Design 0 Hand Calculations:
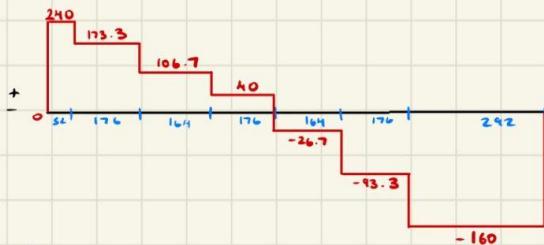
MAX SHEAR FORCE

$\Sigma M_A = 0$

$1200 B_y = 66.7(52 + 228 + 392 + 568 + 732 + 908)$

$B_y = 160 N \qquad A_y = 240 N$

SFD

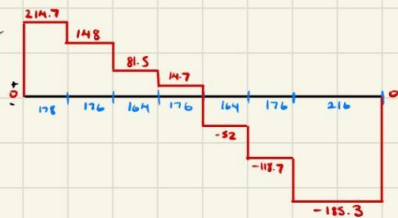240, 173.3, 106.7, 40

0, 52, 176, 164, 176, 164, 176, 242

−26.7, −93.3, −160

BMD

12480

42496.7, 46720

60480, 63146.7

67520

MAX BENDING MOMENT

SFD

214.7, 148, 81.5, 14.7

178, 176, 164, 176, 164, 176, 216, 0

−52, −118.7, −185.3

BMD

27477.3, 40082

53525.3, 60917.3

66564

69445.3

---
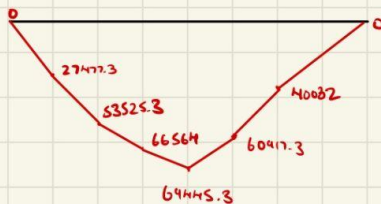
① Flexural stresses

$$\sigma_{tens} = \frac{M \, y_b}{I} \qquad \sigma_{comp} = \frac{M \, y_T}{I}$$

$$= \frac{(69445.3)(41.43)}{418394} \qquad = \frac{(69445.3)(34.84)}{418394}$$

$$\sigma_{tens} = 6.88 \, Mpa \qquad \sigma_{comp} = 5.78 \, Mpa$$

② Shear

$$\tau_{cen} = \frac{V \, Q_{cen}}{I \, b_{cen}}$$

$$= \frac{(240)(6143.1)}{(418394)(2.54)}$$

$$\tau_{cen} = 1.399 \, Mpa$$

③ Glue Shear

$$\tau_{glue} = \frac{V \, Q_{glue}}{I \, b_{glue}}$$

$$= \frac{(240)(4344.035)}{(418394)(10)}$$

$$\tau_{glue} = 0.249 \, Mpa$$

④ Mid Flange Case 1 (K=4)

$$\sigma_1 = \frac{K \pi^2 E}{12(1 - \mu^2)} \left(\frac{t}{b}\right)^2$$

$$= \frac{4 \pi^2 (4000)}{12(1 - 0.2^2)} \left(\frac{1.27}{77.96}\right)^2$$

$$\sigma_1 = 3.68 \, Mpa$$

⑤ Side Flange Case 2 (K=0.425)

$$\sigma_2 = \frac{(0.425) \pi^2 (4000)}{12(1 - 0.2^2)} \left(\frac{1.27}{10}\right)^2$$

$$\sigma_2 = 23.49 \, Mpa$$

⑥ Web Case 3 (K=6)

$$\sigma_3 = \frac{(6) \pi^2 (4000)}{12(1 - 0.2^2)} \left(\frac{1.27}{33.57}\right)^2$$

$$\sigma_3 = 29.4 \, Mpa$$

⑦ Shear Buckling (K=5)

$$\tau = \frac{K \pi^2 E}{12(1 - \mu^2)} \left[\left(\frac{t}{b}\right)^2 + \left(\frac{t}{a}\right)^2 \right]$$

