

**STEEL BRIDGE
PROJECT ID: CEEN_013**

by

**Steel Bridge
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A Capstone Project Final Report

Submitted to

**Dr. Hotchkiss
Brigham Young University**

**Department of Civil and Construction Engineering
Brigham Young University**

April 8, 2024

Executive Summary

PROJECT TITLE: STEEL BRIDGE
PROJECT ID: CEEEn_CPST_013
TEAM NAME: Steel Bridge

Our team successfully designed and fabricated a bridge that spans 20 feet and complies with the specifications laid out in AISC 2024 Steel Bridge Rules. Using programs such as Risa, AutoCAD, and Solid Works we optimized our bridge to be both lightweight and strong with a predicted deflection of only 0.4 inches under the load combinations as described in the AISC rules. We also designed it to have an innovative rotating connection that allowed us to assemble the bridge with only three people, none of which would have to be in the river.

Once the bridge was designed, we began fabrication in the Structures and Prototyping Labs. This process involved cutting and welding steel tubes and plates to create bays, braces, and trusses which were necessary for building the bridge. After all the members were welded, we began assembling the bridge. While doing this we came across various problems that stopped us from being able to build the bridge as we had designed. One of these problems was a cross bracing tab that got in the way as we tried to rotate the members about our innovative connection. This taught us that during design it is especially important to make sure the design is buildable. It also taught us that we should expect issues to arise and be able to plan for them. Another thing that we learned was that despite meticulous modeling, when loading the bridge, we discovered that the measured deflection was almost twice that of what the model predicted. This taught us that models idealize situations, and that practical testing is important.

At the ISWS competition, we built our bridge in 19 minutes and 20 seconds with only three people. When loading our bridge, the deflection at the midpoint was 0.76 inches. These results helped us to achieve second place at the regional competition and secured us a trip to the national competition in June.

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Introduction

The Steel Bridge Capstone project and team is based on the competition put on by ASCE and AISC. Because the project is tied to the competition, the scope is limited by the competition rules and schedule. The regional level competition was on April 11-13th, so everything needed to be completed for the class work and the competition by then. At the competition, the finalized bridge was graded on several criteria including the weight, strength, time it took to build, and number of people to build. To ensure that the project fits the requirements of the competition, the 58-page rule book was read many times. When approaching this project, the main assumptions that were made included the capabilities of the team members and the club members we assumed would still attend to help with the building and construction of the bridge. As for the designing and creation of the bridge, there were some obstacles with trying to figure out how to build it within the designated build zone without “stepping into the river”. To solve this, a unique connection was designed that allowed for building vertically instead of the usual horizontal style.

Schedule

The schedule for this project was tight. In September, the rules for the competition were released which included our site plan and bridge specifications. After careful consideration and detailed analysis, we decided on an undertruss model. By the end of October, we had our final bridge design. In November and December, we designed our connections and drew up CAD Drawings of our bridge. We also ordered steel at this time. In January, we began to cut our steel. In February we finished cutting steel and began welding. Welding took longer than anticipated. We completed our bridge on March 30th. On April 2nd we held our first build practice. We have held daily build practices since April 2nd. April 11th was the Aesthetics portion of our regional competition. April 12th was the building and loading portion of our competition. Following Regionals, we continued build practice until our National Competition on May 31st-June 1st.

Table 1 Schedule

9/26/23 - 10/11/23	2D optimization
10/17/23 - 10/25/23	3D optimization
10/31/23 - 11/8/23	Connections
11/14/23 - 12/13/23	CAD Drawings
1/9/24 - 2/21/24	Cut Steel
2/27/24 - 3/27/24	Weld
4/2/24 - 4/12/24	Build Practice
4/11/24 - 4/13/24	Regionals
4/16/24 - 5/31/24	Build Practice
5/31/24 - 6/1/24	Nationals

Assumptions & Limitations

Various assumptions were made throughout the project. First, we based most of our goals on the assumption that we had an experienced team who was committed to producing a quality product. Rebekah brought three years of experience in steel bridge (with one year as co-captain), Rory brought two years of experience, Jenna brought one year of experience, and Brandon brought an excellent basis in structures. This allowed us to assess our previous years' performances when developing our current design. It permitted us to come up with a bold new hinged design that would allow us to build with three builders. We assumed that the self-supporting columns that we prototyped would provide enough stability to stack bays vertically and make this configuration possible. The Risa analysis modeled roughly a 0.4" of deflection which we took to be reliable. We assumed each of us could meet two times a week for a total of three hours per capstone member. We also counted on receiving supplementary support from other club members who were not part of the capstone team, especially at the welding stage. These assumptions guided our project with the end goal of becoming more competitive at nationals.

While these assumptions permitted us to achieve success, they were not without limitations. While we fielded an experienced team who knew and respected one another, we weren't all experienced in the same components of the project. This inevitably led to delays at certain stages of the design/fabrication processes. Likewise, our schedule was idealistic in the sense that we assumed we would all be present at every meeting. This was clearly not realistic as each of us led different schedules and had to attend to other duties. This would ultimately lead to further lapses in our workflow. Given that the rest of our help was solely given on a volunteer basis, we often lacked the personnel necessary to perform iterative work and receive training for future generations of steel bridge. We were especially hurt at the welding stage. Our workflow was severely limited due to a lack of competent welders which we had not counted on. This led to a severe delay in our build practice schedule. Nevertheless, the teams' commitment allowed us to overcome each of these limitations and achieve the success that we had envisioned.

Design, Analysis & Results

The rules for the 2024 competition were released in the first week of September and gave us all the requirements for the bridge. Figure 1 (Steel Bridge Rules 2024) shows the competition site plan. It shows that the river is 8ft wide this year and the construction zones are unequal in length. This led us to the decision to design the bridge for three builders.

