The Big Beam Theory

PCI Big Beam Competition Proposal

Scope of Staffing and Cost (Draft)

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1.0 Project Understanding

1.1 Purpose of Project

The Precast/Prestressed Concrete Institute (PCI) Big Beam Competition is needed because it encourages young minds to think up innovative designs for a concrete beam and its properties. These students are trying to understand the development of prestressed concrete beams, and teams are trying to predict and analyze their beam's behavior. The behavior being analyzed is cracking, ultimate strength, and change in ultimate strength.

1.2 Project Background

The PCI Big Beam Competition has been around since at least 2005, making this year the 14th year that the competition has taken place. The prize for the best report is $3,000, and there is also a best video competition. Reports and other entry items are due around June every year and up to the top 20 teams receive prizes. The basic idea of the competition is to encourage students to learn about prestressed concrete while estimating the final results with the use of multiple variables and predictions. The students must also help maintain professional alliances that have formed in the past, such as that between NAU and TPAC which is the company that casts the NAU beam in Phoenix every year for the competition.

1.3 Stakeholders

Those most affected by this project are the biggest stakeholders. These stakeholders include the students working on the project, PCI, NAU, and TPAC. The student team holds a lot of stake in this project because they are competing for program funding and a grade. PCI is a stakeholder because they are holding the competition while bearing the costs for casting, form work, and labor. Prizes for competition would need to be funded as well. TPAC is a stakeholder because they cast the NAU beam every year without charging the capstone team and is a continuous supporter and sponsor; and NAU is a stakeholder because doing well in the competition will reflect well on the university.

1.4 Technical Aspects and Considerations

In determining the mix design for the project, the team will follow the standards given by the PCI big beam contest and ideas by Dr. Tuscherer. Light weight aggregates will be used which shall meet ASTM C33 or ASTM C330. Mineral admixtures may be included which will suite the design criteria. Mineral admixtures like silica fume (ASTM C1240), class C or F fly ash (ASTM C618), class N metakaolin (ASTM C618), or Grade 100 or 120 ground granulated blast-furnace slag (ASTM C989) depending on the needs towards strength concerns and environmental conditions. The team plans to test both normal weight and lightweight mixtures to evaluate their advantages and disadvantages on the beam design. This will include standard concrete mixtures from TPAC (sponsor) and our own concrete mixtures based off typical mix proportioning measurements. The mix will be selected based on the ability to achieve a high compressive strength while having a lower weight. The mix characteristics will be determined based on the testing performed for 3-day and 28-day compressive and tensile strengths. Predictions of cracking, ultimate strength failure loading, and maximum deflection will be considered in the selection of the mix.

Supplementary cementitious materials (admixtures) are materials that improves the workability of cement, controls heat by hydration process and minimizes cracking. Some examples of these are fly ash, ground granular blast-furnace slag, and silica fume. Fly ash is a byproduct of burning coal. It improves the workability of plastic concrete and the strength and durability of hardened concrete. Fly ash can also be cost effective because it can replace the amount of cement used in the mix. Ground granular blast-furnace slag is a byproduct of steel production. It improves the workability, strength, and durability of the concrete. Silica fume is a byproduct of silicon. It can increase the strength and durability of the mix [1] [2].

All reinforcing steel must meet one of the following ASTM specifications: A615, A616, A617, A706, A775, A934, A185, A497, A184, A884, A416, A886, A910, A722, or A1035. Non-prestressed or prestressed top steel will be used, and mesh will be used for shear reinforcement.

The three major types of testing to be considered include the concrete compressive test and tensile stress and strain tests. The concrete compressive test is performed based on the ASTM C39 Standard. Compressive strength of concrete cylinders or cores could be used as an alternative to flexural strength testing. Tensile stress and strain are important because the tensile strength of concrete is very low compared to its compressive strength. The tensile strength of concrete is determined by indirect methods of split cylinder test and flexure test following ASTM C496 as the standard.

Prestressed Calculations should be determined before testing. This will include applied total load to cause cracking (in kips), maximum applied point load on midspan (in kips), maximum anticipated deflection only due to applied load (in inches). Cracking moment calculation is done to determine the moment concrete starts cracking. In order to design the beam for the required cracking moment, appropriate cross sections and modulus of sections should be verified by the team. Nominal capacity is another critical requirement for the beam design which is the maximum capacity of loading the beam can hold before failure. Max moments and max shears will be determined using shear and bending moment diagrams.

