



2024 Rules for Fiber-Reinforced Concrete Bowling Ball Competition

Student Teams

All members of a given team must be from the same school.

A team is limited to 2 to 10 students currently enrolled in a graduate or undergraduate college or university program. Each team must have a supervising faculty advisor to provide guidance and to help understand, and ensure compliance with, the rules of the competition. Each team must have one (1) primary contact.

Analysis Test Category of the Bowling Ball Competition

This category is analogous to a project that was analyzed and tested for comparison to plans and specifications. The project is making, bowling, and crushing bowling balls by following competition rules.

At the convention, each Teams' bowling balls will be tested in the mass, diameter, bowling, and toughness test areas. These tests are a typical analysis of practical testing measurements.

The Analysis Test Category compares the team's results during the competition against the target values as stated in these Rules. Teams are scored in the mass, diameter, bowling, and toughness tests as follows:

Absolute value of (Competition target – Team tests at competition)

Each team is then force-ranked from their score into a 90-points based system (i.e., 90%). The remaining 10-points (i.e., 10%) will be from the Specifications Test. Prizes will be awarded for the Analysis Test Category to the 2-teams that have the least difference of all the teams between the competition target values and their team results at the competition.

Bowling Ball Identification

Each Team must ensure that their bowling balls can be individually and uniquely identified. Teams can use letters, symbols, marks, paint, and other coloring for identification. All identification is to be aesthetically pleasing and must not be offensive.

Worksheet Submittal

Each Team must download, fill in, and submit the 2024 Design Submittal.xlsx file (the Submittal file) found at the SUBMITTAL link in the upper right corner of the Competition webpage. Within the Submittal file are two (2) worksheets/tabs: Team Acronym and Example. Each Team's bowling balls are to be constructed with Concrete Materials, Fiber Reinforcement, and Other Ball Materials per the Submittal and sections of these Rules.

Each Team must fill out the Team Acronym worksheet per their chosen mixture type (selected in cell B20) and bowling ball design. Each Team must refer to and follow the Example for cell formatting and number of places after the decimal for the numerical Values and Volumes.

Each Team must fill out the worksheet completely (refer to the Example). Do not add or delete rows or columns to the Team Acronym worksheet. Before submitting their completed Submittal file, each Team must:

1. change the name of the Team Acronym tab to their Team's selected acronym, and
2. change the name of the file to include their team's acronym after the word Submittal (for example, the team submitting the Example submittal would have named their file "2024 Design Submittal TUB.xlsx").

Concrete Materials

Teams are to design and construct their bowling balls from 1 of the 3 FRC mixture types:

- A fiber-reinforced concrete mixture,
- A UHPC mixture
- A UHPC pre-packaged (pre blended) product.

A list of UHPC suppliers from the ACI 239 UHPC committee is provided at the MANUFACTURERS link on the Competition webpage as possible suppliers of UHPC related products. Patching, filling, or repair of honeycombed surfaces after casting is allowed. Materials to correct the honeycombed surfaces must be selected from the same materials as used to construct the Team's bowling balls.

Fiber Reinforcement

The bowling ball must be made with fiber reinforcement. No other type of reinforcement is allowed.

A list of fiber suppliers from the ACI 544 Fiber Reinforced Concrete committee is provided at the MANUFACTURERS link on the Competition webpage as possible suppliers of fiber. Only the fiber material types described by the ASTM specifications listed in the Submittal file can be used.

Fibers must be commercially available and unaltered after receiving from the manufacturer. All fibers must be the same length and between 10 and 55 mm. The fibers may be used at any dosage or volume fraction.

FRC/UHPC Mixture Density

Each Team must calculate the density of the FRC/UHPC mixture used to construct their bowling balls. The mixture density should not include the density of Other Ball Materials.

