Current Design FOS Calculations

From our code we know

$M_{max} = 78098.9926\ Nmm = 78100\ Nmm$

$V_{max} = 304.1033\ N = 304N$

$\bar{y} = 113.22764 = 113.2\ mm$

$I = 16282.0334 = 1.871 \times 10^6\ mm^4$

$Q_{max} = 16282.033\ mm^3 = 16280\ mm^3$

Flexural failure

Tension: Note that the bottom of the bridge is always in tension, because the moment is always positive

$$\sigma_{max} = \frac{M_{max}\bar{y}}{I} = \frac{(78100\ Nmm)(113.2\ mm)}{1.871 \times 10^6\ mm^4}$$

$$= 4.72\ MPa$$

(un rounded values used for calculations, and result rounded to slide rule precision)

$$\Rightarrow F.O.S. = \frac{\sigma_t'}{\sigma_{max}} = \frac{30\ MPa}{4.72\ MPa} = 6.35$$

$$\boxed{\therefore FOS\ (\text{in tension}) = 6.35}$$

Compression: The moment is always positive across the length of the bridge, so the top is always in compression

$$\sigma_{max} = \frac{M_{max}(y_{Top} - \bar{y})}{I} = \frac{(78100\ Nmm)(160.0\ mm - 113.2\ mm)}{1.871 \times 10^6 mm^4}$$

$$= 1.95\ MPa$$

$$\Rightarrow FOS = \frac{\sigma_c'}{\sigma_{max}} = 6/1.95 = 3.07$$

$$\boxed{\therefore FOS\ (\text{in compression}) = 3.07}$$

Shear:

Matboard

$$\tau_{max} = \frac{V_{max}Q_{max}}{Ib}, \quad b = 2.54mm \text{ by design}$$

$$= \frac{304\ N(16280\ mm^3)}{(1.871 \times 10^6\ mm^4)(2.54\ mm)}$$

$$= 1.042\ MPa$$

$$\Rightarrow FOS = \frac{\tau_m'}{\tau_{max}} = \frac{4\ MPa}{1.042\ MPa} = 3.84$$

$$\boxed{\therefore FOS\left(\begin{matrix}\text{matboard}\\ \text{Shear}\end{matrix}\right) = 3.84}$$

Glue $\qquad$ $b = 10\,mm$ based on our glue tab design.

$$\tau_{max,glue} = \frac{V_{max} Q_{max}}{I\,b} = \frac{(304\,N)(16280\,mm^3)}{(1.871\times10^6\,mm^4)(10\,mm)}$$

$$= 0.265\,MPa$$

$$\Rightarrow FOS = \frac{\tau'_{glue}}{\tau_{max,glue}} = \frac{2\,MPa}{0.265\,MPa} = 7.55$$

$$\boxed{\therefore FOS\ (\text{glue shear}) = 7.55}$$

Splice connection

$\tau_{max,splice} = 0.304803\,MPa = 0.305\,MPa$

↳ obtained using our code.

$$\Rightarrow FOS = \frac{\tau'_{glue}}{\tau_{max,splice}} = \frac{2\,MPa}{0.305\,MPa} = 6.56$$

Local buckling:

Local buckling cases were calculated similarly to design 0 calculations hand-calculated above.

The code output for critical shear stresses was obtained using code, shown below.

Case output

```
[['Case 2', [12.5, 159.365], 1.2700000000000102, 160.0, 6.25], ['Case 2', [87.5, 159.365], 1.2700000000000102, 160.0, 93.75], ['Case 1', [87.5, 12.5], 2.539999999999992,
160.0, 50.0], ['Case 1', [157.46, 156.19], 11.27, 157.46, 18.134999999999998], ['Case 1', [157.46, 156.19], 11.269999999999996, 157.46, 81.86500000000001], ['Case 3',
[156.19, 137.46], 1.2699999999999996, 156.19, 13.135], ['Case 2', [137.46, 0.0], 1.2699999999999996, 156.19, 13.135], ['Case 3', [156.19, 137.46], 1.2699999999999996,
156.19, 86.86500000000001], ['Case 2', [137.46, 0.0], 1.2699999999999996, 156.19, 86.86500000000001], ['Case 1', [13.77, 15.04], 9.27000000000001, 137.46, 14.405], ['Case
1', [86.23, 84.06], 9.27000000000001, 137.46, 85.595], ['Case 1', [15.04, 84.96], 1.2700000000000102, 137.46, 50.0]]
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critical Stresses

```
[0.10890981249663557, 0.4548505977297187, 15.722157963967334, 1079462.697311177, 1079462.6973111767, 17.967585481028717, 0.12432284800394511, 17.967585481028618,
0.1243228480039444, 730330.2264712751, 250153.88355571724, 4.522429981442826]
```

calculated using $\sigma_{crit} = \frac{k\pi^2 E}{12(1-\mu^2)}\left(\frac{t^2}{b^2}\right)$

The factor of safeties were calculated as $\dfrac{\sigma_{crit,\ of,\ thin,\ plate}}{\sigma_{at,\ thin,\ plate}}$ ↳ calculated by our code

The minimum factor of safety was $\dfrac{15.72\,MPa}{2.40\,MPa} = 6.55$

↳ from code

Shear buckling failure

$$\tau_{crit} = \frac{5\pi^2 E}{12(1-\mu^2)}\left(\left(\frac{t}{a}\right)^2+\left(\frac{t}{h}\right)^2\right)$$

$t = 1.27$ mm
$a = 160$ mm
$h = \underbrace{1250/11}_{\text{diaphragm spacing}}$ mm ~~web height~~

based on bridge design

$b = 2.54$

$$= \frac{5\pi^2(4000)}{12(1-0.2^2)}\left(\frac{1.27^2}{2.54^2}+\frac{1.27^2}{(1250/11)^2}\right)$$

$= 3.22$ MPa

$$V_{crit} = \frac{\tau_{crit}(Ib)}{Q_{max}} = \frac{3.22\text{ MPa} \times 1.871\times10^6\text{ mm}^4 \times 2.54\text{ mm}}{16280\text{ mm}^3}$$

$= 940$ N

$$\Rightarrow FOS = \frac{V_{crit}}{V_{max}} = \frac{940\text{ N}}{304\text{ N}} = 3.09$$

code output

$$\boxed{\therefore FOS \text{ shear local buckling} = 3.09}$$