

Collaborative Experiential Learning: Building a Pervious Concrete Parking Lot

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This paper describes collaboration among students and faculty of a construction management program with academic and industry partners as they designed and constructed a small pervious concrete parking lot on a university campus. The lot served the multiple purposes of 1) replacing worn asphalt paving with new pervious concrete, 2) capturing and filtering harmful stormwater runoff with a porous pavement, 3) providing an experiential learning opportunity for construction management students, and 4) providing a field study research laboratory for demonstrating the positive environmental effects of pervious vs. impervious paving. The paper describes the process of designing and building the facility with the many collaborators who contributed to the project. The paper also describes the National Ready Mix Concrete Association (NRMCA) pervious concrete technology training and certification of participants, which was integrated into the project. Paper also briefly summarizes research results.

Key Words: Pervious Concrete, Experiential Learning, Industry Collaboration, Stormwater Quality

Introduction

A project conducted on a major university campus, brought together collaborators from industry and academia to replace part of a worn asphalt parking lot with pervious concrete paving. In addition to an experiential learning opportunity for construction students, facilities workers, and industry members, the exercise also created an opportunity for testing the effectiveness of pervious concrete paving to both reduce and treat stormwater runoff flows from an urban surface. Pervious Concrete (PC) paving systems are widely accepted as a beneficial urban stormwater mitigation practice (Schaefer, 2006).

This research project was funded by a $25,000 grant from the Alabama Water Resources Research Institute (AWRRI), an agency of the United States Geological Survey (USGS). A 2:1 combined match from university and construction industry supporting agencies allowed for the successful completion of the project.

The primary objective of the funded research was to establish the benefits of pervious concrete in mitigating the negative effects of stormwater runoff quantity and quality from a parking surface. The method involved replacing the worn asphalt paving on one side of a small parking lot with a PC system, while leaving a matching side with the original impervious paving. Both sides were instrumented to collect stormwater striking the pavements. Samples of the stormwater were collected over an eight month period and lab tested for a variety of pollutants. Research results from data gathered from this side-by-side case study indicated that pervious concrete systems can dramatically reduce all common environmentally harmful impurities from parking slab stormwater runoff.

From an educational perspective, the most exciting and unique aspect of this project was the collaborative way in which the field research facility was designed, built, and implemented by students. Important educational benefit resulted from students and faculty collaborating with industry and university facilities personnel to plan and construct the facility. These collaborators gained valuable knowledge about PC systems by employing best-practice techniques for placing pervious concrete. The collaborators also designed and installed a monitoring system to conduct the field experiment. As a bonus, students were trained and tested by industry experts, which enabled them to become certified by the National Ready Mix Concrete Association (NRMCA) as pervious concrete technicians.

Installation of PC Pavement

Students of Construction Management, Architecture, Landscape Architecture, and Biosystems Engineering programs at Auburn University designed and installed the PC system as a project requirement of their regular coursework. A Landscape Architecture graduate student provided a concept plan and location map for improvements to the parking area of the arboretum (See Figure 1) The plan called for 1) replacement of worn impervious pavement with a porous paving system, and 2) complementary plants, bioswales and rain gardens that assisted in the capture, storage and purification of stormwater. Biosystems Engineering undergraduate students conducted a Hydrology study, including preliminary subsurface investigation and design of pavement subbase for capture and storage of stormwater. Construction management and architecture students of an undergraduate concrete structures class, planned and executed all construction activities. Assistance and guidance was provided to students by a university faculty member from each of the academic programs. The Arboretum Curator served as project client, with arboretum staff members and a construction crew from university facilities actively involved in the project. Substantial consulting and guidance on PC, including mix design, system components, placement tools and proper techniques was provided by industry experts. These experts included, a representative from the state concrete industry association, a specialty PC contractor, and a local concrete supplier.

