

fc252

cod STATUS of PC various trapezes section subject to P_{uxy}

- 1 concrete, no voids
- 1 between 15 passive steels
- 1 between 19 active prestressing steels or materials



Section

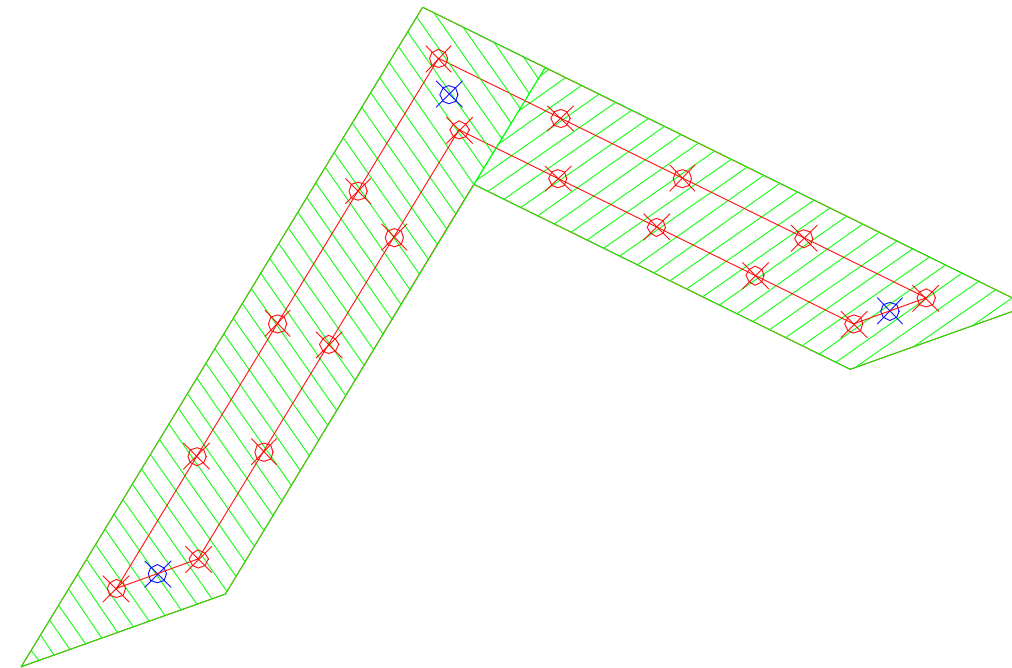
abscissas			ordinates			distance point 3 to 4 paralell to 1-2
Point			Point			
1	2	3	1	2	3	

$$XC_0 := \begin{pmatrix} 0.21 & 0.71 & 0.47 \\ 0.77 & 1.24 & 0.86 \end{pmatrix} \cdot m$$

$$YC_0 := \begin{pmatrix} 0.18 & 1 & 0.27 \\ 0.78 & 0.55 & 0.92 \end{pmatrix} \cdot m$$

$$L_0 := \begin{pmatrix} 0.76 \\ 0.67 \end{pmatrix} \cdot m$$

main trapeze 1 definition
main trapeze 2 definition



- The geometry must be ported by input. Data is referred to your (own, whatever) universal XY system of coordinates.
- Moments you will enter later will be respect axes paralell to such X and Y.
- Each line in the matrices above represents a trapeze.
- First column represents coordinate of first point (aka origin) of the trapeze.
- Straight line to second point (in second column) will form the first side and defines local x axis. It must be one base of the trapeze.
- Straight line from first to third point is the second face.
- Third face is defined with the help of length of corresponding line in L_0 , which runs paralell to x axis. So third face is paralell to the first face and then the second base.
- Fourth point is at the end of such line. So points run 1 to 2 in x, and paralell to it, in the other base, 3 to 4, towards the same side than 1 to 2 (towards the right side in local axis in usual convention). In the matrices at left there are as many points as columns, and as many (main) trapezes as rows.
- Trapezes need not to be contiguous, nor will be checked superpositions to avoid counting surfaces twice; you must enter coherent geometry and be satisfied with that the section will behave for the sollicitation in all its parts in plain remain plane agreement; frankly open and thin sections won't behave so.
- Any warping that may be present is not taken into account.
- You can choose whatever origin of coordinates you want; the sheet automatically will transport origin to the lower X and Y ordinates defined.
- Augment the number of trapezes to as many required to define the section.

This and so oriented is the section we will be solving by default as a demo, not a good one in that is an open one, but efficient to program the sheet and learn operativity. Blue points are surmised prestressing strands, red reinforcing bars.

$$n_{tr} := \text{length}(L_0) \quad n_{tr} = 2 \quad \text{number of (main) trapeze areas that define the section}$$

$$k := 1 .. n_{tr} \quad \alpha_k := \begin{cases} \text{atan}\left(\frac{YC_{0_{k,2}} - YC_{0_{k,1}}}{XC_{0_{k,2}} - XC_{0_{k,1}}}\right) & \text{if } XC_{0_{k,2}} - XC_{0_{k,1}} \geq 0 \cdot m \\ \text{otherwise} \\ \frac{\pi}{2} + \text{atan}\left(\frac{YC_{0_{k,2}} - YC_{0_{k,1}}}{XC_{0_{k,2}} - XC_{0_{k,1}}}\right) & \text{if } \text{AND2}(XC_{0_{k,2}} - XC_{0_{k,1}} < 0 \cdot m, YC_{0_{k,2}} - YC_{0_{k,1}} \geq 0 \cdot m) \\ \pi + \text{atan}\left(\frac{YC_{0_{k,2}} - YC_{0_{k,1}}}{XC_{0_{k,2}} - XC_{0_{k,1}}}\right) & \text{otherwise} \end{cases}$$

$$\alpha = \begin{pmatrix} 58.63 \\ -26.08 \end{pmatrix} \text{deg}$$

$$XC_{1_k} := XC_{0_{k,3}} + L_{0_k} \cdot \cos(\alpha_k) \quad YC_{1_k} := YC_{0_{k,3}} + L_{0_k} \cdot \sin(\alpha_k)$$

$$XC := \text{augment}(XC_0, XC_1) \quad YC := \text{augment}(YC_0, YC_1)$$

$$XC = \begin{pmatrix} 0.21 & 0.71 & 0.47 & 0.87 \\ 0.77 & 1.24 & 0.86 & 1.46 \end{pmatrix} m \quad C = \begin{pmatrix} 0.18 & 1 & 0.27 & 0.92 \\ 0.78 & 0.55 & 0.92 & 0.63 \end{pmatrix} m$$

$$XC_{min} := \min(XC) \quad YC_{min} := \min(YC) \quad XC := XC - XC_{min} \quad YC := YC - YC_{min}$$

$$XC_{max} := \max(XC) \quad YC_{max} := \max(YC)$$

Point

1234

Point

1234

$XC = \begin{pmatrix} 0 & 0.5 & 0.26 & 0.66 \\ 0.56 & 1.03 & 0.65 & 1.25 \end{pmatrix}_m$
 $YC = \begin{pmatrix} 0 & 0.82 & 0.09 & 0.74 \\ 0.6 & 0.37 & 0.74 & 0.45 \end{pmatrix}_m$

this matrix holds the vertices of the trapezes, re-stated so that all coordinates be positive, while adjusted bottom left.