MathCAD will be used to create a set of equations which will help to determine the critical design parameters. In this software, team would be able to create worksheets to tabulate data for stress at release, cracking capacities, required shear strengths, ultimate capacity of a prestressed beam and proportions for the shear reinforcement of the beam. This program will be helpful for the team to analyze data in a time saving manner while keeping an organized set of records since the team will be experimenting on several sets of cross sections and shapes for the beam.

AutoCAD will be used to draw the design of the beam according to proper dimensions, proportions, and parts. It can be properly annotated in a professional manner which will be easily understandable by the design company.

The current rules for the PCI big beam contest are as follows:

1. Each student team must work with a PCI Producer Member to build a precast/prestressed concrete beam. In our case the PCI Producer Member is TPAC.
2. Students must discuss both the structural design and the concrete mixture proportions for the beam. This portion will be done in the report.
3. The contest begins August 15, 2019 and ends June 15, 2020. All beams must be fabricated and tested within this time frame. The results are due by June 15, 2020, at PCI Headquarters. This time frame extends a month after school ends.
4. Each team must have a faculty advisor. The advisor provides advice and assistance to the student teams. The faculty advisor assigned to the NAU team is Robin Tuchscherer.
5. A Producer Member is expected to provide advice and expertise to aid the student teams, all materials, beam fabrication, beam transportation to the testing facility (or provide for testing at the plant), and disposal.

Current Rules for Report

1. A cover page with the name of the school, the team members, the sponsoring PCI Producer Member, the faculty advisor, and the regional director, as applicable. If a school submits more than one entry, the teams shall be numbered.
2. A completed summary/judging form and the total load/midspan deflection graph.
3. Certification that the calculations were performed before testing the beam. The calculations may be certified by the PCI Producer Member, a regional director, or a neutral third party.
4. Drawings of the cross section(s) and elevation of the beam, showing the reinforcement and cost calculation.
5. A one-to-two-page narrative about the concrete mixture used, including proportions, measured unit weight, slump, air content, and 28-day compressive and tensile strengths. A discussion of the reasoning for choosing the mixture, any modifications to the mixture, and a discussion of how the chosen mixture performed with respect to the team's design requirements is required.
6. A one-to-two-page discussion of the structural design. In addition, the design calculations along with a prediction of the cracking load, maximum applied load, and a prediction of the midspan deflection (due to applied load only) at maximum load shall be provided as an appendix.
7. A narrative of not more than 8 pages (including any pictures) describing the beam fabrication and testing. This must include the load/midspan deflection graph showing peak load and cracking load (from the bend-over point).
8. A statement by the team members explaining what they learned from the contest.
9. A video of the test showing at least the highlights of the test and the failure for verification purposes. There shall be a visible scale showing the beam deflection.
10. A permanent address where each team member can be contacted.

1.5 Potential Challenges to Overcome

This project will open doors for the team to design a beam and fabricate it up to engineering standards of the industry which is challenging. Planning out the design according to the criteria, rules and regulations given by the contest and ASTM codes will be a challenging professional experience for the team. Selecting the mix proportions which has the capability to perform best at the competition will be done by performing multiple tests which is time consuming. The best option is to take frequent advice from Dr. Tuchscherer regarding research of typical concrete mixture proportions and standard mixes provided by the sponsor. It will be a challenge for the team when performing different tests to determine the strength and the quality of concrete including the use of different machines in the testing processes. For an example, testing the concrete cylinders for compressive strength and tensile strength. It will also be a challenge for the team to get the prediction values closer to the actual values. Our team is supposed to consider the cost calculations and stay within the range provided by the PCI big beam contest.

Lab access must be scheduled in advance as available time slots fill up quickly. It will be the responsibility of the team to figure out the lab, lab equipment and machines to be used for the project and get the lab access early ahead of time. It is important to make sure that all the machines are in perfect condition for the tests. A fixed date should be scheduled for the lab activities weekly and reserve the lab, lab equipment and machines.

Calculation errors due to mistakes in deflection predictions and various loading considerations during transportation and their underestimations could result in failure of the beam. All team members need to learn how to use Mathcad, since the work will be divided equally between the team members so that every team member has a clear idea of the calculations and the process of design. In addition, the team will be taking an extra step to focus on criteria related to CENE 486.

