The Pioneer Grant Program

The 2016 Pioneer Grant Program aims to reduce nutrient and/or sediment contaminant loads to the Maryland portion of the Chesapeake Bay and Maryland Coastal Bays from any nonpoint source: agriculture, urban or suburban stormwater, air, and septic by seeking proposals that focus on new techniques, information, or programs that increase the rate at which load reductions can occur.

University of Maryland Baltimore County, Center for Urban Environmental Research and Education

Creating a Pervious Concrete Demonstration Site

2007-2011

Project Track: New Information

Research Question: Will creating pervious concrete demonstration sites and conducting a variety of outreach activities result in wider use of this practice in Maryland and the Chesapeake Bay watershed?

Research Results: The project achieved or exceeded the goals of installing two instrumented test plots, engaging at least six regulatory entities for project guidance and feedback and holding at least three education, outreach and technology transfer workshops & seminars. The primary project goal of providing information needed to advance regulatory acceptance and approval was achieved through our collaboration and support of new Environmental Site Design stormwater guidelines by MDE under by the Stormwater Management Act of 2007.

PROJECT PARTNERS

University of Maryland Baltimore County

Increte of Maryland Inc.

Rockville Fuel & Feed Co., Inc.

University of Maryland Baltimore County, Center for Urban Environmental Research and Education

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Summary of Project

The driving questions for our regulatory partners evolved to emphasize hydrologic design and performance, clogging, and the performance and effectiveness of maintenance measures. In response we re-prioritized our data collection and monitoring to emphasize hydrologic performance, clogging, and maintenance effectiveness. Contracting costs saved through material and construction donations have been reallocated to support additional personnel support for revised project priorities in maintenance and field performance evaluation and additional outreach. Beyond the three technical workshops originally planned, a total of 10 technology transfer workshops and seminars were conducted through this project, including two workshops and a field trip for MD State Highway Administration and workshops for Pennsylvania DEP and the Lancaster County, PA Planning Commission.

Water quality monitoring evolved to leverage a new partnership with the US EPA Wet Weather Flows Laboratory in Edison, NJ, and opportunistic technology transfer of our basic monitoring infrastructure in additional pervious pavements being installed by Montgomery County, Queen Anne's County DPW, US EPA, and University of Connecticut. The simple cost-effective monitoring infrastructure designed developed and deployed through this project is being shared at no cost with interested partners to establish an informal network of pervious concrete installations that can be monitored consistently to establish a common community performance database.

Our partnership with the US EPA Wet Weather Flows Lab enabled us to install two CUERE Zero Tension Lysimeters (ZTL) in a heavily instrumented pervious concrete test plot in Edison, NJ. This plot is part of a $1 million renovation of a 1 acre parking lot at the EPA laboratory which has been designed with paired plots of pervious concrete, pervious asphalt, and pervious pavers, and bioretention cells. All of the stormwater facilities are extensively instrumented, and EPA's plan to monitor these sites for at least ten years will make this facility the de facto reference site for BMP performance. The project enabled us to initiate our collaborative partnership with EPA, in which researchers at the EPA lab agreed to collect water quality samples from our lysimeters and ship them to us for analysis by Dr. Timothy Vadas – who started working on this project while a post-doc at UMBC, and has continued our collaboration as a faculty member at the University of Connecticut. CUERE and EPA have agreed to share water quality data, providing direct comparison of the passive composite sample collected by our ZTL and the real-time monitoring data collected by EPA. Our partnership with EPA will establish reference water quality data for comparison with ZTL water quality samples collected by other partners adopting our water quality monitoring infrastructure (e.g. Montgomery and Queen Anne's County). This exceptional opportunity leveraged project outputs far beyond the scope of the current project, and represents one of the very positive unanticipated outcomes made possible through the support of the Chesapeake Bay Trust.

