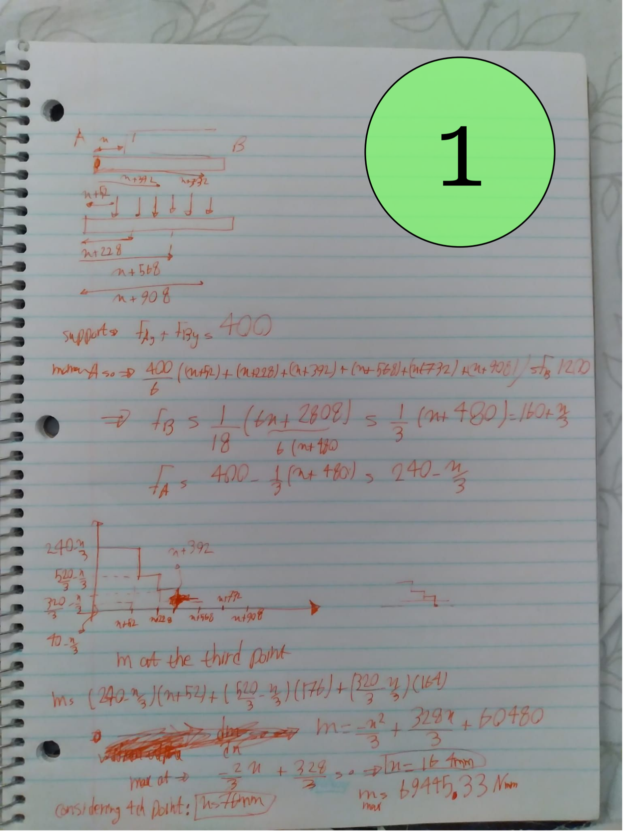


1

Teammate first hand wrote some calculations for design0 (initial bridge design). The 2 other members (me included) also worked on it. We compared answers to make sure we did it right because these calculations are crucial for all the next steps.

The first thing we did when checking for correctness is inspecting the similarity of the shear force diagram.

5

$FOS_{tention} = 4.36$
$FOS_{compression} = 1.038$
$FOS_{flex.buck\ 1,top\ plate} = 0.619$
$FOS_{flex.buck\ 2,flanges} = 3.59$
$FOS_{flex.buck\ 3,webs} = 5.29$
$FOS_{shear} = 2.86$
$FOS_{glue} = 8.03$
$FOS_{shear.buck} = 3.76$

Factor of safeties (FOSs) for design0. One of the FOSs is less than one, so requires optimization. Green text in the following modifications represents increase, red text decrease, and black text same.

$FOS_{tention} = 4.53$
$FOS_{compression} = 1.657$
$FOS_{flex.buck\ 1,top\ plate} = 4.49$
$FOS_{flex.buck\ 2,flanges} = 15.04$
$FOS_{flex.buck\ 3,webs} = 15.56$
$FOS_{shear} = 2.89$
$FOS_{glue} = 6.60$
$FOS_{shear.buck} = 3.78$

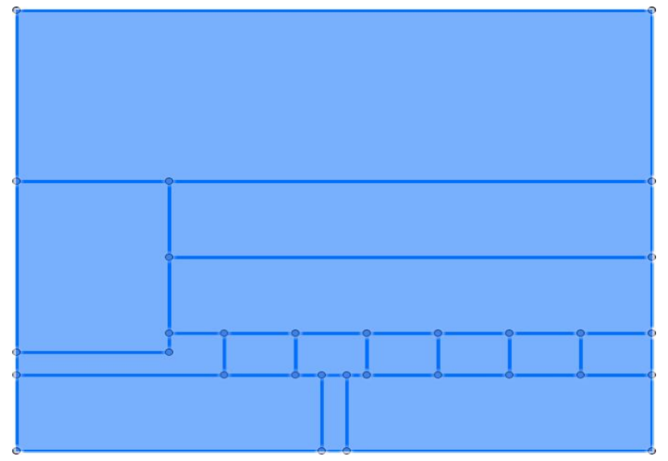
New FOSs after the first round of iteration by changing MATLAB code parameters of bridge dimensions. All FOSs increased except for the 2nd last one.

