```
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 = [52 228 392 568 732 908]; % Train Load Locations
P_train = [1 1 1 1 1 1] * P/6;
n_train = 241; % num of train locations
SFDi = zeros(n_train, n+1); % 1 SFD for each train loc.
BMDi = zeros(n_train, n+1); % 1 BMD for each train loc.
```

```
% Solve for SFD and BMD with the train at different locations
for i = 1:n_train
    start = i-1;% start location of train

    B_y = sum((start+x_train).*P_train)/1200;% sum of moments at A eqn
    A_y = 400 - B_y; % sum of Fy eqn

    w = zeros(1, n+1);
    w(1) = A_y;
    w(1200) = B_y; % construct applied loads
    for j = 1:length(x_train)
        w(x_train(j)+start) = -P_train(j); % w(x)
    end
    SFDi(i,1) = w(1)*1;
    BMDi(i,1) = SFDi(i,1)*1;
    for j = 2:1201
         SFDi(i,j) = SFDi(i,j-1) + w(j)*1; % SFD = num. integral(w)
         BMDi(i,j) = BMDi(i,j-1)+ SFDi(i,j-1)*1; % BMD = num. integral(SFD)
    end
end
SFD = max(abs(SFDi)); % SFD envelope
BMD = max(BMDi); % BMD envelope
```

```
%% 2. Define Bridge Parameters
% = xc, bft, tft,
param = [0, 100, 1.27, 1.27, 5+1.27,75-2*1.27,1.27,80,1.27, 2*(5+1.27),400;
        400, 100, 1.27, 1.27,5+1.27,75-2*1.27,1.27,80,1.27, 2*(5+1.27),400;
        800, 100, 1.27, 1.27, 5+1.27,75-2*1.27,1.27,80,1.27, 2*(5+1.27),400;
        L, 100, 1.27, 1.27, 5+1.27,75-2*1.27,1.27,80,1.27, 2*(5+1.27),400]
```

param = 4×11

10^3 ×

```
         0    0.1000    0.0013    0.0013    0.0063    0.0725    0.0013    0.0800 ···
    0.4000    0.1000    0.0013    0.0013    0.0063    0.0725    0.0013    0.0800
    0.8000    0.1000    0.0013    0.0013    0.0063    0.0725    0.0013    0.0800
    1.2000    0.1000    0.0013    0.0013    0.0063    0.0725    0.0013    0.0800
```

```
%x_c Location, x, of cross-section change
%bft Top Flange Width
%tft Top Flange Thickness
% Extracting user input assuming linear relationship
bft = interp1(param(:,1), param(:,2), x)
```

```
bft = 1×1201
   100   100   100   100   100   100   100   100   100   100   100   100   100 ···
```

```
tft = interp1(param(:,1), param(:,3), x)
```

```
tft = 1×1201
    1.2700    1.2700    1.2700    1.2700    1.2700    1.2700    1.2700    1.2700 ···
```

```
tm = interp1(param(:,1), param(:,4), x);
bm = interp1(param(:,1), param(:,5), x);
hw = interp1(param(:,1), param(:,6), x);
tw = interp1(param(:,1), param(:,7), x);
bfb = interp1(param(:,1), param(:,8), x);
tfb = interp1(param(:,1), param(:,9), x);
a = interp1(param(:,1), param(:,11), x);
bg = interp1(param(:,1), param(:,10), x);
```

```
%% 3. Calculate Sectional Properties
% ybar. location of centroidal axis from the bottom

A = bft.*tft+2*tm.*bm+2*hw.*tw+bfb.*tfb;
AY = bft.*tft.*(tfb+hw+tm+tft/2)+2*tm.*bm.*(tfb+hw+tm/2)+2*hw.*tw.*(tfb+hw/2)+bfb.*tfb.*(tfb/2)


ybar = AY./A
```

```
ybar = 1×1201
   41.4311   41.4311   41.4311   41.4311   41.4311   41.4311   41.4311   41.4311 ···
```

```
ybot = ybar
```

```
ybot = 1×1201
   41.4311   41.4311   41.4311   41.4311   41.4311   41.4311   41.4311   41.4311 ···
```

```
ytop = tfb+hw+tm+tft-ybar
```

```
ytop = 1×1201
   34.8389   34.8389   34.8389   34.8389   34.8389   34.8389   34.8389   34.8389 ···
```

```
% I
I =bft.*tft.^3/12+ bft.*tft.*(tfb+hw+tm+tft/2-ybar).^2+2*(tm.^3.*bm/12+tm.*bm.*(tfb+hw+tm/2-yba
```

```
I = 1×1201
10^5 ×
    4.1835    4.1835    4.1835    4.1835    4.1835    4.1835    4.1835    4.1835 ⋯
```

```
% Q at centroidal axes
Qmid = 2*(ybar - tfb).*tw.*(ybar-tfb-(ybar - tfb)/2)+bfb.*(tfb).*(ybar-tfb/2)
```

```
Qmid = 1×1201
10^3 ×
    6.1933    6.1933    6.1933    6.1933    6.1933    6.1933    6.1933    6.1933 ⋯
```

```
% Q at glue location
Qglue = bft.*tft.*(ytop-tft/2)
```

```
Qglue = 1×1201
10^3 ×
    4.3439    4.3439    4.3439    4.3439    4.3439    4.3439    4.3439    4.3439 ⋯
```

```
%% 4. Calculate Applied Stress
S_top = max(BMD).*ytop./I
```

```
S_top = 1×1201
    5.7832    5.7832    5.7832    5.7832    5.7832    5.7832    5.7832    5.7832 ⋯
```

```
S_bot = max(BMD).*ybot./I
```

```
S_bot = 1×1201
    6.8774    6.8774    6.8774    6.8774    6.8774    6.8774    6.8774    6.8774 ⋯
```

```
T_cent = max(SFD).*Qmid./(I*2*tw(1))
```

```
T_cent = 1×1201
    1.3988    1.3988    1.3988    1.3988    1.3988    1.3988    1.3988    1.3988 ⋯
```

```
T_glue = max(SFD).*Qglue./(I*bg(1))
```

```
T_glue = 1×1201
    0.1987    0.1987    0.1987    0.1987    0.1987    0.1987    0.1987    0.1987 ⋯
```

```
%% 5. Material and Thin Plate Buckling Capacities
E = 4000;
mu = 0.2;
S_tens = 30
```

```
S_tens = 30
```

```
S_comp = 6
```

```
S_comp = 6
```

```
T_max = 4
```

```
T_max = 4
```

```
T_gmax = 2
```

