MATLAB Script

```
clear; close all;

%% 0. Initialize Parameters
L = 1200; % Length of bridge
n = 1200; % Discretize into 1 mm seg.
P = 400; % Total weight of train [N]
x = linspace(0, L, n+1); % x-axis

%% 1. SFD, BMD under train loading
x_train = [172 348 512 688 852 1028]; % Train Load Locations
P_train = [1 1 1 1 1.35 1.35] * P/6; %%Change for force in each wheel,
first two are heaviest

n_train = 3; % num of train locations



y_SFD = zeros(1,1200);
% Solve for SFD and BMD with the train at different locations

moment_a = 0;
for i = 1:length(x_train)
   start_x = x_train(i);% start location of train, each wheel position
   moment_a = moment_a + start_x*P_train(i);% sum of moments at A eqn
end
%moment_a final = moment_b final, fby = moment_a/1200
fby = moment_a/1200;
```

```
% sum of Fy eqn

fay = sum(P_train) - fby;
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```
P_train_neg = -1.*P_train;

%Total forces

load = [fay,P_train_neg(1), P_train_neg(2), P_train_neg(3),
P_train_neg(4), P_train_neg(5), P_train_neg(6), fby];

%Shear force values

SFD = zeros(8,1);

for i = 1:length(SFD)

   if i > 1

       SFD(i) = load(i)+SFD(i-1);

   else

       SFD(i) = load(i);

   end

end

%Force locations

x_SFD = [0, x_train(1), x_train(2), x_train(3), x_train(4), x_train(5),
x_train(6), 1200];
```

```
%SFD

for i = 1:1200

   if i == 1

       y_SFD(i) = 0;

   elseif i <=x_SFD(2)

       y_SFD(i) = SFD(1);

   elseif x_SFD(2)<i & i<=x_SFD(3)

       y_SFD(i) = SFD(2);

   elseif x_SFD(3)<i & i<=x_SFD(4)
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```
        y_SFD(i) = SFD(3);
    elseif x_SFD(4)<i & i<=x_SFD(5)
        y_SFD(i) = SFD(4);
    elseif x_SFD(5)<i & i<=x_SFD(6)
        y_SFD(i) = SFD(5);
    elseif x_SFD(6)<i & i<=x_SFD(7)
        y_SFD(i) = SFD(6);
    elseif x_SFD(7)<i & i<x_SFD(8)
        y_SFD(i) = SFD(7);
    elseif i==x_SFD(8)
        y_SFD(i) = SFD(8);
    end
end
x = 0:1:1199;
y = zeros(1,1200);
figure
hold on
plot(x,y_SFD, "-r")
plot(x,y," r:")
hold off
% BMD
area = zeros(1,8);
for i = 1:8
    if i>1
        area(i) = SFD(i-1)*(x_SFD(i)-x_SFD(i-1)) + area(i-1);
    end
end
plot(x_SFD,area)
```

```
SFD_max = max(abs(SFD)); % SFD envelope

BMD = max(area); % BMD envelope
```

```
bottom = [75, 2*1.27]; %[width, height] in mm

area_bot = bottom(1)*bottom(2);

side = [1.27, 80];

area_side = side(1)*side(2);

tab_top = [15, 1.27];

area_tab_top = tab_top(1)*tab_top(2);

tab_bot = [15, 1.27];

area_tab_bot = tab_bot(1)*tab_bot(2);

top = [100, 2*1.27];

area_top = top(1)*top(2);
```

```
dimensions = [bottom, side, side, tab_top, tab_top, tab_bot, tab_bot,
top];

areas = [area_bot, area_side, area_side, area_tab_top, area_tab_top,
area_tab_bot, area_tab_bot, area_top];
```

```
%% 3. Calculate Sectional Properties

% ybar. location of centroidal axis from the bottom

h_tot = bottom(2) + side(2) + top(2);

%Centroidal axis of each subsection

y_bar_each = [bottom(2)/2, bottom(2)+side(2)/2, bottom(2)+side(2)/2,
bottom(2)+side(2)- tab_top(2)/2, bottom(2)+side(2)- tab_top(2)/2,
bottom(2)+tab_bot(2)/2, bottom(2)+tab_bot(2)/2, bottom(2)+side(2) +
top(2)/2];
```

```
ybar = (area_bot*(bottom(2)/2) + 2*area_side*(bottom(2)+side(2)/2) +
2*area_tab_top*(bottom(2)+side(2)- tab_top(2)/2) +
2*area_tab_bot*(bottom(2)+tab_bot(2)/2) + area_top*(bottom(2)+side(2) +
top(2)/2))/(area_bot+2*area_side+2*area_tab_top+2*area_tab_bot+area_top)
;%manually calculated

ybot = ybar;

ytop = (bottom(2)+side(2)+top(2)) - ybar;
```

```
% I value

I_each = zeros(1,8);

for i = 1:8

   I_each(i) = (dimensions(2*i-1)*dimensions(2*i)^3)/12;

end
```

```
d_each = zeros(1,8);

for i = 1:8

   d_each(i) = (ybar - y_bar_each(i));

end

% I = %sum of I + A*d^2

d_each_squared = d_each.^2;

I = sum(I_each);

for i = 1:8

   I = I + areas(i)*d_each_squared(i);

end
```

```
%Flexural stress = m*y/I

flex_stress_top = max(area)*ytop/I;

flex_stress_bot = max(area)*ybot/I;
```

```
%Shear stress
%centroid
Q = 0;
for i = 1:8
   Q = Q + areas(i)*abs(d_each(i));
end
b = 1.27*2; %length of matter on centroidal axis ybar
shear_centroid = SFD_max*Q/(I*b);
%glue tabs
b_tab = 2*(5+1.27);
shear_glue = SFD_max*Q/(I*b_tab);
```

```
%% 5. Material and Thin Plate Buckling Capacities
E = 4000;
mu = 0.2;
S_tens = flex_stress_bot;
S_comp = flex_stress_top;
T_max = shear_centroid;
T_gmax = shear_glue;
```

```
%Buckling
%top flange (mid part) k=4
S_buck1 = ((4*pi^2*E)/(12*(1-mu^2)))*(top(2)/bottom(1))^2;
```

```
side_flange = (top(1)-bottom(1))/2; %length
S_buck2 = ((0.425*pi^2*E)/(12*(1-mu^2)))*(top(2)/side_flange)^2;
```

```
S_buck3 = ((6*pi^2*E)/(12*(1-mu^2)))*(side(1)/ytop)^2;
```