$$\tau = 5.258 \, mpa$$

FACTORS OF SAFETY

$$FOS_{ten} = \frac{30}{6.88}$$
$$= 4.36$$

$$FOS_{comp} = \frac{6}{5.78}$$
$$= 1.038$$

$$FOS_{shear} = \frac{4}{1.399}$$
$$= 2.86$$

$$FOS_{glue \, shear} = \frac{2}{0.249}$$
$$= 8.03$$

$$FOS_{flex \, buck 1} = \frac{3.68}{5.78}$$
$$= 0.637$$

→ Bridge will fail from flex buckling in middle flange at 255N

$$FOS_{flex \, buck 2} = \frac{23.49}{5.78}$$
$$= 4.06$$
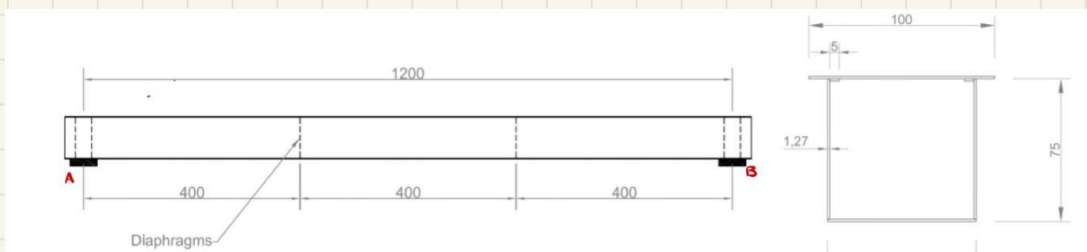
$$FOS_{flex \, buck 3} = \frac{29.4}{5.78}$$
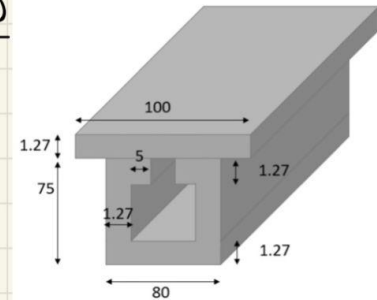$$= 5.09$$

$$FOS_{shear \, buck} = \frac{5.258}{1.399}$$
$$= 3.6964$$

Beam elevation: length 1200, three 400 segments, supports A and B, Diaphragms. Cross-section: 100 wide, 5, 1.27, 75 tall.

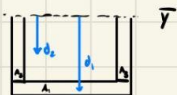Cross-section 3D view with dimensions: 100, 5, 1.27, 75, 1.27, 1.27, 1.27, 80.

$$\bar{y} = \frac{(1.27 \cdot 80)\left(\frac{1.27}{2}\right) + 2(1.27 \times 73.73)(36.135) + 2(5 \cdot 1.27)(74.365) + (100 \cdot 1.27)(75.635)}{(1.27 \cdot 80) + 2(1.27 \cdot 73.73) + 2(5 \cdot 1.27) + (100 \cdot 1.27)}$$

$$= 41.43$$

$$I = \frac{80(1.27)^3 + 2(1.27)(73.73)^3 + 2(5)(1.27)^3 + (100)(1.27)^3}{12} + \left(\left(41.4 - \frac{1.27}{2}\right)^2 (80 \cdot 1.27) + 2\left(41.4 - 36.865\right)^2 (73.73 \cdot 1.27) \right.$$

$$\left. + 2\left(74.365 - 41.4\right)^2 (5 \cdot 1.27) + \left(75.635 - 41.4\right)^2 (100 \cdot 1.27) \right)$$

$$= 0.418394 \times 10^6 \text{ mm}^4$$

$$Q_{cen} = A_1 d_1 + 2(A_2 d_2)$$
$$= (1.27 \cdot 80)\left(41.4 - \frac{1.27}{2}\right) + 2(40.16 \times 1.27)(20.08)$$
$$= 6193.1 \text{ mm}^3$$

$$b_{cen} = 2.54 \text{ mm}$$

$$Q_{glue} = A_1 d_1$$
$$= (100 \cdot 1.27)(34.205)$$
$$= 4344 \text{ mm}^3$$

$$b_{glue} = 10 \text{ mm}$$

Design 0 Code Output:

