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CIV102 Project Team 601 Design Report

1. Introduction

As part of the CIV102 course at the University of Toronto, the final project consisted in using and applying what was studied over the term to construct a small bridge using the specific materials indicated by the teaching team. First, it was required that the students make a script in Matlab or python that would make an internal shear force diagram and bending moment diagram of a bridge due to an applied load of 400 N. Then make hand calculations for the design that was given by the teaching team to check if it would fail. Additionally, make a script to check if the answers for the hand calculations were correct and use it to calculate the failure load for the designs iterated by the group. And finally, choose one design that would support the most load before failing and building the bridge

In this report, the major iterations of the designs for the bridge, the description of the chosen design for the construction, and the building process will be discussed.

2. Design Iterations

Design 0

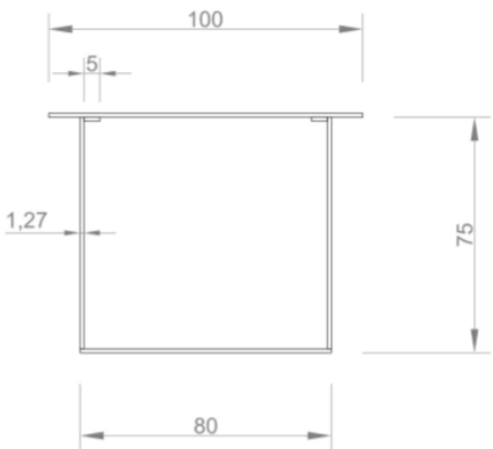

Figure 1 : Representation of design 0

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First, the group worked on design 0, given by the teaching team on the project's documentation. All members made calculations for the cross-sectional geometric properties, applied stresses, and material/thin plate buckling capacities. Then the group compared the applied stresses and capacities to determine Factors of Safety (FOS) against each failure mechanism, and the minimum FOS was found.

After the calculations were made, a script on Matlab was done to check if the calculations were correct. In the end, it was found that Design 0 would fail due to buckling on the top flange (FOS = 0.745) and buckling at the extremities of the top flange (FOS = 0.482). The maximum load Design 0 can handle is 192 N, which is significantly less than the minimum of 400 N the bridge is required to hold. So this specific design could not be an option.

Design 1

The group tried working on design 0 and improving it so that it could handle at least the required 400 N. The same Matlab script was used to check the calculations. Changes to the initial parameters were made until the group found the biggest failure load.

The final parameters that were changed and used in Design 1 were: top flange thickness was doubled, from 1.27 mm to 2.54 mm, and that was done because it doubled the FOS of case 1 of buckling and the FOS of case 2 of buckling to avoid top flange and extremity buckling; web height was increased by 33% (75 mm to 100 mm) considering that raising the value of I(Second moment of area) ensures a lower applied stress, and increasing the centroidal axis improves the ratio between top material and bottom material. According to the code, this design would have a failure load of 600 N. However, the group did not take into account the available material.

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Design 2

The group decided to remove the bottom flange of the cross-section of design 1. This decision was made because without this area, the group would save material to use in other parts of the bridge, and no tension would be experienced by the beam. Additionally, the diaphragms would be spaced out every 114.5 mm starting at the first support to make the cross-section more rigid to counter shear buckling and distribute the load. The group also doubled the thickness of the web height for more reinforcement, as there would be no bottom flange. Aside from these changes, the group used the same measures as the previous design. As with the previous design, the group did not consider the available material.

This design would be able to withstand a failure load of around 800 N, which is higher than what design 1 would be able to resist.

