

**TENNESSEE**  
**CONCRETE**  
**MAGAZINE**

Fall 2012  
VOL. 26, NO. 2



**2012**  
**MEMBERSHIP DIRECTORY**

Ready Mixed Concrete Producer Members

Associate Members

Affiliate Members

Contractor Members

ACI Certified Field Testing Technician, Grade I Sections

NRMCA Pervious Certified Installers/Technicians

ACI Certified Flatwork Technicians/Finishers

# TCA Pervious Concrete Mixture

## Design and Adjustment Method Base on ASTM C 1688

### INTRODUCTION

Historically, pervious concrete mixture design in Tennessee has been based on experience. The most experienced person available was tasked with designing a mixture for a given situation. Field trials were commonly used to adjust the mixture to produce the desired properties. If the materials, compaction method used and properties desired were similar to previous jobs, the number of trials was usually small. However, if property requirements, materials, or compaction were significantly different from previous experience, the number of trials was increased. Typically, a small slab was placed (1 to 3 cubic yards), cores were taken and then sent off to be tested. Even if the number of trials was small, this process was expensive and time consuming. A short-cut mixture design procedure was badly needed to save time and money.

Tennessee Technological University (TTU) researchers, working in conjunction with Tennessee Concrete Association (TCA) have recently developed such a short-cut mixture design procedure. The goal of the procedure is not to eliminate field trials, which are good practice, but rather to minimize the number of field trials, saving both time and money expended to produce viable pervious concrete mixture designs. The method will be described and then supporting information will be presented. The central assumption in the method is that field engineering properties can be correlated with ASTM C 1688 voids (1).

### TCA PERVIOUS CONCRETE MIXTURE DESIGN STEPS

#### STEP 1: SELECT AGGREGATE(S)

Select a coarse aggregate for the mixture. TCA recommends ASTM C 33 (2) No. 8, No. 89 or similar. A fine aggregate may also be selected for the mixture. TCA researchers have used both river sand and manufactured limestone sand in pervious concrete. Crouch, Williams, and Badoe provide extensive guidance on fine aggregate advantages and disadvantages in Tennessee Concrete Summer/Fall 2011 (3). Information on gradation, specific gravity and absorption is required for each aggregate selected. The factors controlling aggregate selection are primarily availability and cost. Aggregate properties, particularly gradation and shape, have a tremendous impact on cementing materials content and compaction.

#### STEP 2: SELECT PERCENTAGE OF FINE AGGREGATE BY TOTAL AGGREGATE VOLUME

TCA recommends that designers keep the  $d_{10}$  of the combined aggregate gradation greater than or equal to 2-mm. The  $d_{10}$ , or effective grain size, of the combined aggregate gradation can be determined by mathematically blending the aggregates and then plotting the combined aggregate gradation. TCA currently recommends that designers not use more than 10 percent fine aggregate by total aggregate volume.

#### STEP 3: SELECT CEMENTING MATERIALS

TCA recommends Type I or Type II portland cement meeting ASTM C 150 (4) and supplementary cementing materials (SCM) may also be used. Extensive guidance on SCM advantages and disadvantages can be found in Tennessee Concrete Summer/Fall 2010 (5) and Green<sup>2</sup>: High Volume Slag Substitution in Pervious Concrete (6).

#### STEP 4: SELECT CHEMICAL ADMIXTURES

Chemical admixtures are optional, but are very beneficial in the opinion of the authors. TCA recommends a mid-range water reducer, a hydration stabilizer and a viscosity modifier be used in cases of typical light compaction. Crouch provides extensive guidance on fine chemical admixture advantages and disadvantages in Tennessee Concrete Winter 2010 (7).

#### STEP 5: BEGIN WITH A STANDARD MIXTURE OR A PREVIOUS MIXTURE BASED ON EXPERIENCE

TCA recommends starting with a maximum 600-lbs/CY of total cementing materials, 180-lbs/CY of water, assuming 20 percent voids, and a total aggregate absolute volume calculated to produce 27 cubic feet of total volume for a mixture that will experience the light compaction common in Tennessee (see Figure 1). However, if a previous mixture is available from a similar situation it should be used as the beginning point.