The final potential challenges the team faces is transportation of the completed beam. TPAC has stated that they will be in charge of transport but there is potential for the beam to fracture or break during its journey from Phoenix to Flagstaff.

2.0 Scope of Services / Research Plan: Required Content

2.1 Task 1: Research

Prestressed concrete is a method that is developed to increase the cracking load capacity of a structure by casting the concrete mix around a tensioning strand. This requires structural analysis and basic mechanics. With regard to loading conditions given by the PCI, the team is required to design the reinforcement and the cross- sectional area so that the beam would not fail.

2.1.1 Task 1.1: Three Stages of Design Prestressed Concrete Beam

2.1.1.1 Task 1.1.1: Release or Transfer

The team will research the release or transfer where the concrete is casted to the tensioned strands and the release the strands which will transfer the prestress to compression at the top of the beam. This process will create a negative bending moment within the beam which helps to counteract the positive bending moments due to loads applied. [3].

2.1.1.2 Task 1.1.2: Cracking Load

The team will research the cracking load, which is when loading the beam to overcome the compression and cracking will appear at the bottom of the beam [3].

2.1.1.3 Task 1.1.3: Ultimate Strength

The team will research the ultimate strength, which is when keep loading the beam to reach its ultimate strength and fails. The cracks will appear at the top of the beam or fracture the strands [3].

2.1.2 Task 1.2: Preliminary Designs

2.1.2.1 Task 1.2.1: I beam

The team will research I-shaped concrete beam is effective in terms of the amount of concrete and reinforcements, bear high load, and Reduces the deflections.

2.1.2.2 Task 1.2.2: T beam

The team will research T-Shape beams and the increases the sagging amount acting on the flange, better head room, more useful for large spans.

2.1.2.3 Task 1.2.3: Rectangular Cross Section

The team will research rectangular beams to see if they are less effective in terms of cost, it requires more concrete and reinforcements materials. Rectangular beam is effective in resisting torsion.

2.1.3 Task 1.3: Decision Matrix

The team will make a decision matrix that will be used to evaluate the characteristics of beam geometric design and concrete mix that will lead to determine which concrete mix is performing the best with cross-section and reinforcement.

2.2 Task 2: Preliminary Beam Design

Once the team has completed their research, preliminary beam design will begin, including cross section and mix selection.

2.2.1 Task 2.1: Initial Beam Designs

The team will design eight to twelve beam options with varying features including depth and cross section types. Once these beams have been designed they will be put into a decision matrix and the team will score them according to competition rules.

2.2.2 Task 2.2: Decision Matrix

Once the preliminary beam options have been designed by the team they will be put into a decision matrix and scored according to the point system the competition will use, as well as cost. One aspect of these beam designs that varies could be the mix. The aspects of the preliminary beams that score the highest in the decision matrix will be incorporated into the final design.

2.2.2.1 Task 2.2.1: Mix Selection

TPAC has given the team two mix options for this competition, one mix being lightweight and the other normal weight. One option the team may consider is using a combination of both mix types in a beam design.

2.2.2.2 Task 2.2.2: Beam Selection

The 8-12 beams created by the team will be put into a decision matrix. They will be scored on cost, weight, and deflection. The team wants lowest cost and weight for the beam. The team wants highest deflection for the beam

2.2.2.3 Task 2.2.3: Reinforcement Selection

TPAC has limited options for reinforcement. The team must work with their options on choosing the optimal reinforcement for the beam.

2.3 Task 3: Final Design and Analysis

Using the highest scoring aspects of the decision matrix, the team will begin the final design process. MathCAD will be used for a majority of the team’s design calculations.

Moment of inertia, flexural strength, loss of prestress, moment of cracking, maximum moment and shear design will be the main components of MathCAD calculations. Maximum moments and shears will be determined by the shear and bending moment graphs.

2.3.1 Task 3.1: Shear Design

The team will be researching design and calculations. This will be based on the results from the tests mentioned in task 2.2.2. Shear force diagram obtained from Response 2000 will be mainly used for the analysis of the shear. The point of maximum shear will be located which will be used to design the stirrups and spacings accordingly.

2.3.1 Task 3.2: Reinforcement Design

The team will be designing rebar, strands (for prestressing) and potentially mesh reinforcement for the beam in order for the beam to properly withstand the applied loads during testing, and to meet the competition requirements of being able to withstand between 32 and 40 kips of force.