Other Ball Materials

The bowling ball mass can be met with different materials of different densities (i.e. Other Ball Materials) in addition to the listed Concrete Materials and Fiber Reinforcement. The Other Ball Materials cannot be a Concrete Material or a Fiber Reinforcement. The Other Ball Materials must be encased within the bowling ball mixture.

The Other Ball Materials can be grouped together as a centered Core. The Other Ball Materials can also be homogeneously Distributed within the FRC/UHPC mixture.

The bowling balls may have multiple layers of different densities and/or one core with a different density. Expanded polystyrene beads mixed into the FRC/UHPC mixture is an example of Distributed materials. A balloon filled with expanded polystyrene beads and encased within the FRC/UHPC mixture is an example of Core materials.

The use of Other Ball Materials is optional. The text used in the Submittal for Other Ball Materials should briefly describe each material.

Competition Submittal

Each team shall bring to the competition:

- 2 bowling balls
- 2 copies of their Submittal worksheet

For teams using UHPC Pre-packaged by Supplier mixtures provide:

- 2 copies of its Technical Data sheet
- 2 translucent sample bags of the dry mixture with approximately 75 grams
including some fibers in each bag

For teams making their own mixtures:

- 2 copies of their fiber's Technical Data sheet
- 2 translucent sample bags of each fiber used with at least 10 fibers in each bag

Specifications Test (10 % of the points for each Category)

This test is about following the Rules with submittals before and during the competition. Every Team starts with the highest score in this test. The Team score will decrease due to incorrect paperwork as described under "Worksheet Submittal" and incorrect quantities as described under "Competition Submittal".

Mass Test (10% of the points for each Category)

The target mass of each bowling ball is 5,500 g. The mass of each bowling ball shall be within the range of 5,500 g +/-500 g. The mass of each bowling ball will be measured during the competition. The average mass of a Team's two bowling balls will determine the Team's points. A Team will have less Mass Test points if any ball's mass is outside of the stated range.

Diameter Test (10% of the points for each Category)

The bowling ball shall be spherical. The target diameter of each bowling ball is 200 mm. The diameter of each bowling ball shall be within the range of 200 +/- 15 mm. The diameter of each bowling ball will be measured along three arbitrarily selected axes during the competition. The average diameter of a Team's 2 bowling balls will determine the Team's points. A Team will have less Diameter Test points if any ball's diameter is outside of the stated range.

Bowling Test (30% of the points for each Category)

The ball selected by the judges for bowling will be used by the team to "roll" and score in modified bowling. The target and highest score for the bowling test is 36. The competition's modified bowling consists of:

- 6 frames of bowling to be completed within an allotted time (determined the day of the competition),
- 6 standard-sized bowling pins,
- Only 1 roll of the ball per frame,
- A modified bowling lane
- A standard metal inclined ramp is used to achieve a reasonable ball speed,
- A safety device is used to release the ball, and directional adjustments of the ramp are allowed.

The ramp is set to a non-aligned starting position before each team bowls. No practice rolls are allowed for any team or individual prior to the competition test. After the ball is released and descends, the rolling ball may not be chased or interrupted. The resulting "knocked down" pin count will be recorded as the score for that frame.

Toughness Test (40% of the points for each Category)

The ball selected by the judges for crushing will be placed in a testing apparatus by the judges for controlled loading. On the day of the competition, the judges will set a constant displacement rate for the test between 5.00 and 12.50 mm per minute. A load is continually applied to the ball. The load will be recorded at every 5 mm of crosshead displacement between 0 and 25 mm.

The target and highest score is obtained when the load at all 5 deflections is constant(same), which results in a coefficient of variation (COV) of 0%. The COV is the standard deviation of the 5 loads divided by the average of the 5 loads, and a 0% COV exemplifies an ideal elasto-plastic behavior from the fiber-reinforced concrete matrix.

A team will have less Toughness Test points if:

- any displacement load is less than 3,000 pounds or more than 60,000 pounds, or
- an average of the loads is less than 5,000 pounds or more than 50,000 pounds.