Letter of Transmittal

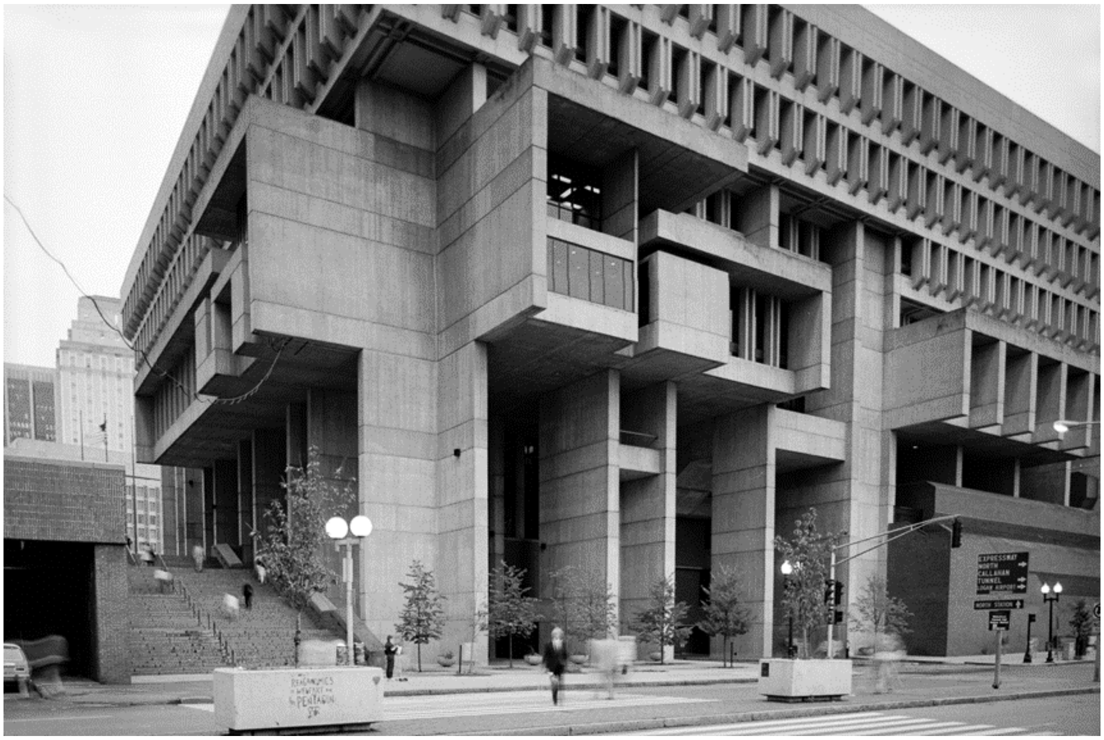
TO: Dr. Tuchscherer

FROM: Nicholas Jokerst, Deena Albustan, Michael O'Reilly, Eman Albdiwyi

DATE: Tuesday, December 15, 2015

SUBJECT: CENE 476 – PCI Big Beam Proposal

Attached please find, the project proposal for the PCI Big Beam capstone team. The proposal includes the Project Understanding, Scope of Services, Project Schedule, and Staffing and Engineering Cost of Services.



PCI Big Beam Proposal

NMDE Design Partners

December 16 2015

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1.0 Project Understanding

1.1 Project Purpose

The purpose of the PCI Big Beam Student Engineering Contest is to design a prestressed concrete beam that will perform within a set of design constraints provided by the PCI Student Education Committee. The beam will be designed, manufactured, and then tested to failure. The results of maximum loading at failure will be entered into the PCI Big Beam contest for evaluation against other engineering teams. Therefore, the true purpose behind the PCI Big Beam is to utilize the skills that have been developed during the team's engineering education in a design scenario that can be presented to and critiqued by industry professionals. Additionally, the purpose of this project is to represent NAU as a premier engineering university with the performance of our beam.

