CASE STUDY: ENHANCED POROUS CONCRETE PAVEMENT SYSTEM CREATES ADVANTAGES FOR ALL STAKEHOLDERS

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ABSTRACT

This paper covers the planning, design and performance monitoring associated with a porous concrete pavement system installed as an innovative storm water management approach for an approximate 1.6 acre retail development project in Franklin, Wisconsin.

Planning for the project required that the development provide measures to meet City of Franklin, Milwaukee Metropolitan Sewerage District (MMSD), and Wisconsin Department of Natural Resources (WDNR) storm water management regulations and requirements. Given the nature of the development and space constraints associated with the project site, utilization of an innovative storm water management approach using a porous concrete pavement system was considered early in the planning and preliminary design phase of the project. Enthusiastic acceptance of the concept by the developer (Zabest Commercial Group), the City of Franklin, the MMSD and the WDNR allowed the project to proceed without delay. The porous concrete pavement system was installed in April 2006 and has been functioning as designed since then.

The pavement system consists of four inches of a proprietary porous concrete pavement (Ecocreto™) placed over a stone storm water detention bed. The permeability of the porous pavement system is approximately 4 inches of rainfall per minute and the stone detention bed beneath the pavement provides for storage of the 100-year, 24-hour rainfall event volume over the entire site.

The system was designed and is operated as a zero storm water discharge system. Monitoring of the pavement system since its construction has shown no surface discharge of storm water from the site. This reduces the potential for downstream sewer surcharging and flooding, reduces downstream pollutant loading and provides for groundwater recharge.

This paper examines the design and technical details associated with the implementation of the pavement system including an examination of regulatory requirements pertaining to storm water management that were applicable to the development project. System performance monitoring is presented and evaluated. Pavement system costs including on-going maintenance costs are also evaluated and compared to costs associated with a more conventional pavement and storm water management system. Advantages accrued to the various stakeholders are also discussed.

KEYWORDS

Enhanced porous concrete pavement system.
INTRODUCTION

Over the past several years there have been a flourish of storm water management regulations promulgated at the state, county and local levels in response to the USEPA’s Phase II storm water management initiatives. These regulations can have a significant impact on site development and in some cases may be the determining factor on the feasibility of a particular development project. Typical storm water management regulation components include peak discharge rate control, discharge quality control, infiltration, buffer yards from sensitive areas, and maintenance of storm water control measures. Various Best Management Practices (BMPs) have evolved in order to address the regulatory requirements.

These regulatory requirements can have significant ramifications for site development projects in terms of space, grades, and cost. Under the evolving storm water management regulations, developers, planners, architects and engineers need to factor in the space considerations for storm water management control in addition to the traditional space needs for building footprint, parking/drives, yards/setbacks, and green space/landscaping elements. These space considerations are particularly important for small, infill developments where space is limited.

The management of storm water also has significant ramifications in regards to site grading. It is generally desirable to maintain gravity flow for storm water conveyance and management systems, and the elevation of storm water discharge points can often dictate site grades. Again, these considerations are of particular importance for small, infill developments where space to accommodate grade changes is limited and there is less flexibility for configuration of the site.

Finally, the storm water management regulations can have significant cost ramifications for developments including costs for storm water collection and conveyance systems (e.g. catch basins, storm sewers), structural best management practices (e.g. detention basins, sediment traps, control structures, etc.), non-structural best management practices (i.e. maintenance of storm water systems) and land costs. The incremental costs to acquire additional land to accommodate traditional storm water control measures (e.g. surface detention basins) and costs associated with the collection and conveyance of storm water can impact the feasibility of a development, particularly for small, infill developments where there may not be multiple end users to defray financial impacts as some larger parcel developments are able to do.

The remainder of this paper presents a case study for a small, urban infill retail development where an innovative approach to storm water management was implemented to mitigate the impacts of the storm water management regulations and requirements for the project.

CASE STUDY – RAWSON COMMONS RETAIL DEVELOPMENT

Project Description

The Rawson Commons retail development is an approximate 1.6 acre urban, in-fill development in the City of Franklin, Wisconsin. Prior to the development, the site was utilized as a residential parcel. The parcel is surrounded by commercial development to the west, north and east and by West Rawson Avenue to the south. Surrounding land uses include a health care clinic to the
west, parking for the health care clinic to the north, a bowling alley and associated parking to the east and residential development to the south across West Rawson Avenue. Prior to the development the parcel was mostly open space with a mix of trees and brush. A residential home with a footprint of approximately 1,000 square feet was located on the parcel. The total impervious area (drives, sidewalks, roofs) on the parcel prior to the Rawson Commons development was 2,224 square feet or approximately 0.05 acres. Native soils at the site are predominantly silt loams with isolated layers of loamy sands and sandy clays. Storm water runoff from the eastern portion of the site sheet flowed uncontrolled to the east and southeast to adjacent property to the east and the adjacent street right-of-way to the south. Storm water from the western portion of the site sheet flowed to a localized depression located along the western boundary of the site.