2.3.2 Task 3.3: Loss Calculations

The team will be researching loss calculations. Loss calculations will be based on the research and information found in task 1, as well as the results from the tests in task 2.2.2.

2.3.3 Task 3.4: Cracking Load

The team will research the cracking load. Cracking load is a load which causes the tensile stress in a structural concrete member to exceed the tensile strength of the concrete.

2.3.4 Task 3.5: Max Load at Midspan

The team will research the max load at the midspan. Max load at the midspan determines the strength of the beam.

2.3.5 Task 3.6: Max Anticipated Deflection

The team will research the max anticipated deflection. The max anticipated deflection is how much the team thinks the beam will deflect when the beam experiences the max load at midspan.

2.4 Task 4: Predictions

Predictions are needed for the PCI report. Response 2000 will be used to do this. Cracking load, max load at midspan, and max anticipated deflection need to be predicted.

2.4.1 Task 4.1: Responses 2000

The team will use Response 200 to predict values of the beam. Response 2000 is a software that has the ability to analyze the calculations of the beam with respect to different load constraints, concrete properties and reinforcement design. The program will generate the diagrams for shear, bending moment deformation and deflected shapes. These diagrams will help to determine the locations of cracking load, max load at midspan, and max anticipated deflection.

2.4.1.1 Task 4.1.1: Cracking Load

The team will predict the cracking load. Cracking load is a load which causes the tensile stress in a structural concrete member to exceed the tensile strength of the concrete.

2.4.1.2 Task 4.1.2: Max Load at Midspan

The team will predict the max load at the midspan. Max load at the midspan determines the strength of the beam.

2.4.1.3 Task 4.1.3: Max Anticipated Deflection

The team will predict the max anticipated deflection. The max anticipated deflection is how much the team thinks the beam will deflect when the beam experiences the max load at midspan.

2.5 Task 5: Shop Drawings

Shop drawings are needed for TPAC to start the fabrication of the beam. Shop drawings are the plans for the construction of the beam.

2.5.1 Task 5.1: AutoCAD

AutoCAD will be used to design and prepare the shop drawings based on calculations, and predictions.

2.5.1.1 Task 5.1.1: Plan View

This will give a demonstration of the skeleton of the beam with its longitudinal dimensions, spacings in between meshes, and spacings between the bottom and top concrete and steel. Also, different types of steel gradings will be displayed.

2.5.1.2 Task 5.1.2: Dimensions

The dimensions of the beam will be indicated in the elevation and section views. Dimensions will be marked clearly in red.

2.5.1.3 Task 5.1.3: Cross-Section Details

Based on the outcome of the decision matrix the team will decide on a cross-section that will best meet the needs of our competition rules. The cross section will be drawn with a clear demonstration of widths, depths, stirrup spacings and the grades of the strands.

2.5.1.4 Task 5.1.4: Spacing of Stirrups

Stirrups will be hatched to make it clear. All spacings will be marked with accurate locations of them based on the loading conditions.

2.5.1.5 Task 5.1.5: Review of Drawings

TPAC and TA will need to review drawings to make sure they are at an acceptable level that meets the standards of TPAC.

2.5.1.6 Task 5.1.6: Revisions of Drawings

After TPAC and TA reviews the shop drawing and revisions will need to be made. The shop drawings are required to be at an acceptable level for the TPAC standards to allow the construction of the beam.

2.5.2 Task 5.2: Reinforcement Details

Rebar must be identified in shop drawings including clear cover, spacing, etc. The team will need to comply with TPAC to schedule the rebar to be cut and tied. All strand details also need to be clearly stated in the shop drawings to ensure that production of the beam is carried out properly.

2.6 Task 6: Casting of Beam

TPAC will cast the beam but the team will be there to supervise and spectate. The team must account for the time that casting will take. Curing is another activity that the team must plan for as well.

2.6.1 Task 6.1: Form Work

TPAC will be doing the form work for the beam. The team must anticipate the busy schedule that TPAC has and plan around it.

2.6.2 Task 6.2: Curing of Beam

The beam will take a few weeks to a month for the concrete to cure. This has been identified in schedule.

2.7 Task 7: Testing of Beam

The team will test the beam in the concrete lab (Rm 115). It will be tested to failure to see the strength.

2.7.1 Task 7.1: Prepare for Testing

Prepping for the testing of the beam must be done. This will be a collaboration with Dr. T. The team must also calibrate the equipment before the tests take place.

