

Steel Bridge Design

E90 Project Proposal

12/5/07

Abstract

We propose to design and construct a steel bridge to the specifications and constraints governing the 2008 ASCE/AISC Steel Bridge Competition. We will use MultiFrame® and ANSYS® for the analysis and manual computation for the sizing of the members. After the full design is complete, construction drawings will be made using AutoCAD® and fabrication will commence. Once fabrication is complete, the bridge will be load-tested to obtain measurements for maximum deflection under vertical and lateral loads. Student members of the Swarthmore ASCE student chapter will assist in fabrication and construction of the bridge at the ASCE Mid Atlantic Regional Steel Bridge Competition to be held at Lafayette College on April 4th and 5th, 2008. The competition judging criterion evaluates bridges based on their structural efficiency and construction efficiency. Our bridge design will be optimized to minimize fabrication complexity and the number of workers necessary for construction. We have consulted steel fabricators and metal suppliers in the greater Philadelphia for assistance in providing/donating our construction materials. The total cost of the project is projected to be \$668 without any sponsorship and as low as \$25 with full sponsorship.

Christopher Caruso

Samuel Garcia

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Advisor: Professor Siddiqui

Introduction

Every year, ASCE (American Society of Civil Engineers) and AISC (American Institute of Steel Construction) sponsor a contest for student ASCE chapters to construct a 1/10 scale model of a steel bridge to span a fictitious river. The challenge is for undergraduate engineering students to design and fabricate such a bridge according to a strict set of constraints issued by ASCE and AISC. This competition is designed to challenge students with a realistic design assignment and expose them to the types of problems encountered in seeing an engineering project from conception to completion. It also emphasizes the importance of team-work in engineering, which is something not necessarily taught in the classroom.

This competition is a popular activity partaken by student ASCE chapters of all sizes but has never before been done at Swarthmore. We are proposing to devote our Engineering Senior Design Projects to designing and fabricating a bridge to the exact specifications and constraints governing this competition. We will conduct load testing in the exact same manner as will be done at the actual steel bridge competition. This consists of a two stage deck loading, 1500 lbs each stage, and maximum vertical deflection measurement of the bridge deck. A lateral load test will also be performed, where a 50 lb. lateral pull will be applied to the side of the bridge while a 75 lb downward load is applied to the deck at midspan. The sway will be measured from the girders in this test.

The Steel Bridge Competition judges bridges on the following categories: Display & Aesthetics, Construction Speed, Construction Economy, Lightness, Stiffness, Structural Efficiency, and Overall Performance. The Display & Aesthetics category judges the elegance, balance, and proportion of the bridge as well as the completeness of our poster, which summarizes the design, fabrication, and features of our bridge. The Construction Speed category judges how fast the bridge can be constructed with a team of students over a fictional river. The Construction Economy category considers the construction speed (time taken to construct the bridge) and the number of workers required for construction and computes a construction cost (C_C) value. The Lightness category judges

the weight of the bridge. The Stiffness category judges the bridge's ability to resist applied loads, both vertical and lateral. The Structural Efficiency category considers both the total weight of the bridge and its maximum deflection and computes a structural cost (C_S) value. Finally, the Overall Performance category simply considers the sum of the construction cost (C_C) and structural cost (C_S). The team with the lowest score for Overall Performance wins the competition.

The bridge will also be an ASCE semester project and, as such, will involve ASCE members in fabrication and construction. By involving members of ASCE, we hope they will be inspired to enter the Steel Bridge Competition again next year and subsequent years in the future. This would allow engineering students at Swarthmore to take advantage of the many learning opportunities this competition has to offer.

The criterion put forth by ABET for Engineering accreditation is the standard by which institutions of higher education must train students in order for them to practice Engineering after graduation. ABET Engineering accreditation criterion 3-c stipulates that "Engineering programs must demonstrate that their students attain an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability."