#### STEP 6: PRODUCE A BATCH OF THE MIXTURE IN THE LAB AND CONDUCT ASTM C 1688

TCA recommends that the exact materials planned for the job also be used in the pervious lab mixture. Figure 2 shows former graduate student Martin L. Medley preparing for a small laboratory batch. Figure 3 shows Medley determining the mass of the



Figure 1: Light Compaction Typical for Pervious Concrete in Tennessee



Figure 4: Preparing a Small Laboratory Batch for ASTM C 1688

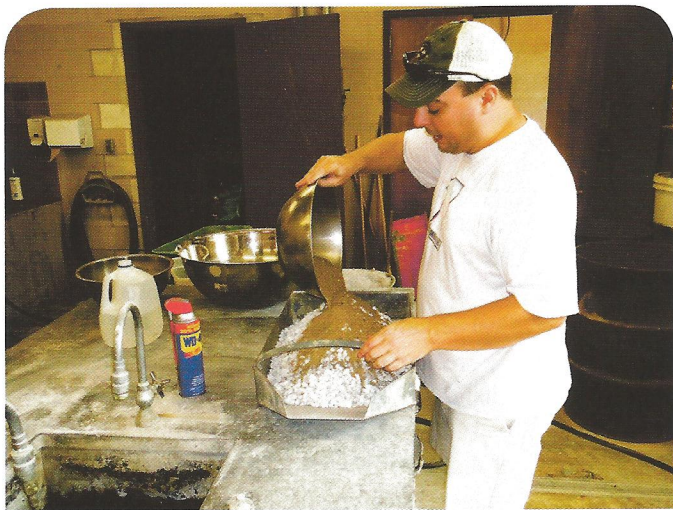


Figure 2: Preparing a Small Laboratory Batch for ASTM C 1688

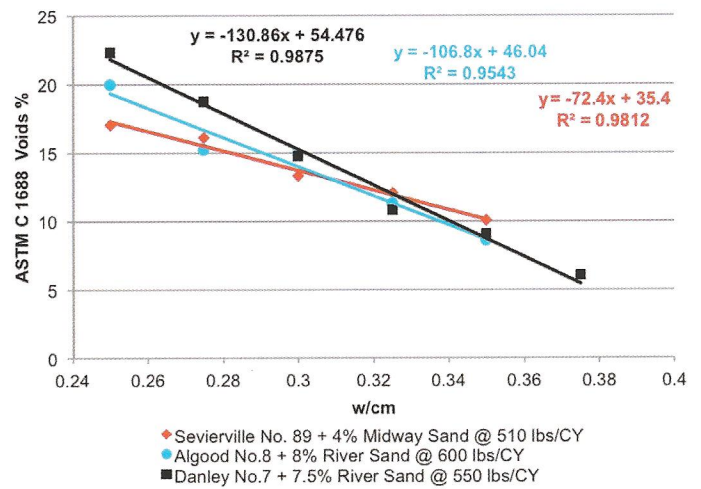


Figure 5: Plastic Voids (ASTM C 1688) vs. w/cm for Constant Cementing Materials



Figure 3: Determining Mass of Measure for ASTM C 1688

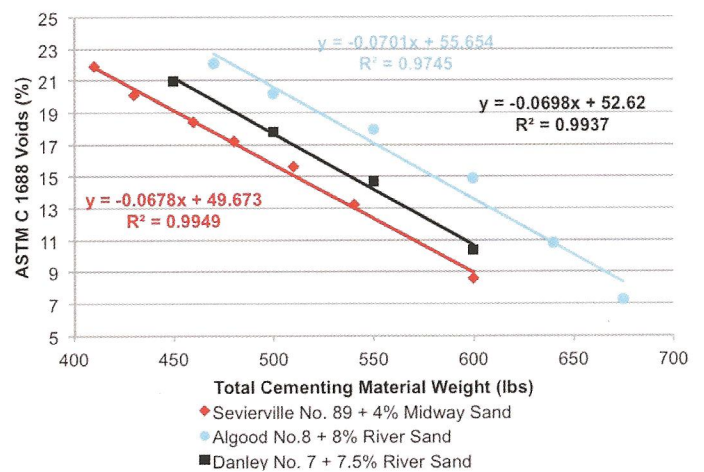


Figure 6: Plastic Voids (ASTM C 1688) vs. Cementing Materials for Constant w/cm

by L. K. Couch, Martin L Medley, John Hendrix and Alan Sparkman

# TCA Pervious Concrete Mixture

## Design and Adjustment Method Base on ASTM C 1688

measure to be used for ASTM C 1688. Figure 4 shows former graduate student John Hendrix conducting ASTM C 1688 on a laboratory batch of pervious concrete.