Following the installation of the ZTL infrastructure at the US EPA Wet Weather Flows Lab, it became apparent that the runoff collection system was not capturing consistent representative inflow volumes. The modified design of the ZTL was unfamiliar to the EPA's site contractor who performed the installation, and several flaws could explain the erratic sample collection, including damage to the extended collectors during subgrade compaction, or failure to maintain constant grade in the collection pipes. To diagnose the flow problems we will rent a fiber optic pipe camera and selectively apply water with bright dye to individual areas of the pavement in order to trace the flow path. This unbudgeted repair was beyond the scope of the current project so water quality sampling from the EPA ZTLs has been suspended pending diagnosis and possible repairs. We have recently secured additional grant funding that will enable us to return to Edison to diagnose the installation problem and repair the ZTL installations if possible. The lessons learned will also be incorporated in future modified designs. An alternate modified design of the ZTL was also developed for Montgomery County Parks and Recreation for installation beneath a new County artificial turf athletic field near Burtonsville. Considerable concerns regarding water quality from artificial turf led the County to incorporate the modified design in their athletic field (with sampling and storage sump located outside the field footprint) in order to create the possibility of collecting water quality samples.

Extensive field work monitoring pervious concrete sites in Maryland helped characterize clogging and maintenance effectiveness at thirteen field sites: UMBC(2) Chaney enterprises (2) Smithsonian Environmental Research Center (1) ; Queen Annes County DPW (2); Shelter Systems (2); Z-con Concrete (1); U.S. EPA Wet Weather Flows lab (3). Pavements at UMBC, Chaney Enterprises, C-con Concrete and Queen Anne's County were also pressure washed to compare post-maintenance effectiveness. Pressure washing proved effective at relieving compaction at two of the sites, but was clearly infeasible for maintenance of the large seven acre pervious concrete installation at Shelter systems. This work demonstrated both the importance and the challenge of reliable maintenance of pervious concrete pavements.

During the project, the asphalt parking lot containing one of the CUERE demonstration plots received a new blacktop treatment. This provided a unique opportunity to draw a "first-storm" sample of runoff from freshly blacktopped asphalt. The design of the CUERE ZTL is not intended (and is not well suited) to collection of hydrocarbons - especially PAHs. Monitoring infrastructure for PAHs would typically involve an active (e.g. ISCO) sampler storing samples in acid washed refrigerated amber bottles, with samples retrieved from the field within hours of collection. The passive PVC ZTL design can be expected to adsorb and volatilize much of the PAH load.

Nevertheless, we cleaned and drained the ZTL immediately before the application of blacktop, and collected a composite water quality sample form the ZTL soon after the first post-treatment rain event. We were able to leverage ongoing research at UMBC to analyze these water quality samples using solid phase micro extraction (SPME) at minimal cost, in the laboratory of Dr. Upal Ghosh. SPME enables low detection limits (in some cases parts per trillion) with small sample volumes. Despite infrastructure that was not designed or intended for PAH sampling, we did find a very distinct elevated naphthalene fingerprint in the first-storm parking lot runoff. Our second identically instrumented pervious concrete plot in an adjoining grass field provided a control signal from which the naphthalene spike was clearly distinguished.

We also collected particulate matter that was trapped in the pervious concrete voids and analyzed the particle size distribution and metals content of the solids. We consistently found elevated particulate concentrations of typical urban metals (Zn, Cu, Ni, Pb, Cr) with the majority of the metals mass in the 125-1,000 micron size range. This analysis framed future and ongoing work on the potential removal and availability of urban metals through physical filtration, leaching, and desorption in pervious pavements.

Approximately 14 cores were taken from each of the UMBC demonstration plots. The bulk density and compressive strength of three cores from each plot were evaluated using standard ASTM methods. The clear correlation between bulk density and compressive strength was seen in all cores, supporting the proposed use of bulk density as one of the field acceptance criteria for delivered pervious concrete.

