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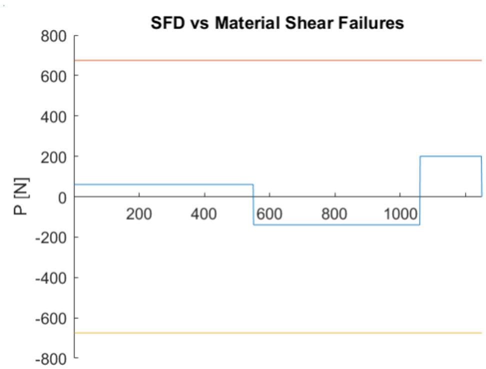
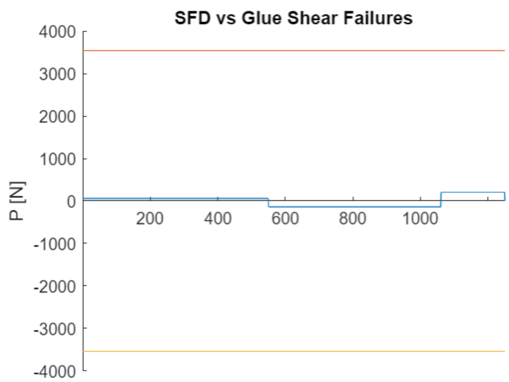
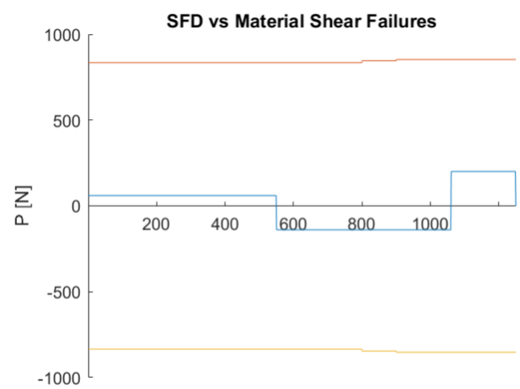
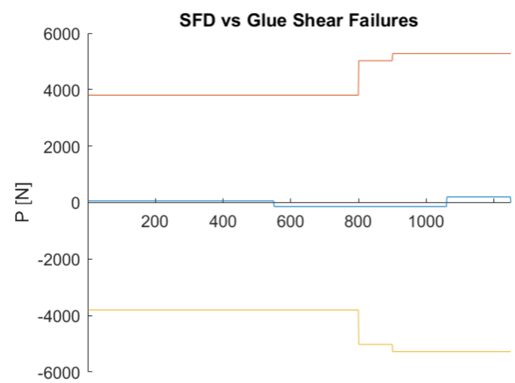
CIV102 Project Report
November 30, 2021

Bridge Design Report

Properties of Design 0 and Final Design

	Design 0	Final Design
FOS against failure	0.735 at first possible point (WILL FAIL)	1.14
Failure load P under Load Case 2	178 N	843 N
Cause of failure under load Case 2	Mid Flange Buckling (Plate Buckling Case 1)	Compression Shear Failure (Flexural Failure)
Plots of SFD	 	 

