# Pervious Concrete Cylinder Competition, sponsored by Committee 522, Pervious Concrete

## Objectives

Teams are challenged to apply sustainability concepts and to use their knowledge of concrete mixture design by producing pervious concrete which balances permeability and splitting tensile strength. Teams are additionally challenged to develop a mixture design which could be selected as "Best in Show" by practicing Pervious Concrete Professionals. The Best in Show mix is that which receives the most votes of the professionals – they will evaluate the mixtures on practicality, expense, ease of placement, and other real-world concepts. The students' ability to accurately create a mix design documenting the concrete is also scored. Only teams judged to have a complete and accurate mix design are eligible for inclusion in the Best in Show prize category.

## Prizes

Two prize categories are offered, Cylinder Performance and Best in Show. First, second, and third place entries in both categories will be awarded a certificate of recognition, will be recognized in Concrete International magazine (if space allows), and will be recognized on ACI's website. In addition, for each category the first-place team will receive a $750 award, the second-place team will receive $500, and the third-place team will receive $250. Results will be announced, and prizes awarded at the student lunch, following the competition on Monday of convention.

Each school shall be eligible for only one prize per category.

## Resources

This competition uses a falling-head permeameter method, see Figure 1. A picture of a similar (but not exact) falling-head permeameter test setup may be obtained in ACI 522R-06 "Pervious Concrete." A parts list used in the permeameter is also available upon request. General information on pervious concrete can be obtained from ACI 522R, ACI 522.1, and ACI 211.3, Appendix 6. Note: ACI documents are available to student chapters in the MCP online through the local chapter.

# Rules

## 1. Eligibility

a. Team members shall consist only of high school, technical school, trade school, or undergraduate college or university student(s) at the time of cylinder casting. Undergraduate students on cooperative or internship work assignment are also eligible to compete. All members of a team shall be from the same school. Each school is limited to a single team.

b. A team is limited to eight individuals. A student may not be a member of more than one team. Each team shall submit a single entry into the competition. Each entry is comprised of two pervious concrete cylinders, one electronic Mix Design Submittal Package, and one Official Mixture Design spreadsheet as defined below.

c. Each team shall have a supervising faculty advisor. The advisor shall be professionally responsible for assuring compliance with the rules of the competition and shall sign the entry forms. Faculty advisors may supervise more than one team.

d. At least one individual (faculty advisor or student team member) must be designated to represent each team and be present during the cylinder testing at the time and location specified for this competition. Participation by additional team members and school members is both permitted and encouraged.

e. In order to participate in the competition on-site, the team has to meet the registration and submission requirements and deadlines detailed herein. Failure to do so may prevent the team's ability to participate in the convention activities. A team-specific schedule for the on-site competition will be released at least one week prior to the start of the in-person convention in Dallas, TX.

## 2. Mixture Materials and Curing

All American Society for Testing and Materials (ASTM) specifications listed refer to the most current version available.

a. Only materials listed in the Official Mixture Design spreadsheet and described below shall be used. Mixtures shall be proportioned to result in a pervious concrete material meeting the definition of pervious concrete according to ACI 522R

   i. Mix Design: In order to score maximum points in the Mix Design category and qualify as a complete mix design for inclusion in the Best in Show prize category, the concrete mixture shall total 1.000 cubic meters. Weights and Volumes shall be related with appropriate material specific gravities used. As part of the Mix Design Spreadsheet, the second tab can be used to convert a concrete design in US units totaling 27.000 cubic feet to 1.000 cubic meter. As this is pervious concrete, be sure to remember that a rather large portion of the concrete mix volume should be void space. It is highly recommended to have an industry mentor from your local sponsoring group or other individual familiar with pervious concrete review your mix design for accuracy.

b. All aggregates shall not exceed 19 mm (3/4 in.) in nominal size. A gradation (ASTM C136) shall be performed of the individual aggregates or final combination of aggregates, a report of which is required as part of the Mix Design submittal.

c. Mixes shall use cementitious materials as a binder. Cementitious materials used in the mixtures shall be portland cement meeting ASTM C150, blended cement meeting ASTM C595, C1157, or C1600, or expansive cement meeting ASTM C845. The following supplementary cementitious materials may also be used: fly ash or natural pozzolans meeting ASTM C618, silica fume meeting ASTM C1240 and slag cement meeting ASTM C989. Epoxies, glues and similar binders shall not be used. Other binders will be considered by the judges on a case-by-case basis. The cementitious products used shall be included in the Mix Design submittal in the form of Product Data Sheets.

