CIV 102 Project Team 106 Design Report

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Introduction

The design of the bridge for CIV102 Project Team 106 progressed through seven iterations, each aimed at enhancing structural performance by addressing critical failure modes and optimizing material usage. The final design features a uniform cross-section, staggered spliced connections, strategically placed diaphragms, and reinforced flanges, all contributing to improved Factors of Safety (FOS) in tension, compression, shear, and glue failure.

In the first iteration, the top flange thickness was increased by adding a second layer, raising the FOS against compression from 1.037 to 1.730. This modification aligns with the findings that increasing flange thickness enhances the buckling capacity of beams by raising the centroidal height ($\bar{y}$) and reducing compressive stress (SteelConstruction.info, n.d.). The second iteration reduced the size of the additional flange layer, optimizing material distribution and maintaining a compression FOS of 2.085. This approach is supported by studies emphasizing that strategic material placement avoids over-reinforcement and maximizes structural efficiency (SteelConstruction.info, n.d.). In the fifth iteration, the top flange width was increased from 100 mm to 120 mm, significantly improving the compression FOS to 3.030 and raising the predicted failure load to 1212.2 N. This change is consistent with research showing that wider flanges improve stability by lowering the slenderness ratio and delaying local buckling (AISC, n.d.). The seventh iteration introduced additional diaphragms, including half-height diaphragms at non-central splice locations, increasing the shear buckling FOS to 4.258. Research shows that diaphragms enhance beam performance under high loads by redistributing stresses and preventing shear-related failures (AISC, n.d.).

The final design incorporates these enhancements, resulting in robust FOS values for tension (4.643), compression (3.030), shear (3.284), and glue failure (10.871). With a 120 mm-wide deck, 80 mm web height, and nine full diaphragms (plus two half-height), the design meets project constraints while achieving a predicted failure load of 1212.2 N. These decisions, supported by external research, ensure the bridge's structural performance aligns with established engineering principles.

Iterations

The initial design of the bridge is design zero, provided in the project handout. Each iteration consists of a single change to the existing design intended to improve the FOS of a chosen failure mechanism. Iterations were repeated until all FOS values were above three.

Original design - Design 0

Material amounts and dimensions of bridge:

Amount of matboard used = 462366mm^2
Amount of matboard still available = 363642mm^2
Amount of glue used = 24370mm^2
Length = 1250mm
Width of base = 80mm
Width of deck = 100mm
Height = 76.27mm

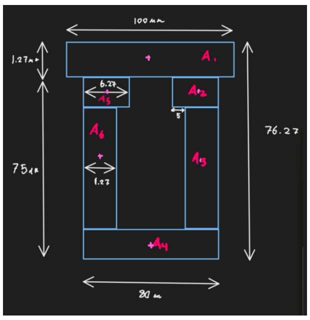

Figure 1: cross-sectional area of design 0

Additional design aspects:

Splice connections	- Splice connection down the centre of the bridge
Cross-section rigidity	- Vertical diaphragms placed at regular intervals help to support the bridge and promote cross-section rigidity
Support sections	- 2 diaphragms situated at each support to help handle the direct vertical compression at supports - flat end portions (allowing for the bridge to be placed onto supports)
Diaphragm placement	- 2 near each support (4) - 2 evenly spaced between each support (2) Total = 6 diaphragms

Code Output - Checked with Hand Calculations:

Buckling Capacities:
Case 1 - Web Buckling: 3.57 MPa
Case 2 - Side Flange Buckling: 20.77 MPa
Case 3 - Middle Flange Buckling: 31.39 MPa
Shear Buckling Capacity: 5.26 MPa

Central Locomotive Location:
Maximum Shear Force: 200.00 N at x = 0.0 mm
Maximum Bending Moment: 68600.00 N·mm at x = 511.0 mm