### STEP 7: ADJUST PASTE VOLUME

If actual ASTM C 1688 voids are higher than target voids, the paste volume should be increased and total aggregate absolute volume should be decreased while still maintaining 27-cubic feet. Similarly, if actual ASTM C 1688 voids are lower than target voids, the paste volume should be decreased and total aggregate absolute volume should be increased while still maintaining 27-cubic feet. Paste volume can be increased or decreased using water-to-cementing materials ratio (w/cm) or cementing materials at a constant w/cm. Figures 5 and 6 show the effects of w/cm and total cementing materials weight on ASTM C 1688 voids, respectively. More information on target void values will be provided later in the paper.

### STEP 8: ITERATE TO CONVERGENCE

Repeat Steps 6, 7 and 8 until actual ASTM C 1688 voids converge upon target voids. It is important to note that Steps 6, 7 and 8 can stand alone as a pervious concrete mixture adjustment method.

### STEP 9: FIELD TRIAL

TCA recommends that after the mixture has been adjusted to significant convergence with the target voids, the final mixture should be field placed, cored and tested as there is no substitute for field placement. The purpose of the TCA mix design and adjustment method is not to eliminate field trials, but rather to reduce the number of field trials required to develop a pervious concrete mixture and their associated expense and delay.

## RESEARCH TO SUPPORT THE TCA MIX DESIGN AND ADJUSTMENT METHOD

### MEDLEY'S WORK

Medley worked with several typical Tennessee limestone coarse aggregate and fine aggregate combinations (see Figures 3 and 4). Fine aggregate percentages were chosen in order to produce  $d_{10}$  values of approximately 2-mm. Mixtures were designed at various different total cementing materials values and w/cm ratios. A batch of each mixture was produced and ASTM C 1688 was conducted on the pervious concrete. A 6x6x24-inch

beam was also fabricated from each batch. The researchers attempted to model the light compaction common in Tennessee (see Figures 1 and 7) and therefore only two passes of a light roller fabricated from a 6x12-inch concrete cylinder were used to compact the beams. The beam was cured for 24-hours in the mold. Subsequently the mold was removed and the beam was cured by limewater immersion until coring at 7 to 10 days after casting. Four cores were cut from each beam (see Figure 8). Two cores were used for ASTM D 7063 Effective Voids (8). The remaining two cores were sulfur-capped as per ASTM C 617 (9) and tested for compressive strength as per ASTM C 39 (10) at 28-days. Medley's work (11) showed good relationships between ASTM C 1688 plastic voids and ASTM D 7063 hardened effective voids (see Figure 9) and core compressive strength (see Figure 10).

### HENDRIX'S WORK

Hendrix (12) worked with one limestone coarse aggregate and fine aggregate combination using the adjustment portion of the method. Hendrix attempted to maximize the compressive strength of a typical pervious mixture while maintaining constant head permeability greater than 100-inches/hour and a combined aggregate gradation  $d_{10}$  of approximately 2-mm. The beginning control mixture had 600-lbs/CY of cementing materials with a 0.3 w/cm ratio, 2584-lbs/CY of No. 89 limestone coarse aggregate and no fine aggregate. Twenty replications of the control mixture yielded average ASTM C 1688 voids, 28-day compressive strengths, and constant head permeabilities (13) of 19.4 percent, 2080-psi and 440-inches/hour, respectively.

Guidance from previous unpublished work showed that for the desired permeability, ASTM C 1688 voids should be approximately 15 percent. Hendrix first attempted to decrease ASTM C 1688 voids by increasing the w/cm to 0.308 and including 3.5 percent river sand by total aggregate volume. Coarse aggregate content was reduced to accommodate these changes. Twenty replications of this first attempt at adjusting the mixture yielded average ASTM C 1688 voids, 28-day compressive strengths and constant head permeabilities of 17.6 percent, 2348-psi, and 294-inches/hour, respectively. Although the first attempt improved the mixture, a second attempt was made to maximize compressive strength.

