PCI Big Beam Competition

2024 - 2025

CENE 476 Project Proposal

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Final Proposal

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Table 1-1: List of Abbreviations

Variable/Abbreviation	Meaning
ACI	American Concrete Institution
ASTM	ASTM International, (formerly known as American Society for Testing and Materials)
CENE	Civil and Environmental Engineering
GI	Grading Instructor
INT	Engineering Intern
LT	Lab Technician
NAU	Northern Arizona University
PCI	Precast/Prestressed Concrete Institute
SENG	Senior Engineer
STE	Structural Engineer
TA	Technical Advisor
Tpac	Precast/prestressed concrete manufacturing company located in Phoenix, Arizona; an EnCon United Company

1.0 Project Understanding

1.1 Project Purpose

The Precast/Prestressed Concrete Institute (PCI) Big Beam Competition [1] involves student teams designing and overseeing the manufacturing of a precast and prestressed 18-foot concrete beam [2]. This project's focus is the design and analysis of the beam's structural integrity. This will be done by testing the beam until failure to compare predicted failure to actual failure. The end goal of the project is to create the most accurate prediction, lightest weight, and largest deflection of the beam within the parameters provided by PCI. Tpac is the team's manufacturer, and the team will work to develop and maintain a professional working relationship with them.

1.2 Project Background

1.2.1 NAU involvement

Northern Arizona University (NAU) has participated in the PCI Big Beam Competition since 2012. In 2021 and 2018, NAU's PCI Big Beam competitors placed second overall, with the 2018 team winning best report. NAU has also placed in the top five competition teams six times since 2012 [3]. The PCI Big Beam Competition typically serves as a capstone senior design project for the student participants.

Dr. Benjamin Dymond, a professor at NAU, will teach a condensed prestressed concrete class that will be useful in preparing the team for beam design work. NAU's Civil Engineering program (CENE) also provides lab access to store and test the concrete beam.

1.2.2 PCI Big Beam Competition

PCI is a professional organization that guides national design standards for precast and prestressed concrete beams [4]. The PCI Student Education Committee hosts the Big Beam Competition that involves student teams creating a technical design of an 18-foot precast/prestressed concrete beam [2]. This is a nationwide design competition [1].

1.3 Technical Considerations

1.3.1 Prestressed Concrete Beams

This competition will require the team to learn about designing prestressed concrete beams. The general process of their fabrication is that prestressing tendons are pulled taut (tensioning) prior to casting a concrete beam inside the formwork. After the concrete hardens, the tendons are cut and the beam is pre-compressed, which allows the beam to better resist tensile stresses (that cause cracking) during its service life [5].

1.3.2 Structural Design

The PCI Design Handbook [6], American Concrete Institute (ACI) 318-19 Building Code [7], and the expertise of Dr. Dymond will be important in helping the team design a beam that can withstand loading until the loading reaches the desired flexural cracking load and ultimate failure load (specified by the competition) [2]. The competition considers both strength and calculated prediction accuracy as part of a team's total score in the judging process.

1.3.3 Concrete Mix Design

This project will involve learning about concrete mixes as the team must explain the thought process for the mix design selection and any modifications made to the concrete mix. Concrete mixes balance factors such as weight, cure time, workability, and strength when hardened, etc. The prestressed tendons can be cut after 16 hours of the concrete being poured. This time period allows the concrete to reach its required strength to handle the recoil of the tendons being cut.

1.3.4 Testing

The team must know how to test both the beam, and any test cylinders created using proper ASTM International guidelines to increase the accuracy of the team's predicted results. The team will study the prestressed beam and test setup in the CENE Concrete and Material Labs to understand how last year's Big Beam team loaded their beam.

1.4 Potential Challenges

1.4.1 Transportation of Fabricated Beam

Transporting the finished precast beam from Tpac in Phoenix, Arizona to NAU in Flagstaff, Arizona introduces risks, including accidental damage, improper handling, and additional stresses that may cause the beam to crack. These issues can impact the beam's structural integrity before testing.

To mitigate this, it is essential to ensure stringent handling protocols during transportation, proper bracing of the beam, and appropriate transportation methods are chosen and followed to minimize the risk of damage. Once the beam arrives at NAU, the team must work with forklift operators and other NAU equipment to ensure that the beam is properly and safely supported on wooden blocks rather than directly on hard surfaces.

