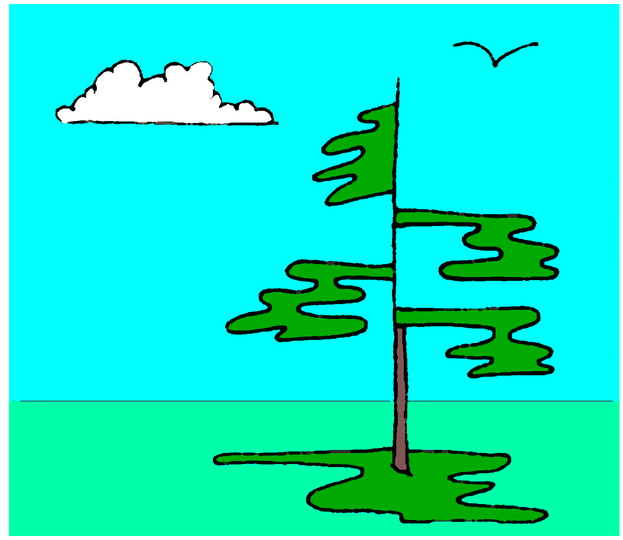
NorthWoods Software



Program Name: Rectangular Beam

Project Name: -

Project Number: -

Project Description: -

Project Designer: Dik

Last Revised (yy-mm-dd): 18-07-29

Reference: Reference?

Created using SMath Studio, a MathCAD workalike from https://en.smath.info/view/SMathStudio
The User is responsible to verify data using an alternative method

Menu:

.... Enter Data Space .... Important Output .... Logical Constructs Blue Text: Units

.... Summation

Defined Units:

$ft\_K := kip\ ft$ Kip-feet (Moment)

$deg := \frac{\pi}{180}\ rad$

$K := kip$ Kips (force)

$ft\_K := ft\ kip$ foot-Kips (Moment)

User Defined Functions:

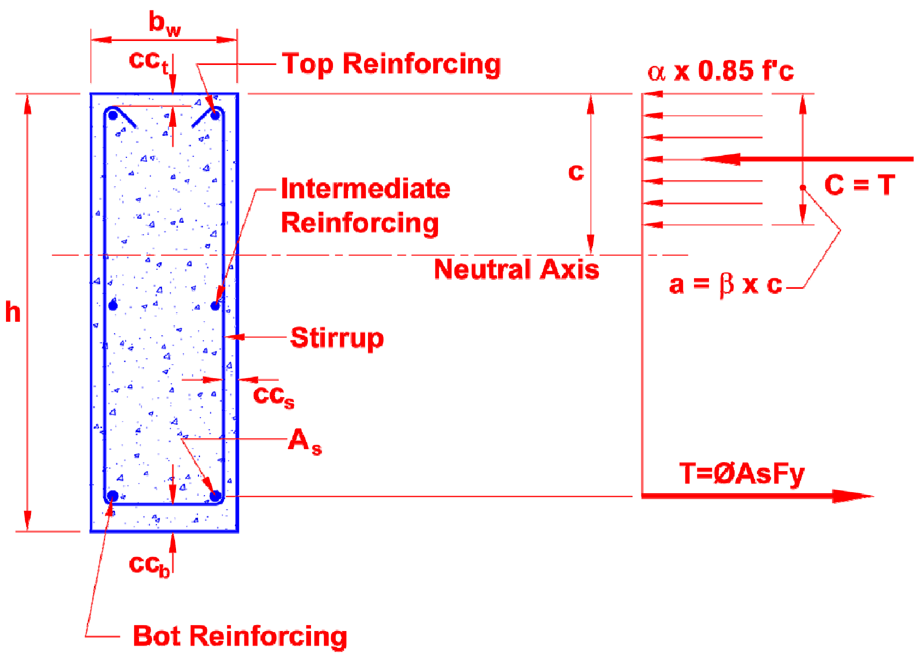
```
ceil(arg1) := if round(arg1, 0) < arg1
                  round(arg1, 0) + 1
              else
                  round(arg1, 0)
```

```
Check(arg) := if arg = 1
                  Check := "...OK"
              else
                  Check := "...NG"
```

