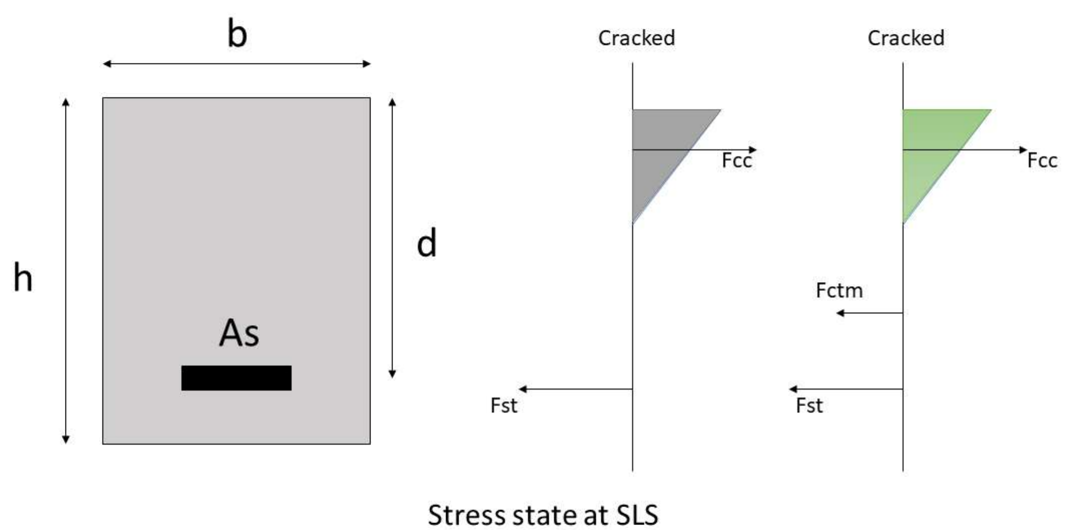
Python module 'handcalcs'

Example

To install handcalcs open the anaconda prompt and type pip install handcalcs

This is an example of how to use handcalcs to produce a calculation report of the transformed section to calculate the stress on the concrete and bottom steel for fatigue analysis. You need to calculate the bending moment prior the calculation. First we import handcalcs using:

In [1]:
```
import handcalcs.render
from math import sqrt
```



Triangular stress block - Cracked section

We proceed to start our calculation by calculating the Elastic modulus of the concrete and steel:

In [2]:
```
%%render
# Parameters
L = 9500#mm
b = 300#mm
d = 600#mm
h = 700#mm
A_s = 490*5#mm2
f_ck = 25#MPa
f_yk = 500#MPa
E_s = 200000 #MPa
```

$$L = 9500 \ \ (\mathrm{mm}) \qquad b = 300 \ \ (\mathrm{mm}) \qquad d = 600 \ \ (\mathrm{mm})$$

$$h = 700 \ \ (\mathrm{mm}) \qquad A_s = 2450 \ \ (\mathrm{mm2}) \qquad f_{ck} = 25 \ \ (\mathrm{MPa})$$

$$f_{yk} = 500 \ \ (\mathrm{MPa}) \qquad E_s = 200000 \ \ (\mathrm{MPa})$$

In [3]:
```
%%render
epsilon_y = f_yk/E_s
E_cm = 22*((f_ck+8)/10)**0.3 # GPa
A_c = b*h#mm2
u = 2*b+2*h#mm
rho = 2*A_c/u
phi = 2.8
E_ceff = (E_cm/(1+phi))*10**3 #MPa
alpha_e = E_s/E_ceff
A_cequ = alpha_e * A_s #mm2
```

$$\epsilon_y = \frac{f_{yk}}{E_s} = \frac{500}{200000} = 2.500 \times 10^{-3}$$

$$E_{cm} = 22 \cdot \left(\frac{f_{ck} + 8}{10} \right)^{0.3} = 22 \cdot \left(\frac{25 + 8}{10} \right)^{0.3} = 31.476 \ \ (\mathrm{GPa})$$

$$A_c = b \cdot h = 300 \cdot 700 = 210000 \ \ (\mathrm{mm2})$$

$$u = 2 \cdot b + 2 \cdot h = 2 \cdot 300 + 2 \cdot 700 = 2000 \ \ (\mathrm{mm})$$

$$\rho = 2 \cdot \frac{A_c}{u} = 2 \cdot \frac{210000}{2000} = 210.0$$

$$\phi = 2.8$$

$$E_{ceff} = \left(\frac{E_{cm}}{1 + \phi} \right) \cdot (10)^{3} = \left(\frac{31.476}{1 + 2.8} \right) \cdot (10)^{3} = 8283.107 \ \ (\mathrm{MPa})$$

$$\alpha_e = \frac{E_s}{E_{ceff}} = \frac{200000}{8283.107} = 24.146$$

$$A_{cequ} = \alpha_e \cdot A_s = 24.146 \cdot 2450 = 59156.547 \ \ (\mathrm{mm2})$$

