PCI Big Beam Proposal

CENE 476
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1.0 Project Understanding

1.1 Purpose of the Project

The purpose of the Precast/ Prestressed Concrete Institute (PCI) Big Beam project is to design a precast/prestressed concrete beam that follows the rules provided by the PCI Student Education Committee. This project will allow students to use their knowledge of concrete and structural analysis to create a mix design and structural design to be used to design a concrete beam. The concrete beam shall be 17 feet to 20 feet long and will be judged on its design accuracy. Other criteria that will be judged are the beams cost, weight, and maximum deflection, as well as the team's prediction accuracy, report quality, and use of the ACI code [1]. The team is going to design a concrete mix and beam design to create a prestressed concrete beam. By the end of the competition, the team will submit the report discussing the structural analysis and mix design, along with all the elements stated by the PCI Student Education Committee.

1.2 Project Background

PCI Big Beam Contest started on 2005. Since then, the PCI Student Education Committee has invited students to participate in the engineering student design competition each year. Each year the PCI Student Education Committee changes the competition rules from the year before. This year our team is going to follow the rules for 2016-2017, which has changed a little bit from the previous year. This year each team should design and create a beam that is 17 to 20 feet long, and the beam should hold at least the factored live load of 32 kips and not more than 39 kips [1]. After designing our beam, our team will work with TPAC in Phoenix, Arizona to fabricate the beam. Once fabricated, the beam will be tested in the Northern Arizona University (NAU) engineering building. The engineering building is locating at south campus in the City of Flagstaff as shows in the figures below. Flagstaff, Arizona is located in Northern Arizona and sits at about 7,000 feet in elevation. The climate is a dry semi-continental climate and has five distinct seasons. With high elevation and mild humidity, the weather is mild throughout the year.

1.3 Technical Considerations

There are several technical considerations for this project. The team should consider the design of the prestressed beam, the concrete mixture design, and the structural analysis to create an optimal design while considering the cost and weight of the beam.

1.3.1 Fabricating

In the case of a concrete beam, concrete is strong when it is in compression, but weak when tension is applied. In order to overcome this, builders can reinforce their concrete or have it prestressed. When fabricating the prestressed concrete beam the team is going to first put tied steel wire and/or strands. Then, the concrete will be poured on top of the steel and the strands will be cut, creating the prestressed concrete beam.

1.3.2 Mixture Design

To design the concrete mixture, the team will create different samples of concrete mixtures to determine a mixture that will not only meet the competition rules, but also create optimal results. The team should make sure that the concrete mixtures are balanced to get a smooth and strong shape. The most important part in mixing the team should focus on is water and cement ratio.

1.3.3 Structural Analysis

During the structural analysis process, the team will design different potential beams, and then all members will decide which design will meet all criteria for the competition and that can hold at least 32 kips. The team will do compressive strength test (ASTM C39) and split cylinder test (ASTM C496). These two tests will determine when the concrete will break due to compression, the tensile strength, and the stress-strain properties. To calculate these two tests, MathLAB and MathCAD will be used. During the final testing stage, the team will use one of the software to calculate when the beams final strength and deflection.

1.4 Potential Challenges

There are several challenges the team is facing. One of the challenges is creating a mix design, because all team members have not yet learned about all the different possibility and options in creating an optimal concrete mix. Another challenge is the reinforcing concrete design, as the team is still in the process of learning about reinforced concrete and all its abilities. Finally, a third challenge for the team will be MathCAD and MathLAB. However, with proper research and practice these three potential challenges will be solved.

1.5 Stakeholders

The following stakeholders will be affected by this project:

- NAU Department of Civil Engineering, Construction Management and Environmental Engineering (CECMEE)
- Precast/Prestressed Concrete Institute (PCI)
- TPAC
- Dr. Robin Tuchscherer

The NAU Department of Civil and Environmental Engineering and Construction Management is one of the stakeholders because the team is representing NAU in the competition. PCI is a stakeholder because the competition is held by PCI and they create and judge all rules and criteria that the teams will follow. TPAC is a stakeholder because TPAC will be fabricating the prestressed beam for the team. Finally, Dr. Robin Tuchscherer is a stakeholder because he is the team's technical advisor and all work from the team will ultimately be under his name.

