

1 ***2023 Rules for Fiber-Reinforced Concrete Bowling Ball Competition***

2
3 ***G1-Student Teams***

4 Only 1 team per school is eligible for this competition.

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

6 A team is limited to 3 to 8 students currently enrolled in an undergraduate college or
7 university program.

8 Each team must have a supervising faculty advisor to provide guidance and to help
9 understand, and ensure compliance with, the rules of the competition.

10 Each team must have one (1) primary contact.

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

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

16
17 ***G2-Design Prediction Category of the Bowling Ball Competition***

18 This category is analogous to a project that was designed and predicted to behave within
19 certain criteria.

20 The project is making, bowling, and crushing bowling balls by following competition
21 rules.

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

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

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

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

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

29 Absolute value of (Team prediction – Team tests at competition)

30 Each team is then force-ranked from their score into a 90-points based system (i.e., 90%).

31 The remaining 10-points (i.e., 10%) will be from the Specifications Test.

32 Prizes will be awarded for the Design Prediction Category to the 3-teams that have the
33 least difference of all the teams between their team predictions and their team results at
34 the competition.

35
36 ***G3-Analysis Test Category of the Bowling Ball Competition***

37 This category is analogous to a project that was analyzed and tested for comparison to
38 plans and specifications.

39 Again, the project is making, bowling, and crushing bowling balls by following
40 competition rules.

41 At the convention, each Teams' bowling balls will be tested in the mass, diameter,
42 bowling, and toughness test areas.

43 These tests are a typical analysis of practical testing measurements.

44 The Analysis Test Category compares the team's results during the competition against
45 the target values as stated in these Rules.

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

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

48 Each team is then force-ranked from their score into a 90-points based system (i.e., 90%).

49 The remaining 10-points (i.e., 10%) will be from the Specifications Test.

50 Prizes will be awarded for the Analysis Test Category to the 3-teams that have the least
51 difference of all the teams between the competition target values and their team results at
52 the competition.

53

54 ***G4-Judging***

55 Safe and professional behavior is expected during the competition.

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

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

60 Teams may not be eligible for prizes if they:

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

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

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

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

76

77 ***G5-Bowling Ball Identification***

78 Each Team must ensure that their bowling balls can be individually and uniquely
79 identified.

80 Teams can use letters, symbols, marks, paint, and other coloring for identification.

81 All identification is to be aesthetically pleasing and must not be offensive.

82

83 ***T1-Specifications Test (10 % of the points for each Category)***

84 This test is about following the Rules with submittals before and during the competition.

85 Every Team starts with the highest score in this test.

86 The Team score will decrease due to incorrect paperwork as described under “S1-
87 Worksheet Submittal” and incorrect quantities as described under “S7-Competition
88 Submittal”.

89

90 ***S1-Worksheet Submittal***

91 Each Team must download, fill in, and submit the *2023 Design Submittal.xlsx* file (the
92 Submittal file) found at the SUBMITTAL link in the upper right corner of the
93 Competition webpage.

94 Within the Submittal file are two (2) worksheets/tabs: *Team Acronym* and *Example*.

95 Each Team's bowling balls are to be constructed with Concrete Materials, Fiber
96 Reinforcement, and Other Ball Materials per the Submittal and sections S2, S3 and S5 of
97 these Rules.

- 98 Each Team must fill out the *Team Acronym* worksheet per their chosen mixture type
99 (selected in cell B20) and bowling ball design.
100 Each Team must refer to and follow the *Example* for cell formatting and number of
101 places after the decimal for the numerical Values and Volumes.
102 Each Team must fill out the worksheet completely (refer to the *Example*).
103 Do not add or delete rows or columns to the *Team Acronym* worksheet.
104 Before submitting their completed Submittal file, each Team must:
105 1. change the name of the *Team Acronym* tab to their Team's selected acronym, and
106 2. change the name of the file to include their team's acronym after the word
107 Submittal (for example, the team submitting the *Example* submittal would have
108 named their file "2023 Design Submittal TUB.xlsx").
109 Each Team must upload their completed Submittal file to ACI via the Competition
110 registration link by the date in the Schedule.

