Bond and Development Length:

$$l_d = max\begin{cases} detailed\ or\ simplified\ equation \\ 300\ mm \end{cases} \quad \rightarrow straight\ Development\ length, SBC-18, 25.4.2.1$$

$$l_d = \begin{cases} \left[\dfrac{f_y \Psi_t \Psi_e}{2.1\lambda\sqrt{f_c'}}\right] d_b & d_b \leq 20 \\ \left[\dfrac{f_y \Psi_t \Psi_e}{1.7\lambda\sqrt{f_c'}}\right] d_b & d_b \geq 22 \end{cases} \quad \rightarrow simplified\ equation, SBC-18, 25.4.2.2$$

$$l_d = \left[\frac{f_y}{1.1\lambda\sqrt{f_c'}} \frac{\Psi_t \Psi_e \Psi_s}{\left(\frac{c_b + K_{tr}}{d_b}\right)}\right] d_b \quad \rightarrow detailed\ equation, SBC-18, 25.4.2.3$$

$$\frac{c_b + K_{tr}}{d_b} \leq 2.5 \quad \rightarrow requirement, SBC-18, 25.4.2.3$$

$$K_{tr} = \frac{40A_{tr}}{sn} \quad \rightarrow transverse\ reinforcement\ index, mm$$

$$c_b = min\begin{cases} distance\ to\ bar\ centroid \\ \frac{1}{2}\ center\ to\ center\ bar\ spacing \end{cases}$$

$$distance\ to\ bar\ centroid = cover + d_s + \frac{d_b}{2}$$

$$\frac{1}{2}\ center\ to\ center\ bar\ spacing = \frac{1}{2}\left(\frac{b - 2cover - 2d_s - d_b}{n-1}\right)$$

$$\lambda = \begin{cases} 0.75 & lightweight\ concrete \\ 1.0 & normal\ concrete \end{cases} \quad \rightarrow concrete\ weight\ factor, SBC-18, Table\ 25.4.2.4$$

$$\Psi_e = \begin{cases} 1.5 & coated, c < 3d_b\ or\ s < 6d_b \\ 1.2 & coated, other\ conditions \\ 1.0 & uncoated \end{cases} \quad \rightarrow coating\ factor, SBC-18, Table\ 25.4.2.4$$

$$\Psi_s = \begin{cases} 0.8 & d_b \leq 20 \\ 1.0 & d_b \geq 22 \end{cases} \quad \rightarrow reinforcement\ size\ factor, SBC-18, Table\ 25.4.2.4$$

$$\Psi_t = \begin{cases} 1.3 & top\ bars \\ 1.0 & bottom\ bars \end{cases} \quad \rightarrow reinforcement\ location\ factor, SBC-18, Table\ 25.4.2.4$$

$$l_{dh} = max \begin{cases} equation \\ 8d_b \\ 150\ mm \end{cases} \quad \rightarrow Development\ of\ standard\ hooks, SBC-18, 25.4.3.1$$

$$l_{dh} = \left(\frac{0.24 f_y \Psi_e \Psi_c \Psi_r}{\lambda\sqrt{f_c'}}\right) d_b \quad \rightarrow Development\ of\ standard\ hooks, SBC-18, 25.4.3.1$$

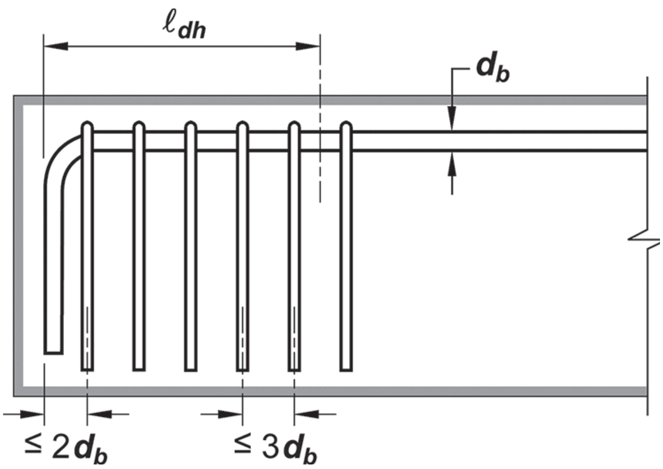
$$\lambda = \begin{cases} 0.75 & lightweight\ concrete \\ 1.0 & normal\ concrete \end{cases} \quad \rightarrow concrete\ weight\ factor, SBC-18, Table\ 25.4.3.2$$