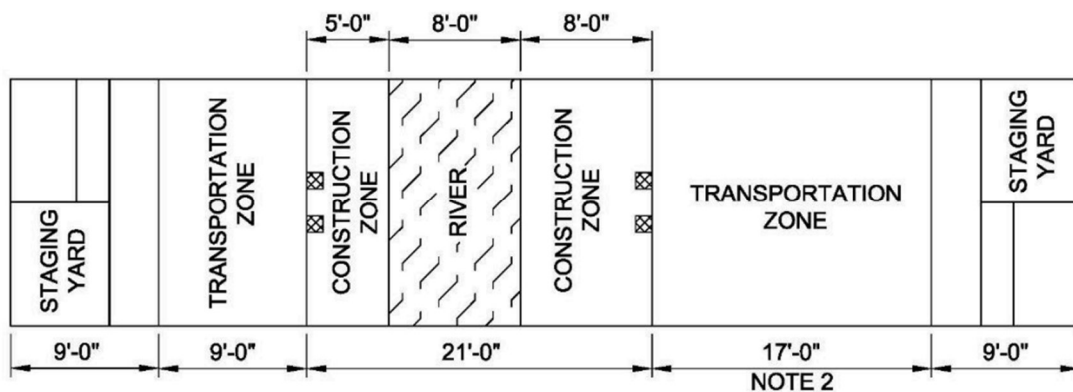


Figure 1 Competition Site Plan

Figure 2 (Steel Bridge Rules 2024) shows a more detailed site plan. It shows the footing locations and the location of the docks in the river. The docks are where barge builders will start. Barge builders cost 230,000 \$/person-minute and non-barge builders cost 115,000 \$/person-minute so we decided to forgo using barge builders and find a different way across the river. This was a unique build plan for our region. We were the only team that did not use barge builders.

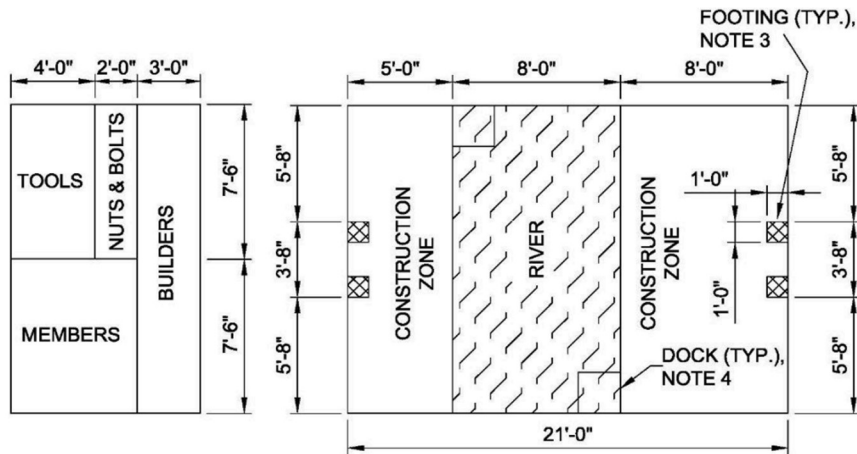


Figure 2 Detailed Construction Zone and Staging Yard

Figure 3 (Steel Bridge Rules 2024) shows the section view of the bridge envelope and gives the height and requirements for the bridge. It also shows that the bridge cannot be lower than 5" above the ground outside of the footings.

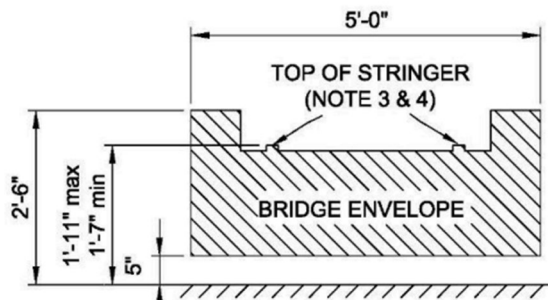


Figure 3 Bridge Envelope Section View

Figure 4 (Steel Bridge Rules 2024) shows the elevation view of the bridge envelope. It shows the length requirement of the bridge and the height limitations. As shown by Figure 3 and Figure 4, the bridge stringers must be between 1'-7" and 1'-11" from the ground. But the bridge may extend up to 2'-6" on the sides. While we did not ultimately take advantage of this, it was considered but determined not to be advantageous for us in the long run.

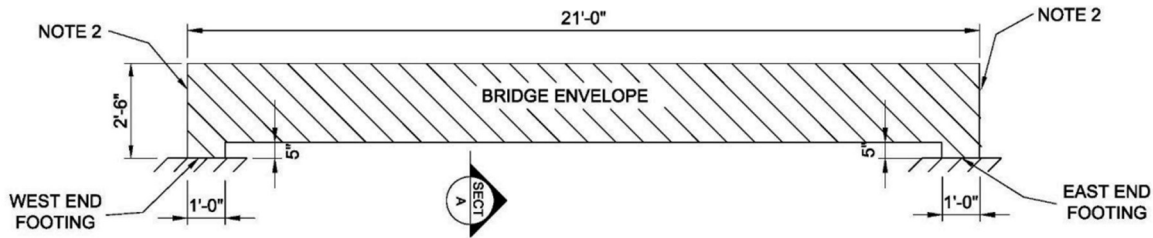


Figure 4 Bridge Envelope Elevation View

Figure 5 (Steel Bridge Rules 2024) shows the stringer template. After the bridge is constructed at competition, the judges ran this template over the bridge to ensure the width of the bridge is correct and consistent throughout the length of the bridge. It also ensured that nothing impedes the stringer template. This template also tells us the width of the stringers. With all these figures, we knew that the bridge must be 1'-11" tall, 20' long, 2'-9" wide, and 5" off the the ground outside of the footings.

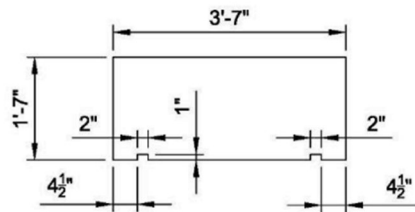


Figure 5 Stringer Template

Figure 6 (Steel Bridge Rules 2024) shows the loads the bridge is required to support. However, the location of the loads is variable as shown in Table 2. There are six different load combinations that could be used, and no one will know which load combination will be used until the day of competition. To determine the load combination, the head judge will roll a six-sided die with all the bridge captains present to witness. At our regional competition, load case 6 was rolled. The load combination is rolled at each competition and is separate from any other competition.

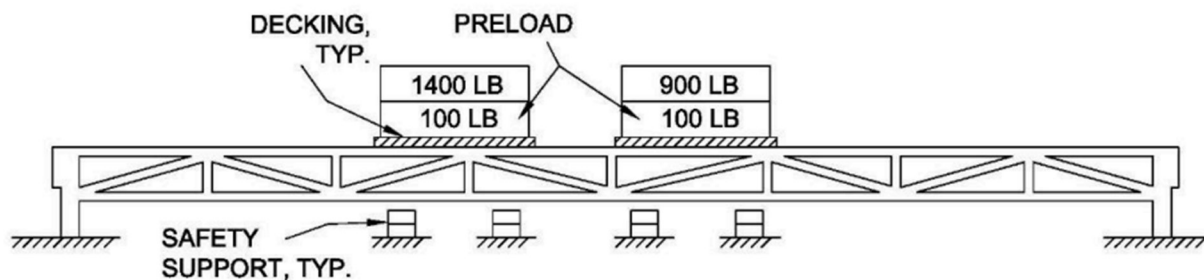


Figure 6 Vertical Load Test

Table 2 (Steel Bridge Rules 2024) also shows the location of the lateral load test. This is column S. Column L1 refers to the 1500 lb. load and column L2 refers to the 1000 lb. load. They show the location of their respective vertical loads. Column N refers to the corresponding dice roll result.

