PCI Big Beam Contest

Work Proposal

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The New Oriental

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Project Understanding

# 1.0 Purpose

This project is sponsored by Precast/Prestressed Concrete Institute (PCI) and Sika Corporation. The PCI Student Education Committee, one branch of the PCI Committee, is inviting students to participate in the Engineering Student Design Competition for the 2012-13 academic years. Each student team must work with a PCI Producer Member to build a precast-pre-stressed concrete beam which is 20 ft. long and tested as an 18 foot span. The beams will be tested and prizes awarded for best performance in the stated areas. Students must discuss both the structural design and the concrete mix design for the beam.

# 2.0 Background

The contest begins August 15, 2012 and ends June 15, 2013. All beams must be fabricated and tested within this time frame. A student team of 3-4 members is optimal, but teams of any size may participate. Only one entry per team is permitted. Schools may have multiple teams. Graduate and undergraduate students and/or students from different degree programs within a university/college may be on the same team. Each team must have a faculty advisor, and a single advisor may work with multiple teams. The advisor provides advice and assistance to the student teams. Advisors are expected to provide for supervision of the beam test. Advisors are also responsible for assuring students wear proper safety equipment and for the safe conduct of the test. All entries must be accompanied by a hard copy and a PDF version of a report containing all the given general elements in the order listed. Entries submitted with an insufficient report may be disqualified by the judges given by Precast/Pre-stressed Concrete Institute. Students are encouraged to submit a video which details the design, fabrication and testing of the beam, along with statements of what the students learned. Prizes will be awarded to the first through fourth places in each of the 6 Zones and an international zone. The Zone winners will compete for the national title. Prizes are offered for the best report and best video. The winning video may be presented at the 2013 PCI Convention.

This contest is sponsored by the Precast/Pre-stressed Concrete Institute (PCI). The PCI Student Education Committee shall be the final judge of the contest and all decisions/interpretations made by that Committee and/or the panel of judges shall be final.

# 3.0 Stakeholders

There are three stakeholders of this project. One is Dr. Robin Tuchscherer, the client of this project as well as the technical adviser. Another one is Precast/Pre-stressed Concrete Institute which provides the requirements of the PCI Big Beam. The PCI Student Education Committee is the last stakeholder. SIKA Corporation provides prize money. Prizes will be awarded to the first through fourth places in each of the 6 Zones and an international zone.

# 4.0 Existing Condition

The New Oriental can get technical advices and assistances from the faculty advisor—Dr. Robin Tuchscherer for the design and test procedures of PCI big beam. Tpac, a Division of Kiewit Western Co. will sponsor build the concrete beam based on the New Oriental’s design. Material costs and beam weight requirements are provided by Precast/Pre-stressed Concrete Institute.

The material unit cost shall be used to determine the beam cost which is given by the PCI Big Beam Contest Committee. Concrete cost is based on actual strength, not design strength. The beam weight shall be estimated by using the measured unit weight of the concrete or by actually weighing the beam.

# 5.0 Technical Basic Requirements

The beam must no longer than 20 feet and must be tested as a simply supported span of 18 feet, center to center of bearing. It may have any cross sectional shape but the top surface must be flat and horizontal along the entire span.

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 318-08 LL = 10 kips each). This translates 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.

The beam shall be loaded by applying two point loads, symmetrically, 7 feet from the center of each support (or 2 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. As the **Figure 1** shown: 

**Figure 1. Permitted Load Configuration**

# 6.0 Project Limitation

The material used must follow the unit cost table for estimating the final cost of the concrete beam. One possible way to overcome this could be negotiate with Sponsor Company concerning materials and cost. This will have no effect on the concrete beam design, if The New Oriental has a flexible design. Tight schedule is another important factor which may affect the whole project. The approved process and fabrication of our concrete beam will take up to two months. In order to finish and improved the design report before May, 2013, the optimum time for The New Oriental to submit final design to the Sponsor Company is January 15th, 2013.

# 7.0 Key Factors

The key factors for success are communication, dedication, and precision. Communication with technical advisor and team members is essential to access the success of this project. Generally speaking, keep good atmosphere during teamwork contributes to effective work. Communication between team and client shall be important factor to improve design and deliver result. Dedication is significant factor to reach achievement as well. Attention to detail will provide accurate calculations needed for precision.