$Check(2 = 3) = "...NG"$

$Check(2 \le 3) = "...OK"$

$Check(3 \ge 2) = "...OK"$



Material Resistance Factors:

$\Phi_s := 0.85$ Material Factor for Reinforcing Steel

$\Phi_c := 0.65$ Material Factor for Concrete 8.4.2

Reinforcing Steel Properties:

$Rebar :=$

1	2	3	4	5	6
1	"10M"	11.3 mm	100 mm^2	35.5 mm	0.785 $\frac{kg}{m}$
2	"15M"	16.0 mm	200 mm^2	50.1 mm	1.570 $\frac{kg}{m}$
3	"20M"	19.5 mm	300 mm^2	61.3 mm	2.355 $\frac{kg}{m}$
4	"25M"	25.2 mm	500 mm^2	79.2 mm	3.925 $\frac{kg}{m}$
5	"30M"	29.9 mm	700 mm^2	93.9 mm	5.495 $\frac{kg}{m}$
6	"35M"	35.7 mm	1000 mm^2	112.2 mm	7.850 $\frac{kg}{m}$
7	"45M"	43.7 mm	1500 mm^2	137.3 mm	11.775 $\frac{kg}{m}$
8	"55M"	56.4 mm	2500 mm^2	177.2 mm	19.625 $\frac{kg}{m}$

1 NDX
2 Bar Size
3 Bar Diameter (mm)
4 Bar Area (mm^2)
5 Bar Perimeter (mm)
6 Bar Mass/Length (kg/m)

Input Data:

Materials

Reinforcing Steel Properties

$f_y := 300\ MPa$ $\quad f_y = 43.5\ ksi$ Reinforcing Steel Yield Strength

$E_s := 200000\ MPa$ $\quad E_s = 29007.5\ ksi$ Steel Modulus of Elasticity (8.5.4.1)

Concrete

$f'_c := 22\ MPa$ $\quad f'_c = 3.2\ ksi$ 28 Day Concrete Compressive Strength

$\gamma_c := 2500\ \frac{kg}{m^3}$

Density of Concrete
λ = 1.00 Regular Weight Concrete 2150=2500
λ = 0.85 Semi-Low Density Concrete 1850-2150
λ = 0.75 Low Density Concrete less than 1850

Concrete Density Factor

$\lambda := 1.00$

Minimum Coarse Aggregate Size

$a_g := 20\ mm$ $\quad a_g = 0.787\ in$ Coarse Aggregate Size

Temperature Reinforcing

$P_{ts} := .2\ \%$ Minimum % Temperature Steel

Reinforcing

NDX	1	2	3	4	5	6	7	8
	10M	15M	20M	25M	30M	35M	45M	55M

Top Reinforcing

$NDX_t := 2$ $\quad N_t := 2$

Enter Index Number Representing Top Bar Size
Number of Top Bars

$Bar_t := Rebar_{NDX_t\ 2}$ $\quad Bar_t = \text{"15M"}$

$A_{st} := Rebar_{NDX_t\ 4} \cdot N_t$ $\quad A_{st} = 0.62\ in^2$ $\quad A_{st} = 400\ mm^2$

$\varphi_t := Rebar_{NDX_t\ 3}$ $\quad \varphi_t = 0.63\ in$ $\quad \varphi_t = 16\ mm$

Intermediate (Skin) Reinforcing

$NDX_i := 1$ Enter Index Number Representing Bot Bar Size

$S_i := 8\ in$ $\quad S_i = 203\ mm$ Maximum Spacing of Intermediate Bars

$N_i := 0$ Initialise Total Number of Intermediate Bars (1/2 ES)

$Bar_i := Rebar_{NDX_i\ 2}$ $\quad Bar_i = \text{"10M"}$

$A_{si} := Rebar_{NDX_i\ 4}$ $\quad A_{si} = 0.155\ in^2$ $\quad A_{si} = 100\ mm^2$

$A_{si\_prov} := A_{si} \cdot N_i$ $\quad A_{si\_prov} = 0\ in^2$ $\quad A_{si\_prov} = 0\ mm^2$