Table 2 Determination of Load Combination

N	L1	L2	S
1	4'-6"	9'-0"	7'-6"
2	6'-0"	12'-0"	9'-0"
3	7'-0"	13'-0"	9'-0"
4	7'-6"	11'-6"	9'-0"
5	8'-6"	12'-6"	10'-6"
6	10'-0"	14'-0"	10'-6"

Figure 7 (Steel Bridge Rules 2024) shows the set up for the lateral load test. The lateral load test measures the sway of the bridge which cannot exceed $\frac{3}{4}$ ". A bridge with a sway measured above $\frac{3}{4}$ " at any point during the lateral or vertical load test cannot proceed and must be unloaded. Ensuring the bridge will not sway more than $\frac{3}{4}$ " was imperative for success. Our bridge passed the sway test easily.

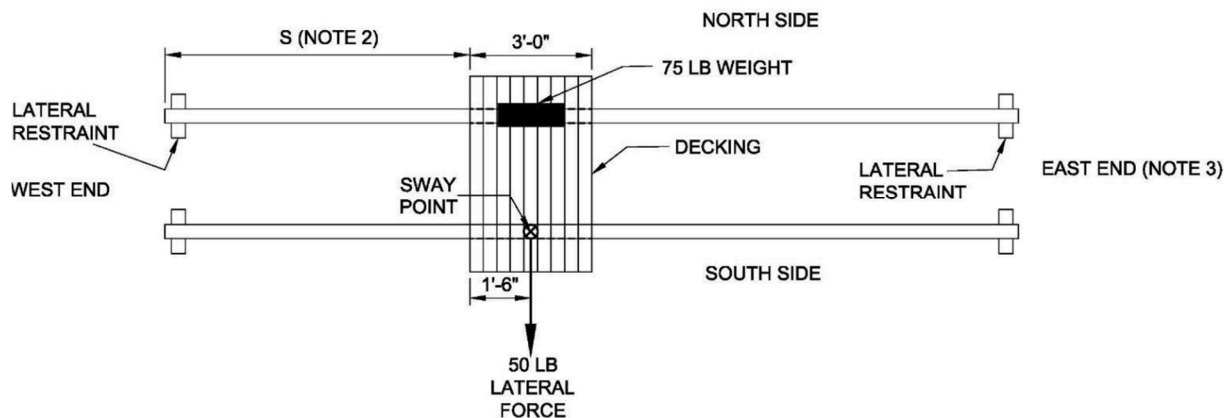


Figure 7 Lateral Load Test

After carefully analyzing the site plan, bridge envelope, stringer template, and loads, we started with preliminary designs. Due to the bridge envelope, a through truss bridge was not viable because we could not build higher than 2'-6". Figure 8 shows a preliminary model for a double deep truss design, but the loads were too high and too close together in some of the load combinations to make this a viable option.

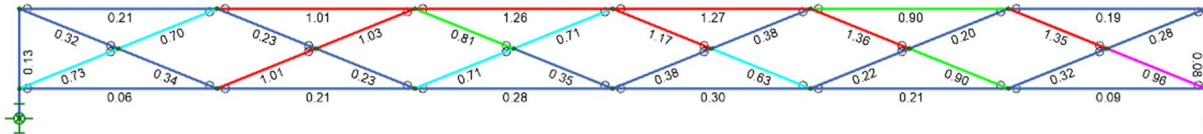


Figure 8 Double Deep Truss Bridge Option

Figure 9 shows a preliminary model for a full deep truss bridge, but it too had the same issues. The loads were too high and too close together in some of the load combinations to make it a viable option.

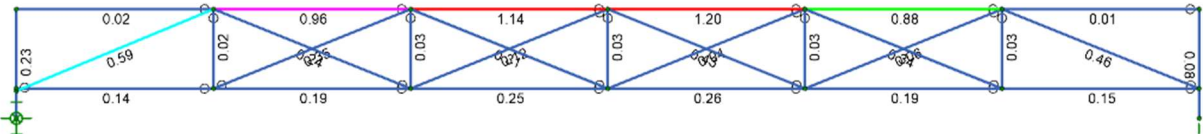


Figure 9 Full Deep Truss Bridge Option

Figure 10 shows a shallow truss preliminary design. We knew that this model would not be viable, but we also knew that it would be highly likely that we would see models like this at our regional competition based on our past experiences. Therefore, we decided it would be valuable to make this model so we could see the projected performance. Additionally, it was used as a starting point for the undertruss model, so it took no additional time or resources.



Figure 10 Shallow Truss Bridge Option

Figure 11 shows the preliminary design of an undertruss model. It performed the best out of all our preliminary models, so we moved forward with the undertruss design. The next

step was to begin optimizing the bridge. This included the size of members, number of members, gauge of tubes, and geometry of the bridge.

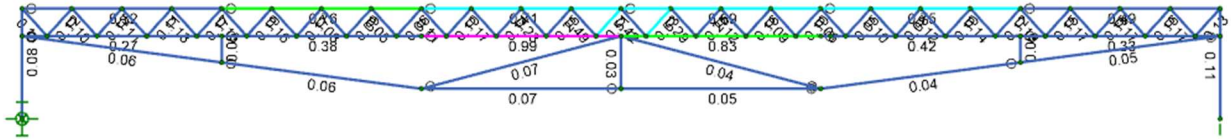


Figure 11 Shallow Truss with Undertruss Bridge Option

Appendix C shows the spreadsheet used for iterations we did in the process of optimization. We created this spreadsheet with the scoring formula as stated in the rules. Each model we built was added to this spreadsheet and if the total cost was less than the previous iteration, the change stayed. Each iteration changed only one variable so we could insure we were optimizing the bridge effectively. We also used this spreadsheet to calculate our own projected scores for the cost estimate, our own actual score, and other teams' competition scores.

Figure 12 shows the final bridge design. The undertruss is 6" from the ground, the height of the stringers is 1'-10 1/2", the width of the bridge is 32" from center to center of the stringers.

