

Pervious Concrete Cylinder Competition, sponsored by the American Concrete Institute

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 demonstrates cementitious efficiency; i.e. maintaining the overall performance of the mix with the lowest amount of cementitious material. A report that documents the team's cylinder production process and ability to generate an accurate mix design is also scored. Only teams judged to have a complete and accurate mix design are eligible for inclusion in the Cementitious Efficiency prize category.

Prizes

Two prize categories are offered, Cylinder Performance and Cementitious Efficiency. 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, the day following the competition.

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 Report 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.

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
- b. All aggregates shall not exceed 19mm (3/4") 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 report 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.
- 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. As such, their use would not be acceptable in this competition and their use may result in disqualification or a penalty. Manufacturers' technical product data sheets (typically 1 to 2 pages) for each admixture used in the final mixture are required to be presented within the report.
- e. Fibers with a maximum length of 64 millimeters (2.5 inches) 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. 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. See Section 10.
- b. Cylinders shall be submitted to the competition site in a dry condition (i.e. as close to oven dry as reasonable). 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 may be used as a tool for mixture design verification.
- c. Cylinders shall be 102 mm (4 inches) in diameter with a tolerance of plus or minus 3 mm (0.1 inches) and 152 mm (6 inches) in length with a tolerance of plus or minus 5 mm (0.2 inches). It is recommended that the 152 mm length be obtained by cutting approximately 25 mm (1 inch) from each end of a standard 200 mm long cylinder (i.e. a standard 4x8 inch 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 on the top surface in permanent marker with the team's name and a 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. Report

- a. Teams shall electronically submit a report meeting the requirements listed in this section for the judges to review and score in advance of the competition. The electronic version of the report shall be submitted prior to the competition as described below in standard PDF format. Failure to follow these rules may result in penalties or disqualification at the judges' discretion. The electronic report due date is indicated in Section 9 below. Teams are strongly encouraged to bring a hard copy version of the report to the competition for display during the competition and general display for the ACI attendees. Teams failing to submit the electronic version of the report (including the mix design) 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 Cementitious Efficiency Prize Category.
- b. Each report shall be in the English language and contain the following. The judges will score the report using the indicated scoring percentages (based on a total of 100%).
 - i. Include a cover page containing the following: – 5%
 1. School name and Team name (i.e. 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. Provide a maximum of two pages of pictures (with proper safety equipment being used) and captions showing the methods of the following: – 20%
 1. Batching and placing procedures
 2. Compaction and Finishing procedures

- 3. Curing procedures
 - 4. Preliminary testing of cylinders, if applicable
- iii. Provide a maximum of two pages of narrative, graphs or flow charts showing the team's decision process in selecting the final mixture design and compaction methods for the pervious specimens – 25%
- iv. Materials Selection – 20%
 - 1. Provide a single picture showing all materials used in the submitted cylinder's mixture grouped together prior to mixing (i.e. measured materials in separate containers showing relative proportions used).
 - 2. Include a copy of the gradation test results (ASTM C136) for the individual aggregates or combined aggregates as mentioned in 2.b.
 - 3. 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.
- v. Include a copy of the Official Mixture Design spreadsheet in SI units (NOTE: this copy DOES NOT replace required submission of official mixture design spreadsheet in Excel file format indicated in Section d, below). It is highly recommended to have an industry mentor from your local sponsoring group review your mix design for accuracy – 30%
- c. All reports will be scored between zero and 100 percent using the indicated scoring percentages, with 100% being the best. The entry with the highest score shall receive the top ranking for the report section in the Cylinder Performance prize category.
- d. In addition to the pdf report above, the mix design spreadsheet must also be submitted in Excel format. In order to qualify as a complete mix design for inclusion in the Cementitious Efficiency 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 27.00 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.

5. **Cylinder Performance Prize Category**

- 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, see Section 10.
- 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 shall 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, see Figure 1. A similar (but not exact) example of a falling-head permeability test can be found in ACI 522R-06 Figure 4.7. 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 inches) 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 inch). The maximum time limit for the test shall be 120 seconds, after which 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 section of the Cylinder Performance prize category.
- d. Splitting Tensile Strength Test
- i. Each entry shall be tested for splitting tensile strength using ASTM C496, "Standard Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens."
 - ii. The entry with the highest splitting tensile strength shall receive the top ranking for the splitting tensile strength test section of the Cylinder Performance prize category.

