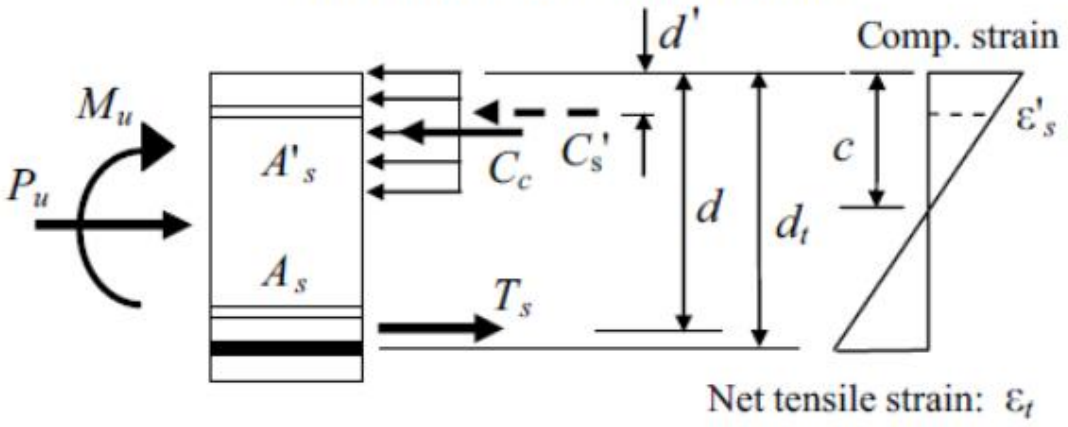
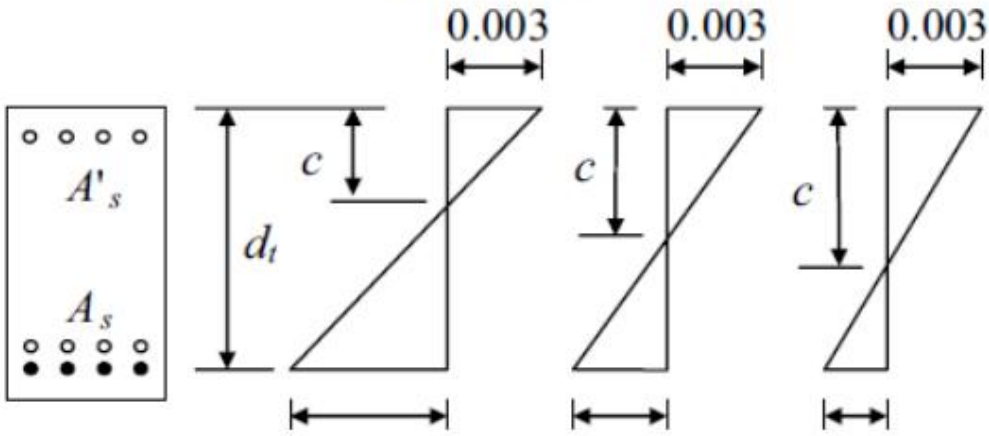
Beam Design Provisions- Singly and Doubly

UNIFIED DESIGN PROVISIONS

Internal Forces and Strains



Strain Conditions



$\varepsilon_t \geq 0.005$ $0.005 > \varepsilon_t > 0.002$ $\varepsilon_t \leq 0.002$

Tension-controlled section: $c \leq 0.375\, d_t$

Transition section

Compression-controlled section: $c \geq 0.6\, d_t$

BEAMS – FLEXURE: $\phi M_n \geq M_u$

For all beams

Net tensile strain: $a = \beta_1 c$

$$\varepsilon_t = \frac{0.003(d_t - c)}{c} = \frac{0.003(\beta_1 d_t - a)}{a}$$

Design moment strength: ϕM_n

where: $\phi = 0.9 \; [\varepsilon_t \geq 0.005]$

$\phi = 0.48 + 83\varepsilon_t \; [0.004 \leq \varepsilon_t < 0.005]$

Reinforcement limits:

$A_{S,max}$ $\varepsilon_t = 0.004$ @ M_n

$$A_{S,min} = \text{larger} \left\{ \frac{3\sqrt{f_c'}\, b_w d}{f_y} \text{ or } \frac{200 b_w d}{f_y} \right.$$

$A_{s,min}$ limits need not be applied if
A_s (provided) $\geq 1.33\, A_s$ (required)

Singly-reinforced beams

$$A_{s,max} = \frac{0.85 f_c' \beta_1 b}{f_y} \left(\frac{3 d_t}{7} \right)$$

$$a = \frac{A_s f_y}{0.85 f_c' b}$$

$$M_n = 0.85 f_c' \, a \, b \, (d - \frac{a}{2}) = A_s f_y \, (d - \frac{a}{2})$$

Doubly-reinforced beams

Compression steel yields if:

$$A_s - A_s' \geq \frac{0.85\beta_1 f_c' d' b}{f_y}\left(\frac{87{,}000}{87{,}000 - f_y}\right)$$

If compression steel yields:

$$A_{s,max} = \frac{0.85 f_c' \beta_1 b}{f_y}\left(\frac{3 d_t}{7}\right) + A_s'$$

$$a = \frac{(A_s - A_s') f_y}{0.85 f_c' b}$$

$$M_n = f_y\left[(A_s - A_s')\left(d - \frac{a}{2}\right) + A_s'(d - d')\right]$$

If compression steel does not yield (two steps):

1. Solve for c:

$$c^2 + \left(\frac{(87{,}000 - 0.85 f_c')\, A_s' - A_s f_y}{0.85 f_c' \beta_1 b}\right) c - \frac{87{,}000\, A_s' d'}{0.85 f_c' \beta_1 b} = 0$$

2. Compute M_n:

$$M_n = 0.85\, b\, c\, \beta_1 f_c'\left(d - \frac{\beta_1 c}{2}\right) + A_s'\left(\frac{c - d'}{c}\right)(d - d')\ 87{,}000$$