

# **2024 ASCE Mid-America Student Symposium Rules for Fiber-Reinforced Concrete Bowling Ball Competition**

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## **G1-Student Teams**

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 3 to 8 students currently enrolled in an 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.

Team members attend the competition and compete with their bowling balls; all members are welcome, a minimum of three (3) members are preferred, but at least one (1) must attend.

Each team will be assigned a Check-In Time by the Judges that will be used for scheduling and scoring the day of the competition.

## **G2-Design Prediction Category of the Bowling Ball Competition**

This category is analogous to a project that was designed and predicted to behave within certain criteria. The project is making, bowling, and crushing bowling balls by following competition rules.

Before the convention, each Team is to design and make bowling balls.

Also, before the convention, each Team is to predict how their bowling balls will perform in the mass, diameter, bowling, and toughness test areas on the day of the competition.

The predictions can be from calculations, experience, and practical knowledge.

The Design Prediction Category compares the team's submitted performance predictions against the team's results during the competition.

Teams are scored in the mass, diameter, bowling, and toughness tests as follows:

Absolute value of (Team prediction – 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 Design Prediction Category to the 3-teams that have the least difference of all the teams between their team predictions and their team results at the competition.

## **G3-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.

Again, 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 3-teams that have the least difference of all the teams between the competition target values and their team results at the competition.

#### **G4-Judging 55**

Safe and professional behavior is expected during the competition.

The judges retain the right to interpret, modify, or eliminate any section or sections of these rules as special circumstances arise.

The judges have final determination regarding what is acceptable for continued participation in the competition.

Teams may not be eligible for prizes if they:

- do not follow the Rules of the competition,
- miss the scheduled dates for Registration or Submittal,
- check-in either too early or too late on the day of the Competition,
- run or walk fast with a ball anywhere,
- throw, launch, or catapult a ball anywhere except when completing the bowling aspect of the competition,
- behave in a way that is not safe,
- behave in a way that is disruptive, offensive, or not professional, and
- submit bowling balls outside the limits of any of the 5 test areas.

The judges may allow teams who are not eligible for prizes to continue to participate in the competition, but they are still not eligible for prizes.

Egregious violation of the Rules may result in a Team being removed from the competition and the school risks recommendations to ACI Committee S801 for sanctioning of the team, their advisor, and/or school/university from participation in future competitions.

The judges retain the right to determine any infraction of the Rules.

#### **G5-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.

## **T1-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 "S1- Worksheet Submittal" and incorrect quantities as described under "S7-Competition Submittal".

### **S1-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 S2, S3 and S5 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 "2023 Design Submittal TUB.xlsx").

Each Team must upload their completed Submittal file to ACI via the Competition registration link by the date in the Schedule.

### **S2-Concrete Materials**

Teams are to design and construct their bowling balls from 1 of the 3 FRC mixture types: a fiber-reinforced concrete mixture, UHPC mixture, or UHPC pre-packaged (pre115 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.

### **S3-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.

#### **S4-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.

#### **S5-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 (see the Example for examples).

#### **S6-Design Predictions**

Each Team must determine their predictions on how their bowling balls will perform in the mass, diameter, bowling, and toughness test areas during the competition.

Indicate your Team's predictions in your Team's Submittal file.

#### **S7-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

**T2-Mass Test** (10% of the points for each Category)

The target mass of each bowling ball is 4,750 g.

The mass of each bowling ball shall be within the range of 4,750 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 no Mass Test points if any ball's mass is outside of the stated range.

**T3-Diameter Test** (10% of the points for each Category)

The bowling ball shall be spherical.

The target diameter of each bowling ball is 215 mm.

The diameter of each bowling ball shall be within the range of 215 +/- 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 no Diameter Test points if any ball's diameter is outside of the stated range.

**T4-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 60.

The competition's modified bowling consists of:

- Teams will throw their balls without the use of a ramp for this portion of the competition.

Note: This is different from typical rules for the ACI concrete bowling ball competition.

- 10 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 for the first 8 frames,
- The last 2 frames will consist of 2 rolls per frame
- A wooden bowling lane with approximate dimensions as described below:
  - Length: Approximately 8m
  - Width: Approximately 1m

Note: For those who attended the 2023 Mid-America Concrete Bowling Ball Competition, the same bowling lane will be used.

Any number of team members may be identified as the "Team Bowler" for any number of frames.

Any number of team members may be identified as the "Team Returner" for any number of frames.

Note: a team member may be identified as both a Team Bowler and Team Returner.

The Judge will tell the Team Bowler when the ball can be released.

After the ball is released, the rolling ball may not be chased or interrupted.  
 The resulting “knocked down” pin count will be recorded as the score for that frame.  
 The Judge will tell the Team Returner when to return the ball to the Team Bowler.  
 If 10 frames are not bowled within the allotted time, the score attained during the allotted time will be the team’s bowling score.  
 The judges will be responsible for setting the pins and recording the score.

**T5-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 no Toughness Test points if:

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

See Image 2 further below.

**G6-Images**

Image 1: Schematic of the “toughness” test and 5 load readings; graphical representation of 0% COV and a perfectly elasto-plastic response.