$FOS_{tention} = 8.21$
$FOS_{compression} = 3.07$
$FOS_{flex.buck\ 1,top\ plate} = 8.34$
$FOS_{flex.buck\ 2,flanges} = 9.00$
$FOS_{flex.buck\ 3,webs} = 11.92$
$FOS_{shear} = 4.27$
$FOS_{glue} = 10.05$
$FOS_{shear.buck} = 2.47$

Attempt to even out the FOSs (maximize the minimum) by playing with parameters to weaken strong parts of the bridge to reinforce weak parts.

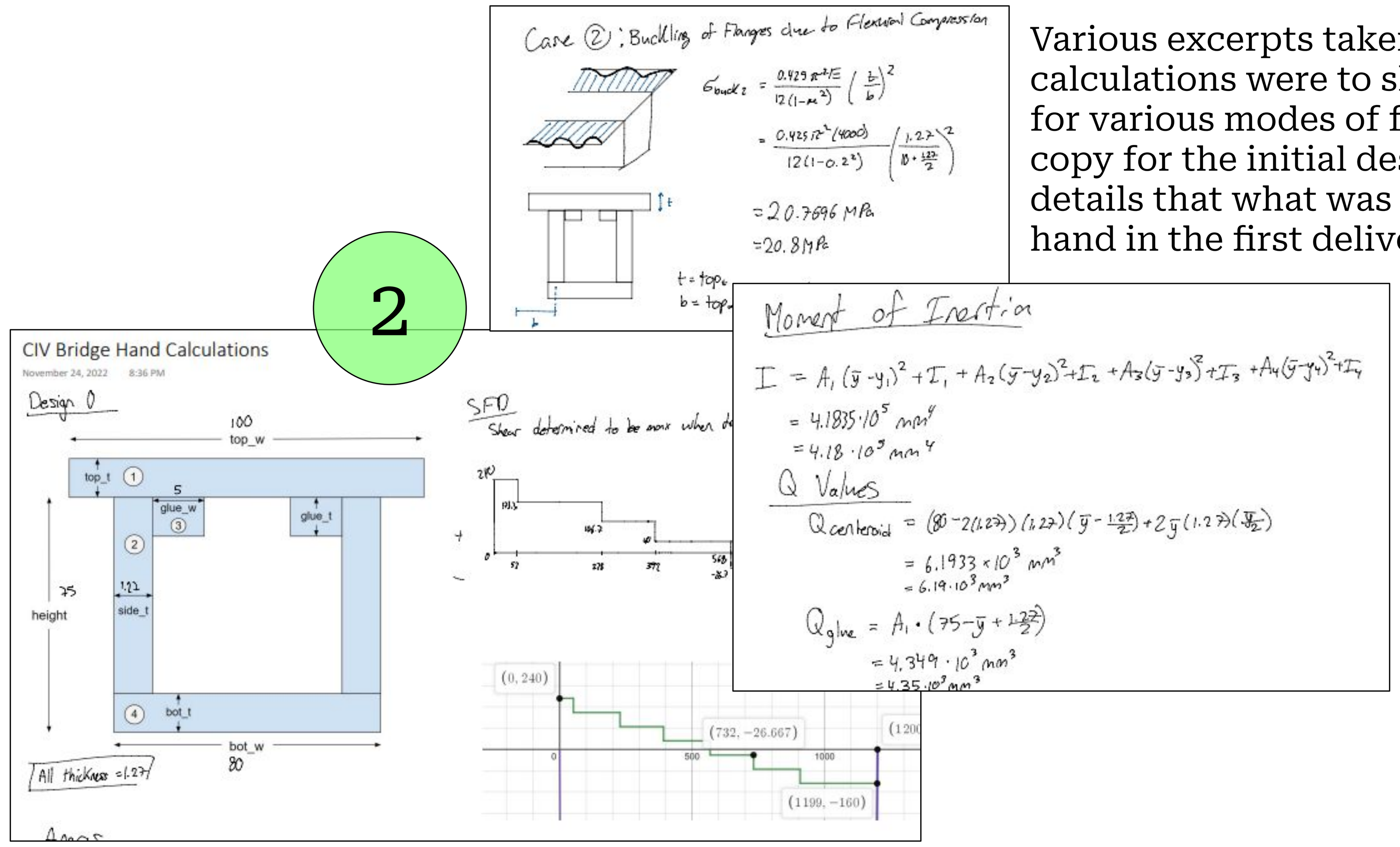
$FOS_{tention} = 8.21$
$FOS_{compression} = 3.07$
$FOS_{flex.buck\ 1,top\ plate} = 8.34$
$FOS_{flex.buck\ 2,flanges} = 9.00$
$FOS_{flex.buck\ 3,webs} = 11.92$
$FOS_{shear} = 4.27$
$FOS_{glue} = 10.05$
$FOS_{shear.buck} = 3.02$

Additional tweaks to the bridge dimensions that brought the lowest FOS up to 3.02. Went through a total of three rounds of iteration.