$\varphi_i := Rebar_{NDX_i\ 3}$ $\quad \varphi_i = 0.445\ in$ $\quad \varphi_i = 11.3\ mm$

Bottom Reinforcing

$NDX_b := 2$ $\quad N_b := 2$ $\quad$ Enter Index Number Representing Bot Bar Size
Number of Bot Bars

$Bar_b := Rebar_{NDX_b\ 2}$ $\quad Bar_b = "15M"$

$A_{sb} := Rebar_{NDX_t\ 4} \cdot N_t$ $\quad A_{sb} = 0.62\ in^2$ $\quad A_{sb} = 400\ mm^2$

$\varphi_b := Rebar_{NDX_b\ 3}$ $\quad \varphi_b = 0.63\ in$ $\quad \varphi_b = 16\ mm$

Stirrup Reinforcing

$NDX_s := 1$ $\quad N_L := 2$ $\quad$ Enter Index Number Representing Stirrup Bar Size
Number of Stirrup Legs / Tie

$N_S := 1$ $\quad$ Number of Ties / Spacing

$s_s := 24\ in$ $\quad s_s = 610\ mm$ $\quad$ Stirrup Spacing

$Bar_s := Rebar_{NDX_s\ 2}$ $\quad Bar_s = "10M"$

$A_{ss} := Rebar_{NDX_s\ 4} \cdot N_L \cdot N_S$ $\quad A_{ss} = 0.31\ in^2$ $\quad A_{ss} = 200\ mm^2$

$\varphi_s := Rebar_{NDX_s\ 3}$ $\quad \varphi_s = 0.445\ in$ $\quad \varphi_s = 11.3\ mm$

Beam Data:

$b_w := 9\ in$	$b_w = 229\ mm$	Beam Width
$h := 29\ in$	$h = 737\ mm$	Beam Depth
$b_t := b_w$	$b_t = 229\ mm$	Width of Beam Tension Zone (Rectangular Beam)
$cc_t := 1.50\ in$	$cc_t = 38\ mm$	Clear Cover to Top Reinforcing
$cc_b := 3.0\ in$	$cc_b = 76\ mm$	Clear Cover to Bottom Reinforcing
$cc_s := 1.5\ in$	$cc_s = 38\ mm$	Clear Cover to Side Reinforcing
$\alpha_f := 90\ °$		

Input Loads

$V_f := 1\ K$	$V_f = 4.4\ kN$	Factored Design Shear
$V_p := 0\ K$	$V_p = 0\ kN$	Factored Prestressing Shear
$M_f := 20\ ft\_K$	$M_f = 27.1\ kN\ m$	Factored Design Moment

Calculations:

Calculate Alpha (Equation 10.1)

$$\alpha_1 := \max\left(\left[\begin{matrix} 0.85 - 0.0015 \cdot \dfrac{f'_c}{MPa} & 0.67 \end{matrix}\right]\right) \qquad \alpha_1 = 0.817$$

Calculate Beta (Equation 10.2)

$$\beta_1 := \max\left(\left[\begin{matrix} 0.97 - 0.0025 \cdot \dfrac{f'_c}{MPa} & 0.67 \end{matrix}\right]\right) \qquad \beta_1 = 0.915$$

Concrete Modulus of Rupture (Equation 8.3)

$$f_r := 0.6 \cdot \lambda \cdot \sqrt{\frac{f'_c}{MPa}} \; MPa \qquad f_r = 2.8142 \; MPa \qquad f_r = 0.408 \; ksi$$

Concrete Modulus of Elasticity (Equation 8.1)

```
if (γc < 1500 kg/m^3) ∨ (γc > 2500 kg/m^3)
  Ec := 0.0
else
  Ec := (3300 · √(f'c/MPa) + 6900) · ((γc / (kg/m^3)) / 2300)^1.5 MPa
```

$$E_c = 3678 \; ksi \qquad E_c = 25360 \; MPa$$

Alternative Modulus of Elasticity (Equation 8.2)

$$E_{ca} := 4500 \cdot \sqrt{\frac{f'_c}{MPa}} \; MPa \qquad E_{ca} = 3061 \; ksi \qquad E_{ca} = 21107 \; MPa$$

