

1 **File 2022 Rules 2021-09-17**

2
3 ***2022 Rules for Fiber-Reinforced Concrete Bowling Ball Competition***

4
5 ***Student Team***

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

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

8 A team is limited to 2 to 8 students currently enrolled in a home school, high school, or
9 an undergraduate college or university program.

10 Undergraduate students on cooperative or internship work assignment are eligible to
11 compete.

12 Each team must have a supervising faculty advisor who will see that the team complies
13 with the rules of the competition.

14 A faculty advisor and 2 student team members must be designated as primary contacts for
15 each team.

16 At least one individual (faculty advisor or student team member) must be present at
17 convention for each of the bowling ball tests.

18 Each team must submit the required files on time to be eligible for prizes.

19 Every team may be assigned a Team Name by the Judges.

20 The Team Name may be used for scheduling and other purposes during the competition.

21
22 ***Bowling Ball Identification***

23 Ensure that your team's bowling balls can be individually and uniquely identified, both
24 from each other and from other team's bowling balls.

25 Teams can use letters, symbols, marks, and coloring for identification.

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

27 Unacceptable markings and unacceptable depictions on the bowling balls will be
28 penalized and may disqualify the students and their school from further competitions.

29 The head judges have final determination regarding what is unacceptable.

30 Bowling balls may be painted.

31 If painted, use only up to 4 colors.

32 Epoxy-based paints are not allowed.

33
34 ***Bowling Ball Materials***

35 Teams design and construct bowling balls from a fiber-reinforced concrete mixture,
36 including UHPC.

37 The bowling balls can be constructed from the Concrete Materials, Fiber Reinforcement,
38 and Other Materials as listed on the 2022 Design Submittal worksheet within the Excel
39 file named *2022 Design Submittal and Examples ABC* (found at the SUBMITTAL link
40 on the Competition webpage).

41 The Other Materials are for constructing a core and/or using distributed materials for
42 achieving the desired bowling ball density.

43 Teams choose their 1 FRC mixture type from the 3 example FRC mixture types A, B, or
44 C, provided within the Excel file.

45 The 3 different mixture types allow the use of different ingredients for different
46 concretes.

47 Example mixtures A and B use individual ingredients.
48 Mixture C uses a prepackaged/pre-blended product as an ingredient.
49 The Team's bowling balls are to be produced from the Team chosen mixture type.
50 Only those Concrete Material ingredients listed in each individual mixture type are
51 allowed.
52 The disallowed Concrete Material ingredients are indicated in each mixture type
53 respectively with cell entries XA, XB, or XC.
54 Fill the cells of the worksheet *2022 Design Submittal* following the chosen mixture type.
55 Do not add or delete rows or columns to the Design Submittal worksheet.
56 You must include the appropriate text XA, XB, or XC in the cells as shown for
57 disallowed ingredient materials.
58 Refer to the Example A, B, or C for the proper number of places after the decimal for the
59 numerical Values and Volumes.
60 The text for Other Materials should use no more than 5 words to describe each material
61 or color.

62

63 ***Concrete Materials***

64 Only the Concrete Materials listed in the Design Submittal can be used.
65 UHPC suppliers from the ACI 239 UHPC committee are listed as possible suppliers of
66 prepackaged/pre-blended product or other concrete materials (found at the
67 MANUFACTURERS link on the Competition webpage).
68 Not all the materials listed are required to be used.
69 Patching, filling, or repair of honeycombed surfaces after casting is allowed.
70 Materials to correct the honeycombed surfaces must be selected from the exact same
71 materials used in the Design Submittal.

72

73 ***Fiber Reinforcement***

74 The bowling ball must be made with fiber reinforcement.
75 No other type of reinforcement is allowed.
76 Fiber suppliers from the ACI 544 Fiber Reinforced Concrete committee are listed as
77 possible fiber suppliers (found at the MANUFACTURERS link on the Competition
78 webpage).
79 The Fiber Reinforced Concrete Association also lists possible fiber suppliers on their
80 website (<http://fiberreinforcedconcrete.org>).
81 The Design Submittal shall use no more than 2 fiber material types from the 4 fiber
82 material types as described by the ASTM specifications listed in the Design Submittal.
83 Do not use any other fiber materials.
84 Fibers must be commercially available.
85 Regardless of fiber material type, all fibers are to be the same length and the maximum
86 length is 60 mm.
87 The fibers may be used at any dosage or volume fraction.

88

89 ***Other Materials***

90 The bowling ball mass can be met with different materials and different densities than the
91 listed Concrete Materials and Fibrous Reinforcement.
92 The Other Materials cannot be a Concrete Material or a Fiber Reinforcement.