1.2 Project Background

The Prestressed/Precast Concrete Institute (PCI) is a national organization whose purpose is to spread an understanding of prestressed and precast concrete applications. PCI was founded in 1954 when six concrete manufacturing entities recognized the need for a central organization. The intention of this organization was to maintain a unified Body of Knowledge that could be used industry-wide. In 1954, "Specification for Pre-Tensioned Bonded Prestressed Concrete" was published as the first PCI specification and was soon followed by the PCI Journal and annual conferences. [1] PCI has continued to maintain and develop the Body of Knowledge for the design, fabrication, and construction of precast concrete systems. This Body of Knowledge is the basis for building codes, educational programs and certifications in precast concrete. Furthermore, PCI publishes a variety of technical manuals, research reports, and offers certification for companies and individuals. [1]

In addition to the aforementioned services, PCI hosts an annual engineering student competition, The PCI Big Beam Contest. The PCI Student Education Committee invites student teams each year to work with a PCI Producer Member to design and manufacture a prestressed concrete beam. The beam will then be loaded to failure and must fail within the constraints provided in the 2016 Official Rules for the PCI Engineering Design Competition. In order to accurately meet the design challenge, the beam must not rupture due to a live load less than 18.75 kips. Additionally, the beam must withstand a factored live load of at least 30 kips, but must fail before a 37 kip factored live load is applied. Lastly, the design team will be judged on the accuracy of predictions, maximum deflection, and maintaining low overall weight and cost. [2]

In addition to design constraints, PCI also mandates that a faculty advisor and PCI Producer Member must be selected by each team. The faculty advisor's role is to provide design advice as well as supervise the beam failure test. The faculty advisor is also responsible for the safety of team members. The PCI Producer Member will provide all materials, beam fabrication, beam transportation to the testing facility and beam disposal. PCI encourages that the student team members participate in fabrication to the extent deemed same by the Producer Member. [2] NMDE Design Partners have verified Dr. Tuchscherer as our faculty advisor and are in the process of selecting a PCI Producer member for manufacturing sponsorship.

1.3 Technical Considerations

In order to perform the design challenge, there are multiple technical factors to consider. The team must consider prestressed beam design, concrete mix design, prestressed reinforcement type and location, and beam manufacturer. The most important technical consideration is the prestressed design. Prestressed concrete design is a type of reinforced concrete design that induces stresses into the beam during casting. Traditional reinforced concrete beams combine the high tensile strength of steel with the compressive strength of concrete to construct a member that is strong in both tension and compression. This is accomplished by laying steel reinforcement bar into the concrete beam as it is cast. Prestressed concrete beams follow this same approach but the steel reinforcement is tied off at the ends and pulled to induce tension while the concrete is cast around it. This method of prestressing is known as pretensioning. Once the beam is cast for 24-96 hours, the reinforcement strands are released and compressive forces are induced in the beam. This causes a natural upward camber and allows the beam to withstand greater tensile forces in application. [3] The figure below demonstrates the technique of pretensioning.