Beam 'd' to Reinforcing

$$d_t := h - cc_t - \varphi_s - \frac{\varphi_t}{2} \qquad d_t = 26.7 \; in \qquad d_t = 679 \; mm$$

$$d_b := h - cc_b - \varphi_s - \frac{\varphi_b}{2} \qquad d_b = 25.2 \; in \qquad d_b = 641 \; mm$$

Minimum Beam Width

$s := \max\left(\left[30\ \text{mm} \quad 1.4 \cdot a_g \quad 1.4 \cdot \varphi_b \quad 1.4 \cdot \varphi_t \right]\right)$

$s = 1.1811\ \text{in}$ $\quad s = 30\ \text{mm}$

$b_{w\_min} := \max\left(\left[\left(2 \cdot \left(cc_s + \varphi_s\right) + \left(N_b \cdot \varphi_b + \left(N_b - 1\right) \cdot s\right)\right) \quad \left(2 \cdot \left(cc_s + \varphi_s\right) + \left(N_t \cdot \varphi_t + \left(N_t - 1\right) \cdot s\right)\right)\right]\right)$

$b_{w\_min} = 6.3\ \text{in}$ $\quad b_{w\_min} = 160.8\ \text{mm}$

'Mr' for Specified Reinforcing

'Mr' for Continuous Span Condition

$a_t := \dfrac{\Phi_s \cdot \left(A_{st}\right) \cdot f_y}{\alpha_1 \cdot \Phi_c \cdot f'_c \cdot b_w}$ $\quad a_t = 1.5036\ \text{in}$ $\quad a_t = 38.2\ \text{mm}$

$M_{rt} := \Phi_s \cdot \left(A_{st}\right) \cdot f_y \cdot \left(d_t - \dfrac{a_t}{2}\right)$ $\quad M_{rt} = 49.7\ \text{ft\_K}$ $\quad M_{rt} = 67.3\ \text{kN m}$

'Mr' for Simple Span or End Span Condition

$a_b := \dfrac{\Phi_s \cdot \left(A_{sb}\right) \cdot f_y}{\alpha_1 \cdot \Phi_c \cdot f'_c \cdot b_w}$

$M_{rb} := \Phi_s \cdot \left(A_{sb}\right) \cdot f_y \cdot \left(d_b - \dfrac{a_b}{2}\right)$ $\quad M_{rb} = 46.8\ \text{ft\_K}$ $\quad M_{rb} = 63.4\ \text{kN m}$

Temperature Reinforcing

$A_{s\_ts} := P_{ts} \cdot b_t \cdot h$ $\quad A_{s\_ts} = 0.522\ \text{in}^2$ $\quad A_{s\_ts} = 337\ \text{mm}^2$

$A_{s\_prov} := A_{sb} + A_{si} + A_{st}$ $\quad A_{s\_prov} = 1.395\ \text{in}^2$ $\quad A_{s\_prov} = 900\ \text{mm}^2$

'Mf' Increased by 1/3

$M_{incr} := M_f \cdot 1.33$ $\quad M_{incr} = 26.6\ \text{ft\_K}$ $\quad M_{incr} = 36.1\ \text{kN m}$

Cracking Moment (Equation 10.3)

$S_x := \dfrac{b_w \cdot h^2}{6}$ $\quad S_x = 1261.5\ \text{in}^3$ $\quad S_x = 2.067 \cdot 10^7\ \text{mm}^3$

$M_{cr} := f_r \cdot S_x$ $\quad M_{cr} = 42.9\ \text{ft\_K}$ $\quad M_{cr} = 58.2\ \text{kN m}$

$M_{f\_cr} := 1.2 \cdot M_{cr}$ $\quad M_{f\_cr} = 51.5\ \text{ft\_K}$ $\quad M_{f\_cr} = 51.5\ \text{ft\_K}$