The Rawson Commons development included two single-story retail buildings with footprints of approximately 4,200 and 6,000 square feet with associated parking, drives and sidewalks. The total hardscape area (parking, drives, sidewalks) for the development is approximately 35,000 square feet (0.80 acres); total greenspace/landscape area for the development is approximately 24,000 square feet. Porous concrete pavement consisting of Ecocrete™ porous concrete was used for parking and drive areas. Storm water runoff from the development is allowed to infiltrate through the porous concrete into a stone detention bed beneath the pavement. A site plan showing the layout of the development is presented as Figure 1.

**Applicable Storm Water Regulations/Requirements**

Design of the site needed to take into account several storm water management regulations that were applicable to the project. These storm water management requirements had the potential to significantly impact the project in regards to site layout and space considerations, grading and development costs. The applicable storm water management regulations and associated requirements are summarized below.

**Wisconsin Administrative Code NR 216 – Storm Water Discharge Permits.** Wisconsin Administrative Code NR 216 is applicable to projects which involve more than one acre of land disturbing activities. NR 216 requires that a Notice of Intent (NOI) for Land Disturbing Activities be submitted to the State prior to initiation of any land disturbing activities. The Notice of Intent is signed by the Owner and certifies that a construction erosion control plan and a post-construction storm water management plan meeting Wisconsin Administrative Code NR 151 requirements has been developed and will be implemented.

**Wisconsin Administrative Code NR151 – Runoff Management.** Storm water runoff for redevelopment sites is regulated under NR 151.12 of the Wisconsin Administrative Code. NR 151.12 sets post-construction performance standards for the management of storm water runoff. For redevelopment sites or in-fill developments of less than 5 acres, NR151.12 requires that storm water runoff be treated to remove 40% of Total Suspended Solids (TSS) based on an annual average rainfall, as compared to no runoff management controls. Requirements for peak storm water discharge control and storm water infiltration under NR 151 are waived for redevelopment sites and in-fill developments of less than five acres.
Figure 1: Rawson Commons Site Plan
The Milwaukee Metropolitan Sewerage District (MMSD) regulates storm water runoff from development projects within their service area, which includes the City of Franklin. The MMSD Chapter 13 storm water management requirements are applicable to projects that create more than ½ acre of additional impervious area. For projects which fall under this regulation, peak storm water discharge control is required such that the peak storm water discharge is less than or equal to 0.50 cfs/acre for the 100-year storm event and 0.15 cfs/acre for the 2-year storm event. For the Rawson Commons project, this translates into a peak storm water discharge rate of 0.80 cfs for the 100-year storm event and to 0.24 cfs for the 2-year storm event. An alternative requirement to meeting the peak storm water discharge rates is to detain storm water runoff from the site such that the volume of storm water discharged over the critical time period established for the watershed by the MMSD for developed conditions is less than or equal to the volume of storm water discharged over the critical time period under existing conditions.

The City of Franklin storm water management regulation combines the requirements of the Wisconsin Administrative Code NR 151 and the MMSD Chapter 13 storm water regulations. For sites that create more than ½ acre of additional impervious surface, the peak storm water discharge rates of 0.50 cfs/acre for the 100-year event and 0.15 cfs/acre for the 2-year storm event apply. Alternatively, storm water can be detained such that the volume of storm water discharged over the critical time period established for the watershed is not increased from existing conditions. For redevelopment sites and in-fill developments less than five acres, storm water runoff must be treated to remove 40% of Total Suspended Solids (TSS) based on an annual average rainfall, as compared to no runoff management controls. Storm water infiltration requirements under the City of Franklin storm water management ordinance are waived for redevelopment sites and in-fill developments under 5 acres.

