2022 Rules for Fiber-Reinforced Concrete Bowling Ball Competition

Student Team

Only 1 team per school is eligible for this competition.
All members of a given team must be from the same school.
A team is limited to 2 to 8 students currently enrolled in a home school, high school, or an undergraduate college or university program.
Undergraduate students on cooperative or internship work assignment are eligible to compete.
Each team must have a supervising faculty advisor who will see that the team complies with the rules of the competition.
A faculty advisor and 2 student team members must be designated as primary contacts for each team.
At least one individual (faculty advisor or student team member) must be present at convention for each of the bowling ball tests.
Each team must submit the required files on time to be eligible for prizes.
Every team may be assigned a Team Name by the Judges.
The Team Name may be used for scheduling and other purposes during the competition.

Bowling Ball Identification

Ensure that your team’s bowling balls can be individually and uniquely identified, both from each other and from other team’s bowling balls. Teams can use letters, symbols, marks, and coloring for identification. All identification is to be aesthetically pleasing and must not be offensive. Unacceptable markings and unacceptable depictions on the bowling balls will be penalized and may disqualify the students and their school from further competitions. The head judges have final determination regarding what is unacceptable.

Bowling balls may be painted.
If painted, use only up to 4 colors.
Epoxy-based paints are not allowed.

Bowling Ball Materials

Teams design and construct bowling balls from a fiber-reinforced concrete mixture, including UHPC. The bowling balls can be constructed from the Concrete Materials, Fiber Reinforcement, and Other Materials as listed on the 2022 Design Submittal worksheet within the Excel file named 2022 Design Submittal and Examples ABC (found at the SUBMITTAL link on the Competition webpage).
The Other Materials are for constructing a core and/or using distributed materials for achieving the desired bowling ball density. Teams choose their 1 FRC mixture type from the 3 example FRC mixture types A, B, or C, provided within the Excel file.
The 3 different mixture types allow the use of different ingredients for different concretes.
Example mixtures A and B use individual ingredients.

Mixture C uses a prepackaged/pre-blended product as an ingredient.

The Team’s bowling balls are to be produced from the Team chosen mixture type.

Only those Concrete Material ingredients listed in each individual mixture type are allowed.

The disallowed Concrete Material ingredients are indicated in each mixture type respectively with cell entries XA, XB, or XC.

Fill the cells of the worksheet 2022 Design Submittal following the chosen mixture type.

Do not add or delete rows or columns to the Design Submittal worksheet.

You must include the appropriate text XA, XB, or XC in the cells as shown for disallowed ingredient materials.

Refer to the Example A, B, or C for the proper number of places after the decimal for the numerical Values and Volumes.

The text for Other Materials should use no more than 5 words to describe each material or color.

**Concrete Materials**

Only the Concrete Materials listed in the Design Submittal can be used.

UHPC suppliers from the ACI 239 UHPC committee are listed as possible suppliers of prepackaged/pre-blended product or other concrete materials (found at the MANUFACTURERS link on the Competition webpage).

Not all the materials listed are required to be used.

Patching, filling, or repair of honeycombed surfaces after casting is allowed.

Materials to correct the honeycombed surfaces must be selected from the exact same materials used in the Design Submittal.

**Fiber Reinforcement**

The bowling ball must be made with fiber reinforcement.

No other type of reinforcement is allowed.

Fiber suppliers from the ACI 544 Fiber Reinforced Concrete committee are listed as possible fiber suppliers (found at the MANUFACTURERS link on the Competition webpage).

The Fiber Reinforced Concrete Association also lists possible fiber suppliers on their website (http://fiberreinforcedconcrete.org).

The Design Submittal shall use no more than 2 fiber material types from the 4 fiber material types as described by the ASTM specifications listed in the Design Submittal.

Do not use any other fiber materials.

Fibers must be commercially available.

Regardless of fiber material type, all fibers are to be the same length and the maximum length is 60 mm.

The fibers may be used at any dosage or volume fraction.

**Other Materials**

The bowling ball mass can be met with different materials and different densities than the listed Concrete Materials and Fibrous Reinforcement.