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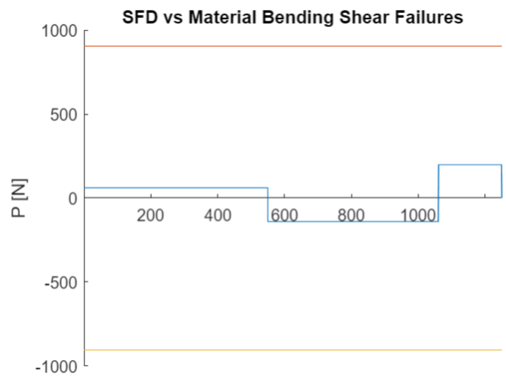
<td>
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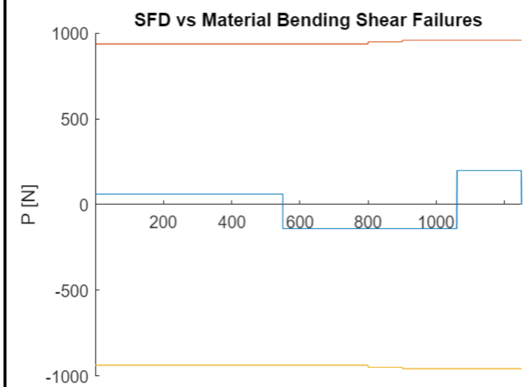
<td>
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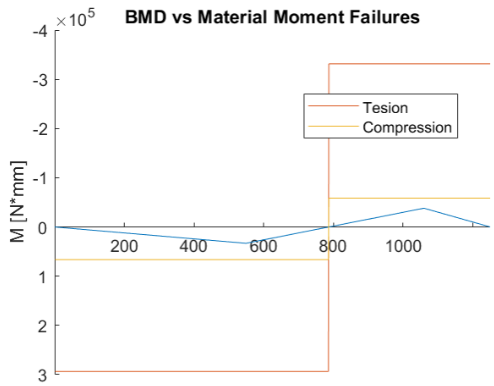
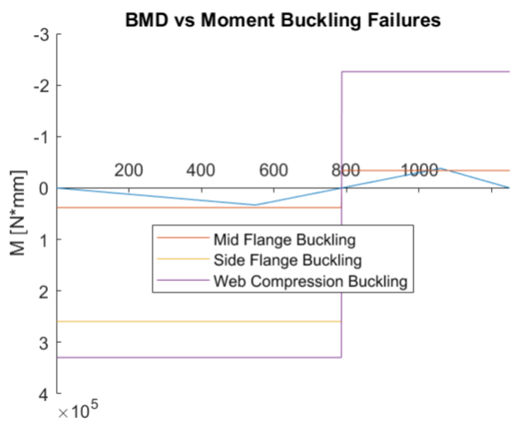
<td>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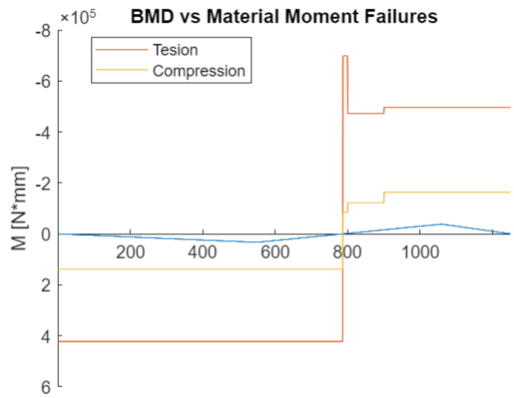
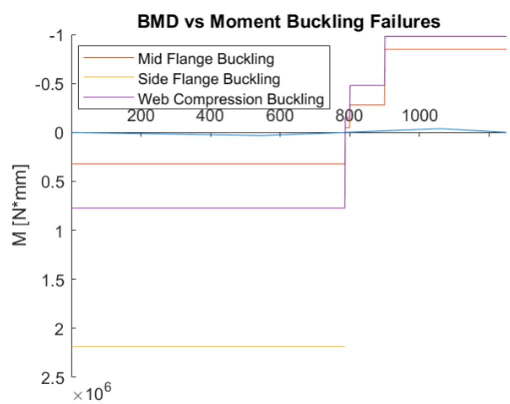
<td>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Final Design Cross-Section Properties

L = 1300

```
xc = [0 400 700 800 900 L];          % Location of X-Section Changes
bft = [100 100 100 100 100 100];     % Top Flange Width
tft = [2 2 2 1 1 1] .* 1.27;         % Top Flange Thickness
hw = [90 90 90 90 90 90];            % Web Height
tw = [1 1 1 1 1 1] .* 1.27;          % Web thickness
bfb = [80 80 80 80 80 80];           % Bottom Flange Width
tfb = [1 1 1 2 3 3] .* 1.27;         % Bottom Flange Thickness
apositions = [-15 15 130 260 390 535 565 700 800 900 1045 1075 1235 1265];
aspacings = apositions(2:end) - apositions(1:end-1); % Diaphragm Spacing
amax = max(aspacings); % Max Diaphragm Spacing
tt = [10 10 10 10 10 10 10]; % Glue tab width
```