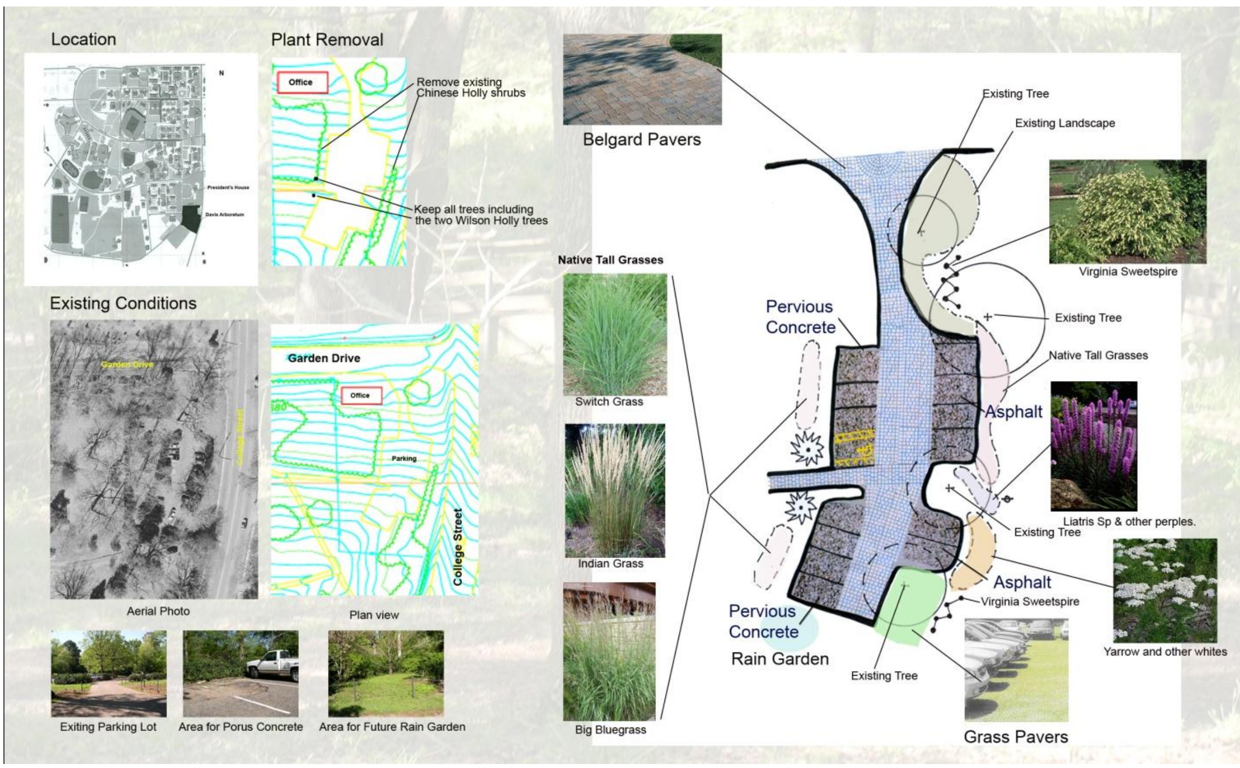

Figure 1: Concept plan featuring arboretum PC parking lot

Parking on the Pond

Pervious concrete is typically part of a pavement system that includes the following essential layers: 1) A pervious concrete surface layer made of a uniform coarse aggregate, a minimum of fine aggregate, low w/cm ratio Portland cement paste, and a variety of admixtures, 2) An open graded aggregate subbase layer that receives and stores infiltrated stormwater, and 3) a geotextile liner or geogrid that separates the subbase from the native soil subgrade. A cross section of the PC paving system, shown in Figure 2, consisted of a 6 in. thickness of pervious concrete, a 6 in. thickness of drainable (#57) aggregate subbase, and a 4 oz. nonwoven geotextile fabric. PC mix design developed by local supplier in collaboration with author: 420 lbs. Portland Cement, 120 lbs. Fly Ash, 2700 lbs. #89 crushed limestone, 5 oz./ 100 wt. water reducer, 4 oz./100 wt. viscosity modifier, 4 oz./100 wt. retarder.