Hendrix's second attempt further reduced the ASTM C 1688 voids by including 7 percent river sand in the combined aggregate gradation and increasing the w/cm ratio to 0.315. Coarse aggregate content was again reduced to accommodate the changes. Twenty replications of the second modified mixture yielded



**Figure 7: Compacting a Beam with a 6x12-inch Concrete Cylinder Roller**

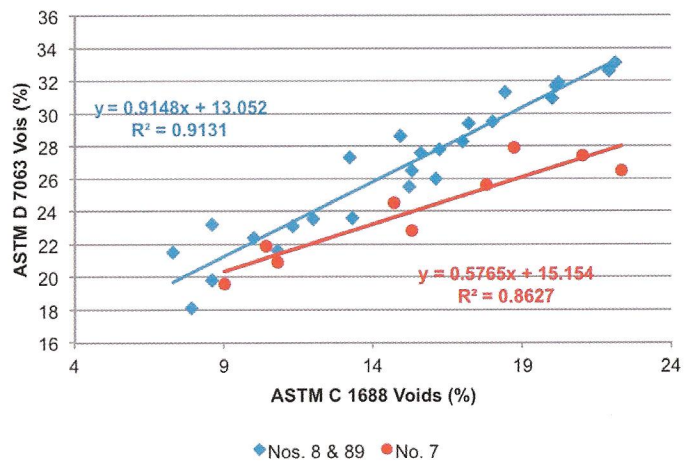


**Figure 8: Cored Pervious Concrete Beam and Four Cores**

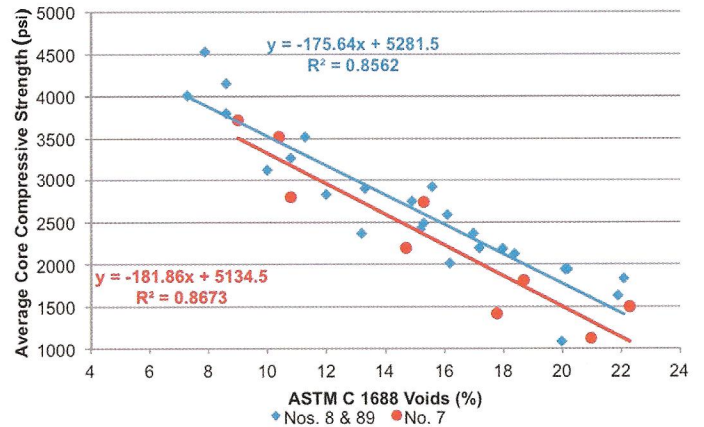
average ASTM C 1688 voids, 28-day compressive strength and constant head permeabilities of 15.5 percent, 2630-psi and 155-inches/hour, respectively. The 26.4 percent increase in compressive strength over the control appears very promising for the TCA Mixture Adjustment Method. Figure 11 below shows permeability values generated by Hendrix.

### CLOSING REMARKS AND CAUTIONS

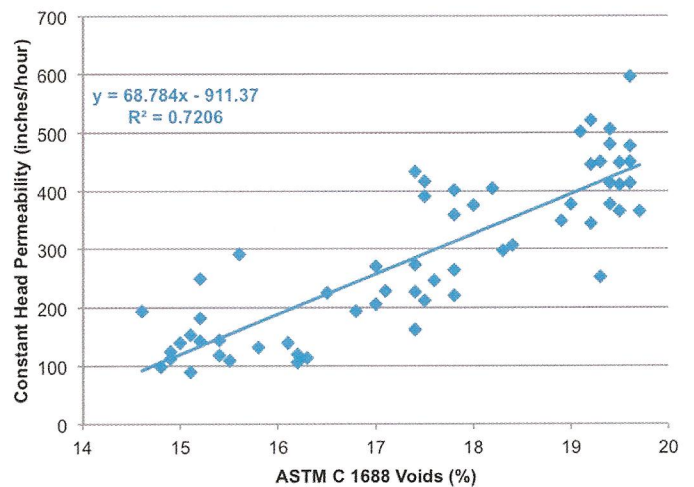
The target ASTM C 1688 voids of approximately 15 percent for 100-inches/hour laboratory constant head permeability are only for No. 8, No. 89 or similar limestone coarse aggregates with less than 10 percent fine aggregate by total aggregate volume. The ASTM C 1688 target voids are also only for the light compaction described in this paper. Other materials or compaction techniques will undoubtedly result in different target ASTM C 1688 void contents. In general, lower ASTM C 1688 void contents will increase compressive strength and reduce permeability. However,



**Figure 9: Hardened Voids (ASTM D 7063) vs. Plastic Voids (ASTM C 1688)**



**Figure 10: Core Compressive Strength (ASTM C 39) vs. Plastic Voids (ASTM C 1688)**



**Figure 11: Constant Head Permeability vs. Plastic Voids (ASTM C 1688)**

by L. K. Couch, Martin L Medley, John Hendrix and Alan Sparkman

# TCA Pervious Concrete Mixture

## Design and Adjustment Method Base on ASTM C 1688

ready-mix producer designers should build their own databases over time for their materials and compaction techniques. TCA recommends that all pervious concrete mixtures be field tested prior to use in an actual job.