Stresses:
Flexural Stress (Tension): 6.73 MPa
Flexural Stress (Compression): 5.35 MPa
Maximum Shear Stress: 1.16 MPa
Maximum Glue Shear Stress: 0.15 MPa

Predicted failure load: 266.9 N

****highlight signifies what is trying to be changed in the next iteration****

Factors of Safety (CRITICAL < 1.1, OK < 2.0, GOOD > 2.0):
FOS against tension: 4.120 (GOOD)
FOS against compression: 1.037 (CRITICAL)
FOS against shear: 3.302 (GOOD)
FOS against glue failure: 12.416 (GOOD)
FOS against buckling in middle flange: 0.616 (CRITICAL)
FOS against buckling in the side flanges: 3.589 (GOOD)
FOS against buckling in webs: 5.424 (GOOD)
FOS against shear buckling: 4.339 (GOOD)

<u>Moving Load Analysis Results:</u>
Maximum Shear Force (Moving): 257.33 N (leftmost wheel at 172.0 mm)
Maximum Bending Moment (Moving): 69260.00 N·mm (leftmost wheel at 44.0 mm)

1st Iteration - Added Thickness to Flange (added layer on top)

In the first iteration, another layer of matboard was added to the flange to increase the FOS against compression and the FOS for case 1 thin plate buckling. The FOS against case 1 buckling was below 1, therefore it would fail load case 1. This means that design 0 would not pass load case 1. By adding this additional layer the FOS of buckling for case 1 is increased as the thickness is increased, and this plate would now require a much larger force to buckle, which is evident in our results. While this occurs, the FOS of compression will also increase. By adding this additional layer, $\bar{y}$ will be higher, due to the new cross-sectional area (Figure 2). As the $\bar{y}$ increases, the compressive stress decreases, as the compression is on the top of the bridge, so y_{top} is used (which decreases). This allows for more force to be applied to the bridge, as this was the second-lowest FOS, and was still at a critical level. By looking at the results from the code output, one can see how this FOS of compression was also increased, resulting in all the FOS values being>1.7.

Material amounts and dimensions of bridge:

Amount of matboard used = 587366mm^2
Amount of matboard still available = 238642mm^2
Amount of glue used = 149370mm^2
Length = 1250mm
Width of base = 80mm
Width of deck = 100mm
Height = 77.54mm

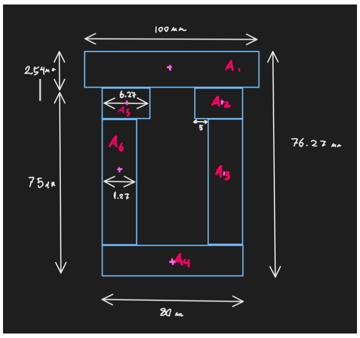

Figure 2: cross-sectional area after 1st iteration

Additional design aspects:

Splice connections	- Splice connection down the centre of the bridge
Cross-section rigidity	- Vertical diaphragms placed at regular intervals help to support the bridge and promote cross-section rigidity
Support sections	- 2 diaphragms situated at each support to help handle the direct vertical compression at supports - flat end portions (allowing for the bridge to be placed onto supports)
Diaphragm placement	- 2 near each support (4) - 2 evenly spaced between each support (2) Total = 6 diaphragms

Code Output:

Buckling Capacities:
Case 1 - Web Buckling: 14.27 MPa
Case 2 - Side Flange Buckling: 83.08 MPa
Case 3 - Middle Flange Buckling: 58.55 MPa
Shear Buckling Capacity: 5.26 MPa

Central Locomotive Location:
Maximum Shear Force: 200.00 N at x = 0.0 mm
Maximum Bending Moment: 68600.00 N·mm at x = 511.0 mm

Stresses:
Flexural Stress (Tension): 6.23 MPa
Flexural Stress (Compression): 3.20 MPa
Maximum Shear Stress: 1.16 MPa
Maximum Glue Shear Stress: 0.18 MPa