We made extensive use of a so-called "DeLatte infiltrometer", fabricated from a 4" x 8" plastic concrete test cylinder to measure the drainage rate of pervious concrete surfaces. Though less accurate and precise than the newly developed ASTM infiltration test for pervious pavements, the DeLatte infiltrometer provides a rapid, inexpensive, non-destructive measurement of the relative drawdown time – indicating the clogging state- of a pervious pavement. The advantages of using this less precise measurement technique include it's low cost, rapid test time, and the relatively small volume of water required to estimate pavement drawdown time. The inherent spatial variability of pervious concrete requires multiple measurements for characterizing the infiltration and degree of clogging on a pavement. Using the Delatte infiltrometer we are able to collect a dense set of measurements over the surface of a pavement, enabling us to develop a more accurate estimate of the overall condition and hotspots for clogging and infiltration. We believe this simple cost-effective non-destructive field test can become a standard tool for routine monitoring of pavement condition to guide and trigger routine maintenance.

The efficacy of being able to easily measure clogging at multiple locations became clear in our field work at the U.S. EPA Wet Weather Flows lab in Edison, NJ. EPA is monitoring its pervious pavements (concrete, asphalt, and pavers) through monthly random measurements using the ASTM approved infiltration technique. The ASTM protocol is time consuming and relatively expensive, leading EPA to limit the number of samples taken each month. Initial analysis of the data collected by EPA seemed to show a statistically significant increase in pavement infiltration with time. During our field work at the EPA Site, we made drawdown time measurements at the identical pavement locations at which EPA had measured infiltration using the ASTM method. We also took a dense gridded sample of drawdown times in every parking space on the parking lot. Our analysis of the drawdown times indicated that the temporal trend in EPA's monthly sampling appears to be an artifact related to their random sampling which, by chance, happened to select one or two test locations with unusually low infiltration early in their sampling, and more common high infiltration sites later in their data collection. These "outliers" appear to have exerted an undue influence on the inferred (statistically significant) trend seen in the limited data collected.

On closer scrutiny, the infiltration of the EPA pervious pavements varies between about 800-1200 in/hr. The high variability and spatial heterogeneity of this material requires a denser set of field measurements to accurately characterize both the mean pavement infiltration as well as the local variations and changes in clogging. Our use of the simple DeLatte infiltrometer appears to be a practical cost-effective tool supporting rapid dense data collection as part of a routine maintenance inspection protocol. The limitations of the DeLatte infiltrometer make it unsuitable for estimating hydraulic conductivity accurately enough to support field acceptance or legal claims for inadequate performance. For these legal standards of performance the ASTM test will likely remain the standard in the foreseeable future. We view the two approaches for evaluating pavement infiltration as complementary – not competitive. We continue to work with regional partners (including DC DOT) to improve and institutionalize a rapid field inspection protocol to guide routine maintenance and inspection of the clogging condition of pervious pavements.

Project Evaluation

Overall we consider this project a significant success. Our project used monitored demonstration projects as the platform to generate key information needed by practitioners, guided by our Technical Advisory Committee. We met or exceeded our goals for project installation and outreach, and the core model and field infrastructure proved to be a rich platform from which we were able to build significant unanticipated partnerships to advance the project goals. The project evolved significantly from its initial formulation, largely in response to the rapidly changing regulatory landscape accompanying the adoption of Environmental Site Design (ESD) for stormwater regulation in the State of Maryland. Working to address the evolving needs of our regulatory partners on the TAC, we were able to develop a consistent procedure for both the hydrologic design and the quantitative evaluation of hydrologic performance of pervious concrete stormwater systems, that was well matched to the new requirements of ESD. Our most significant contribution may be the design computations we provided to MDE, that were the basis for the current pervious concrete design criteria in the State's Revised ESD Stormwater Design Manual. In this way, the project will have a significant lasting effect, on the design and approval of pervious concrete stormwater systems in the State of Maryland.