1.4.2 Time Constraints

Any delays in fabrication, transportation, or setup could push back the testing schedule. This would leave less time for necessary adjustments or further analysis. Building in buffer time and maintaining regular communication with all parties will help mitigate this risk and keep the project on track. Additionally, clear documentation and thorough design will minimize the risk of errors during fabrication.

1.5 Stakeholders

The stakeholders in this project are the project team, Tpac, Dr. Benjamin Dymond, PCI, and NAU. The project team will be responsible for designing, testing, and coordinating the logistics of creating the concrete beam to serve as the team's capstone project. Tpac is the company that will be donating time and materials towards this project, including fabrication of the beam, expertise related to materials and design, concrete materials, and employee time during fabrication. Tpac will also donate time, money, and transportation services to ship the beam from Phoenix to Flagstaff. Dr. Dymond is the technical advisor for this project and will help guide the team with technical expertise, support, feedback, and learning opportunities via a compressed prestressed concrete class. PCI is the competition organizer who will provide the rules, guidelines, and criteria for the competition. NAU is a stakeholder for this project since they will be providing lab access and resources; NAU's reputation also benefits based on the success of the team.

2.0 Scope of Services

2.1 Task 1: Prestressed Concrete Education

2.1.1 Task 1.1: Prestressed Concrete Background

The team will be introduced to the fundamentals of prestressed concrete in reinforced concrete beams through lessons taught by Dr. Dymond. These one-hour not-for-credit sessions will cover the basics of prestressed concrete designs and analysis, with a timeline of approximately ten weeks; the weekly sessions are scheduled for Wednesday mornings from 8-9 am. These lessons start September 25, 2024, and will end November 27, 2024.

Dr. Dymond will also train the team in how to use the software Mathcad [8], which enables efficient mathematical modeling, repetition, and cyclic design in an easy-to-see layout. This software will serve as a fundamental tool for various calculations and analyses needed during the project's progression. The beam will be designed and optimized in Mathcad. This is a free software with a 30-day trial of premium features.

2.1.2 Task 1.2: Competition Research

In order to simplify the iterative design process, a spreadsheet of features of past competitors will be compiled and analyzed to determine common features that work well across many design loads. The team will also submit an online interest form to register for the PCI Big Beam competition.

2.2 Task 2: Concrete Mix Selection

2.2.1 Task 2.1: Concrete Mix Research

Concrete mix research involves exploring various concrete mixtures that comply with the PCI Big Beam Competition rules and that can be made at Tpac. The focus is on identifying suitable combinations of cement, aggregates, water, and permissible admixtures or pozzolans to achieve the required performance criteria. The team will gather data on material availability, standard testing data of potential mixes, their properties to guide the final selection, which will be coordinated with Tpac.

2.2.2 Taks 2.2: Concrete Mix Analysis

Concrete mix analysis consists of evaluating the proportions and performance characteristics of different concrete mixes, such as unit weight, slump, air content, and compressive/tensile strengths at 28 days. This involves analyzing mixture data supplied by Tpac and potentially testing the performance of one or more mixture designs at NAU to ensure that it meets the team's structural and performance requirements.

2.2.3 Task 2.3: Final Concrete Mix Selection

The optimal concrete mix will be chosen based on performance data, compliance with the PCI Big Beam rules, and the ability of industry sponsor Tpac to make the mixture at their batching plant. A decision matrix using criteria such as the mixture's strength, workability, and compatibility with design specifications will be developed in order to select the optimal mix. The selected mix will support the team's design goals while ensuring the beam performs well during testing.

2.3 Task 3: Preliminary Beam Design

An iterative design process will be used to design the beam using the Mathcad calculation file developed in Task 1.1: Prestressed Concrete Background. This process first will consider multiple cross sections and reinforcement combinations, followed by the analysis of each regarding failure modes. As analysis results are obtained, beam cross section and reinforcement combinations will be eliminated, added, or modified. These new combinations will then be analyzed. This process will be repeated until there are at least three optimized designs.

