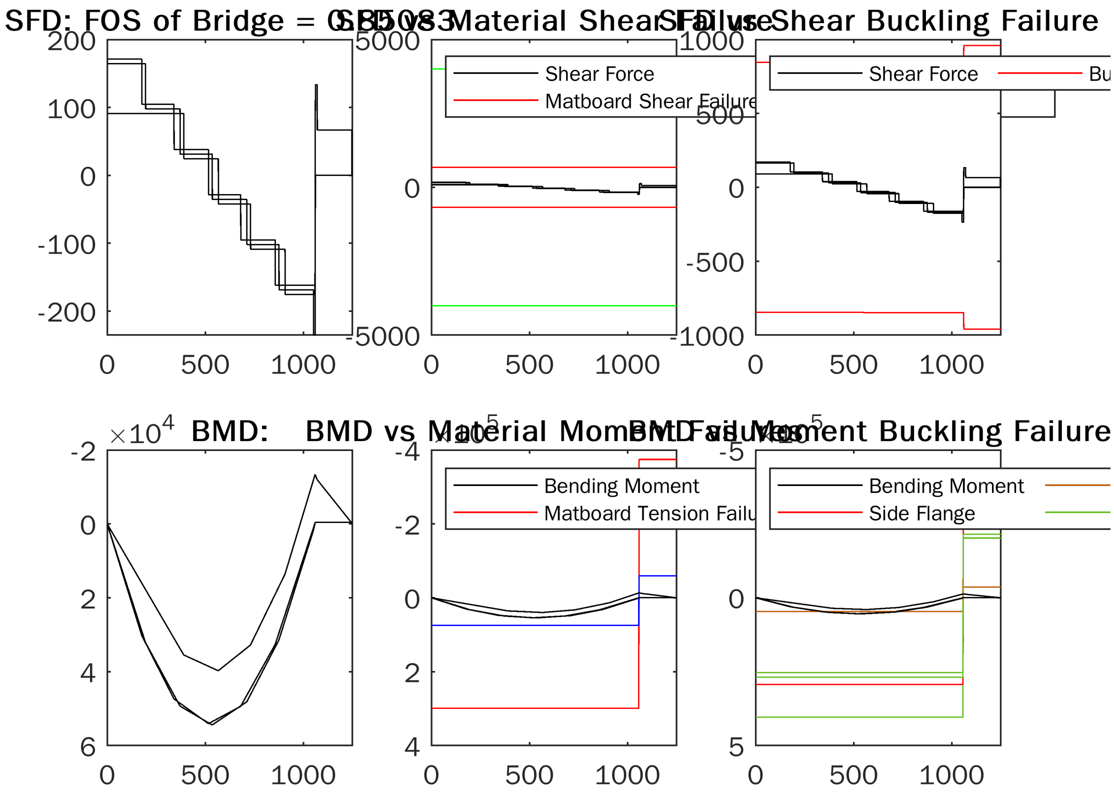
```
%%% Intial Parameters for both designs and cases:
n = 1250;                  % Number of locations to evaluate bridge failure
L = 1250;                  % Length of bridge

x = linspace(1,L,n);     % Define x coordinate

locationA = 1;
locationB = 1060;

%Material properties
SigT = 30;
SigC = 6;
E    = 4000;
TauU = 4;
TauG = 2;
mu   = 0.2;
```

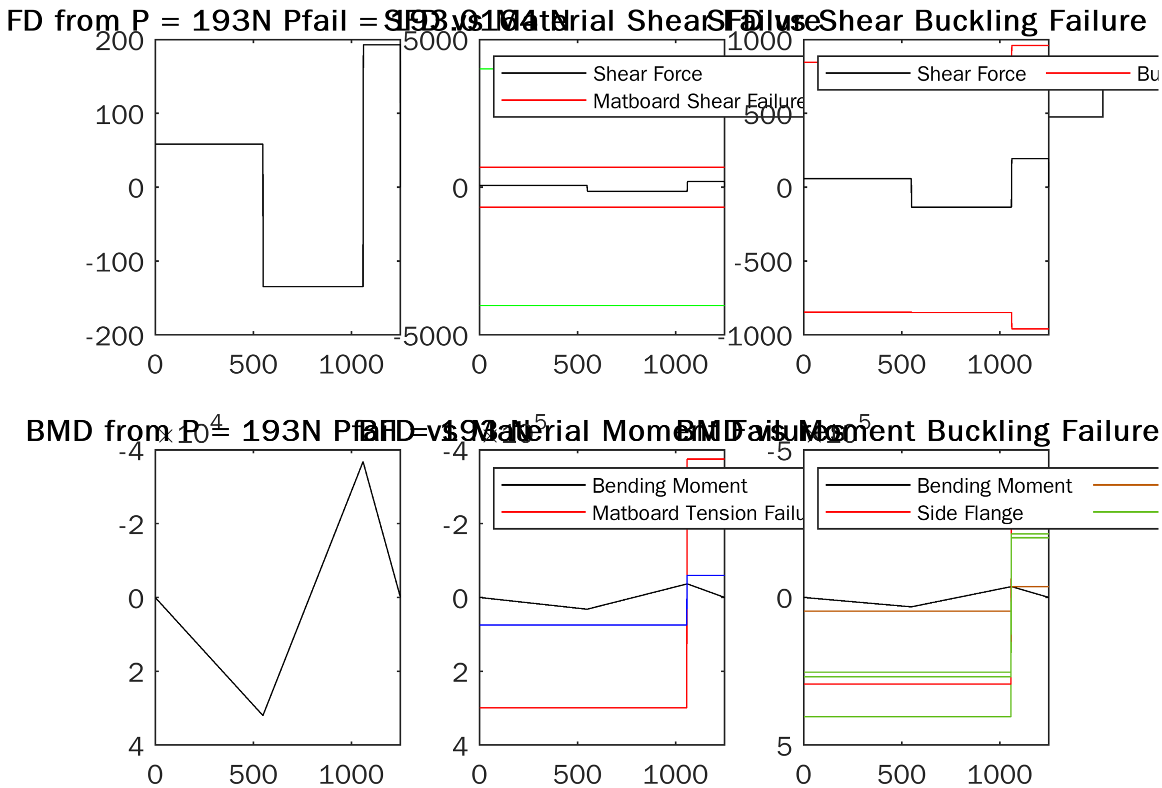
```
%%% Design Zero: Train
SFD_TrainLoad = zeros(1, n);      % Initialize SFD(x)
BMD_TrainLoad = zeros(1, n);      % Initialize BMD
SFD_TrainLoad1 = zeros(1, n);      % Initialize SFD(x)
BMD_TrainLoad1 = zeros(1, n);      % Initialize BMD
SFD_TrainLoad2 = zeros(1, n);      % Initialize SFD(x)
BMD_TrainLoad2 = zeros(1, n);      % Initialize BMD
SFD_TrainLoad3 = zeros(1, n);      % Initialize SFD(x)
BMD_TrainLoad3 = zeros(1, n);      % Initialize BMD
P = 400/6;

%diaphragms for Design 0
a = zeros(1,length(x));
a(1:550) = 550;
a(551:1060) = 510;
a(1061:1250) = 190;

%Cross Section
%% 2. Define cross-sections
% Design 0
dx = n/L; %length between each x coordinate
xc = [1 dx*L]; % x locations of changes in cross section
bVector = [100 1.27 1.27 10 10 80]; %Base of rectangle segments
hVector = [1.27 72.46 72.46 1.27 1.27 1.27]; %height of rectangle segments
yVector = [74.365 37.5 37.5 73.1 73.1 0.635]; % distances between local centroid of sub

I = zeros(1, length(x)); %Initialize I values
yBar = zeros(1, length(x)); %Initialize Y values
[I, yBar] = SectionProperties( I, yBar, xc(1), xc(2), bVector, hVector, yVector); %Calc

cutoffAreaCent = [ 77.46*1.27, 1.27*yBar(1), 1.27*yBar(1)]; %Calculate area from centro
yCentCutoff = [ yBar(1)-0.635, yBar(1)/2, yBar(1)/2]; %Calculate y values from centroi

cutoffAreaGlue = [127];
yGlue = [75-yBar(1)-0.635]; % centroid of the cutoff area
```

```
Qglue = zeros(1, length(x)); %initialize Q at centriod and Q at glue
Qmax = zeros(1, length(x));
[Qmax, Qglue] = calculateQ( Qmax, Qglue, xc(1), xc(2), cutoffAreaCent, cutoffAreaGlue,

%Other constants
b = zeros(1,length(x)); %Width of Shear surface
b(:) = 2*1.27;
bGlue = zeros(1,length(x)); %Width of Shear surface of glue
bGlue(:) = 10;
t = zeros(1,length(x)); %Thickness of board (used for plate buckling)
t(:) = 1.27;
height = zeros(1,length(x)); %Height of cross section
height(:) = 75;

%% Train Load: 6 points for the 6 wheels
TLocation = 1; %Train at Start
[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation, P, x, SFD_TrainLoad, locationA, loc
[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation + 176, P, x, SFD_TrainLoad, location
[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation + 176 + 164, P, x, SFD_TrainLoad, lo
[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation + 176 + 164 + 176, P, x, SFD_TrainLo
[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation + 176 + 164 + 176 + 164, P, x, SFD_T
[SFD_TrainLoad, BMD_TrainLoad] = ApplyPL(TLocation + 176 + 164 + 176 + 164 + 176, P, x,

TLocation = 196; %Train at Start
[SFD_TrainLoad2, BMD_TrainLoad2] = ApplyPL(TLocation, P, x, SFD_TrainLoad2, locationA,
[SFD_TrainLoad2, BMD_TrainLoad2] = ApplyPL(TLocation + 176, P, x, SFD_TrainLoad2, locat
[SFD_TrainLoad2, BMD_TrainLoad2] = ApplyPL(TLocation + 176 + 164, P, x, SFD_TrainLoad2,