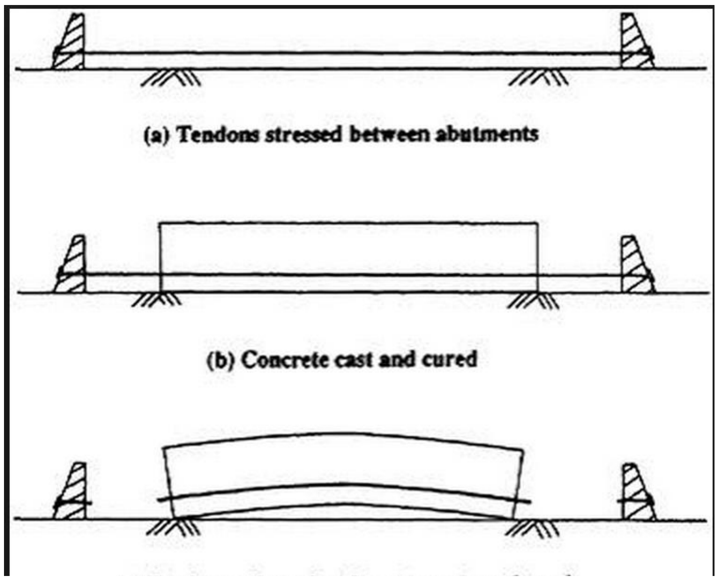

*Figure 1.1: **Pre-tensioning method of pre-stressed concrete. [4]***

The mix design, cross sectional shape, and reinforcement selection control the performance of a prestressed concrete beam. A mix design is the combination of water, air, cement, aggregate, and chemical add mixtures that are combined to form concrete. The contest standard for concrete mixes can be found in ASTM C33, D98, C494, C260, and C150. [2] These sections specify aggregate size and type, acceptable chemical adds, mineral adds, and Portland cement type. Concrete mix designs can be either lightweight concrete or normal weight concrete. While lightweight concrete yields can yield a higher strength per unit weight, it is costlier and the mix procedure is delicate due to the specific required water content and tendency for aggregate to separate from concrete [4]. The mix design of a concrete beam can affect deflection. Deflection is inversely proportional to the moment of inertia of the cross section and the modulus of elasticity of the concrete. As the moment of inertia and modulus of elasticity as increased, the beam can deflect further.

Moment of inertia can be increased by increasing the beam dimensions while the modulus of elasticity can be increased by selecting a mix design with higher compressive strength. The final mix decision will depend on the cost, availability, 28-day compressive strength, ultimate deflection and if it conforms to ASTM standards.

The second technical consideration for the PCI Big Beam is the cross sectional shape of the beam. Since TPAC will be manufacturing the beam, the team must consider cross sectional shapes that TPAC are able to produce. Therefore, the team must select from a rectangular, wide flange and 'T' shaped cross section. Traditionally, a rectangular beam is the simplest shape to cast but it uses excessive concrete and therefore has a high weight to strength ratio which is unfavorable. A rectangular beam cross section with steel reinforcement in the top and bottom of the shape can be seen in Figure 1.2. A second cross sectional shape that can be used is a wide flange beam, Figure 1.3. This cross section removes the unnecessary concrete under each side of the flange which conserves weight while not affecting deflection. This concrete is unnecessary because a wide flange beam's compression zone is only as deep as the top flange. Therefore, the web of the beam does not need to be as wide as the flange because the web does not offer compressive resistance. The web's width must only be thick enough to satisfy clear cover requirements that are laid out in the ACI 318-14: Building Code Requirements for Structural Concrete. The last cross sectional option that will be considered is a T-shaped beam, Figure 1.4. A 'T' shaped beam is commonly used when the amount of required tension reinforcement is small enough that a flange is not required to contain it. In this situation a wider web is used to contain the reinforcement rather than a lower web. However, clear cover requirements in the ACI 318-14: Building Code Requirements for Structural Concrete must be met.

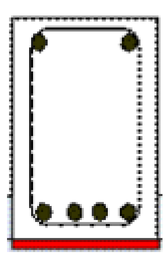

Figure 1.2: Rectangular Cross Section [5]

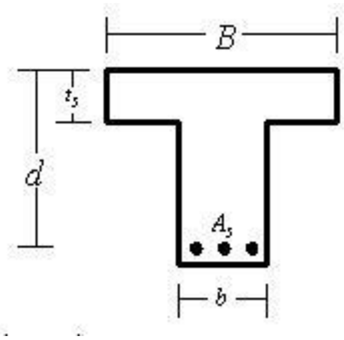

Figure 1.3: Wide Flange Cross Section [6]

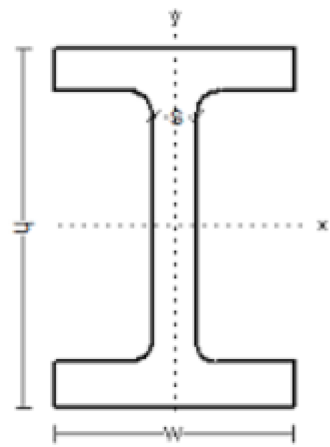

Figure 1.4: T' Cross Section [7]

Steel reinforcement is pretensioned in the concrete beam to provide tensile strength. In traditional reinforced concrete, standard reinforcement bar is used. It is placed before casting and the concrete forms around it. In prestressed concrete, smaller steel strands are used that allow for pretensioning. Rather than one cohesive steel rod, individual strands are woven together that can be pulled during concrete casting. In order to select placement of reinforcement, ACI 318-14 must be used to meet standard and MathCAD can be used as an analysis tool.