Analysis for the beam's cross section will consider weight, cost, amount of formwork required, and ability to be fabricated by Tpac. The beam will be internally reinforced with both steel bar reinforcement and steel prestressing strand reinforcement. The PCI rules for this year have specified five different reinforcing bar sizes and five different prestressing strand types that can be used [2]. Additionally, steel stirrup reinforcement will be placed throughout the beam length to neutralize shear forces to ensure the beam fails in flexure as required by the competition. Analysis for reinforcement will consider material type, size, and placement within the beam.

Analysis will consider two flexural failure limits as specified in the rules [2]. The beam must crack in bending (flexure) after a threshold of 20 kips applied load and fail within the range of 32-40 kips applied load.

Midspan deflection also will be predicted throughout the iterative design of the beam. Considering the competition rules, it is favorable to have a large amount of deflection, which can be more easily achieved with some cross sections compared to others. The analysis will consider additional competition design rules to ensure that all design alternatives meet competition requirements.

2.4 Task 4: Final Design

2.4.1 Task 4.1: Design Decision Matrix

A weighted decision matrix will be used to select the final design out of the three alternatives developed in Task 3: Preliminary Beam Design. The weighted decision matrix will consider competition rules and project goals. Criteria may include design accuracy, lowest cost, lowest weight, largest midspan deflection, practicality, innovation, and code compliance.

2.4.2 Task 4.2: Final Design Selection

Using the weighted decision matrix, a final design will be selected.

2.4.3 Task 4.3: Final Design Calculations

Using the Mathcad calculation file developed in Task 1.1: Prestressed Concrete Background, structural calculations for the final design will be refined and finalized, considering the dimensions and materials that are appropriate for fabrication at Tpac. These calculations will be used to accurately predict total applied cracking load, total applied load at failure, and maximum midspan deflection at the total applied load. This must be done before the beam is fabricated and tested.

2.5 Task 5: Shop Drawings

2.5.1 Task 5.1: NAU AutoCAD Drawings

Once the final design is selected, detailed AutoCAD drawings that indicate how the beam should be fabricated will be created. These drawings will include items such as final dimensions, materials selected for the concrete and steel reinforcement, and locations of all the reinforcement relative to the beam cross section.

2.5.2 Task 5.2: Coordination with Tpac for Shop Drawings

The completed AutoCAD drawings will be sent to Tpac to ensure they are able to fabricate the beam. Tpac will recreate the NAU AutoCAD drawings as in-house shop drawings and piece drawings, which are used by Tpac to fabricate the beam. Tpac will send their finalized shop drawings to the NAU team for verification, to ensure they align with the final design. The team will coordinate with Tpac to identify any issues and confirm that the final design is correct and ready for fabrication.

2.6 Task 6: Beam Manufacture

2.6.1 Task 6.1: Test Cylinder Fabrication

At the time of beam fabrication, test cylinders of the concrete used will be poured and cured in the same way as the beam. This will allow testing for compressive and tensile strength prior to Big Beam testing, which will improve the accuracy of the predicted results.

2.6.2 Task 6.2: Beam Fabrication

At least one of the team members will be at the Tpac plant to document fabrication of the beam. The attendees will observe, take photos, and record footage for the competition video.

2.6.3 Task 6.3: Shipment of Beam

Tpac will ship the beam from their facilities in Phoenix, Arizona to Flagstaff, Arizona. The beam can be shipped between 24 and 72 hours after manufacturing.

2.6.4 Task 6.4: Transportation of Beam Inside Lab Facilities

Once the beam arrives in Flagstaff, Arizona, the team will supervise moving the beam into the CENE Concrete and Materials Lab. The specific materials, methods, and time required to move the beam will depend on the weight of the beam and the availability of Lab Manger, Dr. Adam Bringhurst, and faculty member, Dr. Benjamin Dymond.

2.7 Task 7: Testing

2.7.1 Task 7.1: Lab Access

A Lab Binder will be created as required by the CENE programs for lab access. This binder will contain the following information.