[SFD_TrainLoad2, BMD_TrainLoad2] = ApplyPL(TLocation + 176 + 164 + 176, P, x, SFD_Train
[SFD_TrainLoad2, BMD_TrainLoad2] = ApplyPL(TLocation + 176 + 164 + 176 + 164, P, x, SFD
[SFD_TrainLoad2, BMD_TrainLoad2] = ApplyPL(TLocation + 176 + 164 + 176 + 164 + 176, P,

TLocation = 391; %Train at Start
[SFD_TrainLoad3, BMD_TrainLoad3] = ApplyPL(TLocation, P, x, SFD_TrainLoad3, locationA,
[SFD_TrainLoad3, BMD_TrainLoad3] = ApplyPL(TLocation + 176, P, x, SFD_TrainLoad3, locat
[SFD_TrainLoad3, BMD_TrainLoad3] = ApplyPL(TLocation + 176 + 164, P, x, SFD_TrainLoad3,
[SFD_TrainLoad3, BMD_TrainLoad3] = ApplyPL(TLocation + 176 + 164 + 176, P, x, SFD_Train
[SFD_TrainLoad3, BMD_TrainLoad3] = ApplyPL(TLocation + 176 + 164 + 176 + 164, P, x, SFD
[SFD_TrainLoad3, BMD_TrainLoad3] = ApplyPL(TLocation + 176 + 164 + 176 + 164 + 176, P,

%Find applied stresses
%Shear Stress demand
ShearStress = VStress(I, b, Qmax, SFD_TrainLoad); %Shear Stress at centroid
ShearStressGlue = VStress(I, 20 + 2*1.27, Qglue, SFD_TrainLoad); %Shear Stress at Glue

%Shear Stress Capacity
ShearBuckle = VBuck(I, t, b, height, E, mu, yBar, a, Qmax); %Buckling Shear capacity

%Bending Stress
%Bending Stress Demand
BendingStressT =  MStressT( I,yBar, height, BMD_TrainLoad); %Tension Stress
BendingStressC =  MStressC( I,yBar, height, BMD_TrainLoad); %Compression Stress

%Shear Stress Capacity %Bending Plate Buckling capacity stress
BendingBuck1 = MBuck( I, t, (100-80)/2, E, mu, 2);
```

```
BendingBuck2 = MBuck( I, t, 80-2*1.27, E, mu, 1 );
BendingBuck3 = MBuck( I, t, 75-41.701-1.27, E, mu, 3 );
BendingBuck4 = MBuck( I, t, (100-80)/2, E, mu, 2 );
BendingBuck5 = MBuck( I, t, 75-41.701-1.27, E, mu, 3 );
BendingBuck6 = MBuck( I, t, 41.701-1.27, E, mu, 3 );
BendingBuck7 = MBuck( I, t, 80-2*1.27, E, mu, 1 );
BendingBuck8 = MBuck( I, t, 41.701-1.27, E, mu, 1 );

%Calculate FOS
FOSBridge = FOSCalc(ShearStress, ShearStressGlue, BendingStressT, BendingStressC, SigT,

%Visualization

%Find max Shear Forces and Bending Moments
V_Mat = Vfail(I, b, Qmax, TauU); %Max Shear
V_Buck = VfailBuck( I, t, b, height, E, mu, yBar, a, TauU, Qmax); %Max Shear caused by
V_Glue = Vfail(I, bGlue, Qglue, TauU); %Max Shear at glue

M_MatT = MfailMatT(I, yBar, height, SigT, BMD_TrainLoad); %Max tension
M_MatC = MfailMatC(I, yBar, height, SigC, BMD_TrainLoad); %Max compression
M_Buck1 = MfailBuck(I, t, (100-80)/2, E, mu, BMD_TrainLoad, 2, yBar, height, SigC); %Ma
M_Buck2 = MfailBuck(I, t, 80-2*1.27, E, mu, BMD_TrainLoad, 1, yBar, height, SigC);
M_Buck3 = MfailBuck(I, t, 75-41.701-1.27, E, mu, BMD_TrainLoad, 3, yBar, height, SigC);
M_Buck4 = MfailBuck(I, t, (100-80)/2, E, mu, BMD_TrainLoad, 2, yBar, height, SigC);
M_Buck5 = MfailBuck(I, t, 75-41.701-1.27, E, mu, BMD_TrainLoad, 1, yBar, height, SigC);
M_Buck6 = MfailBuck(I, t, 41.701-1.27, E, mu, BMD_TrainLoad, 3, yBar, height, SigC);
M_Buck7 = MfailBuck(I, t, 80-2*1.27, E, mu, BMD_TrainLoad, 1, yBar, height, SigC);
M_Buck8 = MfailBuck(I, t, 41.701-1.27, E, mu, BMD_TrainLoad, 3, yBar, height, SigC);

%% Visualization
VisualizeTL(x, SFD_TrainLoad, BMD_TrainLoad, SFD_TrainLoad2, BMD_TrainLoad2, SFD_TrainL
```



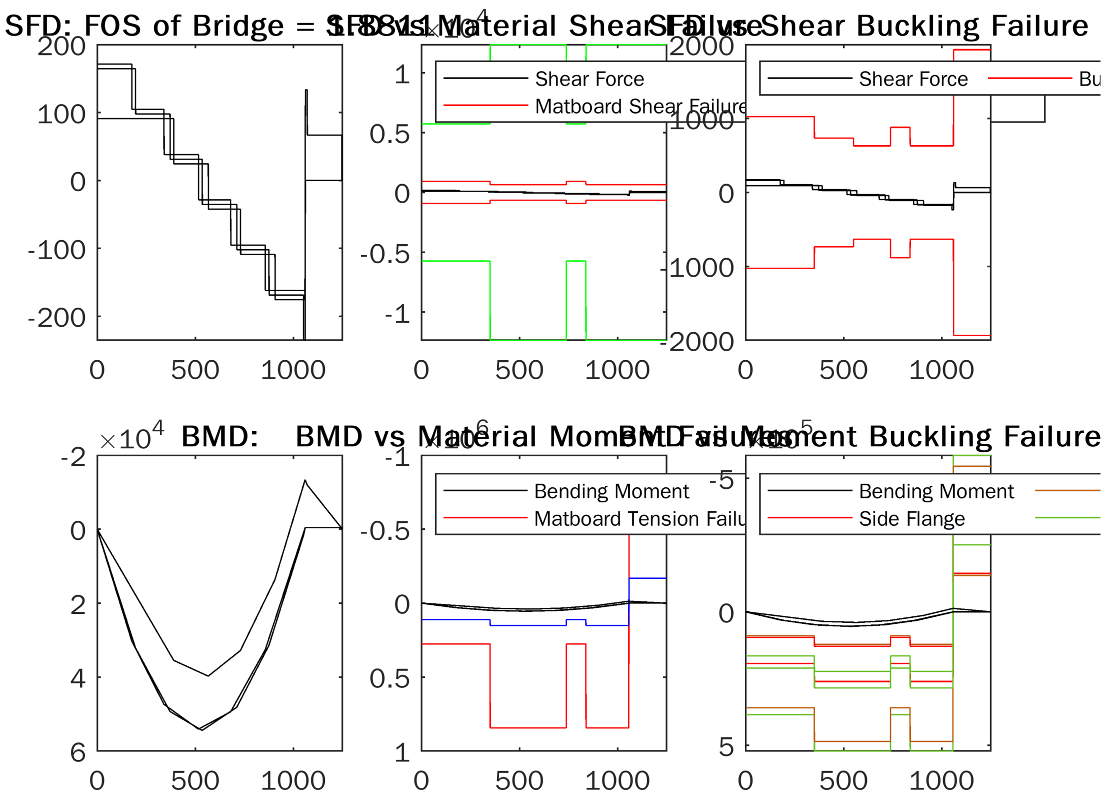

```
%Design 0 Point Loads
SFD_PL = zeros(1, n);      % Initialize SFD(x)
BMD_PL = zeros(1, n);