The last technical consideration is selecting a beam manufacturer that is a PCI Producer Member. The producer must supply all materials, manufacturing, transportation, and disposal for the beam. Therefore, a local manufacturer with adequate availability to accommodate our needs will be the most viable option. TPAC Kiewet Western Co. (TPAC) has been used in the past and remains a viable option.

1.4 Potential Challenges

As a team, NMDE Design Partners has identified a few potential challenges that could arise during the design, manufacturing and testing stages of the project. These include developing our understanding of reinforced concrete design, designing mixes and reinforcement, and confirming TPAC as a manufacturing partner. The greatest challenge for the team will be learning reinforced concrete design without any prior educational experience. This is a challenge because in order to accurately meet the design constraints of the contest, the team must understand the fundamentals of prestressed concrete and the steps to design a prestressed concrete beam. Secondly, NMDE does not have prior experience in designing concrete mix designs and prestressed reinforcement. This will be a challenge because mix design and reinforcement selection control the strength and deflection characteristics of the beam. Without an understanding of these concepts, the beam design will suffer. Thirdly, confirming TPAC as a manufacturing sponsor will be a potential challenge. Even though past teams have used TPAC, their schedule and material availability this year could affect their ability to manufacture our beam. Though the impact of our beam manufacturer will not affect project deadlines until January 2016, NMDE would like to have them confirmed as soon as possible.

1.5 Project Stakeholders

The project stakeholders are as follows:

1. Northern Arizona University: By representing NAU at the PCI contest, we our putting the engineering reputation of NAU up for review. fA strong performance could attract better funding, recognition, and an expanded student body while a poor performance will diminish NAU's reputation as an engineering institution.
2. Dr. Tuchscherer: Dr. Tuchscherer is the sole technical advisor for the project. Therefore, his reputation could be compromised. Though our performance doesn't directly reflect Dr. T's personal work, his name, and therefore reputation, will be associated with the project.

3. PCI Student Education Committee: PCI is a stakeholder in the project because every team performance is public and attracts engineers from the industry to evaluate the projects and teams. If PCI receives consistently strong, innovative projects it will improve the competition for future years and continue to attract young engineering talent.
4. TPAC Kiewet Western Co: TPAC is a stakeholder because they are the primary manufacturing sponsor. Because they are providing all materials, manufacturing and shipping they are representing themselves through our project. Additionally, they are investing time and money into our project that can only be compensated with a strong performance.
5. NMDE: We are representing our engineering education through this project. It is the culmination of many years of hard work, and the product should be very high quality. The design and competition results can be used on a resume and open up job opportunities post-graduation. It is in each of the team member's best interest to invest all the time and focus we have available to execute the best possible design.

2.0 Scope of Services

The scope details the tasks required to complete the PCI Big Beam Project.

2.1 Task 1.0: Beam Design

2.1.1 Sub-task 1.1: Mix Options

NDME will use the TPAC PCI Big Beam competition rules to develop criteria to compare different lightweight and normal weight concrete mix designs. The criteria in the PCI Big Beam Rules (Appendix A) will be used to select three potential mixes. A mix representing the lightest weight, highest deflection, and lowest cost option will be considered for the final selection. The final mix design will be selected after consulting TPAC.

2.1.2 Sub-task 1.2: Beam Cross Section Options

The NDME design team will identify four potential beam cross sections and will detail using AutoCAD. These cross sections will incorporate at minimum: two wide flange design options of varying dimensions and two 'T' beam design options of varying dimensions. A final cross section will be selected after weight, deflection and cost are calculated. The cross section demonstrating the best performance across these three criteria will be selected.