112 ***S2-Concrete Materials***

- 113 Teams are to design and construct their bowling balls from 1 of the 3 FRC mixture types:
114 a fiber-reinforced concrete mixture, UHPC mixture, or UHPC pre-packaged (pre-
115 blended) product.
116 A list of UHPC suppliers from the ACI 239 UHPC committee is provided at the
117 MANUFACTURERS link on the Competition webpage as possible suppliers of UHPC
118 related products.
119 Patching, filling, or repair of honeycombed surfaces after casting is allowed.
120 Materials to correct the honeycombed surfaces must be selected from the same materials
121 as used to construct the Team's bowling balls.

123 ***S3-Fiber Reinforcement***

- 124 The bowling ball must be made with fiber reinforcement.
125 No other type of reinforcement is allowed.
126 A list of fiber suppliers from the ACI 544 Fiber Reinforced Concrete committee is
127 provided at the MANUFACTURERS link on the Competition webpage as possible
128 suppliers of fiber.
129 Only the fiber material types described by the ASTM specifications listed in the
130 Submittal file can be used.
131 Fibers must be commercially available and unaltered after receiving from the
132 manufacturer.
133 All fibers must be the same length and between 10- and 55-mm.
134 The fibers may be used at any dosage or volume fraction.

136 ***S4-FRC/UHPC Mixture Density***

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

141 ***S5-Other Ball Materials***

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

147 The Other Ball Materials can be grouped together as a centered Core.
148 The Other Ball Materials can also be homogeneously Distributed within the FRC/UHPC
149 mixture.
150 The bowling balls may have multiple layers of different densities and/or one core with a
151 different density.
152 Expanded polystyrene beads mixed into the FRC/UHPC mixture is an example of
153 Distributed materials.
154 A balloon filled with expanded polystyrene beads and encased within the FRC/UHPC
155 mixture is an example of Core materials.
156 The use of Other Ball Materials is optional.
157 The text used in the Submittal for Other Ball Materials should briefly describe each
158 material (see the *Example* for examples).

159

160 ***S6-Design Predictions***

161 Each Team must determine their predictions on how their bowling balls will perform in
162 the mass, diameter, bowling, and toughness test areas during the competition.
163 Indicate your Team's predictions in your Team's Submittal file.

164

165 ***S7-Competition Submittal***

166 Each team shall bring to the competition:

- 167 • 2 bowling balls
- 168 • 2 copies of their Submittal worksheet
- 169 • For teams using UHPC Pre-packaged by Supplier mixtures provide:
 - 170 • 2 copies of its Technical Data sheet
 - 171 • 2 translucent sample bags of the dry mixture with approximately 75 grams
172 including some fibers in each bag
- 173 • For teams making their own mixtures:
 - 174 • 2 copies of their fiber's Technical Data sheet
 - 175 • 2 translucent sample bags of each fiber used with at least 10 fibers in each bag

176

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

178 The target mass of each bowling ball is 5,500 g.
179 The mass of each bowling ball shall be within the range of 5,500 g +/-500 g.
180 The mass of each bowling ball will be measured during the competition.
181 The average mass of a Team's two bowling balls will determine the Team's points.
182 A Team will have no Mass Test points if any ball's mass is outside of the stated range.

183

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

185 The bowling ball shall be spherical.
186 The target diameter of each bowling ball is 200 mm.
187 The diameter of each bowling ball shall be within the range of 200 +/- 15 mm.
188 The diameter of each bowling ball will be measured along three arbitrarily selected axes
189 during the competition.
190 The average diameter of a Team's 2 bowling balls will determine the Team's points.
191 A Team will have no Diameter Test points if any ball's diameter is outside of the stated
192 range.