Mesh

$n_v := 4$

number of (stacked) rows per trapeze, where rows are taken paralell to its first (local x aligned) base

$n_h := 10$

number of elements per row and trapeze; preferably define more elements per row than rows



$$N_c := n_v \cdot n_h \cdot \text{length}(L_0) \quad N_c = 80 \quad \text{number of trapecial elements that mesh the whole concrete section}$$

$$\text{dist}(x_1, x_2, y_1, y_2) := \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

$$B_k := \text{dist}(XC_{k,1}, XC_{k,2}, YC_{k,1}, YC_{k,2}) \quad b_k := \text{dist}(XC_{k,3}, XC_{k,4}, YC_{k,3}, YC_{k,4})$$

we need also the height of main trapezes (distance of points 3 to straight lines that pass through points 1 and 2 of each trapeze)

$$h_k := \left| \frac{\frac{YC_{k,2} - YC_{k,1}}{XC_{k,2} - XC_{k,1}} \cdot XC_{k,3} - YC_{k,3} + YC_{k,1} - XC_{k,1} \cdot \frac{YC_{k,2} - YC_{k,1}}{XC_{k,2} - XC_{k,1}}}{\sqrt{\left(\frac{YC_{k,2} - YC_{k,1}}{XC_{k,2} - XC_{k,1}}\right)^2 + 1}} \right|$$

$$B = \begin{pmatrix} 0.96 \\ 0.52 \end{pmatrix}_m \quad b = \begin{pmatrix} 0.76 \\ 0.67 \end{pmatrix}_m \quad h = \begin{pmatrix} 0.18 \\ 0.17 \end{pmatrix}_m \quad \text{Corresponding bottom and top bases of defined trapezes}$$

$$\text{row} := 1..n_v \quad BB_{k, \text{row}} := b_k + \frac{n_v - (\text{row} - 1)}{n_v} \cdot (B_k - b_k) \quad bb_{k, \text{row}} := b_k + \frac{n_v - \text{row}}{n_v} \cdot (B_k - b_k) \quad hh_{k, \text{row}} := \frac{h_k}{n_v}$$

bases of layers, then its height

$$BB = \begin{pmatrix} 0.96 & 0.91 & 0.86 & 0.81 \\ 0.52 & 0.56 & 0.6 & 0.63 \end{pmatrix}_m \quad bb = \begin{pmatrix} 0.91 & 0.86 & 0.81 & 0.76 \\ 0.56 & 0.6 & 0.63 & 0.67 \end{pmatrix}_m \quad hh = \begin{pmatrix} 0.04 & 0.04 & 0.04 & 0.04 \\ 0.04 & 0.04 & 0.04 & 0.04 \end{pmatrix}_m \quad \text{each line denotes pertenance to a main trapeze, and one column to a row}$$

of third generation are trapecial elements themselves, of which there are n_h per row, so

$$BBB := \frac{BB}{n_h} \quad bbb := \frac{bb}{n_h} \quad hhh := hh$$

$$BBB = \begin{pmatrix} 0.1 & 0.09 & 0.09 & 0.08 \\ 0.05 & 0.06 & 0.06 & 0.06 \end{pmatrix}_m \quad bbb = \begin{pmatrix} 0.09 & 0.09 & 0.08 & 0.08 \\ 0.06 & 0.06 & 0.06 & 0.07 \end{pmatrix}_m \quad hhh = \begin{pmatrix} 0.04 & 0.04 & 0.04 & 0.04 \\ 0.04 & 0.04 & 0.04 & 0.04 \end{pmatrix}_m \quad \text{ese matrices give the typical (base base 2, and height) size of the apECIAL) elements in a row, where each line denotes pertenance to a main trapeze, and each column to a row}$$

$$AAA_{k, \text{row}} := \frac{BBB_{k, \text{row}} + bbb_{k, \text{row}}}{2} \cdot hhh_{k, \text{row}} \quad AAA = \begin{pmatrix} 40.95 & 38.76 & 36.57 & 34.37 \\ 22.38 & 23.9 & 25.42 & 26.93 \end{pmatrix}_{cm^2} \quad \text{this matrix holds the area of the typical concrete element in the row, where each line denotes pertenance to a main trapeze, and each column to a row}$$

We will be installing coordinates of elements referring to point 1 in each trapeze, using paralell lines to bases, and so we need to calculate heights of center of

gravity respect own base B as here taken.

$$YG_{k, \text{row}} := \frac{BBB_{k, \text{row}} + 2 \cdot bbb_{k, \text{row}}}{3 \cdot (BBB_{k, \text{row}} + bbb_{k, \text{row}})} \cdot h h_{k, \text{row}} \quad YG = \begin{pmatrix} 0.02 & 0.02 & 0.02 & 0.02 \\ 0.02 & 0.02 & 0.02 & 0.02 \end{pmatrix} \text{m}$$

So this matrix holds height of center of gravity of elemental trapezes respect own base; each line denotes pertenance to a main trapeze, and each column to a row

Of more utility is the accumulated height of centers of gravity in the row (layer) over general base B in the trapeze (local x axis), which we will use to put coordinates into place

$$YGG_{k, \text{row}} := YG_{k, \text{row}} + \frac{\text{row} - 1}{n_v} \cdot h_k \quad YGG = \begin{pmatrix} 0.02 & 0.07 & 0.11 & 0.15 \\ 0.02 & 0.06 & 0.1 & 0.14 \end{pmatrix} \text{m}$$

So this matrix holds height of center of gravity of elemental trapezes respect general base of main trapeze B; each line denotes pertenance to a given main trapeze, and each column to a row

Now we establish points in lines 1-3 and 2-4 at the height YGG of the centers of gravity

$$XL_{k, \text{row}} := XC_{k, 1} + \frac{h_k - YGG_{k, \text{row}}}{h_k} \cdot (XC_{k, 3} - XC_{k, 1}) \quad XL = \begin{pmatrix} 0.23 & 0.16 & 0.1 & 0.03 \\ 0.64 & 0.62 & 0.59 & 0.57 \end{pmatrix} \text{m}$$

these between 1 and 3 points

$$YL_{k, \text{row}} := YC_{k, 1} + \frac{h_k - YGG_{k, \text{row}}}{h_k} \cdot (YC_{k, 3} - YC_{k, 1}) \quad YL = \begin{pmatrix} 0.08 & 0.06 & 0.03 & 0.01 \\ 0.72 & 0.69 & 0.65 & 0.62 \end{pmatrix} \text{m}$$

$$XR_{k, \text{row}} := XC_{k, 2} + \frac{h_k - YGG_{k, \text{row}}}{h_k} \cdot (XC_{k, 4} - XC_{k, 2}) \quad XR = \begin{pmatrix} 0.64 & 0.6 & 0.56 & 0.52 \\ 1.22 & 1.17 & 1.11 & 1.06 \end{pmatrix} \text{m}$$

these between 2 and 4 points

$$YR_{k, \text{row}} := YC_{k, 2} + \frac{h_k - YGG_{k, \text{row}}}{h_k} \cdot (YC_{k, 4} - YC_{k, 2}) \quad YR = \begin{pmatrix} 0.75 & 0.77 & 0.79 & 0.81 \\ 0.44 & 0.42 & 0.4 & 0.38 \end{pmatrix} \text{m}$$

Now we are provided with the elemental geometry, and we need to feed it to a format compatible with the section analyzer. Our requirements are to establish area of each element and position its center of gravity in general coordinates; later we will calculate center of gravity of whole section

$$j := 1 \dots N_c$$

$$kk(n_v, n_h, j) := 1 + \text{floor}\left(\frac{j-1}{n_v \cdot n_h}\right) \quad rrow(n_v, n_h, j) := \begin{cases} \text{DIV}\left(\begin{pmatrix} n_h \cdot n_v & \text{if } \text{mod}(j, n_h \cdot n_v) = 0 \\ \text{mod}(j, n_h \cdot n_v) & \text{otherwise} \end{pmatrix}, n_h\right) & \text{if } \text{mod}\left(\begin{pmatrix} n_h \cdot n_v & \text{if } \text{mod}(j, n_h \cdot n_v) = 0 \\ \text{mod}(j, n_h \cdot n_v) & \text{otherwise} \end{pmatrix}, n_h\right) = 0 \\ 1 + \text{DIV}\left(\begin{pmatrix} n_h \cdot n_v & \text{if } \text{mod}(j, n_h \cdot n_v) = 0 \\ \text{mod}(j, n_h \cdot n_v) & \text{otherwise} \end{pmatrix}, n_h\right) & \text{otherwise} \end{cases}$$