2.1.3 Sub-task 1.3: Reinforcement Options

Reinforcement options will be generated by reviewing the pre-stressed strands TPAC has available. Three pre-stressed reinforcement options will be selected from TPAC's suite of reinforcement options. Additionally, three different compressive reinforcement designs will be selected by comparing the increase in the ductility to the increase in the weight and cost of the beam. The three options which demonstrate the best deflection to cost and weight ratio will be selected for compressive reinforcement.

2.1.3 Sub-task 1.4: Optimize Beam

The design team will use the design options found in Sub-tasks 1.1-1.3 and optimize three potential beam designs. The three optimization criteria are greatest deflection, lowest cost, and lowest weight. Different combinations of mix design, reinforcement selection and cross sectional shape will be analyzed in MathCAD for deflection and flexural capacity. The predicted results will be tabulated in Excel along with cost and weight in order to compare quality of different beam design combinations. The three beam combinations with the highest cumulative performance from the three criteria of evaluation (weight, cost, and deflection) will be selected as a final design option.

2.1.3 Sub-task 1.5: Select Final Design

After the different combinations of mix, shape and reinforcement are optimized, the three highest performing designs will then be scored in accordance with the PCI Big Beam point distribution. These three final design options will be modeled in Response to determine a more accurate flexural capacity and deflection as compared to the Mathcad analysis. A final beam design will be selected based upon the results from Response and the PCI scoring requirements. The beam receiving the highest cumulative score in all categories will be selected.

Deliverables for Task 1.0 include submitting a final beam design and shop drawings to TPAC for manufacturing

2.2 Task 2.0: Beam Manufacturing

TPAC Kiewit Western is the sole manufacturing sponsor for this project. TPAC will be contacted by December 16, 2015 to confirm their availability to manufacture the beam during the spring semester. Once confirmation is received from TPAC, the final beam design will be sent to TPAC. NMDE requests to be present for beam manufacturing.

2.3 Task 3.0: Beam Testing

2.3.1 Sub-task 3.1: Testing

The beam will be tested for deflection, cracking moment, and ultimate flexural capacity. The testing will be conducted in NAU's concrete beam testing facility located in room 114 of Building 69. The beam will be tested by a machine called the 'Hulk" which is shown in Figure 2.1. Strain gauges, force gauges, and a video camera will be used to gather the relevant data to evaluate the properties of interest. Data from the gauges will be taken to determine the performance of the beam. The actual performance of the beam will be compared with NMDE’s predictions for scoring during the PCI competition. These results will be verified by Dr. Tuchscherer and submitted with the final report.

Figure 2.1 The Hulk

2.3.2 Sub-task 3.2: Safety Plan

Additionally, a testing safety plan will be produced two weeks prior to the testing date. The safety plan will be submitted to Dr. Tuchscherer for review to ensure it meet's NAU Safety Standards.

2.3.3 Sub-task 3.3: Beam Disposal

Due to the fact the beam will weigh close to 2000 pounds time will be needed to dispose of the beam after testing. The beam will be disposed of using the construction material dumpster located on the south east side of Building 69. Deliverables for Task 3.1 including recording the maximum deflection, load at cracking, and load at flexural failure. A video of the testing will also be recorded for submission to the PCI competition.

2.4 Task 4: Project Management

Project management for the PCI Big Beam Competition includes the following sections.

2.4.1 Sub-task 4.1: PCI Application Form

The competition application form will be completed and submitted to PCI. The application will identify the team members, the school being represented (Northern Arizona University), and the manufacturer (TPAC).

2.4.2 Sub-task 4.2: NAU Capstone Website

A NAU capstone website will be created that includes project information, project members and all information on the design process will be created.

2.4.3 Sub-task 4.3: Team Meetings

The team will meet twice a week for one hour for internal project management purposes during the months of January through April.

2.4.3 Sub-task 4.4: 50% Design Report

A 50% design report will be submitted to Dr. Bero on March 15, 2016.

2.4.3 Sub-task 4.5: Final Report

The final report will be delivered to PCI on or before May 5, 2016.

2.4.4 Sub-task 4.6: Final Presentation

The team will provide a final presentation of the project on April 29, 2016.

