IPRO 315

Design of a Large-Scale Bridge Structure

Final Report

Advisor: Jeffrey Budiman

1.0. Introduction

The objectives of this IPRO are to design and build a steel bridge to the specifications given by AISC and, using teamwork, to win this year's ASCE/AISC Regional Steel Bridge Competition.

The current objectives of IPRO 315 are to finish manufacturing the bridge in order to begin testing and practicing assembly for the competition on April 27.
This differs from the original objectives stated above because the design is complete, and construction has begun.

2.0. Background

The ASCE Steel Bridge Competition is co-sponsored by ASCE (American Society of Civil Engineers) and AISC (American Institute of Steel Construction). ASCE is an organization that is over 150 years old with a history in engineering and problem solving. The rules for the steel bridge competition are written by AISC and updated yearly.

The students are to design, fabricate and construct a scaled down steel bridge. The rules are based on real life build scenarios. Examples of said problems include: cost of the project, management, design, analysis, fabrication techniques, methods, and construction time, efficiency and safety.

Various technologies are used. SAP (Structural Analysis Program) is used to analyze the integrity and strength of the structure, AutoCAD is used to draw out the design, Strength of Materials is used in the choice of steel used, and fabrication using wood and metals is used in building templates and building the bridge. The use of tools is found throughout the entire project from fabrication to actual construction.

IIT has participated in this competition for many years. Our greatest success is the 2004 competition where the team went to nationals and placed in several events. The group last year was seriously hampered by bad fabrication and slow construction time.

Some scientific issues that can be investigated are different design methods and use of analysis to find the best overall design. Cultural problems arise in communication between the group members who come from different cultures. Ethical problems may arise in scoring of the competition.

All costs are absorbed by organization involved in solving the problem. There are no costs on society. Any costs arising to businesses are by their own choice through sponsorship.

The solution will be implemented by splitting off tasks into sub groups. There is a group for designing the bridge, another to fundraise for expenses, a group to help fabricate the bridge, the construction team for building the bridge at competition, a group to make posters and any presentation material, and any other tasks for individuals.

Attached are the bridge layout rules set by AISC and the introduction and summary of the competition provided by AISC.

3.0. Purpose

The state Department of Transportation (DOT) has requested design/build proposals for replacing the existing bridge. Any appropriate type of bridge will be considered but the DOT has specified steel as the material because of its durability, fast erection, and high level of recycled content. Clearance under the bridge must be provided for passage of floods. The bridge must be able to carry specified patterns of loads without exceeding sway and deflection limits. Based on past experience with performance and maintenance, the DOT prefers bridges that are relatively light and stiff. The new bridge must accommodate modular decking that was salvaged from another structure.

Due to environmental concerns, construction of permanent piers is permitted only on the existing footings. Temporary piers may be used. Construction barges and other equipment are not permitted in the river. Soil conditions limit the weight of loads that may be moved. Existing revetments protect steep slopes and must not be damaged by construction equipment.

Your company's design/build proposal is among those that the DOT has deemed responsive, and winning the contract would be a step toward becoming a leader in the bridge replacement market. The DOT has asked each competing firm to submit a 1:10 scale model to demonstrate its concept. Models will be erected under simulated field conditions and then load tested. A panel of DOT personnel will judge the models by multiple criteria including durability, constructability, usability, stiffness, construction speed, efficiency, economy, and display. The contract will be awarded to the company whose model best meets the DOT's needs and requirements. Any attempt to gain advantage by circumventing the intent of the competition as expressed by the rules, including this Problem Statement, will be grounds for rejection of the model and termination of the company's eligibility.

4.0. Research Methodology

To make the project more successful the team needs to first make sure the rules of the competition and specifications of design are understood. The team will then assign tasks to sub-teams to make everyone work more efficiently toward finalization of the project. A conceptual design will be produced by the design team using software such as AutoCAD and SAP2000. The design team will draw on past experiences and the knowledge of team members for the design, as well as the support of academic advisors.

Concurrently, funding will be raised for materials and fabrication and a website will be designed for the project by the other sub-teams. After selection of the design and a fabricator, the design process will begin. Wooden templates will be made to hold the steel sections in place for welding. Templates will also be made for connections and other parts of the bridge as needed. After fabrication, assembly of the bridge will be practiced and load testing will be done with the bridge. Final modifications of the bridge will be made as needed to facilitate assembly and satisfy loading requirements.

