```
%design 1 parameters

tensile_strength = 30;
compressive_strength = 6;
shear_strength = 4;
young_modulus = 4000;
poisson_r = 0.2;
shear_glue = 2;

diaphragm = 400;

L = 1200;

%% 0. Initialize Parameters
P = 400;
%% 1. SFD, BMD under train loading
x_train = [52 228 392 568 732 908]; P_train=[1 1 1 1 1 1]*P/6;
n_train = 240;
n = L;

% Length of bridge
% Discretize into 1 mm seg.
% Total weight of train [N]
% x-axis
% Train Load Locations
% num of train locations
% 1 SFD for each train loc.
% 1 BMD for each train loc.
% Solve for SFD and BMD with the train at different locations
max_sfd = zeros(1, n_train);
max_bmd = zeros(1, n_train);

for i = 1:240
    locations = linspace(0,n,L+1);
    loads = zeros(0, L+1);
    x_train = [52 228 392 568 732 908]+i;

    r_B = (sum(x_train)*P/6)/L;
    cumsum(x_train);

    r_A = P - r_B;

    loads(1) = r_A ;
    loads(L+1) = r_B ;

    for wheel = 1:length(x_train)
        loads(x_train(wheel)) = -P/6;
    end
```

```
    for j = 1:length(loads)
        sfd = cumsum(loads);
        bmd = cumsum(sfd*1);
    end
    max_sfd(1, i) = max(sfd);
    max_bmd(1, i) = max(bmd);
end


[max_shear, location_max_sfd] = max(max_sfd) ;
[max_bending, location_max_bmd] = max(max_bmd) ;


envelope_bmd = zeros(1, L+1);
envelope_sfd = zeros(1, L+1);

envelope_bmd;
envelope_sfd;


for i = 1:240
    cur_max_bmd = 0;
    cur_max_sfd = 0;
    locations = linspace(0,n,L+1);

    loads = zeros(0, L+1);
    x_train = [52 228 392 568 732 908] + i;

    r_B = (sum(x_train)*P/6)/L+1;
    cumsum(x_train);
    r_A = P - r_B;

    loads(1) = r_A ;
    loads(L+1) = r_B ;

    for wheel = 1:length(x_train)
        loads(x_train(wheel)) = -P/6;
    end

    for j = 1:length(loads)
        sfd = cumsum(loads);
        bmd = cumsum(sfd*1);
    end
    for k = 1:L+1
        if bmd(k) > envelope_bmd(1,k)
            envelope_bmd(1,k) = bmd(k);
        end
        if abs(sfd(k)) > envelope_sfd(1,k)
            envelope_sfd(1,k) = abs(sfd(k));
        end
```

```
    end
end


GEOMETRY
x_Tflange = 100;
y_Tflange = 1.27*2;
y_Bflange = 1.27;
x_Bflange = 66.27;

x_ledge = 7.83;
y_ledge = 1.27;
x_web = 1.27;
y_web = 135;

Tflange = [x_Tflange, y_Tflange, 136.27, 1];
ledge = [x_ledge, y_ledge, 135, 2];
web = [x_web, y_web, 1.27, 2];
Bflange = [x_Bflange, y_Bflange, 0, 1];
diaphragm = 156.25;






parameters = [Bflange; web; ledge; Tflange];

height = sum(parameters(:,2)) - 1.27;

%% local_centroids + areas
local_centroids = zeros(length(parameters), 1);
local_areas = zeros(length(parameters), 1);
for i = 1:length(parameters)
    local_centroids(i, 1) = parameters(i, 3) + (parameters(i,2)/2);
    local_areas(i, 1) = parameters(i, 1) * parameters(i,
2)*parameters(i,4);
end
local_centroids;
local_areas;

total_area = sum(local_areas);
% centroid
centroid = dot(local_centroids, local_areas)/sum(local_areas);


% second moment of area
second_moment_I = dot(parameters(:,1).* parameters(:,4),
parameters(:,2).^3)/12 + dot(local_areas, (local_centroids-