Then we proceed to calculate the equivalent area and location of neutral axis

In [4]:
```
%%render
# long
x_cr = (-alpha_e*A_s+sqrt((alpha_e*A_s)**2 + 2*b*alpha_e*A_s*d))/b #mm
```

$$
\begin{aligned}
x_{cr} &= \frac{(-\alpha_{e}) \cdot A_{s} + \sqrt{(\alpha_{e} \cdot A_{s})^{2} + 2 \cdot b \cdot \alpha_{e} \cdot A_{s} \cdot d}}{b} \\
&= \frac{(-24.146) \cdot 2450 + \sqrt{(24.146 \cdot 2450)^{2} + 2 \cdot 300 \cdot 24.146 \cdot 2450 \cdot 600}}{300} \\
&= 327.701 \ \ (\mathrm{mm})
\end{aligned}
$$

In [5]:
```
%%render
M = 200000000#Nmm
f_cc = 2*M/(b*x_cr*(d-x_cr/3))#MPa
f_st = (1/2)*b*x_cr*f_cc/A_s#MPa
```

$$M = 200000000 \ \ (\mathrm{Nmm})$$

$$f_{cc} = 2 \cdot \frac{M}{b \cdot x_{cr} \cdot \left(d - \frac{x_{cr}}{3}\right)} = 2 \cdot \frac{200000000}{300 \cdot 327.701 \cdot \left(600 - \frac{327.701}{3}\right)} = 8.291 \ \ (\mathrm{MP}$$

$$f_{st} = \left(\frac{1}{2}\right) \cdot b \cdot x_{cr} \cdot \frac{f_{cc}}{A_{s}} = \left(\frac{1}{2}\right) \cdot 300 \cdot 327.701 \cdot \frac{8.291}{2450} = 166.337 \ \ (\mathrm{MP}$$

Curvature - Cracked

In [6]:
```
%%render
# long
I_cr = (b*x_cr**3)/3+alpha_e*A_s*(d-x_cr)**2#mm4
k_cr = M/(E_ceff*I_cr)#/mm
```

$$
\begin{aligned}
I_{cr} &= \frac{b \cdot (x_{cr})^{3}}{3} + \alpha_{e} \cdot A_{s} \cdot (d - x_{cr})^{2} \\
&= \frac{300 \cdot (327.701)^{3}}{3} + 24.146 \cdot 2450 \cdot (600 - 327.701)^{2} \\
&= 7905379116.555 \ \ (\mathrm{mm4})
\end{aligned}
$$

$$
\begin{aligned}
k_{cr} &= \frac{M}{E_{ceff} \cdot I_{cr}} \\
&= \frac{200000000}{8283.107 \cdot 7905379116.555} \\
&= 3.054 \times 10^{-6} \ \ (/\mathrm{mm})
\end{aligned}
$$

Triangular stress block - Uncracked section

In [7]:
```
%%render
f_ct = 2.6 #MPa
r = A_s/(b*h)#1
x_uc = (h+2*alpha_e*r*d)/(2+2*alpha_e*r)#mm
f_st = ((d-x_uc)/(h-x_uc))*alpha_e*f_ct#MPa
```

$$f_{ct} = 2.6 \ \ (\mathrm{MPa})$$

$$r = \frac{A_s}{b \cdot h} = \frac{2450}{300 \cdot 700} = 1.167 \times 10^{-2}$$

$$x_{uc} = \frac{h + 2 \cdot \alpha_e \cdot r \cdot d}{2 + 2 \cdot \alpha_e \cdot r} = \frac{700 + 2 \cdot 24.146 \cdot 1.167 \times 10^{-2} \cdot 600}{2 + 2 \cdot 24.146 \cdot 1.167 \times 10^{-2}} = 404.946 \ \ (\mathrm{m}$$

$$f_{st} = \left(\frac{d - x_{uc}}{h - x_{uc}} \right) \cdot \alpha_e \cdot f_{ct} = \left(\frac{600 - 404.946}{700 - 404.946} \right) \cdot 24.146 \cdot 2.6 = 41.501 \ \ (\mathrm{M}$$

In [8]:
```
%%render
# Symbolic
M_cr = A_s*f_st*(d-x_uc/3)+(1/2)*b*(h-x_uc)*f_ct*((2/3)*x_uc+(2/3)*(h-x_uc))
```

$$M_{cr} = A_s \cdot f_{st} \cdot \left(d - \frac{x_{uc}}{3} \right) + \left(\frac{1}{2} \right) \cdot b \cdot (h - x_{uc}) \cdot f_{ct} \cdot \left(\left(\frac{2}{3} \right) \cdot x_{uc} + \left(\frac{2}{3} \right) \cdot (h - x$$