T_gmax = 2

```
S_buck1 = ((4*pi^2*4000)/(12*(1-0.2^2)))*(tft(1)/(bfb(1)-tw(1)))^2
```

S_buck1 = 3.5669

```
S_buck2 = ((0.425*pi^2*4000)/(12*(1-0.2^2)))*(tft(1)/((bft(1)-(bfb(1)-tw(1)))/2))^2
```

S_buck2 = 20.7696

```
S_buck3 = ((6*pi^2*4000)/(12*(1-0.2^2)))*(tw(1)/(ytop(1) - tft(1)-tm(1)/2))^2
```

S_buck3 = 30.5759

```
T_buck = ((5*pi^2*4000)/(12*(1-0.2^2)))*((1.27/a(1))^2 + (1.27/((ytop(1)+ybot(1)-tft(1)-tfb(1)
```

T_buck = 5.2566

```
%% 6. FOS
FOS_tens = S_tens./S_bot
```

FOS_tens = 1×1201
    4.3621   4.3621   4.3621   4.3621   4.3621   4.3621   4.3621   4.3621 ···

```
FOS_comp = S_comp./S_top
```

FOS_comp = 1×1201
    1.0375   1.0375   1.0375   1.0375   1.0375   1.0375   1.0375   1.0375 ···

```
FOS_shear = T_max./T_cent
```

FOS_shear = 1×1201
    2.8596   2.8596   2.8596   2.8596   2.8596   2.8596   2.8596   2.8596 ···

```
FOS_glue = T_gmax./T_glue
```

FOS_glue = 1×1201
   10.0642   10.0642   10.0642   10.0642   10.0642   10.0642   10.0642   10.0642 ···

```
FOS_buck1 = S_buck1./S_top
```

FOS_buck1 = 1×1201
    0.6168   0.6168   0.6168   0.6168   0.6168   0.6168   0.6168   0.6168 ···

```
FOS_buck2 = S_buck2./S_top
```

FOS_buck2 = 1×1201
    3.5914   3.5914   3.5914   3.5914   3.5914   3.5914   3.5914   3.5914 ···

```
FOS_buck3 = S_buck3./S_top
```