Our E90 project satisfies criterion 3-c in all aspects. First, the steel bridge design is original and based around environmental, economic, and manufacturability constraints set forth in the ASCE/AISC guidelines. Since the bridge is a scale-model of a full sized bridge, it is unfit for anything other than its design purpose of providing a safe crossing over a fictional river. Our bridge project fits the economic constraints of E90 because the major construction materials required will be acquired through sponsorship donations from local steel fabricators and metal suppliers. The final material cost of the bridge will not exceed \$50. Social and political constraints are of little concern in this project because the bridge will be disassembled and deconstructed once adequate load-testing is finished and we have taken it to the ASCE/AISC Bridge Competition. The bridge's lasting impact is therefore minimal because it will have a short lifetime.

The bridge will satisfy ethical constraints by serving as a valuable learning experience on project design and execution under constraints for all students involved, including ASCE student chapter members. Health and Safety will also be paramount concerns during fabrication and construction of the bridge. Students will only operate machinery or tools if they have proven themselves competent or have taken the department Shop Class. The bridge fits manufacturability constraints because we are aware that we are personally responsible for most of the bridge's fabrication. As such, our design details will emphasize simplicity so as to minimize difficulties from inexperience and minimize the time required for fabrication and construction.

Finally, we have designed our bridge such that it is consistent with contemporary sustainability practices. At the end of the bridge's life, its steel members will either be cut and saved so the department can re-use them or sold to a scrap yard so they can be melted and recast for other some other purpose. The fasteners will also be saved for department use because they are versatile and not likely to sustain permanent damage during the bridge's lifetime. The most significant consumable resources used in fabrication of the bridge will be welding wire and electricity needed to power the shop machines. The most significant carbon footprint will come from the power used to electrically melt the scrap steel after the bridge is disassembled. This footprint can be reduced by scrapping the steel at a mill where renewable energy sources are used.

Technical Discussion

We chose the truss form for the bridge because there are many weight-reduction options possible, it can be simply constructed if designed carefully, and it has smaller vertical deflections than a similar girder bridge under the constraints of the competition (no mid-river supports). The bridge will consist of two truss panels connected along their bottom chords by horizontal joists. These panels will stand on four legs, each placed at one corner of the bridge. A competition constraint is that none of the members may be longer than 3'6", which forces us to pay particularly close attention to joint details. A side-profile of the bridge concept is shown in Fig. 1.

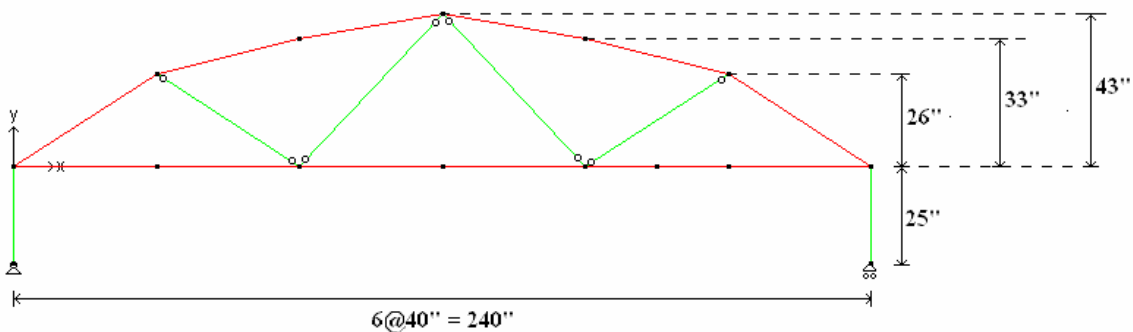


Fig. 1. Side profile concept of Steel Bridge

Bridge Deck

The bridge deck will consist of two open-web girders running the entire bridge's span (20 ft.). These girders will consist of two thin-walled round pipes serving as flanges with small, solid steel rods ($\frac{1}{4}''$ Dia. Bar) connecting them. These rods will be welded to the flange pipes and angled 45° up from the long axis of the bridge. These rods will serve primarily as shear reinforcement, much like shear stirrups in concrete beams, and will be spaced evenly along the entire bridge's span. A schematic of a short section of the open-web girder concept is shown in Fig. 2.

