Development Length, l_d for Tension Bars

(ACI 318-08 Equation 12-1)

$$l_d = \frac{3}{40}\left(\frac{f_y}{\lambda\sqrt{f_c'}}\right)\left(\frac{\Psi_t\ \Psi_e\ \Psi_s}{\left(\frac{c_b + K_{tr}}{d_b}\right)}\right) d_b$$

In which $\left(\frac{c_b + K_{tr}}{d_b}\right)$ shall not be taken greater than 2.5

l_d = development length (in)

f_y = Yield strength of the tension rebars (psi)

f_c' = Compressive strength of Concrete (psi); $\sqrt{f_c'}$ **shall not exceed 100 psi**

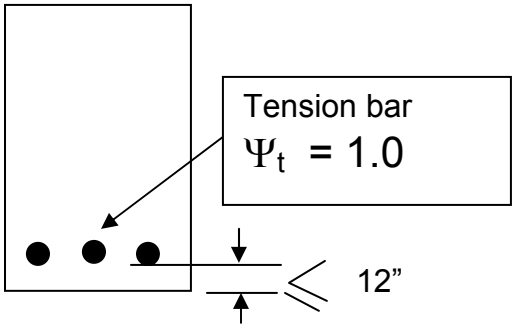
d_b = bar diameter (in)

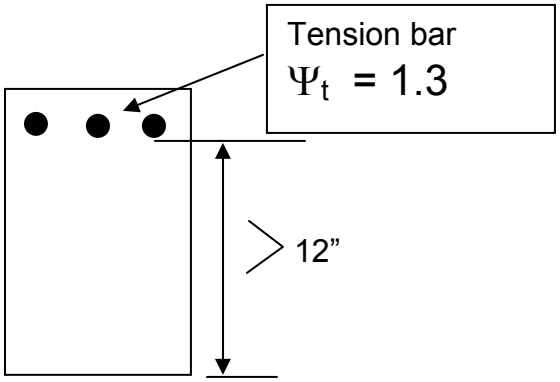
According to ACI 318-08, Section 12.2.4

1. Ψt is a rebar location factor that accounts for the position of rebars in freshly placed concrete.

Where the horizontal rebars so placed that more than 12 inch of fresh concrete is cast in the member below he development length or splice, use Ψ_t = 1.3 (ACI 12.2.4). This condition contributes to the formation of entrapped air and moisture underneath of the rebars, resulting in partial loses of bond between concrete and rebars.

For other reinforcement, use Ψ_t = 1.0





2. Ψ_e is rebar coating factor reflecting the effects of epoxy coating. Studies show that bond strength between rebar and concrete is reduced because of the coating prevents adhesion and friction between the rebar and concrete.

For epoxy coating bars having cover less than $3d_b$ or clear space between bars less than $6d_b$, use $\Psi_e = 1.5$

For all other conditions for epoxy coating bars, use $\Psi_e = 1.2$

For uncoated bars, use $\Psi_e = 1.0$

NOTE: $\Psi_t \times \Psi_e$ shall not be greater than 1.7 (ACI 12.2.4)

3. Ψ_s is a rebar size factor.

For #6 or smaller rebar, use $\Psi_s = 0.8$

For #7 or larger rebar, use $\Psi_s = 1.0$

4. λ (lamda) is a lightweight-aggregate concrete factor.

Normal-weight concrete is used, use $\lambda=1.0$
Sand-lightweight concrete is used, use $\lambda=0.85$
All-lightweight concrete is used, use $\lambda=0.75$

For lightweight-aggregate concrete when the average splitting tensile strength f_{ct} is not specified, use $\lambda=1.3$

When f_{ct} is specified, use

$$\lambda = f_{ct} / [6.7\sqrt{(f_c')}] \leq 1.0$$

5. The variable c_b represents the bar spacing or concrete cover (in). The value of c_b will be the smaller of either the distance from the center of bar to the nearest concrete surface (cover) or one-half the center-to-center spacing of bars being developed (spacing).

NOTES:

The rebar spacing “s” will be the actual center-to-center rebar spacing if adjucent rebars are all being developed at the same location.

However, if an adjucent rebar has been developed at another location, the spacing “s” to be used will be greater than the actual spacing to the adjucent rebars. This case, “s” should be the shortest center-to-center distance between two rebars being developed at the same location.