Scope of Services

The following Scope of Services provides the necessary work breakdown structure (WBS) to describe and control the proposed work and deliverables. The New Oriental’s scope includes the primary top tasks listed below:

Task 1 – Project Management

Task 2 – Literature Search and Background

Task 3 – Engineering Studies

Task 4 – Preliminary Analysis and Design

Task 5 – Final Analysis and Design

Task 6 – Services during Fabrication

Task 7 – Test Instrumentation Setting up

Task 8 – Beam Test

Task 9 – Design Report

# 1.0 Project Management

## 1.1 Weekly Team Meeting

The New Oriental regular meetings will serve as the primary forum for understanding the project and identifying and resolving the project issues. The meeting will be scheduled weekly between technical advisor and team of the New Oriental. Throughout the anticipated nine-month duration of the project, team will provide meeting notices, prepare meeting materials and agenda, attend and facilitate the meeting, and prepare meeting minutes for up to eight monthly meetings. (This assumes there are months where there is nothing substantial to report/discuss and therefore no meeting is needed)

*Deliverables: Meeting Notice, Agenda and Minutes*

## 1.2 Technical Coordination Meeting

The New Oriental will coordinate technical design issues with the technical advisor, project manager of Tpac, a Division of Kiewit Western Co. (Sponsoring Company) and others through meeting and correspondence. Team will meet with the project manager of A Division of Kiewit Western, David L. Chapin, to discuss the materials and fabrication constraints/ logistics. Agendas of eight meetings will be prepared as necessary.

*Deliverables: Meeting Notes, Correspondence and Presentation Materials*

# 2. 0 Literature Search and Background

Based on a careful review of the project requirements, The New Oriental proposes to obtain expertise about precast/prestressed concrete by literature review. In order to accomplish this project, The New Oriental needs to be familiar with ACI 318-08 code, PCI Design Manual 7th edition, and other relevant precast/prestressed concrete literature and cite the correct resources for the design report. ACI 318 code is American Concrete Institute-Code for the design of concrete structure. PCI Design hand book is published by the Precast/Prestressed Concrete Institute, reflecting recent changes in the building codes and standards issued by American Society of Civil Engineering (ASCE), and ACI. The New Oriental needs to find some constant values, such as concrete beam cover, prestressed strength, and other relevant factors that impact the performance of the concrete beam from both ACI 318 code and PCI Design Manual. The technical advisor will provide lectures and give suggestions concerning precast/prestressed concrete design to The New Oriental during the weekly meetings. Ultimately, The New Oriental will be responsible for managing the project and making sure that the product meets all project goals and benchmarks.

The judges shall select a beam report for the “Best Report”. The criteria shall be that report which best demonstrates student learning, application of sound engineering judgment and excellence in presentation. Proper use of the professional terms will make the report comprehensive.

The references used in the Response 2000 software will be looked up as well. These materials will help to determine how the properties of concrete are modeled.

*Deliverables: Reference Documents of Beam Design*

# 3. 0 Engineering Studies

## 3.1 Materials Report

A materials report will be prepared to summarize the materials used in the design, including the size of reinforcement bar, type of concrete and concrete mix. The materials used are given in the materials cost table by the Precast/Prestressed Concrete Institute. A visit to the sponsor Company is scheduled at 30th Oct, 2012 as a meeting with Dave, a project manager of Tpac in order to negotiate the standard of materials used for design. All the materials will be regulated by the Sponsor Company during the meeting, included size of reinforcement bar, and type of concrete and concrete mix.

*Deliverables: Preliminary Materials Memorandum and Materials Report*

3.2 Selection of Cross Section Type

The New Oriental will document its findings and recommendations of selection of cross section type in design report without breaking any rules of the competition. This part will include the following:

* Preparation of a beam general plan sheet including plan, height, and size of cross section.
* Preparation of a construction cost estimate for the proposed competition.

The New Oriental will conduct the review meeting concerning cross section type selection to discuss the findings and obtain consensus on the preferred options. Upon approval of the cross section type, The New Oriental will proceed with the final design.

*Deliverables: Type Selection Report and Type Section Meeting Agenda, Notes.*

# 4. 0 Preliminary Analysis and Design

The New Oriental will prepare a design report that summarizes the preliminary design and beam analysis. This report will concisely document stress at released, cracking moment, moment capacity, and design load.

## 4.1 Material Selection

Concrete mix of normal weight concrete and lightweight concrete, compressive strength of the concrete, yield strength of reinforcement will be given by the Tpac Company. The selection of concrete type will be based on the considerations of cost and weight. Tpac Company requires that only ASTM Standard #4 or #5 reinforcement strand can be used in the concrete beam design. The compressive strength of the concrete and yield strength of reinforcement from different materials will be analyzed in the design spread sheet. The decision will be made based on lowest cost and lowest weight.

*Deliverable: Material Selection Design Matrix*

## 4.2 Design Spreadsheet

Microsoft Excel software will be used to set up the design frame which contains about 40 elements or factors involved calculations of beam design. Amount of formulas need to be input on excel program to calculate stress at released, cracking moment, moment capacity, and design load. These four core factors can be adjusted by changing dimension of the beam cross section. The final design spread sheet will be prepared as an appendix of final design report.

4.2.1 65% spreadsheet

Based on the review session from Dr. Robin Tuchscherer, the New Oriental will develop a fundamental spreadsheet which contains input variables and calculated variables. The calculated variables will be formulated depending on the cells of input variables. Therefore, by changing of input variables, calculated variables are changed correspondingly.