3. Final Design - Constructed Bridge Description

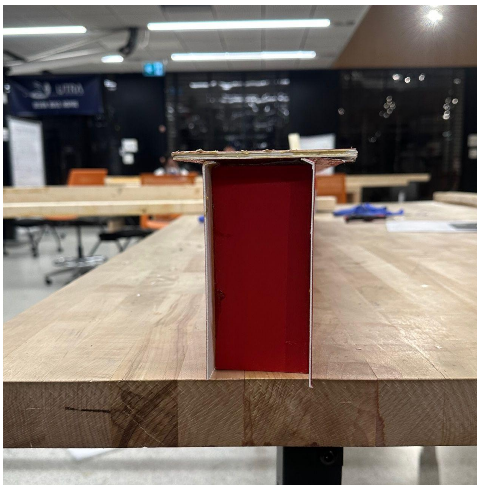

Figure 2 : Cross-Section of the beam

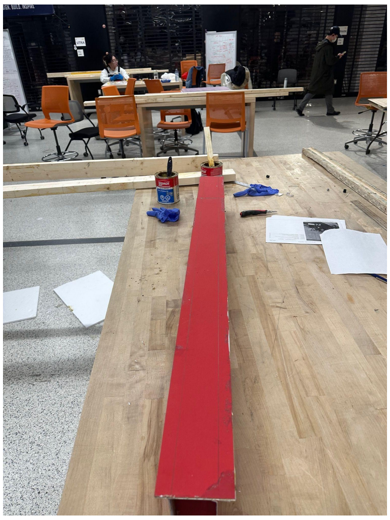

Figure 3 : Top view of the bridge

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The final design cross section was based on design 2, as that gave us a high failure load. The group changed the geometries until it found the design that would support the highest failure load, now taking into account the available material.

The bridge would be 1260 mm considering that this measure should be between 1250 and 1270 mm according to the project document. The deck width is 100 mm due to the minimum requirement for this being 100 mm. And the width between the webs is 60 mm, considering that the distance between the wheels of the train is 65 mm.

The width of the matboard used is 1.27 mm, so using one layer of matboard for the webs and the diaphragms meant they had a thickness of 1.27 mm. However, when choosing the thickness of the deck, the group chose to use 3 layers, so that it could handle the applied load and compressive force better, thus the thickness of the top flange is 3.81 mm. They were glued together with the contact cement.