$$\Psi_e = \begin{cases} 1.2 & coated \\ 1.0 & uncoated \end{cases} \quad \rightarrow coating\ factor, SBC-18, Table\ 25.4.3.2$$

$$\Psi_c = \begin{cases} 0.7 & d_b \le 36, side\ cover \ge 65, end\ cover \ge 50 \\ 1.0 & other \end{cases} \quad \rightarrow cover\ factor, SBC-18, Table\ 25.4.3.2$$

$$\Psi_r = \begin{cases} 0.8 & see\ figure \\ 1.0 & other \end{cases} \quad \rightarrow confining\ reinforcement\ factor, SBC-18, Table\ 25.4.3.2$$

enclosed along ℓ_{dh} within stirrups perpendicular to ℓ_{dh} at $s \le 3d_b$,



enclosed along the bar extension beyond hook including the bend within stirrups perpendicular to ℓ_{ext} at $s \le 3d_b$

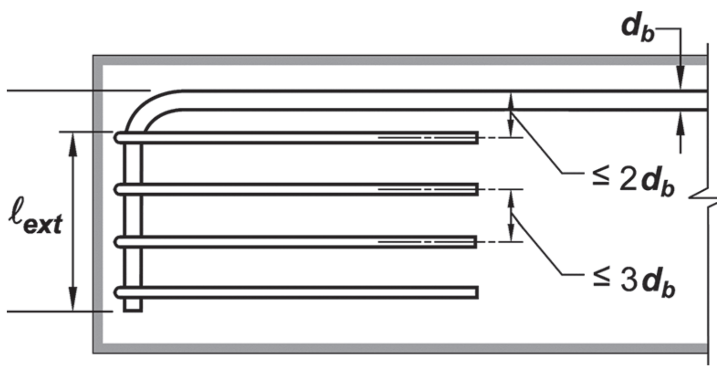
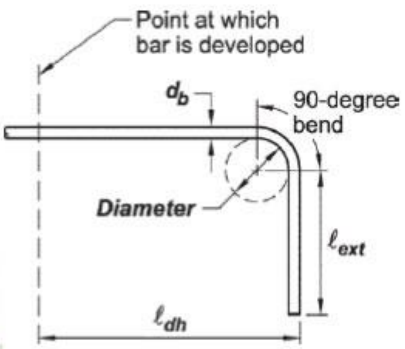
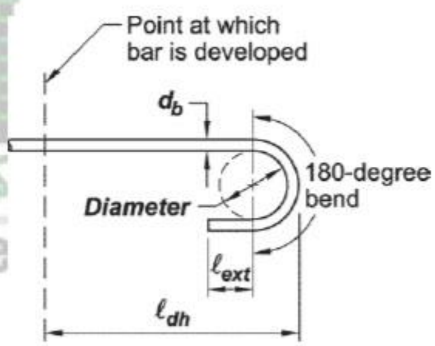
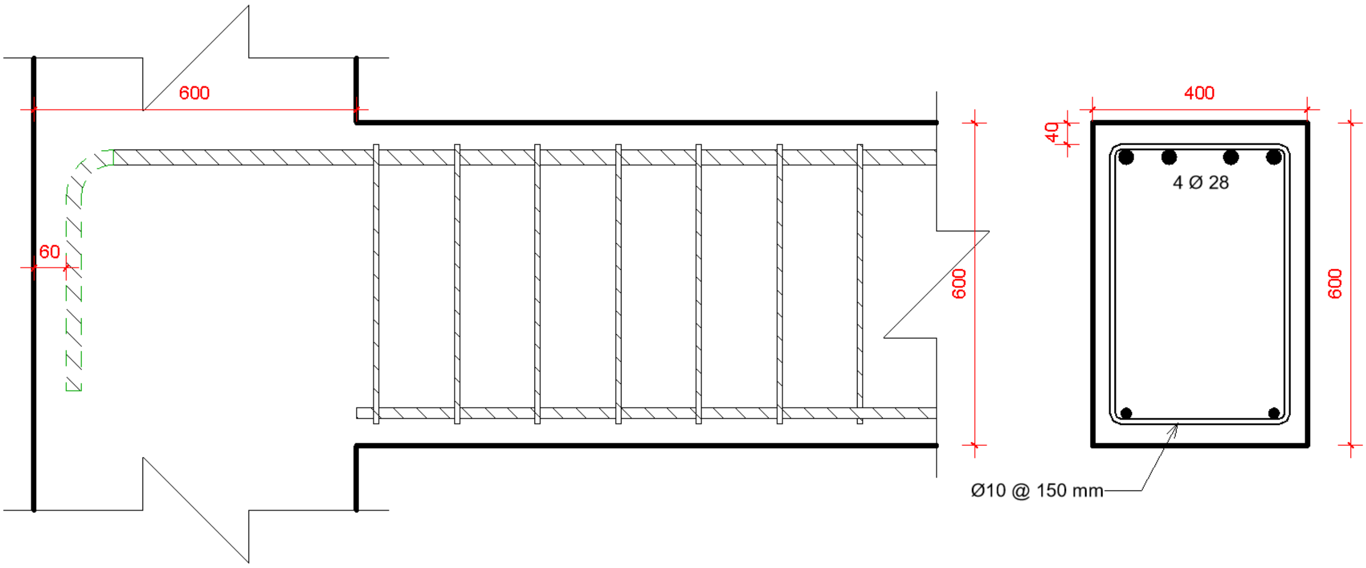