Deliverables for task 4 include completion and submittal of PCI competition application form, functional website, complete final report, and final presentation.

2.5 Exclusions:

Fabrication, manufacturing and shipping of the beam will be the responsibility of TPAC Kiewit Western.

3.0 Project Schedule

The project will start on October 16, 2015 and will be completed on May 5, 2016. Table 3.1: shows the tasks required to complete the project.

Table 3.1: PCI Big Beam Project Subtask

Task 1.0: Beam Design	**10/16/15**	**01/25/16**	**72d**
Sub-task 1.1: Mix Options	**10/16/15**	**12/18/15**	**46d**
Sub-task 1.2: Beam Cross Section Options	10/16/15	12/18/15	46d
Sub-task 1.3: Reinforcement Options	10/16/15	12/18/15	46d
Sub-task 1.4: Optimize Beam	11/19/15	01/18/16	43d
Sub-task 1.5: Select Final Design	01/18/16	01/25/16	6d
Task 2.0: Beam Manufacturing	**01/25/16**	**02/29/16**	**26d**
Task 3.0: Beam Testing	**03/01/16**	**03/11/16**	**9d**
Sub-task 3.1: Testing	03/01/16	03/04/16	4d
Sub-task 3.2 Safety Plan	03/01/16	03/04/16	4d
Sub-task 3.3: Beam Disposal	03/04/16	03/11/16	6d
Task 4.0: Project Management	**02/15/16**	**05/06/16**	**60d**
Sub-task 4.1: Application Form	04/18/16	05/06/16	15d
Sub-task 4.2: Website	02/29/16	03/04/16	5d
Sub-task 4.3: Team Meetings	05/02/16	05/02/16	1d
Sub-task 4.4: 50% Design Report	02/15/16	03/18/16	25d
Sub-task 4.5: Final Report	03/18/16	05/06/16	36d
Sub-task 4.6: Final Presentation	04/25/16	05/06/16	10d

Figure 3.1 shows a Gantt chart of the project schedule. The critical path for the project includes the design and manufacturing portions of the project. The design portion will take the greatest amount of time to complete and controls the progression of the rest of the project. The manufacturing will follow the design portion and is part of the critical path because due to TPACs availability, the manufacturing has the potential to hold up the project. The project schedule has been provided in Gantt chart form in Figure 3.1. The critical path of the project has been identified in red on Figure 3.1

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4.0 Staffing and Cost of Engineering Services

4.1 NMDE Qualifications

NMDE consists of Michael O'Reilly, Eman Albdiwyi, Deena Albustan, and Nick Jokerst, who are all Civil Engineering students at Northern Arizona University.

- Michael O'Reilly has worked as an intern at Devco Engineering. He has experience with structural engineering such as determining loading per code, seismic design, and deflection controlled design. Additionally, he has completed Structural Analysis I, Structural Analysis II, and is current taking Reinforced Concrete Design. This experience gives him the knowledge and experience to design a pre-stressed concrete beam in accordance with the PCI competition rules.
- Nick Jokerst has worked at W.L. Butler Construction. At W.L. Butler, Nick gained experience in project management and client relations as a project engineer. Additionally, Nick has successfully completed Structural Analysis I and is in Reinforced Concrete Design. These classes give Nick the theoretical background to design the beam for the TPAC competition.
- Deena Albustan has completed Mechanics of Materials and is currently taking Structural Analysis. Additionally, she is studying concrete design under Dr. Tuchscherer. This knowledge allows Deena to competently assist in a pre-stressed concrete beam design.
- Eman Albdiwyi has completed Structural Analysis I and she is currently taking Reinforced Concrete Design. Therefore, she is able to perform all the calculations required for designing the beam for the PCI competition.

4.2 Cost and Staffing Analysis

Table 4.1 shows the tasks for the project and the number of hours each personnel group will spend on the tasks. Table 4.2 shows total project cost. Overhead is incorporated into the salary line.