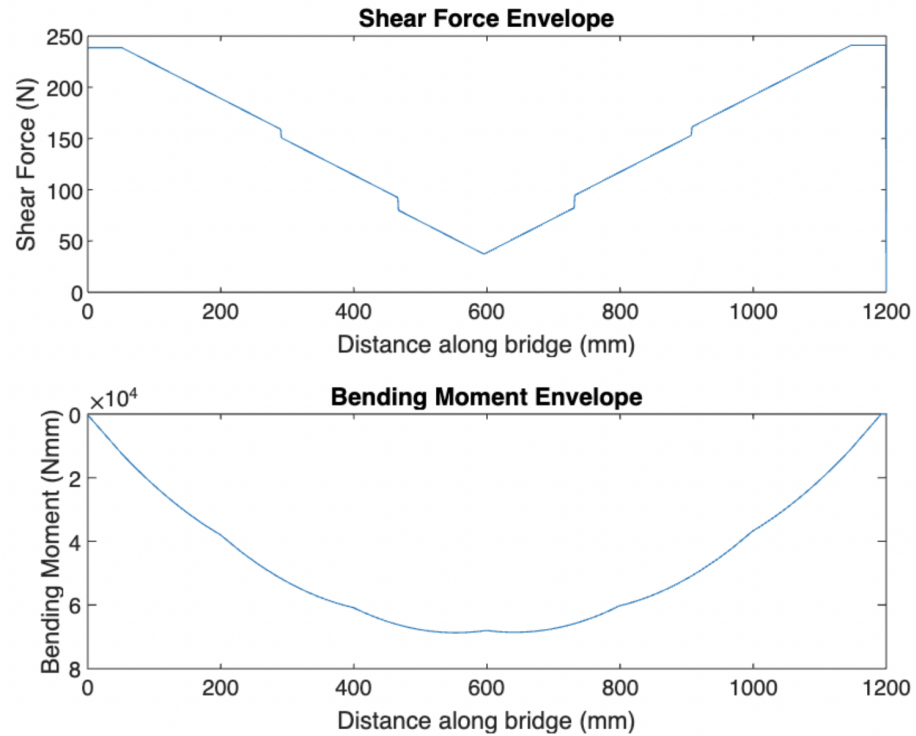| Types of Failure	Flexural Tensile	Flexural Comp	$T_{centroid}$	T_{glue}	Mid Flange (1)	Side Flange (2)	Web Comp (3)	Diaphragm Shear Buckle (C4)
Capacity	30	6	4	2	3.68	23.4	29.3	5.26
Applied	6.86	5.77	1.397	0.1985	5.77	5.77	5.77	1.397
FOS	4.37	1.040	2.86	10.08	0.639	4.07	5.10	3.76
Theoretical Load	1750	416	1145	4030	256	1629	2040	1505

```
Geometrical Properties
max_area = 8.2680e+05
length = 1200




total_area = 428.5742
centroid = 41.4311
second_moment_I = 4.1835e+05
first_moment_Q_cent = 6.1933e+03
first_moment_Q_glue = 4.3439e+03

Loads + Failures



M = 5×9 string
    "Types of Fai…  "Flexural Ten…  "Flexural Compres…  "Shear Failure …  "Shear Failure…  "Mid Flange (…  "Side Flange (…  "Web (TPB…  "Diaphragm/Shear Buck (…
    "Capacity"      "30"            "6"                 "4"               "2"              "3.68485"       "23.4911"        "29.4301"   "5.25662"
    "Applied"       "6.8591"        "5.7677"            "1.3969"          "0.19845"        "5.7677"        "5.7677"         "5.7677"    "1.3969"
    "FOS"           "4.37375"       "1.04027"           "2.86357"         "10.0782"        "0.638873"      "4.07285"        "5.10254"   "3.76317"
    "Theoretical …  "1749.5019"     "416.10824"         "1145.4264"       "4031.276"       "255.54934"     "1629.1411"      "2041.017…  "1505.2678"

Minimum FOS
ans = 0.6389
height = 76.2700
```
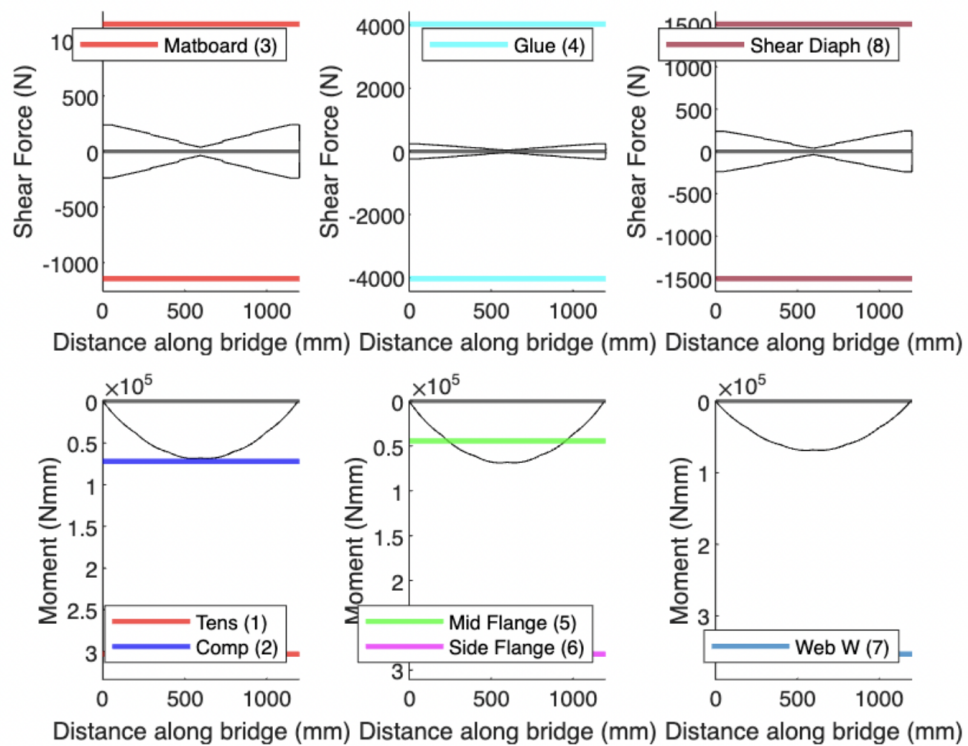
Shear Force Envelope