193

194 ***T4-Bowling Test (30% of the points for each Category)***

195 The ball selected by the judges for bowling will be used by the team to “roll” and score in
196 modified bowling.

197 The target and highest score for the bowling test is 36.

198

199 The competition’s modified bowling consists of:

- 200 • 6 frames of bowling to be completed within an allotted time (determined the day
201 of the competition),
- 202 • 6 standard-sized bowling pins,
- 203 • Only 1 roll of the ball per frame,
- 204 • A bowling lane with approximate dimensions as shown in Image 4,
- 205 • A standard metal inclined ramp is used to achieve a reasonable ball speed,
- 206 • A safety device is used to release the ball, and
- 207 • 3 directional adjustments of the ramp are allowed in total.
- 208 • See Images 1, 2, 3, and 4 further below.

209 The ramp is set to a non-aligned starting position before each team bowls.

210 No practice rolls are allowed for any team or individual prior to the competition test.

211 A team member will be identified as the “Team Bowler” for all frames.

212 A team member will be identified as the “Team Returner” for all frames.

213 The Team Bowler will put the ball in the safety device at the top of the ramp.

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

215 After the ball is released and descends, the rolling ball may not be chased or interrupted.

216 The resulting “knocked down” pin count will be recorded as the score for that frame.

217 The Judge will tell the Team Returner when to return the ball to the Team Bowler.

218 If 6 frames are not bowled within the allotted time, the score attained during the allotted
219 time will be the team’s bowling score.

220 The judges will be responsible for setting the pins and recording the score.

221

222 ***T5-Toughness Test (40% of the points for each Category)***

223 The ball selected by the judges for crushing will be placed in a testing apparatus by the
224 judges for controlled loading.

225 On the day of the competition, the judges will set a constant displacement rate for the test
226 between 5.00 and 12.50 mm per minute.

227 A load is continually applied to the ball.

228 The load will be recorded at every 5 mm of crosshead displacement between 0 and
229 25 mm.

230 The target and highest score is obtained when the load at all 5 deflections is constant
231 (same), which results in a coefficient of variation (COV) of 0%.

232 The COV is the standard deviation of the 5 loads divided by the average of the 5 loads,
233 and a 0% COV exemplifies an ideal elasto-plastic behavior from the fiber-reinforced
234 concrete matrix.