centroid).^2);
```

```
% first moment of area cent
first_moment_Q_cent = 0;
for i=1:length(local_centroids)
    if (centroid > parameters(i, 3)) && (centroid > parameters(i,
2)+parameters(i,3))
        first_moment_Q_cent = first_moment_Q_cent + parameters(i,
4)*local_areas(i, 1)*(centroid-local_centroids(i, 1));

    elseif (centroid < parameters(i, 3)+parameters(i, 2)) && (centroid
> parameters(i, 3))
        first_moment_Q_cent = first_moment_Q_cent + parameters(i,
4)*(centroid-parameters(i,3))*parameters(i,1)*(centroid-
parameters(i,3))/2;
    else
    end
end
first_moment_Q_cent;

% first moment of area glue INPUT MANUALLY
first_moment_Q_glue =
local_areas(4,1)*parameters(4,4)*(local_centroids(4,1)-centroid);

%%%%%%%Failure
% flexural stresses

sigma_tens = (max_bending*centroid)/second_moment_I; % take cent since
tens @ bottom

sigma_comp = (max_bending*(height - centroid)/second_moment_I);

% shear stresses

tau_cent = (max_shear*first_moment_Q_cent)/
(second_moment_I*parameters(2,1)*parameters(2,4)); % looking at
thickness of web

tau_glue = (max_shear*first_moment_Q_glue)/
(second_moment_I*2*(x_ledge+x_web)); % input the width of glue
manually


% thin plate buckling
c = (pi^2 * young_modulus)/(12*(1-poisson_r^2));
ks = [4 0.425 6 5];

% case 1 k = 4
sigma_1 = ks(1, 1) * c * (parameters(4, 2)/
(parameters(1,1)-2*parameters(2,1)))^2;
```

```
% case 2 k = 0.425
sigma_2 = ks(1, 2) * c * (parameters(4, 2)/((parameters(4,1)-
parameters(1,1))/2))^2;

% case 3 k = 6
sigma_3 = ks(1, 3) * c * (parameters(2,1)/(parameters(4,3)-
centroid))^2;

% case 4 k = 5
tau_tpb = ks(1, 4) * c * ( (parameters(2,1)/parameters(2,2))^2 +
(parameters(2,1)/diaphragm)^2 );

capacities = [tensile_strength, compressive_strength, shear_strength,
shear_glue, sigma_1 , sigma_2, sigma_3, tau_tpb]; % maximum capacities

applied = [sigma_tens, sigma_comp, tau_cent, tau_glue, sigma_comp,
sigma_comp, sigma_comp, tau_cent];

FOS = capacities ./ applied ;

theoretical = FOS * 400;

min(FOS);
Other Envelopes
tiledlayout(2,1)

nexttile
plot(locations, envelope_sfd)
title("Shear Force Envelope")
xlabel("Distance along bridge (mm)")
ylabel("Shear Force (N)")
nexttile

plot(locations, envelope_bmd)
set(gca, "YDir", "reverse")
title("Bending Moment Envelope")
xlabel("Distance along bridge (mm)")
ylabel("Bending Moment (Nmm)")


%max_bending
%max_shear

%% failure due to shear of matboard (tau_cent) 3rd type of failure
subplot(2, 3, 1)
hold on
yline(theoretical(1, 3), Color="red", LineWidth=2)
yline(-theoretical(1, 3), Color="red", LineWidth=2)
plot(locations, -envelope_sfd, Color="k")
plot(locations, envelope_sfd, Color="k")
```

```
yline(0, LineWidth=1.5)
ylim([-theoretical(1, 3)*1.1 theoretical(1, 3)*1.1])
legend("Matboard (3)")
xlabel("Distance along bridge (mm)")
ylabel("Shear Force (N)")

%% failure due to shear of glue (tau_glue) 4th type of failure
subplot(2, 3, 2)
hold on
yline(theoretical(1, 4), Color="cyan", LineWidth=2)
legend("Glue (4)", "AutoUpdate","off")