Based on the applicable storm water regulations summarized above, the following criteria were used for development and design of the storm water management plan for the Rawson Commons development:

- Limit peak storm water discharge from the site to 0.80 cfs (0.50 cfs/acre) for the 100-year storm event.
- Limit peak storm water discharge from the site to 0.24 cfs (0.15 cfs/acre) for the 2-year storm event.
- Provide for 40% TSS removal for storm water discharge based on an average annual basis, as compared to no runoff management controls.

**Site Specific Storm Water Management Approach**

A conventional approach to providing storm water management for a retail development of this nature would be to utilize a conventional asphalt pavement system, collect the storm water in catch basins and storm inlets and convey the storm water through underground storm sewer piping to a surface detention basin provided with an outlet control device to control peak storm water discharge and to allow total suspended solids to settle. A surface detention basin for this development would have required an estimated 0.35 acres of additional land. Because the project
site is an infill development, additional land outside of the project site was not available to accommodate a surface detention basin. Additionally, placing a surface detention basin on the project site would have precluded construction of the second retail building on the site thus reducing revenues from the development.

Due to space and cost constraints, the developer, Zabest Commercial Group, desired to pursue an innovative storm water management approach utilizing a porous concrete pavement system as an alternative to a more conventional above ground storm water detention system. The system utilized porous concrete pavement for parking and drive areas placed over a stone detention bed to provide for storm water storage. Storm water collected in the stone detention bed would be allowed to infiltrate into the subsoils at the site and the system would operate as a zero discharge system under normal conditions. The concept was presented to and enthusiastically accepted by the various regulatory agencies having jurisdiction over storm water management at the site: the City of Franklin, the Milwaukee Metropolitan Sewerage District and the Wisconsin Department of Natural Resources. A more detailed description of the system is presented below.

**Porous Concrete Pavement.** The porous concrete pavement used for parking and drives was 4 inches of Ecocreto™ Enhanced Porous Concrete. The Ecocreto™ porous concrete is in effect a concrete produced without fines to incorporate void spaces and allow for infiltration. The concrete consists of an aggregate of 3/8-inch rounded pea gravel, Type I or Type II portland cement conforming to ASTM C150, air entraining agents complying with ASTM C26, admixtures including water retaining admixtures meeting ASTM C494 and the Ecocreto™ admixture and potable water. The Ecocreto™ admixture provides added strength for the concrete mix which meets or exceeds standard concrete pavement strengths. The concrete mix can achieve strengths of 3,000 psi within 24 hours and up to 5,000 psi at 28 days. The porous concrete pavement system has a permeability which allows 4 inches of rainfall per minute to infiltrate through the pavement.

**Stone Detention Bed.** A clean stone bed was provided under the pavement to provide storm water storage and detention beneath the porous concrete. The stone detention bed consisted of 6 inches of 1 to 1.5 inch diameter clean washed stone over a minimum of 18 inches of 2 to 2.5 inch diameter clean washed stone. The stone detention bed specified provided a minimum void ratio of 0.40. The thickness of the detention bed was sized to store the total volume of the 100-year, 24-hour storm event over the site.

**Overflow Piping.** Six inch diameter perforated PVC piping was placed at the top of the stone detention bed to provide for an overflow route in the case of successive heavy rainfall events. The perforated piping was connected to a storm manhole to allow for monitoring of storm water discharge through the overflow piping. A storm sewer connection was made from the discharge manhole to the public storm sewer system in the adjacent street right-of-way.

**Detention Bed Monitoring Ports.** Several monitoring ports were installed through the pavement into the stone detention bed to allow for monitoring of ponding in the detention bed. The monitoring ports consisted of six inch diameter perforated PVC pipe sections installed through the porous concrete to the base of the stone detention bed. A total of five monitoring ports were installed: one in each quadrant of the parking area and one in the center of the parking area.
A typical sectional detail of the porous pavement/stone detention bed is presented in Figure 2: a typical sectional detail of the overflow piping is presented in Figure 3; and a typical detail of the monitoring ports is presented in Figure 4.

Figure 2: Porous Concrete Pavement System Cross Section

Figure 3: System Overflow Piping Section
Technical Design Considerations

Several technical considerations needed to be accounted for in the design of the porous concrete pavement/stone detention bed system to ensure system performance and address regulatory agency requirements and concerns. These included selection of the design storm, pavement permeability capacity and rainfall intensity, infiltration capacities of site subsoils, stone detention bed capacity, storm water discharge rate and storm water discharge quality.

