# CIV102 Project Team 703 Design Report

## 1. Introduction

The bridge, constructed from a mat board with dimensions of 32” x 40” x 0.05”, is designed to carry a train with a load of 466.6 N, comprising a locomotive of 180 N and a freight train of 133.3 N (Load Case 2). The bridge can carry the train across a main span of 1200 mm, with a conservative Factor of Safety (FOS) of at least 2.27, which is ideally a train with 1058 N weight. Considering the construction precision, the actual value may be lower.

### Dimension:

1. Length = 1260 mm
2. Height of support = 140 mm
3. Width of support = 1.27 mm
4. Thickness of deck = 2.54 mm
5. Diaphragm distribution: (50), 150, 205, 550, 205 150, (50)

### Material property:

Matboard:

1. Tensile Strength ($\sigma_t$): 30 MPa
2. Compressive Strength ($\sigma_c$): 6 MPa
3. Shear Strength ($\tau_m$): 4 MPa
4. Young’s Modulus ($E_m$): 4000 MPa
5. Poisson’s Ratio ($\nu_m$): 0.2

Contact Cement:

1. Shear Strength ($\tau_g$): Up to 2 MPa if properly cured

### Major design decisions:

With the assistance of the Java program, the width is initially set to 110 mm and the height to 180 mm.

1. After reviewing the loading conditions, the width is reduced to 100 mm.
2. lowered the height from 180 mm to 160 mm to accommodate material usage.
3. Lowered the height from 160 mm to 140 mm to accommodate the shear buckling.
4. The final glue joint width is set at 10 mm to ease cutting difficulty.

# Basic geometry design decision

The team opts for a bridge constructed solely with 90-degree angles to facilitate precise measurement and, consequently, enhance construction quality. The basic geometry is confirmed before calculations based on the intuition that the y_bar should be as high as possible to allow the bridge to resist more tension stress than compression stress, considering the material property of the mat board. In this geometry, the deck is constructed based on 2 pieces of mat board, and the supporting beam is 1 matboard.

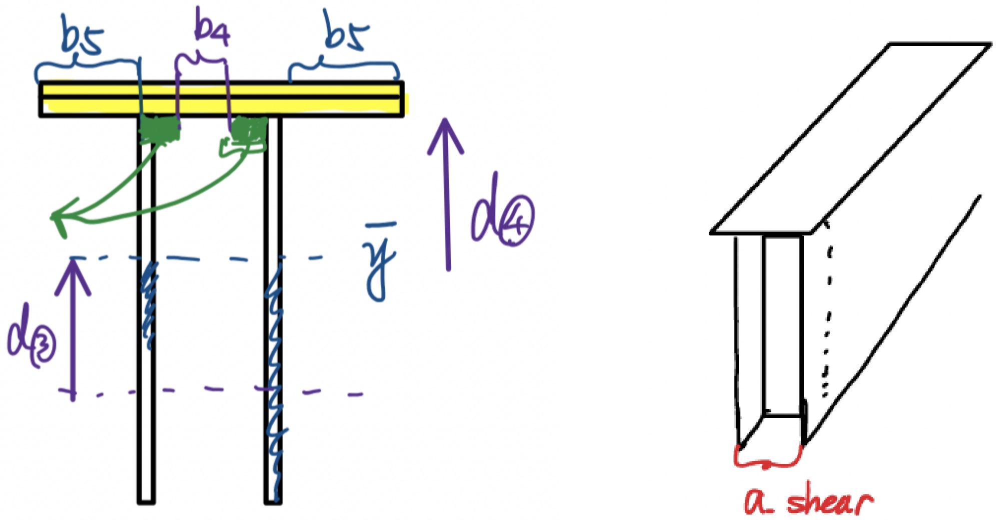


Figure 1: Basic geometry configuration

The more precise geometry is calculated and determined by Java code. The major algorithm is:

1. Find the maximum shear force and moment based on Load Case 2 of every point on the bridge with an increment of 1 mm.
2. Find the highest shear force and bending moment on every point to create a shear force and bending moment envelope.
3. Find the y_bar and I based on variables b and h.
4. Calculate for the 8 different fail cases: Compression, tension, shear force, glue's shear force, plate buckling-middle, plate buckling-side, plate buckling-joints, and shear buckling.
5. Find the peak value from the data above. Then, find the smallest FOS among the 8 fail cases.
6. Run loops to adjust the width, height, and thickness of the bridge to find the 8 FOS in different geometry.
7. Finally, determine the one with the highest lowest FOS.