$$A_{c_j} := AAA_{kk(n_v, n_h, j), rrow(n_v, n_h, j)}$$

$$\text{mult}(n_v, n_h, j) := -1 + \begin{cases} n_h & \text{if } \text{mod}\left(\begin{pmatrix} n_h \cdot n_v & \text{if } \text{mod}(j, n_h \cdot n_v) = 0 \\ \text{mod}(j, n_h \cdot n_v) & \text{otherwise} \end{pmatrix}, n_h\right) = 0 \\ \text{mod}\left(\begin{pmatrix} n_h \cdot n_v & \text{if } \text{mod}(j, n_h \cdot n_v) = 0 \\ \text{mod}(j, n_h \cdot n_v) & \text{otherwise} \end{pmatrix}, n_h\right) & \text{otherwise} \end{cases}$$

$$X_{c_j} := XL_{kk(n_v, n_h, j), rrow(n_v, n_h, j)} + \frac{XR_{kk(n_v, n_h, j), rrow(n_v, n_h, j)} - XL_{kk(n_v, n_h, j), rrow(n_v, n_h, j)}}{2 \cdot n_h} + \text{mult}(n_v, n_h, j) \cdot \frac{XR_{kk(n_v, n_h, j), rrow(n_v, n_h, j)} - XL_{kk(n_v, n_h, j), rrow(n_v, n_h, j)}}{n_h}$$

$$Y_{c_j} := YL_{kk(n_v, n_h, j), rrow(n_v, n_h, j)} + \frac{YR_{kk(n_v, n_h, j), rrow(n_v, n_h, j)} - YL_{kk(n_v, n_h, j), rrow(n_v, n_h, j)}}{2 \cdot n_h} + \text{mult}(n_v, n_h, j) \cdot \frac{YR_{kk(n_v, n_h, j), rrow(n_v, n_h, j)} - YL_{kk(n_v, n_h, j), rrow(n_v, n_h, j)}}{n_h}$$

$$X_g := \frac{\sum_{j=1}^{N_c} A_{c_j} \cdot X_{c_j}}{\sum_{j=1}^{N_c} A_{c_j}}$$
$$Y_g := \frac{\sum_{j=1}^{N_c} A_{c_j} \cdot Y_{c_j}}{\sum_{j=1}^{N_c} A_{c_j}}$$

$X_g = 0.56 \text{ m}$

$Y_g = 0.46 \text{ m}$

of concrete section only, respect new (or calculation) axes

$$A_{c_total} := \sum_{j=1}^{N_c} A_{c_j}$$

$A_{c_total} = 2492.79 \text{ cm}^2$

gross section (no voids deducted)

Passive Steel

Steel := 12

Type following list

$\gamma_y := 1.15$

Steel Material Safety Factor

- Choose one passive Steel type from the list below.
- If you choose one Safety Factor for Steel γ_y (must be bigger than -or equal to- 1) the strength assumed in calculation will be the real one divided by the steel strength reduction factor. Reduction will be by affinity. This normally will be safe
- For earthquake loads safety factor must be 1 to properly capture behaviour
- You can assess the chosen steel performance by the stress-strain diagram as plotted below.
- Any number not corresponding to the list will default to case 1 (perfectly elastic-perfectly plastic steel)

- Spanish
MPa denoted
as per code

1. Any perfectly elastic-perfectly plastic
2. AEH-400 N
3. AEH-500 N
4. AEH-600 N
5. AEH-400 S
6. AEH-500 S
7. B 400 S
8. B 500 S
9. AEH-400 F
10. AEH-500 F
11. AEH-600 F
- US
ksi denoted

12. Grade 60
13. Grade 65
14. Grade 70
15. Grade 75

Input for and if Steel=1 (Perfectly Elastic-Perfectly Plastic steel)

$f_y := 4100 \frac{\text{kgf}}{\text{cm}^2}$

will affect exclusively Steel type 1.

$$E_s := \begin{cases} 2100000 \cdot \frac{\text{kgf}}{\text{cm}^2} & \text{if Steel} \leq 11 \\ 29000 \cdot \text{ksi} & \text{otherwise} \end{cases}$$

$E_s = 2038903 \frac{\text{kgf}}{\text{cm}^2}$

Will assume antimetrical stress-strain laws

Any perfectly elastic, perfectly plastic steel (1)

$\epsilon_y := \frac{f_y}{E_s}$

$\epsilon_y = 0.00201$

yield strain when Steel =1

$\frac{f_y}{\gamma_y} = 3565.22 \frac{\text{kgf}}{\text{cm}^2}$

assumed yield stress when Steel=1

Cold strain-hardened deformed bar steels (9 to 11)

$\sigma_x := 5000$ seed, implied kgf/cm2

Given The Ramberg-Osgood branch thing

$$\frac{\frac{\sigma_x}{E_s}}{\frac{\text{kgf}}{\text{cm}^2}} + 0.823 \cdot \gamma_y^5 \cdot \left(\frac{\frac{\sigma_x}{\frac{\text{kgf}}{\text{cm}^2}}}{\frac{f_y}{\frac{\text{kgf}}{\text{cm}^2}}} - \frac{0.7}{\gamma_y} \right)^5 = \varepsilon$$

$$\sigma_{\text{over_prop}}(\varepsilon) := \frac{\text{kgf}}{\text{cm}^2} \cdot \text{Find}(\sigma_x)$$

Ramberg-Osgood no closed form, and we want such, so we make a fit to it

$$\text{Parts} := 200 \quad j := 1 \dots \text{Parts} + 1 \quad \varepsilon_{sj} := \frac{\frac{f_y}{\gamma_y}}{E_s} + \frac{0.035 - \frac{f_y}{E_s}}{\text{Parts}} \cdot (j - 1) \quad \sigma_{sj} := \sigma_{\text{over_prop}}(\varepsilon_{sj})$$

$$vs := \text{cspline}(\varepsilon_s, \sigma_s) \quad f_{ss}(\varepsilon) := \text{interp}(vs, \varepsilon_s, \sigma_s, \varepsilon)$$

$$f_{\text{sold}}(\varepsilon) := \left\{ \begin{array}{ll} E_s \cdot \varepsilon & \text{if } \varepsilon \leq 0.7 \cdot \frac{\gamma_y}{E_s} \\ f_{ss}(\varepsilon) & \text{otherwise} \end{array} \right.$$

Spanish Steels whose stress-strain diagrams are formed by only 2 straight lines per quadrant (2 to 8)

New B 400 S and B 500 S are made equal to AEH-400 S and AEH-500 S which are very similar

$$f_y := 4100 \cdot \frac{\text{kgf}}{\text{cm}^2} \qquad f_u := 4305 \cdot \frac{\text{kgf}}{\text{cm}^2} \qquad \varepsilon_u := 0.08$$

$$f_{\text{inc}}(f_u) := f_u - f_y \qquad \text{increment of stress from turning point (fy is surmised data)}$$

$$E_2(\varepsilon_y, \varepsilon_u, f_u) := \left\{ \begin{array}{ll} \frac{f_{\text{inc}}(f_u)}{\varepsilon_u - \varepsilon_y} & \text{if } \gamma_y = 1 \\ \frac{\frac{f_{\text{inc}}(f_u)}{\gamma_y}}{\left(\frac{\frac{\gamma_y - 1}{\gamma_y} \cdot f_u \right)} - \frac{\varepsilon_y}{\gamma_y}} & \text{otherwise} \end{array} \right. \qquad \text{slope at strain hardening if any}$$

$$f_{\text{s2lines}}(\varepsilon, \varepsilon_y, \varepsilon_u, f_u) := \left\{ \begin{array}{ll} E_s \cdot \varepsilon & \text{if } \varepsilon \leq \frac{\varepsilon_y}{\gamma_y} \\ \frac{f_y}{\gamma_y} + E_2(\varepsilon_y, \varepsilon_u, f_u) \cdot \left(\varepsilon - \frac{\varepsilon_y}{\gamma_y} \right) & \text{otherwise} \end{array} \right.$$

American Reinforcing Passive Deformed Bars
(12 to 15)

These we rarely will use with any (steel) strength reduction factor, since this is not usual in american codes; still, we will formulate this also for consistency and completeness of formulation.