P = 1; %P = 1 * whatever value, so I can set p to 1

%% 1. Point Loading Analysis (SFD, BMD) Two loads for two points
[SFD_PL, BMD_PL] = ApplyPL(550, P, x, SFD_PL, locationA, locationB); % Construct SFD, E
[SFD_PL, BMD_PL] = ApplyPL(L, P, x, SFD_PL, locationA, locationB);   % Construct SFD, E

%%Calculate Failure Load
Pf = FailLoad( SFD_PL, BMD_PL, V_Mat, V_Glue, V_Buck, M_MatT, M_MatC, M_Buck1, M_Buck2,

%% Visualization
SFD_FAIL = zeros(1,length(x));
BMD_FAIL = zeros(1,length(x));
[SFD_FAIL, BMD_FAIL] = ApplyPL(550, Pf, x, SFD_FAIL, locationA, locationB); % Construct
[SFD_FAIL, BMD_FAIL] = ApplyPL(L, Pf, x, SFD_FAIL, locationA, locationB);   % Construct
VisualizePL(x, SFD_FAIL, BMD_FAIL, V_Mat, V_Glue, V_Buck, M_MatT, M_MatC, M_Buck1, M_Bu
```



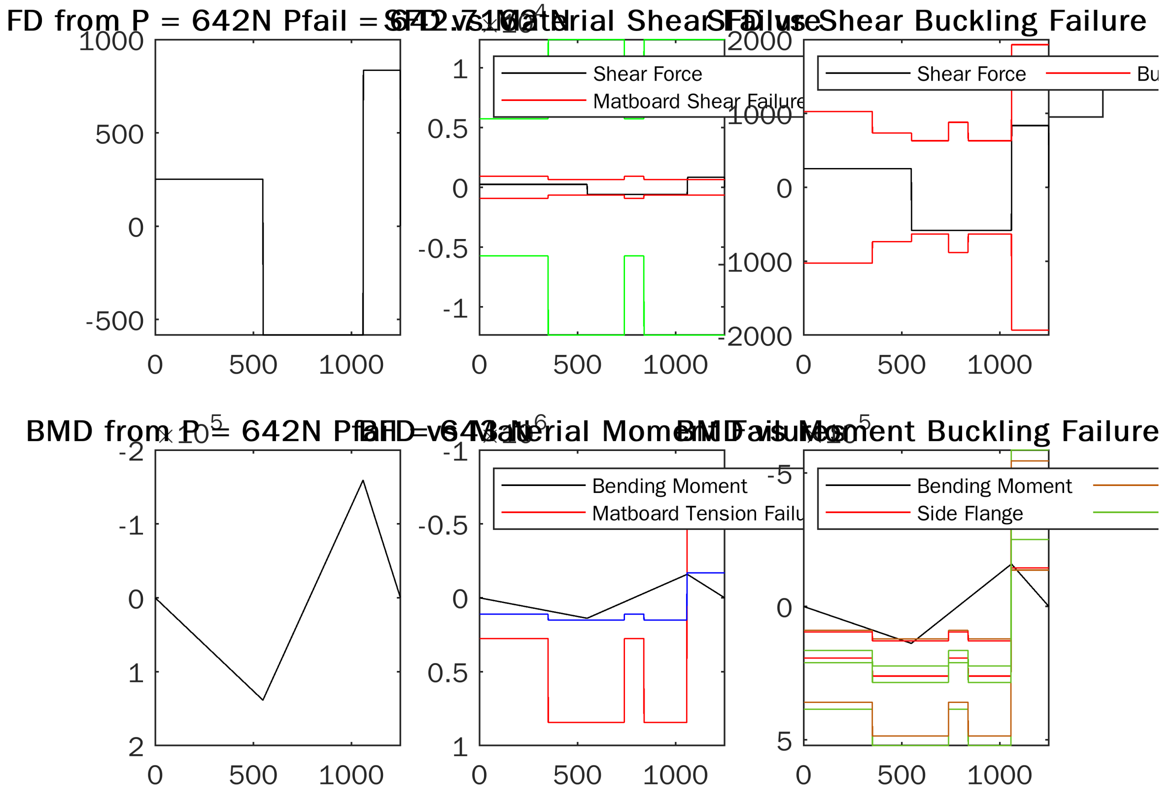

```
%Our Design
%Train:

%diaphragms
a = zeros(1,length(x)); %Our design has 3 different diaphragm spacings
a(1:550) = 104;
a(551:1060) = 120;
a(1060:1250) = 53;

%% 2. Define cross-sections
% Cross Section A
dx = n/L;
xc = [1 dx*350 dx*738 dx*838 dx*L]; % x locations of changes in cross section
I = zeros(1, length(x));
yBar = zeros(1, length(x));
Qglue = zeros(1, length(x));
Qmax = zeros(1, length(x));

%Cross Section A
bVector = [100 1.27 1.27 10 10];
hVector = [1.27 120 120 1.27 1.27];
```

```
yVector = [120.635 60 60 119.365 119.365]; % distances between local centroid of subcom
[I, yBar] = SectionProperties( I, yBar, xc(1), xc(2), bVector, hVector, yVector); %This
[I, yBar] = SectionProperties( I, yBar, xc(3)+1, xc(4), bVector, hVector, yVector);
cutoffAreaCent = [ 1.27*yBar(1), 1.27*yBar(1)];
yCentCutoff = [ yBar(1)/2, yBar(1)/2];
cutoffAreaGlue = [127];
yGlue = [121.27-yBar(1)-0.635]; % centroid of the cutoff area
[Qmax, Qglue] = calculateQ( Qmax, Qglue, xc(1), xc(2), cutoffAreaCent, cutoffAreaGlue,
[Qmax, Qglue] = calculateQ( Qmax, Qglue, xc(3)+1, xc(4), cutoffAreaCent, cutoffAreaGlue

% Cross Section B
bVector = [100 1.27 1.27 10 10 10 10 70 70];
hVector = [1.27 117.46 117.46 1.27 1.27 1.27 1.27 1.27 1.27];
yVector = [120.635 61.27 61.27 119.365 119.365 3.175 3.175 1.905 0.635]; % distances be
[I, yBar] = SectionProperties( I, yBar, xc(2)+1, xc(3), bVector, hVector, yVector); %Th
[I, yBar] = SectionProperties( I, yBar, xc(4)+1, xc(5), bVector, hVector, yVector);
cutoffAreaCent = [ 127 12.7 12.7 (120-yBar(900))*1.27 (120-yBar(900))*1.27];
yCentCutoff = [ 121.27-yBar(900)-0.635 120-yBar(900)-0.635 120-yBar(900)-0.635 120-yBar
cutoffAreaGlue = [127];
yGlue = [121.27-yBar(1)-0.635]; % centroid of the cutoff area
[Qmax, Qglue] = calculateQ( Qmax, Qglue, xc(2)+1, xc(3), cutoffAreaCent, cutoffAreaGlue
[Qmax, Qglue] = calculateQ( Qmax, Qglue, xc(4)+1, xc(5), cutoffAreaCent, cutoffAreaGlue

%Other constants
b = zeros(1,length(x));
b(:) = 2*1.27;
bGlue = zeros(1,length(x));
bGlue(:) = 10;
t = zeros(1,length(x));
t(:) = 1.27;
height = zeros(1,length(x));
height(:) = 120;

% It was uncessary to calculate the SFD and BMD again since it was already
% done for Design 0

%Find applied stresses
%Shear Stress demand
ShearStress = VStress(I, b, Qmax, SFD_TrainLoad);
ShearStressGlue = VStress(I, 20 + 2*1.27, Qglue, SFD_TrainLoad);

%Shear Stress Capacity
ShearBuckle = VBuck(I, t, b, height, E, mu, yBar, a, Qmax);

%Bending Stress
%Bending Stress Demand