We decided against adding a bottom flange to save material and to raise the centroidal axis of the bridge to counter compressive stress, which was one of our most critical stresses causing failure. The group decided to add diaphragm to add rigidity lost from the absence of the bottom flange. 8 diaphragms were spaced at 115 mm with 2 additional diaphragms spaced 112.5 mm from the ends of the beam as seen in Figure 4 below, this helped to counter shear buckling which was greatest closer to the ends of the bridge. 2 more diaphragms were added 20 mm from the ends so that the bridge has more material touching the 50mm supports on either end. The height of the webs is 130 mm as this would raise the centroidal axis while staying within material limitations.

The matboard length was not long enough for the webs and top flange, so the group had to cut two pieces - 1015 mm and 245 mm - and attach them in the construction process to reach 1260 mm. This design was our most optimal, as according to the calculations from the code, it should have a minimum FOS of 3.11 and a failure load of 1245 N due to compression.

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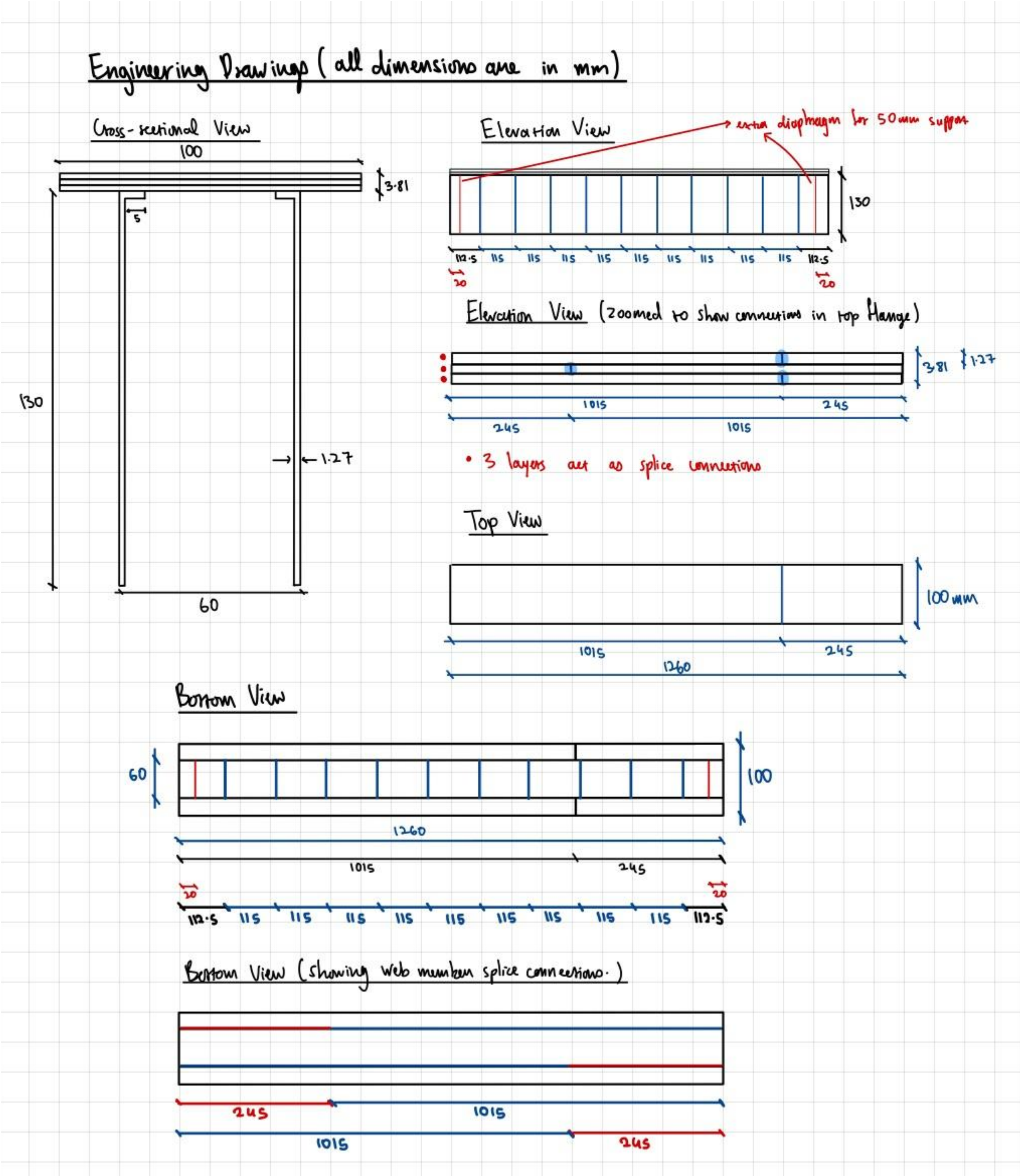