93 The Other Materials can be mixed or used within the bowling ball to meet the mass
94 requirement.
95 Some examples are:
96 The Other Materials can be grouped together as a centered Core.
97 The Other Materials can also be homogeneously Distributed within the FRC Mixture.
98 The bowling balls may have multiple layers of different densities or one core with a
99 different density.
100 Expanded polystyrene beads are an example of an acceptable homogeneously distributed
101 Other Materials.
102 A balloon filled with expanded polystyrene beads is an example of an acceptable core
103 using 2 Other Materials.
104 The use of Other Materials is optional.
105 Use none or up to 4 Other Materials.
106 The Other Materials used are to be listed on the submittal with the respective volumes for
107 Core and Distributed Other Materials.
108

109 ***Curing***

110 Curing shall be at atmospheric pressure.
111 The curing temperatures shall not exceed the boiling point of water.
112 Use of a standard moist-curing room is permitted.
113

114 ***Bowling Ball Design Category***

115 Design makes choices with predictions.
116 Design occurs prior to the convention.
117 Design is indeterminate and predicts how the bowling ball will behave.
118 The predictions can be from calculations and practical knowledge.
119 The design category compares predictions and convention results, so each team is
120 competing against itself.
121 The winning team for this category has the least difference between predictions and
122 results.
123 The intended analogy is about a project proposal (designed behavior prediction).
124

125 ***Bowling Ball Analysis Category***

126 Analysis evaluates choices with testing.
127 Analysis occurs during the convention.
128 Analysis is determinate and tests how the bowling ball has behaved.
129 The analysis will be from tests and practical experience.
130 The analysis category compares convention test results, so each team is competing
131 against all the other teams.
132 The winning team for this category has more points than the other teams.
133 The intended analogy is about an executed project (judged analysis testing).
134

135 ***Scoring***

136 These scores will be converted into category points based on relative importance and a
137 100-points based score.

138 The team rankings will be based on the number of category points earned as a result of
139 each bowling ball test for that category.

140 The bowling ball tests and score percentages are listed and summarized with the
141 percentage of the total score for each category.

142 Prizes will be awarded in the Design and Analysis categories of this competition.

143

144 ***Judging***

145 The judges retain the right to use any means or methods they feel are necessary to verify
146 and enforce the rules and requirements of the competition.

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

149 Judges may allow teams to compete that are not eligible for prizes.

150

151 ***Bowling Ball Tests and Competition***

152 Each team shall bring to the competition: 2 bowling balls, 2 copies of their Design
153 Submittal, and 2 “see-through or clear” sample bags of each fiber used.

154 Each sample bag must contain at least 10 fibers.

155 For example, if 2 fiber material types are used then 4 bags are necessary.

156 Both balls will be used in the competition and based on the judges' selection.

157 The judge will select either ball for crushing or bowling.

158 Teams with bowling balls outside the test range or limits of the test may be disqualified
159 from the competition and ineligible for prizes.

160 The head judges may allow the team with balls outside the range or limits to continue in
161 the competition but are not required to do so.

162 Continuation in the competition does not mean the Team is eligible for Prizes.

163 Modification of entries shall not be permitted once they are accepted for the competition
164 at check-in during the day of the competition.

165

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

167 Each team must submit their forms and files for consideration for prizes.

168 Fill forms and files completely, correctly, and in a readable and timely manner.

169 Directions for filling forms and files are mostly self-explanatory with examples.

170 Compliance with these specifications and files and schedule will establish your score.

171 Penalties will apply for missing the scheduled dates for Registration and Submittals.

172 Teams will receive 0.5-point penalty per day after Registrations are due.

173 Teams will receive 1.0-point penalty per day after Submittals are due.

174 Teams with 8.0-point penalties or more are not eligible for prizes.

175 Penalties will apply for Teams that check-in either too early or too late for the scheduled
176 times on the day of the Competition.

177 Before convention, the judges will evaluate the files.

178 Safe and professional behavior is expected during the competition.

179 Disruptive and unsafe behavior will be penalized in the scoring of the team.

180

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

182 Each bowling ball mass shall be 5,500 +/- 500 g.

183 The mass of each ball will be measured and documented by the judges for adherence to
 184 the bowling ball mass consistency requirements set forth in these rules.

185 All balls will be weighed using the same scale of the judges' choice.

186 Any ball outside of the stated mass range receives a Mass Test Score of zero (0).

187 Any ball within the stated mass range receives a Mass Test Score = $5,500 - \text{absolute}$
 188 value of (actual ball's mass - 5,500).