5.0. Assignments

Gbadebo Atewologun
Major: Civil Engineering
Skills: SAP, MathCAD, and proficient with hand and mechanized tools.
Strengths: Problem-solving ability and aptitude with structural analysis and design. Meticulous and organized work ethic.
Experiences: Steel analysis and design courses. Has been apart of a design sub-team in an internship, the project was a success and was presented to the project sponsors.
Sub-Teams: Design

Christina Barrett
Major: Computer Science
Skills: Microsoft Office and anything Adobe
Strengths: Working with computers and following rules.
Experience: Has created an IPRO website during Fall 06 semester. Helped build a trebuchet, two catapults, and a loft.
Sub-Teams: Leader of Website
Representative to the IPRO office
Bridge Construction

John Brilla
Major: Architecture
Skills: AutoCAD, CAModeling/Manufacturing, Photoshop/Illustrator, Web Design, some coding, and public speaking
Experiences: Presentations, Construction Documents, Model Building, and Personal Websites.
Sub-Teams: Website
Presentation
Posters/CAD
Template Fabrication

David Fahs
Major: Civil Engineering
Sub-Teams: Design

Patrick Fong
Major: Architecture
Skills: AutoCAD, Adobe Photoshop, and Adobe Illustrator
Strengths: How to get drawings to print for AutoCAD, Adobe Photoshop, and Adobe Illustrator.
Sub-Teams: Template Fabrication
Posters/CAD

Bernard Froehlich
Major: Civil Engineering

Skills: Has worked in construction.
Strengths: Tall
Experiences: AFROTC
Sub-Teams: Design
Bridge Fabrication
Bridge Construction

Emiliano Giana
Major: Civil Engineering
Skills: Has worked in construction.
Strengths: Tall
Experiences: AFROTC
Sub-Teams: Design
Bridge Fabrication
Bridge Construction

Naomi Heler
Major: Civil Engineering
Skills: Design and Analysis, Management
Strengths: Organized, Technical
Experiences: Has done this IPRO before and was the project leader then.
Has been to the conference before and is fairly knowledgeable in what is expected and of problems that may arise.
Sub-Teams: Leader of Fundraising
Design
ASCE competition Representative

Daniel Hernandez
Major: Civil Engineering
Skills: Design
Strengths: Structural engineering
Sub-Teams: Design
Bridge Fabrication
Bridge Construction

Ei Hong
Major: Civil Engineering
Skills: Design, AutoCAD, and SAP2000
Strengths: Structural analysis
Sub-Teams: Design
Template Fabrication
Bridge Fabrication

Thomas Huang
Major: Architecture
Skills: AutoCAD, 3D modeling, and model making

Sub-Teams: Posters/CAD
Template Fabrication

Mohamad Khudeira
Major: Civil Engineering
Skills: Planning, construction, and management
Strengths: Team-work and communication
Experiences: Is working in an office doing drawing, and has worked in the field as an inspector of the jobsite.
Sub-Teams: Fundraising
Design

Yong-Wan Kim
Major: Civil Engineering
Skills: AutoCAD, MathCAD, MS Word, MS Excel, SAP2000
Strengths: Fast, diligent, and team-work
Experiences: Learned bridge designing from CAE 408 and structural analysis.
Sub-Teams: Design
Posters/CAD
Bridge Construction
Bridge Fabrication

Linda Lee
Major: Architecture
Skills: AutoCAD
Strengths: Teamwork
Experiences: Has learned about steel structures and has studied steel buildings
Sub-Teams: Posters/CAD

Man Leung
Major: Civil engineering
Strength: theoretical, frame, and structure analysis
Experience: Official and unofficial participation in both regional and international high school bridge building competitions at IIT from 1999- current.
Student bridge judge in both regional and International competitions in
2003
Sub-Teams: Design
Bridge Construction

Heather Mahoney
Major: Civil engineering
Skills: Construction experience
Sub-Teams: Fundraising
Leader of Bridge Fabrication

Jinit Patel

Major: Civil Engineering
Skills: cutting steal
Experiences: Working with cars and metal cutting.
Sub-Teams: T-Shirts
Design
Bridge Fabrication
Bridge Construction

Robert Pershey
Major: Political Science
Skills: Construction experience and editing
Strengths: Negotiation/compromise
Experiences: NROTC and helped build a trebuchet, a catapult, and a loft.
Sub-Teams: Fundraising
Bridge Construction

Sotiel Polena
Major: Civil Engineering and Construction Management
Skills: Project Management and Structural Design
Experiences: Has been in construction related work for five years and is currently working in construction management.
Sub-Teams: Design
Presentation

Fuzel Shethwala
Major: Architecture
Skills: AutoCAD, 3D Max, Model Making, and working with related tools.
Sub-Teams: Posters/CAD

Lucas Shorette
Major: Civil Engineering
Experiences: Has done this IPRO before.
Sub-Teams: T-Shirts
Presentation
Minute Taker of Design

Milena Stopic
Major: Architecture
Skills: Spatial and Urban Planning, Material Modelling, 3D Modelling, Animation, Presentations, and Visualizations
Sub-Teams: Leader of Posters/CAD

Melissa Swinderski
Major: Civil Engineering
Skills: AutoCAD
Experiences: Has done this IPRO before.