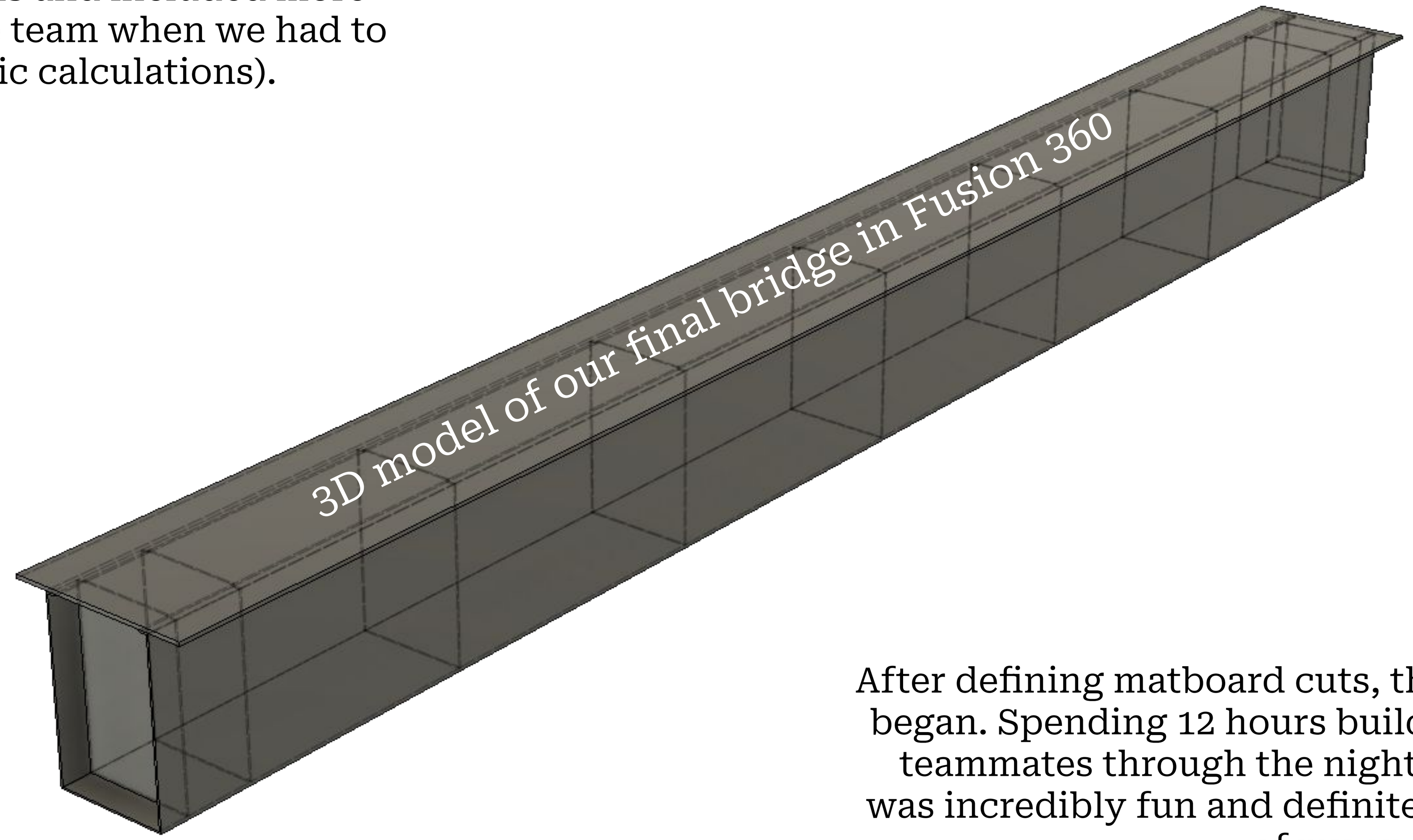
Version 1 of our matboard cutout, designed in Fusion 360. We realized that the space can be optimized, so we tried another cut