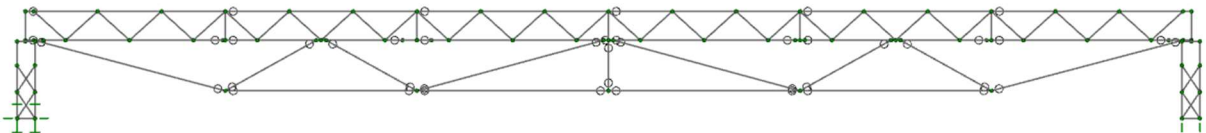


Figure 12 Bridge Final Risa Design

After determining the final design of the bridge, we created CAD drawings. These are shown in Figure 13, Figure 14, and Figure 15. The CAD drawings give us the actual lengths

to be cut as well as any angles that need to be cut. Figure 13 shows the plan view of the bridge and gives us the locations and length of the cross bracing.

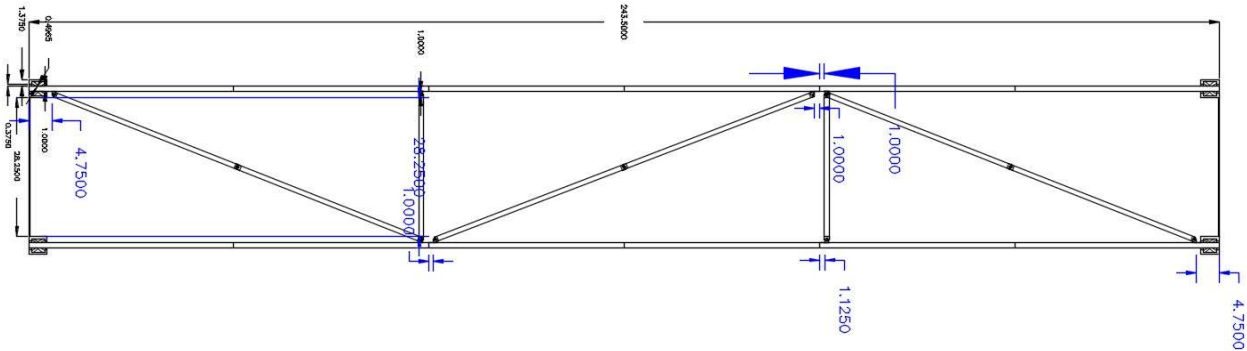


Figure 13 CAD Drawings - Plan View

Figure 14 shows the elevation view of the bridge. It has the most information we use in fabrication. It gives the lengths of the undertruss members, stringers, webbing, columns and any associated angles.

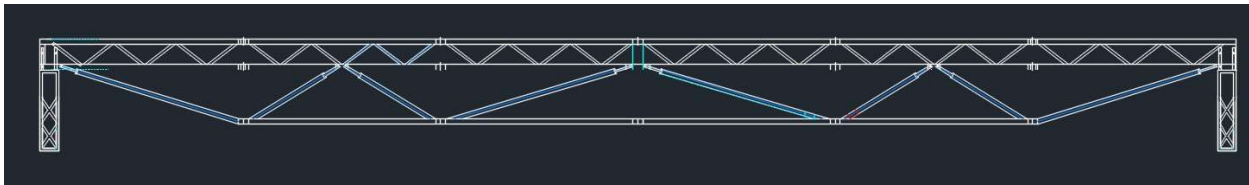
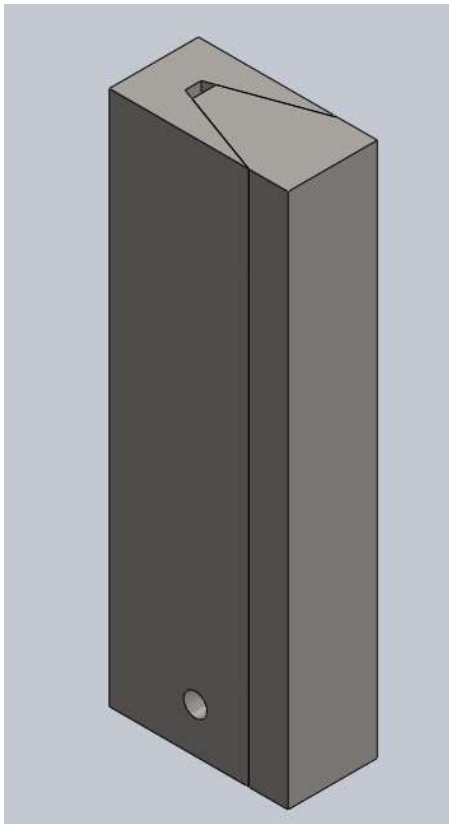


Figure 14 CAD Drawings - Elevation View

Figure 15 shows a section view of the bridge. This gives us more information about the columns, the width of the bridge, and the location and size of the name plate.



Figure 15 CAD Drawings - Section View



separating as load is applied.

Figure 16 Typical Connection

Figure 16 shows the connections between all bays except bays 2 and 3. This was designed to connect our bays with only one bolt. The rules state “Each connection shall contain at least one and at most two faying surfaces associated with each member being connected. Faying surfaces are the only locations where members are in contact with each other ... Every faying surface shall be penetrated by at least one loose bolt secured by a loose nut such that the members cannot be separated without first unscrewing and removing the loose bolt(s) that connects them,” (Steel Bridge Rules 2024). We designed the connections to extend through the whole bay so we could consider it one continuous faying surface and only use one bolt at the bottom of the bay. The wedge shape prevents the top of the connection from moving inward as load is applied. The bolt at the bottom satisfies the faying surface requirements and prevents the bottom from

Figure 17 shows the connection between bays 2 and 3. As noted earlier in Figure 1 and Figure 2, the river is 8ft wide. It was not reasonable to assume we could just reach into the river to build. Nor was it reasonable to use barge builders due to the heavy costs associated with barge builders. We came up with a way to unfold the bridge over the river that allows the connection to be reachable from the other side. We also decided to build with only three builders so it was important that our columns were self-supporting and could hold the weight of two bays without additional support. The plan was to build two bays straight up on both sides. The long side would then attach bay 3 to bay 2 as shown in Figure 17 on the left. Then, bays 3 and 4 are rotated around a pivot as shown in the middle of Figure 17. Finally, the connection can be slid together and secured as bays 4 and 5 are connected by the single builder on the short side. This was a build plan unique to our team. At the competition, we were the only team to forego barge builders. We had a fully unique build plan due to these connections. This significantly decreased our Construction Economy Score and directly resulted in our advancing to nationals. We had a higher deflection, slower build time, and a heavier bridge but because of our lack of barges and this unique connection that allowed us to build with three people, we were able to take second overall.