Predicted failure load: 748.9 N

Factors of Safety:
FOS against tension: 4.449 (GOOD)
FOS against compression: 1.730 (OK)
FOS against shear: 3.317 (GOOD)
FOS against glue failure: 10.677 (GOOD)
FOS against buckling in middle flange: 4.113 (GOOD)
FOS against buckling in the side flanges: 23.952 (GOOD)
FOS against buckling in webs: 16.882 (GOOD)
FOS against shear buckling: 4.359 (GOOD)

Moving Load Analysis Results:
Maximum Shear Force (Moving): 257.33 N (leftmost wheel at 172.0 mm)
Maximum Bending Moment (Moving): 69260.00 N·mm (leftmost wheel at 44.0 mm)

2nd Iteration - Added top layer (smaller - underneath current flange)

In the second iteration, another layer of matboard was added between the webs and the current flange to increase the FOS against compression and buckling in the middle flange. The FOS against compression was the lowest FOS after the first iteration, so the bridge would fail due to compression on the top surface. The piece of matboard added increased the thickness of the top flange, increasing the stress required to cause buckling in the middle flange. By adding this additional layer, the location of $\bar{y}$ will be higher, due to the new cross-sectional area distribution (Figure 3). As the height of $\bar{y}$ increases, y_{top} decreases which will in turn cause the compressive stress to decrease, as the maximum compression is on the top of the bridge. This significantly increased the FOS of compression and middle flange buckling, as shown in the code output. The width of this piece of matboard was limited to the distance between the webs to avoid wasting material, as the side flanges FOS were high enough. By making the width of the matboard less, we are not only saving material, but we are also limiting the variation in FOS values, effectively avoiding making a section of the beam "too strong" or using material that is unnecessary or could be used later to strengthen other parts of the bridge.

Material amounts and dimensions of bridge:

Amount of matboard used = 687366mm^2 Amount of matboard still available = 138642mm^2 Amount of glue used = 249370mm^2 Length = 1250mm Width of base = 80mm Width of deck = 100mm Height = 78.81mm

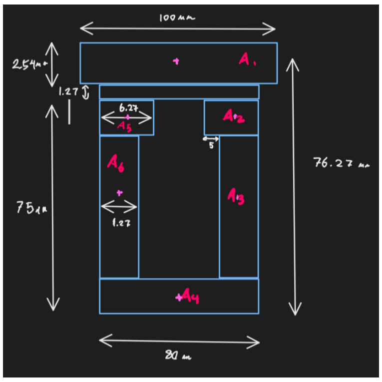

Figure 3: cross-sectional area after 1st iteration

Additional design aspects:

Splice connections	- Splice connection down the centre of bridge
Cross-section rigidity	- Vertical diaphragms placed at regular intervals help to support the bridge and promote cross-section rigidity
Support sections	- 2 diaphragms situated at each support to help handle the direct vertical compression at supports - flat end portions (allowing for the bridge to be placed onto supports)
Diaphragm placement	- 2 near each support (4) - 2 evenly spaced between each support (2) Total = 6 diaphragms

Code Output:

<u>Buckling Capacities</u>:
Case 1 - Web Buckling: 14.27 MPa
Case 2 - Side Flange Buckling: 83.08 MPa
Case 3 - Middle Flange Buckling: 78.97 MPa
Shear Buckling Capacity: 5.09 MPa

<u>Central Locomotive Location</u>:
Maximum Shear Force: 208.00 N at x = 0.0 mm
Maximum Bending Moment: 74250.00 N·mm at x = 687.5 mm

<u>Stresses</u>:
Flexural Stress (Tension): 6.97 MPa
Flexural Stress (Compression): 2.88 MPa
Maximum Shear Stress: 1.26 MPa
Maximum Glue Shear Stress: 0.21 MPa

