PCI Big Beam Competition

Official Rules for the PCI Engineering Design Competition
Academic Year 2019-2020

PROGRAM

The PCI Student Education Committee is inviting entries from students to participate in the Engineering Student Design (Big Beam) Competition for the 2019-2020 academic year. Each student team must work with a PCI Producer Member to build a precast/prestressed concrete beam. 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, 2019, and ends June 15, 2020. All beams must be fabricated and tested within this time frame. **Results are due by June 15, 2020, at PCI Headquarters. The winning team will be recognized at the 2021 PCI Convention.**

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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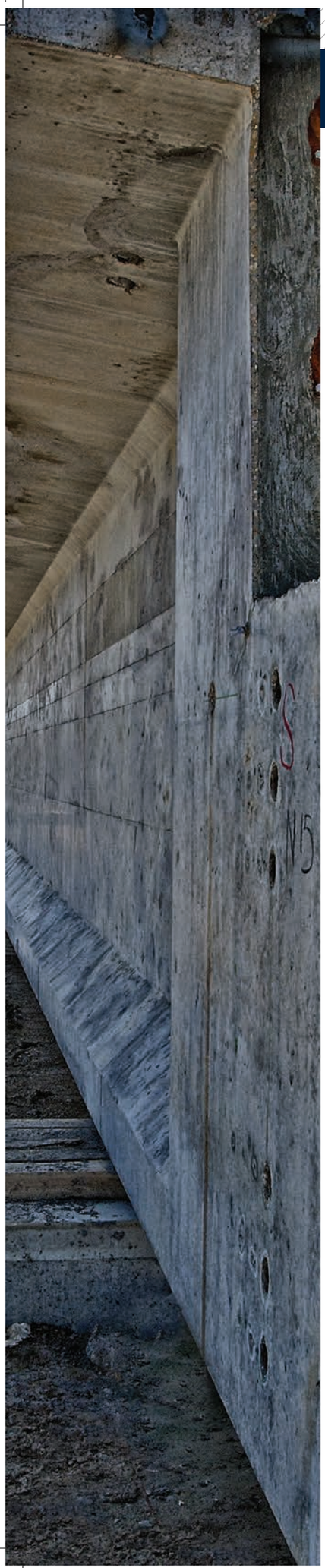

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STUDENT TEAMS

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 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 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 (DVD or flash drive) 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.

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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^3) _____

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)‡ _____
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) = _____

‡ 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, 2020.

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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.

Aggregates	Shall meet ASTM C33 or ASTM C330 (Lightweight Aggregates).
Chemical Admixtures	Shall meet ASTM specifications D98, C494, C260, or C1017.
Compressive Strength of Concrete	Shall be determined according to ASTM C39.
Concrete	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.
Concrete Beam	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.
Enclosed Reinforcement	The reinforcement must be completely enclosed within the concrete with adequate cover as stated by ACI 318-14.
Mineral Admixtures	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).
Portland Cement	Conforms to ASTM C150.
Proprietary Materials	Any material whose contents are not available to the public. These materials are banned, as the judges cannot verify compliance with the rules.
Reinforcing Steel	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.
Steel Plates	Steel plates are permitted as bearing plates or as anchorage plates for mild reinforcement or prestressing steel.
Tensile Strength of Concrete	Determined using either ASTM C78 or C496.

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

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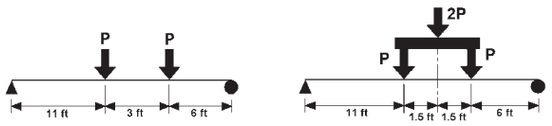
THE BIG BEAM

1. The beam must be tested as a simply supported span of 20 ft, center-to-center of bearing. It 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 kip (that is, in equations under section 5.3 in ACI 318-14, LL = 10 kip each). This corresponds to factored live loads of 16k 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 unsymmetrical point loads, as shown. The loads are 3 ft apart. One load is applied 6 ft from one support and the other is 11 ft from the opposite support. The loading mechanism must apply the loads equally at both points. Use of a single jack and a spreader beam to create two loads is permitted.