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Dϕ_σ

e_{σ1}

A

C

Gr

f_{σU}

e_ψ

e_{σU}

B

D

USA :=
$$\begin{pmatrix} 60 & 4218.42 & 7354.11 & 3135.69 & .002016 & .0091 & .0729 & 1.748272 & .173674 & -.251726 & 1.173672 \\ 65 & 4569.96 & 7536.91 & 2966.96 & .002204 & .0086 & .0717 & 1.75624 & -.145637 & -.243758 & .854363 \\ 70 & 4921.49 & 7719.71 & 2798.22 & .002396 & .0082 & .0706 & 1.766823 & -.416587 & -.233175 & .583412 \\ 75 & 5273.03 & 7902.51 & 2629.48 & .002592 & .0077 & .0694 & 1.780521 & -.655189 & -.219478 & .344811 \end{pmatrix}$$

The values are for static loads and don't take into account the higher values attainable under high strain loading rates

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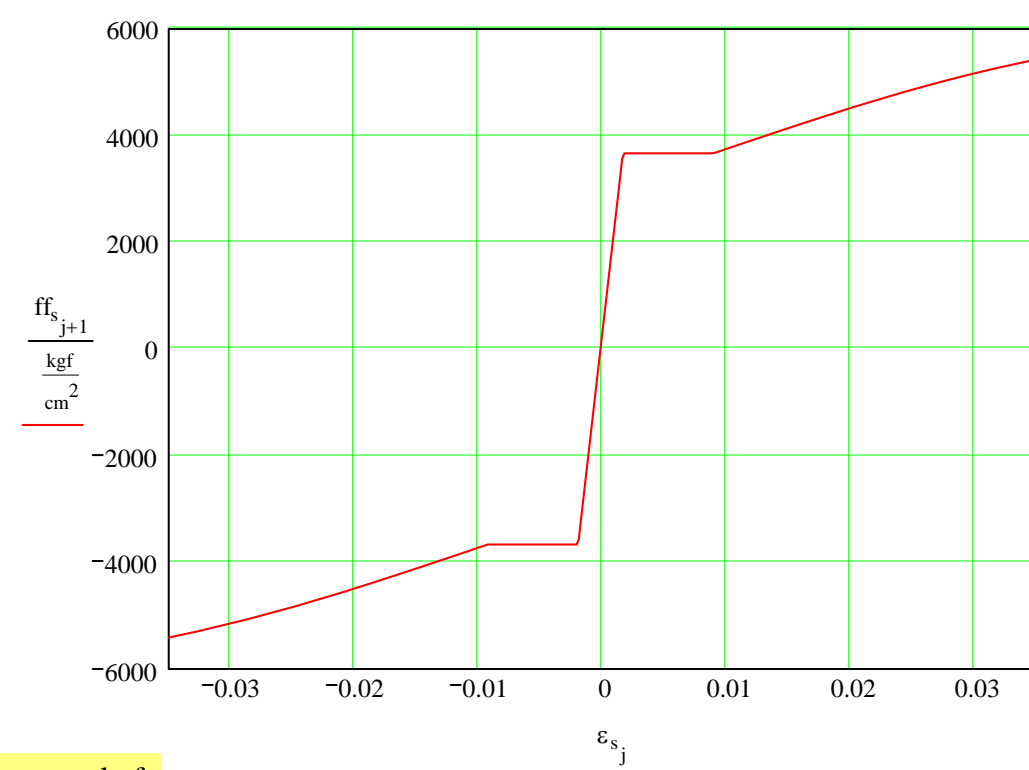
7

$$\begin{aligned}
 f_{s_positive}(\varepsilon) &:= \begin{cases} f_{s2lines}\left(\varepsilon, \frac{4100 \cdot \frac{\text{kgf}}{\text{cm}^2}}{E_s}, 0.1, 4100 \cdot \frac{\text{kgf}}{\text{cm}^2}\right) & \text{if Steel} = 2 \\ f_{s2lines}\left(\varepsilon, \frac{5100 \cdot \frac{\text{kgf}}{\text{cm}^2}}{E_s}, 0.1, 5100 \cdot \frac{\text{kgf}}{\text{cm}^2}\right) & \text{if Steel} = 3 \\ f_{s2lines}\left(\varepsilon, \frac{6100 \cdot \frac{\text{kgf}}{\text{cm}^2}}{E_s}, 0.1, 6100 \cdot \frac{\text{kgf}}{\text{cm}^2}\right) & \text{if Steel} = 4 \\ f_{s2lines}\left(\varepsilon, \frac{4100 \cdot \frac{\text{kgf}}{\text{cm}^2}}{E_s}, 0.08, 4305 \cdot \frac{\text{kgf}}{\text{cm}^2}\right) & \text{if Steel} = 5 \\ f_{s2lines}\left(\varepsilon, \frac{5100 \cdot \frac{\text{kgf}}{\text{cm}^2}}{E_s}, 0.05, 5355 \cdot \frac{\text{kgf}}{\text{cm}^2}\right) & \text{if Steel} = 6 \\ f_{s2lines}\left(\varepsilon, \frac{4100 \cdot \frac{\text{kgf}}{\text{cm}^2}}{E_s}, 0.08, 4305 \cdot \frac{\text{kgf}}{\text{cm}^2}\right) & \text{if Steel} = 7 \\ f_{s2lines}\left(\varepsilon, \frac{5100 \cdot \frac{\text{kgf}}{\text{cm}^2}}{E_s}, 0.05, 5355 \cdot \frac{\text{kgf}}{\text{cm}^2}\right) & \text{if Steel} = 8 \\ \text{if Steel} = 9 \\ \quad \left| \begin{array}{l} f_y \leftarrow 4100 \cdot \frac{\text{kgf}}{\text{cm}^2} \\ \text{return } f_{scold}(\varepsilon) \end{array} \right. \\ \text{if Steel} = 10 \\ \quad \left| \begin{array}{l} f_y \leftarrow 5100 \cdot \frac{\text{kgf}}{\text{cm}^2} \\ \text{return } f_{scold}(\varepsilon) \end{array} \right. \\ \text{if Steel} = 11 \\ \quad \left| \begin{array}{l} f_y \leftarrow 6100 \cdot \frac{\text{kgf}}{\text{cm}^2} \\ \text{return } f_{scold}(\varepsilon) \end{array} \right. \\ \text{if Steel} = 12 \\ \quad \left| \begin{array}{l} \text{Row} \leftarrow 1 \\ \text{return } f_{USA}(\varepsilon, \text{Row}) \end{array} \right. \\ \text{if Steel} = 13 \\ \quad \left| \begin{array}{l} \text{Row} \leftarrow 2 \\ \text{return } f_{USA}(\varepsilon, \text{Row}) \end{array} \right. \\ \text{if Steel} = 14 \\ \quad \left| \begin{array}{l} \text{Row} \leftarrow 3 \\ \text{return } f_{USA}(\varepsilon, \text{Row}) \end{array} \right. \\ \text{if Steel} = 15 \\ \quad \left| \begin{array}{l} f_y \leftarrow 4100 \cdot \frac{\text{kgf}}{\text{cm}^2} \\ \text{return } f_{USA}(\varepsilon, \text{Row}) \end{array} \right. \end{cases} \\
 f_y := \left| \begin{array}{l} 4100 \cdot \frac{\text{kgf}}{\text{cm}^2} \\ \text{return } f_{USA}(\varepsilon, \text{Row}) \end{array} \right. \text{ if Steel} = 2 \\
 \end{aligned}$$