The Other Materials cannot be a Concrete Material or a Fiber Reinforcement.
The Other Materials can be mixed or used within the bowling ball to meet the mass requirement. Some examples are:
The Other Materials can be grouped together as a centered Core.
The Other Materials can also be homogeneously Distributed within the FRC Mixture.
The bowling balls may have multiple layers of different densities or one core with a different density.
Expanded polystyrene beads are an example of an acceptable homogeneously distributed Other Materials.
A balloon filled with expanded polystyrene beads is an example of an acceptable core using 2 Other Materials.
The use of Other Materials is optional.
Use none or up to 4 Other Materials.
The Other Materials used are to be listed on the submittal with the respective volumes for Core and Distributed Other Materials.

Curing
Curing shall be at atmospheric pressure.
The curing temperatures shall not exceed the boiling point of water.
Use of a standard moist-curing room is permitted.

Bowling Ball Design Category
Design makes choices with predictions.
Design occurs prior to the convention.
Design is indeterminate and predicts how the bowling ball will behave.
The predictions can be from calculations and practical knowledge.
The design category compares predictions and convention results, so each team is competing against itself.
The winning team for this category has the least difference between predictions and results.
The intended analogy is about a project proposal (designed behavior prediction).

Bowling Ball Analysis Category
Analysis evaluates choices with testing.
Analysis occurs during the convention.
Analysis is determinate and tests how the bowling ball has behaved.
The analysis will be from tests and practical experience.
The analysis category compares convention test results, so each team is competing against all the other teams.
The winning team for this category has more points than the other teams.
The intended analogy is about an executed project (judged analysis testing).

Scoring
These scores will be converted into category points based on relative importance and a 100-points based score.
The team rankings will be based on the number of category points earned as a result of each bowling ball test for that category. The bowling ball tests and score percentages are listed and summarized with the percentage of the total score for each category. Prizes will be awarded in the Design and Analysis categories of this competition.

**Judging**

The judges retain the right to use any means or methods they feel are necessary to verify and enforce the rules and requirements of the competition. The judges retain the right to interpret, modify, or eliminate any section or sections of these rules as special circumstances arise. Judges may allow teams to compete that are not eligible for prizes.

**Bowling Ball Tests and Competition**

Each team shall bring to the competition: 2 bowling balls, 2 copies of their Design Submittal, and 2 “see-through or clear” sample bags of each fiber used. Each sample bag must contain at least 10 fibers. For example, if 2 fiber material types are used then 4 bags are necessary. Both balls will be used in the competition and based on the judges' selection. The judge will select either ball for crushing or bowling. Teams with bowling balls outside the test range or limits of the test may be disqualified from the competition and ineligible for prizes. The head judges may allow the team with balls outside the range or limits to continue in the competition but are not required to do so. Continuation in the competition does not mean the Team is eligible for Prizes. Modification of entries shall not be permitted once they are accepted for the competition at check-in during the day of the competition.

**Specifications Test (10% of each Category)**

Each team must submit their forms and files for consideration for prizes. Fill forms and files completely, correctly, and in a readable and timely manner. Directions for filling forms and files are mostly self-explanatory with examples. Compliance with these specifications and files and schedule will establish your score. Penalties will apply for missing the scheduled dates for Registration and Submittals. Teams will receive 0.5-point penalty per day after Registrations are due. Teams will receive 1.0-point penalty per day after Submittals are due. Teams with 8.0-point penalties or more are not eligible for prizes. Penalties will apply for Teams that check-in either too early or too late for the scheduled times on the day of the Competition. Before convention, the judges will evaluate the files. Safe and professional behavior is expected during the competition. Disruptive and unsafe behavior will be penalized in the scoring of the team.

**Mass Test (10% of each Category)**

Each bowling ball mass shall be 5,500 +/- 500 g.
The mass of each ball will be measured and documented by the judges for adherence to the bowling ball mass consistency requirements set forth in these rules. All balls will be weighed using the same scale of the judges’ choice. Any ball outside of the stated mass range receives a Mass Test Score of zero (0). Any ball within the stated mass range receives a Mass Test Score = 5,500 – absolute value of (actual ball’s mass – 5,500). The Team’s Mass Test Score is the sum of each ball’s Mass Test Score.