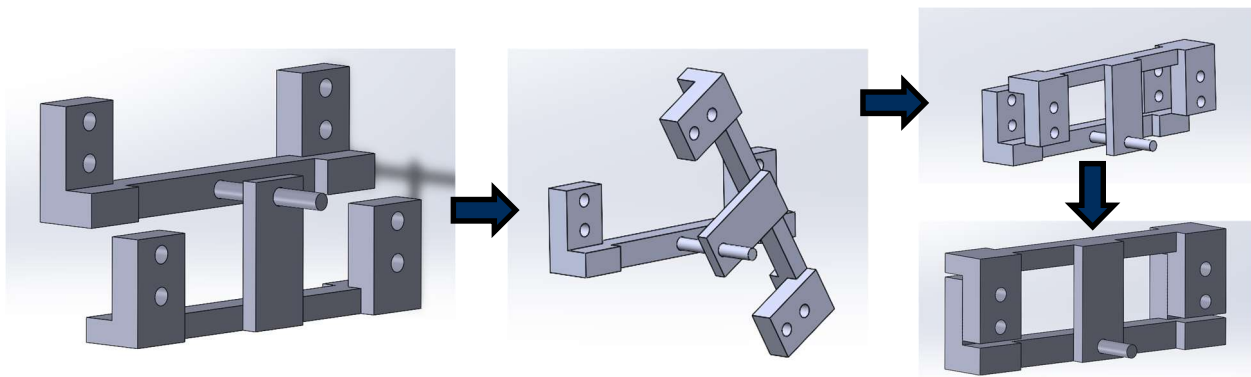


Figure 17 Bay 2 to Bay 3 Connection

Figures 18 and 19 show the unfolding action as it played out at our regional competition. We ended up with a build time of 19 minutes 20 seconds with 4 bolt drops. This was not our best build time. With more practice, we could become more efficient and significantly decrease our build time.

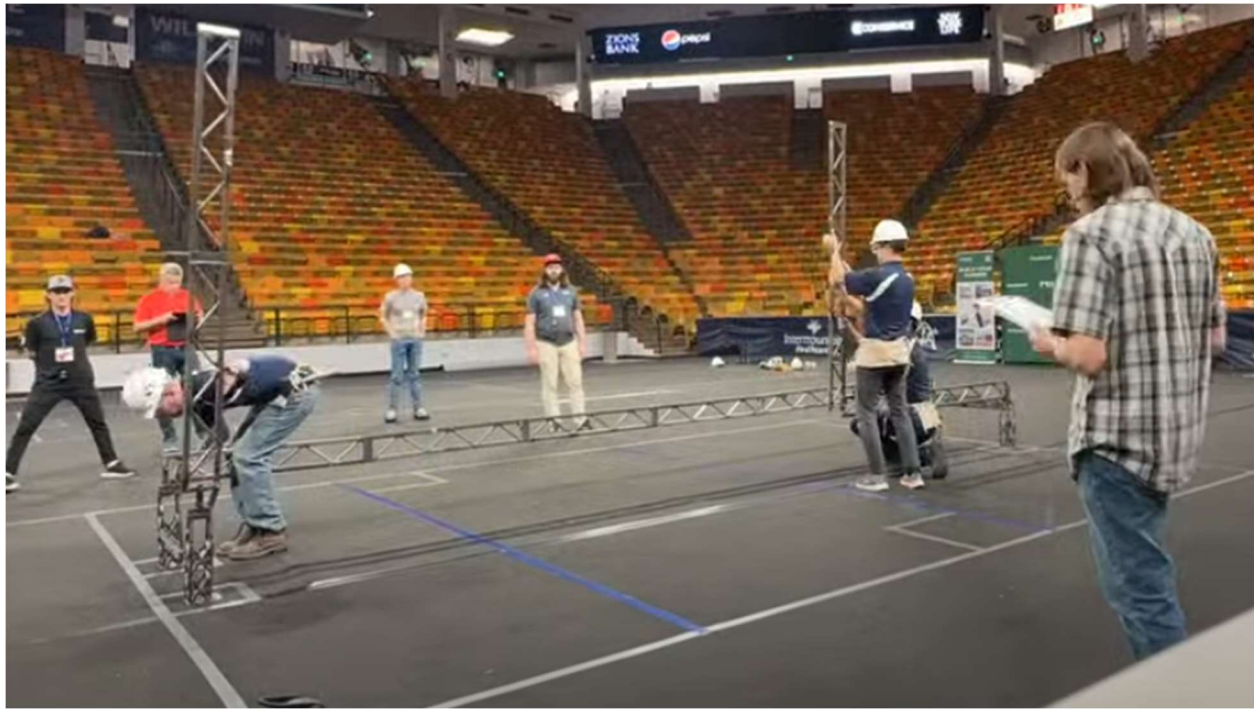


Figure 18 Bays Before Unfolding



Figure 19 Bays After Unfolding

Related Issues

Although this project is not being implemented in real life, we learned many things pertaining to seeing a project built and knowing how our design impacts the application portion. This taught us a little more about the relationship between the engineering portion and construction portion. Part of the scope and point to this competition is to design and build a 1:10 scale model of a bridge for Lincoln Parish Park in Louisiana. To make it as real as possible we have a location selected and are supposed to carry on as if we are bidding for this project and want to be selected for it.

Within the project description is stated that the aesthetics and beauty of the park is supposed to be taken into consideration and that the aesthetics of the bridge must match and add to it instead of taking from it. This can relate to both social and cultural factors. The current users and attendees of the park do not want a functional piece of the park to take away from the natural beauty. Therefore, in designing the bridge a smaller less eye-catching design was selected. Although the bridge is going to be big and will change the scenery of the park, a less grandiose appearance will limit the demand and space it occupies. The color of the bridge was also taken into account. Not many people think that a “big pile of steel” is pretty, but steel is the required material, so something had to be done to appease the consumers. The decision was made to pick a subtle color that resembled nature that would make the steel blend in with its surroundings.

In addition to aesthetics, the bridge has to both look and feel sturdy for the consumers to want to use it. This takes safety to the next level. A bridge can be safe and still sway or bend, but someone who does not know the details of the physics behind the individual design may doubt the structural soundness of it because it moves. Therefore, in order for the bridge to be safe for people to use and for them to feel safe and secure, the bridge is designed with specific bending, swaying, and deflection maximums.