Table 25.3.1—Standard hook geometry for development of deformed bars in tension

Type of standard hook	Bar size	Minimum inside bend diameter, mm	Straight extension[1] l_{ext}, mm	Type of standard hook
90-degree hook	Dia 10 through Dia 25	$6d_b$	$12d_b$	
	Dia 28 through Dia 36	$8d_b$		
	Dia 45 and Dia 60	$10d_b$		
180-degree hook	Dia 10 through Dia 25	$6d_b$	Greater of $4d_b$ and 65 mm	
	Dia 28 through Dia 36	$8d_b$		
	Dia 45 and Dia 60	$10d_b$		



A 400×600 mm cantilever beam, reinforced by 4Ø28, is supported by a 400×600 mm column.

a) Calculate the required straight development length using the detailed equation assuming $K_{tr} = 0$. $f'_c = 35$ MPa, $f_y = 420$ MPa.

b) Is the width of the column sufficient to develop the bars straight? If not, design the suitable standard hook for the beam-column joint and draw the reinforcement details.

a)

$$\lambda = 1.0 \quad normal\ weight\ concrete$$

$$\Psi_t = 1.3 \quad top\ bars$$

$$\Psi_e = 1.0 \quad uncoated$$

$$\Psi_s = 1.0 \quad d_b = 28 \geq 22$$

$$K_{tr} = 0 \quad given$$

$$c_b = min \begin{cases} distance\ to\ bar\ centroid = cover + d_s + \frac{d_b}{2} = 40 + 10 + 14 = 64\ mm \\ \frac{1}{2}\ center\ to\ center\ bar\ spacing = \frac{1}{2}\left(\frac{400 - 2 \times 40 - 2 \times 10 - 28}{4 - 1}\right) = 45.33\ mm \end{cases}$$

$$c_b = 45.33\ mm$$

$$\frac{c_b + K_{tr}}{d_b} = \frac{45.33 + 0}{28} = 1.62 \leq 2.5 \rightarrow OK$$

$$l_d = \left[\frac{f_y}{1.1\lambda\sqrt{f_c'}} \frac{\Psi_t \Psi_e \Psi_s}{\left(\frac{c_b + K_{tr}}{d_b}\right)}\right] d_b = \left[\frac{420}{1.1 \times \lambda \times \sqrt{35}} \frac{1.3 \times 1.0 \times 1.0}{1.62}\right] d_b$$

$$l_d = 51.27 d_b = 51.27 \times 28 = 1435.6\ mm$$

b) l_d = 1435.6 mm is larger than the column dimensions (600 mm), standard hook should be used.