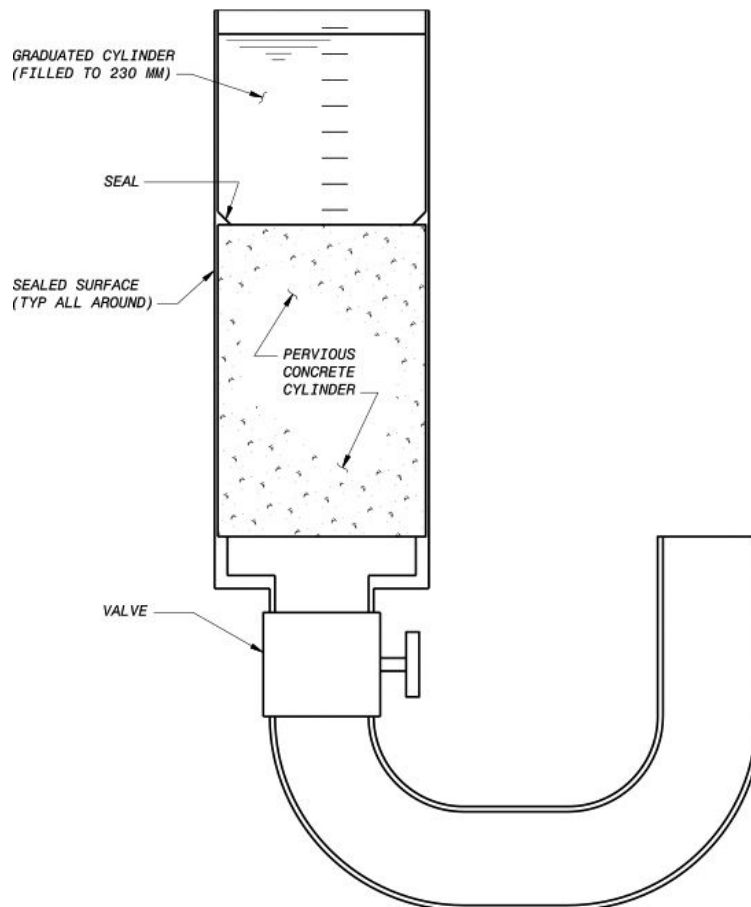


FIGURE 1 - PERMEABILITY TEST SETUP

6. Cementitious Efficiency Prize Category

- a. Only teams judged to have a complete and accurate mix design according to 4.d. are eligible for inclusion in the Cementitious Efficiency prize category.

- b. 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, see Section 10.
- c. Each entry will have its Cementitious Efficiency Score calculated. The load shall be the splitting tensile strength determined in Section 5d. The Total Cement Mass will be determined from the Official Mixture Design spreadsheet.

7. Scoring

- a. **Cylinder Performance Prize Category** - Entries in the Cylinder Performance prize category shall be ranked in the permeability test, splitting tensile test and report sections as indicated above. 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 report ranking; if still tied, the team with the better permeability ranking shall be the winner.

$$\text{Performance Score} = (0.540)(P) + (0.430)(S) + (0.20)(R)$$

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

S = Overall ranking of entry in the splitting tensile test

R = Overall ranking of entry in the report

- b. **Cementitious Efficiency Prize Category** – Cementitious Efficiency will be determined for each qualifying submission. Entries shall be scored according to the following:

$$\text{Total Cementitious Score, } TC = C + (0.5)(FA) + (2)(SF)$$

Where: C = Total Cement mass, in kg/m³

FA = Total mass of Fly Ash and Slag Cement, in kg/m³

SF = Total mass of Silica Fume and Metakaolin, in kg/m³

$$\text{Cementitious Efficiency} = [(ST) \times (IN)] \times 10^6 / TC^3$$

Where: ST = Split Tensile result, in MPa

IN = Infiltration Test Result, in cm/s

TC = Cementitious Score, from above

Teams not providing an accurate mix design sheet as determined in 4.d. will not be eligible for this prize category. The team with the highest Cementitious Efficiency score, as calculated above, will be the winner of the Cementitious Efficiency prize category. In the case of a tie, the team with the lower

Total Cementitious Score (TC) will receive the better ranking; if still tied, the team with the higher infiltration will place higher.

8. 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 will 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. 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.

9. 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 30 September 2018. 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. Hard copies will not be faxed or mailed to the team members or to U.S. embassies. All international students must submit a valid passport number when requesting invitation letters from ACI; only preregistered teams with accurate passport numbers will receive an invitation letter.
- 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 30 September 2018. Teams shall be responsible for ensuring their submission is completed and received (i.e. email not bounced or returned due to file size restrictions or other problems) 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, 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 14 October 2018, 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.

10. 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, errors (intentional or unintentional) in the Official Mixture Design spreadsheet, and for plagiarism in the report. 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 or plagiarized, the team, their advisor, and all of their 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, use of student reports and competition results for future competitions, presentations, or data analysis by ACI committees and members is expressly permitted

11. Contact Information

Sharon Schuman

American Concrete Institute

38800 Country Club Drive

Farmington Hills, MI 48331

Fax: (248) 848-3801

E-mail: students@concrete.org