CHAPTER 11 — ONE-WAY SLABS

11.1 — Scope

11.1.1 — The provisions of this chapter shall apply to the design of nonprestressed and prestressed slabs reinforced for flexure in one direction, including:

a) slabs cast on stay-in-place, noncomposite steel deck
b) composite slabs of interconnected concrete elements
c) hollow-core slabs

11.2 — General

11.2.1 — The effects of concentrated loads and openings shall be considered in design.

11.2.2 — Materials

11.2.2.1 — Design properties for concrete shall conform to Chapter 5.

11.2.2.2 — Design properties for steel reinforcement shall conform to Chapter 6.

11.2.3 — Connection to other members

11.2.3.1 — For cast-in-place slabs, transmission of column loads through the slab system shall conform to 17.2.

11.2.3.2 — For precast slabs, connections shall conform to the force transfer requirements of 17.3.

11.3 — Design Limits

11.3.1 —Minimum slab thickness

11.3.1.1 — For solid nonprestressed slabs not supporting or attached to partitions or other construction likely to be damaged by large deflections, overall slab thickness ***h*** shall not be less than the limits in Table 11.3.1.1, unless the deflection requirements of 11.3.2 are satisfied.

Table 11.3.1.1 — Minimum thickness of solid nonprestressed one-way slabs

Support conditions	Minimum *h*, in.	
Simply supported	**ℓ /20**	**(a)**

One end continuous	**ℓ /24**	**(b)**
Both ends continuous	**ℓ /28**	**(c)**
Cantilever	**ℓ /10**	**(d)**

11.3.1.1.1 — For f_y other than 60,000 psi, the values in Table 11.3.1.1 shall be multiplied by (**0.4** + f_y /**100,000**).

11.3.1.1.2 — For nonprestressed slabs made of lightweight concrete having w_c in the range of 90 to 115 lb/ft^3, the values in Table 11.3.1.1 shall be multiplied by the greater of (a) and (b):

(a) **1.65 – 0.005w_c**

(b) **1.09**

11.3.1.1.3 — For nonprestressed composite concrete slabs, shored during construction, and made of a combination of lightweight and normalweight concrete components, the portion of the member in compression shall determine if 11.3.1.1.2 applies.

11.3.1.2 — The thickness of a concrete floor finish shall be permitted to be included in ***h*** if it is placed monolithically with the floor slab, or if the floor finish is designed to be composite with the floor slab in accordance with 17.7.

11.3.2 — Calculated deflection limits

11.3.2.1 — For nonprestressed slabs not satisfying 11.3.1 and for prestressed slabs, deflections shall be calculated in accordance with 10.2.3 through 10.2.5 and shall not exceed the deflection limits in Table 10.2.2.

11.3.2.2 — For nonprestressed composite concrete slabs satisfying 11.3.1, deflections occurring after the member becomes composite need not be calculated. The long-term deflection of the slab shall be investigated for magnitude and duration of load before composite action becomes effective.

11.3.3 — Reinforcement strain limit: nonprestressed slabs

11.3.3.1 — For nonprestressed slabs, calculated ε_t shall be at least 0.004.

11.3.4 —Stress limits: prestressed slabs

11.3.4.1 — Prestressed slabs shall be classified as Class U, T, or C in accordance with 10.5.2.

11.3.4.2 — Stresses in prestressed slabs immediately after transfer and at service loads shall not exceed the permissible stresses in 10.5.

11.4 — Required strength

11.4.1 — General

11.4.1.1 — Required strength shall be calculated in accordance with the factored load combinations defined in Chapter 7 and analysis procedures defined in Chapter 8.

11.4.2 — Factored moment

11.4.2.1 — For slabs built integrally with supports, M_u at the support shall be permitted to be calculated at face of support.

11.4.3 — Factored shear

11.4.3.1 — For slabs built integrally with supports, V_u at the support shall be permitted to be calculated at face of support.

11.4.3.2 — Sections between the face of support and the critical section defined in Table 11.4.3.2 shall be permitted to be designed for V_u at the critical section if (a) through (c) are satisfied:

(a) Support reaction, in direction of applied shear, introduces compression into the end region of the slab;

(b) Loads are applied at or near the top surface of the slab;

(c) No concentrated load occurs between face of support and critical section.

Table 11.4.3.2 — Location of critical section for one-way shear in slabs

Type of slab	Distance from the face of support	
Nonprestressed	d	(a)
Prestressed	$h/2$	(b)

11.5 — Design strength

11.5.1 — General

11.5.1.1 — Design strength at all sections along the slab shall be in accordance with (a) and (b) for each applicable factored load combination.

(a) $\phi_f M_n \geq M_u$

(b) $\phi_v V_n \geq V_u$

11.5.2 — Flexure

11.5.2.1 — $\phi_f M_n$ shall be calculated in accordance with 9.3.

11.5.3 — Shear

11.5.3.1 — $\phi_v V_n$ shall be calculated in accordance with 9.5.