Minimum Flexural Reinforcing (Equation 10.4)

$$A_{s\_min} := 0.2 \cdot \frac{\sqrt{\frac{f'_c}{MPa}}}{\frac{f_y}{MPa}} \cdot b_w \cdot h$$

$A_{s\_min} = 0.8161\ in^2$ $A_{s\_min} = 527\ mm^2$

$$a_{min} := \frac{\Phi_s \cdot (A_{s\_min}) \cdot f_y}{\alpha_1 \cdot \Phi_c \cdot f'_c \cdot b_w}$$

$a_{min} = 1.9792\ in$ $a_{min} = 50.3\ mm$

Minimum Moment for Continuous Span Condition (Equation 10.5)

$$M_{r\_mint} := \Phi_s \cdot (A_{s\_min}) \cdot f_y \cdot \left(d_t - \frac{a_{min}}{2}\right)$$

$M_{r\_mint} = 64.8\ ft\_K$ $M_{r\_mint} = 87.8\ kN\ m$

Minimum Moment for Simple Span or End Span Condition (Equation 10.5)

$$M_{r\_minb} := \Phi_s \cdot (A_{s\_min}) \cdot f_y \cdot \left(d_b - \frac{a_{min}}{2}\right)$$

$M_{r\_minb} = 61\ ft\_K$ $M_{r\_minb} = 82.7\ kN\ m$

Minimum Design Moment for Continuous Span Condition

Mf = Factored Design Moment

Mr = Design Moment Resistance with Specified Reinfocing

Mincr = Factored Design Moment increased by 1/3

Mf_cr = 1.2 x Cracking Moment

Mr_min = Minimum Moment based on Min Flexural Reinforcement

Mdes = Design Moment

```
if M_f < M_r_mint
  if M_incr < M_r_mint
    M_dest := M_incr
  else
    M_dest := M_r_mint
else
  M_dest := M_f
```

$M_f = 20\ ft\_K$ $M_{rt} = 49.7\ ft\_K$

$M_{r\_mint} = 64.8\ ft\_K$ $M_{incr} = 26.6\ ft\_K$

$M_{f\_cr} = 51.5\ ft\_K$ $M_{dest} = 26.6\ ft\_K$

```
if M_dest < M_f_cr
  M_dest := M_f_cr
else
  dummy := 0
```

$M_{dest} = 51.5\ ft\_K$

```
if M_f < M_r_minb
  if M_incr < M_r_minb
    M_desb := M_incr
  else
    M_desb := M_r_minb
else
  M_desb := M_f
```

$M_f = 20$ ft_K $\quad M_{rb} = 46.8$ ft_K

$M_{r\_minb} = 61$ ft_K $\quad M_{incr} = 26.6$ ft_K

$M_{f\_cr} = 51.5$ ft_K $\quad M_{desb} = 26.6$ ft_K

```
if M_desb < M_f_cr
  M_desb := M_f_cr
else
  dummy := 0
```

$M_{dest} = 51.5$ ft_K

Balanced Condition for Continuous Span Condition (Equation 10.5)

$$c_{bal} := \frac{700}{700 + \frac{f_y}{\text{MPa}}} \cdot d_t$$

$c_{bal} = 18.7181$ in $\quad c_{bal} = 475$ mm

Depth of Compression Block

$$a_{bal} := c_{bal} \cdot \beta_1$$

$a_{bal} = 17.1271$ in $\quad a_{bal} = 435$ mm

Compression Force

$$C_{bal} := \alpha_1 \cdot \Phi_c \cdot f'_c \cdot b_w \cdot a_{bal}$$

$C_{bal} = 261.2$ K $\quad C_{bal} = 1161.9$ kN

Area of Steel for Balanced Condition

$$A_{s\_bal} := \frac{C_{bal}}{\Phi_s \cdot f_y}$$

$A_{s\_bal} = 7.0623\ \text{in}^2 \quad A_{s\_bal} = 4556\ \text{mm}^2$

Balanced Moment

$$M_{bt} := \Phi_s \cdot A_{s\_bal} \cdot f_y \cdot \left(d_t - \frac{a_{bal}}{2}\right)$$