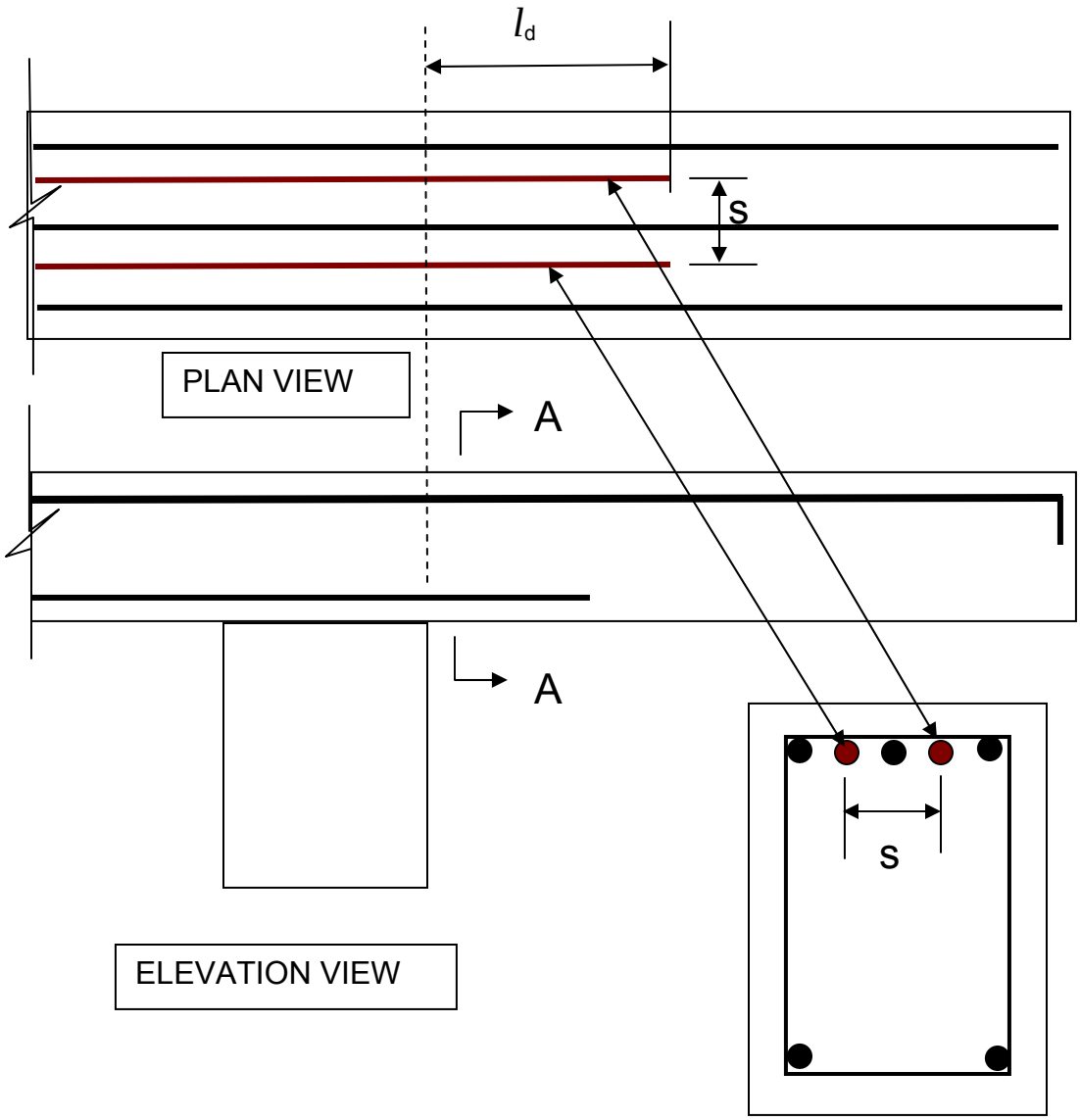


FIG. Spacing “s” for rebars being developed

6. K_{tr} = Transverse reinforcement index.

$$K_{tr} = \frac{40\ A_{tr}}{s\ n}$$

A_{tr} = total cross-sectional area (sq.in) of all transverse reinforcement that is within the spacing **s** and that crosses the potential plane of splitting through the rebar being developed.

s = maximum center-to-center spacing (in) of transverse bars within l_d.

n = number of bars being developed along the plane of splitting.

K_{tr} = 0 can be used for a design simplification.

ACI 318-08, Section 12.15

Splices of deformed bars and deformed wire in Tension

Class A Splice ……. 1.0 l_d (must not be less than 12 inch)

Class B Splice ……. 1.3 l_d (must not be less than 12 inch)

ACI 318-08, Section 12.16.1

Splices of deformed bars in Compresstion

Compression lap length

For f_y = 60,000 psi, or less, compression lap length = $\mathbf{0.0005\ f_y\ d_b}$ (must not be less than 12 inch)

For f_y greater than 60,000 psi, compression lap length = $\mathbf{(0.0009\ f_y - 24)d_b}$ (must not be less than 12 inch)

For f_c' less than 3,000 psi, lap length shall be increased by one-third.

Examples of compression lap length:

For f_y = 40,000 psi, Compression Lap length = 20 d_b

For f_y = 60,000 psi, Compression Lap length = 30 d_b

For f_y = 75,000 psi, Compression Lap length = 44 d_b