$$\begin{aligned}
 \text{Passive_SteelType} &:= \begin{cases} \text{"AEH-400 N"} & \text{if Steel} = 2 \\ \text{"AEH-500 N"} & \text{if Steel} = 3 \\ \text{"AEH-600 N"} & \text{if Steel} = 4 \\ \text{"AEH-400 S"} & \text{if Steel} = 5 \\ \text{"AEH-500 S"} & \text{if Steel} = 6 \\ \text{"B 400 S"} & \text{if Steel} = 7 \\ \text{"B 500 S"} & \text{if Steel} = 8 \\ \text{"AEH-400 F"} & \text{if Steel} = 9 \\ \text{"AEH-500 F"} & \text{if Steel} = 10 \\ \text{"AEH-600 F"} & \text{if Steel} = 11 \\ \text{"Grade 60"} & \text{if Steel} = 12 \\ \text{"Grade 65"} & \text{if Steel} = 13 \\ \text{"Grade 70"} & \text{if Steel} = 14 \\ \text{"Grade 75"} & \text{if Steel} = 15 \\ \text{return "Generic Perfectly Elastic - Perfectly Plastic"} & \text{otherwise} \end{cases}
 \end{aligned}$$

$$f_s(\varepsilon) := \begin{cases} 5100 \cdot \frac{\text{kgf}}{\text{cm}^2} & \text{if Steel} = 3 \\ 6100 \cdot \frac{\text{kgf}}{\text{cm}^2} & \text{if Steel} = 4 \\ 4100 \cdot \frac{\text{kgf}}{\text{cm}^2} & \text{if Steel} = 5 \\ 5100 \cdot \frac{\text{kgf}}{\text{cm}^2} & \text{if Steel} = 6 \\ 4100 \cdot \frac{\text{kgf}}{\text{cm}^2} & \text{if Steel} = 7 \\ 5100 \cdot \frac{\text{kgf}}{\text{cm}^2} & \text{if Steel} = 8 \\ 4100 \cdot \frac{\text{kgf}}{\text{cm}^2} & \text{if Steel} = 9 \\ 5100 \cdot \frac{\text{kgf}}{\text{cm}^2} & \text{if Steel} = 10 \\ 6100 \cdot \frac{\text{kgf}}{\text{cm}^2} & \text{if Steel} = 11 \\ 60\text{-ksi} & \text{if Steel} = 12 \\ 65\text{-ksi} & \text{if Steel} = 13 \\ 70\text{-ksi} & \text{if Steel} = 14 \\ 75\text{-ksi} & \text{if Steel} = 15 \\ f_{s_positive}(\varepsilon) & \text{if } \varepsilon \geq 0 \\ -f_{s_positive}(-\varepsilon) & \text{otherwise} \end{cases}$$

$$j := 0..400 \quad \varepsilon_{s_{j+1}} := \frac{0.035}{200} \cdot (j - 200) \quad \text{ff}_{s_{j+1}} := \text{f}_s(\varepsilon_{s_{j+1}})$$



$$f_y = 4218.42 \frac{\text{kgf}}{\text{cm}^2}$$

$$\gamma_y = 1.15$$

Steel = 12

Passive_Steel_Type = "Grade 60"

Passive Steel Geometry

- For a universal section analyzer like this is better and more general to input bar per bar.
- Specific shapes can be amenable to short rule input, instead.
- Enter directly matrices of given names with abscissas and ordinates respect same origin than your entered input for section.
- From $\begin{pmatrix} 0 & 13 \end{pmatrix}$ to calculation $\begin{pmatrix} 0 & 31 \end{pmatrix}$ g box origin

Figure 1 illustrates the experimental setup for the study. The diagram shows a cross-section of a concrete beam with a central vertical crack. The beam is supported by two vertical supports. A horizontal force is applied at the top center. The distance from the support to the crack is labeled $X_{s0} := \dots \text{m}$. The distance from the crack to the other support is labeled $Y_{s0} := \dots \text{m}$. The total length of the beam is labeled $N_s := \text{length}(X_{s0})$. The number of passive bars is labeled $N_s = 18$. The diameter of the passive bars is labeled $\phi_{ks} := 10 \text{ mm}$.

$$A_{s_{ks}} := \frac{(\phi_{ks})^2}{4} \cdot \pi \quad X_{s_{ks}} := X_{s0_{ks}} - XCmin \quad Y_{s_{ks}} := Y_{s0_{ks}} - YCmin$$

Active (PRESTRESSING or POSTENSIONING) Steel (or FRP cable)

$\text{Prest}_{\text{mat}} := 11 \quad \gamma_{\text{py}} := 1$

Type following list	Prest. Material Safety Factor
------------------------	----------------------------------

fpvf := 0.915 this is fpv/fpu

fraction of f_{pu} at which the prestressing material is assumed to pass the section (without taking into account the moment effects brought by prestress)
this percent permits to evaluate the prestress forces, initial without moment and then in equilibrium with the moment

- must be lower than f_{pyf} (the prestressing material is not allowed to undergo anelastic deformation at prestress nor service level limit states)
- it is assumed the same degree of prestress will be imparted to all prestressing material.

Input for material 1 (only affects it)

$$E_{p1} := 20000 \cdot \text{ksi}$$

$$f_{pu1} := 250 \cdot \text{ksi}$$

$$\varepsilon_{\text{pu1}} := \frac{f_{\text{pu1}}}{E_{\text{p1}}}$$

$$f_{py1} := f_{pu1}$$

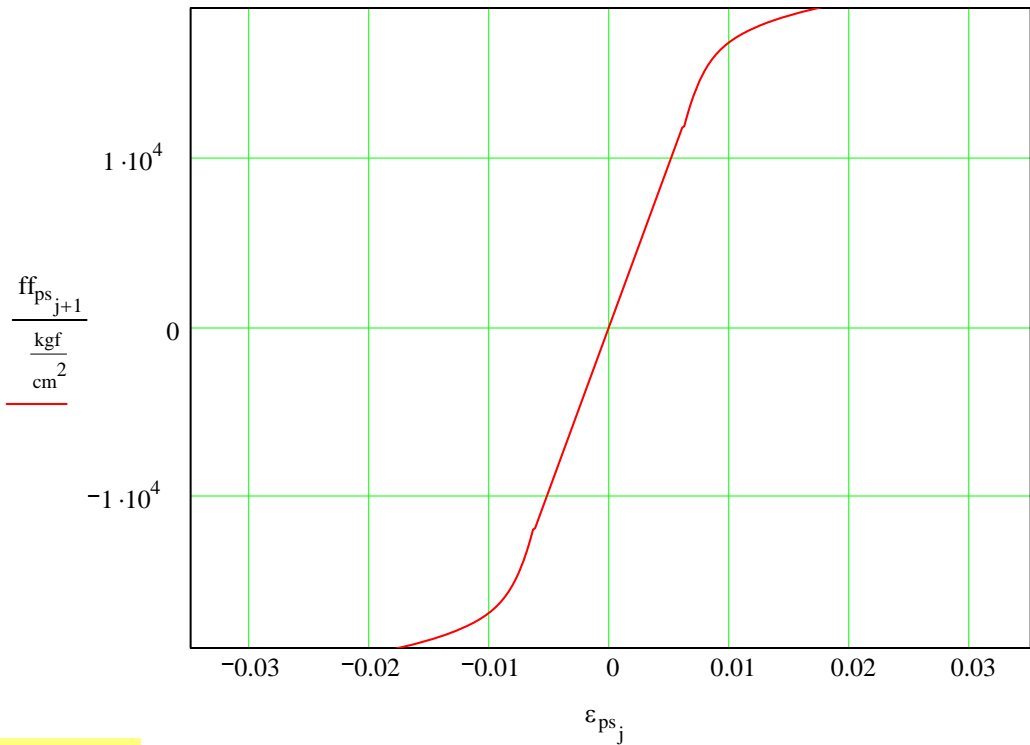
$$f_{pu1} = 17576.75 \frac{\text{kgf}}{\text{cm}^2}$$

$$\varepsilon_{pu1} = 0.0125$$

Spanish MPa denoted as per code	1.	Any perfectly elastic material till fracture
	2.	Y 1570 C wire
	3.	Y 1670 C wire
	4.	Y 1770 C wire
	5.	Y 1860 C wire
	6.	Y 1770 S2-wires
	7.	Y 1860 S3-wires
	8.	Y 1960 S3-wires
	9.	Y 2060 S3-wires
	10.	Y 1770 S7 strand
US ksi denoted	11.	Y 1860 S7 strand
	12.	ASTM A 421 Grade 270 wire
	13.	ASTM A 416 Grade 270 strand
	14.	Lo-rex 300 strand
	15.	ASTM A 722 Grade 150 bar
	16.	ASTM A 722 Grade 160 bar
	17.	ASTM A 722 Grade 157 bar