Sub-Teams: Fundraising
Template Fabrication
Bridge Fabrication

Chintan Thakkar
Major: Mechanical Engineering
Skills: Design and management
Strengths: Team-work
Sub-Teams: Design

Lee Welsh
Major: Civil Engineering
Skills: Design and construction management
Experiences: Seven years in US Army and an internship with F. H. Paschen.
Sub-Teams: Leader of Design
Template Fabrication
Bridge Fabrication
Presentation

Sub-Teams

Design
This sub-team is responsible for completing the bridge design that will be built, as well as running virtual structural tests.

Fundraising
This sub-team will create a list of possible sponsors and send personalized donation requests to each.

Posters/CAD
This sub-team will create and print the IPRO Day and ASCE Competition posters. This team will also help make the AutoCAD drawings.

Presentation
This sub-team will be in charge of the IPRO Day presentation.

T-Shirts
This sub-team will design and get competition t-shirts made.

Website
This sub-team will create and maintain the IPRO 315's website.

Template Fabrication
This sub-team will be building the templates for us to use for cutting the sections as well as the templates to send to the fabricators to weld the pieces. Passing the safety test at Crown Hall is a requirement.

Bridge Fabrication
This sub-team will be used to track and manage the fabrication of the bridge. It will include visits to the fabricator as well as any design changes.

Bridge Construction
This sub-team will be the competition team. Being a member of ASCE is a requirement as well as the trip to Purdue for the assembly at the regional competition.

Sub-Team Leaders:

Leader of Design Lee Welsh
Leader of Fundraising Naomi Heler
Leader of Posters/CAD Milena Stopic
Leader of Presentation unassigned
Leader of T-Shirts Lucas Shorette
Leader of Website Christina Barrett
Leader of Template Fabrication unassigned
Leader of Bridge Fabrication Heather Mahoney
Leader of Bridge Construction unassigned

Other Roles:
ASCE competition Representative Naomi Heler
Representative to the IPRO office Christina Barrett

6.0. Obstacles

7.0. Results

The design team developed a design, and the design was tested in SAP, looking for a Safety Rating of 3.

The fundraising team sent out over sixty letters in search of funding.

For construction purposes, the bridge has been broken down into three truss designs which need to be assembled and replicated before being joined to complete the bridge.

The team decided to use outside welders to assemble the pieces in order to complete each individual truss.

Because of this, in an effort to maintain uniformity between these trusses, each of the three trusses needs its own set of templates. These templates have been designed and were assembled while the cutting team cut the individual pieces for the trusses. The templates and the cut pieces for each truss are then taken to the welder for assembly. At this point, all templates have been produced, and all cutting is complete.

Construction team will practice to build the bridge for two or more weeks before the competition on April 27th. The goal is to construct the bridge in 5 minutes or less.

T-Shirt almost done, want it to go the press on 4/10/07.

The Poster sub-team has the goal to finalize the posters by mid-April.

The presentation team needs to finalize the presentation by April 22 , 2007 so as to be able to practice and be ready by IPRO day April 27, 2007.

For this Inter-professional project, our objective is to design and build a steel bridge that can compete in the ASCE/AISC Regional Steel Bridge Competition. The overall performance of the bridge is based on two categories, and as expected, the goal is to obtain the highest score through a combination of the two scores. Construction economy is based essentially on the amount of "person-minutes" needed to correctly assemble the bridge. Succeeding in this area requires a bridge designed with simplicity in mind. A huge bridge with complicated trusses could be incredibly strong; if it takes an outrageous time period to build, then failure could result on that basis alone. The next category, Structural Efficiency, is based on a rather simple calculation—weight times 5000$/lb added to the deflection times 500,000$/inch. The project team aspires to design and construct a bridge that is light, stiff, and simple. If those criteria are met, then we will have a steel bridge that can easily vie for first place in the regional competition.