$$\lambda = 1.0 \qquad \textit{normal concrete}$$

$$\Psi_e = 1.0 \qquad \textit{uncoated}$$

$$\Psi_c = 1.0 \qquad d_b = 28 \leq 36, \textit{side cover} = 40 \leq 65, \textit{end cover} = 60 \geq 50$$

$$\Psi_r = 1.0 \qquad \textit{assumed since no available information}$$

$$l_{dh} = \left(\frac{0.24 \times 420 \times 1.0 \times 1.0 \times 1.0}{1.0 \times \sqrt{35}}\right) d_b = 17.04 d_b = 17.04 \times 28 = 477.07\ mm$$

Room available for hook development = column dimension – end cover = 600 – 60 = 540 mm

Hook development length = 477.07 mm < available room = 540 mm ➔ OK

Check if 90° hook can be used.

- Minimum inside bend diameter from SBC304-18, Table 25.3.1 = $8d_b$ = 224 mm
- Minimum straight extension l_{ext} from SBC304-18, Table 25.3.1 = $12d_b$ = 336 mm
- Total required hook tail height = bend dia/2 + l_{ext} + d_b = 224/2 + 336 + 28 = 476 mm
- Available room for hook tail = h – 2 clear covers = 600 - 2×50 = 500 mm

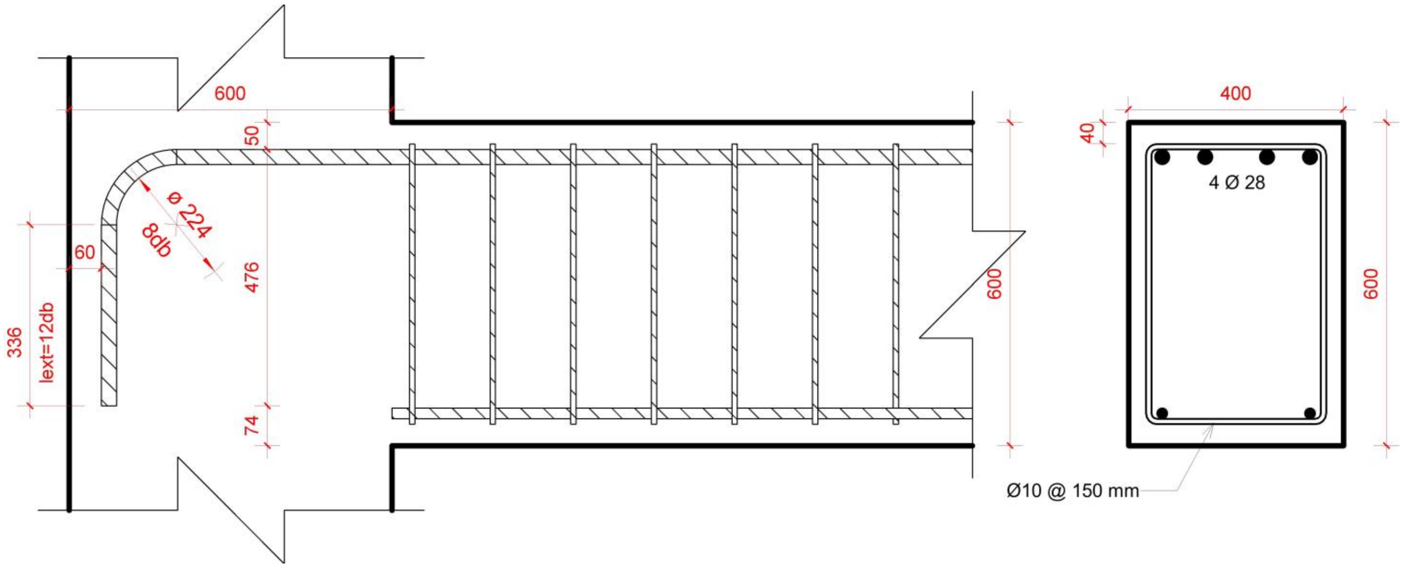
Available room = 500 mm > required hook tail heigh = 476 mm ➔ 90° hook can be used.