BendingStressT =  MStressT( I,yBar, height, BMD_TrainLoad);
BendingStressC =  MStressC( I,yBar, height, BMD_TrainLoad);

%Shear Stress Capacity
%Cross Section A
BendingBuck1 = MBuck( I, t, 15, E, mu, 2);
BendingBuck2 = MBuck( I, t, 70-2*(1.27), E, mu, 1);
BendingBuck3 = MBuck( I, t, 39.859, E, mu, 3 );
```

```
BendingBuck4 = MBuck( I, t, 80.1411, E, mu, 3 );

%Cross Section B
BendingBuck5 = MBuck( I, t, 56.4858-2*1.27, E, mu, 3 );
BendingBuck6 = MBuck( I, t, 117.46-56.4858, E, mu, 3 );
BendingBuck7 = MBuck( I, 2*t, 70-2*1.27, E, mu, 1 );
BendingBuck8 = MBuck( I, t, 56.4858-2*1.27, E, mu, 3 );

FOSBridge = FOSCalc(ShearStress, ShearStressGlue, BendingStressT, BendingStressC, SigT,

%Visualization

V_Mat = Vfail(I, b, Qmax, TauU);
V_Buck = VfailBuck( I, t, b, height, E, mu, yBar, a, TauU, Qmax);
V_Glue = Vfail(I, bGlue, Qglue, TauU);

M_MatT = MfailMatT(I, yBar, height, SigT, BMD_TrainLoad);
M_MatC = MfailMatC(I, yBar, height, SigC, BMD_TrainLoad);
M_Buck1 = MfailBuck(I, t, 15, E, mu, BMD_TrainLoad, 2, yBar, height, SigC);
M_Buck2 = MfailBuck(I, t, 70-2*(1.27), E, mu, BMD_TrainLoad, 1, yBar, height, SigC);
M_Buck3 = MfailBuck(I, t, 39.859, E, mu, BMD_TrainLoad, 3, yBar, height, SigC);
M_Buck4 = MfailBuck(I, t, 80.1411, E, mu, BMD_TrainLoad, 3, yBar, height, SigC);
M_Buck5 = MfailBuck(I, t, 56.4858-2*1.27, E, mu, BMD_TrainLoad, 3, yBar, height, SigC);
M_Buck6 = MfailBuck(I, t, 117.46-56.4858, E, mu, BMD_TrainLoad, 3, yBar, height, SigC);
M_Buck7 = MfailBuck(I, 2*t, 70-2*1.27, E, mu, BMD_TrainLoad, 1, yBar, height, SigC);
M_Buck8 = MfailBuck(I, t, 56.4858-2*1.27, E, mu, BMD_TrainLoad, 3, yBar, height, SigC);

%% Visualization
VisualizeTL(x, SFD_TrainLoad, BMD_TrainLoad, SFD_TrainLoad2, BMD_TrainLoad2, SFD_TrainL
```




```
%Point Load our Design:
Pf = FailLoad( SFD_PL, BMD_PL, V_Mat, V_Glue, V_Buck, M_MatT, M_MatC, M_Buck1, M_Buck2,
[SFD_FAIL, BMD_FAIL] = ApplyPL(550, Pf, x, SFD_FAIL, locationA, locationB); % Construct
[SFD_FAIL, BMD_FAIL] = ApplyPL(L, Pf, x, SFD_FAIL, locationA, locationB);   % Construct
VisualizePL(x, SFD_FAIL, BMD_FAIL, V_Mat, V_Glue, V_Buck, M_MatT, M_MatC, M_Buck1, M_Bu
```




```
%% Train failure Functions:
```

```
function [ ShearFail ] = VStress(I, b, Qcent, SFD )
%Calculates the Shear Stress at Applied load for every x value

    ShearFail = ((SFD .* Qcent) ./ (I .* b));
end

function [ ShearBuckle ] = VBuck( I, t, b, height, E, mu, y, a, Qcent )
% Calculates the Shear Buckle capacity at every x value

    %pi
    pi = 355/113; %Pi approximation

    for i = 1:length(I)
        ShearBuckle(i) = ((5*E*pi^2)/(12*(1-mu^2))) * ((t(i)/height(i))^2 + (t(i)/a(i)
    end

end

function [ BendingTensionStress ] = MStressT( I,y, height, BMD )  %Tension
% Calculates Tension Stress at every x value based on applied load
```

```
BendingTensionStress = zeros(1,length(I));

for i = 1 : length(I)
        ybot = y(i);
        ytop = height(i) - y(i);

        if BMD(i) >= 0 % If the moment is positive, the tension failure will be at the
            BendingTensionStress(i) = (BMD(i) * ybot) / I(i);
        elseif BMD < 0 % If the moment is negative, the tension failure will be at the
            BendingTensionStress(i) = (BMD(i) * ytop) / I(i);
        end
end

end