In [9]:
```
%%render
# Parameters
M_cr = (A_s*f_st*(d-x_uc/3)+(1/2)*b*(h-x_uc)*f_ct*((2/3)*x_uc+(2/3)*(h-x_uc)))
#Nmm
```

$$M_{cr} = 100982135.048 \ \ (\mathrm{Nmm})$$

Curvature Uncracked

In [10]:
```
%%render
# long
I_uc = b*h**3/12+alpha_e*A_s*(d-x_uc)**2#mm4
k_uc = M_cr/(E_ceff*I_uc)#/mm
```

$$
\begin{aligned}
I_{uc} &= b \cdot \frac{(h)^{3}}{12} + \alpha_{e} \cdot A_{s} \cdot (d - x_{uc})^{2} \\
&= 300 \cdot \frac{(700)^{3}}{12} + 24.146 \cdot 2450 \cdot (600 - 404.946)^{2} \\
&= 10825668462.379 \; \mathrm{(mm4)}
\end{aligned}
$$

$$
\begin{aligned}
k_{uc} &= \frac{M_{cr}}{E_{ceff} \cdot I_{uc}} \\
&= \frac{100982135.048}{8283.107 \cdot 10825668462.379} \\
&= 1.126 \times 10^{-6} \; \mathrm{(/mm)}
\end{aligned}
$$

Average curvature

In [11]:
```
%%render
# long
beta = 0.5#(0.5 for sustained or cyclic loading and 1 for single short-term lo
ad)
xi = 1 - beta*(M_cr/M)**2
k_av = xi*k_cr+(1-xi)*k_uc#/mm
```

$$\beta = 0.5 \; \mathrm{((0.5\ for\ sustained\ or\ cyclic\ loading\ and\ 1\ for\ single\ short\text{-}term\ load))}$$

$$
\begin{aligned}
\xi &= 1 - \beta \cdot \left(\frac{M_{cr}}{M} \right)^{2} \\
&= 1 - 0.5 \cdot \left(\frac{100982135.048}{200000000} \right)^{2} \\
&= 8.725 \times 10^{-1}
\end{aligned}
$$

$$
\begin{aligned}
k_{av} &= \xi \cdot k_{cr} + (1 - \xi) \cdot k_{uc} \\
&= 8.725 \times 10^{-1} \cdot 3.054 \times 10^{-6} + \left(1 - 8.725 \times 10^{-1}\right) \cdot 1.126 \times 10^{-6} \\
&= 2.809 \times 10^{-6} \; \mathrm{(/mm)}
\end{aligned}
$$

Shrinkage curvature - Cracked section

In [12]:
```
%%render
epsilon_cs = 470*10**-6
S = A_s*(d-x_cr)
k_cscr = epsilon_cs*alpha_e*S/I_cr#/mm
```

$$\epsilon_{cs} = 470 \cdot (10)^{-6} = 4.700$$

$$S = A_s \cdot (d - x_{cr}) = 2450 \cdot (600 - 327.701) = 667$$

$$k_{cscr} = \epsilon_{cs} \cdot \alpha_e \cdot \frac{S}{I_{cr}} = 4.700 \times 10^{-4} \cdot 24.146 \cdot \frac{667131.357}{7905379116.555} = 9.577 \times 10^{-7}$$

Shrinkage curvature - Uncracked section

In [13]:
```
%%render
S = A_s*(d-x_uc)
k_csuc = epsilon_cs*alpha_e*S/I_uc#/mm
```

$$S = A_s \cdot (d - x_{uc}) = 2450 \cdot (600 - 404.946) = 47$$

$$k_{csuc} = \epsilon_{cs} \cdot \alpha_e \cdot \frac{S}{I_{uc}} = 4.700 \times 10^{-4} \cdot 24.146 \cdot \frac{477881.744}{10825668462.379} = 5.010 \times 10^{-7}$$

Shrinkage average curvature

In [14]:
```
%%render
k_csav = xi*k_cscr+(1-xi)*k_csuc#/mm
```

$$\begin{aligned} k_{csav} &= \xi \cdot k_{cscr} + (1 - \xi) \cdot k_{csuc} \\ &= 8.725 \times 10^{-1} \cdot 9.577 \times 10^{-7} + \left(1 - 8.725 \times 10^{-1}\right) \cdot 5.010 \times 10^{-7} \\ &= 8.995 \times 10^{-7} \;\; (/\mathrm{mm}) \end{aligned}$$

Deflection

In [15]:
```
%%render
k_total = k_av+k_csav#/mm
Delta = 0.104*L**2*k_total #mm
Delta_limit = L/250 #mm
```

$$k_{total} = k_{av} + k_{csav} = 2.809 \times 10^{-6} + 8.995 \times 10^{-7} = 3.708 \times 10^{-6} \quad (/\mathrm{r}$$

$$\Delta = 0.104 \cdot (L)^{2} \cdot k_{total} = 0.104 \cdot (9500)^{2} \cdot 3.708 \times 10^{-6} = 34.803 \quad (\mathrm{r}$$

$$\Delta_{limit} = \frac{L}{250} = \frac{9500}{250} = 38.0 \quad (\mathrm{r}$$