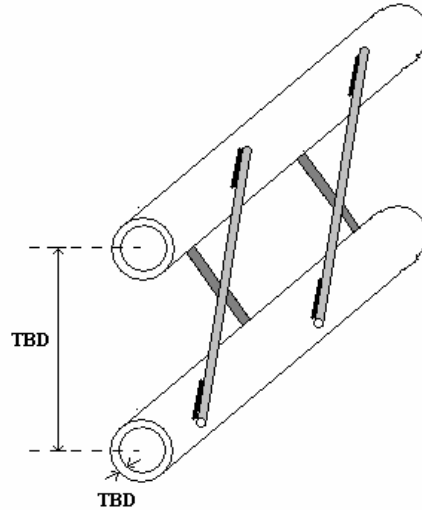


Fig. 2. Schematic of Open-Web Girder

The two girders will be connected at seven points along the span by transverse joists consisting of the same pipe sections as the girder flanges. Additionally, two steel tension rods will be welded in an “X” pattern between the upper and lower pipes of these joists to provide sway-resistance. These joists will support the flat decking surface upon which the loads will be applied during the competition and load testing. The joists divide the deck length into 6 clear spans. Their schematic is shown in Fig. 3.

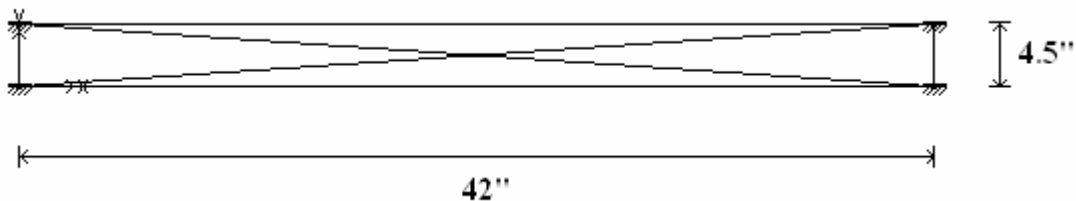


Fig. 3. Joist Schematic. Fixed restraints at each corner indicate rigid joint connections with girders.

Truss Panels

The truss panels will consist of a top chord, a bottom chord, and four connecting links in between them. The bottom chord of each panel will be an open-web girder, as described above. The top chord will be constructed of round steel pipe. The top chord members will connect to each other with bolted connections through gusset plates as will the girders. The connecting links in the truss panel will be steel rods that also connect to

gusset plates on the top and bottom chords. The truss panel arrangement is shown on the bridge schematic in Fig. 1 (pg. 4).

Supports

The bridge will sit on four steel legs, which will likely be steel angles acting as columns. Each leg will be laterally braced at mid-span with two round steel rods, one connecting to the bottom of the adjacent girder and the other connecting to the bottom of the adjacent joist.

Project Plan

All needs pertaining to the construction have been identified and estimates of times for critical milestones in the progress of the projects completion can be readily found in graphic form in the appendix. Issues such as concept design, material acquisition, construction planning, actual construction, and report writing have been considered prior to the writing of this proposal. Our plan proceeds as follows:

- Design bridge geometry and members (Present -Dec 1, 2007)
- Find steel suppliers/sponsors and order materials (Present -Dec 16, 2007)
- Design joints (Jan. 21-Feb 4, 2008)
- Order the joint materials (Feb. 4- Feb. 18, 2008)
- Build bridge (Feb. 18-Mar. 17, 2008)
- Determine the bridge's optimal construction procedure to minimize time and effort. (Mar 17-Mar. 28, 2008)
- Test the bridge by applying loads similar to those of the competition and determine personal records of deflection and weight. (Mar. 28 - Apr. 3, 2008)
- Finalize final project report (Apr. 6- Apr. 18)

The dates next to each milestone of the project represent the critical path dates. Each of these actions requires a series of tasks to be completed, which are outlined in the Critical Path method and GANNT chart that can be found in the appendix to this proposal. According to the current estimates, this project will take a minimum of 139 working days or 5.5 months to complete including breaks and assuming a start date of November 1st.

Project Qualifications

Christopher Caruso and Samuel Garcia are senior engineering students who have specialized in Civil Engineering by completing courses such as Mechanics and Dynamics (E6), Structural Theory and Design I and II (E60 & E62), and Mechanics of Solids (E59) at Swarthmore College. Their academic experiences and familiarity with computing programs such as ANSYS® and MultiFrame® will allow them to perform a quick analysis of any design. Both have completed a machine shop course that will allow them to avoid the cost of hiring a professional fabricator.