Figure 4: Engineering drawings, dimensions and design features shown, along with splice connection decisions. These drawings visualise most of what was outlined in the previous page, which described the bridge's design features.

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4. Construction Process

Figure 5: members of the group drawing the measurements of the pieces on matboard

For the construction for the bridge, the group used the piece of matboard given by the teaching team, contact cement and a utility knife.

After choosing the groups' final design, we used the app "Shapr3D CAD modeling", to make the drawing showing how the piece of Matboard would be cut with the measurements in mm. Then after finishing the digital drawing, the group drew the measurements on the Matboard.

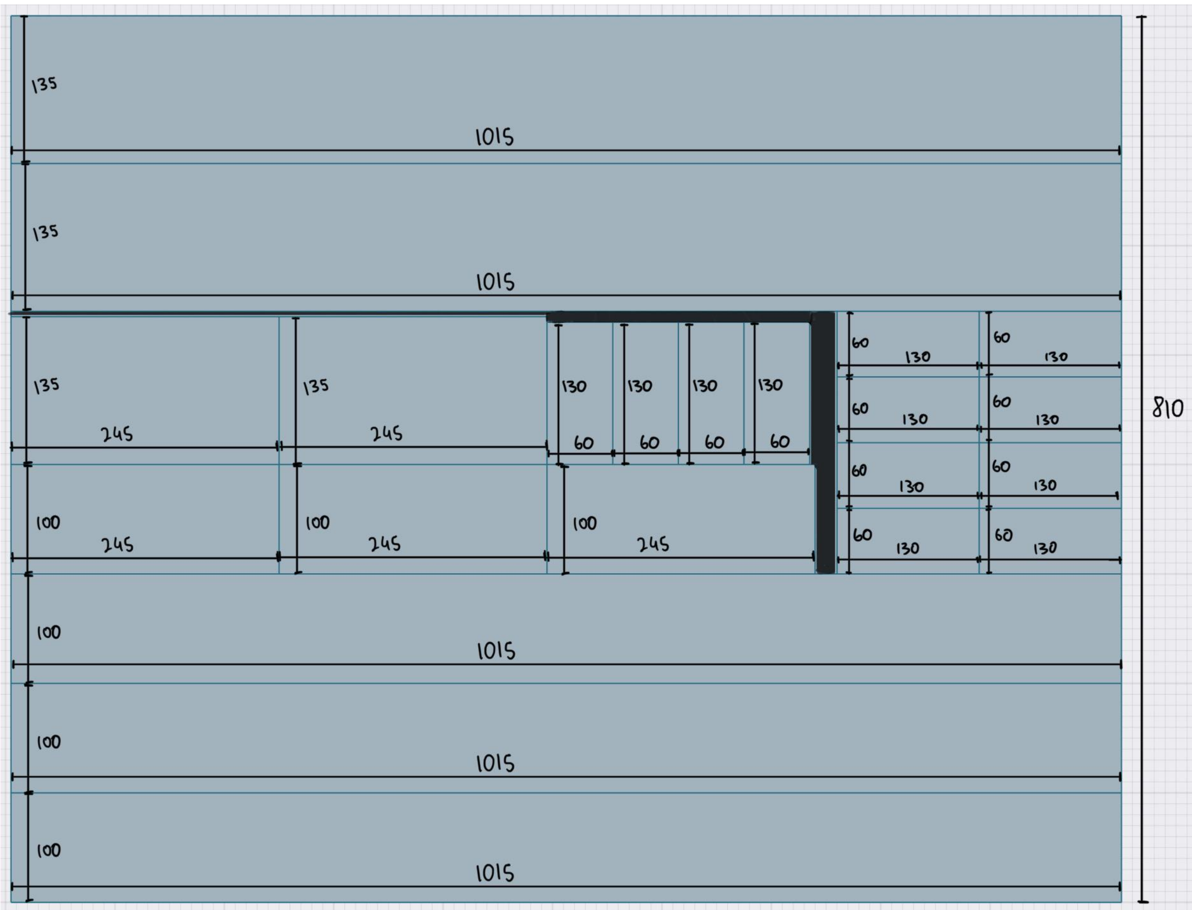

Figure 6: Matboard sectioning blueprint showing how we will cut the matboard to create all the pieces of the board

We used 100% of our matboard by maximising the surface area by using the source code to calculate the surface area our design uses and the surface area available on the board. Figure 6 shows how the matboard was sectioned, the area highlighted in black was used as stitchings to secure our splice connections at the web members, as seen in Figure 4 and Figure 10.

With the top flange drawings made on the matboard, they were cut. The group decided to cut this section before we drew the other measurements so we could already apply the contact cement on the different layers and use our time more efficiently, so while one member of the group was applying the cement, the other two were making the markings on the matboard.

Figure 7 : group member gluing the top flange

When the rest of the measures were marked on the matboard, the group cut all of them and by that time the top flange was already glued. Two pieces of wood and clamps were used to make the structure stable when glueing the parts. The top flange was put on the table to serve as the base for the construction. First the webs were glued and then the diaphragms.To assist when glueing the diaphragms, markings in the wood were made so that the group knew exactly where they should be put.

Figure 8 : Member of the group gluing the web

In the end, to connect the two webs from the same side, the group used what was left of the matboard, and glued those pieces on the connection so that the structure would be more stable. Then the group waited some time so that all the parts were well glued. After 40 minutes the bridge was turned over and taken into storage. The construction process was made four days before the group's tutorial so that the glue would have enough time to dry.

Figure 9 : Piece to connect the interior of the two webs

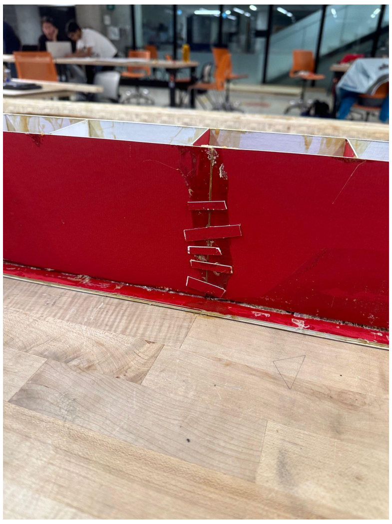

Figure 10 : Pieces to connect the outside of the two webs

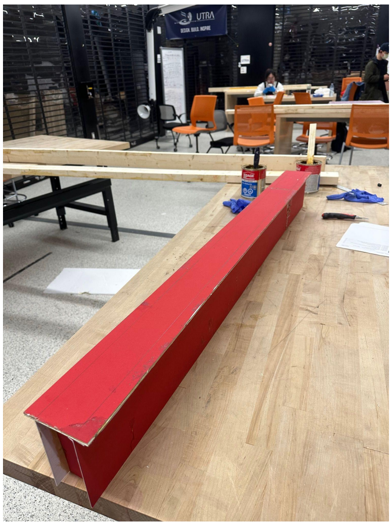

Figure 11 : Constructed bridge