yline(-theoretical(1, 4), Color="cyan", LineWidth=2)
plot(locations, -envelope_sfd, Color="k")
plot(locations, envelope_sfd, Color="k")
ylim([-theoretical(1, 4)*1.1 theoretical(1, 4)*1.1])
yline(0, LineWidth=1.5)
xlabel("Distance along bridge (mm)")
ylabel("Shear Force (N)")


%% failure due to shear buckling 8th type of failure
subplot(2, 3, 3)
hold on
yline(theoretical(1, 8), Color="#A2142F", LineWidth=2)
legend("Shear Diaph (8)", "AutoUpdate","off")
yline(-theoretical(1, 8), Color="#A2142F", LineWidth=2)
plot(locations, -envelope_sfd, Color="k")
plot(locations, envelope_sfd, Color="k")
ylim([-theoretical(1, 8)*1.1 theoretical(1, 8)*1.1])
yline(0, LineWidth=1.5)
xlabel("Distance along bridge (mm)")
ylabel("Shear Force (N)")

hold off

%%bending moment

% failure due to flexural tension 1st failure and compression 2nd
failure

subplot(2, 3, 4)
hold on
yline(FOS(1,1)*max_bending, Color="red", LineWidth=2) % red is in
tension
yline(FOS(1,2)*max_bending, Color="blue", LineWidth=2) % blue is
compression
legend("Tens (1)", "Comp (2)", "AutoUpdate","off", Location="south")
plot(locations, envelope_bmd, Color="k")
set(gca, "YDir", "reverse")
xlabel("Distance along bridge (mm)")
```

```
ylabel("Moment (Nmm)")
ylim([0 FOS(1,1)*max_bending*1.1])
yline(0, LineWidth=1.5)


% failure due to buckling of middle and side flange 5 and 6 failure

subplot(2, 3, 5)

hold on
yline(FOS(1,5)*max_bending, Color="green", LineWidth=2)
yline(FOS(1,6)*max_bending, Color="magenta", LineWidth=2)
legend("Mid Flange (5)", "Side Flange (6)", "AutoUpdate","off",
Location="south")
plot(locations, envelope_bmd, Color="k")
set(gca, "YDir", "reverse")
xlabel("Distance along bridge (mm)")
ylabel("Moment (Nmm)")
ylim([0 FOS(1,6)*max_bending*1.1])
yline(0, LineWidth=1.5)

% failure due to web buckling 7 failure

subplot(2, 3, 6)
hold on
yline(FOS(1,7)*max_bending, Color="#0072BD"        , LineWidth=2)
legend("Web W (7)", "AutoUpdate","off", Location="south")
plot(locations, envelope_bmd, Color="k")
set(gca, "YDir", "reverse")
xlabel("Distance along bridge (mm)")
ylabel("Moment (Nmm)")
ylim([0 FOS(1,7)*max_bending*1.1])
yline(0, LineWidth=1.5)
Summary of all the bridge properties
disp("Geometrical Properties")
max_area = 826804.8
length = 1250

current_area_left = max_area  - (x_Tflange*2*length +x_ledge*2*length+
y_web*2*length+ (x_Bflange)*length + y_web*63.73*9)

current_area_used=x_Tflange*2*length +x_ledge*2*length+
y_web*2*length+ (x_Bflange)*length

total_area
centroid
second_moment_I
first_moment_Q_cent
first_moment_Q_glue
```

```
disp("Loads + Failures")
types_of_failure = ["Flexural Tension", 'Flexural Compression', 'Shear
Failure (MB)', 'Shear Failure (G)' ,'Mid Flange (TPB)' ,'Side Flange
(TPB)' ,'Web (TPB)' ,'Diaphragm/Shear Buck (TPB)'];
capacities;
applied ;
FOS;
theoretical;

M = [ 0,  types_of_failure; 0, capacities; 0, applied; 0, FOS ; 0,
theoretical];
M(:,1) = ["Types of Failure"; "Capacity"; "Applied" ; "FOS" ;
"Theoretical Load"];
M
```