<u>Predicted failure load</u>: 834.1 N

<u>Factors of Safety</u>:
FOS against tension: 4.306 (GOOD)
FOS against compression: 2.085 (GOOD)
FOS against shear: 3.184 (GOOD)
FOS against glue failure: 9.498 (GOOD)
FOS against buckling in middle flange: 4.959 (GOOD)
FOS against buckling in side flanges: 28.874 (GOOD)
FOS against buckling in webs: 27.444 (GOOD)
FOS against shear buckling: 4.049 (GOOD)

<u>Moving Load Analysis Results</u>:
Maximum Shear Force (Moving): 263.04 N (leftmost wheel at 222.0 mm)
Maximum Bending Moment (Moving): 74370.33 N·mm (leftmost wheel at 76.0 mm)

3rd Iteration - Add thickness to webs (not used in final design)

The third iteration doubled the thickness of the webs, which will allow the bridge to better resist shear force, which is the second-lowest FOS after the second iteration. By increasing this FOS, the overall FOS won't be increased, but when the other failure mechanisms are addressed the shear FOS will not be an issue if this change is made. This iteration almost doubles the FOS for shear, as the width at the place of the largest shear is doubled. However, this design is not feasible as it uses too much material. Therefore, this iteration will not be used in our final design, and the measurements below are ignored for future iterations and calculations.

Material amounts and dimensions of bridge:

Amount of matboard used = 868616mm^2 Amount of matboard still available = - 42608mm^2 Amount of glue used = 430520mm^2 Length = 1250mm Width of base = 80mm Width of deck = 100mm Height = 78.81mm

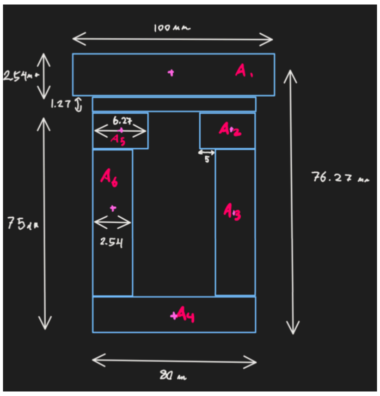

Figure 4: cross-sectional area after 3rd iteration

Additional design aspects:

Splice connections	- Splice connection down the centre of the bridge
Cross-section rigidity	- Vertical diaphragms placed at regular intervals help to support the bridge and promote cross-section rigidity

Support sections	- 2 diaphragms situated at each support to help handle the direct vertical compression at supports - flat end portions (allowing for the bridge to be placed onto supports)
Diaphragm placement	- 2 near each support (4) - 2 evenly spaced between each support (2) Total = 6 diaphragms

Code Output:
Buckling Capacities:
Case 1 - Web Buckling: 14.74 MPa
Case 2 - Side Flange Buckling: 73.98 MPa
Case 3 - Middle Flange Buckling: 229.50 MPa
Shear Buckling Capacity: 20.34 MPa

Central Locomotive Location:
Maximum Shear Force: 208.00 N at x = 0.0 mm
Maximum Bending Moment: 74250.00 N·mm at x = 687.5 mm

Stresses:
Flexural Stress (Tension): 5.45 MPa
Flexural Stress (Compression): 2.77 MPa
Maximum Shear Stress: 0.67 MPa
Maximum Glue Shear Stress: 0.17 MPa

Predicted failure load: 865.1 N

Factors of Safety:
FOS against tension: 5.504 (GOOD)
FOS against compression: 2.163 (GOOD)
FOS against shear: 6.002 (GOOD)
FOS against glue failure: 11.713 (GOOD)
FOS against buckling in middle flange: 5.313 (GOOD)
FOS against buckling in side flanges: 26.666 (GOOD)
FOS against buckling in webs: 82.723 (GOOD)
FOS against shear buckling: 30.527 (GOOD)

Moving Load Analysis Results:
Maximum Shear Force (Moving): 263.04 N (leftmost wheel at 222.0 mm)
Maximum Bending Moment (Moving): 74370.33 N·mm (leftmost wheel at 76.0 mm)