### REFERENCES

1. ASTM C 1688-08. "Standard Test Method for Density and Void Content of Freshly Mixed Pervious Concrete." ASTM International, West Conshohocken, PA, 2008. [www.astm.org](http://www.astm.org).
2. ASTM C 33-03. "Standard Specification for Concrete Aggregates." American Society for testing and Materials. Vol. 04.02, 2006, pp. 10-20.
3. "Help for Pervious PCC Producers Pat 3: Fine Aggregate for Pervious PCC", L. K. Crouch, Cameron Williams, and Daniel Badoe, in *Tennessee Concrete* Summer/Fall 2011, Volume 25, No. 2.
4. ASTM C 150-04a. "Standard Specification for Portland Cement." American Society for Testing and Materials. **Annual Book of ASTM Standards**. Vol. 04.01. 2005. pp. 144-151.
5. "Help for Pervious PCC Producers Pat 1: Supplementary Cementing Materials Substitution Rates – It's Good to be Green", L. K. Crouch, in *Tennessee Concrete* Summer/Fall 2010, Volume 24, No. 2.
6. "Green?: High Volume Slag Substitution in Pervious Concrete", L. K. Crouch, G. Allen Browning, Alan Sparkman, and Sarah Dillon, Presented at 2012 NRMCA International Concrete Sustainability Conference, May 7-10 in Seattle, WA. Soon to be published on the NRMCA website.
7. "Help for Pervious PCC Producers Pat 2: Chemical Admixtures for Pervious PCC", L. K. Crouch, in *Tennessee Concrete* Winter 2010, Volume 24, No. 3.
8. "Standard Test Method for Effective Porosity and Effective Air Voids of Compacted Bituminous Paving Mixture Samples<sup>1</sup>," (ASTM D 7063-05), available at [www.astm.org](http://www.astm.org).
9. ASTM C 617-98. "Standard Practice for Capping Concrete Specimens." American Society for Testing and Materials. **Annual Book of ASTM Standards**. Vol. 04.02, 2006. pp. 321-325.
10. ASTM C 39-01. "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens." American Society for Testing and Materials. **Annual Book of ASTM Standards**. Vol. 04.02. October 2002. pp. 21-25.
11. Medley, Martin L., II, "Pervious Concrete Mixture Design by the Unit Weight Method." Master of Science Thesis. Tennessee Technological University. Cookeville, TN 38505. December 2010.
12. Hendrix, John P., "Utilizing TCA Mix Design and Adjustment Method to Improve Pervious Concrete." Master of Science Thesis. Tennessee Technological University. Cookeville, TN 38505. May 2011.
13. Crouch, L., Smith, N., Walker, A., Dunn, T., "Determining Pervious PCC Permeability with a Simple Triaxial Flexible-Wall Constant Head Permeameter." NRMCA Concrete Technology Forum: Focus on Pervious Concrete. May 2006.

### ACKNOWLEDGEMENTS

Thanks to the Tennessee Concrete Association for sponsoring this project and providing many of the materials. Specifically, we greatly appreciate the materials provided by Denny Lind of BASF Admixtures, Inc., Brian Strevel of SEFA Group, Clark Simpson of Builder's Supply, Vulcan Materials of Sevierville and Nashville and Rogers Group, Inc. of Algood, TN. Thanks to TTU students Allen Browning, Aaron Crowley, Lindsay Bryant, Sarah Dillon and Samantha Jeffries for their assistance. The authors gratefully acknowledge the assistance in editing, formatting and grammar from Kayla Kelly. Special thanks to Jeff Holmes and Perry Melton for their expertise in supply procurement as well as equipment fabrication and repair. We also gratefully acknowledge the financial support, financial project management and computer assistance of the TTU Center for Energy Systems Research. Appreciation is extended to the TTU Department of Civil and Environmental Engineering for providing supplies for the project.

### AUTHOR INFORMATION

L. K. Crouch, Ph.D., P.E. is a professor of Civil Engineering at Tennessee Technological University.  
 Martin L. Medley, II, E.I.T. is a staff professional at TTL, Inc. in Nashville, Tennessee.  
 John Hendrix., P.E. is the Operations Manager at McClone Construction Company, Mid-Atlantic Division  
 Alan Sparkman, CAE, CCPf, LEED AP is executive director of the Tennessee Concrete Association.