When designed and placed properly, the PC system provides a strong matrix of aggregate bridged by cement paste with a system of interconnected pores for the passage of water, which comprise around 20% of the pavement volume. PC compressive strengths in excess of 3,000 psi and infiltration rates in excess of 1,000 in/hr are easily achieved. This unique combination of properties allows PC systems to support the weight of light vehicles while infiltrating and storing all of the rain that strikes the slab, depending on the depth of slab and subbase. Some practitioners have described PC pavements as “Parking on the Pond.” (Tenant, 2004)

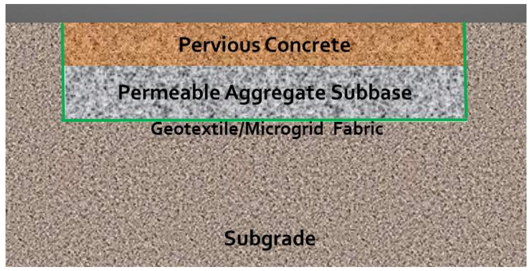

Figure 2: Pervious concrete system cross section

Construction of the PC parking lot was conducted over a one-month period in spring of 2009. Coordination of the many collaborators required good communication and flexibility by all parties. A schedule of key design and construction activities and participants is shown in Table 1:

Table 1: Schedule of Construction Activities for PC Pavement

	Activity	Dates	Collaborators
1	Develop Master Plan	3/16/2009	LARCH
2	Design Hydrology	3/23/2009	BSEN
3	Design PC Pavement	3/27/2009	BSCI
4	Layout PC Pavement	3/30/2009	BSCI & BSEN
5	Demolition existing asphalt pavement	4/6/2009	BSCI, AUFAC
6	Excavate 12“ sub surface and cross drains	4/9/2009	BSCI, AUFAC
7	Install & Test Water Collection System	4/10/2009	BSCI,BSEN,AUFAC,AUARB
8	Backfill with drainable subbase gravel	4/13/2009	BSCI, AUFAC
9	Install steel 6” side-forms	4/15/2009	BSCI, AUFAC
10	Place 6” PC pavement	4/16/2009	BSCI, AUFAC, PCI
11	Cure fresh PC for 10 days	4/27/2009	BSCI, AUFAC
12	Install surface drain on asphalt side	5/4/2009	BSCI, BSEN, AUFAC

Legend: LARCH = Landscape Architecture at Auburn University
BSEN = Biosystems Engineering at Auburn University
BSCI = Building Science at Auburn University
AUFAC = Auburn University Facilities Division
AUARB = Auburn University Arboretum Staff
PCI = PCI Systems of Atlanta, PC Consultants
USA = USA Ready Mix concrete suppliers

Note: A complete photo story of the activities may be found at the following photo website:
https://picasaweb.google.com/aubscipervious/DavisArboretumPerviousPavingSpring2009

The research method of stormwater evaluation was to collect both leachate trickling through the PC system and compare with surface runoff results from the impervious pavement. Figure 2 shows completed cast PC pavement, showing the cast, striped and instrumented pavement, including 8 standard parking spaces and one handicap space.

As shown, the new PC lot is divided into two segments, an upper lot of four parking spaces with an 8% cross slope (upper right in photo), and a lower lot of four spaces with a 4% cross slope (lower left in photo). Due to the sloping surfaces, researchers anticipated that during a rain event, the infiltrated water would accumulate in the open graded subbase and quickly run downslope, exiting the pavement along the downslope edge.