Personal Accomplishments

Gbadebo Atewologun:
-Worked with the design team on the structural elements of the bridge.
-Developed a rudimentary design for truss number two on which Danny Hernandez based the main geometry for his design of truss two.
-Helped with cutting the various steel sections.
-Used the grinder to smooth the edges of pieces that had imperfections after they were cut.
-Wrote the Expected Results portion of the Project Plan.
-Before the end of the semester
-Will help the fabrication team finish cutting the steel.

Christina Barrett:
-In charge of putting together the project plan.
-Obtained login and password for the website.
-Started designing the website with John.
-Has uploaded a basic website with deliverables on it.
-In charge of putting together the midterm report.
-Before the end of the semester
-Plans to work with John and finish the Website.
-Will participate in the bridge building practices.
-Hopes to be on the construction team for the competition.
-Plans to go to the competition.

John Brilla
-Involved in updating the list of necessary pieces for the construction of the bridge, although we simply updated the original order sheet.
-Has been working on an animation of the building process for the bridge, so that both the general audience and the build team understand how the bridge must ultimately be constructed. Has created the initial scenes for the animation, and has begun to render them.

-Looked through the questions posted to the competition officials, and ran across a rule which our construction process is in violation. Thus, having alerted the design leader, the project is subsequently being addressed.
-Has been going through some of the initial brain-storming steps toward the visual design of the IPRO website.
-Before the end of the semester
-In the process of editing and rendering each of the scenes in the animation. After the completion of this, the team can use it as their build template. Thus, it must be complete before mid-April.
-The visual design of the website must be completed, and paired with the code, in order to truly represent the project.
-For the Poster, the images that have been composed for the animation must be arranged and compounded with other information on the project in order to clearly represent it at the competition, as well as at IPRO day.
-Will prepare the IPRO Day presentation to clearly represent both the construction process and the website to the general IPRO day public.

David Fahs
-Attended all IPRO testings and meetings
-Contributed to the design of the bridge's overall geometry.
-Contributed to the designing of individual bridge members
-Contributed to the fabrication of bridge members.
-Before the end of the semester
-Plans on helping to finish bridge fabrication and to assist in the construction phase also.

Patrick Fong
-Worked on template fabrication for steel bridge.
-Before the end of the semester
-Will work on the posters for the competition and IPRO Day.

Danny Hernandez
-Has been around throughout.
-Worked with the design team to help finish up the design as soon as possible, worked most extensively with truss 3.
-Has helped with the cutting, grinding, and sanding over the past couple weeks.
-Before the end of the semester
-Will continue to help cut steel.
-Will help practice and hopefully make the construction team for the competition.

Ei Sheng Hong
-Took part in designing Truss 1 and Truss 3 together with other members in the design sub-team.
-Helped find out which kind of truss would deflect the least and be the lightest.
-Helped check for buckling in compression members and yielding in tension members.
-Helped measure the dimensions of templates and cut them in the model shop in crown hall.
-Helped cut steel for truss members.

-Did the finishing of each truss member and plate
-Before the end of the semester
-Will continue to work on the templates if there are any left to be finished.
-Will regularly come to help the fabrication sub-team finish cutting the steel members.

Thomas Huang:
-Showed up to all the template meetings
-Made at least 60-70% of the templates.
-Before the end of the semester
-Will help with posters.
-May attend the competition.

Mohamad Khudeira
-Helped the design team by participating in scheduled meetings.
-Helped with the fundraising efforts by sending out letters to sponsors.
-Worked hard on constructing the trusses and needed pieces for constructing the bridge.
-Has been thinking of ways to make the bridge lighter than projected.

Yong-Wan Kim
-Worked on the design sub-team and fabrication sub-team.
-Attended almost every design team meeting, and discussed about the design of truss and connections.
-Performed load test with 'bridge option 2' by SAP and concluded that it was worse than other two options.
-Checked the maximum deflection of truss 1, 2, and 3 with design team members
-Put labels on the drawing of truss 1.
-Worked on making templates of truss 2 and 1.
-Helped cut wood and carry it.
-Currently working on cutting steel as a member of the fabrication sub-team.
-Has helped cut and grind some of the steel beams.
-Labeled truss members in order to identify the position of them.
-Before the end of the semester
-Will keep working on cutting steel pieces.
-Plans to work on the construction team for the competition.
-Will participate in the practice of building the bridge.

Linda Lee
-Helped make the templates in and outside of class.