Table 4.1: PCI Big Beam Cumulative Hour Breakdown

PCI Big Beam Total Billable Hours				
Task	Hours SENG	Hours ENG	Hours AA	Hours INT
Task 1.0 Beam Design	**60**	**94**	**25**	**123**
Task 1.1 Deam Cross Sections	18	30	9	38
Task 1.2 Reinforcement Options	18	27	7	33
Task 1.3 Optimize Beam	9	22	7	40
Task 1.4 Select Final Design	15	15	2	12
Task 2.0 Beam Manufacturing	**12**	**15**	**3**	**22**
Task 3.0 Beam Testing	**22**	**30**	**15**	**37**
Task 4.0 Project Management	**59**	**30**	**52**	**15**
Total	**153**	**169**	**95**	**197**

SENG = Senior Engineer: A senior engineer is required to oversee the whole project and will provide experience to facilitate an efficient design and proposal.

ENG = Project Engineer: A project engineer is required to facilitate day-to-day tasks for team members. The ENG will also assist the intern with concrete analysis.

INT = Engineering Intern: An intern is required to perform fundamental analysis and produce CAD shop drawings throughout the project.

AA = Administrative Assistance: An administrative assistant is required to maintain communication with project stake holders and ensure the project proceeds according to the schedule.

Table 4.2 shows the overall cost for the design services required to complete the project and the associated travel costs. It can be seen below the estimated cost for the project will be $55,254.00.

Table 4.3: PCI Big Beam Project Cost.

Billing Breakdown Table				
Senior Engineer	$175			
Engineer	$75			
Administrative Assistant	$60			
Intern	$50			
1.0 Personnel	Classification	Hours	Rate $/hr	Cost
	SENG	153	175	$26,775.00
	ENG	169	75	$12,675.00
	AA	95	60	$5,700.00
	INT	197	50	$9,850.00
	Total			$55,000.00
2.0 Travel	2 trips to Phoenix @286 mi/trip	$0.56 [1]		$254.00
4.0 Total				$55,254.00

References:

1. About Precast. (2014, February). Retrieved October 5, 2015, from http://www.pci.org/Design_Resources/Precast_Components/About_Precast/
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Appendix

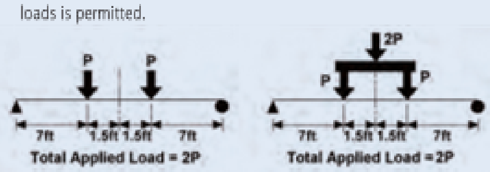
Appendix A: PCI Big Beam Competition Rules

THE BIG BEAM

1) The beam must be tested as a simply supported span of 17 feet, center to center of bearing. It cannot be longer than 19 feet overall. It may have any cross sectional shape but the top surface must be flat and horizontal along the entire span.

2) The beam shall be designed for dead load plus TWO applied service (UNFACTORED) live loads of 10 kips (i.e in equations 9-1 through 9-7 in ACI 318-11 L = 10 kips each). This corresponds to factored live loads of 16 kips at each loading point. The beam must not crack under service live load of 10 kips at each point (20 kips total service live load).

3) The beam shall be loaded by applying two point loads, symmetrically, 7 feet from the center of each support (= 1.5 ft on either side of mid-span) as shown. The loading mechanism must apply the loads equally at both points. Use of a single jack and a spreader beam to create two loads is permitted.



PERMITTED LOAD CONFIGURATIONS

4) Bearing pads and/or bearing plates, not exceeding 6" in length (along the span) may be used at supports and/or under the load.

5) The load may be measured at each point or, if a spreader beam is used, the total load applied to the spreader beam may be measured. Report load as the TOTAL applied load (sum of two point loads). Midspan deflection must be measured.

6) The beam must resist load primarily through flexure. **Trusses, arches and other non-flexural members are prohibited.**

7) The beam must be made primarily of concrete – cement, coarse aggregates, fine aggregates and water. Pozzolans, fibers, lightweight aggregates and admixtures are permitted. UHPC as defined in publication FHWA-HRT-11-038 is permitted.

8) Longitudinal tension reinforcing shall be pretensioned and/or post-tensioned. Nonprestressed or prestressed top steel is allowed. Embedded or partially embedded steel sections are not allowed. Bar or mesh may be used for shear reinforcement. Reinforcement must be completely embedded in the beam and meet applicable spacing and cover requirements.