11.5.3.2 — For composite concrete slabs, horizontal shear strength**,** $\phi_v V_{nh}$, shall be calculated in accordance with 17.7.

11.6 — Reinforcement limits

11.6.1 — General

11.6.1.1 — Minimum reinforcement shall be as required by this section.

11.6.2 — Flexure: nonprestressed slabs

11.6.2.1 —$A_{s,min}$ shall be in accordance with Table 11.6.2.1.

Table 11.6.2.1 — $A_{s,min}$**: nonprestressed one-way slabs**

Reinforcement Type	f_y, psi	$A_{s,min}$		
Deformed bars	< 60,000	$0.0020A_g$		(a)
Deformed bars or welded wire reinforcement	≥ 60,000	Greater of:	$\frac{0.0018 \times 60{,}000}{f_y} A_g$	(b)
			$0.0014\ A_g$	(c)

11.6.3 — Flexure: prestressed slabs

11.6.3.1 — For slabs with bonded prestressed reinforcement, total quantity of A_s and A_{ps} shall be adequate to develop a factored load at least 1.2 times the cracking load calculated on the basis of f_r as specified in 5.2.3.1.

11.6.3.2 — For slabs with both flexural and shear design strength at least twice the required strength, 11.6.3.1 shall not be required.

11.6.3.3 — For slabs with unbonded prestressed reinforcement, a minimum quantity of bonded deformed reinforcement A_s shall be provided in accordance with Eq. 11.6.3.3.

$$A_s \geq 0.004 A_{ct} \qquad (11.6.3.3)$$

where A_{ct} is the area of that part of the cross section between the flexural tension face and the center of gravity of the gross section.

11.6.4 — Shrinkage and temperature reinforcement

11.6.4.1 — Deformed reinforcement

11.6.4.1.1 — Deformed shrinkage and temperature reinforcement perpendicular to flexural reinforcement shall be provided in accordance with 10.4.4.

11.6.4.2 — Prestressed reinforcement

11.6.4.2.1 — Prestressed shrinkage and temperature reinforcement perpendicular to flexural reinforcement shall be provided in accordance with 10.4.5.

11.6.4.2.2 — For monolithic, cast-in-place, post-tensioned beam-and-slab construction, gross concrete area shall consist of the total beam area including the slab thickness and the slab area within half the clear distance to adjacent beam webs. It shall be permitted to include the effective force in beam tendons in the calculation of total prestress force acting on gross concrete area.

11.6.4.2.3 — If slabs are supported on walls or not cast monolithically with beams, gross concrete area is the slab section tributary to the tendon or tendon group.

11.6.4.2.4 — At least one tendon is required in the slab between faces of beams or walls.

11.6.5 — Shear

11.6.5.1 —As required by Table 11.6.5.1, a minimum amount of shear reinforcement $A_{v,min}$ shall be provided in accordance with 13.6.4.2.

Table 11.6.5.1: Minimum shear reinforcement

Slab Type	Condition	$A_{v,min}$
Hollow-core with untopped h > 12.5 in.	$V_u > 0.5\phi_v V_{cw}$	Required
Other	$V_u > \phi_v V_c$	Required

11.6.5.2 — The requirements of 11.6.5.1 shall be permitted to be waived if shown by testing that the required M_n and V_n can be developed. Such tests shall simulate effects of differential settlement, creep, shrinkage, and temperature change, based on a realistic assessment of these effects occurring in service.

11.7 — Reinforcement detailing

11.7.1 — General

11.7.1.1 — Flexural reinforcement shall be uniformly distributed as close as practicable to the concrete surface in tension.

11.7.1.2 — Concrete cover for reinforcement shall be in accordance with 6.10.5.

11.7.1.3 — Development lengths of deformed and prestressed reinforcement shall be calculated in accordance with 21.3.

11.7.1.4 — Splice lengths of deformed reinforcement shall be calculated in accordance with 21.4.

11.7.1.5 — Bundling of bars shall be calculated in accordance with 21.5.

11.7.2 — Flexural reinforcement: spacing

11.7.2.1 — Minimum s shall be in accordance with 21.2.

11.7.2.2 — Maximum **s** of deformed reinforcement shall be the lesser of 3***h*** and 18 in.

11.7.2.3 — For nonprestressed and Class C prestressed slabs, spacing of bonded reinforcement closest to the tension face shall not exceed s required in 10.3.

11.7.3 — Flexural reinforcement: nonprestressed slabs

11.7.3.1 — General

11.7.3.1.1 — Calculated tension or compression force in reinforcement at each section of the slab shall be developed on each side of that section.

11.7.3.1.2 — Critical locations for development of reinforcement are at points of maximum stress and at points within the span where adjacent reinforcement terminates or is bent.

11.7.3.1.3 — Reinforcement shall extend beyond the point at which it is no longer required to resist flexure for a distance equal to the greater of ***d*** or $\mathbf{12}d_b$, except at supports of simply-supported spans and at free ends of cantilevers.

