ACI 408.1R-90

Suggested Development, Splice, and Standard Hook Provisions for Deformed Bars in Tension

Reported by ACI Committee 408

American Concrete Institute®

First Printing
1990

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Suggested Development, Splice, and Standard Hook Provisions for Deformed Bars in Tension*

Reported by ACI Committee 408

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This document presents recommendations for code provisions for development, splice length, and hooked anchorages for bars in tension. The recommendations explicitly consider cover, bar spacing, and transverse steel. There is no difference between development and splice length provisions, and hook design is independent of the development of straight bars.

Keywords: anchorage; bond; building codes; development length; hooks; reinforced concrete; reinforcing steel; splices; structural design.

CONTENTS

1.1—Development length of deformed bars in tension

1.1.1 The development length ℓ_d in inches, of deformed bars in tension shall be computed as the product of the basic development length, ℓ_{db}, from Section 1.1.2 and the applicable modification factor or factors in Section 1.1.3, but ℓ_d shall not be less than 12 in.

1.1.2 The basic development length, ℓ_{db}, for Grade 60 reinforcement may be computed by Section 1.1.2.1 if the limitations therein are satisfied. Otherwise, or to consider transverse reinforcement, Section 1.1.2.2 shall be used.

1.1.2.1 The basic development length for any of the bars in a layer where the clear cover of the bars is not less than 2 in. and the center-to-center spacing between bars is not less than 5 in. shall be taken as

$$\ell_{bd} = 23d_b/\phi \text{ for No. 6 and smaller and for } f'_c \text{ equal to or greater than 3000 psi} \quad \text{(A1)}$$

and

$$\ell_{bd} = 2200A_b{}^*/\phi\sqrt{f'_c} \text{ for No. 7 and larger} \quad \text{(A2)}$$

1.1.2.2 The basic development length shall be taken as

$$\ell_{bd} = \frac{5500A_b^{\dagger}}{\phi K\sqrt{f'_c}} \quad \text{(B)}$$

where K is the confinement factor which is a function of the actual concrete cover and the transverse reinforcement factor K_{tr}. Transverse steel provided for shear, flexure, or temperature may be included in K, provided it is placed outside the bar being developed.

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*No change is suggested for compression development and compression splices.

Minor revisions were done in 1989. The intent of the revisions is to make this document more compatible with terminology used in ACI 318-89. Certain items that are in ACI 318-89 regarding splice length and epoxy bar factors are noted in this document.

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1.1.3 The basic development length shall be multiplied by the applicable factor or factors for:†

1.1.3.1 Reinforcement having yield strength other than 60,000 psi ..... f_y/60,000

1.1.3.2 Top horizontal reinforcement where more than 12 in. of fresh concrete is cast in the member below the bar 1.3

1.1.3.3 Lightweight aggregate to replace all or a portion of the aggregate 1.25

1.1.3.4 Reinforcement in a flexural member (not subjected to seismic loads) in excess of that required..... A_{sr}/A_{sp}

1.2—Lap splices of deformed bars in tension

1.2.1 The minimum length for lap splices of bars in tension shall be taken equal to the development length ℓ_d in Section 1.1.‡ Only deformed bars #11 or smaller may be lap-spliced. The value of C_s reflects the effect of splicing only a portion of the reinforcement at one location; bars spliced greater than $\ell_d/2$ from another splice shall not be considered in the computation of C_s.

1.3—Splices and development of bundled bars in tension

1.3.1 The development or splice length of individual bars within bundles shall be that for the individual bar, increased 20% for a three-bar bundle and 33% for a four-bar bundle. Individual bar splices within a bundle shall not overlap.

1.3.2 The development and splice length of bundles shall be computed using Sections 1.1 and 1.2, with A_b being the combined area of the bars in the bundle taken as a single bar with its centroid at the centroid of the bundle and d_{be} taken as $\sqrt{A_b}$. Bundles shall not be spliced if d_{be} of the bundle is 1.5 in. or greater.