Made in Japan

18. Leadline Grade 285 ksi FRP cable
19. CFCC Grade 250 ksi FRP cable



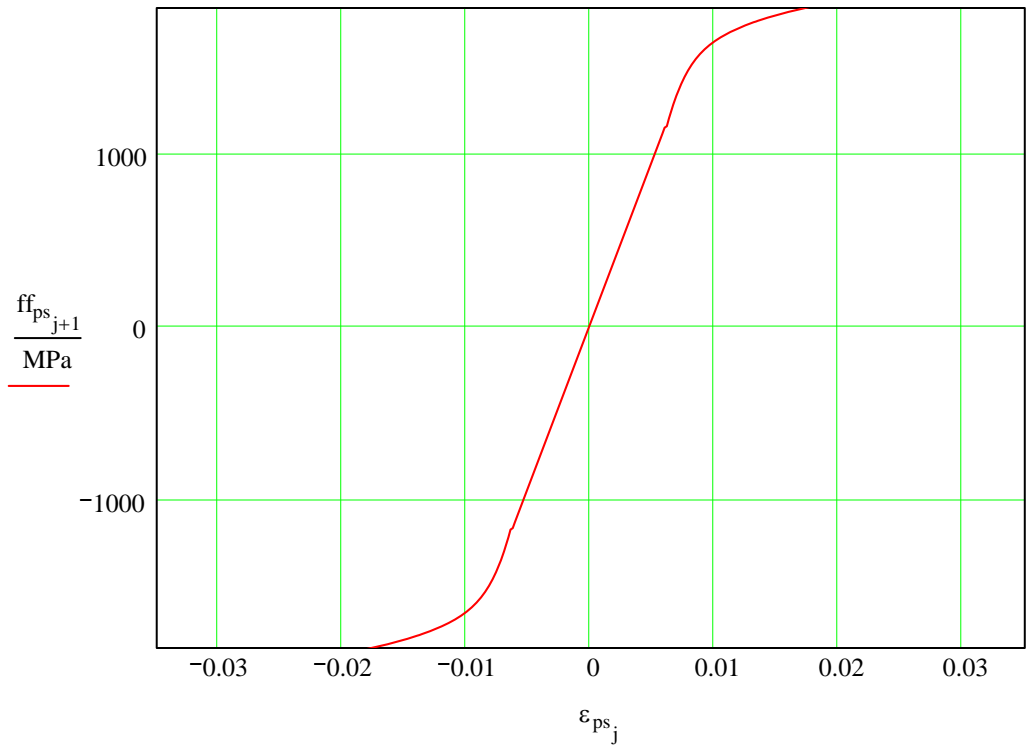
Prest_{mat} = 11

$\epsilon_{pu} = 0.035$

$f_{pu} = 18966.72 \frac{\text{kgf}}{\text{cm}^2}$

$f_{py} = 17354.55 \frac{\text{kgf}}{\text{cm}^2}$

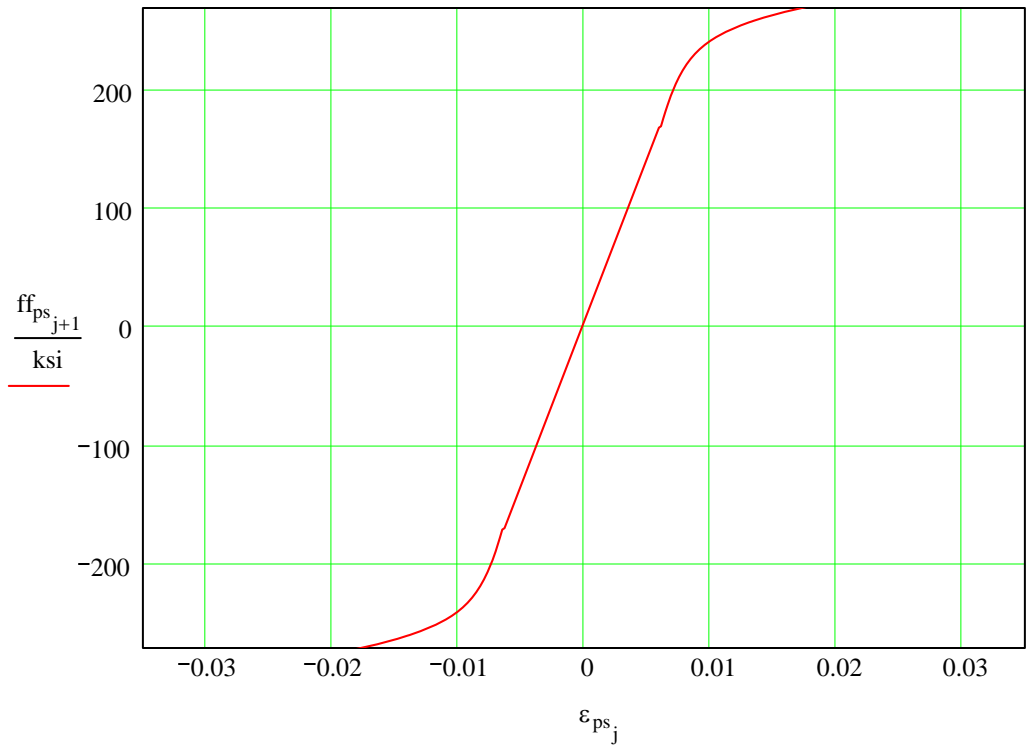
$E_p = 1.94 \times 10^6 \frac{\text{kgf}}{\text{cm}^2}$



$f_{pu} = 1860 \text{ MPa}$

$f_{py} = 1701.9 \text{ MPa}$

$E_p = 190000 \text{ MPa}$



$f_{pu} = 269.77 \text{ ksi}$

$f_{py} = 246.84 \text{ ksi}$

$E_p = 27557.15 \text{ ksi}$

Prestress

$\epsilon_0 := -\frac{f_{pu} \cdot k_{ps}}{E_p}$

$\epsilon_0 = -0.00538$

negative since initial tensile status of prestressing material

$f_{ps_as_prestressed} := f_{ps}(\epsilon_0)$

$f_{ps_as_prestressed} = -1023 \text{ MPa}$

negative since tensile

Prestressing material Geometry

- For a universal section analyzer like this is better and more general to input strand per strand.
- Specific shapes can be amenable to short rule input, instead.
- Enter directly matrices of given names with abscissas and ordinates respect same origin than your entered input for section.
- Sheet will transport to calculation bottom left of holding box origin

$X_{p0} := \begin{pmatrix} 0.38 \\ 0.74 \\ 1.28 \end{pmatrix} \cdot \text{m}$

$Y_{p0} := \begin{pmatrix} 0.29 \\ 0.89 \\ 0.62 \end{pmatrix} \cdot \text{m}$

$N_p := \text{length}(X_{p0})$

$N_p = 3$

number of active strands...

$k_p := 1..N_p$

$A_{p_{kp}} := 1 \cdot \text{cm}^2$



$X_{p_{kp}} := X_{p0_{kp}} - X_{Cmin}$

$Y_{p_{kp}} := Y_{p0_{kp}} - Y_{Cmin}$



Concrete

$f_{c28} := 35 \cdot \text{MPa}$

You may feel adequate to enter a fcd reduced one, or a mean (probabilistic) real value

Take into account?

Confinement := 0 1 for YES
0 for NO

Take into account?

Tensile_stress := 0 for YES
for NO

Note

Formulation believed to be adequate even for the most exacting HPC, VHS concretes.

