Evaluating Hydrologic Significance of Evaporation in Pervious Concrete Systems

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Outline

- Pervious pavement systems
- Research objectives
- Experimental setup
- Data and results
- Conclusions
Pervious pavement SCM (PP system)
PP system water balance

RUNOFF

Temp storage

Ground infiltration

Outflow

Moisture Retention

Evaporation

Groundwater Recharge
PP system water balance

RUNOFF

= Temp. storage

= Ground infiltration

+ Outflow

EVAPORATION

Moisture Retention

Groundwater Recharge
Research program

- Simulate pervious concrete (PC) system in the lab
- Quantify evaporation rates
- Assess hydrologic significance
- Provide recommendations for the system design
Experimental setup

- Laboratory settings
- PC system core
- Ambient conditions, rain: simulated
- Measure evaporation
- No infiltration
Evaporation parameters

- Thermal profile at any given time
- Ambient temperature and relative humidity (RH)
- Time since the last rain event
- Depth to the ponded water
- Wind speed
Thermal profile: seasonal fluctuation

Images courtesy of:
Nofziger and Wu, 2005
Thermal profile: daily fluctuation

FIGURE 10 Warm weather response of the PCPC system

Image courtesy of: Kevern et al., 2009
Iowa State University
Calibration parameters: VU research site

**Target thermal profile**

- Temperature, °C
- Radiation, Watts/m²

**Target relative humidity (RH)**

- Temperature, °C / RH, %
- Radiation, Watts/m²

Key:
- Surface Temp
- Bed Temp (40 in)
- Solar Radiation
- RH
- Solar Radiation
Solar simulator

24-hour cycle operation

Software

Hardware

- Solar Radiation
- Lamp PULSE
Experimental setup: final version

- 3.5' deep column (full-scale)
- Insulation
- RH control/monitoring
- Thermal profile calibration/monitoring
- Wind tunnel
Instrumentation

- Environmental room (temp, RH)
- Ambient temperature and RH: I-Buttons
- Thermal profile: TCs, TC data logger
- Wind: fan + anemometer
- Scale, 0.1 gram resolution
- Solar simulator
Schematics and the experiment program

- 3 days in August
- Simulated rain event
- 6 Scenarios: d = 0", 1", 3", 6", 10", 15"
Typical dataset ($d=0''$)
Evaporation rate datasets, 2-hr

NOTE: PEAKS OCCUR @ SOLAR NOON
Evaporation rate datasets, 24-hr

NOTE: EVAP @ 10” ~ EVAP @ 15”
Findings: water surface influence zone

- **Depth** \(\uparrow\) \(\Rightarrow\) **EVAP** \(\downarrow\)

- **WS influence zone (~10’):**
  - **Depth** \(\uparrow\) \(\Rightarrow\) **no change in EVAP**
Findings: EVAP = f (Depth, Time)

- EVAP = 33.36 * [(D/25.4 + 1.5)*T - 5.24]^{0.647} + 0.47, where:
  - EVAP = evaporation rate, in mm/day
  - D = initial depth to a ponded water surface, in mm
  - T = hours since the end of the rain event; \( T \geq 12 \) hrs

- \( R^2 = 0.98 \)
$\text{EVAP}_{\text{VU site}} \ldots \% \text{ of annual water budget}$

**EVAP share: no infiltration**

![Bar chart showing the percentage of annual water budget for different initial depths to water surface. The highest percentage is 4.2% at 0" depth.](chart.png)
EVAP$_{\text{VU site}}$ ...... % of annual water budget

Notes:
- loading ratio at VU was 2.6:1
- IF loading ratio was of 1:1 → the results 2.6 times higher
Hydrologic performance of a hypothetical PC system

- Storage: $P = 0.5'' (12 \text{ mm})$ ........... [$\sim 70\%$ of all rain events]
- No infiltration
- Saturated conditions
- EMPTY in 3 days !!
  (August, Philadelphia)

Pervious concrete, 20% voids
Thickness = 2.4'' (60 mm)
Design recommendations to enhance evaporation performance

- Use shallow PC systems (10” or less)
- Use smaller tributary area
- Allow saturated conditions
Conclusions

- Evaporation can be significant

- Potential uses of PP systems:
  - poor soils
  - high ground water
  - contaminated runoff
Acknowledgements | References

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- WBCM
- Kevern et.al, “Temperature Behavior of a Pervious Concrete System”, University of Missouri / Iowa State University 2009
- D. L. Nofziger and J. Wu: “Soil Temperature Changes with Depth and Time”, Oklahoma State University, 2005
- PA Stormwater BMP manual, 2006
Questions?