Improvements Process from Design 0 to Final Design

From Design 0, we went through 14 iterations before settling on a final design. Changes to designs were made to accommodate for the cause of failure during the last design as calculated by our code. For example, to accommodate for mid-flange buckling failure, we increased the thickness of the mid-flange at the point of maximum moment, and to accommodate for moment compression failure, we increased the thickness of the top/bottom (whichever was on the compression side of the BMD) at those points. A large modification we made was from Design 5 to Design 6, in which we increased the web height which increased the height of $\bar{y}$, which increased the tolerance of bending moment throughout. Further design modifications after Design 6 were mainly with the intent to conserve matboard usage/be feasible in matboard usage while maintaining a reasonable failure load, as Design 6 required more matboard than given. Area usage calculations were also done with Google Sheets to aid this process.

```
Design 0

xc = [0 786 L];
bft = [100 100 100];
tft = [1.27 1.27 1.27];
hw = [75 - 2.54 75 - 2.54 75 - 2.54];
tw = [1.27 1.27 1.27];
bfb = [80 80 80];
tfb = [1.27 1.27 1.27];
apositions = [-15 15 535 565 1045 1075 1235 1265];
tt = [10 10 10];

Fails under train load
Fails under point load of 178 N
because of mid-flange moment buckling failure

Design 1

xc = [0 786 L];
bft = [100 100 100];
tft = [2.54 2.54 2.54];
hw = [75 75 75];
tw = [1.27 1.27 1.27];
bfb = [80 80 80];
tfb = [1.27 1.27 1.27];
apositions = [-15 15 535 565 1045 1075 1235 1265];
tt = [10 10 10];

Fails under train load
Fails under point load of 202 N
because of mid-flange moment buckling failure
```

```
Design 5

xc = [0 300 790 1000 L];
bft = [100 100 100 100 100];
tft = [2 3 3 2 2] .* 1.27;
hw = [75 75 75 75 75];
tw = [2 2 2 2 2] .* 1.27;
bfb = [80 80 80 80 80];
tfb = [1 1 2 3 3] .* 1.27;
apositions = [-15 15 535 565 1045 1075 1235 1265];
tt = [10 10 10 10 10];

Does not fail under train load
Fails under point load of 831 N
because of moment compression failure

Design 6

xc = [0 300 790 1000 L];
bft = [100 100 100 100 100];
tft = [2 3 3 2 2] .* 1.27;
hw = [100 100 100 100 100];
tw = [1 1 1 1 1] .* 1.27;
bfb = [80 80 80 80 80];
tfb = [1 1 3 3 3] .* 1.27;
apositions = [-15 15 535 565 1045 1075 1235 1265];
tt = [10 10 10 10 10];
```