- Project and team information
- Initial Project Plan that contains information such as planned laboratory activities, hazard and risk identification, waste generation and disposal plans, safety protocols, and training.
- Emergency Response Plan
- Safety training documentation and lab agreements
- Project activity log

2.7.2 Task 7.2: Setup of Beam and Instrumentation

Lab Manager, Dr. Adam Bringhurst and faculty member, Dr. Benjamin Dymond will assist in the setup of the Big Beam in accordance with PCI rules. This will include placing the beam on pin and roller supports, aligning the applied load to match the pattern specified in the rules, placing two hydraulic jacks and a spreader beam on top of the Big Beam, placing load cells in-line to measure applied load, and placing a linear displacement transducer under the beam at midspan to measure the deflection during testing.

2.7.3 Task 7.3: Cylinder Testing and Failure Predictions

Per the PCI Big Beam Competition rules, the tensile strength of the cylinders will be determined as described in ASTM C78 or C496. The compressive strength of the cylinders will be determined as described in ASTM C39. Based upon cylinder testing, the estimated failure predictions will be revised. The PCI Big Beam Competition is judged partially based on the accuracy of the predictions compared to the measured cracking load, failure load, and midspan deflection.

The competition requires the submittal of final calculations predicting the cracking load, maximum applied load, and midspan deflection at maximum load to Tpac prior to testing for validation. After modifications made to the calculations from the cylinder tests, predicted results will be sent to Tpac, who will affirm that the predictions were made prior to testing [2].

2.7.4 Task 7.4: Testing the Big Beam and Documenting Behavior

The PCI Big Beam Competition designates a load pattern that will be applied until the beam fails. Maximum total applied load, total applied cracking load, and midspan deflection at maximum total applied load will be measured. A load/midspan deflection graph showing the peak load and cracking load is also required. The load test will be documented with a video.

2.8 Task 8: Analysis of Results and Comparison to Predicted Failure

The team will analyze the results and compare the actual results to the predicted failure. Competition performance is partially based on the accuracy of predictions.

2.9 Task 9: Cost of Implementation

The PCI Big Beam Competition is partially judged based on the lowest beam cost. The cost of the final design will be determined using the material prices outlined in the PCI rules. Cost calculations must be submitted as part of the competition and final report.

2.10 Task 10: Project Impacts

The social, environmental, and economic impacts of the project will be discussed.

2.11 Task 11: Deliverables

2.11.1 Task 11.1: 30% Submittal

This submittal includes a 30% report and presentation Task 1: Prestressed Concrete Education through Task 5: Shop Drawings will be completed for this deliverable.

2.11.2 Task 11.2: 60% Submittal

This submittal includes a 60% report and presentation. Task 6: Beam Manufacture through Task 7.2: Setup of Beam and Instrumentation will be completed for this deliverable.

2.11.3 Task 11.3: 90% Submittal

This submittal includes a 90% report and a 90% website to present project information including a short video showcasing the entire project’s process. All technical tasks will be completed for this deliverable.

2.11.4 Task 11.4: Final Submittal

This submittal includes a report, a final website, and a final presentation.

2.11.5 Task 11.5: PCI Big Beam Competition Submittal

This submittal includes a report and competition video per the PCI Big Beam Competition rules [2]. The final report may need to be edited in order to meet the specifications of the competition. All tasks will be completed by the due date of May 9, 2025 which marks the end of the project.

2.12 Task 12: Project Management

2.12.1 Task 12.1: Resource Management

Resource management includes tracking team hours, budget tracking, and managing communication between the client, GI, TA and team. An agenda will be created 24 hours before any meeting; meeting minutes will be drafted within 24 hours of any meeting. Agendas and minutes will be documented in a Memo Binder.

2.12.2 Task 12.2: Schedule Management

Weekly team meetings will occur to ensure that the project is on track and that deadlines/deliverables are met.

2.13 Exclusions

Specific proportions of the concrete mix will not be determined; either Tpac's normal weight or lightweight concrete mixes will be used per specifications and competition rules [2]. Tpac will manufacture and ship the beam. The project team is not responsible for the disposal of the beam, although the team will work with Tpac to determine if the previous year's beam can be sent back to Tpac.

3.0 Schedule

3.1 Schedule Overview

The project will start on September 25, 2024 and be completed on May 09, 2025.

The schedule is shown on a Gantt Chart in Appendix A: Project Schedule. Table 3-1 summarizes the major tasks and their start and completion dates.