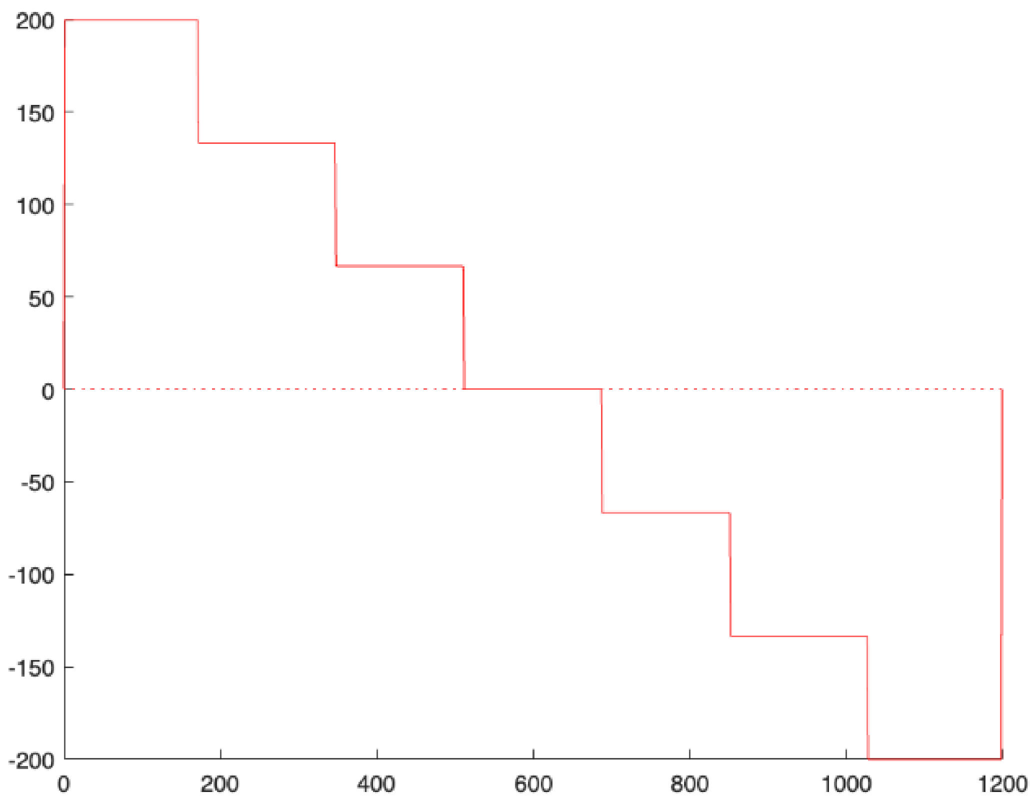
```
a = 210; %the distance between diaphragms   (needs to be decided from design plan)

T_buck = ((5*(pi^2)*E)/(12*(1-mu^2)))*((side(1)/a)+(side(1))/(side(2)+bottom(2)))^2;
```

```
%% 6. FOS

FOS_tens = 30/S_tens

FOS_comp = 6/S_comp

FOS_shear = 4/T_max

FOS_glue = 2/T_gmax

FOS_buck1 = S_buck1/S_tens

FOS_buck2 = S_buck2/S_tens

FOS_buck3 = S_buck3/S_tens

FOS_buckV = T_buck/T_max

%

% %% 7. Min FOS and the failure load Pfail

FOS_vector = [FOS_tens, FOS_comp, FOS_shear, FOS_glue, FOS_buck1, FOS_buck2, FOS_buck3, FOS_buckV];

minFOS = min(FOS_vector)

%Failure Load

Ff= 4/(Q/(I*b));

percent = Ff/fby;

Pf = sum(P_train)*percent
```