function [ BendingCompressionStress ] = MStressC( I,y, height, BMD )  %Compression
% % Calculates Compression Stress at every x value based on applied load

BendingCompressionStress = zeros(1,length(I));

for i = 1:length(I)

        ybot = y(i);
        ytop = height(i) - y(i);

        if BMD(i) >= 0 % If the moment is positive, the compression failure will be at
            BendingCompressionStress(i) = (BMD(i) * ytop) / I(i);
        elseif BMD(i) > 0 % If the moment is negative, the compression failure will be
            BendingCompressionStress(i) = (BMD(i) * ybot) / I(i);
        end
end


end

function [ MBuckStress ] = MBuck( I, t, bBuck, E, mu, caseNum )
% Calculates Bending Capacity based on plate buckling for every x value

    if caseNum == 1
        k = 4;
    end
    if caseNum == 2
        k = 0.425;
    end
    if caseNum == 3
        k = 6;
    end

    for i = 1:length(I)
        MBuckStress(i) = ((k*E*pi^2)/(12*(1-mu^2))) * (t(i)/bBuck)^2;
    end


end
```

```
function [ FOS ] = FOSCalc( ShearFail, GlueFail, BendingTensionStress, BendingCompressi
    %Finds FOS based on every capacity and every demand -> FOS =
    %Capacity/Demand
    ShearFOS = min(TauCapacity ./ abs(ShearFail));
    GlueFOS = min(GlueCapacity ./ abs(GlueFail));
    ShearBucklingFOS = min(TauBuckling ./ abs(ShearFail));
    TensionFOS = min(TensionCapacity ./ abs(BendingTensionStress));
    CompressionFOS = min(CompressionCapacity ./ abs(BendingCompressionStress));
    CompressionBucklingFOS1 = min(CompressionBucklingCapacity1 ./ abs(BendingCompressio
    CompressionBucklingFOS2 = min(CompressionBucklingCapacity2 ./ abs(BendingCompressio
    CompressionBucklingFOS3 = min(CompressionBucklingCapacity3 ./ abs(BendingCompressio
    CompressionBucklingFOS4 = min(CompressionBucklingCapacity4 ./ abs(BendingCompressio
    CompressionBucklingFOS5 = min(CompressionBucklingCapacity5 ./ abs(BendingCompressio
    CompressionBucklingFOS6 = min(CompressionBucklingCapacity6 ./ abs(BendingCompressio
    CompressionBucklingFOS7 = min(CompressionBucklingCapacity7 ./ abs(BendingCompressio
    CompressionBucklingFOS8 = min(CompressionBucklingCapacity8 ./ abs(BendingCompressio

    %Finds the minimum of the FOS
    FOSes = [ShearFOS GlueFOS ShearBucklingFOS TensionFOS CompressionFOS CompressionBuc
    FOS = min(FOSes);
end

%Cross Section Functions
function [I, yBar] = SectionProperties( I, yBar, xStart, xEnd, bVector, hVector, yVecto
   % Input: Geometric Inputs. Format will depend on user
   % Output: Sectional Properties at every value of x. Each property is a 1-D array of

   % finding global centroid
   for i = xStart : xEnd
       sumAY = 0;
       sumA = 0;

       for j = 1:length(bVector)
           sumAY = sumAY + bVector(j) * hVector(j) * yVector(j);
           sumA = sumA + bVector(j) * hVector(j);
       end

       yBar(i) = sumAY/sumA;

       %finding I
       for j = 1:length(bVector)
           I(i) = I(i) + (bVector(j)*hVector(j)^3)/12 + bVector(j)*hVector(j)*(yVector(
       end

   end

end


function [Qmax, Qglue] = calculateQ( Qmax, Qglue, xStart, xEnd, cutoffAreaCent, cutoffA

   for i = xStart : xEnd
       %finding Q at centroid
```

```
        for j = 1:length(cutoffAreaCent)
            Qmax(i) = Qmax(i) + cutoffAreaCent(j)*yCentCutoff(j);
        end