PERMITTED LOAD CONFIGURATIONS

4. Bearing pads and/or bearing plates, not exceeding 6-in. in length (along the span), may be used at supports and/or under the load.
5. The load may be measured at each point or, if a spreader beam is used, the total load applied to the spreader beam may be measured. Report load as the TOTAL applied load (sum of two point loads). Midspan deflection must be measured.
6. The beam must resist load primarily through flexure. **Trusses, arches, and other 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. UHPC 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 only be used as bearing plates and/or as anchorage plates for post-tensioning steel. Steel plate may not be used as any type of reinforcement or for confinement.
10. All entries from US schools must meet the provisions of ACI-318-14 or 19 (specify version used) or the 8th 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 which, in the opinion of the judges, are obviously impractical, attempts 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 award "0" points in the categories where the violation occurred.
13. All entries must include a hard copy AND a PDF version of the final report.

JUDGING CRITERIA

The Big Beam Competition will consist of a national competition, where each entry will be judged in relationship to other entries in the country. All entries must contain sufficient information for the judges to verify the design and accompanying calculations for each category.

The judging categories shall be:

1. **Design accuracy.** The beam must carry at least a total factored live load of 32 kip and must not have a total peak applied load of more than 40 kip. The beam shall not crack under the total applied service load of 20 kip. Total applied load is defined as the sum of the two applied point loads. Beams meeting these criteria receive 20 points.
   - **a.** Beams which do NOT hold a total applied load of 32 kip shall be penalized 2 points for each kip, or part of a kip, below 32.
   - **b.** Beams which hold a total applied load of more than 40 kip shall be penalized 1 point for each kip, or part of a kip, above 40.
   - **c.** Beams which crack before a total applied load of 20 kip receive a 5 point penalty.
   - **d.** The load/midspan deflection graph must show a peak load either by post-peak softening or by collapse of the beam. Stopping the test to avoid the overstrength penalty will result in a score of 0 for this category.
2. **Lowest cost** (calculation must be provided).
3. **Lowest weight.**
4. **Largest measured deflection at maximum total applied load.**
5. **Most accurate prediction** of maximum total applied load, total applied cracking load and midspan deflection at maximum total applied load. Total applied load is the sum of the two applied point loads.
6. **Report quality.** Reports MUST contain a discussion of the concrete mix design and the beam structural design.
7. **Practicality, innovation, and conformance with code.**

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

Points = 10 × (value in entry – worst value)/(best value − worst value)

Example: A submission with a beam weight of 108 pounds would receive 9 points if the lightest beam submitted weighs 100 pounds and the heaviest beam submitted weighs 200 pounds (=INT(10 × (108-200)/(100-200))).

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

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

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

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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

Predicted Maximum Load

Predicted Cracking Load

Predicted Deflection at Midspan

THIS CERTIFICATION MUST BE PART OF THE FINAL REPORT

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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 Cost (yd^3):	$100 ≤ $20 + $10 (concrete strength ksi) ≤ $200	Round concrete strength down to nearest ksi
Ultra-High-Performance Concrete	$400/$yd^3$	
Prestressing Strand:		Use estimated lengths used in the beam
⅜ in. diameter	$0.17/ft	
½ in. diameter	$0.30/ft	
½ in. special	$0.32/ft	
0.6 in. diameter	$0.42/ft	
0.7 in. diameter	$0.55/ft	
Steel:		Use estimated lengths and nominal unit weights in this calculation as provided in the *PCI Design Handbook*
A615/A706	$0.45/lb	
Welded Wire (deformed or smooth; for shear)	$0.50/lb	
Epoxy Coated	$0.50/lb	
A1035	$0.70/lb	
Plate Steel	$0.55/lb	
Forming	$1.25/$ft^2$ 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 2021 PCI Convention.

PRIZES

Sponsors make prizes possible. The winning team will receive free travel, accommodations, and registration for the 2021 PCI Convention. (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, 2020, 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. If there are not enough acceptable entries, not all prizes will be awarded. PCI reserves the right to award additional prizes.

PCI
Precast/Prestressed Concrete Institute

HOW PRECAST BUILDS.

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