235 A team will have no Toughness Test points if:

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

238 See Image 5 further below.

239

240 **G6-Images**

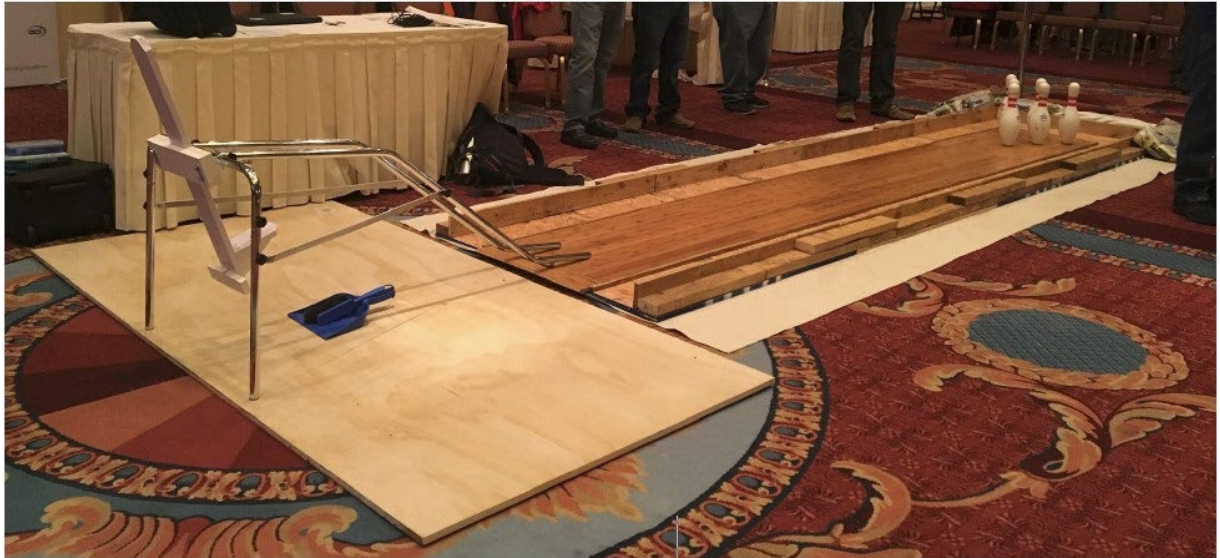


Image 1: Bowling lane set up from 2018 competition in Salt Lake City, UT.

241

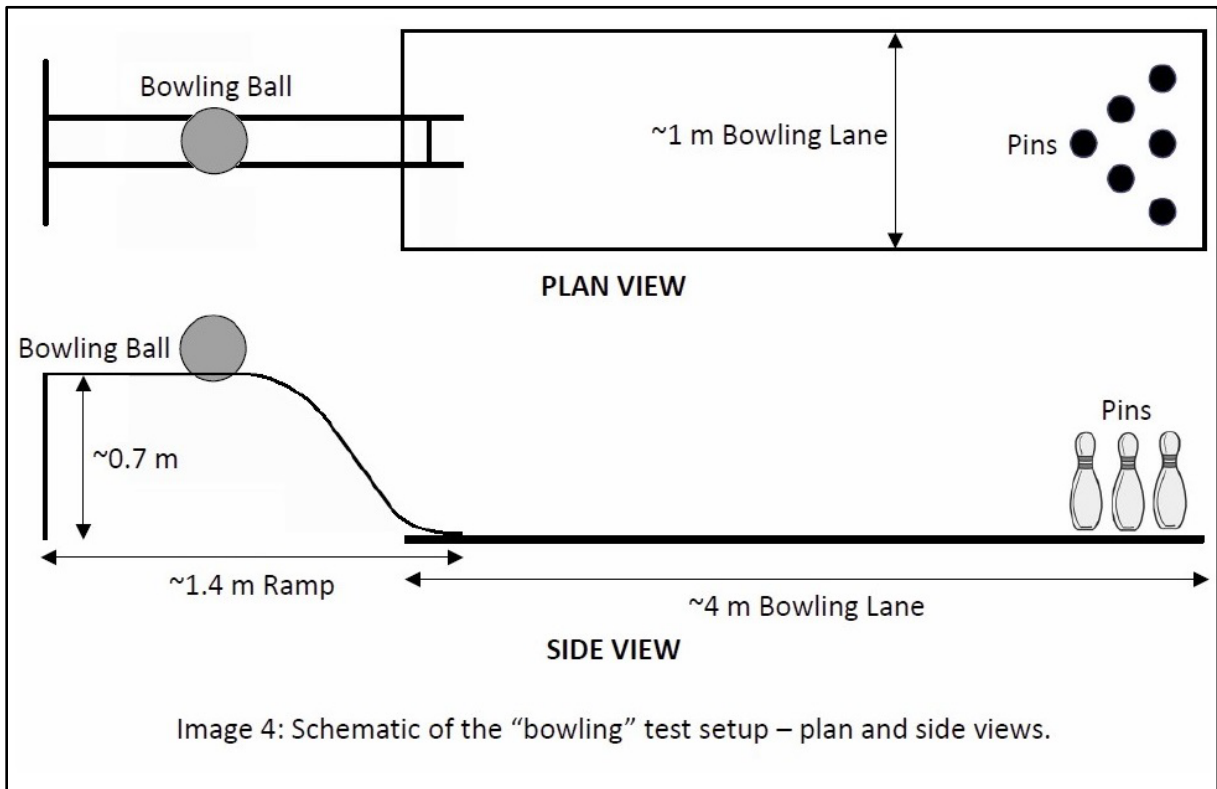


Image 2 : Bowling lane set up from 2018 competition in Salt Lake City, UT.