*Deliverable: 65% Spreadsheet*

4.2.2 95% spreadsheet

The comments from Dr. Robin Tuchscherer on the 65% frame structure design will be addressed in spreadsheet. Input variables for calculating the stress at release and cracking moment will be formulated.

*Deliverable: 95% Spreadsheet*

4.2.3 100% spreadsheet

The New Oriental Team will update the design spreadsheet to incorporate review comments from Dr. Robin Tuchscherer regarding the 95% design spreadsheet. Input variables for calculating the moment capacity and design load will be formulated.

*Deliverable: 100% Spreadsheet*

## 4.3 Deign Matrix

In order to select an optimal design, the New Oriental will prepare a design matrix with six to eight design options. Each option in the matrix will contain the cracking load, cracking moment, ultimate moment, ultimate load, cost, and weight. The prior option will be the least cost and lowest weight.

*Deliverable: Design Matrix*

# 5.0 Final Analysis and Design

Once the final design selected from design matrix, the New Oriental will verify the final design by utilizing Response-2000 software to make sure the design is credible

## 5.1 Responses-2000 Verification

Response-2000 is a sectional analysis program that will calculate the strength and ductility of a reinforced concrete cross-section subjected to shear, moment, and axial load. All three loads are considered simultaneously to find the full load-deformation response using the latest research based on the modified compression field theory. Response-2000 is able to calculate the strength of traditional beams better than existing methods and, more importantly, is able to make predictions of shear strengths for sections that cannot easily be modeled.

*Deliverable: Output Sheet from Response-2000 and Predication Form*

## 5.2 Plans

Cross section and side view of the final design will be drawn by Auto CAD. For cross section, height, width, number of reinforcement strand and location of reinforcement strand will be clearly labeled. For side view, length of beam, compression reinforcement strand and tension reinforcement strand will be clearly labeled. The Auto CAD drawing will be submitted to Tpac Company for future fabrication. In addition, this drawing will be prepared as an appendix of final design report.

*Deliverable: Auto CAD Profile Drawings*

# 6.0 Services during Fabrication

Fabrication process needs to be completed carefully because it is the most essentially part in the whole project. During the fabrication, the team shall provide services to help the producers understand the design profile and requirements of testing.

## 6.1 Fabrication Assistance

All the problems need to be solved before the final design. However, if the producer has some questions about the design, the New Oriental needs to response as soon as possible to avoid mistakes and reduce errors during fabrication. As part of this task, the New Oriental will:

* Attend the fabrication meeting
* Provide consultation and interpretation of design report, as required
* Review and comment on design report
* Prepare design revisions as necessitated

*Deliverable: Meeting Summary and Commentary of Design Report*

# 7.0 Test Instrumentation Setting Up

Before the concrete beam test, the New Oriental needs to spend a fair amount of time on setting up the test instrumentation. The team also needs to figure out requisite accessories, installment procedure, troubleshooting, etc.

*Deliverable: Test Instrumentation*

# 8.0 Beam Test

When the fabrication is complete, beam needs to be tested as follows:

* Weight
* Measured cracking load
* Actual maximum applied load
* Largest measured deflection
* Most accurate calculation

*Deliverable: Beam Test Record*

# 9.0 Design Report

A design report is required to be submitted to Tpac, a Division of Kiewit Western Company. This design report contains information used for fabricating a beam by A Division of Kiewit Western Company. The design report includes:

* Dimension of the beam
* Design Matrix
* A prediction of the concrete beam performance
* A detailed discuss of shape and percentage of steel occupied in concrete
* Auto CAD drawings
* Cost table

*Deliverable: Final Design Report*

Project Schedule

A detailed project development schedule is provide on the following page with critical path tasks shown in red and tasks by others shown in green. Key project milestones are summarized in the **Figure 2**:



**Figure 2.** **Project Schedule**

This schedule is based on the following assumptions:

* The design of the concrete beam is verified by Response 2000 Software to be correct with multiple design reviews.
* 100% design of Concrete beam is submitted before January 15th, 2013.
* Tpac Company can finish the fabrication of concrete beam before April, 2013.
* No serious design errors or construction errors

If Tpac, a Division of Kiewit Western Co. (Sponsoring Company) prefers to accelerate the schedule, one option is to submit final design before December 15th, 2012. However, the analysis of design performed during this time would be insufficiency. In addition, the differences between predicted results and test results might be large and complex. The quality of the design report will not be affected if the schedule is intensive.

The key to maintaining the project schedule will be continual and consistent coordination with Tpac such that information is provided in a timely manner and everyone is on the same page and functioning with the same understanding regarding project delivery and execution. The New Oriental will continually monitor and update the schedule to track critical tasks and prioritize our work effort to ensure that the key milestones are met.