        %finding Q at glue
        for j = 1:length(cutoffAreaGlue)
            Qglue(i) = Qglue(i) + cutoffAreaGlue(j)*yGlueCutoff(j);
        end

    end

end

function [] = VisualizeTL(x, SFD_PL, BMD_PL, SFD2, BMD2, SFD3, BMD3, V_Mat, V_Glue, V_E
    %Plots all outputs of design process
    figure;

    hold on;
    %shear force diagram
    subplot(2, 3, 1)
    plot(x, SFD_PL, "k")
    hold on
    plot(x, SFD2, "k")
    hold on
    plot(x, SFD3, "k")
    hold off
    title1 = strcat("SFD: FOS of Bridge = ", num2str(FOS));
    title(title1)

    %shear force vs mat shear fail
    subplot(2, 3, 2)
    plot(x, SFD_PL, "k")
    hold on
    plot(x, V_Mat, "r")
    hold on
    plot(x, V_Glue, "g")
    hold on
    plot(x, -V_Mat, "r")
    hold on
    plot(x, -V_Glue, "g")
    hold on
    plot(x, SFD2, "k")
    hold on
    plot(x, SFD3, "k")
    hold on
    hold off
    legend("Shear Force", "Matboard Shear Failure", "Glue Shear Failure",'Location','nor
    title("SFD vs Material Shear Failure")

    subplot(2, 3, 3)
    plot(x, SFD_PL, "k")
    hold on
    plot(x, V_Buck, "r")
    hold on
```

```
    plot(x, -V_Buck, "r")
    hold on
    plot(x, SFD2, "k")
    hold on
    plot(x, SFD3, "k")
    hold on
    hold off
    legend("Shear Force", "Buckling Failure", 'Location','northwest','NumColumns',2)
    title("SFD vs Shear Buckling Failure")

    %BMD Diagrams
    subplot(2, 3, 4)
    plot(x, BMD_PL, "k")
    hold on
    plot(x, BMD2, "k")
    hold on
    plot(x, BMD3, "k")
    hold on
    title2 = strcat("BMD:");
    title(title2)
    set(gca, 'YDir', 'reverse')
    set(gca, 'YDir', 'reverse')
    hold off

    subplot(2, 3, 5)
    plot(x, BMD_PL, "k")
    hold on
    plot(x, M_MatT, "r")
    hold on
    plot(x, M_MatC, "b")
    hold on
    plot(x, BMD2, "k")
    hold on
    plot(x, BMD3, "k")
    hold on
    legend("Bending Moment", "Matboard Tension Failure", "Matboard Compression Failure",
    title("BMD vs Material Moment Failures")
    set(gca, 'YDir', 'reverse')
    hold off

    subplot(2, 3, 6)
    plot(x, BMD_PL, "k")
    hold on
    plot(x, M_Buck1, "-r")
    hold on
    plot(x, M_Buck2,  'Color', [0.74, 0.36, 0.04])
    hold on
    plot(x, M_Buck3, 'Color', [0.4, 0.75, 0.13])
    hold on
    plot(x, M_Buck4, "-r")
    hold on
    plot(x, M_Buck5, 'Color', [0.4, 0.75, 0.13])
    hold on
    plot(x, M_Buck6, 'Color', [0.4, 0.75, 0.13])
```

```
    hold on
    plot(x, M_Buck7, 'Color', [0.74, 0.36, 0.04])
    hold on
    plot(x, M_Buck8, 'Color', [0.4, 0.75, 0.13])
    hold on
    plot(x, BMD2, "k")
    hold on
    plot(x, BMD3, "k")
    hold on
    %legend("Bending Moment", "Mid Flange Buckling", "Side Flange Buckling", "Web Compre
    title("BMD vs Moment Buckling Failures")
    legend("Bending Moment", "Side Flange", "Mid Flange", "Web Flange", 'Location','nort
    set(gca, 'YDir', 'reverse')
    hold off


end
```

```
%%Point Load Functions:
function [ SFD, BMD ] = ApplyPL( xP, P, x, SFD, locationA, locationB ) %(Location, Forc
% Constructs SFD and BMD for every x value
% Can be iterated since SFD and BMD diagrams can be added together

    %Calculate reaction forces
    SupportB = ((xP * P) / (locationB)); %Using Sum of Moments = 0
    SupportA = (P - SupportB); %Using sum of vertical force = 0

