Microprocessor Pressure Volume Controller

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Franciszek J. Hasiuk,

Joseph F. Orso

Kevin Jones

M. Robert Dawson

Office of Construction and Materials

Background

The Iowa Pore Index device is a key piece of test equipment for analyzing new sources for concrete stone for use in projects by the Iowa Department of Transportation (DOT), as well as other state DOT's. The equipment was developed in the 1970's, basic automation was added in the 1990's, and the test was formalized by the American Association of State Highway Transportation Officials as a standard test (AASHTO TP 120-16). Recent research at the Iowa DOT, Iowa State University, and the Kansas Geological Survey has suggested that modification to the current Pore Index test procedure and apparatus may yield better information about the pore structure of aggregates. To study and implement the new procedures, the Pore Index controls needed to be upgraded with a microprocessor-controlled pressure volume controller ("controller"), which was achieved through this SP&R funding. This controller provides higher precision in measuring water intrusion. The new controller will also enhance the capability of the Iowa Pore Index test equipment and provide the bases of a new Iowa Pore Index test apparatus (see Figure 1 at the end of this report). This apparatus was tested through research titled: *"Calibrating the Iowa Pore Index with Mercury Intrusion Porosimetry and Petrography – Phase II"* (18-SPR0-010).

Evaluation Procedure

The controller is being used to develop a new Iowa Pore Index test system that can operate at pressures up to 200 psi and record the volume of water intruded over short time intervals (<2 seconds) throughout the test (Figure 2). The test results were compared to results from Pore Index test apparatus used by the Iowa DOT Materials Laboratory. Additionally, the pore system of these samples were evaluated using helium and mercury porosimetry and compared to the new test apparatus.

Results

Previous work (Hasiuk et al., 2017) has shown that absorption in the first one minute is positively correlated with helium porosity as well as with coarse grain size in dolostones and grainier textures in limestones. Absorption between 1 and 15 minutes is inversely correlated to the modal pore throat size (smaller pore throats lead to higher absorption) as determined by mercury porosimetry. This "secondary" absorption is also correlated with finer-grain size in dolostones and muddier textures in limestones. These findings suggest that the Pore Index device effectively measures a macropore-to-micropore ratio.

The principle results can be summarized as: 1) the new Pore Index device correlates with the apparatus currently in use in the Iowa DOT Materials Laboratory; 2) the new device correlates with porosities determined using helium porosimetry; and 3) the new device can provide some information about an aggregate pore system also determined using mercury porosimetry.

Improvements in test performance and efficiencies include:

- Data collection automation minimizes operator error
- The test apparatus allows analyses of smaller sample sizes, down to 1 kg
- Higher pressure (up to 70 psi) allows the investigation of smaller pore sizes than the previous device that was limited to 35 psi
- Data acquisition at 0.1 – 2 s intervals improves precision and resolution of incremental volume measurements
- Reduced soak time can yield more accurate Primary and Secondary loads, meaning a more accurate characterization of the aggregate pore system
- Faster operation and better leak detection can yield more accurate data
- Use of standard equipment (GeoComp microprocessor-controlled pressure volume controller) will make repairs and upgrades easier
- Use of separate microprocessor-controlled pressure volume controller allows the use of a transparent sample cell that allows the operator to monitor the state of the sample during the analysis

Recommendations and Implementation

The new Iowa Pore Index test apparatus is the next generation of a tool capable of evaluating the pore system smaller aggregate samples, as well as samples that require more test information than the standard Pore Index apparatus can provide. The controller will meet equipment requirements for the AASHTO test procedure.

Implementation in the Iowa DOT Materials Laboratory is recommended, if only on a trial basis. The controller is a newer model of the Geocomp version and according to Geocomp can't be used with the older version triaxial equipment in the Iowa DOT Soils Laboratory. If accepted by laboratory personnel, it is recommended to make budgetary plans for additional apparatuses in the future.

It is also recommended that a publication be produced describing the new apparatus, previous versions of Iowa Pore Index apparatus, and how variations in sample size, water pressure, fill time, and other factors compare to the AASHTO test method. This is important to better explain the parameters of the AASHTO test method and to avoid patent interference. This may provide the basis of commercial production of a water intrusion porosimetry apparatus.

References

Hasiuk FJ, Ridzuan MFA, Taylor P, 2016. Calibrating the Iowa Pore Index with Mercury Intrusion Porosimetry and Petrography. Institute for Transportation Report 15-553. 66 p.