**Design Storm Selection.** As with the design of any storm water system, a reoccurrence interval for the design storm event must be selected for which to base the design of the system. The selection of a design storm with a low reoccurrence interval (e.g. 2-year storm event) results in lower capital costs for the system because the capacity and size of the system will be smaller as compared to a design based on a high storm reoccurrence interval (e.g. 100-year storm event) where the capacity and size of the system will be greater. However, a system design based on storm event with a low reoccurrence interval will carry greater risks that the system will be overburdened as compared to a system design based on a storm event with a high reoccurrence interval. The balance between costs versus risks must be considered by the designer. For design of the porous concrete/stone detention bed system at the Rawson Commons development, a 100-year, 24-hour storm event was used as the basis of design. The selection of this storm event as the basis of design was largely regulatory driven as both the City of Franklin and the MMSD storm water management regulations require management of the 100-year storm event.
Pavement Permeability/Rainfall Intensity. Based on Southeastern Regional Planning Commission (SEWRPC) rainfall data for the area, the peak rainfall intensity for a 100-year storm event with a 5-minute duration is 8.9 inches per hour. The permeability rate of the Ecocreto™ enhanced porous concrete pavement system is 4 inches per minute – over 26 times the 100-year, 5-minute rainfall intensity. This ensures that any rain falling on the pavement will immediately infiltrate through the porous pavement and into the stone detention bed without any runoff.

With its high permeability, water immediately infiltrates through the Ecocreto™ porous concrete pavement without runoff.

Infiltration Capacities Site Subsoils. Infiltration capacities of site subsoils is one of the major site specific variables that should be evaluated as part of the design process. The infiltration capacities of site subsoils can impact design of the system elements including the depth/volume of the stone detention bed, use of collection piping placed on the bottom of the stone detention bed and use of overflow piping placed on the top of the stone detention bed. Based on soil borings advanced at the site, subsoils are predominantly silt loams, with isolated layers of sandy clays and loamy sands. In-situ infiltration testing was performed on the subsoils at the site to determine infiltration capacities of the soils. The in-situ infiltration rates measured ranged from 0.18 inches/hour to 0.80 inches per hour. Based on these rates, it would take from 9 to 39 hours to infiltrate the entire volume of the 100-year, 24-hour storm event into the site subsoils. This raised concerns over flooding of the system and potential surface ponding in the case of successive major storm events occurring before the storm water could fully infiltrate into the subsoils. The use of collection piping placed at the bottom of the stone detention bed was considered to address this concern; however, it was desired by the developer to design the system to operate as a zero discharge system under normal conditions. Therefore, perforated PVC overflow piping was provided at the top of the stone detention bed to provide relief and prevent surface ponding in the case there were successive major storm events occurring before the storm water could fully infiltrate into the subsoils.
Stone Detention Bed Capacity. The depth of the stone detention bed was designed to store the entire volume of the 100-year, 24-hour storm event over the entire site without regard to infiltration into site subsoils. The volume of the 100-year, 24-hour storm event over the site was calculated to be approximately 18,730 cubic feet. The volume of the stone detention bed provided was approximately 48,250 cubic feet. With a void ratio of 0.40, this translates into a storage volume of approximately 19,300 cubic feet which is approximately 3% greater than the volume of the 100-year, 24-hour storm event over the site. By factoring in the infiltration rates of the site subsoils, the depth/volume of the stone detention could have been reduced. However, it was decided to provide a more conservative design approach by not factoring in infiltration rates into the subsoils.

Allowable Storm Water Discharge Rate. As previously summarized, the allowable peak storm water discharge rate for the site is 0.50 cfs/acre for the 100-year storm event and 0.15 cfs/acre for the 2-year storm event in accordance with MMSD and City of Franklin storm water management regulations. This translates into allowable peak discharge rates of 0.80 cfs and 0.24 cfs for the 100-year and the 2-year storm events, respectively. In order to meet these requirements, the porous pavement/stone detention bed system was designed to allow storm water to infiltrate into the site subsoils with zero discharge under normal conditions (overflow discharge would only occur in the case of successive major storm events that would use the entire storage volume of the stone detention bed before the storm water could infiltrate in the subsoils).

Storm Water Discharge Quality. In accordance with applicable WDNR and City of Franklin storm water management regulations and requirements, storm water discharge must be treated to provide 40% TSS removal on an average annual basis as compared to providing no runoff management controls. Because the porous concrete pavement/stone detention bed system was designed to operate as zero discharge system under normal conditions, this requirement was satisfied.