4th Iteration - Increase web height (to fit requirements)

In the fourth iteration, the height of the webs was increased by 1.19mm so that the bridge fit the requirement of having the track that is a multiple of 20 mm above the supports outlined in the project handout. This iteration wasn't made to add strength or improve the design in any way other than making it a viable submission. Unintentionally, due to the change in height the FOS for most causes of failure changed slightly, causing the FOS against compression to increase slightly, increasing the overall FOS as compression had the lowest FOS and was where the bridge would fail first. This change allowed the bridge to fit all requirements, so it is now a viable design.

Material amounts and dimensions of bridge:

Amount of matboard used = 690341mm^2 Amount of matboard still available = 135667mm^2 Amount of glue used = 249370mm^2 Length = 1250mm Width of base = 80mm Width of deck = 100mm Height = 80mm

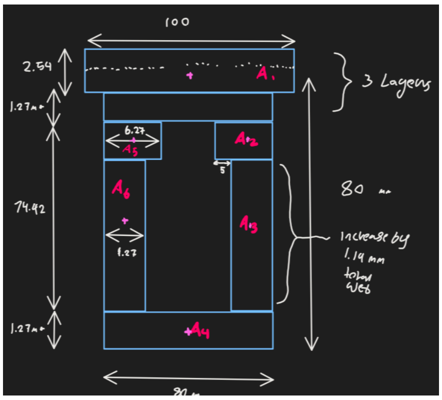

Figure 5: cross-sectional area after 4th iteration

Additional design aspects:

Splice connections	- Splice connection down the centre of bridge
Cross-section rigidity	- Vertical diaphragms placed at regular intervals help to support the bridge and promote cross-section rigidity
Support sections	- 2 diaphragms situated at each support to help handle the direct vertical compression at supports - flat end portions (allowing for the bridge to be placed onto supports)
Diaphragm placement	- 2 near each support (4) - 2 evenly spaced between each support (2) Total = 6 diaphragms

Code Output:

Buckling Capacities:
Case 1 - Web Buckling: 14.27 MPa
Case 2 - Side Flange Buckling: 83.08 MPa
Case 3 - Middle Flange Buckling: 75.91 MPa
Shear Buckling Capacity: 4.93 MPa

Central Locomotive Location:
Maximum Shear Force: 208.00 N at x = 0.0 mm
Maximum Bending Moment: 74250.00 N·mm at x = 687.5 mm

<u>Stresses</u>:
Flexural Stress (Tension): 6.83 MPa
Flexural Stress (Compression): 2.83 MPa
Maximum Shear Stress: 1.24 MPa
Maximum Glue Shear Stress: 0.21 MPa

<u>Predicted failure load</u>: 848.1 N

<u>Factors of Safety:</u>
FOS against tension: 4.394 (GOOD)
FOS against compression: 2.120 (GOOD)
FOS against shear: 3.228 (GOOD)
FOS against glue failure: 9.643 (GOOD)
FOS against buckling in middle flange: 5.042 (GOOD)
FOS against buckling in side flanges: 29.359 (GOOD)
FOS against buckling in webs: 26.827 (GOOD)
FOS against shear buckling: 3.982 (GOOD)

<u>Moving Load Analysis Results</u>:
Maximum Shear Force (Moving): 263.04 N (leftmost wheel at 222.0 mm)
Maximum Bending Moment (Moving): 74370.33 N·mm (leftmost wheel at 76.0 mm)

5th iteration - increase the width of the top flange

In the fifth iteration, the width of the top layers of the flange was increased to raise the placement of $\bar{y}$ on the cross-section, so the FOS of compression could be increased. The FOS of compression was the lowest FOS after iteration four and was therefore also the overall FOS. Increasing the width of the flange will adjust the area distribution in the cross-section, causing the location of $\bar{y}$ to increase and the value of y_{top} to decrease. Since the maximum compression force is on the top of the bridge, this will reduce the compressive stress and increase the FOS of compression. Increasing the FOS of compression increased the predicted loading of the bridge by a large amount, as it caused the overall FOS of the bridge to increase significantly.