2.7.2 Task 7.2: Test Beam

The machine with the hydraulic press will be used to apply loads and analyze the deflections and failing capacities of the beam which the data could be exported to the computer.

2.7.7 Task 7.3: Test Mix

Tests will be performed using the hydraulic press machine in the concrete lab at Northern Arizona University's engineering building. Hydraulic press will be used to apply the loads to the beam. The data recordings from the tests will be finalized at the point of cracking and uploaded to the computer. The sensors will be used to obtain a stress- strain graph which will be used in finding the failure loading conditions. In order to perform these tests, the team will ask that cylinders be cast when the beam is being poured.

2.7.3.1 Task 7.3.1: Concrete Compressive Test (ASTM C39)

ASTM C39 will be used. This test is useful in determining the capacity and the strength of selected concrete mixes. Concrete mixes are poured into test cylinders allowing them to cure for periods of 3 days and 28 days. Usually, testing in the hydraulic press is done on the 28th day. A gradually increasing force is applied to the cylinder from the flat circular side until it cracks and breaks.

2.7.3.2 Task 7.3.2: Tensile Strength Test (ASTM C496)

ASTM C496 will be used. This is also called the split cylinder test. This test will determine the strength of the cylinder in tension due to the horizontal loading applied. This will help to figure out the need of reinforcement by loading the cylinder by its long side until the internal stresses of tensile force reaches the failure by splitting the cylinder into half.

2.8 Task 8: Project Management

2.8.1 Task 8.1: Report

Reports are due throughout the class and for the report for PCI. There is a 30%, 60%, 90% due for the class and a final report due for the class and PCI.

2.8.1.1 Task 8.1.1: 30%

This will be an initial draft of the report the team will submit based on the results of the associated project.

2.8.1.2 Task 8.1.2: 60%

This will be a revised version of the 30% report with additional information gained as the project progresses.

2.8.1.3 Task 8.1.3: 90%

This will be a draft of the teams report that needs minimal editing and final touches towards the end of the project, right before it's completion.

2.8.1.4 Task 8.1.4: Final

The final report will include all necessary information on the project including data from tests conducted and proper analysis.

2.8.2 Task 8.2: Website

As the project is completed the team will update a website discussing their progress on the big beam. Towards the end of the project, the team will be posting their video of testing the designed beam to failure and their initial predictions, as well as a discussion of why the results may have been different than expected, as well as all other major information.

2.8.3 Task 8.3: Video

A video is required to be created showing the highlights of the beam design, testing and failure events in the lab and deflections of the beam. The team will be presenting in a creative manner to make the video more attractive.

2.8.4 Task 8.4 Meetings

2.8.4.1 Task 8.4.1 Weekly Meetings with TA

Team will have weekly meetings with Dr. T where the team will be guided about the beam design, related calculations and updates regarding the schedule.

2.8.4.2 Task 8.4.2 Bi-Weekly Meetings with Grader

Meetings will be conducted with the grader prior to submissions of deliverables. Team will be completing deliverables ahead of time and submitting it to the grader via email in order to get feedback on the work. Feedback and comments on the previous deliverables and procedures to be followed for the upcoming deliverables will be discussed.

2.8.5 Task 8.5 Project Impacts

The impacts of the projects would be regulatory, health/environmental, economic, and social. The regulatory impacts of this project would be the guidelines that PCI states for the competition. The health/environmental impacts for this project is that prestressed concrete is stronger than concrete poured on site. Which means it is safer and less likely to collapse. The economic impact is that there is a donation for the winning team. The social impact is that NAU can lose reputation from PCI, TPAC, and the public.

2.9 Exclusions

2.9.1 Mix Design

TPAC has two mix options that the team will be choosing from so no mix design will be completed.

2.9.2 Steel Design

The team will not be designing any steel specifically for this project, but simply selecting the reinforcement that is deemed necessary in the design process.

2.9.3 Material Testing

The team will be using the provided reinforcement and concrete options from TPAC because of this material testing will not be necessary as TPAC already has data on the materials they provide.

3.0 Project Schedule

The total duration of our project is from September 9th to June 15th, adding up to 280 days. The major tasks are research, mix, design and calculations, predictions, shop drawings, casting of the beam, testing of beam, and project management. The deliverables that are due are reports (30%, 60%, 90%, and final), website, and a video. A full schedule can be found in the appendix.