**Diameter Test (10% of each Category)**
The bowling ball shall be spherical. The bowling ball shall measure 200 ± 15 mm diameter. Each ball will be measured along three different axes arbitrarily selected by the judges for adherence to the bowling ball diameter consistency requirements set forth in these rules. Any ball that has any one diameter measurement outside of the stated diameter range receives a Diameter Test Score of zero (0). Any ball with all diameter measurements within the stated diameter range receives a Diameter Test Score = 600 – absolute value of (sum of three diameter measurements – 600). The Team’s Diameter Test Score is the sum of each ball’s Diameter Test Score.

**Bowling Test (30% of each Category)**
The ball selected by the judges for bowling will be used by the team to “roll” and score modified frames of bowling. The bowling apparatus (ramp, lane, and pins) will be provided at the competition. The Ramp is approximately 1470 mm long, 670 mm wide, and 620 mm in height to achieve a reasonable ball speed. The bowling lane will be approximately 1000 mm wide and 4000 mm long or longer. Six standard-sized bowling pins will be used. During the day of the competition, the judges will decide these details based upon the total number of teams for the competition:

1. Pin arrangement and spacing,
2. How many rolls per frame,
3. How many frames will be bowled, and
4. Horizontal adjustments to the ramp for aiming the ball.

Further, judges will have the right to control the time for the bowling by imposing a time limit for the bowling portion of the competition to ensure that not too much time is spent aiming or adjusting for the ball roll or a maximum amount of time to accomplish the number of rolls for the chosen number of frames. In this case and if the total allowed number of rolls are not completed at the expiration of the allowed time, the score attained during the time limit will be the team’s bowling score. No practice rolls will be given to any team or individual prior to the test. Any practice rolls on ACI equipment will result in team disqualification. Under no circumstances is any ball to be run with, walked fast with, thrown, launched, or catapulted anywhere within the hotel venue.
Under no circumstances is any ball to be run with, walked fast with, thrown, launched, or catapulted anywhere within the competition area. Unacceptable behavior with and without the bowling balls will be penalized and may disqualify the students and their school from further competitions. The head judges have final determination regarding what is unacceptable. One, and only one, team member can be identified as the “Team Bowler”. One, and only one, team member can be identified as the “Team Returner”. The Team Bowler, with no assistance from any other members of the team, will position the test ball at the top of an inclined ramp and release it down the ramp onto a flat, non-oiled, hard-surfaced lane. The inclined ramp must be used to “roll” the ball. Once the bowling ball is released and begins its descent down the incline, the rolling ball may not be chased after or interrupted. If the ball rolls off the side of the lane prior to striking the pins, it is considered a gutter ball and no pins will be scored for that roll. The Team Returner will return the bowled ball to the Team Bowler. The resulting “knocked down” pin count will be recorded as the score for that frame. The judges will be responsible for setting the pins and recording the score. The team’s score at the completion of the number of frames selected for the competition will be the Bowling Test Score.

**Toughness Test (40% of each Category)**

The ball selected by the judges for crushing will be placed in a testing apparatus by the judges for controlled loading. The load shall be applied to maintain a constant rate of displacement (crushing). During the day of the competition, the judges will decide the displacement rate based upon the total number of teams for the competition. The displacement rate will be set between 5.00 and 12.50 mm per minute. The load will be recorded for every 5 mm of crosshead displacement and the average of the five loads will be computed. The load will be applied until the crosshead displacement of the testing apparatus has traveled 25 mm. The range for the average of the loads is to be greater than 5,000 pounds and less than 50,000 pounds. The standard deviation for the 5 loads will be normalized for the Toughness Test Score. The highest score is zero standard deviation for the 5 specified displacement loads. (A standard deviation of zero indicates no strain hardening or softening and ideal post-crack, elasto-plastic behavior from the fiber-reinforced concrete matrix.) The Toughness Test Score will be zero for any displacement load less than 3,000 pounds or more than 60,000 pounds.