# 2. Major design iterations

* Our group did not have many iterations because we designed a Java program that can run through most of the geometry and select the most optimized geometry. We only needed to make a few minor adjustments after the Java program finished.

## Design iteration 1

**Change to the design parameter:**

The width of the deck is changed from 110 mm to 100 mm

**Justification/result:**

After carefully reviewing the loading condition, we discovered that the width of the train will remain 75 mm unchanged, which means 100 mm - 75 mm = 25 mm side space should be sufficient for the train to move through the bridge. Reducing the deck width increases the critical stress of buckling with one free side, thus increasing the FOS for buckling failure. It also ensures the train's wheel can be closer to the support of the bridge, decreasing the possibility of the wheel breaking the bridge deck.

* As the width of the deck is in the denominator of the buckling equation, decreasing its value will increase the critical stress.

## Design iteration 2

**Change to the design parameter:**

The height of the bridge is lowered from 180 mm to 160 mm.

**Justification/result:**

The calculation from the Java program concluded that a height of 180 mm is optimal for increasing all the FOS. However, after reviewing the material usage, we found that we will run out of material before we even start to build diaphragms. With a rough calculation of the amount of materials used on the bridge deck and bridge support, we end up with 705600 mm^2 of matboard being used and we only have 825804.8 mm^2 for all parts. Thus, we decided to reduce the height of the bridge to accommodate the material limitation.

# Design iteration 3

**Change to the design parameter:**

The height of the bridge was reduced to 140 mm and was finalized to this value.

**Justification/result:**

After the height was reduced to 160 mm, we found that the FOS for shear buckling will be lower than 1.3(all the calculation is based on the load case 2) and we have used up all the materials, which means the bridge will have little flexibility to increase in loads. Thus, we tried to calculate the FOSs for the bridge with a height of 140 mm and found all FOSs will be increased to above 2 even for the shear buckling ones. Therefore, we decided to finalize the height of the bridge to 140 mm.

# Design iteration 4

**Change to the design parameter:**

The width of the glue joint is finalized to be 10 mm each.

**Justification/result:**

Before starting to cut the matboard, we used AutoCAD to assist us in dividing the region of the matboard. After finishing organizing each piece, we found the original design of 5 mm for the glue joint was too difficult for us. With further calculation about the material usage of the matboard, we found we have enough space to reorganize the pieces to 10 mm wide each to reduce the cutting difficulty.

# 3. Construction process

## 1. Material Preparation

### a) Gather Materials

For the construction of the matboard bridge, we gathered all the necessary items. These included two varieties of glue, a pencil for markings, a tape measure for precise dimensions, a ruler for exact line measurements, and a craft knife and scissors for cutting the matboard. To ensure a clean and organized workspace, we used tarps and garbage bags.