FOS_buck3 = 1×1201

```
    5.2871    5.2871    5.2871    5.2871    5.2871    5.2871    5.2871    5.2871 ⋯
```

```
FOS_buckV = T_buck./T_cent
```

```
FOS_buckV = 1×1201
    3.7579    3.7579    3.7579    3.7579    3.7579    3.7579    3.7579    3.7579 ⋯
```

```
%% 7. Min FOS and the failure load Pfail
minFOS = FOS_buck1
```

```
minFOS = 1×1201
    0.6168    0.6168    0.6168    0.6168    0.6168    0.6168    0.6168    0.6168 ⋯
```

```
pf = 400
```

```
pf = 400
```

```
%% 8. Vfail and Mfail
Mf_tens = FOS_tens.* max(BMD)
```

```
Mf_tens = 1×1201
10^5 ×
    3.0293    3.0293    3.0293    3.0293    3.0293    3.0293    3.0293    3.0293 ⋯
```

```
Mf_comp = FOS_comp.* max(BMD)
```

```
Mf_comp = 1×1201
10^4 ×
    7.2049    7.2049    7.2049    7.2049    7.2049    7.2049    7.2049    7.2049 ⋯
```

```
Vf_shear = FOS_shear .* max(SFD)
```

```
Vf_shear = 1×1201
  686.3013  686.3013  686.3013  686.3013  686.3013  686.3013  686.3013  686.3013 ⋯
```

```
Vf_glue = FOS_glue .* max(SFD)
```

```
Vf_glue = 1×1201
10^3 ×
    2.4154    2.4154    2.4154    2.4154    2.4154    2.4154    2.4154    2.4154 ⋯
```

```
Mf_buck1 = FOS_buck1 .* max(BMD)
```

```
Mf_buck1 = 1×1201
10^4 ×
    4.2832    4.2832    4.2832    4.2832    4.2832    4.2832    4.2832    4.2832 ⋯
```

```
Mf_buck2 = FOS_buck2 .* max(BMD)
```

```
Mf_buck2 = 1×1201
10^5 ×
    2.4941    2.4941    2.4941    2.4941    2.4941    2.4941    2.4941    2.4941 ⋯
```

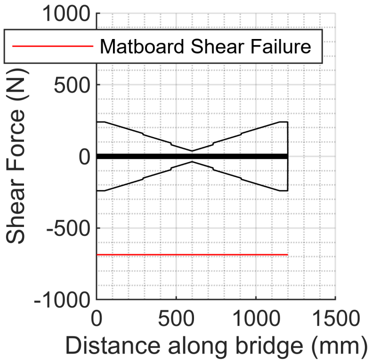
```
Mf_buck3 = FOS_buck3 .* max(BMD)
```

```
Mf_buck3 = 1×1201
10^5 ×
    3.6716    3.6716    3.6716    3.6716    3.6716    3.6716    3.6716    3.6716 ⋯
```

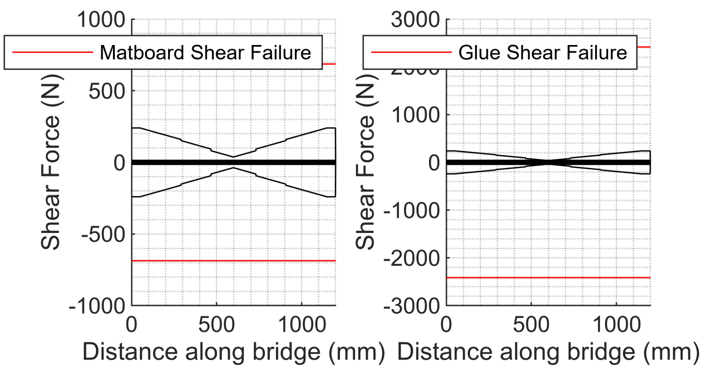
```
Vf_buckV = FOS_buckV .* max(SFD)
```

```
Vf_buckV = 1×1201
  901.9063  901.9063  901.9063  901.9063  901.9063  901.9063  901.9063  901.9063 ⋯
```

```
%% 9. Output plots of Vfail and Mfail
subplot(2,3,1);
hold on; grid on; grid minor;
plot(x, Vf_shear, 'r');
plot(x, -Vf_shear, 'r');
plot(x, SFD, "k");
plot(x, -SFD, "k");
% plot(x, [SFD(1:600) - SFD(601:end)],'k')
plot([0, L], [0, 0], 'k', 'LineWidth', 2)
legend('Matboard Shear Failure')
xlabel('Distance along bridge (mm)')
ylabel('Shear Force (N)')
```



```
%% 9. Output plots of Vfail and Mfail
subplot(2,3,2);
hold on; grid on; grid minor;
plot(x, Vf_glue, 'r')
plot(x, -Vf_glue, 'r')
plot(x, SFD, "k");
plot(x, -SFD, "k");
% plot(x, [SFD(1:600) - SFD(601:end)],'k')
plot([0, L], [0, 0], 'k', 'LineWidth', 2)
legend('Glue Shear Failure')
xlabel('Distance along bridge (mm)')
ylabel('Shear Force (N)')
```