1.4—Standard hooks in tension

1.4.1 The development length ℓ_{dh} of a deformed bar in tension terminating in a standard hook shall be computed as the product of the basic development length ℓ_{hb} from Section 1.4.2 and the applicable factor or factors in Section 1.4.3, but ℓ_{dh} shall not be taken less than $8d_b$ or 6 in., whichever is greater.

1.4.2 The basic development length for Grade 60 hooked reinforcement shall be computed by

$$\ell_{hb} = \frac{960 d_b^{****}}{\phi\sqrt{f'_c}} \qquad \text{(C)}$$

1.4.3 The basic development length shall be multiplied by the applicable factor or factors for:

1.4.3.1 Reinforcement having yield strength other than 60,000 psi ..... f_y/60,000

1.4.3.2 *Confinement*

1.4.3.2.1 For # 11 bars or smaller with side cover normal to the plane of the hooked bar not less than 2-1/2 in. and cover on the tail extension of 90-degree hooks not less than 2 in. 0.7

1.4.3.2.2 For additional confinement by closed stirrups or hoops at a spacing of $3d_b$ or less ..... 0.

1.4.3.3 Lightweight aggregate replacing all or a portion of the aggregate 1.25

1.4.3.4 Reinforcement in a flexural member (not subjected to seismic loads) in excess of that required..... A_{sr}/A_{sp}

NOTATION

A_b = area of bar being developed, in.^{2}
A_{sp} = area of flexural reinforcement provided, in.^{2}
A_{sr} = area of required flexural reinforcement, in.^{2}
A_{tr} = area of transverse reinforcement crossing plane of splitting adjacent to a single anchored reinforcing bar. This reinforcement is parallel to the layer of bars for C_c and perpendicular to the layer of bars for C_s
C_c = the cover measured from extreme tension fiber to the outermost edge of the bar being developed, in.
C_s = the smaller of the cover measured along the line through the layer of bars, or half the clear distance between bars in the layer, in. For splices C_s shall be the smaller of the side cover to the edge of the outside bar, or one-half the clear spacing of bars spliced at the same location
d_b = diameter of main reinforcement, in.
d_{be} = equivalent diameter of a bundle, in.
f'_c = specified compressive strength of concrete, psi
f_h = stresses developed by standard hook, psi
f_s = steel stress, psi
f_y = specified yield strength of anchored bar, psi
f_{yt} = specified yield strength of transverse reinforcement, psi
K = the smaller of: (a) $0.5d_b + C_c + K_{tr}$; or (b) $00.5d_b + C_s + \Sigma K_{tr}/n$, but no larger than $3d_{db}$
K_{tr} = an index of the transverse reinforcement provided along the bar being developed, $A_{tr} \cdot f_{yt}/1500s$ in inches, calculated for each bar being developed. This constant 1500 carries the unit of lb/in.^{2}. The value of K_{tr} shall be taken as not more than d_b and, for it to be considered, at least three transverse bars shall be provided within ℓ_d
ΣK_{tr} = sum of K_{tr} values along plane of splitting
ℓ_d = development length, in.
ℓ_{db} = basic development length of a straight bar, in.
ℓ_{dh} = development length of hooked bars, in., including straight embedment between critical section and point of tangency of hook, bend radius, and one bar diameter
ℓ_{hb} = basic development length for a hooked bar, in.
n = number of bars along plane of splitting
s = maximum spacing of transverse reinforcement within ℓ_d, center-to-center, in.
ϕ = capacity reduction factor for development length and splices = 0.8

†Constant carries unit of lb/in.^{3}. In ACI 318-89, a factor for epoxy-coated reinforcement is included. The factor is 1.5 for cases where C_e or C_s is less than $3d_b$; otherwise, the factor is 1.2.

‡In ACI 318-89, the splice length is $1.0\ell_d$ for Class A splices (i.e., for cases where up to a maximum of 50% of A_s is spliced within the required splice length and where A_{sp}/A_{sr} is equal to or greater than 2). For Class B splices (i.e., for cases other than that described in Class A), the splice length is $1.3\ell_d$.

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