2.0 Scope of Services

The scope of services specifies the technical and general work necessary to complete the PCI Big Beam project. The goal of the PCI Big Beam project is to create a strong, cheap, and lightweight prestressed beam with the largest deflection possible that meets all the PCI competition rules and regulations. The following details the regulatory tasks, design analysis tasks and subtasks, data collection tasks and subtasks, risk and project management, and exclusions for the project.

2.1 Mix Design

To create a beam that will produce optimal results, the team will be designing and testing six different mix designs. These mix designs will test different concrete types, pozzolans, and aggregates. After testing and gathering data for each mix design, three different mixes will be chosen based on the cheapest mix, the lightest mix, and the mix that creates the largest deflection. These mixes will then be paired with the three different cross section designs to help determine the final design of the beam.

2.1.1 Design Mix Experimental

A cylinder test matrix will be made up consisting of all of the mix designs that will be tested. This matrix will show what is changing in each mix designs and the amount of material needed. By adjusting TPAC's lightweight and normal weight design mixes, the matrix will help the team determine if and how any changes to the mix designs affect the compressive strength, tensile strength, and stress-strain curve and ultimately determine the optimal mix design for the beam.

2.1.2 Mix Design

The first two mix designs the team will test will be TPAC's lightweight and normal weight mix designs. Provided from TPAC, the compressive strength is already known and only tensile test and stress-strain test need to be done. For the other four mix designs, the team will tweak and TPAC's two mix designs by changing the concrete type, pozzolans, and aggregates. After designing each mix design, classed fees will be used to collect and order the mix materials through various companies.

2.1.3 Cylinder Creation

During the last week of the Fall 2016 semester, a total of 118 cylinders will be made - 13 cylinders each of TPAC's mix design and 23 cylinders each of the teams four mix designs. The team has talked to Gary about cylinders and will be using some of NAU's cylinders and lids for the project. The curing time will be between 28-38 days depending on the exact day they are made and tested. The amount of curing days will be taken into account when testing the final beam.

2.1.4 Cylinder Tests

After creating all the cylinders for each different mix, three tests will be completed using the ASTM standards. For each of TPAC's mix designs, 10 tensile test and 3 stress-strain test will be done and for each of the teams four mix designs, 10 compression test, 10 tensile test, and 3 stress-strain test will be done.

2.1.4.1 Cylinder Compression Test

Per ASTM C39 Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, a minimum of 10 4" X 8" cylinders will be tested for each mix design. From this test, the ultimate compression strength of each mix design will be collected.

2.1.4.2 Cylinder Tensile Test

Per ASTM C496 Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens, a minimum of 10 4" X 8" cylinders will be tested for each mix design. From this test, the tensile strength of each mix design will be collected.

2.1.4.3 Cylinder Stress-Strain Test

Per ASTM C469 Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression, a minimum of 3 4" X 8" cylinders will be tested for each mix design. From this test, the stress-strain relation and deflection data of each mix design will be collected.

2.2 Beam Cross-Section Design

To create a beam that will produce optimal results, cross-sections will be designed and then put into a MathCAD model. These cross sections will test different sizes and determine different properties of each cross-section. The final designs will then be paired with the three different mix designs to help determine the final design of the beam.

2.2.1 Creating a MathCAD Model

A MathCAD model will be created and used to aid the design and help with calculations. The MathCAD model will calculate the max moment the beam can withstand and the tensile strength.

2.2.2 Cross-Section Designs

Three different cross section designs representing the lowest cost, lowest weight and highest deflection will be designed using AutoCAD. These designs will then be implemented into MathCAD to be analyzed more accurately in determining how much weight the design can hold, how much deflection there will be and how much it will weigh and cost.

2.3 Final Beam Design

By combining the chosen three mix designs and three beam cross sections, three final designs will be chosen based on the same three criteria. The team will then follow the PCI Big Beam judging criteria and score each design. The judging criteria are shown in Appendix A. To score our beams, categories 1-4 will be used. For category 1, the beam will be given 20 points for holding a load between 32 and 39 kips and will be penalized 2 points for each kip below 32 kips and 1 point for each kip above 39 kips. For categories 2-4, 15 points will be given to each beam that has the lowest cost, lowest weight, and largest deflection, 10 points for the beam that is in the middle, and 5 points for the beam that has the highest cost, highest weight, and lowest deflection. During the competition, these categories will be based on the best and worst performances in the competition. Based on this scoring system, the beam that receives the highest points will be selected.