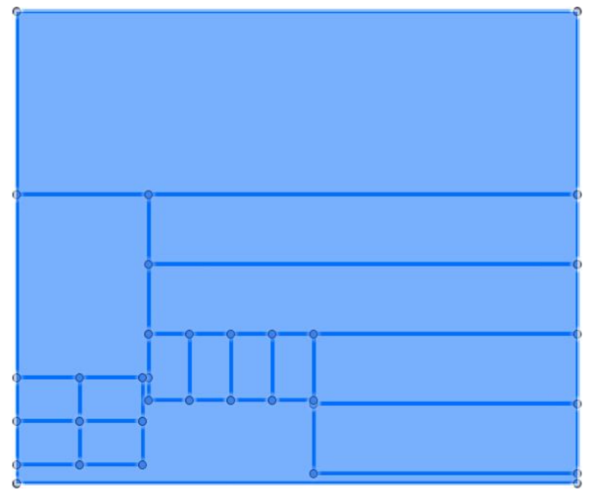
6



2

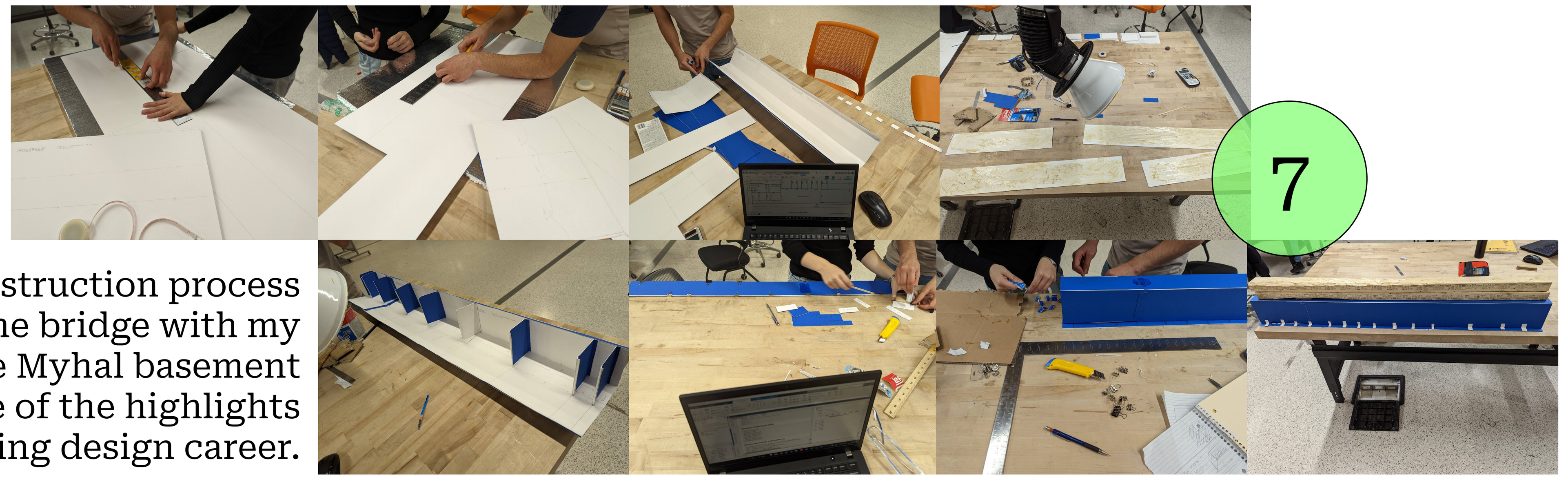
Various excerpts taken from sample calculations. The end calculations were to show different Factors of Safeties (FOSs) for various modes of failure. These Calculations were a good copy for the initial design0 calculations and included more details that what was expected for the team when we had to hand in the first deliverable (more basic calculations).





Version 2 of our matboard cutout, which saved quite a bit more space, leaving many scrap pieces at the end to reinforce our bridge and also inspired the name of the bridge: "The Scrapper"