Another part of designing for safety included making sure service vehicles can drive over the bridge. Because the river intersects the park and splits it into two, having a way for the vehicles to cross the river improves mobility and the time to which they can get through the park. In the designing phase of the bridge, loads were added within the models to ensure the bridge could handle point loads along the length of itself. Once the bridge was constructed, load tests were run ensuring that the model displayed the correct

behavior of the bridge under the actual loads. The load tests proved that the designed bridge could hold up the weight of the expected vehicles and other heavy items that may at some point be on the bridge.

Although there was no official limit to the price tag of the design, materials, and construction costs, many decisions throughout the different processes were made to lessen the total cost. The competition is supposed to simulate a real-life construction project including a bidding portion meaning that the total cost plays a role in the overall ranking of our team to others. In order to rank well and please our potential client, intentional decisions like things like the gage of the steel and the overall weight of the bridge. In places where there is less force that the members need to resist, thinner pieces were used. When selecting how many builders were needed, efficiency and the optimum builder to time ratio were considered. This ensured the cost and time would both be within appropriate ranges for the client to be satisfied and choose our bid.

Lessons Learned

Our team was confronted with various challenges throughout the course of the project. A list of obstacles that we faced is as follows:

- Differing schedules between capstone members
- Lack of volunteer hours
- Lack of trained individuals to assume team leadership next year
- Lack of communication/uniformity between design phases (RISA models, CAD models, CNC jigs)
- Lack of necessary equipment for completing fabrication tasks
- Lack of precision when cutting steel
- Lack of precision when welding
- Limited build practice time

As engineers oft must do, we had to adjust when things didn't go according to plan. We never completely resolved the challenge of differing schedules or lack of volunteer hours. However, we relied on remote communication to ensure most of the tasks were completed by their respective deadlines. To address the lack of volunteer hours/steel bridge succession, members of the team actively recruited juniors in the program who had some prior experience with steel bridge. This gives us some clarity as to who may assume leadership of the team; nevertheless, we should have been actively working on this earlier. Much of the success in steel bridge comes from succession and team members who are passionate about what they do. The lack of uniformity between tasks hurt us most at the CAD/fabrication stages. We ultimately had to make additional time to correct CAD files, recut steel, and re-weld. These delays seriously hurt us at the build practice stage, leaving us with only two weeks of practice. Again, we had to make extra time before the regional competition to perform build practices. It shows the grit and determination of our team that we were willing to see things through despite our setbacks; nevertheless, there is much to learn and correct for future generations.

Conclusions

One of the things we learned was that no matter how much we thought we had thought everything through, when it came to assembling the bridge and running build practices, we would discover issues that we had not expected. Examples of this include we had made detailed plans about the tab locations for the crossing bracing, but it wasn't till we were trying to assemble it that we noticed when rotating the bays they now get caught on each other because of the tabs. This meant we had to cut them off and reweld them which wasn't a big deal, but having built in time for adjustments would have helped us stay on track. Because we had to make changes to the tabs and didn't have proper time allocated to making these changes, we forgot to recheck that our new welded tabs fit within the dimensional restrictions. We did not discover this oversight till we were at our competition and the judges docked us points for not meeting the designated criteria. This concept of planning for mistakes or failures applies to all aspects of life, so it was a good reminder to continue to do our best to limit these oversights during the design process, but to expect issues and plan for them. Had we planned for them we may have had proper time to double check everything before the competition. Another thing we learned is that the models always seemed to have better results than our actual built bridge. The models create idealistic scenarios which we didn't plan around. Again, this didn't impact the bridge's ability to hold the load to which it was designed for, but the slightly worse values mean that our bridge performed at a lower standard than what we thought we were building to. This is seen in places like the total deflection. For the most conservative load case, our model said we would get a 0.4in and 0.42in deflection, but we measured values of 0.82in and 0.76in when loading the bridge. At our competition we got an aggregate deflection of 1.29in even though our model expected less than .5in. This drastic difference in values resulted in us not placing as high or being as competitive as we thought we might be. The best deflection at the competition was USU with a 1.02in deflection, and had our model represented real life we would have been able to beat this number as we were aiming for a deflection that was less than an inch. The biggest takeaway was again being flexible and expecting to make changes along the way to the design, that our project is fluid and constantly needed us to reevaluate and double check our decisions. Overall, we still did well as we placed second at Regionals and are advancing to Nationals. We were only able to accomplish this by being willing to make

changes and we will continue to improve our bridge until Nationals to ensure we accomplish our desired goals and reach our highest potential.

Recommendations

For future teams participating in the steel bridge competition, it is crucial to address the issues of confusion surrounding project plans and dimensions that have arisen during this year's build. To mitigate such problems, we strongly recommend implementing a streamlined communication and documentation system. One effective approach could involve generating a final set of project plans and dimensions and printing them on large, easily accessible sheets. These printed sheets would serve as a reference point for all team members, ensuring that everyone is consistently working from the most up-to-date information.

Moreover, establishing clear protocols for updating and disseminating information is essential. Regular team meetings should be held to review any changes or updates to the project plans, and it's crucial to designate a point person responsible for managing and distributing these updates promptly. Additionally, fostering a culture of open communication and accountability within the team will help minimize misunderstandings and errors.

By implementing these recommendations, future teams can streamline their workflow, reduce the likelihood of errors stemming from confusion, and ultimately enhance their performance in the steel bridge competition.

Appendix A

Brandon Goodrich

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EDUCATION

Brigham Young University Dec 2024
Bachelor of Civil Engineering: Fulton College of Engineering, Emphasis in Structures Provo, UT

- GPA 3.93
- Structural Analysis, Soil Mechanics, Engineering Drafting

RELEVANT EXPERIENCE

CKR Engineers May 2022-Present
Engineer in Training Orem, UT

- Perform structural calculations
- Create details and redline drawings
- Model structures and forces to assist with calculations
- Create Excel spreadsheets to streamline repetitive tasks

Prices Doors Jun 2021-Aug 2021
Garage Door Installer Salt Lake, UT

- Installed commercial and residential doors working in a small team
- Managed time effectively to install quickly while maintaining quality work

BARCO Jun 2020-Aug 2020
Construction Worker Lehi, UT

- Erected metal buildings including framing, sheeting, roofing, and finish work
- Set forms, tied rebar prior to concrete pouring
- Operated a needle concrete vibrator to ensure the proper setting of concrete
- Gained valuable insight by working one-on-one with a site foreman

VOLUNTEER EXPERIENCE

The Church of Jesus Christ of Latter-day Saints Aug 2018-Apr 2020
Volunteer Representative Adelaide, Australia