The program's reliance on a Technical Advisory Committee composed of the most knowledgeable and experienced stakeholders for our products and information was an essential element of the project's success. We experienced numerous unexpected anomalies throughout the project (from the wholesale change in the State's regulatory criteria, to permitting problems and unexpected failure in technology and infrastructure). Our adaptive management model for the project was richly informed by periodic TAC input that ensured changes in the emphasis and priority of project activities remained consistent and on target with the larger goals of providing key information to critical stakeholders in order to advance the adoption and approval of pervious concrete.

Significant successes include:

- Installation of two instrumented test plots, and opportunistic incorporation of CUERE monitoring infrastructure in three other pervious concrete plots (NJ, Queen Anne's County & Montgomery County) as well as a synthetic turf athletic field.
- A total of ten outreach and technology transfer workshops and seminars, including the development of a pervious concrete resource site with online video, audio and digital documentation of a major workshop developed with the Maryland Ready Mix Concrete Association.
- Peer reviewed publication of our hydrologic design procedure in the Journal of Hydrologic Engineering. We believe the effective curve number (ECN) characterization developed in this project can emerge as a standard, not just for pervious concrete, but for a broad range of LID BMPs and environmental site design.
- The project adapted to changing demands associated with the Stormwater Management Act of 2007 and successfully adapted our work plan and products to respond to changing needs for critical information on hydrologic design, performance, maintenance, and clogging. The understanding of clogging and maintenance gained through this project frames ongoing research and partnerships to address reliable long-term maintenance – which we now consider to be critical information needed to advance the confident adoption of pervious pavements.
- The unanticipated emphasis on clogging and restoration grew to be (and remains) the single greatest source of uncertainty in routine long-term adoption. Initial maintenance testing showed pressure washing to be very effective at renovating small clogged pavements. Routine vacuum sweeping had positive effects on moderately clogged pavement but proved ineffective on fully clogged (i.e. sealed) pavements. Although pressure washing

was effective on test plots, manual pressure washing on large pavements (such as Shelter Systems' 7 ac site) is not practical.

- We have overcome design obstacles to address standard design and approval and freeze-thaw performance. Remaining obstacles are maintenance, and institutionalization of specification and approval. This is a national issue for which several standard committees – including ASTM standard committees are actively working.

The greatest challenges we faced included:

- Technical challenges – The capacitance based sensors originally specified for this project proved unreliable (capacitance based sensors) Requiring a reevaluation and shift to more traditional sealed pressure transducers with atmospheric corrections. We also ran into unexpected difficulties in securing required permits to install the demonstration plot at the Carroll Park location originally planned. The decision to install two demonstration plots on the UMBC campus proved to be a very productive response to this challenge. Our inexpensive passive monitoring infrastructure was unexpectedly damaged by heavy vehicular traffic, leading us to curtail some of the anticipated data collection activities. Repairs will require excavating a section of the concrete to replace portions of the infrastructure. We have subsequently modified the basic design to protect the infrastructure using a flush-mounted cast-iron cleanout with a brass screw cap as the standard surface access for all monitoring ports. We have secured additional grant funding that will allow these repairs to be made in the Fall of 2011. Perfecting data collection protocol and implementing it at Queen Anne's County DPW with student intern form Chesapeake college.
- Value of WQ data proved less critical to project success than originally expected due to changes in State stormwater regulations that allows pervious pavement to be treated as an "alternate surface" rather than a "BMP" (which has attendant requirements for TP and TSS reduction), as well as the higher priority placed on hydrologic information by TAC.
- The greatest challenge remains institutionalized practices that do not accurately accommodate the unique requirements of pervious concrete. We are optimistic that many of these challenges can be overcome through continuing education outreach and technology transfer partnerships. Our technology transfer efforts with MD SHA have clarified the additional information and unique institutional challenges that still must be addressed in order to gain acceptance of pervious concrete among transportation agencies (distinct from stormwater management stakeholders).
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Advice For Future Projects: Two lessons we take from this project are (1) the great value of establishing a knowledgeable engaged carefully composed Technical Advisory Committee; and (2) the importance of adaptive project management. Advancing new technologies in regulatory and practitioner communities involves fundamental changes in established practices. Ensuring a high probability of success requires the capacity to identify true drivers of practice, and collaborative capacity to target joint efforts and partnerships to constructively address those drivers. We found it essential to distinguish useful data from useful information, and to recognize the very different sources on which each stakeholder community relies for credible information for decision making. Our ongoing efforts to provide credible reliable information for MD-SHA reflects our somewhat belated understanding of the very different role, and the very different information requirements that transportation agencies (with their deep roots in material science and testing) require, to incorporate a non-traditional "material" like pervious concrete into their well-established culture, grounded in infrastructure design, construction, maintenance, and management.