The matboard dimensions:
1016mm by 812mm



7

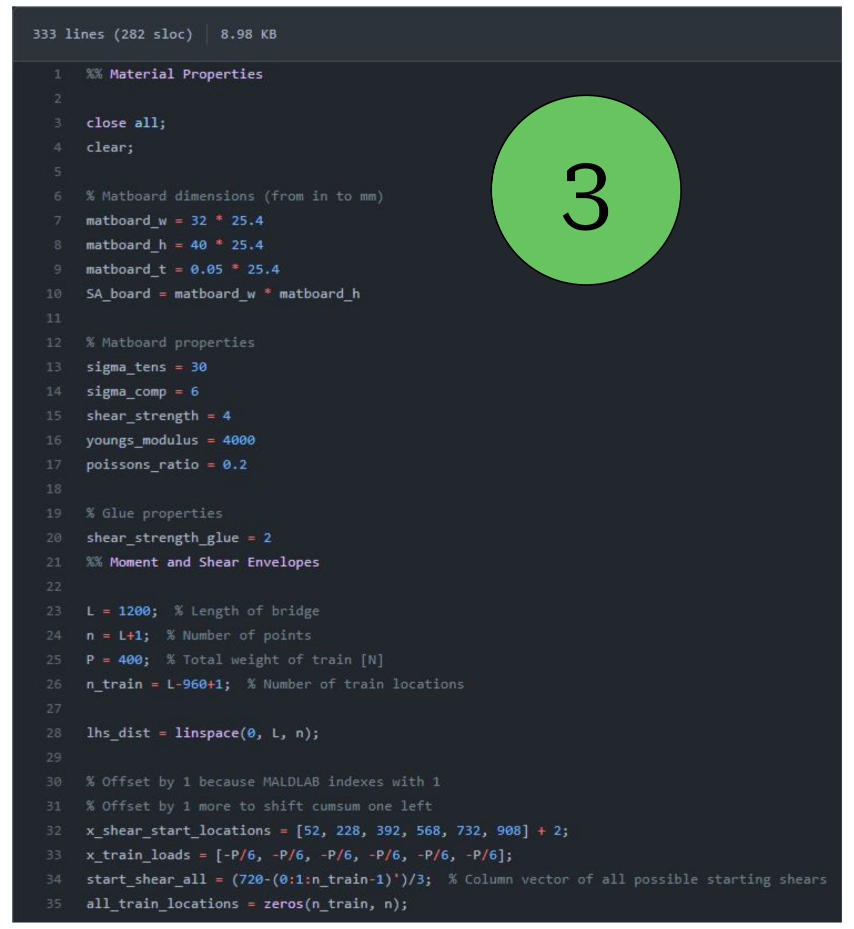
After defining matboard cuts, the construction process began. Spending 12 hours building the bridge with my teammates through the night in the Myhal basement was incredibly fun and definitely one of the highlights of my engineering design career.

All hand calculations were ported over to a MATLAB script with modifiable parameters that are based on the draft of the bridge in the sketch.

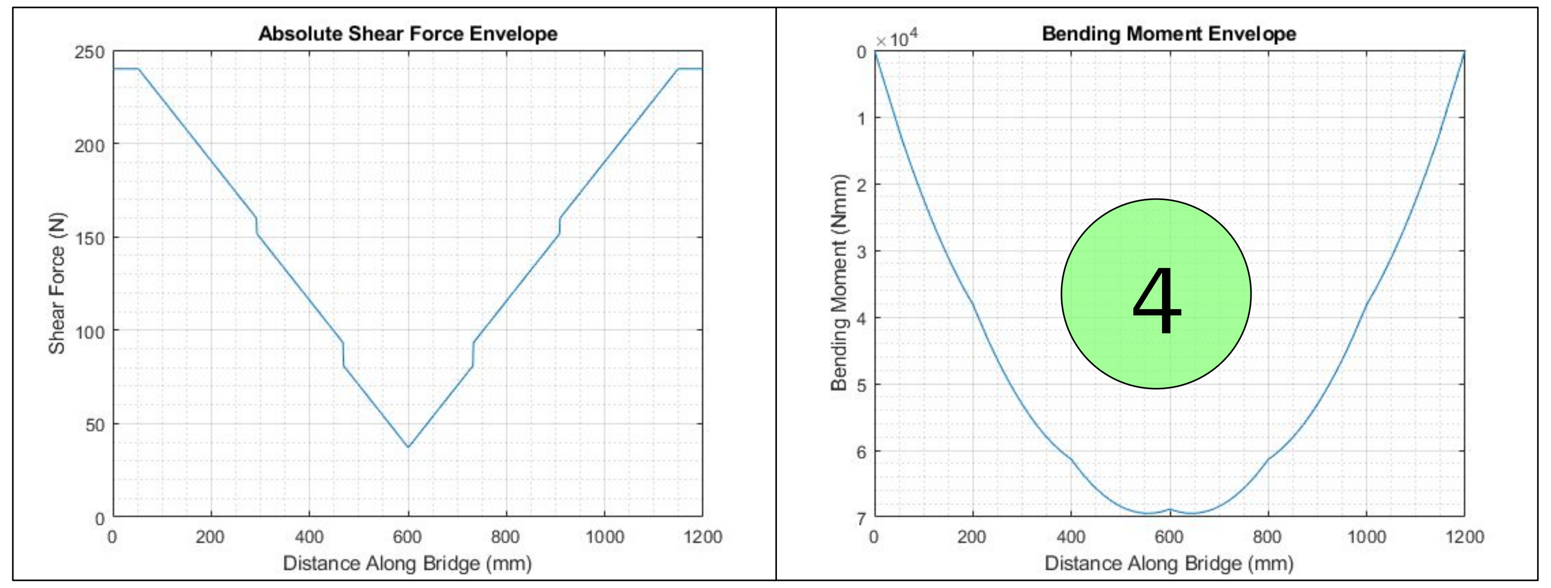
The MATLAB script is able to output FOS values for all possible ways that the bridge could fail (assuming ideal conditions).