Table 3-1: Major Task Start and End Dates

Task	Task Name	Start	Finish
Task 1	Prestressed Concrete Education	09/25/24	11/27/24
Task 2	Concrete Mixture Design	11/04/25	11/22/25
Task 3	Preliminary Beam Design	11/28/24	01/17/25
Task 4	Final Design	01/20/25	01/24/25
Task 5	Shop Drawings	01/24/25	02/07/25
Task 6	Manufacturing of Beam	02/10/25	02/21/25
Task 7	Testing	10/17/24*	03/21/25
Task 8	Analysis of Results and Comparison to Predicted Failure	03/24/25	04/04/25
Task 9	Cost of Implementation	04/07/25	04/11/25
Task 10	Project Impacts	04/07/25	04/18/25
Task 11	Deliverables	09/25/24	05/09/25

Task	Task Name	Start	Finish
Task 12	Project Management	09/25/25	05/09/25
*Excluding Task 7.1 Lab Access (10/17/24 through 11/27/25), the start date of Task 7 is 2/24/25			

The total duration of the project is 163 days.

Although the competition closes on June 13, 2025, the project will be completed before the NAU spring semester ends on May 09, 2025. The project schedule reflects this, and all tasks are due to be completed on or prior to this date.

3.2 Critical Path

The critical path consists of tasks that are interdependent, meaning each task relies on the completion of the previous one to proceed. Since any delay in these tasks will directly affect the following ones and thereby the project schedule. The critical path is highlighted in yellow on the Gantt Chart in Appendix A: Project Schedule.

The first task on the critical path is Task 1: Prestressed Concrete Education, which is crucial to setting up calculations and learning what is necessary to design a prestressed concrete beam.

Task 2: Concrete Mix Selection determines the concrete mix to be used. This also has to be done before the next task, Task 3: Preliminary Beam Design, so that the iterative design process can be completed.

The completion of this task allows for the selection of the final design, which will be made in Task 4: Final Design. Task 5: Shop Drawings requires the final design in order to coordinate the fabrication process with Tpac.

The completion of all prior tasks is required to complete Task 7: Testing. The results from the test will then be compared to the team's prediction in Task 8: Analysis of Results and Comparison to Predicted Failure. Task 9: Cost of Implementation requires the measured strength of the Big Beam in order to price it correctly according to the rules [2].

Task 10: Project Impacts requires all previous tasks to be completed in order to properly analyze the social, economic, and environmental impacts. Task 11: Deliverables will be worked on throughout the project and requires information obtained throughout the other tasks to complete.

To ensure these tasks stay on track and finish by their planned dates, weekly meetings will be conducted. During these meetings, the team will review the current schedule, discuss progress, and outline what needs to be completed before the next meeting. This approach promotes accountability, allows for early detection of potential delays, and enables adjustments to keep the project on schedule.

4.0 Staffing Plan

4.1 Positions and Qualifications

The staffing positions needed to complete the project include a Structural Engineer (STE), a Senior Engineer (SENG), an Engineering Intern (INT), and a Lab Technician (LT).

Structural Engineer (STE):

The structural engineer must have a bachelor's degree in civil or structural engineering and have passed the Fundamentals of Engineering (FE) and Professional Engineer (PE) exam to obtain their license in structural engineering. The structural engineer should have experience in designing structural elements, an understanding of engineering principles, and proficiency in structural analysis software.

Senior Engineer (SENG)

The senior engineer must have a bachelor's degree in civil engineering and have passed the FE and PE exams in civil engineering, structural engineering, or a similar field. They must also have at least ten to fifteen years of experience as a licensed PE.

Engineering Intern (INT)

The engineering intern should be currently enrolled or graduated from an engineering program. The intern should have some experience with related engineering work and projects as well as a GED or high school diploma.

Lab Technician (LT)

The lab technician must have a GED or high school diploma, and ideally, a relevant degree in civil engineering technology or chemistry. Additionally, they must have at least two years of expertise testing materials, ideally in the building or cement industry.

4.2 Staffing Plan

Table 4-1 shows the estimated contribution of time for each position towards each task listed in 2.0 Scope of Services].