Cost Considerations

Life cycle costs for the Ecocreto™ porous concrete pavement/stone detention bed system utilized for this development were compared to estimated life cycle costs for a conventional asphalt pavement/surface detention basin system. The cost comparison is presented in Table 1 and includes present value costs based on a 20-year life cycle. As shown, the porous concrete pavement/stone detention bed system represents a slightly lower life cycle investment than a conventional asphalt pavement/surface detention system for this development. Although the capital costs for the porous concrete pavement/stone detention bed are considerably higher than the capital costs for a conventional asphalt/crushed aggregate base course pavement system, the porous concrete pavement system had slightly lower initial costs overall when additional land and infrastructure needs for the conventional asphalt pavement/surface detention basin system are factored in. It was estimated that an additional 0.35 acres of land would have been required for this project to provide for surface detention. The additional land costs along with costs for additional infrastructure construction (e.g. catch basins, storm sewer pipe, detention basin construction) made the overall initial capital costs for the conventional asphalt pavement/surface detention basin system slightly higher. Annual maintenance and monitoring costs for the two systems are very close. However, the Ecocreto™ porous concrete pavement has a life of 20-
Table 1: Cost Comparison
Ecocreto™ Porous Pavement/Stone Detention Bed System vs. Conventional Storm Water Collection/Surface Detention System

<table>
<thead>
<tr>
<th>Capital Costs</th>
<th>Ecocreto Porous Concrete/Stone Detention Bed System</th>
<th>Conventional Storm Water Collection/Surface Detention System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land Cost (1.6 acres)</td>
<td>$550,000</td>
<td>$550,000</td>
</tr>
<tr>
<td>Land Cost - Detention Basin (0.35 acres)</td>
<td>$0</td>
<td>$120,300</td>
</tr>
<tr>
<td>Building Costs</td>
<td>$1,343,000</td>
<td>$1,343,000</td>
</tr>
<tr>
<td>Asphalt Pavement/Base Course</td>
<td>$0</td>
<td>$43,000</td>
</tr>
<tr>
<td>Ecocreto Pavement/Stone Detention Bed</td>
<td>$192,400</td>
<td>$0</td>
</tr>
<tr>
<td>Catch Basins (5)</td>
<td>$0</td>
<td>$17,500</td>
</tr>
<tr>
<td>Storm Manhole</td>
<td>$4,500</td>
<td>$4,500</td>
</tr>
<tr>
<td>Storm Piping</td>
<td>$5,530</td>
<td>$11,800</td>
</tr>
<tr>
<td>Detention Basin Construction</td>
<td>$0</td>
<td>$12,000</td>
</tr>
<tr>
<td>Outlet Control Manhole</td>
<td>$0</td>
<td>$5,000</td>
</tr>
<tr>
<td><strong>Total First Costs</strong></td>
<td><strong>$2,095,730</strong></td>
<td><strong>$2,107,100</strong></td>
</tr>
</tbody>
</table>

Annual Maintenance Costs

| Annual Inspections                                 | $500                                                | $500                                                       |
| Annual Cleanout of Catch Basins                   | $0                                                  | $500                                                       |
| Parking Lot Sweeping (Twice per year)             | $0                                                  | $400                                                      |
| Parking Lot Vacuuming (Twice per year)            | $600                                                | 0                                                         |
| Annual Parking Lot Power Washing                  | $400                                                | 0                                                         |
| **subtotal**                                      | **$1,500**                                          | **$1,400**                                                |

Other Annual Costs

Incremental Property Taxes (with Pond)              | $0                                                  | $8,836                                                    |

**Total Annual Costs**                               | **$1,500**                                          | **$10,236**                                               |

**Present Value Annual Costs**                       | **$14,730**                                         | **$100,518**                                              |
(20 years, 8%)                                      |                                                     |                                                           |

Replacement/Repair Costs                             | 0                                                   | $20,900 years 10 and 20                                   |

**Present Value Replacement/Repair Costs**           | **$0**                                              | **$14,166**                                               |
(20 years, 8%)                                      |                                                     |                                                           |

**Total Present Value All Costs**                    | **$2,110,460**                                      | **$2,221,784**                                            |

1) Porous pavement represents a similar life-cycle investment, if not slightly lower cost, than a conventional storm water management system.
2) Porous pavement selection results in a slightly lower initial cost than conventional storm water management system when additional land and infrastructure needs for conventional system are factored in.
3) Porous pavement selection results in property tax savings given land requirements are lower than conventional storm water management system.