- Provided leadership, development, and training for 130 volunteer representatives
- Scheduled and coordinated the return of eighty volunteers to America, eight to New Zealand, four to Tonga, and several to other countries during the early stages of the Covid Pandemic

RELEVANT SKILLS/ACHIEVEMENTS

-
- Advanced in MS Excel
 - Certified in SolidWorks
 - Knowledge of CAD software, PDF editing, and Mathcad

Jenna Dayley

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EXPERIENCE

- Civil Engineering Technician | Epic Engineering** August 2022 – Current
- Civil Department Intern
 - Structural Engineering Intern
 - Quality Assurance
- Civil Eng Research Assistant | Brigham Young University** August 2022 – Current
- Structural Department

EDUCATION

- B.S. Civil Engineering | Brigham Young University** Expected graduation: April 2025
- Minor: International Development
 - Coursework:
 - CAD: Revit and Civil 3D
 - Computational Methods: Learned to code in VBA and HTML
 - Structural Analysis: Learned to code in python
 - Weidman Center Scholarship
 - GPA: 3.7

EXTRACURRICULAR

- Student Steel Bridge | AISC Club** September 2022 – Current
- **Analysis**: Studying and analyzed different types of bridges to discover which one would perform best
 - **Construction**: Learned how to cut and weld steel as well as assemble a bridge
- Earthquake Engineering Research Institute** September 2022 – Current
- **Social Media Officer**: Created social media platform that drew in new club members
 - **Historian**: Compiled the year's work
- Concrete Canoe | ASCE Club** September 2022 – April 2023
- **Team member**: Assisted in the design and construction phases

PROJECTS

- Global Engineering Outreach** August 2023 – June 2024
- **Research**: Finding local products, building prototypes and testing them out
 - **Coordination**: Working with several people in Bolivia and Peru to understand their needs and to make a product that meets their needs

Rory Albrecht

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Email-Rorvsa98@gmail.com

EDUCATION

BS, Civil Engineering, Brigham Young University, Provo, UT, April 2024

Minor in Spanish

- GPA 3.83
- Member: Tau Beta Pi Honor Society – Utah Beta Chapter (2023 inductee)
- Member: Phi Eta Sigma Honor Society (2018-current)
- Recipient of Brigham Young University academic scholarship (2020-current)
- Member: ASCE, BYU Steel Bridge Club (2021-current), co-captain (current)
- Relevant coursework: Engineering Statics, Engineering Dynamics, Mechanics of Materials, Geomatics, Sustainable Infrastructure, Engineering Drafting with CAD Applications, Computational Methods (introduction to Microsoft Excel and VBA), Geology for Engineers, Calculus I, Calculus II, Calculus of Several Variables, Linear Algebra, Differential Equations, Structural Analysis, Introduction to Transportation Engineering, Hydraulics/Fluid Flow Theory, Elementary Soil Mechanics, Hydrology

SKILLS

- AutoCAD-Civil 3D
- Bluebeam Revu
- Microsoft Word, PowerPoint, Excel
- ACTFL certified at advanced mid in Spanish speaking and composition

WORK EXPERIENCE

Land Development Intern, Dibble Engineering, Phoenix, AZ, (May 2023-August 2023)

- Performed site visits and prepared preliminary exhibits for City of Phoenix
- Performed utility coordination with utility entities at SD, DD, and CD phases
- Performed rational method calculations to determine number of retention basins/drywells needed
- Assisted in AutoCAD-Civil 3D drafting at SD, DD, and CD phases
- Assisted in writing project narratives
- Assisted in preliminary sewer design

Water/Wastewater Intern, Dibble Engineering, Tucson, AZ, (June 2022-August 2022)

- Assisted in AutoCAD-Civil 3D drafting for sewer and potable transmission line projects
- Completed contractor submittals and RFIs
- Performed auxiliary calculations for pipe profiles and thrust block design
- Participated in site visits to assess progress and compliance
- Attended client meetings

Teaching Assistant, Brigham Young University, Provo, UT, (September 2023-current)

- Led laboratory section for group of seven students in material science
- Provided homework/lab assistance to students seeking help

SERVICE

Volunteer/Service Leader, Villahermosa, Mexico, (2018-2020)

- Trained new volunteers to help adapt to language and culture
- Managed statistics and trainings of groups of up to 10-20 personnel
- Developed advanced Spanish fluency

PERSONAL INTERESTS

- Language learning, hiking, skiing, racquetball, tennis, piano performance and composition

Rebekah Higgins

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rebekaehiggins@gmail.com

EDUCATION

Brigham Young University, Utah

May 2024

- Civil Engineering Major - Structures Emphasis
- Computer Science Minor
- GPA: 3.66

EXPERIENCE

BYU Civil Engineering Department — Research Assistant

January 2024 - PRESENT

- Develop interactive spreadsheets to interpret and model data efficiently
- Run tests using software programs

Vector Engineering — Intern

June 2022 - PRESENT

- Interpret building plans and building codes
- Use various software to perform structural analysis
- Suggest structural reinforcements to structures
- Steel Design

BYU Civil Engineering Department — Structural Analysis TA

January 2023 - December 2023

- Lead structural analysis project sessions and review sessions
- Teach students to code the method of joints and the stiffness method
- Help students understand material

BYU Steel Bridge Team — Captain

January 2021 - PRESENT

- Design and build a bridge out of steel
- Use various software to test the bridge
- Build the bridge as a team in The Intermountain Conference Steel Bridge Competition and at Nationals

BYU Special Collections — Digital Imaging Lab Technician

May 2021 - June 2022

- Complete Staff and Patron Orders in a timely manner
- Use various software and hardware
- Communicate with coworkers about order progress

BYU Acoustics — Time Reversal Research Assistant

September 2020 - August 2021

- Identify problems and create solutions
- Test, collect, and interpret data
- Communicate with other Research Assistants and Research Professor

SKILLS

Software:

AutoCad	●●●○○
Civil 3D	●●●○○
SolidWorks	●●●○○
ArcGISPro	●●●○○
Revit	●●●○○
Risa	●●●●○
Microsoft Excel	●●●●●
Microsoft Office	●●●●○
Adobe Suite	●○○○○
Mathematica	●○○○○
Capture One	●○○○○

Computer Languages:

C++	●●●●●
C	●●●●●
VBA	●●●●●
Python	●●●●○
Java	●●●●○
Matlab	●●○○○
HTML	●○○○○
RStudio	●○○○○

Soft Skills:

Communication
Critical Thinking
Customer Service
Ingenuity
Leadership
Organization
Problem Solving
Responsibility
Teamwork

Appendix B - References

Student Steel Bridge Competition Rules Committee. (2024, April 8). *AISC Student Steel Bridge Competition Rules And Clarifications*. Retrieved from AISC Student Steel Bridge Competition: <https://www.aisc.org/education/university-programs/student-steel-bridge-competition/ssbc-rules-and-clarifications/>

Appendix C – Optimization Spreadsheet

File name	Passes Unity Check?	North Weight
Shallow Truss	N(2.17)	74
Undertruss	Y (0.97)	116
Double Deep	N	
Full Deep	N	
Undertruss double triangle	Y (0.90)	123
Undertruss 5 Vertical Brace	Y(0.74)	129
Undertruss top 10 gu, bottom 12 gu	Y(0.91)	118
Three triangles but an arch	Y(0.84)	125
Three triangles but an arch 8 webs	Y(0.78)	121
Undertruss top 10 gu, bottom 12 gu, 9 webs	Y(0.77)	122
Undertruss top 10 gu, bottom 12 gu, 7 webs	Y(0.75)	120
Undertruss top 10 gu, bottom 12 gu, 6 webs	Y(0.80)	119
Undertruss top 10 gu, bottom 12 gu, 5 webs	Y(0.91)	119
6in undertruss	Y(0.77)	120
12gu all stringers	Y(0.85)	115
12gu top 16 gu bottom	Y(0.85)	105
12gu top 16 gu bottom 16 undertruss	Y(0.92)	87
12gu top 16 gu bottom 16 undertruss 12gu middle triangle	Y(0.92)	91
12gu top 16 gu bottom 12gu undertruss 16gu outer triangles	Y(0.86)	101
12gu top 16 gu bottom 12gu bottom chord undertruss 16gu triangle	Y(0.87)	97
12gu top 16 gu bottom and outside bays 12gu bottom chord undert	Y(0.87)	94
11ga top, 16 ga bottom	Y(0.85)	
Load Case 4	Y(0.869)	5
16 ga undertruss to column	Y()	

South Weight	Penalty Weight	Total Weight	Weight Cost	D1 (Left) - N(39)	D2 (Right) - N(10)
124		198	\$924,110.39	1.734	2.73
166		282	\$1,809,394.63	0.445	0.422
173		296	\$1,983,874.72	0.346	0.318
179		308	\$2,139,470.75	0.317	0.291
168		286	\$1,858,469.57	0.432	0.403
175		300	\$2,035,121.65	0.446	0.403
171		292	\$1,933,247.29	0.401	0.351
172		294	\$1,958,483.51	0.398	0.361
170		290	\$1,908,166.15	0.4	0.372
169		288	\$1,883,240.21	0.418	0.358
169		288	\$1,883,240.21	0.428	0.388
170		290	\$1,908,166.15	0.366	0.341
165		280	\$1,785,090.55	0.387	0.361
155		260	\$1,550,634.18	0.396	0.375
137		224	\$1,168,237.72	0.517	0.49
141		232	\$1,248,783.53	0.513	0.487
151		252	\$1,461,238.21	0.4	0.379
147		244	\$1,374,360.49	0.405	0.383
144		238	\$1,310,859.69	0.407	0.384
		0			
		0	\$0.00	0.363	0.305
		0	\$0.00		
270		275	\$1,725,011.96	0.8	0.7
280		280	\$1,785,090.55	0.31	0.266

Aggregate Defl	Deflection Cost	Structural Efficiency	Estimated Build Time (min)	# normal Builders
4.46	\$17,856,000.00	\$18,780,110.39	7	3
0.87	\$3,468,000.00	\$5,277,394.63	13	3
0.66	\$2,656,000.00	\$4,639,874.72	15	3
0.61	\$2,432,000.00	\$4,571,470.75	15	3
0.84	\$3,360,000.00	\$5,218,469.57	13	3
0.85	\$3,396,000.00	\$5,431,121.65	13	3
0.75	\$3,008,000.00	\$4,941,247.29	13	3
0.76	\$3,036,000.00	\$4,994,483.51	13	3
0.77	\$3,088,000.00	\$4,996,166.15	13	3
0.78	\$3,104,000.00	\$4,987,240.21	13	3
0.82	\$3,264,000.00	\$5,147,240.21	13	3
0.71	\$2,828,000.00	\$4,736,166.15	13	3
0.75	\$2,992,000.00	\$4,777,090.55	13	3
0.77	\$3,084,000.00	\$4,634,634.18	13	3
1.01	\$4,028,000.00	\$5,196,237.72	13	3
1.00	\$4,000,000.00	\$5,248,783.53	13	3
0.78	\$3,116,000.00	\$4,577,238.21	13	3
0.79	\$3,152,000.00	\$4,526,360.49	13	3
0.79	\$3,164,000.00	\$4,474,859.69	13	3
0.67	\$2,672,000.00	\$2,672,000.00	13	3
0.00	\$0.00	\$0.00		
1.50	\$6,000,000.00	\$7,725,011.96	17.5	3
0.58	\$2,304,000.00	\$4,089,090.55	13	3

# barge builders	Penalty Time	Construction Cost (\$)	Total Cost (\$)
0		\$2,415,000.00	\$21,195,110.39
0		\$4,485,000.00	\$9,762,394.63
		\$0.00	
		\$0.00	
0		\$5,175,000.00	\$9,814,874.72
0		\$5,175,000.00	\$9,746,470.75
0		\$4,485,000.00	\$9,703,469.57
		\$4,485,000.00	\$9,916,121.65
		\$4,485,000.00	\$9,426,247.29
		\$4,485,000.00	\$9,479,483.51
		\$4,485,000.00	\$9,481,166.15
		\$4,485,000.00	\$9,472,240.21
		\$4,485,000.00	\$9,632,240.21
		\$0.00	
		\$4,485,000.00	\$9,221,166.15
		\$0.00	
		\$4,485,000.00	\$9,262,090.55
		\$4,485,000.00	\$9,119,634.18
		\$4,485,000.00	\$9,681,237.72
		\$4,485,000.00	\$9,733,783.53
		\$4,485,000.00	\$9,062,238.21
		\$4,485,000.00	\$9,011,360.49
		\$4,485,000.00	\$8,959,859.69
		\$0.00	
		\$4,485,000.00	\$7,157,000.00
		\$0.00	\$0.00
	0.75	\$6,225,000.00	\$13,950,011.96
		\$4,485,000.00	\$8,574,090.55