3.1 Critical Path

The critical path for the team is as seen in the schedule. It is the critical path because it is the shortest amount of time to complete our project, completing all tasks that need to be done in a specific order. The team intends to maintain the timing and duration of all items on the critical path by sticking to the schedule, updating the team and the GA/TA on our progress, and having goals and timelines for their completion.

4.0 Staffing Plan/ Personnel

4.1 Staffing Titles and Positions

The staffing titles and positions are as follows:
Senior engineer – SENG
Project engineer – ENG
Lab technician – LAB
Engineering intern – INT
Administrative Assistant – AA

4.2 Qualifications of Personnel

4.2.1 Senior Engineer

A Senior Engineer must have a bachelor's degree from an ABET accredited university, have passed the FE exam, passed the PE exam, completed their EIT (engineer in training) period, and have a few more years of experience in engineering leadership roles. In some fields it is required that a senior engineer has a master's degree in their field of specialty as well. One can become a senior engineer is as little as 8 years after obtaining a bachelor's degree.

4.2.2 Project Engineer

A Project Engineer must have many of the same qualifications as a senior engineer but tends to have a little bit less experience. A bachelor's degree in engineering from an ABET accredited university is still a requirement, along with passing the FE and PE exams and completing an EIT period.

4.2.3 Lab Technician

A Lab Technician needs to have a high school diploma and it is recommended that they have an associate's degree as well. On the job training and approved programs by the Accreditation Board for Engineering and Technology are typical and highly recommended for a lab tech position.

4.2.4 Engineering Intern

Engineering Interns tend to be college students pursuing a degree in engineering that wish to gain experience before they have graduated and passed the fundamentals exam.

4.2.5 Administrative Assistant

An Administrative Assistant must have a high school diploma or an equivalent, as well as word processing and typing skills. Often administrative assistants will take meeting minutes and review technical documents. [4]

4.2.6 Student Team Qualifications

While the student team is not yet certified professional engineers they do bring practical skills and experience to the table. The team has taken courses relating to reinforced concrete design, mechanics of materials, structural analysis, and the basics of civil engineering design. Additionally, members of the team have had civil engineering internships and have gained valuable knowledge and experience from holding these positions which can aid the team in project success.

4.3 Matrix

Figure 1 shows the project time estimated by the team. Tasks are on the left and personnel are on top. The total estimated hours for the project are 720.

Project Time Estimate Breakdown						
Task	SENG Hours	ENG Hours	LAB Hours	INT Hours	AA Hours	Total Hours per Task
Task 1: Research	14	46	0	77	12	149
Task 1.1: Three stages of design of prestressed concrete	1					1
Task 1.1.1:release or transfer	1	4	0	7	1	13
Task 1.1.2: Cracking Load	1	4	0	7	1	13
Task 1.1.3: Ultimate Strength	1	4	0	7	1	13
Task 1.2: Preliminary Design	1					1
Task 1.2.1: I Beam	1	5	0	9	2	17
Task 1.2.2: T Beam	1	5	0	9	2	17
Task 1.2.3: Rectangle Beam	1	5	0	9	2	17
Task 1.3: Decision Matrix	1					1
Task 1.3.1: Mix	2	7	0	10	1	20
Task 1.3.2: Beam	1	4	0	7	1	13
Task 1.3.3: Reinforcement	2	8	0	12	1	23
Task 2: Mix	1	16	16	20	0	53
Task 2.1: Test Mix	1					1
Task 2.1.1: Concrete Compressive Test	0	8	8	10	0	26
Task 2.1.2: Tensile Strength Test	0	8	8	10	0	26
Task 3: Design and Calculation	2	10	0	20	0	32
Task 3.1: Shear Design	1	5	0	10	0	16
Task 3.2: Loss Calculations	1	5	0	10	0	16
Task 4: Predictions	1	12	0	16	3	32
Task 4.1: Response 2000	1				3	4
Task 4.1.2: Max Load at Midspan	0	6	0	9	0	15
Task 4.1.3: Max Anticipated Deflection	0	6	0	7	0	13
Task 5: Shop Drawings	2	13	8	22	5	50
Task 5.1: AutoCAD	2					2
Task 5.1.1: Elevation View	0	4	2	6	2	14
Task 5.1.2: Dimensions	0	2	2	3	2	9
Task 5.1.3: Cross-Section Details	0	4	2	7	1	14
Task 5.1.4: Stirrup Spacing	0	3	2	6	0	11
Task 5.1.5: Review of Drawings	0	2	2	3	4	
Task 5.1.6: Revisions of Drawings	0	2	2	3	0	
Task 5.2: Rebar	0	3	2	5	0	
Task 6: Casting of Beam	0	11	0	15	0	26
Task 6.1: Form Work	0	5	0	7	0	
Task 6.2: Curing of beam	0	6		8	0	
Task 7: Testing of Beam	0	9	6	12	0	
Task 7.1: Prepare for Testing	0	3		5	0	
Task 7.2: Testing	0	6	6	7	0	
Task 8: Project Management	33	113	39	155	38	378
Task 8.1: Report						0
Task 8.1.1: 30%	3	17	0	25	5	50
Task 8.1.2: 60%	3	13	0	20	2	38
Task 8.1.3: 90%	1	11	8	15	2	37
Task 8.1.4: Final	1	9	1	15	2	28
Task 8.2: Website	2	8	1	15	3	29
Task 8.3: Video	1	5	8	15	3	32
Task 8.4: Meetings/Meeting Minutes	20	40	20	40	20	140
Task 8.5: Project Impacts	2	10	1	10	1	24
Total Hours	53	221	63	325	58	720
Total Cost	13642.2	29172	2744.28	9009	1939.52	56507