Table 4-1: Summary of Staffing by Position

Task No.	Task Name	SENG	INT	STE	LT	Total
Task 1	**Prestressed Concrete Education**	-	-	-	-	-
Task 1.1	Prestressed Concrete Research		103.5			103.5
Task 1.2	Competition Research		30			30
Task 2	**Concrete Mixture Design**	-	-	-	-	-
Task 2.1	Concrete Mix Research		10			10

Task No.		Task Name	SENG	INT	STE	LT	Total
	Task 2.2	Concrete Mix Analysis		10			10
	Task 2.3	Concrete Mix Selection	4	6			10
Task 3		**Preliminary Beam Design**		37	74		111
Task 4		**Final Design**	-	-	-	-	-
	Task 4.1	Design Decision Matrix	2	2	4		8
	Task 4.2	Final Design Selection	4	4	8		16
	Task 4.3	Final Design Calculations	8	8	16		32
Task 5		**Shop Drawings**	-	-	-	-	-
	Task 5.1	NAU AutoCAD Drawings	4	28			32
	Task 5.2	Coordination with Tpac Shop Drawings	2	4			6
Task 6		**Beam Manufacture**	-	-	-	-	-
	Task 6.1	Test Cylinder Fabrication			12		12
	Task 6.2	Beam Fabrication			12		12
	Task 6.3	Shipment of Beam					
	Task 6.4	Transportation of Beam Inside Lab Facilities				4	4
Task 7		**Testing**	-	-	-	-	-
	Task 7.1	Lab Access	3	6		3	12
	Task 7.2	Setup of Beam and Instrumentation	3	6		3	12
	Task 7.3	Cylinder Testing & Failure Prediction	5	10		5	20
	Task 7.4	Testing the Big Beam and Documenting Behavior	3	6		3	12
Task 8		**Analysis of Results and Comparison to Prediction Failure**	4	8			12
Task 9		**Cost of Implementation**	4				4
Task 10		**Project Impacts**	4				4
Task 11		**Deliverables**	-	-	-	-	-
	Task 11.1	30% submittal	8	24			32
	Task 11.2	60% submittal	8	24			32
	Task 11.3	90% submittal	8	24			32
	Task 11.4	Final submittal	8	24			32

Task No.	Task Name	SENG	INT	STE	LT	Total
Task 11.5	Website	8	24			32
Task 12	**Project Management**	-	-	-	-	-
Task 12.1	Resource Management	3	3	3	3	12
Task 12.2	Schedule Management	16	16	16	16	64
Total Hours		109	417.5	145	37	708.5

5.0 Costs of Engineering Services

The total cost of engineering services is $86,959 and includes personnel, travel expenses, supplies, and subcontracting fees. Personnel costs are calculated based on the total hours worked and the billing rate for each position throughout the project. Travel expenses include one day trip to Tpac in Phoenix, AZ to observe the pouring of the Big Beam. Supply costs are influenced by the lab equipment and software required for concrete analysis and creating shop drawings for the beam design. Specifically, the Materials Lab and the Concrete Lab will be utilized. Subcontracting fees reflect the work performed by Tpac to fabricate and ship the PCI Big Beam.

Table 5-1 shows a detailed breakdown and justification for personnel, travel, supplies, and subcontractor costs.

Table 5-1: Estimated Cost of Engineering Services

1.0 Personnel	**Classification**	**Rate/Hour ($)**		**Hours**	**Cost ($)**
1.0 Personnel	SENG	247		109	26,923
1.0 Personnel	INT	59		418	24,662
1.0 Personnel	STE	130		145	18,850
1.0 Personnel	LT	63		37	2,331
1.0 Personnel	**Total Personnel Cost**				**72,766**
2.0 Travel	**Classification**	**Billing Rate**	**Units**	**Miles**	**Cost ($)**
2.0 Travel	1-day Car Rental for Tpac Visit	77	$	--	77
2.0 Travel	Miles	0.4	$/mile	288	115
2.0 Travel	**Total Travel Cost**				**192**
3.0 Supplies	**Classification**	**Rate/Day ($)**		**Days**	**Cost ($)**
3.0 Supplies	Lab Rental	100		5	500
3.0 Supplies	**Total Supplies Cost**				**500**
4.0 Subcontractors	**Classification**	**Rate/Hour ($)**		**Hours**	**Cost ($)**
4.0 Subcontractors	Beam Materials & Fabrication	--		--	9,000

	Dr. Dymond Lessons and Advising	200	20	4,000
	Total Subcontractors Cost			**10,500**
Total Cost of Engineering Services				**86,958**

6.0 References

[1] PCI, "PCI Big Beam Competition," [Online]. Available: https://www.pci.org/PCI/PCI/Education/Student_Competitions.aspx.