11.7.3.1.4 — Continuing flexural tensile reinforcement shall have an embedment length not less than ℓ_d beyond the point where terminated tensile reinforcement is no longer required to resist flexure.

11.7.3.1.5 — Flexural tensile reinforcement shall not be terminated in a tensile zone unless (a) or (b) is satisfied.

(a) V_u at the cutoff point does not exceed $(2/3)\phi_v V_n$;

(b) For No. 11 bars and smaller, continuing reinforcement provides double the area required for flexure at the cutoff point and V_u does not exceed $(3/4)\phi_v V_n$.

11.7.3.1.6 — In slabs not exceeding 10 ft in span, welded wire reinforcement, with wire size not greater than W5 or D5, shall be permitted to be curved from a point near the top of slab over the support to a point near the bottom of slab at midspan, provided such reinforcement is continuous over, or developed at, the support.

11.7.3.2 — Reinforcement termination: slabs at simple supports

11.7.3.2.1 — At least one-third the maximum positive moment reinforcement shall extend along the slab bottom into the support a minimum of 6 in. For precast slabs, such reinforcement shall extend at least to the center of the bearing length.

11.7.3.2.2 — If reinforcement terminates beyond the centerline of supports by a standard hook or a mechanical anchorage at least equivalent to a standard hook, 11.7.3.2.3 and 11.7.3.2.4 need not be satisfied.

11.7.3.2.3 — At simple supports, d_b for positive moment tensile reinforcement shall be limited such that ℓ_d for that reinforcement satisfies Eq. 11.7.3.2.3.

$$\ell_d \le M_n/V_u + \ell_a \qquad (11.7.3.2.3)$$

where:

M_n is calculated assuming all reinforcement at the section is stressed to f_y;
V_u is calculated at the section; and
ℓ_a is the embedment length beyond the center of the support.

11.7.3.2.4 — If the ends of reinforcement at a support are confined by a compressive reaction, d_b for positive moment tensile reinforcement shall be limited such that ℓ_d for that reinforcement satisfies Eq. 11.7.3.2.4.

$$\ell_d \le 1.3M_n/V_u + \ell_a \qquad (11.7.3.2.4)$$

11.7.3.3 — Reinforcement termination: Continuous slabs

11.7.3.3.1 — At least one-fourth the maximum positive moment reinforcement shall extend along the slab bottom into the continuous support a minimum of 6 in.

11.7.3.3.2 — At points of inflection, d_b for positive moment tensile reinforcement shall be limited such that ℓ_d for that reinforcement satisfies Eq. 11.7.3.3.2.

$$\ell_d \leq M_n/V_u + \ell_a \qquad (11.7.3.3.2)$$

where:

M_n is calculated assuming all reinforcement at the section is stressed to f_y;
V_u is calculated at the section; and
ℓ_a is the greater of d or $12d_b$.

11.7.3.3.3 — At least one-third the negative moment reinforcement at a support shall have an embedment length beyond the point of inflection greater than d, $12d_b$, and $\ell_n/16$.

11.7.4 — Flexural reinforcement: prestressed slabs

11.7.4.1 — Post-tensioned anchorage zones shall be designed and detailed in accordance with 18.5.

11.7.4.2 — Post-tensioning anchorages and couplers shall be designed and detailed in accordance with 21.6.

11.7.4.3 — If nonprestressed reinforcement is provided to satisfy flexural strength requirements, the detailing requirements of 11.7.3 shall be satisfied.

11.7.4.4 — Reinforcement termination: deformed reinforcement in slabs with unbonded prestressed reinforcement

11.7.4.4.1— Length of deformed reinforcement required by 11.6.3.3 shall be in accordance with (a) and (b).

(a) In positive moment areas, length of reinforcement shall be at least $\ell_n/3$ and be centered in that area.

(b) In negative moment areas, reinforcement shall extend at least $\ell_n/6$ on each side of support.

11.7.5 — Shrinkage and temperature reinforcement

11.7.5.1 — Shrinkage and temperature reinforcement in accordance with 10.4 shall be placed perpendicular to flexural reinforcement.

11.7.5.2 – Nonprestressed reinforcement

11.7.5.2.1 — Spacing of deformed shrinkage and temperature reinforcement shall not exceed the lesser of 5***h*** or 18 in.

11.7.5.3 – Prestressed reinforcement

11.7.5.3.1 — Spacing of slab tendons required by 11.6.4.2, and the distance between face of beam or wall to the nearest slab tendon, shall not exceed 6 ft.

11.7.5.3.2 — If spacing of slab tendons exceeds 4.5 ft., additional deformed shrinkage and temperature reinforcement conforming to 11.6.4.1 shall be provided parallel to the tendons, except 10.4.4.3 shall not apply. This shrinkage and temperature reinforcement shall extend from the slab edges for a distance not less than the slab tendon spacing.

11.7.6 — Shear reinforcement

11.7.6.1 — If required, transverse reinforcement shall be detailed according to 13.X.Y.

Based on the results of LB11-1, the provisions for one-way joists have been moved to Chapter 13, Beams.