Man Leung
-Personally did the design and analysis of truss 3
-Helped grind the steel pieces once the steel was cut.
-Before the end of the semester
-Plans to go to the competition and construct the bridge and support the construction team members.
Heather Mahoney

-Worked on fundraising.
-Coordinated steel material order and delivery.
-Helped coordinate fabrication, brought material and templates to the fabricator, contacted them with our progress, and met with them at the school to go over our plans.
-Before the end of the semester
-Will continue coordinating with fabricator.
-Will help with fundraising thank you notes.
-Plans to attend the competition.

Jinit Patel
-Involved in the design of the bridge
-Designed the T-Shirt for the competition
-Is in charge of cutting steal and getting the pieces ready for the fabricators.
-He did most of the cutting in the lab.
-Before the end of the semester
-Will be looking, with Luke, for the fastest people for the construction team for the competition.
-Will help finish cutting the steel.
-Will help put all the pieces together for the fabricators.
-Will help get all the pieces back from the fabricators and pre-assemble the bridge to make sure it fits well.

Robert Pershey:
-Sent out letters and made phone calls in search of funding.
-Double-checked the bridge against the specifications set out in the rules with Jorge, Naomi, and Christina.
-Reviewed rules for timed construction with Jorge and Christina.
-Edited Project Plan
-Edited Midterm Report
-Took delivery of the steel with Lee and Heather
-Before the end of the semester
-Plans to be on the construction team for the competition.

Sotiel Sam Polena:
-Involved in the design process of the bridge.
-Worked on sap analysis for trusses 2 and 3, along with other members of the design sub-team.
-Involved in the fabrication of the bridge, cutting of several members of the bridge as well as grinding and finishing of the members.
-Helped write the Research Methodology section of the project plan.
-Currently working on the Poster that will be displayed at the Bridge Competition
-Continuing work on the cutting of the bridge pieces.
-Before the end of the semester
-Will be working on the poster. This includes designing the poster, including information about the analysis of the bridge, the design, and fabrication process.
-Plans to be involved in placing the bridge together.

-Will be presenting on IPRO Day, will start preparing the presentation, as well as coordinating with other members of the sub-team to finalize the order of people for the IPRO day presentations.

Fuzel Shethwala
-Helped cut the templates out for welding the steel together.
-Was part of the CAD team.
-Before the end of the semester
-Will help design and make the posters for IPRO Day
-Will help with the IPRO Day presentation.

Lucas Shorette:
-Helped with the templates that the welders will be using.
-Assisted in the fabrication of parts for the welders to weld together.
-Helped with the design of the t-shirts.
-Before the end of the semester
-Will assist in finishing the cutting for the bridge.
-Plans to be on the Bridge Construction Sub-Team.
-Will be driving the bridge down to Purdue for the competition.

Milena Stopic:
-Participated in producing, laying out and printing the preliminary CAD drawings, shop drawings, as well as drawings for the planning and manufacture of welding templates for the steel parts.
-Participated in producing (cutting and assembly) of the templates.
-Before the end of the semester
-Will help plan out and produce the presentation poster for the competition and for IPRO day.
-Plans to participate in producing the PowerPoint presentation for IPRO day.

Melissa Swiderski:
-Helped with fundraising by calling companies to find out the appropriate person to contact regarding donations.
-Was involved in sending fundraising letters out and making follow-up phone calls.
-Helped in the assembly of one of the templates and the tweaking of another.
-Helped grind and finish the cut steel pieces.
-Helped to slot some of the sections for the plates.
-Helped to fit the pieces into the templates and label them so they could be sent to the fabricator.
-Before the end of the semester
-Plans to help sand finish the sections once they come back from the fabricator.
-Will help with the testing of the bridge prior to the competition.

Lee Welsh
-For the design team, he worked on the load analysis and design of member sizes.

-Started the project working on the design.
-Is the primary contact with the MMAE department who were machining parts for the bridge.
-Created plans and initiated work on the templates.
-Supervised and took part in the cutting and fabrication.
-Is one of the two primary contacts with the welders.
-Organizes meetings and work times and tracks the work progress.
-Before the end of the semester
-By Monday, March 26, the goal is to have all pieces cut, drilled and fitted to templates, and to have the pieces sent to the welders.
-The pieces are tentatively scheduled to return on Friday April 6.
-The following week he plans on overseeing the testing and creating a checklist of changes or repairs that need to be made.
-Plans on attending the competition, but probably will not be on the construction team.

8.0. Recommendations

Start early in the semester.

9.0. References

2007 Student Steel Bridge Rules

10.0. Acknowledgements

Professor Jeffery Budiman
Professor Jie-Hua Shen
Jorge Cobo
Leo W. Wikes
William Sidenstick
Thomas Brodzik
Donald Graowski