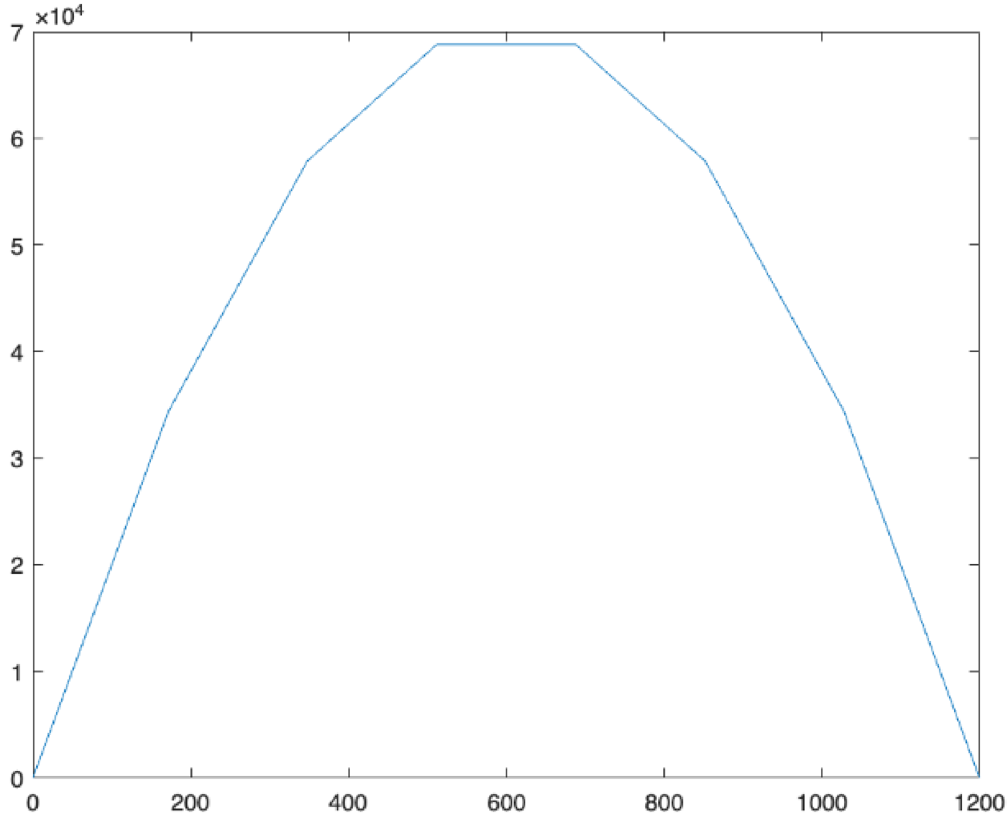
MATLAB Output

Design 0 under load case 1

SFD



BMD



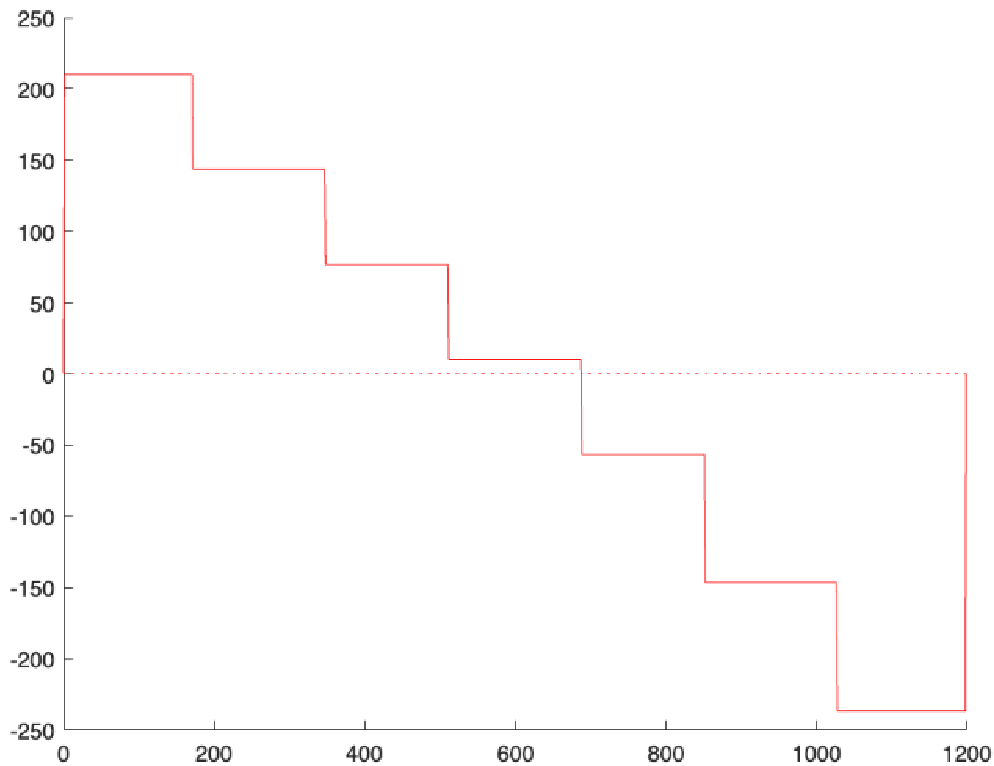
Intermediate Steps

fby = 200.0000 mm
fay = 200.0000 mm
SFD_max = 200.0000 N
BMD = 6.8800e+04 N*mm
ybar = 40.2935 mm
ybot = 40.2935 mm
ytop = 35.9765 mm
I = 8.4871e+04 mm^4
S_tens = 6.3346 MPa
S_comp = 5.6560 MPa
T_max = 3.5417 MPa
T_gmax = 0.3587 MPa
S_buck1 = 3.4546 MPa
S_buck2 = 23.4911 MPa
S_buck3 = 25.6229 MPa