$M_{bt} = 395.6$ ft_K $\quad M_{bt} = 536.4$ kN m

Balanced Condition for Simple Span or End Span Condition (Equation 10.5)

$$c_{bal} := \frac{700}{700 + \frac{f_y}{\text{MPa}}} \cdot d_b$$

$c_{bal} = 17.6681$ in $\quad c_{bal} = 449$ mm

Depth of Compression Block

$a_{bal} := c_{bal} \cdot \beta_1$ $\quad a_{bal} = 16.1663 \text{ in} \quad a_{bal} = 411 \text{ mm}$

Compression Force

$C_{bal} := \alpha_1 \cdot \Phi_c \cdot f'_c \cdot b_w \cdot a_{bal}$ $\quad C_{bal} = 246.5 \text{ K} \quad C_{bal} = 1096.7 \text{ kN}$

Area of Steel for Balanced Condition

$A_{s\_bal} := \dfrac{C_{bal}}{\Phi_s \cdot f_y}$ $\quad A_{s\_bal} = 6.6661 \text{ in}^2 \quad A_{s\_bal} = 4301 \text{ mm}^2$

Balanced Moment

$M_{bb} := \Phi_s \cdot A_{s\_bal} \cdot f_y \cdot \left(d_b - \dfrac{a_{bal}}{2} \right)$ $\quad M_{bb} = 352.5 \text{ ft\_K} \quad M_{bb} = 477.9 \text{ kN m}$

Crack Control for Continuous Span Condition (10.6.1) and Equation 10.6

$d_c := h - d_t$ $\quad d_c = 2.2598 \text{ in} \quad d_c = 57 \text{ mm}$

$y_t := d_c$ $\quad y_t = 2.2598 \text{ in} \quad y_t = 57 \text{ mm}$

$A := \dfrac{2 \cdot y_t \cdot b_w}{N_t}$ $\quad A = 20.3386 \text{ in}^2 \quad A = 13122 \text{ mm}^2$

$f_s := 0.6 \cdot f_y$ $\quad f_s = 26.1068 \text{ ksi} \quad f_s = 180 \text{ MPa}$

$z_t := \dfrac{f_s}{\text{MPa}} \cdot \left(\dfrac{d_c \cdot A}{\text{mm}^3} \right)^{\frac{1}{3}} \dfrac{\text{N}}{\text{mm}}$ $\quad z_t = 16377 \dfrac{\text{N}}{\text{mm}}$

$Exp01 := [$ "Exterior" "Interior" "Not Permitted" $]$

```
if z_t ≤ 25000 N/mm
  Exposure_ct := Exp01_1
else
  if z_t ≤ 30000 N/mm
    Exposure_ct := Exp01_2
  else
    Exposure_ct := Exp01_3
```

$Exposure_{ct} =$ "Exterior"

Crack Control for Simple Span or End Span Condition (10.6.1) and Equation 10.6

$d_c := h - d_b$ $\qquad d_c = 3.7598\ \text{in} \qquad d_c = 96\ \text{mm}$

$y_b := d_c$ $\qquad y_t = 2.2598\ \text{in} \qquad y_t = 57\ \text{mm}$

$A := \dfrac{2 \cdot y_b \cdot b_w}{N_b}$ $\qquad A = 33.8386\ \text{in}^2 \qquad A = 21831\ \text{mm}^2$

$f_s := 0.6 \cdot f_y$ $\qquad f_s = 26.1068\ \text{ksi} \qquad f_s = 180\ \text{MPa}$

$z_b := \dfrac{f_s}{\text{MPa}} \cdot \left(\dfrac{d_c \cdot A}{\text{mm}^3}\right)^{\frac{1}{3}} \dfrac{\text{N}}{\text{mm}}$ $\qquad z_b = 22995\ \dfrac{\text{N}}{\text{mm}}$

```
if z_b ≤ 25000 N/mm
  Exposure_cb := Exp01_1
else
  if z_b ≤ 30000 N/mm
    Exposure_cb := Exp01_2
  else
    Exposure_cb := Exp01_3
```