    %Fill out SFD diagram as if by hand
    SFDLocal = zeros(1, length(SFD));
    if xP < locationB %Force is closer to the left side than support B
        for i = 1:(xP-1) %SFD before new load
            SFDLocal(i) = SupportA;
        end

        for i = xP:locationB %SFD after new load
            SFDLocal(i) = (SupportA - P);
        end

        for i = 1:length(SFD) %add the new SFD with the old ones
            SFD(i) = SFD(i) + SFDLocal(i);
        end

    else %Force is farther from left side than support B
        for i = 1:(locationB-1) %SFD before new load
            SFDLocal(i) = SupportA;
        end

        for i = locationB:xP-1 %SFD after new load
            SFDLocal(i) = (SupportA + SupportB);
        end
```

```
        for i = xP:length(SFD)
           SFDLocal(i) = 0;
        end

        for i = 1:length(SFD) %add the new SFD with the old ones
            SFD(i) = SFD(i) + SFDLocal(i);
        end
    end

    %form BMD:
    dx = x(2) - x(1);
    BMD = cumsum((SFD * dx));
end

function [ V_fail ] = Vfail(I, b, Qcent, TauU )
% Calculates Shear Fail based on Tau Ultimate

    V_fail = TauU .* I .* b ./ Qcent;
end

function [ V_Buck ] = VfailBuck( I, t, b, height, E, mu, y, a, TauU, Qcent )
% Calculates Shear Fail based on Buckling

    %pi
    pi = 355/113;

    for i = 1:length(I)
        sigma(i) = ((5*E*pi^2)/(12*(1-mu^2))) * ((t(i)/height(i))^2 + (t(i)/a(i))^2);
    end

    %Calculate buckle fail by using the above formula
    V_Buck = Vfail(I, b, Qcent, sigma);

end

function [ M_MatT ] = MfailMatT( I,y, height, SigT, BMD )
% Calculates Tension Fail

for i = 1 : length(I)

        ybot = y;
        ytop = height(i) - y; %I need somesort of height vector

        if BMD(i) > 0 % If the moment is positive, the tension failure will be at the b
            M_MatT(i) = (SigT * I(i)) / ybot(i);
        elseif BMD(i) < 0 % If the moment is negative, the tension failure will be at t
            M_MatT(i) = (-SigT * I(i)) / ytop(i);
        end
    end
end

function [ M_MatC ] = MfailMatC( I,y, height, SigC, BMD )
% Calculates Compression Fail
```

```
ybot = y;
ytop = height - y;

for i = 1 : length(I)
        if BMD(i) > 0 % If the moment is positive, the compression failure will be at t
            M_MatC(i) = (SigC * I(i)) / ytop(i);
        elseif BMD(i) < 0 % If the moment is negative, the compression failure will be
            M_MatC(i) = (-SigC * I(i)) / ybot(i);
        end
    end
end

function [ M_Buck ] = MfailBuck( I, t, bBuck, E, mu, BMD, caseNum, y, height, SigC )
% Calculates Bending Fail based on buckling

    %Assign a k value based on the case
    if caseNum == 1
        k = 4;
    end
    if caseNum == 2
        k = 0.425;
    end
    if caseNum == 3
        k = 6;
    end

    for i = 1:length(I)
        sigma(i) = ((k*E*pi^2)/(12*(1-mu^2))) * (t(i)/bBuck)^2;
    end

    %Calculate buckle fail using the above function
    M_Buck = MfailMatC(I,y, height, min(sigma), BMD);

end

function [ Pf ] = FailLoad( SFD, BMD, V_Mat, V_Glue, V_Buck, M_MatT, M_MatC, M_buck1, M
%Calculate the point load that causes the failure

%Flexural Stress
%Because P = 1, the BMD and SFD are simply the coefficients of P. By
%dividing them, we are finding P despite the fact that there is no actual P
%variable.