*Figure 1: Collection of materials for bridge construction.*

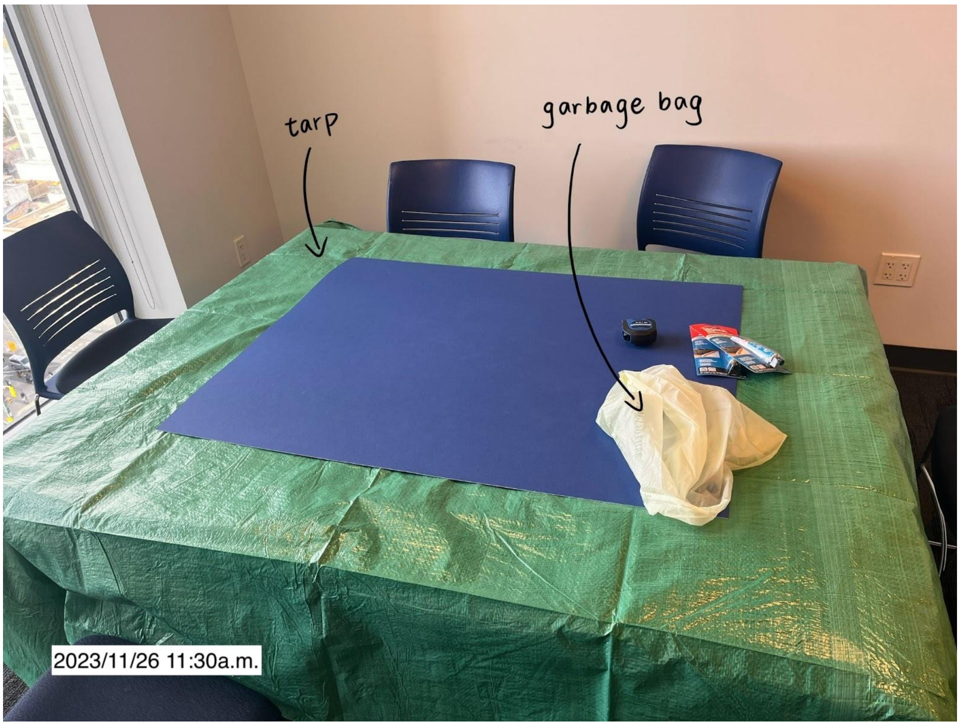


*Figure 2: The photo shows our team's precautions to maintain a clean workspace using a tarp and garbage bags.*

**b) design how to cut Matboard**

Following 4 comprehensive iterations, the dimensions of the bridge were finalized and accurately calculated. Later, a discussion was conducted to strategize the cutting of the matboard. This discussion centred around maximizing material usage while adhering to the structural requirements dictated by our design.

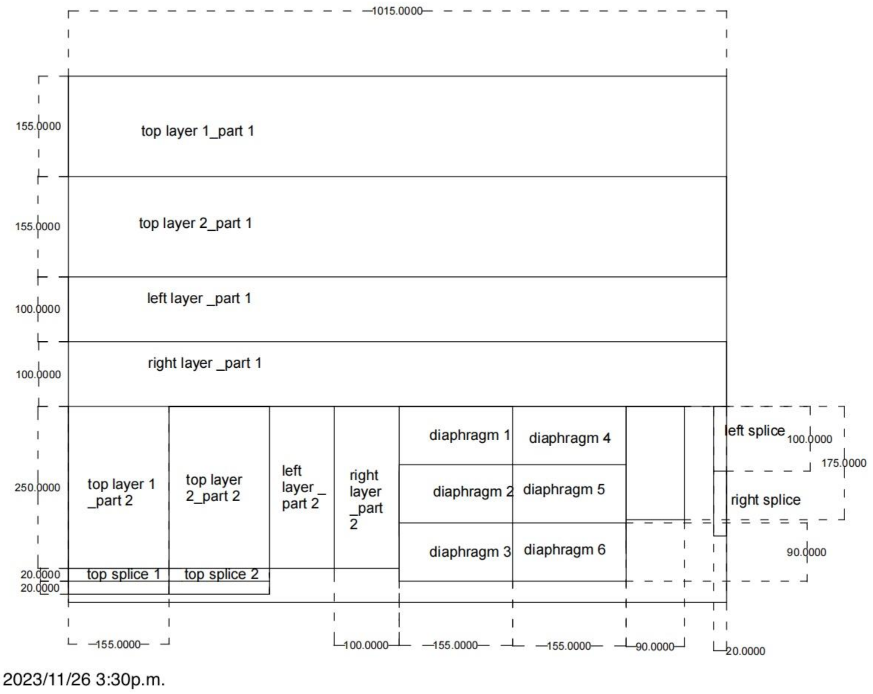


*Figure 3: AutoCad-generated plan for cutting matboard.*


*Figure 4: the hand-drawn plan of cutting matboard.*

### c) cut the matboard

In the following step, we commenced the cutting of the matboard, adhering strictly to the construction blueprint provided previously.


*Figure 5: matboard cut into different pieces/shapes based on our constructing drawing.*

## 2. Constructing/Assembly

### a) Construct the Deck

Our team started by constructing the top flat of the bridge, meticulously gluing two pieces to create a stable and flat deck. To fold the glueing parts, we carefully cut a 90-degree groove to where the board is going to be folded., which allows us to avoid breaking the fibre structure.