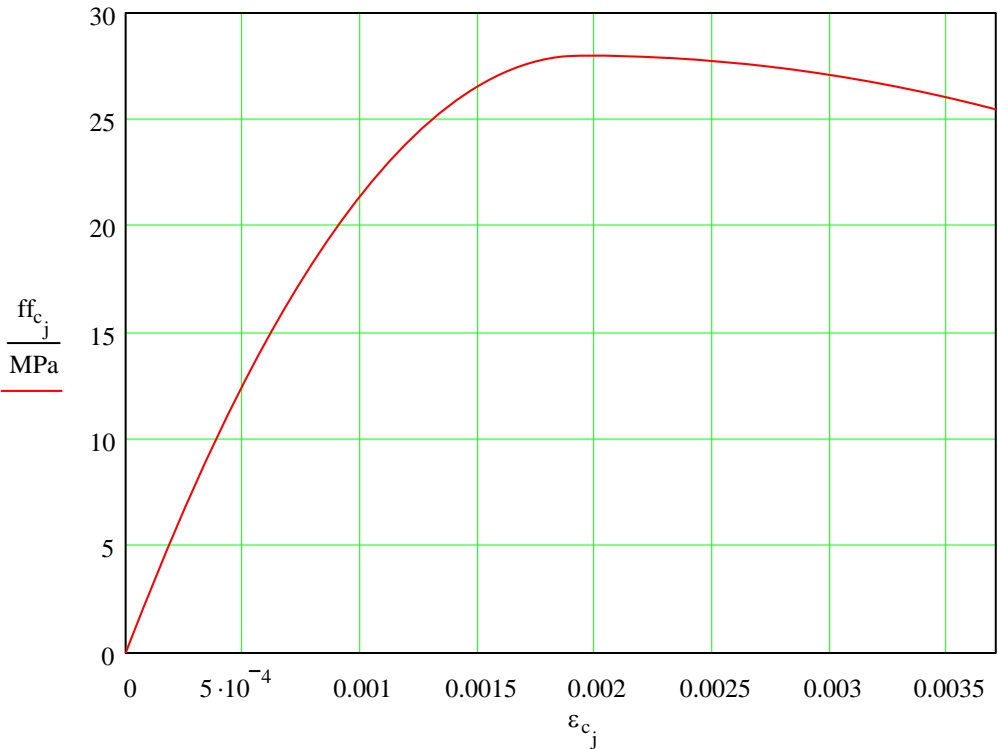
confinement 1 only if per ACI 318

v_{SL} := 0.8

Sustained Loading strength reduction factor (from 0.75 to 0.85)
see fig 39.3 in EHE code (preferably not bigger than 0.8)

f_c := f_{c28}·v_{SL}

the Sustained Loading strength reduction factor will have scarce effect in the strength of beams designed to fail by steel fracture, but will be essential to the safety of columns



f_{c28} = 35 MPa

f_c = 28 MPa

- the stress-strain diagram is scaled down to the effective (really available) strenght for sustained loads.
- any load that must be held about two hours is to strength effects a sustained load, and for what I know most structures are used for, if any overload can occur it is almost sure it can also stay for such time or more, i.e., the sustained load strenght reduction factor is required.
- this means you can only count on about 80% of the average strength you would get from probes tested at the normal rate.
- probability considerations, the fact of that part of the load is live load and if it grows it won't know when to stop (so the failure is likely to be by instantaneous overload), the safety factors, and the growth of strength of concrete with age make that a sustained load reduction factor bigger than 0.8 can be taken without much structural concern; in fact 0.9 is explicitly permitted by some codes (may be undermining a bit safety for short term sustained loads); we prefer our more substantiated value of 0.8 applied to specified strength

Solicited by

P := 329·ton

M_x := 22·m·ton

Enter (positive)
compression

M_y := 9·m·ton

- enter both moments positive
- will be assumed to compress atop and towards right when positive
- P assumed to act at center of gravity of gross section
- M_x is respect axis paralll to abscissas and M_y respect axis paralll to ordinates,
both as of X and Y in your data for the geometry input



We use some parameters to evaluate the ultimate strain available. Now we calculate them.
See solving below, for meanings

P_{max} := A_{c_total}·f_c P_{max} = 711.74 ton we accept this

$$\epsilon\left(x,y,\epsilon_1,\epsilon_2,\epsilon_3\right):=\epsilon_1+\frac{y}{Y_g}\cdot\left(\epsilon_2-\epsilon_1\right)+\frac{x}{X_g}\cdot\left(\epsilon_3-\epsilon_1\right)$$

$$\epsilon_1:=0.000 \quad \epsilon_3:=0.000 \quad \epsilon_2:=\epsilon_{cu}\left(f_c\right)\cdot\frac{Y_g}{YCmax}$$

$$P_{ref_1}:=\sum_{k=1}^{N_c}A_{c_k}\cdot\sigma\left(\epsilon\left(X_{c_k},Y_{c_k},\epsilon_1,\epsilon_2,\epsilon_3\right)\right)$$

at decompression on X while in in-plane Y flexure

$$\epsilon_1:=0.000 \quad \epsilon_3:=\epsilon_{cu}\left(f_c\right)\cdot\frac{X_g}{XCmax} \quad \epsilon_2:=0.000$$

Note that if you are not compressing towards the top right corner you better change evaluation of Prefs accordingly (sections can be defined that are frankly unsymmetric in their ability to take load towards the other side)

$$P_{ref_2}:=\sum_{k=1}^{N_c}A_{c_k}\cdot\sigma\left(\epsilon\left(X_{c_k},Y_{c_k},\epsilon_1,\epsilon_2,\epsilon_3\right)\right)$$

at decompression on Y while in in-plane X flexure

$$P_{ref}:=\min\left(\left(P_{ref_1}\right),\left(P_{ref_2}\right)\right)$$

P_{ref} = 598.26 ton

the decompression milestone against which to gauge how much we will be curtailing the ultimate strain towards that of at maximum compressive strength from that of a non compressively loaded case.

Solving

We take compression stresses positive, and tension stresses negative.
We dump the areas of both steel reinforcement and concrete layers at their c.o.g.

We need 3 epsilons to define a status of the section in the plane remain plane hypothesis.

We set these unwarranted assumptions

$$\varepsilon_1 := 0.000 \quad \text{at common origin (bottom, left)}$$

$$\varepsilon_2 := 0.0005 \quad \text{at Yg height (on ordinate axis)}$$

$$\varepsilon_3 := 0.0005 \quad \text{at Xg abscissa (on abscissas axis)}$$

Now we establish the strain in any point in the plane by interpolation

$$\varepsilon(x, y, \varepsilon_1, \varepsilon_2, \varepsilon_3) := \varepsilon_1 + \frac{y}{Y_g} \cdot (\varepsilon_2 - \varepsilon_1) + \frac{x}{X_g} \cdot (\varepsilon_3 - \varepsilon_1)$$

We will take into account the displaced concrete diminishing the ability of steel to contribute to equilibrium in exactly the value of the displaced (absent) concrete force. So, the corresponding total forces for passive steel with the effect of displaced concrete dumped unto them are

$$\text{SteelForce}(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \sum_{k=1}^{N_s} A_{s_k} \cdot \left(f_s(\varepsilon(X_{s_k}, Y_{s_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) - \sigma(\varepsilon(X_{s_k}, Y_{s_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) \right)$$

$$\text{SteelMoment}_X(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \sum_{k=1}^{N_s} Y_{s_k} \cdot \left[A_{s_k} \cdot \left(f_s(\varepsilon(X_{s_k}, Y_{s_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) - \sigma(\varepsilon(X_{s_k}, Y_{s_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) \right) \right] \quad \text{respect bottom (abscissas) axis}$$

$$\text{SteelMoment}_Y(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \sum_{k=1}^{N_s} X_{s_k} \cdot \left[A_{s_k} \cdot \left(f_s(\varepsilon(X_{s_k}, Y_{s_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) - \sigma(\varepsilon(X_{s_k}, Y_{s_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) \right) \right] \quad \text{respect left (ordinates) axis}$$

$$\text{PrestressForce}(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \sum_{k=1}^{N_p} A_{p_k} \cdot \left(f_{ps}(\varepsilon_0 + \varepsilon(X_{p_k}, Y_{p_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) - \sigma(\varepsilon(X_{p_k}, Y_{p_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) \right)$$

$$\text{PrestressMoment}_X(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \sum_{k=1}^{N_p} Y_{p_k} \cdot A_{p_k} \cdot \left(f_{ps}(\varepsilon_0 + \varepsilon(X_{p_k}, Y_{p_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) - \sigma(\varepsilon(X_{p_k}, Y_{p_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) \right)$$

$$\text{PrestressMoment}_Y(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \sum_{k=1}^{N_p} X_{p_k} \cdot A_{p_k} \cdot \left(f_{ps}(\varepsilon_0 + \varepsilon(X_{p_k}, Y_{p_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) - \sigma(\varepsilon(X_{p_k}, Y_{p_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3)) \right)$$