$Exposure_{cb} = \text{"Exterior"}$

Skin Reinforcing for Continuous Span Condition (10.6.2)

Rebar Size for Skin Reinforcing:

$x := cc_s + \varphi_s + \dfrac{\varphi_i}{2}$ $\qquad x = 2.1673\ \text{in} \qquad x = 55\ \text{mm}$

$d_{skin} := \left(\dfrac{h}{2} - 2 \cdot \left(h - d_t\right)\right)$ $\qquad d_{skin} = 9.9803\ \text{in} \qquad d_{skin} = 254\ \text{mm}$

$N_{skin} := ceil\left(\dfrac{d_{skin}}{S_i}\right)$ $\qquad N_{skin} = 2$

$A_{cst} := d_{skin} \cdot x$ $\qquad A_{cst} = 21.6306\ \text{in}^2 \qquad A_{cst} = 13955\ \text{mm}^2$

if $h > 750\ mm$

  if $z_t \le 25000\ \frac{N}{mm}$

$$\rho_{sk} := 0.010$$
$$A_{cst} := \rho_{sk} \cdot A_{cst}$$
$$N_{it} := \max\left(\left[\frac{A_{cst}}{A_{si}} \quad N_{skin}\right]\right)$$
$$A_{cst\_prov} := N_{it} \cdot A_{si} \cdot 2$$

  else

    if $z_t \le 30000\ \frac{N}{mm}$

$$\rho_{sk} := 0.008$$
$$A_{cst} := \rho_{sk} \cdot A_{cst}$$
$$N_{it} := \max\left(\left[\frac{A_{cst}}{A_{si}} \quad N_{skin}\right]\right)$$
$$A_{cst\_prov} := N_{it} \cdot A_{si} \cdot 2$$

    else

$$\rho_{sk} := 0.010$$
$$A_{cst} := \rho_{sk} \cdot A_{cst}$$
$$N_{it} := \max\left(\left[\frac{A_{cst}}{A_{si}} \quad N_{skin}\right]\right)$$
$$A_{cst\_prov} := N_{it} \cdot A_{si} \cdot 2$$

else

$$\rho_{sk} := 0.0$$
$$A_{cst} := 0.0$$
$$N_{it} := 0$$
$$A_{cst\_prov} := 0$$

$N_{it} = 0$

$A_{cst} = 0\ in^2$ $\qquad A_{cst} = 0\ mm^2$

$A_{cst\_prov} = 0\ in^2$ $\qquad A_{cst\_prov} = 0\ mm^2$

Skin Reinforcing for Simple Span or End Span Condition (10.6.2)

$x := cc_s + \varphi_s + \frac{\varphi_i}{2}$ $\qquad x = 2.1673\ in$ $\qquad x = 55\ mm$

$d_{skin} := \left(\frac{h}{2} - 2 \cdot \left(h - d_b\right)\right)$ $\qquad d_{skin} = 6.9803\ in$ $\qquad d_{skin} = 177\ mm$

$N_{skin} := ceil\left(\frac{d_{skin}}{S_i}\right)$ $\qquad N_{skin} = 1$

$A_{csb} := d_{skin} \cdot x$ $\qquad A_{csb} = 15.1286\ in^2$ $\qquad A_{csb} = 9760\ mm^2$

```
if h > 750 mm
  if z_b ≤ 25000 N/mm
    ρ_sk := 0.010
    A_csb := ρ_sk · A_csb
    N_ib := max([ A_csb/A_si  N_skin ])
    A_csb_prov := N_ib · A_si · 2
  else
    if z_t ≤ 30000 N/mm
      ρ_sk := 0.008
      A_csb := ρ_sk · A_csb
      N_ib := max([ A_csb/A_si  N_skin ])
      A_csb_prov := N_ib · A_si · 2
    else
      ρ_sk := 0.10
      A_csb := ρ_sk · A_csb
      N_ib := max([ A_csb/A_si  N_skin ])
      A_csb_prov := N_ib · A_si · 2
else
  ρ_sk := 0.0
  A_csb := 0.0
  N_ib := 0
  A_csb_prov := 0
```