Material amounts and dimensions of bridge:

Amount of matboard used = 740341mm^2
Amount of matboard still available = 85667mm^2
Amount of glue used = 299370mm^2
Length = 1250mm
Width of base = 80mm
Width of deck = 120mm
Height = 80mm

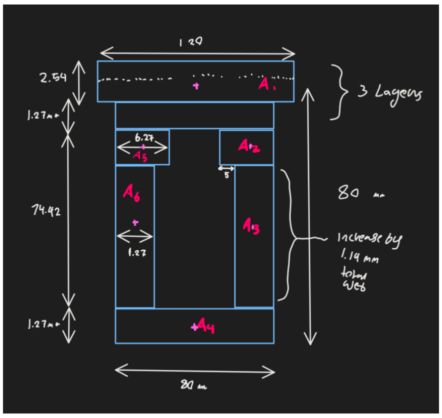

Figure 6: cross-sectional area after 5th iteration

Additional design aspects:

Splice connections	- Splice connection down the centre of the bridge
Cross-section rigidity	- Vertical diaphragms placed at regular intervals help to support the bridge and promote cross-section rigidity
Support sections	- 2 diaphragms situated at each support to help handle the direct vertical compression at supports - flat end portions (allowing for the bridge to be placed onto supports)
Diaphragm placement	- 2 near each support (4) - 2 evenly spaced between each support (2) Total = 6 diaphragms

Code Output:
<u>Buckling Capacities</u>:
Case 1 - Web Buckling: 14.27 MPa
Case 2 - Side Flange Buckling: 10.01 MPa
Case 3 - Middle Flange Buckling: 126.00 MPa
Shear Buckling Capacity: 4.93 MPa

<u>Central Locomotive Location</u>:
Maximum Shear Force: 208.00 N at x = 0.0 mm
Maximum Bending Moment: 74250.00 N·mm at x = 687.5 mm

<u>Stresses</u>:
Flexural Stress (Tension): 6.46 MPa
Flexural Stress (Compression): 1.98 MPa
Maximum Shear Stress: 1.22 MPa
Maximum Glue Shear Stress: 0.18 MPa

<u>Predicted failure load</u>: 1212.2 N

<u>Factors of Safety</u>:
FOS against tension: 4.643 (GOOD)
FOS against compression: 3.030 (GOOD) – *The lowest FOS is 3 under Load Case 1*
FOS against shear: 3.284 (GOOD)
FOS against glue failure: 10.871 (GOOD)
FOS against buckling in middle flange: 7.206 (GOOD)
FOS against buckling in the side flanges: 5.057 (GOOD)
FOS against buckling in webs: 63.640 (GOOD)
FOS against shear buckling: 4.051 (GOOD)

<u>Moving Load Analysis Results:</u>

Maximum Shear Force (Moving): 263.04 N (leftmost wheel at 222.0 mm)
Maximum Bending Moment (Moving): 74370.33 N·mm (leftmost wheel at 76.0 mm)

6th iteration - Change in Splice Location, adding glue tabs to some splices, and adding a piece of matboard across the bottom splice

In the sixth iteration, a possible weakness at the splice location was addressed by placing the splices in varying locations, adding glue tabs for the splicing of the bottom and webs, and adding a piece of matboard across the bottom where it is spliced. The glue has a lower maximum stress than the matboard, causing the bridge to be more susceptible to failure at splicing locations. Placing the splicing locations at various locations along the bridge will hopefully decrease the chance of the bridge breaking at the splice location, as other parts of the bridge are solid and holding the bridge together at this location (Figure 7). Adding a piece of matboard along the bottom of the splice will hopefully help the splice resist tension by resisting some of the tension force, as the glue is weaker in tension. Currently, we are unaware of the effects as we have not yet learned the calculations to be able to check this value. Therefore, this change is purely intuitive, however, these choices were thought through and are predicted to provide support and improve the failure loading of the bridge.