189 The Team's Mass Test Score is the sum of each ball's Mass Test Score.

190

191 ***Diameter Test (10% of each Category)***

192 The bowling ball shall be spherical.

193 The bowling ball shall measure 200 ± 15 mm diameter.

194 Each ball will be measured along three different axes arbitrarily selected by the judges for
 195 adherence to the bowling ball diameter consistency requirements set forth in these rules.

196 Any ball that has any one diameter measurement outside of the stated diameter range
 197 receives a Diameter Test Score of zero (0).

198 Any ball with all diameter measurements within the stated diameter range receives a
 199 Diameter Test Score = $600 - \text{absolute value of (sum of three diameter measurements -}$
 200 $600)$.

201 The Team's Diameter Test Score is the sum of each ball's Diameter Test Score.

202

203 ***Bowling Test (30% of each Category)***

204 The ball selected by the judges for bowling will be used by the team to "roll" and score
 205 modified frames of bowling.

206 The bowling apparatus (ramp, lane, and pins) will be provided at the competition.

207 The Ramp is approximately 1470 mm long, 670 mm wide, and 620 mm in height to
 208 achieve a reasonable ball speed.

209 The bowling lane will be approximately 1000 mm wide and 4000 mm long or longer.

210 Six standard-sized bowling pins will be used.

211 During the day of the competition, the judges will decide these details based upon the
 212 total number of teams for the competition:

213 1-Pin arrangement and spacing,

214 2-How many rolls per frame,

215 3-How many frames will be bowled, and

216 4-Horizontal adjustments to the ramp for aiming the ball.

217 Further, judges will have the right to control the time for the bowling by imposing a time
 218 limit for the bowling portion of the competition to ensure that not too much time is spent
 219 aiming or adjusting for the ball roll or a maximum amount of time to accomplish the
 220 number of rolls for the chosen number of frames.

221 In this case and if the total allowed number of rolls are not completed at the expiration of
 222 the allowed time, the score attained during the time limit will be the team's bowling
 223 score.

224 No practice rolls will be given to any team or individual prior to the test.

225 Any practice rolls on ACI equipment will result in team disqualification.

226 Under no circumstances is any ball to be run with, walked fast with, thrown, launched, or
 227 catapulted anywhere within the hotel venue.

228 Under no circumstances is any ball to be run with, walked fast with, thrown, launched, or
229 catapulted anywhere within the competition area.
230 Unacceptable behavior with and without the bowling balls will be penalized and may
231 disqualify the students and their school from further competitions.
232 The head judges have final determination regarding what is unacceptable.
233 One, and only one, team member can be identified as the “Team Bowler”.
234 One, and only one, team member can be identified as the “Team Returner”.
235 The Team Bowler, with no assistance from any other members of the team, will position
236 the test ball at the top of an inclined ramp and release it down the ramp onto a flat, non-
237 oiled, hard-surfaced lane.
238 The inclined ramp must be used to “roll” the ball.
239 Once the bowling ball is released and begins its descent down the incline, the rolling ball
240 may not be chased after or interrupted.
241 If the ball rolls off the side of the lane prior to striking the pins, it is considered a gutter
242 ball and no pins will be scored for that roll.
243 The Team Returner will return the bowled ball to the Team Bowler.
244 The resulting “knocked down” pin count will be recorded as the score for that frame.
245 The judges will be responsible for setting the pins and recording the score.
246 The team’s score at the completion of the number of frames selected for the competition
247 will be the Bowling Test Score.
248
249 ***Toughness Test (40% of each Category)***
250 The ball selected by the judges for crushing will be placed in a testing apparatus by the
251 judges for controlled loading.
252 The load shall be applied to maintain a constant rate of displacement (crushing).
253 During the day of the competition, the judges will decide the displacement rate based
254 upon the total number of teams for the competition.
255 The displacement rate will be set between 5.00 and 12.50 mm per minute.
256 The load will be recorded for every 5 mm of crosshead displacement and the average of
257 the five loads will be computed.
258 The load will be applied until the crosshead displacement of the testing apparatus has
259 traveled 25 mm.
260 The range for the average of the loads is to be greater than 5,000 pounds and less than
261 50,000 pounds.
262 The standard deviation for the 5 loads will be normalized for the Toughness Test Score.
263 The highest score is zero standard deviation for the 5 specified displacement loads.
264 (A standard deviation of zero indicates no strain hardening or softening and ideal post-
265 crack, elasto-plastic behavior from the fiber-reinforced concrete matrix.)
266 The Toughness Test Score will be zero for any displacement load less than 3,000 pounds
267 or more than 60,000 pounds.