$N_{ib} = 0$

$A_{csb} = 0\ in^2$ $A_{csb} = 0\ mm^2$

$A_{csb\_prov} = 0\ in^2$ $A_{csb\_prov} = 0\ mm^2$

Summary:

28 Day Concrete Compressive Strength:	$f'_c = 3.2$ ksi	$f'_c = 22$ MPa
Reinforcing Steel Yield Strength:	$f_y = 43.5$ ksi	$f_y = 300$ MPa
Beam Width:	$b_w := 9$ in	$b_w = 229$ mm
Beam Depth:	$h := 24$ in	$h = 610$ mm
Top Reinforcing	$Bar_t = $ "15M"	
As for Top Reinforcing	$A_{st} = 0.62\ in^2$	$A_{st} = 400\ mm^2$
Intermediate Reinforcing	$Bar_i = $ "10M"	
As for Intermediate Reinforcing	$A_{si\_prov} = 0\ in^2$	$A_{si\_prov} = 0\ mm^2$
Maximum Spacing for Intermediate Rfg	$S_i := 8$ in	$S_i = 203$ mm
Bottom Reinforcing	$Bar_b = $ "15M"	
As for Bottom Reinforcing	$A_{sb} = 0.62\ in^2$	$A_{sb} = 400\ mm^2$
Stirrup Reinforcing	$Bar_s = $ "10M"	
As for Stirrup Reinforcing	$A_{ss} = 0.31\ in^2$	$A_{ss} = 200\ mm^2$
Number of Stirrup Legs / Tie	$N_L := 2$	
Number of Ties / Spacing	$N_S := 1$	
Stirrup Spacing	$s_s = 24$ in	$s_s = 609.60$ mm
Av Required	See Shear Calculation Sheet for Av	
As (Total) Provided	$A_{s\_prov} = 1.395\ in^2$	$A_{s\_prov} = 900\ mm^2$
As (Temperature Steel) Required:	$A_{s\_ts} = 0.522\ in^2$	$A_{s\_ts} = 337\ mm^2$
As (Minimum Flexural)	$A_{s\_min} = 0.816\ in^2$	$A_{s\_min} = 527\ mm^2$
Design Factored Moment:	$M_f = 20$ ft_K	$M_f = 27.1$ kN m
Moment for 1.33 x Factored Moment	$M_{incr} = 26.6$ ft_K	$M_{incr} = 36.1$ kN m
Moment for 1.2 x Cracked Section:	$M_{f\_cr} = 51.5$ ft_K	$M_{f\_cr} = 51.5$ ft_K
Moment Capacity Provided (Top):	$M_{rt} = 49.7$ ft_K	$M_{rt} = 67.3$ kN m
Minimum Moment Capacity Required (Top):	$M_{dest} = 51.5$ ft_K	$M_{dest} = 69.8$ kN m
Exposure (Top):	$Exposure_{ct} = $ "Exterior"	
Skin Reinforcing (Top):	$A_{cst} = 0\ in^2$	$A_{cst} = 0\ mm^2$
Moment Capacity Provided (Bottom):	$M_{rb} = 46.8$ ft_K	$M_{rb} = 63.4$ kN m
Minimum Moment Capacity Required (Bot):	$M_{desb} = 51.5$ ft_K	$M_{dest} = 69.8$ kN m
Exposure (Bottom):	$Exposure_{cb} = $ "Exterior"	
Skin Reinforcing (Bot):	$A_{csb} = 0\ in^2$	$A_{csb} = 0\ mm^2$

$Check\left(b_{w\_min} \leq b_w\right) = "...OK"$

$Check\left(M_{incr} \leq M_{rt}\right) = "...OK"$

$Check\left(M_{incr} \leq M_{rb}\right) = "...OK"$

$Check\left(M_{rt} \geq M_{dest}\right) = "...NG"$

$Check\left(M_{rb} \geq M_{dest}\right) = "...NG"$

$Check\left(A_{s\_prov} \geq A_{s\_min}\right) = "...OK"$

$Check\left(M_{rt} \geq M_{f\_cr}\right) = "...NG"$