d. Chemical admixtures meeting ASTM C260, C494 or C1017 may also be used. It is important to note that some special packaged "pervious admixtures" are on the market but are not yet accepted as meeting any of the above ASTM standards. These admixtures may also be used, but in this case, lack of a detailed Technical Product Data Sheet in the Mix Design submittal may result in disqualification of the team, rather than a less severe penalty. Manufacturers' technical product data sheets (typically 1 to 2 pages) for each admixture used in the final mixture are required to be included as part of the Mix Design submittal.

e. Fibers with a maximum length of 64 mm (2.5 in.) and made of glass, synthetic or natural materials may be used. Steel fibers shall not be used. Glass fibers shall meet ASTM C1666. Synthetic and natural fibers shall meet the classifications in ASTM C1116 Section 4.1. Fiber materials may be mixed (i.e., hybrid fibers) and any dosage rate may be used. No other type of reinforcement may be used.

f. 102 mmx200 mm (4 in.x8in.) Cylinders shall be cured at atmospheric pressure and curing temperatures shall not exceed the boiling point of water; steam curing shall not be used. Please note that cylinders must be in a dry condition prior to submission at the competition (see Section 3.b.). This may affect the curing methods selected.

## 3. Cylinder Configuration

a. Each entry for the competition shall consist of two cylinders. One cylinder will be tested during the competition, and both will be kept for verification of compliance with the competition rules if needed.

b. Cylinders shall be submitted to the competition site in a dry condition (i.e., as close to oven dry as possible). Teams are cautioned that submitting wet cylinders is disadvantageous. Cylinders will be submerged in water for a minimum of 30 minutes prior to testing once their dry weight is obtained. The dry weight will be used as a tool for mixture design verification. Cylinders should closely mimic the expected unit weight of the mix design – a large deviation would be indicative of either an improper mix design or concrete batch that does not match the design.

c. Cylinders shall be 102 mm (4 in.) in diameter with a tolerance of plus or minus 3 mm (0.1 in.) and 152 mm (6 in.) in length with a tolerance of plus or minus 5 mm (0.2 in.). It is recommended that the 152 mm length be obtained by cutting approximately 25 mm (1 in.) from each end of a standard 200 mm long cylinder (i.e., a standard 4x8 in. cylinder), thus removing less permeable

portions of the standard cylinder. The cylinders shall have flat and parallel surfaces at right angles with perpendicular sides and no indentations, cupped edges, fins or other features to bias water flow over the specimen.

d. Cylinders shall be homogeneous (i.e., have the same composition and porosity throughout the cylinder) and shall not have been cut from larger sections except as required in Section 3.c. or modified in any other way.

e. Each cylinder shall be marked only on the top surface in permanent marker with the team's five-character entry identification marking (same marking for both cylinders in each entry). The marked surface will be considered the top of the cylinder and placed upwards during permeability testing. Painting or otherwise coating the cylinders is not permitted.

f. Modifications to cylinders are not permitted once submitted for the competition.

## 4. Mix Design Submittal

a. Teams shall electronically submit their mix design along with supporting manufacturer's data sheets meeting the requirements listed in this section and Rules Section 2 for the judges to review and score in advance of the competition. The submittal shall be sent prior to the competition as described below in standard PDF format through the competition website system. Failure to follow these rules may result in penalties or disqualification at the judges' discretion. The submittal due date is indicated in Section 9 below. Teams are strongly encouraged to bring a hard copy version of the submittal to the competition for both display during the competition and reference during the scoring process. Teams failing to submit the electronic version of the submittal as required shall receive a score of 0 in the Performance Score equation given in Section 7.a. and will not be eligible for competition in the Best in Show Prize Category.

b. Each submittal shall be in the English language and contain the following. The judges will score the mix design using the indicated scoring percentages (based on a total of 100%).

   i. Include a cover page containing the following:

      1. School name and Team name (e.g., University of Concrete, Team Holey),

      2. Team members and faculty advisor names

      3. Entry Identification Marking matching the specimen marking mentioned in 3.e.

   ii. Mix Design on the Official Mix Design Spreadsheet (main tab in excel file) along with required data sheets for mixture components

      1. Official Mix Design Spreadsheet (NOTE: this copy DOES NOT replace required submission of official mixture design spreadsheet in Excel file format indicated in Section d, below)

      2. ASTM C136 Gradation of Aggregates

      3. Technical Product Data Sheets for mixture ingredients, as required in Rules Section 2. We understand that these may not be available in English, depending upon your location. An exception for Rule 4.b. will be considered for Product Data Sheets within the submittal.