*Figure 6: pictures show the splice is used to connect with 2 parts of the top layers.*

### b) Add splices and diaphragms

In constructing the bridge, splices were utilized to join the segments of both the left and right flats. Additionally, diaphragms were implemented to integrate the top, right, and left layers into a unified and sturdy structure, ensuring both cohesion and robustness in the bridge's overall design.

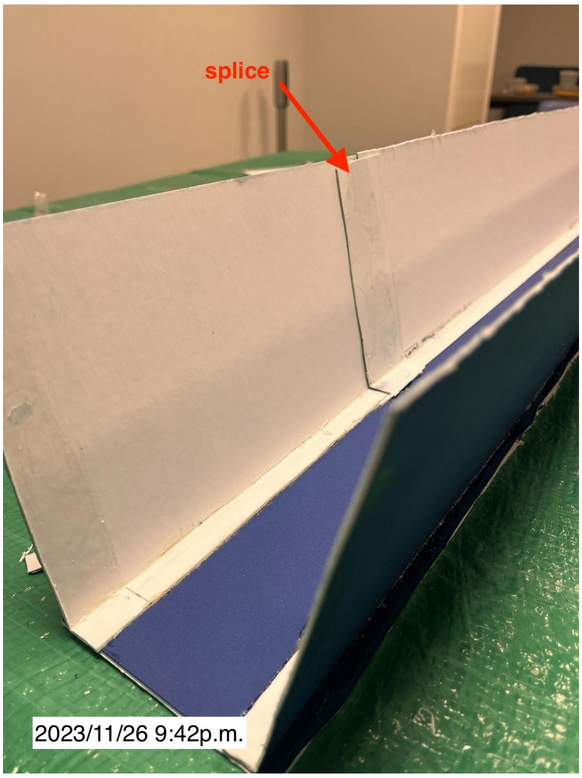


*Figure 7: Image showing the splice connecting two parts(segments) of the left layer (similar to the right layer).*

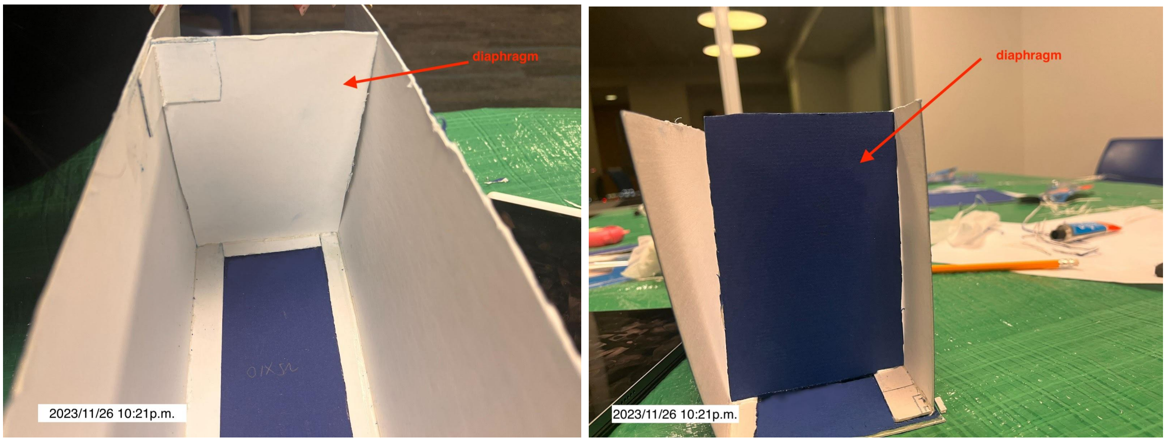


*Figure 8-9: Images displaying the diaphragms connecting all layers, including left, right, and top.*

## 3. Reinforcement

After assembling the bridge, we strengthened the diaphragm connections using leftover matboard pieces at crucial points. Binder clips were also used for reinforcing splices, ensuring a firm and quickly drying bond.