T_buck = 9.0493 MPa

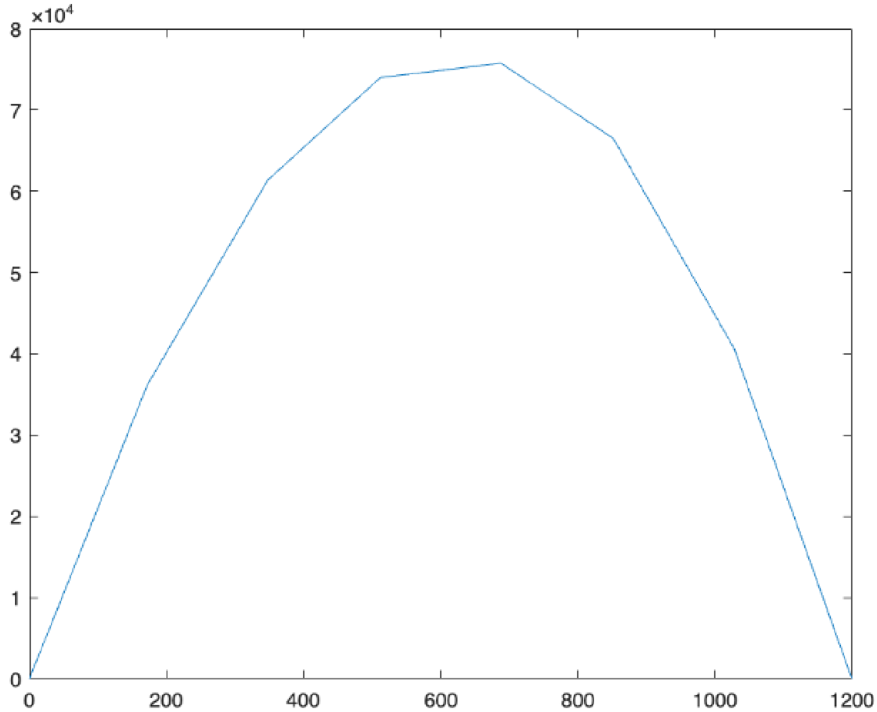
FOS_tens = 4.7359
FOS_comp = 1.0608
FOS_shear = 1.1294
FOS_glue = 5.5758
FOS_buck1 = 0.5453
FOS_buck2 = 3.7084
FOS_buck3 = 4.0449
FOS_buckV = 2.5550
minFOS = 0.5453

Final design under load case 2

SFD



BMD



FOS_tens = 5.7118
FOS_comp = 1.8475
FOS_shear = 1.8003
FOS_glue = 4.4441
FOS_buck1 = 2.9934
FOS_buck2 = 11.4497
FOS_buck3 = 6.1577
FOS_buckV = 3.6230
minFOS = 1.8003
Pf = 804.1352N