

# PCI BIG BEAM COMPETITION

## Official Rules for the PCI Engineering Design Competition Academic Year 2017-18

### PROGRAM

The PCI Student Education Committee is inviting entries from students to participate in the Engineering Student Design (Big Beam) Competition for the 2017-18 academic year. Each student team must work with a PCI Producer Member to build a precast/prestressed concrete beam that is 22 ft long. 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 mixture proportions for the beam.**

### CONTEST PERIOD

The contest begins August 15, 2017, and ends June 15, 2018. All beams must be fabricated and tested within this time frame. **Results are due by June 15, 2018, at PCI Headquarters. The winning team will be recognized at the 2018 PCI Committee Days and Membership Conference in Chicago, Ill.**

### HOW TO ENTER

All teams are required to submit an online application to establish their participation in the competition. Please visit <http://www.pci.org/bigbeam> to complete the application. Applications must identify all members of the student team and supply a permanent email and mailing address for each team member.

### ELIGIBILITY

Any student enrolled in an Associate, Baccalaureate, or Graduate Degree Program in any of the following areas is eligible:

- **Civil Engineering (including all subdisciplines) or Technology**
- **Construction Engineering or Technology, Construction Management**
- **Architecture, Architectural Engineering or Technology**
- **Building Sciences or Technology**

Students enrolled any time during the contest period are eligible.

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## STUDENT TEAMS

A student team of 3 to 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. Joint teams between one or more schools are permitted.

## FACULTY ADVISOR

Each team must have a faculty advisor. 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 ensuring that students wear proper safety equipment and for the safe operation of the test.

## PRODUCER MEMBER PARTICIPATION

Each team must work with a PCI Producer Member. A Producer Member may work with more than one team and may work with teams from different schools. There is no limit to the number of teams a given Producer Member may support. Producers who are members of PCI chapters, partners, affiliates, or allied organizations meet this requirement.

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. The actual design must be done by the students, but the faculty advisor and the Producer Member are encouraged to assist in this phase. Students are expected to participate in the fabrication of the beam to the extent deemed safe and practical by the Producer Member. If a team cannot find a Producer Member who will work with them or if there is no Producer Member within a reasonable driving distance, a team may obtain a waiver of this requirement from the chair of the Student Education Committee or the PCI staff liaison to the Student Education Committee.

## GENERAL RULES

**All entries must be accompanied by a hard copy and a PDF version of a report** containing all of the following elements in the order listed. Entries submitted with an insufficient report may be disqualified by the judges.

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.
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 DVD 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.

# PCI BIG BEAM COMPETITION 2017-18

Date \_\_\_\_\_

Student Team (school name) \_\_\_\_\_

Team Number \_\_\_\_\_

Date of Casting \_\_\_\_\_

## Basic Information

1. Age of beam at testing (days) \_\_\_\_\_

### 2. Compressive cylinder tests\*

Number tested \_\_\_\_\_

Size of cylinders \_\_\_\_\_

Average (psi) \_\_\_\_\_

### 3. Concrete properties

Unit weight of concrete (lb/ft<sup>3</sup>) \_\_\_\_\_

Slump (in.) \_\_\_\_\_

Air content (%) \_\_\_\_\_

Tensile strength (psi) \_\_\_\_\_

Circle one: Split cylinder MOR beam

### 4. Pretest calculations

a. Applied load (total) to cause cracking (kip) \_\_\_\_\_

b. Maximum applied point load at midspan (kip) \_\_\_\_\_

c. Maximum anticipated deflection due to applied load only (in.) \_\_\_\_\_

**Pretest calculations MUST be completed before testing.**

\* International entries may substitute the appropriate compressive strength test for their country.

## Judging Criteria

**Teams MUST fill in these values.**

1. Actual maximum applied load (kip) \_\_\_\_\_

2. Measured cracking load (kip)<sup>‡</sup> \_\_\_\_\_

3. Cost (dollars) \_\_\_\_\_

4. Weight (lb) \_\_\_\_\_

5. Largest measured deflection (in.) \_\_\_\_\_

6. Most accurate calculations

a. Absolute value of (maximum applied load – calculated applied load)/calculated applied load \_\_\_\_\_

b. Absolute value of (maximum measured deflection – calculated deflection)/calculated deflection \_\_\_\_\_

c. Absolute value of (measured cracking load – calculated cracking load)/calculated cracking load \_\_\_\_\_

**Total of three absolute values (a + b + c) = \_\_\_\_\_**

<sup>‡</sup> Measured cracking load is found from the “bend-over” point in the load/deflection curve. Provide load/deflection curve in report.