[2] PCI, "2024-2025 Big Beam Rules," 2024-2025. [Online]. Available: https://www.pci.org/PCI/PCI/Education/Student_Competitions.aspx.

[3] *PCI Big Beam Top 10 Competition Banners from 2012 - 2023 in Engineering Building (#69), 1st Floor, NAU Campus,* Flagstaff, Arizona, 2024.

[4] PCI, "Precast/Prestressed Concrete Institute "About Us" Page," [Online]. Available: https://www.pci.org/PCI/PCI/About/About_PCI.aspx?hkey=e4f4b6a5-5aa4-40d8-a291-c787dc6d4b80&hkey=4e3a5f0e-d2e2-4222-af25-8b2e5afe4a20.

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[6] P. C. I. (PCI), "PCI Design Handbook (MNL120-17)," 2027.

[7] American Concrete Institute (ACI), "Building Code Requirements for Structural Concrete (ACI 318-19)," 2019.

[8] PTC, "MathCAD Prime 10," PTC.

[9] ASTM International, "ASTM C78-09: Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)," ASTM International, 31 December 2010. [Online].

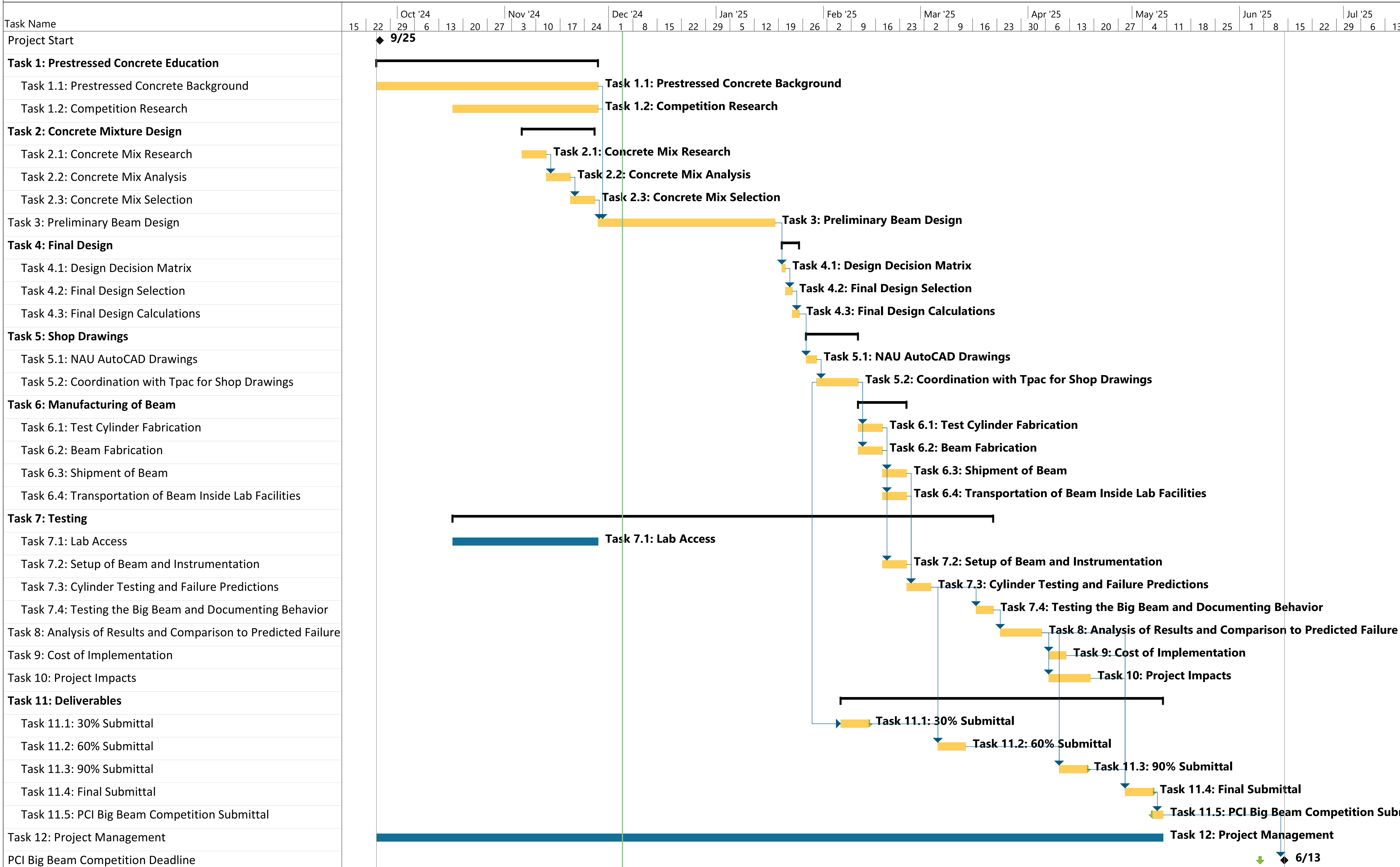
[10] ASTM International, "ASTM C496/C496M-17: Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens," 2 November 2017. [Online].