With discretization, integration of stresses for concrete becomes summation

$$\text{ConcreteForce}(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \sum_{k=1}^{N_c} A_{c_k} \cdot \sigma(\varepsilon(X_{c_k}, Y_{c_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3))$$

$$\text{ConcreteMoment}_X(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \sum_{k=1}^{N_c} Y_{c_k} \cdot A_{c_k} \cdot \sigma(\varepsilon(X_{c_k}, Y_{c_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3))$$

respect bottom (abscissas) axis

$$\text{ConcreteMoment}_Y(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \sum_{k=1}^{N_c} X_{c_k} \cdot A_{c_k} \cdot \sigma(\varepsilon(X_{c_k}, Y_{c_k}, \varepsilon_1, \varepsilon_2, \varepsilon_3))$$

respect left (ordinates) axis

$$\text{Totalforce}(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \text{SteelForce}(\varepsilon_1, \varepsilon_2, \varepsilon_3) + \text{ConcreteForce}(\varepsilon_1, \varepsilon_2, \varepsilon_3) + \text{PrestressForce}(\varepsilon_1, \varepsilon_2, \varepsilon_3)$$

$$\text{Totalmoment}_X(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \text{SteelMoment}_X(\varepsilon_1, \varepsilon_2, \varepsilon_3) + \text{ConcreteMoment}_X(\varepsilon_1, \varepsilon_2, \varepsilon_3) + \text{PrestressMoment}_X(\varepsilon_1, \varepsilon_2, \varepsilon_3)$$

$$\text{Totalmoment}_Y(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \text{SteelMoment}_Y(\varepsilon_1, \varepsilon_2, \varepsilon_3) + \text{ConcreteMoment}_Y(\varepsilon_1, \varepsilon_2, \varepsilon_3) + \text{PrestressMoment}_Y(\varepsilon_1, \varepsilon_2, \varepsilon_3)$$

$$\text{MaxC}_{\text{strain}}(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \left\{ \begin{array}{l} \text{maxe} \leftarrow 0 \\ \text{for } j \in 1..N_c \\ \text{maxe} \leftarrow \varepsilon(X_{c_j}, Y_{c_j}, \varepsilon_1, \varepsilon_2, \varepsilon_3) \text{ if } \varepsilon(X_{c_j}, Y_{c_j}, \varepsilon_1, \varepsilon_2, \varepsilon_3) \geq \text{maxe} \\ \text{maxe} \end{array} \right.$$

re maximum (mean) compressive stress

on our meshed elements

$$\varepsilon_{\text{cu_current}}(\varepsilon_1, \varepsilon_2, \varepsilon_3) := \left\{ \begin{array}{l} \varepsilon_{\text{cu}}(f_c) \text{ if } \text{ConcreteForce}(\varepsilon_1, \varepsilon_2, \varepsilon_3) \leq P_{\text{ref}} \\ \left[\varepsilon_{\text{cu}}(f_c) + (\varepsilon_{f_c}(f_c) - \varepsilon_{\text{cu}}(f_c)) \frac{\left(\frac{\text{ConcreteForce}(\varepsilon_1, \varepsilon_2, \varepsilon_3)}{P_{\text{max}}} - \frac{P_{\text{ref}}}{P_{\text{max}}} \right)^2}{\left(1 - \frac{P_{\text{ref}}}{P_{\text{max}}} \right)^2} \right] \text{ otherwise} \end{array} \right.$$

Solving the problem

Given

$$\text{Totalforce}(\varepsilon_1, \varepsilon_2, \varepsilon_3) = P$$

$$\text{Totalmoment}_X(\varepsilon_1, \varepsilon_2, \varepsilon_3) = P \cdot \left(Y_g + \frac{M_x}{P} \right)$$

$$\text{Totalmoment}_Y(\varepsilon_1, \varepsilon_2, \varepsilon_3) = P \cdot \left(X_g + \frac{M_y}{P} \right)$$

$$\text{MaxC}_{\text{strain}}(\varepsilon_1, \varepsilon_2, \varepsilon_3) \leq \varepsilon_{\text{cu_current}}(\varepsilon_1, \varepsilon_2, \varepsilon_3)$$

$$\text{Result} := \text{Find}(\varepsilon_1, \varepsilon_2, \varepsilon_3)$$

Equilibrium

Total_{force}(ε₁,ε₂,ε₃) = 329 ton

Total_{moment_X}(ε₁,ε₂,ε₃) = 173.84 m·ton

Total_{moment_Y}(ε₁,ε₂,ε₃) = 193.39 m·ton

P = 329 ton

M_x + P·Y_g = 173.84 m·ton

M_y + P·X_g = 193.39 m·ton

Attack_{Angle} = 22.25 deg

Trace_{Angle} = −10.74 deg

atan(My/Mx), clockwise

Attack and Response Angles

Concrete Strains and Stresses

in calculated fibers

MaxC_{strain}(ε₁,ε₂,ε₃) = 0.00098

Max_Concrete_stress = 216.11 $\frac{\text{kgf}}{\text{cm}^2}$

$\frac{\text{MaxC}_{\text{strain}}(\epsilon_1,\epsilon_2,\epsilon_3)}{\epsilon_{\text{cu_current}}(\epsilon_1,\epsilon_2,\epsilon_3)} = 26.52\%$

at center of gravity

ε₄ = 0.00056

f_{conc}(X_g,Y_g) = 141.21 $\frac{\text{kgf}}{\text{cm}^2}$

$\frac{\epsilon_4}{\epsilon_{\text{cu_current}}(\epsilon_1,\epsilon_2,\epsilon_3)} = 15.12\%$

negative percents in concrete
are of not concern

extrapolated

Max_corner_strain = 0.00105

Max_corner_stress = 225.22 $\frac{\text{kgf}}{\text{cm}^2}$

$\frac{\text{Max_corner_strain}}{\epsilon_{\text{cu_current}}(\epsilon_1,\epsilon_2,\epsilon_3)} = 28.27\%$



Steel stresses

- if negative tensile
- if positive compressive

Lower_Steel_stress = 369.14 $\frac{\text{kgf}}{\text{cm}^2}$

If negative tensile

$\frac{\text{Lower_Steel_stress}}{f_y} = 8.75\%$

Higher_Steel_stress = 1938.63 $\frac{\text{kgf}}{\text{cm}^2}$

if positive compressive

$\frac{\text{Higher_Steel_stress}}{f_y} = 45.96\%$

Prestressing Material Stresses

Prior to apply moments and axial force

f_{ps_as_prestressed} = −1023 MPa



- if negative tensile
- if positive compressive

Lower_Prestress_Mat_stress = −985.97 MPa

If negative tensile

$\frac{\text{Lower_Prestress_Mat_stress}}{f_{\text{pu}}} = -53.01\%$

Δp₁ = 37.03 MPa

Higher_Prestress_Mat_stress = −852.83 MPa

if positive compressive,
otherwise remains tensile

$\frac{\text{Higher_Prestress_Mat_stress}}{f_{\text{pu}}} = -45.85\%$

Δp₂ = 170.17 MPa