9) All materials must be commercially available. No experimental materials. Steel plates may be used as bearing plates and/or as anchorage plates for post-tensioning steel only. Steel plate may not be used as any type of reinforcement or for confinement.

10) All entries must meet the provisions of ACI-318-11 or the 7th Edition of the PCI Design Handbook for a precast/prestressed beam, interior exposure. International entries must meet the equivalent specifications for their country and must state which specification was used.

11) Entries which, in the opinion of the judges, are obviously impractical, an attempt to circumvent the rules or are of very poor quality may be disqualified.

12) If an entry fails to meet some aspect of the rules, the judges may, at their option:

   a. Disqualify the entry entirely

   b. Allow the entry to stand, but award "0" points in the categories where the violation occurred

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 must be able to carry at least a total factored live load of 32 kips and must not have a total peak applied load of more than 40 kips. The beam shall not crack under the total applied service load of 20 kips. Total applied load is defined as the sum of the two applied point loads. Beams meeting these criteria receive 20 points.

Beams that do NOT carry a total applied load of at least 32 kips shall be penalized 2 points for each kip, or part of a kip, below 32 kips.

Beams that carry a total applied load of more than 40 kips shall be penalized 1 point for each kip, or part of a kip, above 40 kips.

Beams that crack before a total applied load of 20 kips will receive a 5 point penalty.

The load-midspan deflection graph must show the peak load either by post-peak softening or by collapse of the beam. Stopping the test to avoid the overstrength penalty will result in a score of 0 for this category.

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.

For judging categories 2 -4, the values of the best and worst performance in that category will be identified. Points, rounded down, are awarded based on:

Points = 10*(value in entry – worst value)/(best value-worst value)

In category 5 (most accurate calculations) entries receive points based on the following scale:

Less than 10% = 10 points;
Deduct 1 point for each 10% increment above 10% rounded UP to the nearest 10% (e.g. 25% is rounded to 30% and receives 8 points).
Above 110% receives 0 points.

In category 6, the judges will award 0-5 points for the quality of the report. In category 7, the judges will award 0-5 points for practicality, innovation, compliance with the applicable code and demonstration of good engineering judgment. For any category, no entry can receive less than "0".

Prizes shall be awarded based on total points. In the event of a tie in total score, the value of the load closest to, but exceeding, the target total load (32 kips) shall be used to break the tie. If the tie is not broken by this method, the prizes for the tied positions shall be combined and split equally.

MATERIAL COSTS AND BEAM WEIGHT

The following unit cost shall be used to determine the beam cost. Concrete cost is based on actual strength, not design strength.

Material	Cost	Notes/Instructions
Concrete	$100/cu yd	Using gross section geometry.
High-Strength Concrete	$120/cu yd	Defined as $f_c' \geq 10$ ksi.
Fiber-Reinforced Concrete	$110/cu yd	
UHPC	$400/CU YD	
Lightweight Concrete		Add $10/cu yd to the concrete cost.
Prestressing Strand:		Use estimated lengths used in the beam.
⅜ in. diameter	$0.17/ft	
½ in. diameter	$0.30/ft	
½ in. special	$0.32/ft	
0.6 in. diameter	$0.42/ft	
0.7 in. diameter	$0.55/ft	
Steel:		Use estimated lengths and nominal unit weights in this calculation as provided in the PCI Design Handbook
A615/A706	$0.45/lb	
Welded wire (deformed or smooth; for shear)	$0.50/lb	
Epoxy Coated	$0.50/lb	
A1035	$0.70/lb	
Plate steel	$.055/lb	
Forming	$1.25/ square foot of formwork	

There is no need to include cost of steel fabrication, concrete fabrication, curing, inserts, etc. Concrete cost is based on actual strength.

The beam weight shall be estimated by using the measured unit weight of the concrete or by actually weighing the beam. If the beam weight is estimated, it is estimated based on the gross concrete cross section only, ignoring reinforcing, bearing plates, etc.