As co-presidents of Swarthmore's American Society of Civil Engineers (ASCE) student chapter, they have access to resources such as skilled student labor and networking ties that will facilitate the search for sponsors.

Christopher Caruso is currently undertaking Engineering Materials (E82), which will allow him to further analyze material properties. He has also done research and acquired welding experience at the University of Houston.

Samuel Garcia has experience in project planning through the Experimentation for Engineering Design (E14) course.

CAD drawing of our bridge design is a requirement of our project. Samuel and Christopher both have a cursory knowledge of CAD and plan on expanding their knowledge and proficiency over the winter break.

Project Cost

An estimate of all the materials required and their costs are tabulated in the following two tables (Table 1 and Table 2). Table 1 contains all materials pledged for donation by Metals USA Inc. and Table 2 contains all materials pledged for donation by Cherry Steel, Inc. If these donations are not realized some reason, the \$400 allotted to us for the project by the department will cover some of the project costs. ASCE funds are a possible source of additional funding if no material donations are received.

In addition to the materials tabulated in Tables 1 and 2, several miscellaneous tools and expendable materials will be required to complete the project. A sponsor for these materials has not yet been found. If none is found by the time they are needed, their total cost is relatively low and thus they should be easily covered by our E90 budget. These materials are presented in Table 3.

Table 1: Materials and sponsorship costs from Metals USA, Inc.

Material	Amount	Cost/unit	Total Cost dollars
1" OD 1/16" wall-thickness Round Steel Tube - A36	180 feet	35.04 24 ft	280.32
1/4" Dia Round Bar HR CQ Steel	220	8 20 ft	88
1" x 1" x 1/8" Angle A36	10 feet	10 10 ft	10
1' x 1' x 3/16" Plate A36	4 sq. ft	29.19 1 sq. ft	116.76
Total (estimated)			495.08

Table 2: Materials and sponsorship costs from Cherry Steel, Inc.

Material	Amount	Cost/unit	Total Cost dollars
3/8-16 x 2" Bolts Grade 8	100 bolts	26 100 bolts	26
3/8" washers Grade 8	200 washers	11.1 100 washers	11.1
3/8" Hex Nuts Grade 8	100 nuts	5 100 nuts	5
Paint 5-gal Latex - Maroon			55
5-gal Latex Primer			50
Total (estimated)			147.1

Table 3: Miscellaneous tools and expendable materials with estimated costs.

Material	Amount	Cost/unit	Total Cost dollars
Paint Brushes	6	1.5 1 brush	9
E70S Solid Carbon Steel Welding Wire: 0.03" dia	2	8 832 ft	16
Total (estimated)			25

The total material costs of the project are therefore estimated to be the sum of the total cost values from Tables 1, 2, and 3, which is \$668. After considering sponsorship donations, this cost reduces to simply the total from Table 3, which is \$25. The total time estimated to complete the project is at least 450 man hours. Since this is an experimental project, that number is likely to be exceeded.

References

Anonymous (2008). Student Steel Bridge Competition: 2008 Rules. ASCE and AISC, <http://www.aisc.org/Content/ContentGroups/Documents/University_Relations3/2008Rules.pdf> .

AISC Manual Committee. LRFD Manual of Steel Construction (3rd edition). American Institute of Steel Construction.

Appendix: Project Task List

Structural Analysis and Steel Design	Label	Days	Needs	Feeds
Select bridge geometry	1-A	14		1-C
Select member properties	1-B	7		1-C
Acquire frame supplies	1-C	36	1-A, 1-B	1-D,2-A
Select joint configurations	1-D	14	1-A, 1-B,1-C	1-E
Select bolts	1-E	7	1-D	1-F
Acquire joint supplies	1-F	14	1-D, 1-E	2-A
Construction Planning and Practice				
Build bridge	2-A	28	1-C, 1-F	2-B,2-C
Add aesthetic features	2-B	5	1-C, 1-F, 2-A	2-C, 3-A
Select efficient assembly method	2-C	13	2-A, 2-B	2-D,3-B
Practice assembly	2-D	5	2-C	3-A
Testing and Report				
Test deflection and determine weight	3-A	6	2-B	3-B
Write report	3-B	12	3-A	

Critical Path Analysis