CompressionFailure = abs(M_MatC) ./ abs(BMD);
TensionFailure = abs(M_MatT) ./ abs(BMD);
BendingBucklingFailure1 = abs(M_buck1) ./ abs(BMD);
BendingBucklingFailure2 = abs(M_buck2) ./ abs(BMD);
BendingBucklingFailure3 = abs(M_buck3) ./ abs(BMD);
BendingBucklingFailure4 = abs(M_buck4) ./ abs(BMD);
BendingBucklingFailure5 = abs(M_buck5) ./ abs(BMD);
BendingBucklingFailure6 = abs(M_buck6) ./ abs(BMD);
BendingBucklingFailure7 = abs(M_buck7) ./ abs(BMD);
BendingBucklingFailure8 = abs(M_buck8) ./ abs(BMD);

%Shear Stress
```

```
ShearFailureMat = V_Mat ./ abs(SFD);
ShearFailureGlue = V_Glue ./ abs(SFD);
ShearBuckliingFailure = V_Buck ./ abs(SFD);

%Find the lowest Pf
Pforces = [min(CompressionFailure) min(TensionFailure) min(BendingBucklingFailure1) min
Pf = min(Pforces);


end

function [] = VisualizePL(x, SFD_PL, BMD_PL, V_Mat, V_Glue, V_Buck, M_MatT, M_MatC, M_B
   %Plots all outputs of design process
   figure;

   hold on;
   %shear force diagram
   subplot(2, 3, 1)
   plot(x, SFD_PL, "k")
   title1 = strcat("SFD from P = ", int2str(floor(Pf)), "N Pfail = ", num2str(Pf), " N'
   title(title1)

   %shear force vs mat shear fail
   subplot(2, 3, 2)
   plot(x, SFD_PL, "k")
   hold on
   plot(x, V_Mat, "r")
   hold on
   plot(x, V_Glue, "g")
   hold on
   plot(x, -V_Mat, "r")
   hold on
   plot(x, -V_Glue, "g")
   hold on
   legend("Shear Force", "Matboard Shear Failure", "Glue Shear Failure",'Location','nor
   title("SFD vs Material Shear Failure")
   hold off

   subplot(2, 3, 3)
   plot(x, SFD_PL, "k")
   hold on
   plot(x, V_Buck, "r")
   hold on
   plot(x, -V_Buck, "r")
   hold on
   legend("Shear Force", "Buckling Failure", 'Location','northwest','NumColumns',2)
   title("SFD vs Shear Buckling Failure")
   hold off

   %BMD Diagrams
   subplot(2, 3, 4)
   plot(x, BMD_PL, "k")
   hold on
   title2 = strcat("BMD from P = ", int2str(floor(Pf)), "N Pfail = ", int2str(Pf), " N'
```

```
    title(title2)
    set(gca, 'YDir', 'reverse')
    set(gca, 'YDir', 'reverse')
    hold off

    subplot(2, 3, 5)
    plot(x, BMD_PL, "k")
    hold on
    plot(x, M_MatT, "r")
    hold on
    plot(x, M_MatC, "b")
    hold on
    legend("Bending Moment", "Matboard Tension Failure", "Matboard Compression Failure",
    title("BFD vs Material Moment Failures")
    set(gca, 'YDir', 'reverse')
    hold off

    subplot(2, 3, 6)
    plot(x, BMD_PL, "-k")
    hold on
    plot(x, M_Buck1, "-r")
    hold on
    plot(x, M_Buck2,  'Color', [0.74, 0.36, 0.04])
    hold on
    plot(x, M_Buck3, 'Color', [0.4, 0.75, 0.13])
    hold on
    plot(x, M_Buck4, "-r")
    hold on
    plot(x, M_Buck5, 'Color', [0.4, 0.75, 0.13])
    hold on
    plot(x, M_Buck6, 'Color', [0.4, 0.75, 0.13])
    hold on
    plot(x, M_Buck7, 'Color', [0.74, 0.36, 0.04])
    hold on
    plot(x, M_Buck8, 'Color', [0.4, 0.75, 0.13])
    hold on
    %legend("Bending Moment", "Mid Flange Buckling", "Side Flange Buckling", "Web Compre
    title("BMD vs Moment Buckling Failures")
    legend("Bending Moment", "Side Flange", "Mid Flange", "Web Flange", 'Location','nort
    set(gca, 'YDir', 'reverse')
    hold off

end
```