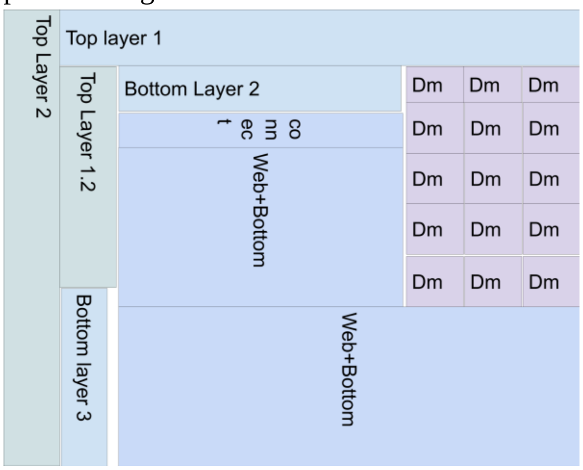
Area Calculations

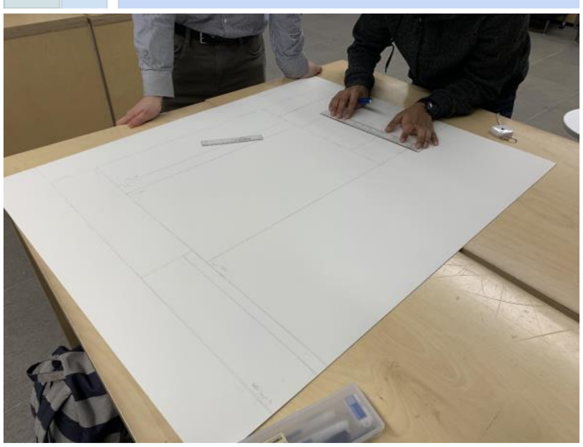
	A	B	C	D	E	F	G	H	I
1	Top	Length of Layer	Width of Layer	Area (Li * Wi)	Total Area	Total	Max	remainder	Possible?
2	Layer 1	1300	100	130000	210000	808000	826008	18008	TRUE
3	Layer 2	800	100	80000					
4	Layer 3	0	100	0					
5									
6	Web	Length of Layer	Height of Layer	Area of one (Li * hi)					
7	Layer 1	1300	90	117000	234000				
8									
9	Bottom	Length of Layer	Width of Layer	Area (Li * Wi)					
10	Layer 1	1300	80	104000	168000				
11	Layer 2	500	80	40000					
12	Layer 3	400	60	24000					
13									
14	Glue	Length	Width	Area of one (Li * Wi)					
15		1300	10	13000	26000				
16									
17	Diaphram Numb	Height (includinc	Width (including	Area of one (h * w)					
18	17	100	100	10000	170000				
19									

Construction Process

1. Planning Matboard Usage

Planning matboard usage required planning how we would cut the pieces from the matboard. This was done on Google Drawings. This process also validated our final design (ensuring that it was feasible given our materials). After the piece placement was finalized, the pieces were traced on the matboard with pencil and ruler, and the piece tracing is shown below.





2. Cutting and Folding Pieces

Pieces were cut using utility knives and Exacto knives, on the “outer edge” of the lines (in order to prevent area loss). The pieces were folded against an object at the fold line or by clampers. Clampers were used mainly for shorter pieces (i.e. diaphragms) while folding over a right-angled object was done for longer pieces, as seen on the right. Each fold was done with the intent of being right on line indicating the fold

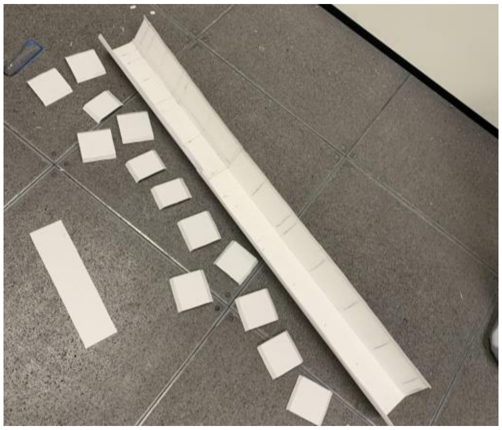
3. Assembling the Bridge

3.1. Gluing Bottom Layers and Top Layers

The first step in the assembling of the bridge was gluing the top layers together and two of the bottom/web layers -- this step was also the step in which we connected the sides of the top and bottom/web layers to create the length of the bridge. The image to the right depicts the process of holding the bottom/web pieces together and applying pressures and the spots of contact cement after connecting the joints.

3.2. Gluing Diaphragms

The next step in the gluing process was gluing diaphragms. The positions of the diaphragms were marked within the bottom/web part of the bridge before applying glue to areas. After sticking the diaphragms in, some diaphragms came loose, so we reiterated this process for the loose diaphragms. The image below shows the alignment of diaphragms before applying glue.



3.3. Gluing Top onto Web

Next, we glued the top onto the web. Glue was applied about 5 mm inwards from either edge of the underside of the top piece and generously applied (as extra glue is preferable to not enough glue on the areas of contact). The image below depicts the middle of the process of applying glue to the web glue tabs and the underside of the top. To ensure adequate pressure during the connecting process, all team members applied pressure on the top of the bridge for about 3 minutes.

3.4. Gluing Final Bottom Layers

The final step was gluing the third and final bottom layer. The bridge was flipped upside down while the glue was applied, and after making contact, pressure was applied for about 3 minutes to ensure adequate connection, as shown below.

4. Allowing the Contact Cement to Settle for over 72 Hours