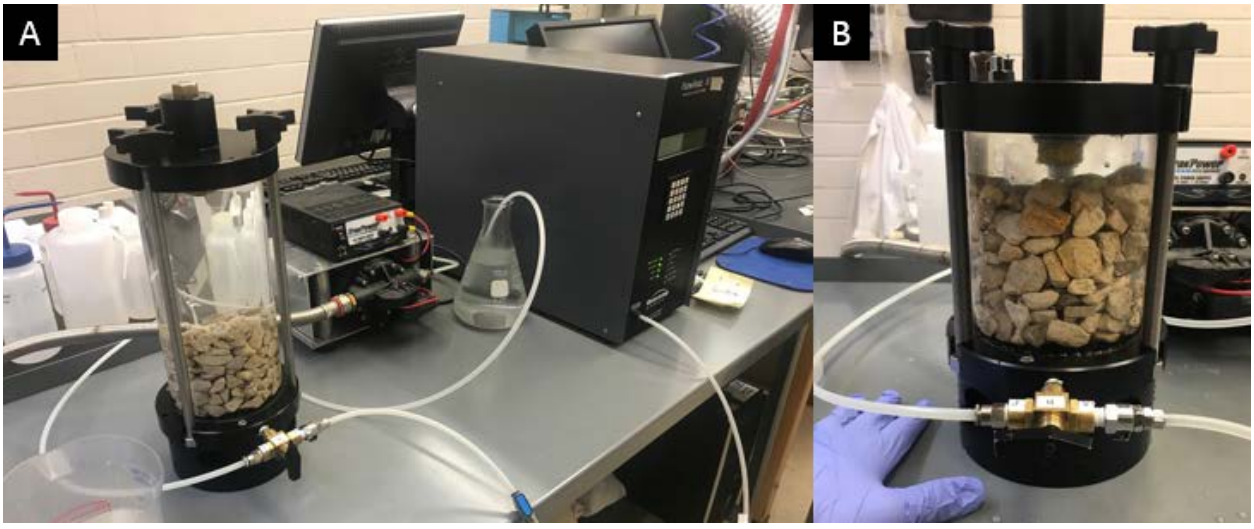

Figure 1. A) Sample chamber (left), pretest chamber fill pump (center), and microprocessor pressure volume generator and controller (right) for the new Iowa Pore Index apparatus. B) The sample chamber was modified to allow faster fill times and less flexure at increased pressures.

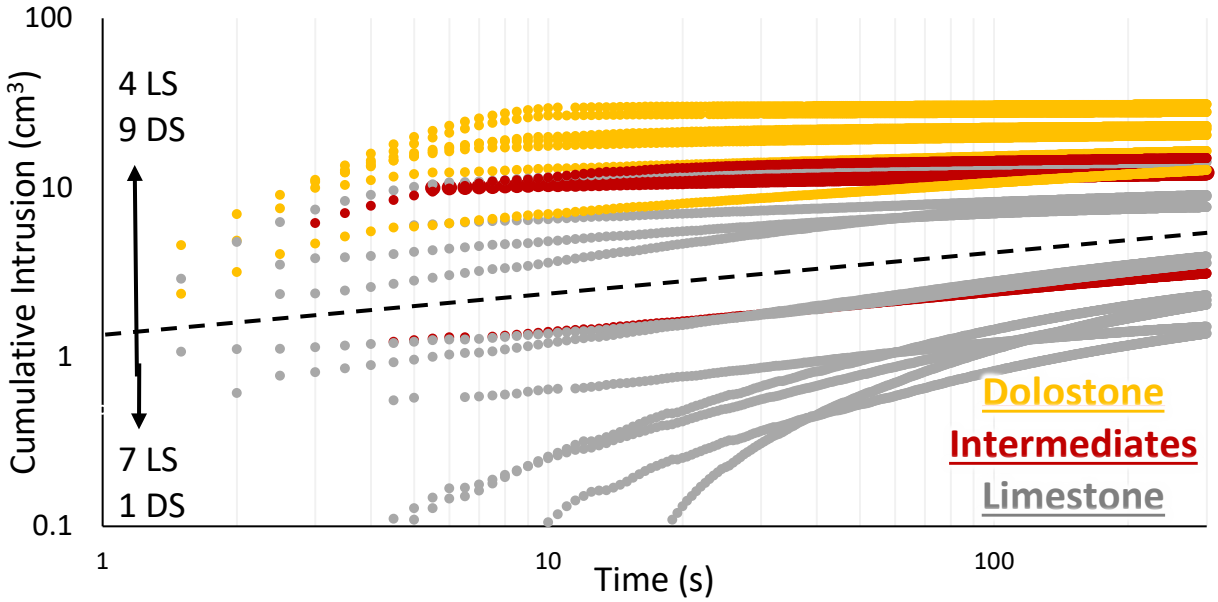

Figure 2. Data output from the new Iowa Pore Index apparatus showing water intrusion into the pore space of aggregate particles over time (in seconds).