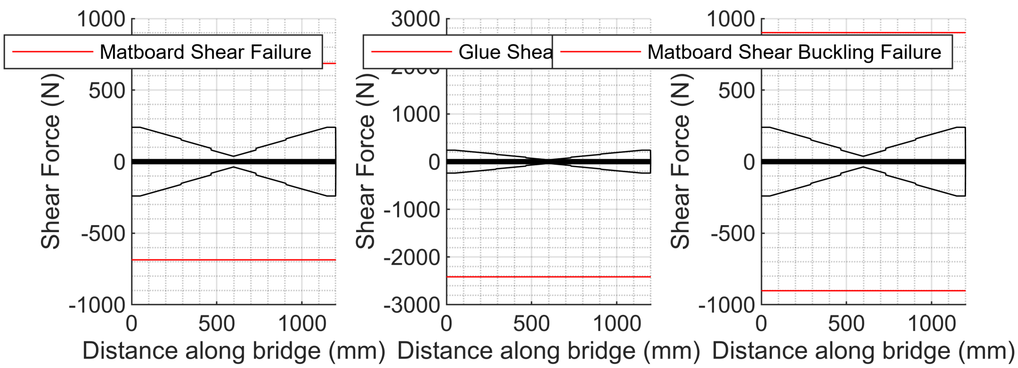



```

```

```
%% 9. Output plots of Vfail and Mfail
subplot(2,3,3);
hold on; grid on; grid minor;
plot(x, Vf_buckV, 'r')
plot(x, -Vf_buckV, 'r')
plot(x, SFD, "k");
plot(x, -SFD, "k");
```

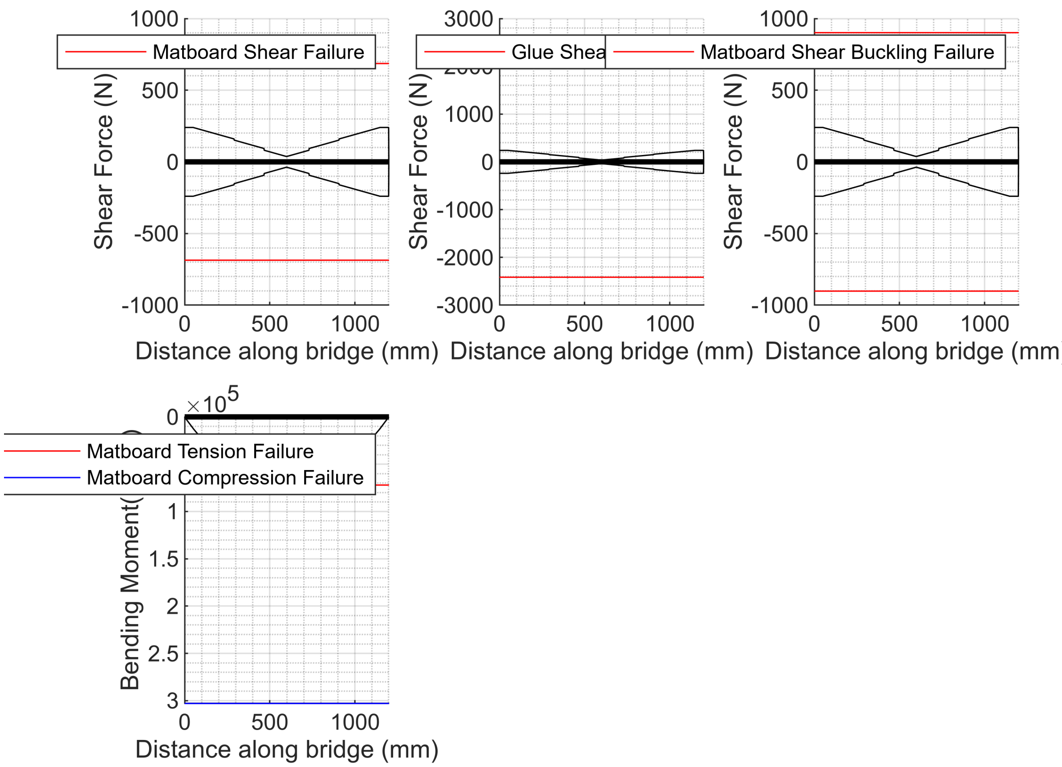
```
% plot(x, [SFD(1:600) - SFD(601:end)],'k')
plot([0, L], [0, 0], 'k', 'LineWidth', 2)
legend('Matboard Shear Buckling Failure')
xlabel('Distance along bridge (mm)')
ylabel('Shear Force (N)')
```