2.4 Beam Fabrication

After choosing the optimal design the team will submit shop drawing to TPAC. The shop drawing will include a plan view, cross section, and elevation view with all the dimensions needed. Once the shop drawings are sent, any necessary changes and edits will be made until approved by TPAC. When the drawings are approved, the team will be present on beam fabrication day.

2.5 Beam Testing

The final prestressed beam will be tested for the actual maximum applied load, the measured cracking load, and the largest measured deflection. Before the final beam is tested, the team will need to set up the testing machine and do final cylinder tests to determine the final predictions.

2.5.1 Test Setup

Following PCI competition rules, the team will setup the testing machine so that the beam will be loaded by applying two point loads, symmetrically, 7.5 feet from the center of each support. When the beam is ready to be tested, the loading machine will then apply the loads equally at both points until the beam breaks.

2.5.2 Final Predictions

Besides design accuracy, cost, weight, and deflection, another judging criteria is the accuracy of the team's predictions. The team will do final cylinder test to have an accurate prediction of the cracking load, ultimate load and ultimate deflection before testing the beam. This will be done one day before testing the beam.

2.5.3 Beam Test

After curing for the determined amount of days, the beam will be tested according to the PCI Big Beam rules on or before April 15th. The beam will be loaded by applying two point loads symmetrically 7.5 feet from the center of each support. Figure 2.1 below shows the load configurations. The loading machine will then apply loads equally at both points until the beam breaks and the maximum applied load, measured cracking load, and largest deflection will be determined. After testing the beam, the results will be analyzed and compared to the predicted values.

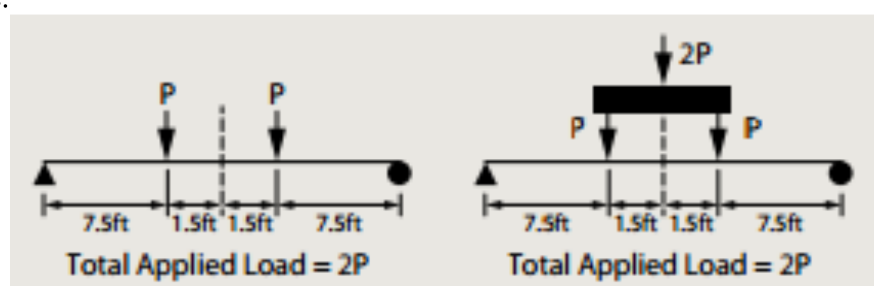

Figure 2.1 Load Configurations [1]

2.6 Beam Analysis

After testing the beam, the final results will be analyzed and compared against the final predictions made.

2.7 Project Management

2.7.1 Communications

2.7.1.1 Team Meetings

The team will meet a minimum once a week to discuss the progress of the project during the Spring 2017 semester.

2.7.1.2 Client Meetings

During the two semesters, two meeting will be set up. The first meeting will be during the first semester to meet the TPAC workers, visit the plant, and ask any question needed about the project and the second meeting will be during the second semester on beam fabrication day.

2.7.2 Deliverables

2.7.2.1 50% Design Report

A 50% design report will be turned half way through the Spring 2017 semester.

2.7.2.12 Final Draft of Report

A final draft of the report will be turned in to Dr. Tuchscherer on or before May 1st and the team will make any necessary corrections before submitting the final report.

2.7.2.3 Website

At the end of the project, a website will be created with the capstone project information, documents, pictures and team information.

2.7.2.4 Final Presentation

At the end of the Spring 2017 semester, the team will present a final presentation of the PCI Big Beam project.

2.7.2.5 Final Report

A hard copy and PDF copy of the final report will be submitted to PCI by May 10, 2016.

2.8 Risk Management

Throughout this project two important risks to be managed are the team's safety and the project timeline.

2.8.1 Safety
While working in the laboratory at Northern Arizona University and while visiting the TPAC factory all lab and factory safety precautions and procedures will be followed. Proper clothes and safety gear will be worn and any necessary training will be done.

2.8.2 Project timeline
To keep the project on schedule and to make sure the project is completed by the end of the Spring semester, extra time will be allotted for each task, to prepare for any unforeseen circumstances that can delay any part of the project.

