in ACI 318-02, ACI 318-08, ACI 318-11, and ACI 318-14 that impact the design of prestressed concrete members and unify the design approach for prestressed and nonprestressed members. ACI 318 limits for flexural reinforcement and moment redistribution are specified in terms of the net tensile strain in the extreme tension reinforcement ε_t. Prestressed members are grouped into three design categories: uncracked (U), transition (T), and cracked (C). Each category is defined according to the maximum calculated flexural tensile stress under service load conditions. For C members, there is no upper limit on calculated flexural tensile stresses under service loads, and any combination of stressed and unstressed reinforcement is permitted. Serviceability requirements related to C and T members are given in ACI 318.

3.2—One-way systems

One-way slabs are addressed in ACI 318-14 Chapter 7. The chapter organization provides design limits, required strength, required design strength, reinforcement limits, and reinforcing detailing.

3.2.1 *Minimum bonded reinforcement*—The minimum bonded reinforcement required in ACI 318-14, 7.6.2, is considered adequate to limit crack widths due to dead load and live load by providing adequate crack distribution (Burns et al. 1978; Yamazaki et al. 1969; Burns and Pierce 1967). This amount of reinforcement also provides an independent load-carrying system in the event of a catastrophic failure of the tendons or abnormal loading in one span of a continuous one-way post-tensioned element with unbonded tendons. For this reason, ACI 318-14, 7.7.4.2, requires that bonded reinforcement used as part of the design moment strength be detailed in accordance with the provisions of ACI 318-14, 7.7.3. Such bonded reinforcement provides an independent load path in one-way systems.

All prestressed concrete slabs (Classes U, T, and C) in ACI 318-11 were exempt from the reinforcement spacing limits in ACI 318-11, 7.6.5 (deformed flexural reinforcement spacing to be less than 3h and 18 in. [610 mm]). However, this requirement was changed in 7.7.2 of ACI 318-14 for Class C prestressed concrete slabs to make it similar to nonprestressed. Based on field experience with the performance of Class U and Class T unbonded post-tensioned slabs, the maximum spacing of the deformed reinforcement should be limited to six times the slab thickness or 36 in. (910 mm), whichever is less. Extension requirements for