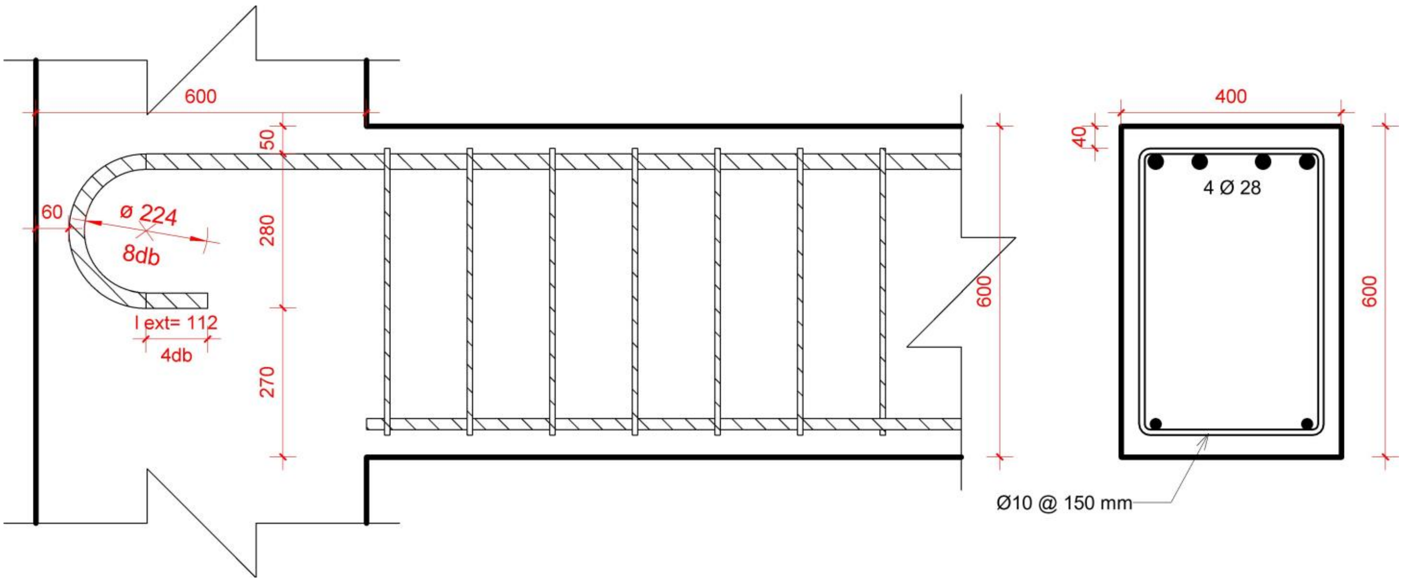
Actually, since the bars are developed into a column, it can be used. That is because a column has greater depth than the beam.

Check if 180° hook can be used.

- Minimum inside bend diameter from SBC304-18, Table 25.3.1 = $8d_b$ = 224 mm
- Minimum straight extension l_{ext} from SBC304-18, Table 25.3.1 = $4d_b$ = 112 mm > 65 mm
- Total required hook tail height = bend dia + $2d_b$ = 224 +2×28 = 280 mm
- Available room for hook tail = h – 2 clear covers = 600 - 2×50 = 500 mm

Available room = 500 mm > required hook tail heigh = 280 mm ➔ Use 180° hook.


600
50
ø 224
8db
60
476
336
lext=12db
74
600
400
40
4 Ø 28
600
Ø10 @ 150 mm


600
50
60
ø 224
8db
280
l ext= 112
4db
270
600
400
40
4 Ø 28
600
Ø10 @ 150 mm