*Figure 3: Completed PC paved parking lot***.**

To avoid the potential loss of infiltrated stormwater, a system of 4 ft. wide by 3 ft. deep cross-slope trenches was installed to hold the captured stormwater. (Figure 4a). Trenches were lined with porous geotextile fabric, trench bottoms lined with perforated pipe, then filled with an open-graded #57 aggregate (40% porosity). (Figure 4b)

Figure 4a: Constructing Cross Trenches for captured stormwater storage

Figure 4b: Backfilling Cross Trenches with open graded gravel

Collaborators constructed a subsurface leachate collection system to capture filtered stormwater through the new pervious concrete parking slab (Figure 5), and a surface collection system to collect surface runoff from the impervious asphalt parking section (Figure 6). For the new PC section, researchers wanted to be sure that they were testing water quality from stormwater samples that had been filtered through the complete PC system cross section. Figure 5. shows installation of an original innovative under-drain system for leachate collection designed by students and professors. This consisted of a series of upturned collection troughs located beneath the PC system of pervious concrete, drainable base and nonwoven filter fabric. The trough was fashioned from a split 10" diameter Polyvinyl chloride (PVC) pipe, which fed into a PVC funnel drain and 2" diameter line that carried leachate to the collection reservoir. The trough is covered with filter fabric and filled with #57 aggregate before placement of the final six-inch layer of subbase and six-inch layer of pervious concrete.

Figure 5: Under drain system for collection of leachate through PC pavement system.

Surface runoff was collected from the traditional asphalt pavement side by means of a surface drain installed at the low end of the pavement, which is on approximately a 6% slope. (See Figure 6).

Figure 6: Drain for collection of surface runoff from asphalt pavement

Figure 7 is a comparison of stormwater collected from both pervious and impervious parking slabs after a rain event. Figure 7a shows leachate collection reservoir fed by PVC collection piping from which stormwater samples were taken. Note the clarity of rainwater leachate that has been collected following a rain event and after infiltrating through the PC system. Figure 7b shows stormwater surface runoff from the asphalt surface following the rain event. In addition to chemical pollutants present in the surface runoff, significant amounts of sediment from the surface runoff have completely filled the reservoir after a two-year period. Table 2 indicates the significant reduction in contaminants of the PC pavement compared to the impervious asphalt pavement. Percentage decreases are shown for all major pollutants tested associated with vehicles, Iron (Fe), Copper (Cu), Total Suspended Solids (TSS), Oil & Grease, Zinc (Zn), and Lead (Pb). A more detailed analysis of research results is presented in another paper.

Table 2: Percent difference in stormwater runoff quality for newly installed pervious pavement vs. impervious pavement, Auburn University parking lot, Auburn, AL 5/26/09 – 1/ 27/10.

Lab analyses	Fe(μg/L)	Cu (μg/L)	TSS (mg/L)	Oil & Grease (mg/L)	Zn (μg/L)	Pb (μg/L)
Rainwater (N=20)	- 57	- 85	- 82	- 44	- 78	- 64

Figure 7a: PC Leachate collection reservoir

Figure 7b: Runoff collection reservoir

Training in PC Installation:

Figure 8: Students and university facilities workers place PC pavement with contractor

A Master Pervious Concrete Craftsman who is also President of a local specialty pervious concrete construction company provided hands-on training. The expert conducted ½ day National Ready Mix Concrete Association (NRMCA) certification training for all students and AU Facilities workers on the project. This was followed by a hands-on demonstration during the PC placement. (See Figure 8) Twenty-seven individuals passed the NRMCA exam following the placement, certifying them as Pervious Concrete Technicians.

Communication and Publicity

Publicity of the concrete placement was provided through a feature article in the local newspaper. Online version of the story included a video segment of the placement. The complete photo story of the PC placement was posted on a Picasa photo website, with invitations sent to all project participants and inquiring parties. See https://picasaweb.google.com/aubscipervious/DavisArboretumPerviousPavingSpring2009 Researchers were invited to present results of the project at a regional sustainability conference, a statewide water quality conference, a campus sustainability luncheon, and a national conference on pervious concrete. In addition the PI has worked with the client and fellow collaborators to produce a 3-hr. Engineering Professional Development video course on PC, featuring the arboretum PC project (Hein, 2010). The researchers have led numerous tours of the PC parking lot for small groups of interested faculty, students, and visitors. The project is featured on the website of the new Center for Construction Innovation and Collaboration at Auburn University. Alabama Concrete Industries Association has published a story on the placement in their news magazine, sent to concrete industry association members statewide. The AU Building Science featured the project in the Fall 2010 edition of *Quoin*, its semiannual Alumni Publication.

