**2019 IA Structure Design Course**

**Final Report**

**Louis Zeng (lz406)**

**Lab Group 94**

* Summary

For the structural design project, the objection is to design, build and test a lightweight truss bridge to carry a working load of 3500N (failure load of 7000N) over a span of 840mm with certain height restrictions. Cost minimisation is also among the goals, 3 different initial ideas are first compared as per graphs below. The idea best suit for the design objections was selected & constructed based on our loading calculations and drawings. However, unplanned imperfections were encountered during the construction process and deviations from design affected structure symmetry and specific loadings to a large extent.

As a result, our tested bridge lost structural integrity at small load (around 1/7 theoretically load) due to failure at one bracing in the z-axis (a joint which did not supposed to carrying load), detailed analysis and introspection of the program are elaborated below.

A picture containing wall

Description automatically generated

* Alternative design concepts

We have considered a few designs during the sessions leading up to the actual construction.

1. Design A

Consists of a series of equilateral triangles

Advantage: well proofed design, similar to real life truss bridges, easy to manufacture, beams doesn’t need to be cut into special angles. Beams can be potentially fabricated “beefy” without restrictions on space.

Disadvantage: common design, litter indigenous design input, large amount of beam used, negative effect on cost-loading ratio.

A picture containing text

Description automatically generated

1. Design B

Consists of a similar series of equilateral triangles

Advantage: Easy to manufacture from bottom up, average less beams need to be riveted or bolted at the joints. Less potential error in manufacturing.

Disadvantage: Beam BF carrying tension in comparison with 3 beam at joint F carrying tension in design A, might cause unexpected failure on HD.

A close up of text on a white surface

Description automatically generated

1. Design C (Final adoption)

Consists of a series of triangles as shown in the graph

At last, we build two of these structures drawn and connect them together with extra horizonal members and bracing.

Disadvantage: Low tolerance in manufacturing accuracy, minor error could potentially jeopardise structural stability.

Advantage: aesthetically pleasing, indigenous design, beams can be fabricated generally slim to reduce cost.

After general balancing between aesthetic, practicality in manicuring, structure rigidity. Plan C was adopted. Though it would be more tedious to build. We are able to use thinner steel bars for any given load. This provides a good trade-off between the weight of the Bridge and its ability to bear load, and the shear pleasing outlook is believed to make it stand out.

* Deviations in manufacturing process

Deviations from original drawings/calculations would certainly be made due to lack of craftmanship and limitation of the tools be used. The accumulation of deviations would have cascading effect on the overall loading and therefore result in further discrepancies between actual stricture performance and ideal calculations.

Possible causes for deviations (in decreasing significance order):

1. Beam cutting angle: any angles other than 90 degree will require the beam to be cut in the assembly process, the angle trusses actually cut would significantly deviate from the initial design, try and error is not applicable due to only one cut can be made to each beam. In our example the core part of the frames isn’t made with exact same geometry which eventually results in the asymmetry of the overall bridge, one side will experience higher loading as consequence, such deviation directly creates structure weakness.
2. Inaccuracy in drilling process: While we can locate the design location for each drilling to decent accuracy, and making marks with the hammer, it is not possible for us to ensure that the mid-point would be exactly as such as it is almost inevitable for the drill to slip away from the original marked mid-point and deviate in randam direction of the plane perpendicular to the drill, especially before the drill goes into the material. Even slight deviation sometimes caused the screw to be unable to fit. And repeated drilling follows on will further weakening the beam strength.
3. Difficulties while drilling 9.5mm×9.5 mm beams (Inadequate space): smallest drill available to use has diameter of 4mm, the actually accessible length of the beam is around 6mm, which results in very little tolerance in drilling accuracy, and it’s reasonable to assume the structure rigidity is compromised in certain degree.
4. Length of Member might vary a little from design. (might cause minor deviation, accuracy in measuring and machine cutting is generally satisfactory.)

* A tripod in a room

  Description automatically generatedA tripod in a room

  Description automatically generated**Test results and observations**

Our design, in theoretical, is supposed to withstand more than double the working load of 3.5kN. We have engineered it with safety factor about 25% more than 7kN load in case of redundancy, thus resulting in its overall high cost.

However, our structure design was only able to withstand 1.35KN of Load. This is due to the fact that its weakness section at the bolted bracing beam and the unaccounted shear force experienced by the bottom beam. Inadequate drilling space eventually results in the integrity compromise, and directly leading to the eventual failure.

While we have had a few diagonal braces at the top, the bottom was not braced with strong enough beams, and this caused the ends to be weak in the axis connecting the two plane trusses. This caused the buckling of the last section of our bridge very early into the loading process as the section was merely relying on the bending moment of the gusset plate, which, not surprisingly, was small.

* **Conclusions.**

One of the major takeaways is that zero loading force members are not really zero force in the real world. This could be either due to manufacturing imperfections as mentioned previously, or the asymmetric loading. Regardless, it is important to have enough constraints in each axis as the bridge would fail at the weakest section. Constraints will contain/prevent any potential movement.

The other main takeaway is that we should almost always expect and account for variances in the actual manufacturing process and the limitations on the building methods as opposed to the ideal situation as drawn.