4. Attach a submittal sheet for each chemical admixture used in the mixture – these are easily obtained from the manufacturer and will confirm compliance with rule 2.d. We understand that these may not be available in English, depending upon your location. An exception for Rule 4.b. will be considered for Product Data Sheets within the submittal.

c. All mix design submittals will be scored between zero and 100 percent using the indicated scoring percentages, with 100% being the best. Mixture Designs shall total 1.000 cubic meters and use appropriate and logical values for the specific gravities of the mixture components. As mentioned in Section 2. a. i., it is recommended to have an industry mentor or someone experienced with pervious concrete review your mixture design for accuracy.

d. In addition to the pdf Mix Design Submittal above, the mix design spreadsheet must also be submitted in Excel format through the competition website platform.

## 5. Testing

a. The judges will inspect both pervious concrete cylinders prior to testing to verify compliance with the rules including dimensional and material requirements. Both cylinders shall comply with the rules and be made from the same batch of concrete. For conditions of the specimens at the time of submittal, see section 9 of the Rules.

b. The judges will randomly select one of the cylinders for testing. All tests shall use the same cylinder.

c. Permeability Test

i. All cylinders will be submerged in water once dry weight has been obtained for a minimum of 30 minutes. The cylinder selected for testing shall be removed from the water when prepared for testing.

ii. The cylinder will be prepared for testing by the judges. Cylinders will be wrapped with a pvc shrinkwrap for testing. Specimens awaiting testing will be returned to the water bath until being placed in the testing apparatus.

iii. Each entry will be tested for permeability using a falling-head permeameter test setup. With the valve closed, water shall be poured into the graduated cylinder above the cylinder until the water level remains steady at 230 mm (9 in.) above the cylinder and air pockets are minimized. Time begins when the valve is opened. The test is complete and time is stopped when the water level in the graduated cylinder reaches 25 mm (1 in.). If the water level does not reach the 25 mm mark by the maximum time limit (120 s), the water level above the cylinder is recorded. Teams failing to meet the maximum time limit shall be placed in descending order based on the lowest water level and ranked below the entries completing the test within the time limit.

iv. The entry with the highest measured permeability shall receive the top ranking for the permeability test.

NOTE: A parts list for a permeameter is available from ACI upon request.

d. Splitting Tensile Strength Test

i. Each entry shall be tested for splitting tensile strength in general accordance with ASTM C496, "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens."

ii. The load rate used to test the specimens will be determined based on the total number of teams submitted and will likely be higher than the rate stated in the test standard. All specimens will be tested using the same rate of loading.

iii. The entry with the highest splitting tensile strength will receive the top ranking for the splitting tensile strength test.

## 6. Scoring and Prize Categories

a. **Cylinder Performance Prize Category** - the entry with the lowest Performance Score as calculated below shall be declared the winner of the Cylinder Performance prize category. In the case of a tie, the winner shall be the team with the better mix design ranking; if still tied, the team with the better permeability ranking shall be the winner.

Performance Score = [(0.60)(P) + (0.40)(S)]/(M/100)

Where: P = Overall ranking of entry in the permeability test

S = Overall ranking of entry in the splitting tensile test

M = Overall mix design score

b. **Best in Show Prize Category** – In order to qualify for the Best in Show Prize Category, cylinders must have a permeability of at least 0.5 cm/s (700 in./hr) and splitting tensile of at least 2.5 MPa (363 psi). Specimens that meet these requirements will be evaluated by a panel of judges composed of Industry Professionals. Judges will rank the Pervious Concrete mixes based on what they believe to be the "Best in Show." The qualities of this concrete mix include practicality, expense, ease of placement, and innovation.

i. Only teams judged to have a complete and accurate mix design according to Section 4 are eligible for inclusion in the Best in Show prize category.

ii. Teams shall fully complete the Official Mixture Design spreadsheet. The spreadsheet shall be submitted by the deadline indicated below in Microsoft Excel file format. Teams are strongly encouraged to have their spreadsheet and mixture design reviewed by an experienced industry professional and/or their supervising faculty advisor prior to submission. The Official Mixture Design spreadsheet will be reviewed by the judges for accuracy and compliance with the rules. Unresolved discrepancies shall be grounds for disqualification.