Material amounts and dimensions of bridge:

Amount of matboard used = 740341mm^2
Amount of matboard still available = 85667mm^2
Amount of glue used = 300931mm^2
Length = 1250mm
Width of base = 80mm
Width of deck = 120mm
Height = 80mm

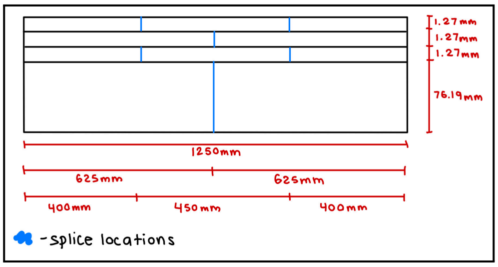

Figure 7: Splice Location Diagram after 6th Iteration (elevation view)

Additional design aspects:

Splice connections	- Bottom piece (webs and bottom flange) and middle layer of top flange spliced at centre - Top and bottom layers of the top flange are spliced 400 mm from the edges of the bridge
Cross-section rigidity	- Vertical diaphragms placed at regular intervals help to support the bridge and promote cross-section rigidity
Support sections	- 2 diaphragms situated at each support to help handle the direct vertical compression at supports - flat end portions (allowing for the bridge to be placed onto supports)
Diaphragm placement	- 2 near each support (4) - 2 evenly spaced between each support (2) Total = 6 diaphragms

Code Output (same as 5th iteration):
Buckling Capacities:
Case 1 - Web Buckling: 14.27 MPa
Case 2 - Side Flange Buckling: 10.01 MPa
Case 3 - Middle Flange Buckling: 126.00 MPa
Shear Buckling Capacity: 4.93 MPa

Central Locomotive Location:
Maximum Shear Force: 208.00 N at x = 0.0 mm
Maximum Bending Moment: 74250.00 N·mm at x = 687.5 mm

Stresses:
Flexural Stress (Tension): 6.46 MPa
Flexural Stress (Compression): 1.98 MPa
Maximum Shear Stress: 1.22 MPa
Maximum Glue Shear Stress: 0.18 MPa

Predicted failure load: 1212.2 N

Factors of Safety:
FOS against tension: 4.643 (GOOD)
FOS against compression: 3.030 (GOOD)
FOS against shear: 3.284 (GOOD)
FOS against glue failure: 10.871 (GOOD)
FOS against buckling in middle flange: 7.206 (GOOD)
FOS against buckling in side flanges: 5.057 (GOOD)
FOS against buckling in webs: 63.640 (GOOD)
FOS against shear buckling: 4.051 (GOOD)

7th iteration - Adding extra diaphragms

In the 7th iteration, more diaphragms were added throughout the beam to increase the FOS of shear buckling and to help support the directly applied load. Diaphragms were added at the supports where the bridge will face the largest amount of shear stress, and where the bridge will have a directly applied load. Diaphragms were also added at the splice locations, and the original diaphragms were removed. Having more diaphragms closer together at the point with the highest shear force will increase the FOS of shear buckling by reducing the distance between the diaphragms, which will increase the critical shear force value. While this was not our lowest FOS, it was shared that most bridges will fail due to shear buckling, and by increasing this FOS we are increasing the chance of our bridge making it to the predicted maximum load. Based on given information in the document and throughout the course, areas near supports will be subjected to direct vertical compression. Although we are not yet able to calculate and quantize these values, it was suggested to ensure cross-section rigidity that more diaphragms are placed in these locations as well as throughout the bridge. It is an intuitive decision choice to place diaphragms at splice locations, however, it is predicted that this will help to reinforce the bridge at these locations to help eliminate the chance of buckling or breaking as the splices are already weaker due to glue. The final location where diaphragms were added was between the outer splice locations and the supports. Due to a material limitation, these diaphragms are “half diaphragms” as they are the least important of the other ones added. They are 3mm shorter, but are there in case the flange starts to buckle due to compression or shear buckling at these locations