7.0 Appendices

Appendix A: Project Schedule

The Gantt Chart schedule is located on the following page.

Appendix A: Project Schedule



Appendix B: Staffing

Table 7-1: Staffing by Position and Task

Task No.		Task Name	SENG	INT	STE	LT	Total
Task 1		**Prestressed Concrete Education**	--	--	--	--	--
	Task 1.1	Prestressed Concrete Research	0	103.5	0	0	103.5
	Task 1.2	Competition Research	0	30	0	0	30
Task 2		**Concrete Mixture Design**	--	--	--	--	--
	Task 2.1	Concrete Mix Research	0	10	0	0	10
	Task 2.2	Concrete Mix Analysis	0	10	0	0	10
	Task 2.3	Concrete Mix Selection	0	10	0	0	10
Task 3		**Preliminary Beam Design**	0	37	74	0	111
Task 4		**Final Design**	--	--	--	--	--
	Task 4.1	Design Decision Matrix	4	4	8	0	16
	Task 4.2	Final Design Selection	8	8	16	0	32
	Task 4.3	Final Design Calculations	8	8	16	0	32
Task 5		**Shop Drawings**	--	--	--	--	--
	Task 5.1	NAU AutoCAD Drawings	0	0	32	0	32
	Task 5.2	Coordination with Tpac Shop Drawings	0	0	6	0	6
Task 6		**Beam Manufacture**	--	--	--	--	--
	Task 6.1	Test Cylinder Fabrication	0	0	12	0	12
	Task 6.2	Beam Fabrication	0	0	12	0	12
	Task 6.3	Shipment of Beam	0	0	0	0	
	Task 6.4	Transportation of Beam Inside Lab Facilities	0	0	0	16	16
Task 7		**Testing**	--	--	--	--	--
	Task 7.1	Lab Access	0	0	0	12	12
	Task 7.2	Setup of Beam and Instrumentation	0	0	0	12	12
	Task 7.3	Cylinder Testing & Failure Prediction	0	0	0	20	20
	Task 7.4	Testing the Big Beam and Documenting Behavior	0	0	0	12	12
Task 8		**Analysis of Results and Comparison to Prediction Failure**	**0**	0	0	12	12
Task 9		**Cost of Implementation**	4	0	0	0	4
Task 10		**Project Impacts**	4	0	0	0	4
Task 11		**Deliverables**	--	--	--	--	--
	Task 11.1	30% submittal	12	36	0	0	48
	Task 11.2	60% submittal	12	36	0	0	48
	Task 11.3	90% submittal	12	36	0	0	48
	Task 11.4	Final submittal	12	36	0	0	48

	Task No.	Task Name	SENG	INT	STE	LT	Total
	Task 11.5	Website	12	36	0	0	48
Task 12		**Project Management**	--	--	**--**	**--**	**--**
	Task 12.1	Resource Management	0	0	0	0	0
	Task 12.2	Schedule Management	16	16	16	16	64