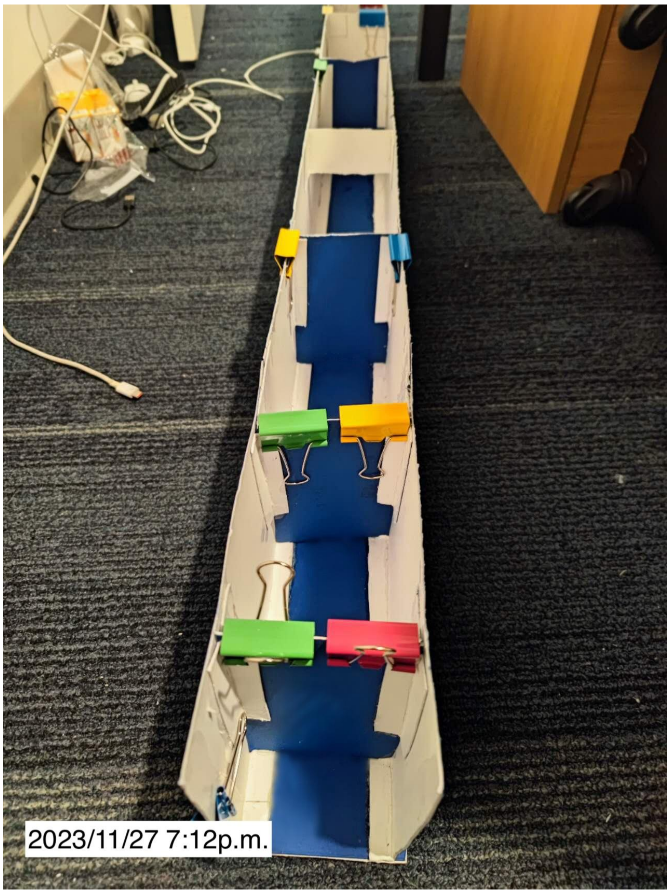


*Figure 10: The bridge is reinforced with colourful binder clips along its sides.*

## 4. Dry and Test

Once the bridge construction was complete, we meticulously cleaned the building space, ensuring all waste materials were collected. We then allowed a drying period of 72 hours, giving the glue ample time to set fully. Before the formal load testing, we conducted a preliminary evaluation by positioning various weights on the bridge to verify its load-bearing capacity.

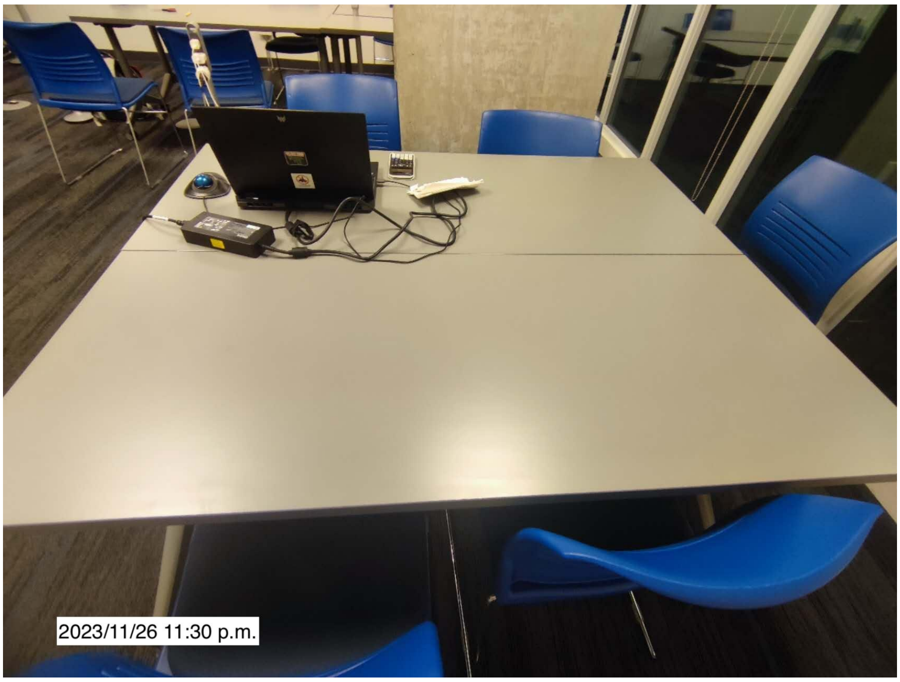


*Figure 11: The workspace post-construction.*


*Figure 12: The final image of the constructed bridge before testing*