The script was crucial for us to play around with parameters and try to maximize the minimum FOS value.

I used Git to track versions of our MATLAB code and made it open source.

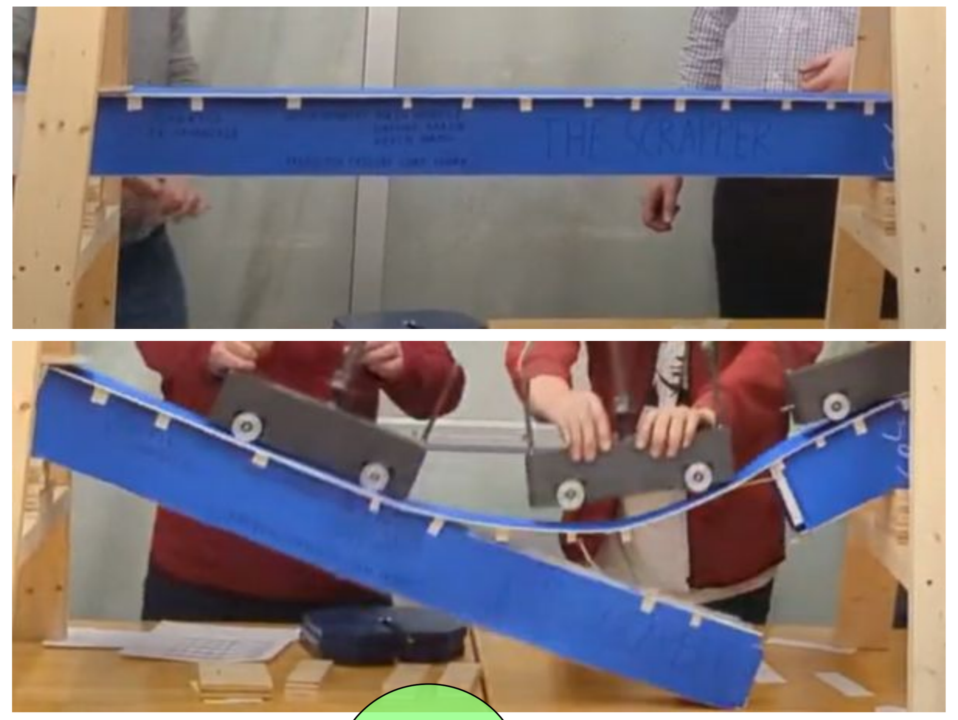


3



4

Graphs generated with MATLAB code for the maximum values of shear force and bending moment for any given train location. These graphs are useful when comparing against FOSs because we are only concerned about the maximum possible shear force and bending at any moment.



8

Unfortunately, our bridge did not pass the initial loading. As an engineer, it is always important to consider why something happens and learn from them. After (painfully) rewatching the fail a couple of times, I made several predictions:

- The way we cut and folded the matboard made the bridge fail by peeling, as seen in the thin slices of matboard
- The matboard bridge failed by shear in the splice connection. In the moment after failing, the bridge was completely straight, meaning it did not buckle.
- Despite theory, the glue joint was far too thin to have it covered entirely with glue so the actual FOS was lower.
- Our glue tab at the splice covered far too little surface area to account for vertical shear stresses