Bending Moment Envelope

```
max_bending = 6.9260e+04
max_shear = 239.6667
```

Final Design Code Output:

Types of Failure	Flexural Tensile	Flexural Comp	$T_{centroid}$	T_{glue}	Mid Flange (1)	Side Flange (2)	Web Comp (3)	Diaphragm Shear Buckle (C4)
Capacity	30	6	4	2	3.68	23.4	29.3	5.26
Applied	3.09	1.818	0.806	0.0856	1.818	1.818	1.818	0.806
FOS	9.70	3.30	4.96	23.3	12.0	18.1	7.64	3.29
Theoretical Load	3880	1320	1985	9340	4790	7270	3060	1314

```
Geometrical Properties
max_area = 8.2680e+05
length = 1250

current_area_left = 5.9460e+04

current_area_used = 6.8991e+05

total_area = 700.9511
centroid = 87.4061
second_moment_I = 1.9584e+06
first_moment_Q_cent = 1.6726e+04
first_moment_Q_glue = 1.2734e+04

Loads + Failures




M = 5x9 string
    "Types of Fai…  "Flexural Ten…  "Flexural Compres…  "Shear Failure …  "Shear Failure…  "Mid Flange (…  "Side Flange (…  "Web (TPB…  "Diaphragm/Shear Buck (…  ···