Figure 1: Project Time Estimate Breakdown

5.0 Cost of Engineering Services

The total project costs $56,925.30. This is shown below in figure 2. The team has listed the needed cost of the project.

1.0 Personnel	Classification	Total Hours		Billing Rate $/hr		Personnel Cost
	SENG	53		257		$ 13,642
	ENG	221		132		$ 29,172
	LAB	63		44		$ 2,744
	INT	325		28		$ 9,009
	AA	58		33		$ 1,940
				Total Personnel Cost		$ 56,507
2.0 Travel	Classification	Units (miles)	No. of visits	Unit Cost (/mile)	Cost	
	meetings w/ gary @ town hall	2	20	0.445	$ 18	
	TPAC site visit	300	3	0.445	$ 401	
				Total Travel Expenses		$ 418
3.0 Supplies	Classification	Units	Item Total	Unit cost	Cost	
	Mix	DONATED				
	Stirrups					
	Fabricating equip.					
4.0 Subcontracting	Classification	Tasks		Unit Cost	Cost	
	TPAC	Beam Casting		NONE/DONATED		
		Beam Delivery				
					Total Overall Cost	$ 56,925

Figure 2: Cost of Engineering Services

The cost justifications for the hourly rate of each position are as follows:

The Senior Engineer has the lowest number of hours in the project but will have the most experience in the field. The Senior Engineer will give a touch on the main task of the project to assure the quality and accuracy of the work and therefore their time is the most valuable.

The Project Engineer will be the main project leader, delegating work and reporting to the senior engineer to ensure that the project is moving in the correct direction in the proper time frame. Because of this level of responsibility and experience they have the second highest hourly wage and hourly billing rate.

The Lab Technician will be in charge of all the lab work related to AutoCAD and lab tests for concrete. This position does not require as much schooling or experience and is therefore one of the lower paying positions on the team for this project.

The Interns have the highest number of hours in the staffing. Interns are involved in almost every task of the project. Preliminary work for each task such as data collection, data organizing, field work and minor calculations which are typically completed using a spreadsheet such as excel. Because of their lack of experience and need for training, the intern position is another of the lower paying positions on this team which is cost effective for the company.

The administrative assistant will mostly be in charge of meeting scheduling and reviewing documents before they are sent out to clients to ensure quality and that there are not too many technical terms that would not be understood by the reader/client.

Because this position does not require engineering abilities it also has a lower pay and billing rate.

6.0 References

[1] R. Tuchscherer, *Lecture Slides*, Flagstaff: NAU, 2019.

[2] U. D. o. Transportation, "Fly Ash Facts for Highway Engineers," Federal Highway Administration.

[3] “Open-Section Beams,” *Thin-Walled Composite Beams Solid Mechanics and Its Applications*, pp. 525–555.

[4] "Engineering Lab Technician: Job Description, Duties and Requirements", *Study.com*, 2019. [Online]. Available: https://study.com/articles/Engineering_Lab_Technician_Job_Description_Duties_and_Requirements.html. [Accessed: 04- Dec- 2019]

7.0 Appendix