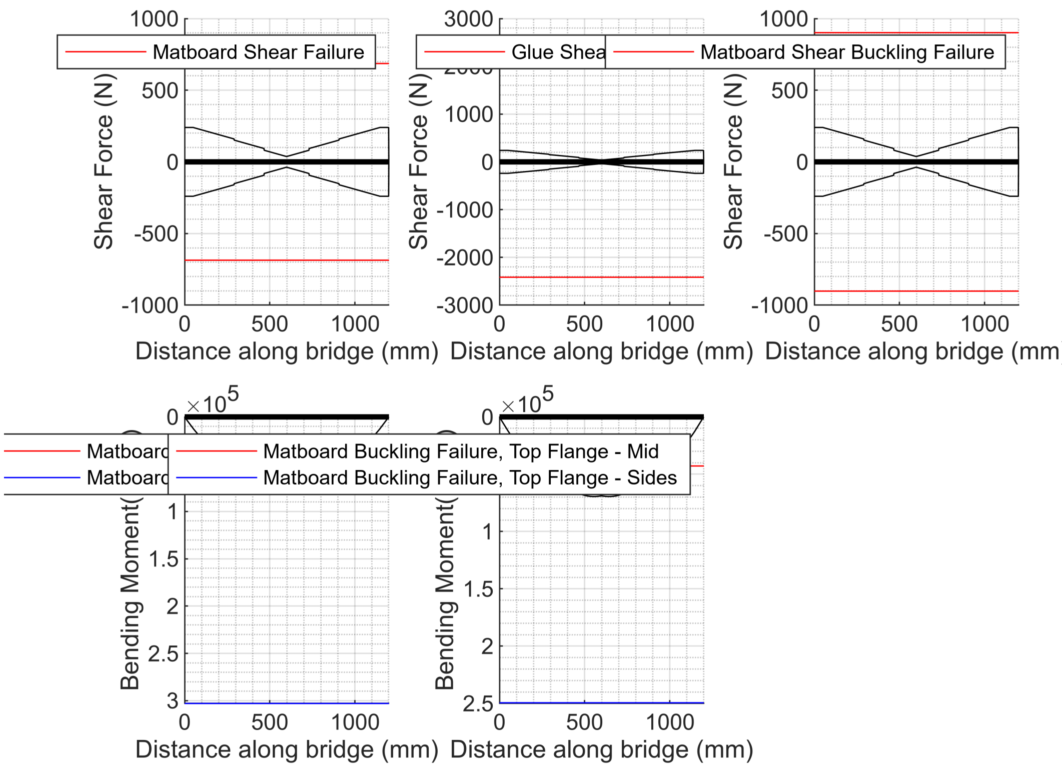

```

```

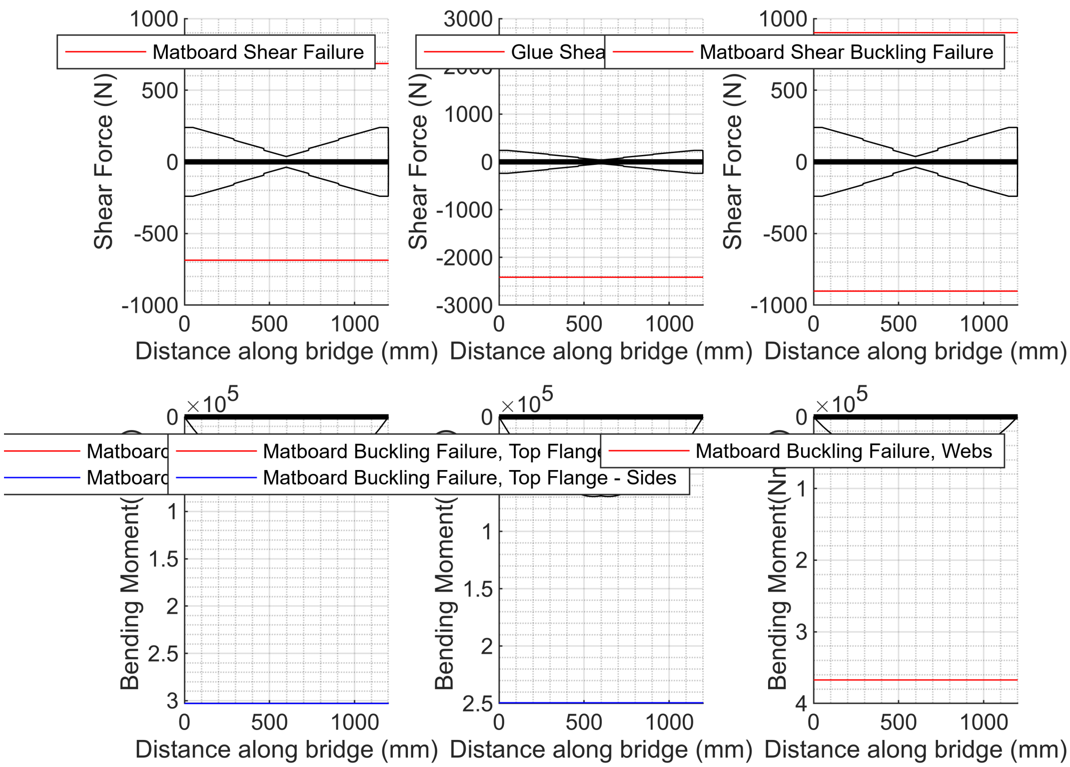
```
%% 9. Output plots of Vfail and Mfail
subplot(2,3,4);
hold on; grid on; grid minor;
set(gca,'YDir','reverse')
plot(x, Mf_comp, 'r')
plot(x, Mf_tens, 'b')
plot(x, BMD, "k");
% plot(x, [SFD(1:600) - SFD(601:end)],'k')
plot([0, L], [0, 0], 'k', 'LineWidth', 2)
legend('Matboard Tension Failure','Matboard Compression Failure')
xlabel('Distance along bridge (mm)')
ylabel('Bending Moment(Nmm)')
```




```
%% 9. Output plots of Vfail and Mfail
    subplot(2,3,5);
hold on; grid on; grid minor;
set(gca,'YDir','reverse')
plot(x, Mf_buck1, 'r');
plot(x, Mf_buck2, 'b');
plot(x, BMD, "k");
% plot(x, [SFD(1:600) - SFD(601:end)],'k')
plot([0, L], [0, 0], 'k', 'LineWidth', 2)
legend('Matboard Buckling Failure, Top Flange - Mid','Matboard Buckling Failure, Top Flange -
xlabel('Distance along bridge (mm)')
ylabel('Bending Moment(Nmm)')
```




```
%% 9. Output plots of Vfail and Mfail
subplot(2,3,6)
hold on; grid on; grid minor;
set(gca,'YDir','reverse')
plot(x, Mf_buck3, 'r')
plot(x, BMD, "k");
% plot(x, [SFD(1:600) - SFD(601:end)],'k')
plot([0, L], [0, 0], 'k', 'LineWidth', 2)
legend('Matboard Buckling Failure, Webs')
xlabel('Distance along bridge (mm)')
ylabel('Bending Moment(Nmm)')
```


Matboard Shear Failure
Glue Shea
Matboard Shear Buckling Failure
Shear Force (N)
Distance along bridge (mm)
Matboard
Matboard Buckling Failure, Top Flange
Matboard Buckling Failure, Top Flange - Sides
Matboard Buckling Failure, Webs
Bending Moment(
Bending Moment(Nm
$\times 10^5$