2.9 Exclusions
TPAC Kiewit Western will be doing the fabrication in Phoenix, Arizona and shipping the beam to Northern Arizona University to be analyzed. Anything not expressly describe in the above will not be included in the project. The project is limited to the above tasks as well as a two-semester deadline.

3.0 Project Schedule
The project will begin on October 14, 2016 and will be finished by May 11, 2016. Table 3.1 below shows the schedule start date and schedule end date for each task and subtask.

Table 3.1: Project Schedule

Task	Schedule Start	Schedule End
Task 1: Mix Design	Fri 10/14/16	Sun 1/22/17
1.1 Design Mix Experimental	Mon 12/5/16	Fri 12/9/16
1.2 Mix Design	Fri 10/21/16	Thu 11/3/16
1.3 Collect Materials	Fri 11/4/16	Fri 12/9/16
1.4 Cylinder Creation	Mon 12/12/16	Tue 12/13/16
1.5 Curing Time	Mon 12/12/16	Tue 1/17/17
1.6 Cylinder Testing	Wed 1/18/17	Mon 1/23/17
Task 2: Beam Cross-Section Design	Fri 10/21/16	Fri 12/9/16
2.1 Creating a MathCAD model	Mon 12/5/16	Mon 1/9/17
2.2 Cross-Section Designs	Mon 11/28/16	Mon 12/12/16
Task 3: Final Design	Mon 1/23/17	Tue 2/28/17
Task 4: Beam Fabrication	Wed 3/1/17	Thu 4/13/17
4.1 Submit Shop Drawings	Wed 3/1/17	Thu 3/9/17
4.2 Beam Fabrication	Fri 3/10/17	Mon 3/13/17
4.3 Curing Time	Tue 3/14/17	Mon 4/17/17
Task 5: Beam Testing	Sun 4/9/17	Fri 4/14/17
5.1 Test Setup	Sun 4/9/17	Wed 4/12/17
5.2 Final Predictions	Thu 4/13/17	Thu 4/13/17
5.3 Beam Test	Fri 4/14/17	Fri 4/14/17
Task 6: Beam Analysis	Mon 4/17/17	Tue 4/25/17
Task 7: Project Management	Fri 9/2/16	Thu 5/11/17
7.1 Communications	Fri 9/2/16	Fri 5/5/17
7.1.1 Team Meetings	Fri 9/2/16	Fri 5/5/17
7.1.2 Client Meetings	Fri 10/21/16	Fri 3/10/17
7.1.2.1 TPAC Tour	Fri 9/2/16	Fri 9/2/16
7.1.2.2 Beam Fabrication Day	Fri 9/2/16	Fri 9/2/16
7.2 Deliverables	Wed 2/1/17	Thu 5/11/17
7.2.1 50% Design Report	Mon 12/5/16	Fri 1/13/17
7.2.2 Final Draft of report	Wed 4/26/17	Mon 6/12/17
7.2.3 Website	Mon 12/5/16	Tue 12/13/16
7.2.4 Final Presentation	Mon 12/5/16	Mon 12/19/16
7.2.5 Final Report	Tue 5/2/17	Thu 5/11/17

The Gantt chart shown in Figure 3.1 shows the project schedule with the critical path indicated with the red arrows. The design section, which includes the mix design and cross-section design, will take the most amount of time and will need to be completed before a final beam design can be determined and the beam can be fabricated and then tested and analyzed.