    "Capacity"      "30"            "6"                 "4"               "2"              "21.7744"       "33.0363"        "13.8896"   "2.64841"
    "Applied"       "3.0912"        "1.818"             "0.80586"         "0.085626"       "1.818"         "1.818"          "1.818"     "0.80586"
    "FOS"           "9.70491"       "3.3004"            "4.96363"         "23.3573"        "11.9774"       "18.1721"        "7.64019"   "3.28643"
    "Theoretical …  "3881.9641"     "1320.1602"         "1985.4524"       "9342.9163"      "4790.9564"     "7268.8599"      "3056.077…  "1314.5716"



Minimum FOS
ans = 3.2864
height = 138.8100
```
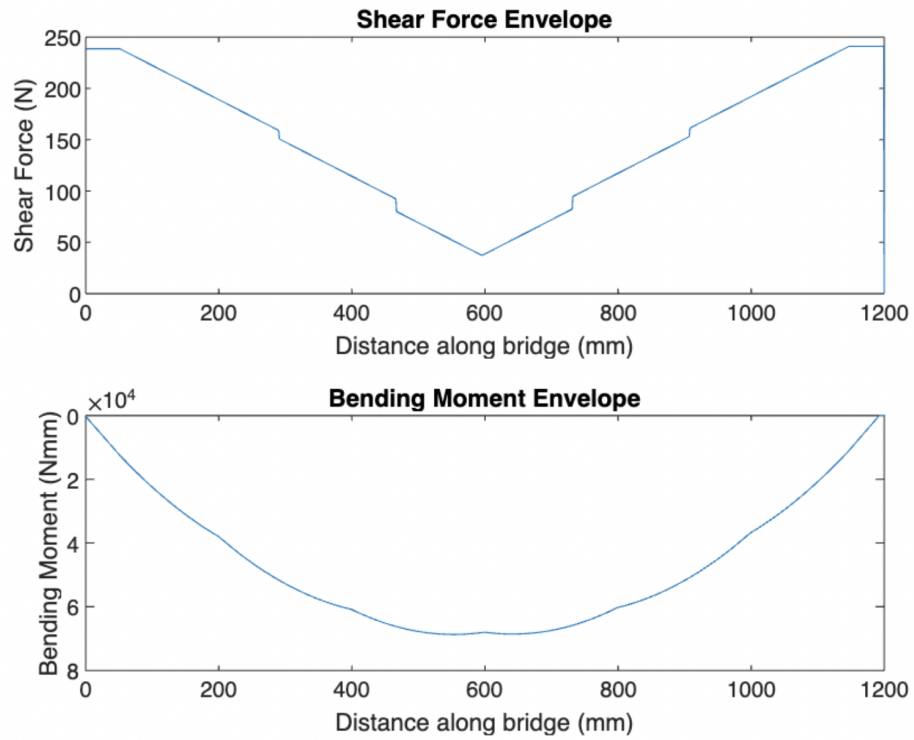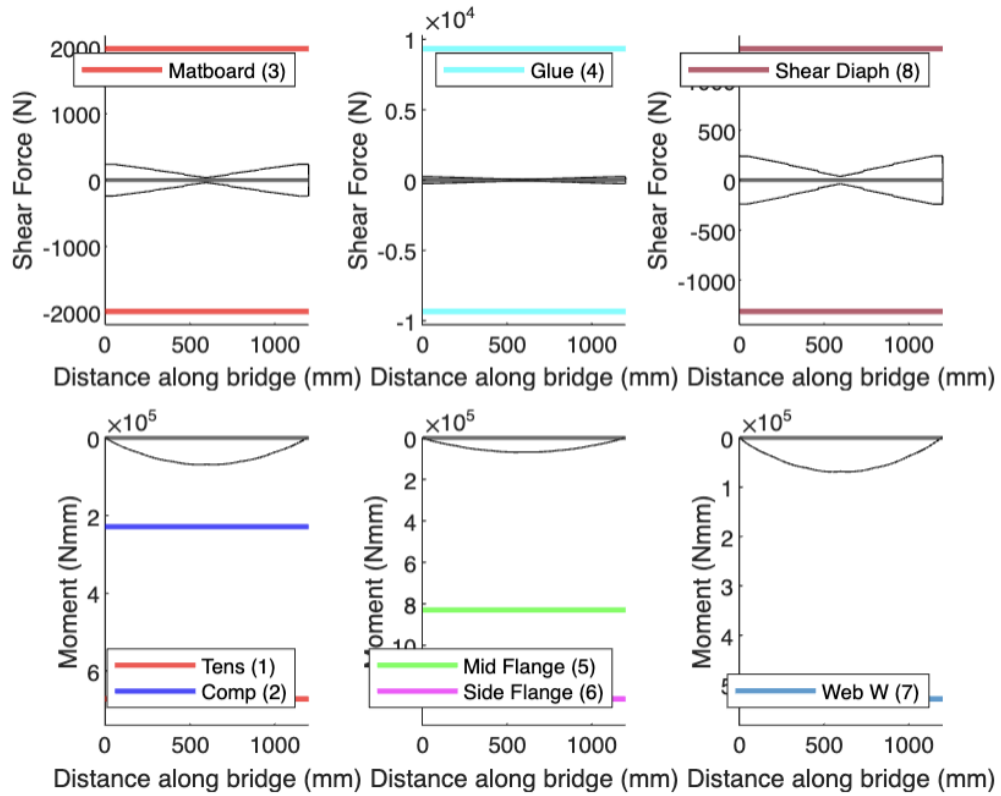
Shear Force Envelope

Bending Moment Envelope

```
max_bending = 6.9260e+04
max_shear = 239.6667
```