**Test summary forms must be included with the final report, due June 15, 2018.**

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# PCI BIG BEAM COMPETITION 2017-18

## DEFINITIONS, SPECIFICATIONS, AND INTERPRETATIONS FOR THE BIG BEAM CONTEST

For the standards listed below, contestants may use either the inch-pound version or the equivalent metric version.

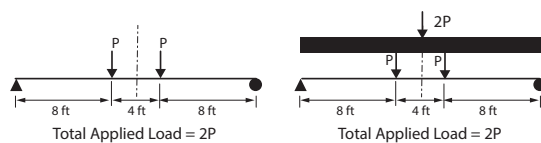
<b>Aggregates</b>	Shall meet ASTM C33 or ASTM C330 (Lightweight Aggregates).
<b>Chemical Admixtures</b>	Shall meet ASTM specifications D98, C494, C260, or C1017.
<b>Compressive Strength of Concrete</b>	Shall be determined according to ASTM C39.
<b>Concrete</b>	Concrete is a mixture of portland cement, water, and aggregate. Mineral and chemical admixtures may be included. The material must have both coarse and fine aggregate. Fiber-reinforced concrete is permitted.
<b>Concrete Beam</b>	A concrete beam resists load through flexure and the primary load-resisting system is made of concrete and reinforcing steel. Composite systems, trusses, and arches do not qualify under this definition.
<b>Enclosed Reinforcement</b>	The reinforcement must be completely enclosed within the concrete with adequate cover as stated by ACI 318-14.
<b>Mineral Admixtures</b>	Shall meet indicated ASTM specifications and be silica fume (C1240), class C or F fly ash (C618), class N metakaolin (C618), or Grade 100 or 120 ground granulated blast-furnace slag (C989).
<b>Portland Cement</b>	Conforms to ASTM C150.
<b>Proprietary Materials</b>	Any material whose contents are not available to the public. These materials are banned, as the judges cannot verify compliance with the rules.
<b>Reinforcing Steel</b>	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. Structural steel plates or shapes are not allowed as primary or confining reinforcement. Fiber-reinforced plastics are not allowed.
<b>Steel Plates</b>	Steel plates are permitted as bearing plates or as anchorage plates for mild reinforcement or prestressing steel.
<b>Tensile Strength of Concrete</b>	Determined using either ASTM C78 or C496.

International entries may use the equivalent specifications from their respective countries.

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## THE BIG BEAM

1. The beam must be tested as a simply supported span of 20 ft, center-to-center of bearing. It cannot be longer than 22 ft 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 (LL) of 10 kips (that is, in equations under section 5.3 in ACI 318-14, LL = 10 kip each). This corresponds to factored live loads of 16 kip at each loading point. The beam must not crack under service live load of 10 kip at each point (20 kip total service live load).
3. The beam shall be loaded by applying two point loads, symmetrically, at 4 ft spacing as shown in the figure. The loading mechanism must apply the loads equally at all points. Use of a single jack and spreader beams to create the loads is permitted.



4. Bearing pads and/or bearing plates, not exceeding 6 in. in length (along the span), may be used at supports and/or under the load.
5. Load and midspan deflection shall be measured.
6. The beam must resist load primarily through flexure. **Trusses, arches, and other nonflexural 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. Ultra-high-performance concrete 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 are allowed. 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-318-14 or the seventh edition of the *PCI Design Handbook* for a precast/prestressed beam, interior exposure. International entries must meet the equivalent specifications for their respective country and must state which specification was used.
11. Entries that, in the opinion of the judges, are obviously impractical, are 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 zero points in the categories where the violation occurred

## JUDGING CRITERIA

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

Entries will be judged in the following categories:

1. **Design accuracy.** The beam should hold at least the FACTORED live load of 32 kip and should not hold more than 39 kip. The beam shall not crack under the service load of 20 kip. Beams meeting these criteria receive 20 points.
  - a. Beams that do NOT hold 32 kip shall be penalized 2 points for each kip, or part of a kip, less than 32.
  - b. Beams that hold more than 39 kip shall be penalized 1 point for each kip, or part of a kip, greater than 39.
  - c. Beams that crack before 20 kip receive a 5 point penalty.
2. **Lowest cost.**
3. **Lowest weight.**
4. **Largest measured deflection at maximum total applied load.**
5. **Most accurate prediction** of maximum total applied load the beam can carry, total applied load at first flexural cracking, and midspan deflection at maximum total applied load. Total applied load is the sum of the two applied point loads.
6. **Report quality.** Reports MUST contain a discussion of the concrete mixture proportions 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 each category will be identified. Points, rounded down, are awarded based on:

$$\text{Points} = 10 \times (\text{value in entry} - \text{worst value}) / (\text{best value} - \text{worst value})$$

In category 5 (most accurate prediction), 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% (for example, 25% is rounded to 30% and receives 8 points). Greater than 110% receives zero 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 zero points.

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 kip) 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.

**NOTE: Students must submit a hard copy AND a PDF version of the final report.**

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## CERTIFICATION

As a representative of (name of PCI Producer Member or sponsoring organization)

Sponsoring (name of school and team number)

### I certify that:

- The beam submitted by this team was fabricated and tested within the contest period.
- The calculations of predicted cracking load, maximum load, and deflection were done prior to testing of the beam.
- The students were chiefly responsible for the design.
- The students participated in the fabrication to the extent that was prudent and safe.
- The submitted test results are, to the best of my knowledge, correct, and the video submitted is of the actual test.

### Certified by:

Signature

Name (please print)

Date

## THIS CERTIFICATION MUST BE PART OF THE FINAL REPORT

Sponsored by:

AUTODESK'S SOLUTION ASSOCIATE FOR PRECAST



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GRACE CONSTRUCTION & PACKAGING

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## 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/yd <sup>3</sup>	Using gross section geometry
High-Strength Concrete	\$120/yd <sup>3</sup>	Defined as ≥ 10 ksi
Fiber-Reinforced Concrete	\$110/yd <sup>3</sup>	
Ultra-High-Performance Concrete	\$400/yd <sup>3</sup>	
Lightweight Concrete		Add \$10/yd <sup>3</sup> to the concrete cost
Prestressing Strand:		Use estimated lengths used in the beam
3/8 in. diameter	\$0.17/ft	
1/2 in. diameter	\$0.30/ft	
1/2 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 <i>PCI Design Handbook</i>
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	\$0.55/lb	
Forming	\$1.25/ft <sup>2</sup> of formwork (include all contact surfaces)	

- 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 reinforcement, bearing plates, etc. \* Special circumstances or special materials not addressed in these rules must be reviewed by the chairman of the committee and/or PCI staff.

## REPORT COMPETITION

The judges shall select a “Best Report” winner for the report that best demonstrates student learning, application of sound engineering judgment, and excellence in presentation. The judges may elect not to award a prize if there are no suitable entries or to award multiple prizes if there is more than one worthy report.

## BEST VIDEO

Students are encouraged to submit a video (in addition to the test video required in item 9 of the General Rules) that details the design, fabrication, and testing of the beam, along with statements of what the students learned. A prize will be awarded for the most creative and entertaining video. The judges may elect not to award a prize if there are no suitable entries or to award multiple prizes if there is more than one worthy entry. The winning video may be presented at the 2019 PCI Convention and National Bridge Conference.

## PRIZES

Sponsors make prizes possible. The winning team will receive free travel, accommodations, and registration for the 2019 PCI Convention and National Bridge Conference. (Permanent mailing addresses are required with the application). Prizes will be awarded to the top 20 submissions. The value of the prize awarded is based on the entry’s placement in the competition. Prizes may be offered for the best report and best video.

## DISCLAIMER:

This contest is sponsored by the Precast/Prestressed 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. Entries received by PCI by June 15, 2018, will be accepted; entries received after this date but before the contest is judged may be accepted at the discretion of the judges and PCI.

All entries become property of PCI and will not be returned. PCI reserves the right to publish any entry, in whole or in part, without compensation. By entering, contestants agree to allow their photographs/videos to be used by PCI without compensation.

PCI reserves the right to disqualify an entry if any part of it does not meet these rules. PCI and/or the judges may revise submitted calculations or quantities to correct errors or inconsistencies as an alternative to disqualification. If there are not enough acceptable entries, not all prizes will be awarded. PCI reserves the right to award additional prizes.



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