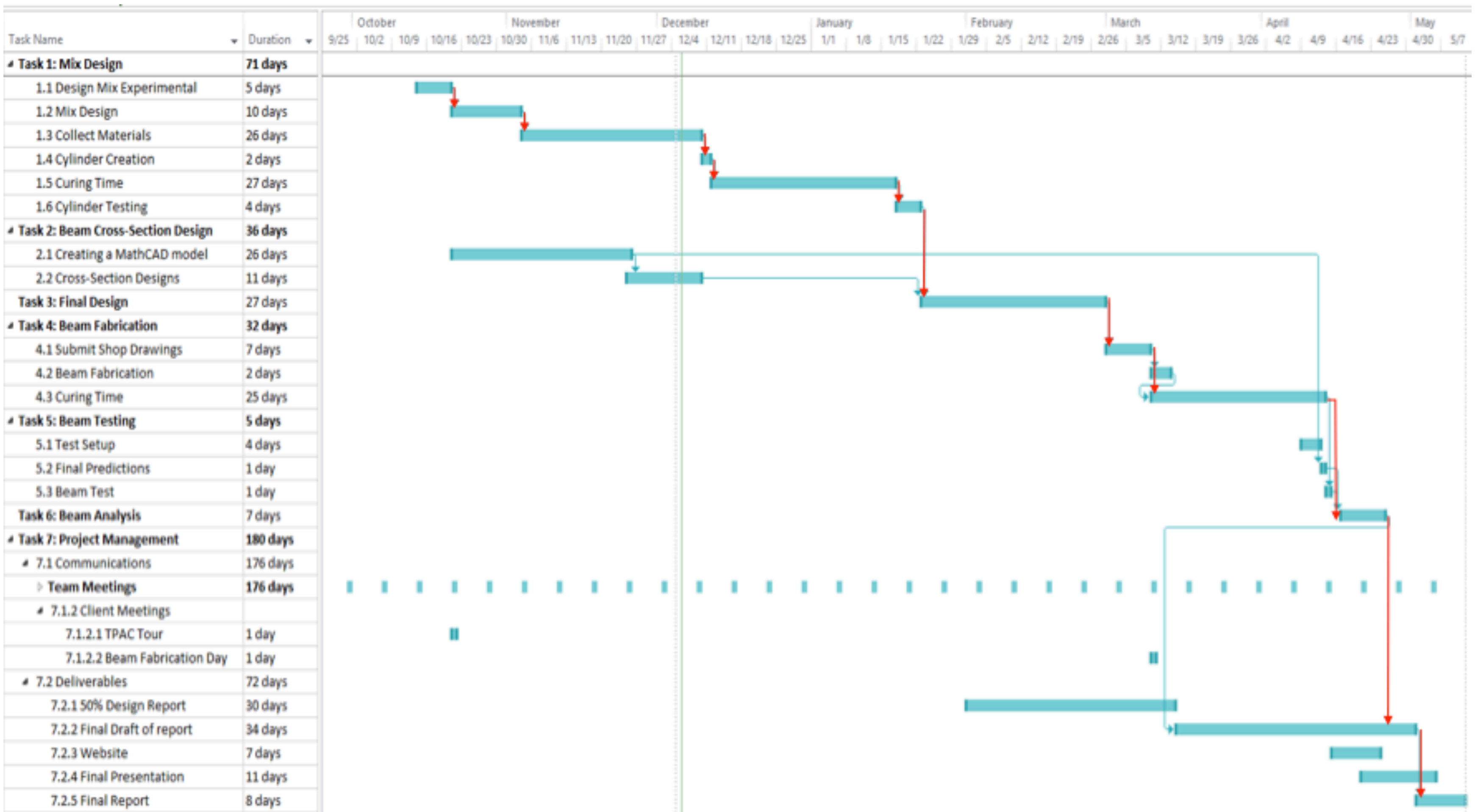

Figure 3.1 Gantt chart

4.0 Staffing and Cost of Engineering Services

This section includes the qualifications of the project members and includes the cost and hours of the project.

4.1 Qualifications

The staffing is divided into four different positions. The following explains what each position is required to do.

4.1.1 SENG

Senior Engineer- The senior engineer for this project is required to oversee the engineering calculations and the lab work. This entails helping create and edit the MathCAD model, know the types of concrete mix designs and help with the final selection of the mix, and aide in the development of shop drawings and beam design.

4.1.2 EGR

Engineer- The engineer for this project, much like the SENG is responsible for the creation of the MathCAD model, overseeing the mix designs and the analysis of the lab results, and the creation and design of the beam and shop drawings.

4.1.3 LAB

Lab Technician- The lab technician is responsible for the lab work involved with creating the concrete mixes, making test cylinders, and testing them in the lab. Also the LAB is responsible for conducting the final test of the beam.

4.1.4 AA

Administrative Assistant- The job responsibilities of the AA include compiling and editing project documents; this includes the reports and presentations, scheduling meetings and interacting with the client, recording meeting minutes and itineraries.