Transferability and Sustainability

The single most significant impact of our results will be its propagation as part of the MDE ESD Stormwater Design Manual. The peer-reviewed publication of these engineering design procedures in the ASCE Journal of Hydrologic Engineering will further institutionalize our results in the practice of professional engineers. In addition to our hydrologic design procedure, the structural design procedure developed by co-PI Delatte has also been published in the Proceedings of the National Academy's Transportation Research Board (TRB). Beyond the credibility this conveys within the transportation community, the design procedure has also been encoded in the American Concrete Paving Association's Pervious Pave© design software, further inoculating our project results in professional practice.

For regional practitioners (e.g .in the Bay Watershed) our technology transfer workshops have brought (and continue to bring) project results to the broader community of practitioners, including workshops and seminar for the Lancaster County Planning Commission, PA DEP, Lancaster County Clean Water Consortium, and design computations provided to Lancaster, PA DPW. The workshop presentations that have been assembled online, on the Web site of the Maryland Ready Mix Concrete Association remain a useful "one-stop" resource site for practitioners undertaking pervious concrete design, installation, specification, or contracting.

Looking forward, project results will be sustained through the vibrant partnerships formed in this project, including ongoing performance monitoring partnerships with Queen Anne's and Montgomery Counties, the Susquehanna River Basin Commission, Northern Virginia SWCD, USGBC, the National Ready Mix Concrete Association, and the Alliance for the Chesapeake Bay.

Monitoring and Maintenance

1. Tipping bucket rainfall data has been collected at the site of our two original demonstration plots since the start of the project. Hydrologic monitoring was originally delayed by technical deficiencies in the water level sensors originally specified for the plots. Structural damage to the monitoring infrastructure prevented installation of data loggers during the project period. However additional grant funding has been secured that will enable us to excavate the pavement in the Fall of 2011 to effect infrastructure repairs and resume data collection. We also partnered with Queen Anne's DPW to instrument a 15,000 s.f. parking lot. QA-DPQ has procured data loggers and tipping bucket rain gauges but personnel cuts at DPW have thus far delayed their installation. We are currently negotiating with Chesapeake College to provide student support for routine monitoring of these pavements which we hope to begin in the Fall of 2011. ZTL infrastructure installed by EPA contractors also experienced problems in reliable sampling. The diagnosis and repair will require underground inspection using fiber optic technology. We have secured grant funding that will enable this diagnosis and repair (if possible) to resume sampling in Edison NJ.

2. We have performed laboratory analysis of water holding capacity of the internal surface of pervious concrete samples taken from cores. Results show high water retention on the internal surface area (distinct from pavement voids) Conventional pavement has "depression storage" of 1-5 mm. We conservatively estimate the water retention within some 6" thick pavements could be nearly twice that depth.

3. Metals Particulate-bound heavy metals in grit loading our test plots showed "typical" urban heavy metals, at moderate concentrations – lower concentrations than found in stormwater ponds or parking structures at Towson State University.

4. PAHs Routine maintenance of our UMBC parking lot provided an unanticipated opportunity to monitor PAH runoff from freshly blacktopped asphalt. Using the ZTL water quality sample from our grass test plot as a control, elevated levels of dissolved naphthalene (3x greater than control) were found in the pavement ZTL following the first storm after blacktopping. Subsequent events showed no significant differences in PAH concentrations.

