Python module 'handcalcs'

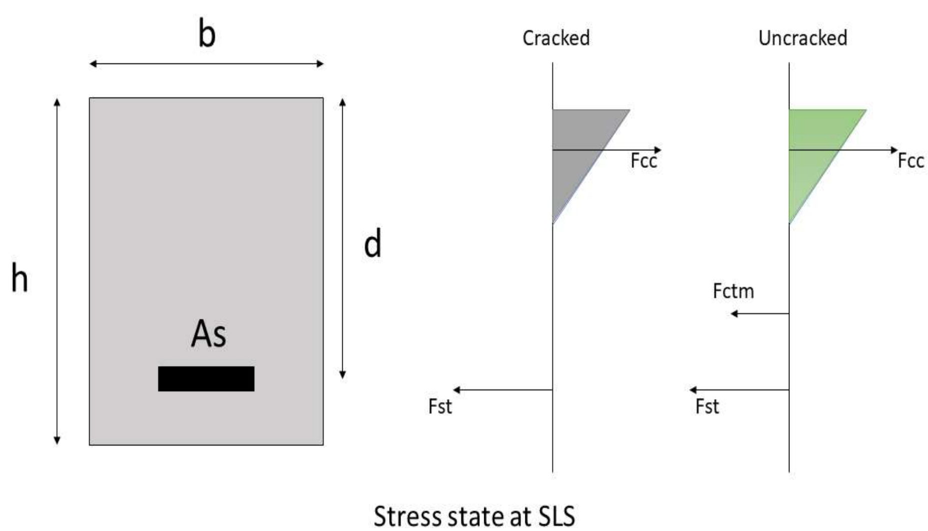
MCV - Session 5

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 report of the transformed section to calculate the stress on the concrete and bottom steel for fatigue analysis, short and long term deflection. You need the bending moment of the analysed section.

Based on example 6.3 of Reinforced Concrete Design to Eurocode 2, Mosley et al.(2012)



Triangular stress block - Cracked section

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

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

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

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

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

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

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

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

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

$$\phi = 2.8$$

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

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

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

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

$$\begin{aligned} x_{cr} &= \frac{(-\alpha_e) \cdot A_s + \sqrt{(\alpha_e \cdot A_s)^2 + 2 \cdot b \cdot \alpha_e \cdot A_s \cdot d}}{b} \\ &= \frac{(-24.146) \cdot 2450 + \sqrt{(24.146 \cdot 2450)^2 + 2 \cdot 300 \cdot 24.146 \cdot 2450 \cdot 600}}{300} \\ &= 327.701 \ \ \text{(mm)} \end{aligned}$$

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

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

$$f_{st} = \left(\frac{1}{2}\right) \cdot b \cdot x_{cr} \cdot \frac{f_{cc}}{A_s} = \left(\frac{1}{2}\right) \cdot 300 \cdot 327.701 \cdot \frac{8.291}{2450} = 166.337 \ \ \text{(MPa)}$$

Curvature - Cracked

$$\begin{aligned} I_{cr} &= \frac{b \cdot (x_{cr})^3}{3} + \alpha_e \cdot A_s \cdot (d - x_{cr})^2 \\ &= \frac{300 \cdot (327.701)^3}{3} + 24.146 \cdot 2450 \cdot (600 - 327.701)^2 \\ &= 7905379116.555 \quad (\text{mm4}) \end{aligned}$$

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

Triangular stress block - Uncracked section

$$f_{ct} = 2.6 \quad (\text{MPa})$$

$$r = \frac{A_s}{b \cdot h} = \frac{2450}{300 \cdot 700} \qquad = 1.167 \times 10^{-2} \quad (1)$$

$$x_{uc} = \frac{h + 2 \cdot \alpha_e \cdot r \cdot d}{2 + 2 \cdot \alpha_e \cdot r} = \frac{700 + 2 \cdot 24.146 \cdot 1.167 \times 10^{-2} \cdot 600}{2 + 2 \cdot 24.146 \cdot 1.167 \times 10^{-2}} \qquad = 404.946 \quad (\text{mm})$$

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

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

$$M_{cr} = 100982135.048 \quad (\text{Nmm})$$

Curvature Uncracked

$$\begin{aligned} I_{uc} &= b \cdot \frac{(h)^3}{12} + \alpha_e \cdot A_s \cdot (d - x_{uc})^2 \\ &= 300 \cdot \frac{(700)^3}{12} + 24.146 \cdot 2450 \cdot (600 - 404.946)^2 \\ &= 10825668462.379 \quad (\text{mm4}) \end{aligned}$$

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

Average curvature

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

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

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

Shrinkage curvature - Cracked section

$$\epsilon_{cs} = 470 \cdot (10)^{-6} \qquad = 4.700 \times 10^{-4}$$

$$S = A_s \cdot (d - x_{cr}) = 2450 \cdot (600 - 327.701) \qquad = 667131.357$$

$$k_{cscr} = \epsilon_{cs} \cdot \alpha_e \cdot \frac{S}{I_{cr}} = 4.700 \times 10^{-4} \cdot 24.146 \cdot \frac{667131.357}{7905379116.555} \qquad = 9.577 \times 10^{-7} \quad (/\mathrm{mm})$$

Shrinkage curvature - Uncracked section

$$S = A_s \cdot (d - x_{uc}) = 2450 \cdot (600 - 404.946) \qquad = 477881.744$$

$$k_{csuc} = \epsilon_{cs} \cdot \alpha_e \cdot \frac{S}{I_{uc}} = 4.700 \times 10^{-4} \cdot 24.146 \cdot \frac{477881.744}{10825668462.379} \qquad = 5.010 \times 10^{-7} \quad (/\mathrm{mm})$$

Shrinkage average curvature

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

Deflection

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

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

$$\Delta_{limit} = \frac{L}{250} = \frac{9500}{250} \qquad = 38.0 \quad (\mathrm{mm})$$