Teams not providing an accurate mix design sheet as determined in Section 4 will not be eligible for this prize category. The team with the lowest overall average ranking from the judges will be awarded the winner in this prize category. In the case of a tie, the team with the lower Total Cementitious content in their mixture will receive the better ranking; if still tied, the team with the higher infiltration will place higher.

## 7. Judging

a. The judges shall be appointed by the Chair of ACI Committee S801. Judges may be different for each prize category or portions of a prize category. The lead judge will be identified and will act as the main point of contact for students with rules-related questions and issues. The lead judge will act as the final decision maker for all rules and penalties associated with the competition.

b. The judges will make the final determination on compliance with the rules and penalties for rule violations up to and including the disqualification of entries if required. Disqualified entries shall not be included in the scoring or considered for awards but may be tested if time permits. See Section 10.

c. Teams are reminded that results in competition may not match those as measured in the university lab with a different testing setup.

d. Judges with a conflict of interest (example: a professor reviewing the testing for a team at their same University) are expected to recuse themselves from such instances in order to maintain a lack of judging bias for or against any team.

e. The decision of the judges shall be final, and appeals will not be considered - this includes additional review of competition results following the student lunch. Suggestions for improvement may be submitted to the Chair of ACI Committee S801. Student teams and advisors are reminded that the competition judges and personnel are volunteers and the competition is meant to provide a fun learning experience.

## 8. Registration and Submission Requirements

a. Advance registration is required to participate in the competition. Teams shall submit an online registration for their entry – the link to which is on the ACI student competition website. This process shall be completed and submitted to ACI by 4 October 2022. It indicates the team's intent to compete and includes all necessary submissions. The pervious concrete cylinders themselves will be submitted on the day of the competition.

b. Questions regarding the rules and competition shall be submitted to the ACI contact listed below. Competition volunteers will respond as promptly as possible, but please remember that the competition is run by volunteers.

c. For students requiring a U.S. entry VISA letter, an invitation letter from ACI will be sent upon request after receiving a completed registration online form only IF the school/university is located outside of the U.S. or Canada, AND the team has indicated it plans to attend the convention. Invitation letters will be emailed to the faculty advisor email address listed on the registration form. Hard copies will not be faxed or mailed to the team members or to U.S. embassies.

d. The electronic Report and Official Mixture Design spreadsheet, as described above, shall be submitted through the registration website no later than 11:59 p.m. Eastern Standard Time on 4 October 2022. Teams shall be responsible for ensuring their submission is completed and are strongly encouraged to allow sufficient time for verification prior to the deadline. Late submissions will be accepted on a case-by-case basis and will be penalized a minimum of 10%, if allowed to compete at all.

e. Both pervious concrete cylinders with the identifying markings clearly displayed on the cylinders as required, shall be submitted at the competition site in person on the day of the competition. Cylinders arriving past their established check-in times will not be accepted for entry into the competition and will only be tested after the competition is complete, should time permit. The individual bringing the cylinders to the competition does not have to be a member of the team and does not need to remain in the testing area.

f. The competition will likely begin at 9:00 a.m. local time on 23 October 2022, though the actual starting time will be finalized pending total team count and participation. Student teams will be notified once the schedule is finalized. Posters in the competition area at the convention will also list team orders and check-in times.

## Compliance with Pervious Concrete Cylinder Competition Rules

ACI reserves the right to perform a detailed examination and check all entries for compliance with the competition rules and errors (intentional or unintentional) in the Official Mixture Design spreadsheet. Due to the complexity of this task, the examination may be done after the competition if needed. If the examination shows that a team did not follow the rules, the team, their advisor, and all affiliated school teams may be disqualified. ACI Committee S801 will further document recommendations to disallow the team, their advisor, and/or school/university from participation in future ACI competitions and submit this to the Student and Young Professional Activities Committee for possible action. By participating in the competition, the school and teams give tacit approval for use of their submissions and competition results for future competitions, presentations, or data analysis by ACI committees and members.

### Contact Information

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