CODE

Table 25.4.2.5—Modification factors for development of deformed bars and deformed wires in tension

Modification factor	Condition	Value of factor
Lightweight λ	Lightweight concrete	0.75
	Normalweight concrete	1.0
Reinforcement grade ψ_g	Grade 280 or Grade 420	1.0
	Grade 550	1.15
	Grade 690	1.3
Epoxy[1] ψ_e	Epoxy-coated or zinc and epoxy dual-coated reinforcement with clear cover less than $3d_b$ or clear spacing less than $6d_b$	1.5
	Epoxy-coated or zinc and epoxy dual-coated reinforcement for all other conditions	1.2
	Uncoated or zinc-coated (galvanized) reinforcement	1.0
Size ψ_s	No. 22 and larger bars	1.0
	No. 19 and smaller bars and deformed wires	0.8
Casting position[1] ψ_t	More than 300 mm of fresh concrete placed below horizontal reinforcement	1.3
	Other	1.0

[1]The product $\psi_t\psi_e$ need not exceed 1.7.

25.4.3 *Development of standard hooks in tension*

25.4.3.1 Development length ℓ_{dh} for deformed bars in tension terminating in a standard hook shall be the greater of (a) through (c):

(a) $\left(\dfrac{f_y\psi_e\psi_r\psi_o\psi_c}{23\lambda\sqrt{f'_c}}\right)d_b^{1.5}$ with ψ_e, ψ_r, ψ_o, ψ_c, and λ given in 25.4.3.2

(b) $8d_b$

(c) 150 mm

25.4.3.2 For the calculation of ℓ_{dh}, modification factors ψ_e, ψ_r, ψ_o, ψ_c, and λ shall be in accordance with Table 25.4.3.2. At discontinuous ends of members, 25.4.3.4 shall apply.

COMMENTARY

the anchorage of epoxy-coated bars that show bond strength is reduced because the coating prevents adhesion and lowers the coefficient of friction between the bar and the concrete. The factors reflect the type of anchorage failure likely to occur. If the cover or spacing is small, a splitting failure can occur and the anchorage or bond strength is substantially reduced. If the cover and spacing between bars is large, a splitting failure is precluded and the effect of the epoxy coating on anchorage strength is not as large. Studies (Orangun et al. 1977) have shown that although the cover or spacing may be small, the anchorage strength may be increased by adding transverse reinforcement crossing the plane of splitting, and restraining the splitting crack.

Because the bond of epoxy-coated bars or zinc and epoxy dual-coated bars is already reduced due to the loss of adhesion and lower coefficient of friction between the bar and the concrete, an upper limit of 1.7 is established for the product of the factors for top reinforcement casting position and epoxy-coated reinforcement or zinc and epoxy dual-coated reinforcement.

The reinforcement size factor ψ_s reflects the more favorable performance of smaller-diameter reinforcement.

The reinforcement location or casting position factor ψ_t accounts for the position of the reinforcement in freshly placed concrete. The factor 1.3 is based on research (Jirsa and Breen 1981; Jeanty et al. 1988). The application of the casting position factor should be considered in determination of development lengths for inclined reinforcement.

R25.4.3 *Development of standard hooks in tension*

R25.4.3.1 The provisions for hooked bars are only applicable to standard hooks (refer to 25.3.1). The development length ℓ_{dh} is measured from the critical section to the outside end (or edge) of the hook.

In research by Sperry et al. (2017a), concrete breakout failure was the predominant failure mode of hooked bars. Closely-spaced hooks provide a lower strength per hooked bar than more widely-spaced hooked bars because the area of the breakout surface is reduced for the more closely-spaced bars (Ajaam et al. 2018). For bars located adjacent to the side of a member, the percentage of hooked bars exhibiting splitting failure increased with increasing bar size.

The effects of bar yield strength, spacing, and confinement by ties or stirrups have been updated to reflect test results (Sperry et al. 2018). The minimum values of ℓ_{dh} are specified to prevent failure by direct pullout in cases where a hook may be located near the critical section. Hooks in beam-column joints and corbels should be placed as close as practical to the back face of the joint.

R25.4.3.2 Unlike straight bar development, no distinction is made for casting position.