Material amounts and dimensions of bridge:

Amount of matboard used = 777836mm^2 Amount of matboard still available = 48127mm^2 Amount of glue used = 304741mm^2 Length = 1250mm Width of base = 80mm Width of deck = 120mm Height = 80mm

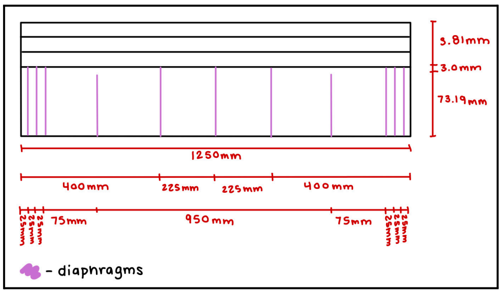

Figure 8: Diaphragm Location Diagram after 7th Iteration (elevation view)

Additional design aspects:

Splice connections	- Bottom piece (webs and bottom flange) and middle layer of top flange spliced at centre - Top and bottom layers of the top flange are spliced 400 mm from the edges of the bridge
Cross-section rigidity	-An increase in vertical diaphragms placed at regular intervals helps to increase support to the bridge and promote cross-section rigidity, leading to a higher overall FOS
Support sections	- 3 diaphragms situated at each support to help handle the direct vertical compression at supports - flat end portions (allowing for the bridge to be placed onto supports)
Diaphragm placement	- 3 near each support (6) - 1 in the centre - at splice location (1) - 1 at each non-centre splice location (2) - 1 half diaphragm between each support and non-centred splice location (2) Total = 9 full diaphragms and 2 half diaphragms (not full height - 3mm off due to material restrictions)

Code Output:

<u>Buckling Capacities:</u>
Case 1 - Web Buckling: 14.27 MPa
Case 2 - Side Flange Buckling: 10.01 MPa
Case 3 - Middle Flange Buckling: 126.00 MPa
Shear Buckling Capacity: 5.19 MPa

<u>Central Locomotive Location:</u>
Maximum Shear Force: 208.00 N at x = 0.0 mm
Maximum Bending Moment: 74250.00 N·mm at x = 687.5 mm

<u>Stresses:</u>
Flexural Stress (Tension): 6.46 MPa
Flexural Stress (Compression): 1.98 MPa
Maximum Shear Stress: 1.22 MPa
Maximum Glue Shear Stress: 0.18 MPa

Predicted failure load: 1212.2 N

<u>Factors of Safety:</u>
FOS against tension: 4.643 (GOOD)
FOS against compression: 3.030 (GOOD)
FOS against shear: 3.284 (GOOD)
FOS against glue failure: 10.871 (GOOD)
FOS against buckling in middle flange: 7.206 (GOOD)
FOS against buckling in the side flanges: 5.057 (GOOD)
FOS against buckling in webs: 63.640 (GOOD)
FOS against shear buckling: 4.258 (GOOD)

<u>Moving Load Analysis Results:</u>
Maximum Shear Force (Moving): 263.04 N (leftmost wheel at 222.0 mm)
Maximum Bending Moment (Moving): 74370.33 N·mm (leftmost wheel at 76.0 mm)

References

[1] American Institute of Steel Construction. (n.d.). *Determining the buckling resistance of steel and composite bridge members*. Retrieved from https://www.aisc.org

[2] American Institute of Steel Construction. (n.d.). *Strength requirements for shear diaphragms used for stability bracing of steel beams*. Retrieved from https://www.aisc.org

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