Image 3: Release device.

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243

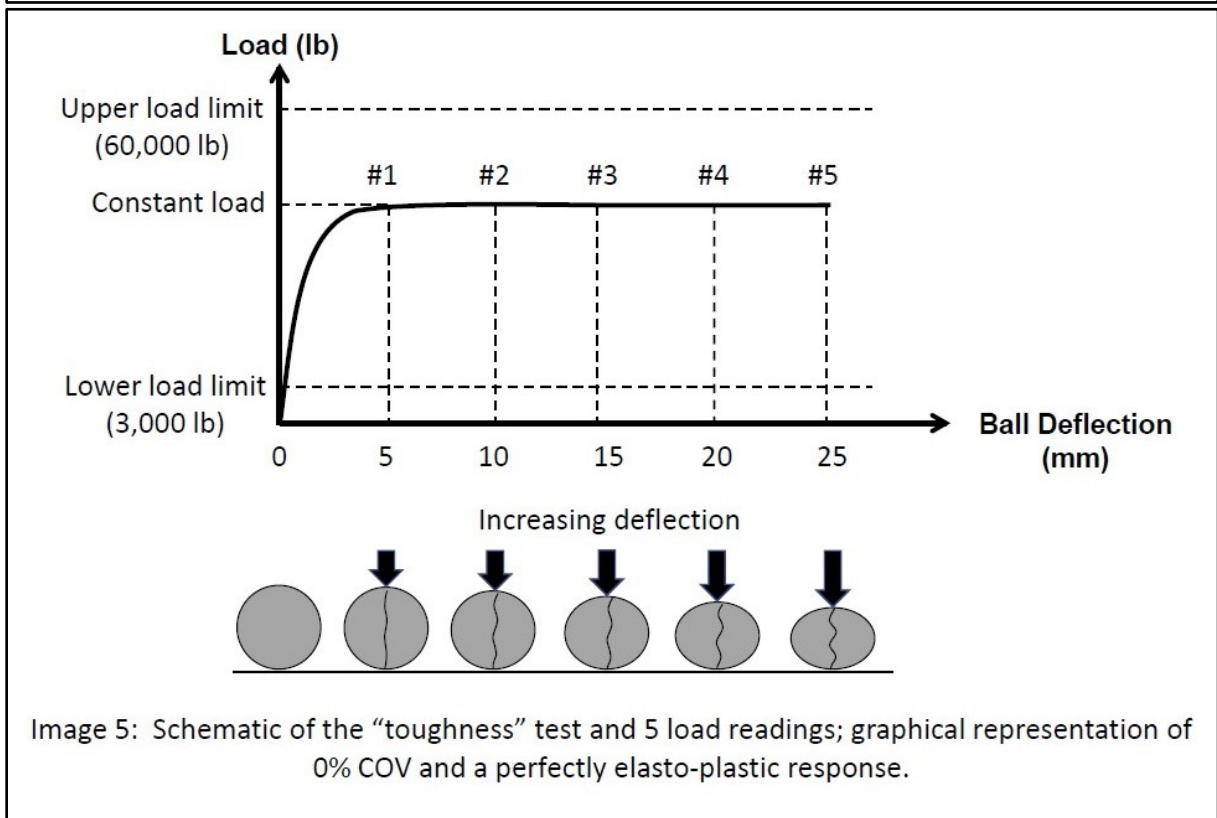


Image 5: Schematic of the “toughness” test and 5 load readings; graphical representation of 0% COV and a perfectly elasto-plastic response.

244
245

End of Rules