4.2 Staffing Analysis and Cost

The total staffing and cost of engineering services are broken down in the following tables.

Table 4.1 below shows the hours per person per task for the project. These are our projected hours that everything is going to take in order to complete the project. The table is broken up into four positions, a senior engineer, an engineer, a lab technician, and an administrative assistant. For each of the positions the hours per task are then listed.

Table 4.1 Hourly design projection

Task	SENG (hrs)	ENG (hrs)	LAB (hrs)	AA (hrs)
Task 1.0: Mix Design				
Task 1.1: Design Mix Experimental	8	21	20	5
Task 1.2: Mix Design	5	22	24	5
Task 13: Cylinder Creation	1	9	32	3
Task 1.4: Cylinder Testing	1	9	25	4
Task 2.0 Beam Cross-Section Design				
Task 2.1 Creating MathCAD model	7	28	15	3
Task 2.2 Cross Section Designs	9	18	16	3
Task 3.0: Final Design	13	26	36	16
Task 4.0: Beam Fabrication	17	33	51	7
Task 5.0 Beam Testing				
Task 3.1: Test Set Up	3	6	28	0
Task 3.2: Final Predictions	10	17	10	3
Task 3.3: Beam Test	6	8	43	1
Task 6.0:Beam Analysis	12	46	16	8
Task 7.0: Project Management				
Task 7.1: Communication	20	12	0	8
Task 7.2: Deliverables	26	24	0	13
Total Hours Per Person	138	279	320	79
Total project hours	**816**			

Table 4.2 below depicts the pay rate per person for the project. This includes the overhead costs, as well as the actual, base and bill rates per person.

Table 4.2 Breakdown of Billing Rate

Classification	Base Pay $/hr	Actual Pay $/hr	OH % of Base Pay	Actual Pay + OH $/hr	Billing Rate $/hr
SN	80	104	20	124.8	140
ENG	35	56	40	78.4	87.80
LAB	20	36	50	54	60.50
AA	16	19.2	30	24.96	27.95

Table 4.3 below shows the total cost of services for the project. This table includes the cost of each personal. This is the billing rate multiplied by the predicted hours. It also shows the total cost of meetings and how it will be charged, as well as lab costs and sub contracting costs. The total cost of all staffing and engineering services for this project is $75,987.

Table 4.3 Total Cost

	Classification	Hours (hr)	Rate/ Hour ($)	Cost ($)
1.0 Personnel	SENG	138	140	$19,320
	ENG	279	88	$24,552
	LAB	320	61	$19,520
	AA	79	28	$2,212
	Total			$45,039
2.0 Travel	3 meetings @ 290 miles/meeting	$0.44/mile		$383
3.0 Lab	Lab cost for equipment and facilities	30	100	$5,000
4.0 Subcontract	Beam fabrication			$5,000
5.0 Total				$75,987

5.0 References

[1] “Official Rules for the PCI Engineering Design Competition”, *Precast/Prestressed Concrete Institute,* 2016. [Online] Available: http://www.pci.org/education/student_education/

6.0 Appendix

Appendix A: Judging Criteria [1]

JUDGING CRITERIA

The Big Beam Competition will consist of a national competition, where each entry will be judged in relationship to all other entries. Entries will also be ranked within their zone for local reporting purposes, but the zonal will have no bearing on national awards.

The judging categories shall be:

1. **Design accuracy.** The beam should hold at least the FACTORED live load of 32 kips and should not hold more than 39 kips. The beam shall not crack under the service load of 20 kips. Beams meeting this criteria receive 20 points.
   a. Beams which do NOT hold 32 kips shall be penalized 2 points for each kip, or part of a kip, below 32.
   b. Beams which hold more than 39 kips shall be penalized 1 point for each kip, or part of a kip, above 39.
   c. Beams which crack before 20 kips receive a 5 point penalty.
2. **Lowest cost.**
3. **Lowest weight.**
4. **Largest measured deflection at maximum total applied load.**
5. **Most accurate prediction** of maximum total applied load the beam can carry, total applied load at first flexural cracking, and midspan deflection at maximum total applied load. Total applied load is the sum of the two applied point loads.
6. **Report quality.** Reports MUST contain a discussion of the concrete mix design and the beam structural design.
7. **Practicality, innovation and conformance with code.**