Evidence of Project Impacts

Researchers believe that the following subsequent impacts are a direct or indirect result of the successful project and its positive research findings communicated and promoted through the variety of means outlined above:

1. Subsequent PC Projects on Auburn campus carried out by groups of Architecture and Construction Management students - Since completion of this demonstration project, there have been more than eight follow-up student PC projects on campus, requested by university and city clients: a) A PC playground tricycle track at the university Child Study Center, b) A picnic table pad at the university Forest Ecology Preserve, c) PC driveway inserts for stormwater runoff detention at the university Arboretum, d) A major parking lot for the local city, e) A 750 ft. long walking trail in a park in Greensboro, AL, f) a major parking lot at a university fisheries extension facility, g) multiple projects totaling several hundred feet of colored pervious concrete waking trail winding through the university arboretum.
2. Subsequent PC projects at Auburn University - There have been two major projects on campus contracted by the university: a) Parking at the new student housing facility, and b) PC paving and parking lots for a new university track building.
3. Subsequent PC projects in the greater city area – There have been four major commercial PC placements in the university's host city following the project. One was for a parking lot at a sustainably constructed Salvation Army retail outlet. Another involves driveway and parking areas at a housing development in an attempt to mitigate damage from stormwater runoff into a local stream.
4. Adoption by university Facilities Division – University Facilities has invested in Striker Screed equipment, enabling them to cast PC more efficiently in large paving areas, such as parking lots around campus. They continue to work side-by-side with PI and his students, advancing the presence of PC on campus.
5. Financial support by the state concrete industries association – As result of the success of the project and convincing test results, Alabama Concrete Industries Association has committed $17,000 funding to further study and place PC at Auburn University.

Subsequent and Future Study

Many ideas for future study emerged as a result of this research project. A few of these are: 1) Study of surface clogging of PC pores over time and effective cleaning methods. 2) Thermal Pollution study to compare temperature of leachate trickling through PC to surface runoff from asphalt paving, 3) Biological study of decomposition of hydrocarbons by microbes in residence within PC, 4) Continuation of chemical analysis, focusing on oil and grease in PC leachate vs. surface runoff from asphalt paving.

Since the completion of the project, two separate studies have been conducted on clogging of PC paving. The first study involved a quick field infiltration test for determining if and when PC pavements require cleaning to restore adequate infiltration (Dougherty, 2010). The second study evaluated effective methods of cleaning PC pavements (Hein, 2012). A thermal pollution study is currently under way, which measures heat gain by stormwater in contact with a variety of both pervious and impervious pavements.

Summary and Conclusions

Experiential learning in construction is by nature collaborative. In spring 2009, a large variety and number of students, faculty, facilities workers, material suppliers, and concrete practitioners came together to design and build a small parking lot at the Auburn University arboretum. The new slab replaced older worn asphalt paving and became part of a side-by-side study that compares the environmental benefits of pervious concrete versus traditional impervious paving. Results of the 8-month research study following the installation demonstrated that pervious concrete paving reduces through infiltration all of the common pollutants found in stormwater. The pavement utilized the latest technology for installing a pervious concrete system that would support light traffic as well as infiltrate stormwater. Many beneficial learning experiences were experienced by all of the participants. Students and university facilities workers received NRMCA training by industry experts on the technology of pervious concrete, and they were tested and certified. Communication of results through participation, publication, and publicity has influenced and inspired subsequent pervious concrete projects in the wider geographic region.

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