5. Clogging Extensive field testing and evaluation of pressure washing to restore clogged pavement was conducted with our clogging monitoring. Pressure washing proved effective for mitigating clogging on small pavements (for which suspended grit could be washed from the pavement). For deeply clogged pavements in which maintenance had been ignored to the point of "sealing" the pavement surface, pressure washing proved ineffective at removing deep clogging. This helped frame our mental model for clogging and maintenance that distinguishes routine maintenance form renovation of sealed or "failed" pavements. Our clogging monitoring has led to new research partnerships to evaluate criteria for routine maintenance sufficient to avoid progression to the point of failure.

6. Compressive Strength and Bulk Density In situ strength and bulk density of pavement from our installed demonstration plots was also tested using standard ASTM methods on cores drilled form in situ pavements.

Community Involvement and Outreach Activities

1. Workshop 1 UMBC
2. Workshop 2 Baltimore Engineers Club – joint meeting of American Concrete Institute and Portland Cement Association
3. Workshop 3 Upper Marlboro MD- with MRMCA and Chaney Enterprises, established a community workshop website with online access to all workshop materials and presentations: http://www.marylandconcrete.com/NonBuildingApplications/index.cfm/go/PerviousWorkshop.cfm
4. Design paper published the ASCE Journal of Hydrologic Engineering
5. Sustainability Benefits of Pervious Concrete – presented at 2nd International Conference on Sustainable Building Materials.
6. Earth Magazine Article, "Dull as Concrete" June 2009.
7. UMBCTube Video, http://www.umbc.edu/window/green_concrete.html
8. UMBC Magazine article and press release http://www.umbc.edu/blogs/umbcnews/2008/08/can_a_parking_lot_be_good_for.html
9. UMBC blog http://www.umbc.edu/magazine/winter09/discovery.html
10. Extensive support in MDE ESD stormwater revisions
11. State Highway Administration – in-house Lunch .n Learn
12. State Highway Administration – All divisions workshop with MRMCA
13. State Highway Administration – MRMCA tour of MD Pervious concrete installations
14. Provided Zero Tension Lysimeter design and synopsis online, as Jing screencast: http://www.screencast.com/users/sss_JING/folders/Jing/media/7814ec95-a114-4aa3-a45f-469e78b27d4c
15. Engineering Green Conference - Baltimore Engineers Society
16. ASCE Baltimore Stormwater Section. – Monthly Technical Speaker
17. Anne Arundel County DPW – Staff Workshop
18. Alliance for the Chesapeake: Chesapeake Forum
19. Lancaster County Planning Commission – Seminar for the Stormwater Planning Workgroup

Partnerships

1. Zcon Concrete – Donated installation; installed site for field testing.
2. Increte of Maryland – donated site preparation and materials.
3. Rockville Fuel & Feed – concrete supplier
4. MDRMCA-partner on workshops and outreach.
5. Cleveland State University – partner on workshops and material testing
6. Baltimore City – technical advisory team
7. Chaney Enterprises – hosted Dec 08 workshop and placement; installed site for field testing; established YouTube video of our maintenance site testing at: http://www.youtube.com/watch?v=BKyuucFGfSU&feature=channel_page
8. MDE – technical advisory committee;
9. Carroll County- technical advisory committee; workshop partner
10. Baltimore County- technical advisory committee
11. Montgomery County- technical advisory committee
12. Northern VA Commission- technical review and liaison to Chesapeake Bay Program Urban workgroup
13. Ohio DNR – technical review
14. Baltimore Chapter, Green Building Coalition- workshop partner

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15. USEPA Wet Weather Flows Lab – installed two CUERE Zero Tension Lysimeters, and partnering in comparative water quality sampling.
16. S. Lev and R. Casey at Towson State University – collaborated on metals analysis
17. Upal Gosh, UMBC – provided solid phase microextraction (SPME) PAH analysis

Accounting of Expenditures

CBT Funds: $150,000
Total Funds: $150,000