2007 Assessed Value: $1,789,700
2007 Real Estate Tax Rate: $22.57 per $1,000 of assessed value
years while typical asphalt pavement systems require replacement or significant patching approximately every 10 years increasing its long term life cycle costs. Finally, the porous concrete pavement/stone detention bed system results in property tax savings given the additional land requirements that would have been needed for a conventional surface detention basin. For this particular development, costs associated with the porous concrete pavement/stone detention bed system were slightly lower than a conventional asphalt pavement/surface detention basin system. However, this may not be the case for every development and should be evaluated on a case by case basis.

**Porous Concrete Pavement System/Stone Detention Bed Construction**

Construction of the system was initiated in April 2006 by excavating down to proposed subgrades. The subgrade was graded flat and great care was taken to limit compaction of the subgrade to maintain the infiltration capacity of the subsoils. A geotextile fabric was placed over the subgrade, and the excavation was backfilled with a minimum of 18 inches of 2 to 2.5 inch diameter clean, washed stone. A 6 inch layer of 1 to 1.5 inch clean, washed stone was placed over this to serve as a base for pavement placement.

A 4 inch layer of the Ecocreto™ porous concrete pavement was then poured over the stone bed. The pavement was poured in maximum 24 foot wide sections. After pouring of each section of pavement, the concrete pavement was then raked and strucked off using a Bunyan roller screed to provide proper compaction.

*Ecocreto™ porous concrete pavement being poured.*
Curing procedures proceeded within 20 minutes of the pavement placement. The pavement surface was misted with a water solution of the Ecocreto™ admixture. The pavement surface was then covered with a 6-mil thick polyethylene sheet. The polyethylene sheet was allowed to stay in place for a minimum of 72 hours.
Following removal of the polyethylene sheeting, transverse control (contraction) joints were then sawcut into the pavement at 15 to 20 foot intervals. The joints were cut into the pavement to a depth of approximately one inch. Longitudinal control joints were sawcut into the pavement at the midpoint of constructed sections wherever the width of the sections exceeded 20 feet. Construction joints were installed wherever new pavement sections were installed adjacent to already hardened and cured pavement sections. In order to ensure aggregate bond at construction joints, a binding agent suitable for bonding fresh concrete to existing concrete was brushed, rolled or sprayed on the existing pavement surface edge.
System Performance Monitoring

In order to monitor the performance of the system, a monitoring program was initiated after completion of site construction activities in May 2006. The monitoring program was performed for a period of slightly greater than one year and was terminated in June 2007. Monitoring of the system was performed after and/or during every rainfall event of ½ inch or greater. The monitoring included the manual measurement of water levels within the five site monitoring points to monitor ponding within the stone detention bed. The monitoring was performed by utilizing an electronic water level indicator. The discharge manhole for the overflow piping system was also visually monitored for each event to monitor and measure system discharge.

System Monitoring Results/Performance. System monitoring results are presented in Table 2. A total of 22 monitoring events occurred from May 11, 2006 to June 19, 2007. Rainfall depths for the monitoring events, based on reported rainfall depths at Mitchell International Airfield in Milwaukee, Wisconsin, ranged from 0.50 inches to 2.76 inches. With the exception of the May 11, 2006 rainfall event, no measurable ponding was reported in the southeastern and the southwestern monitoring ports for any of the rainfall events. Ponding depths of 0.02 feet (0.24 inches) and 0.03 feet (0.36 inches) were reported for the May 11, 2006 rainfall event at the southeastern and the southwestern monitoring reports, respectively. No measurable ponding depth was observed in the center monitoring port for any of the rainfall events. Ponding depths in the northwestern port ranged from a low of zero reported for six of the twenty two monitoring events to a high of 0.13 feet (1.56 inches) for the May 11, 2006 monitoring event. Ponding depths in the northeastern monitoring port ranged from a low of zero reported for six of the twenty two monitoring events to a high of 0.23 feet (2.76 inches) for the November 30, 2006 monitoring event.

There seems to be little correlation between the reported rainfall depths and the ponding depths measured in the monitoring ports making it difficult to observe any trends in the data. However, the following observations and inferences regarding the data can be made.

- The greatest ponding depths were consistently reported in the northeastern and the northwestern monitoring ports. It is speculated that this is due to the fact that the roof downspouts for the two buildings are directed to these areas and that these areas receive additional runoff from adjacent green space areas on the perimeter of the site that are sloped down to the pavement grades.
- The generally low ponding depths indicate that the precipitation infiltrating through the porous pavement and into the stone detention bed is not accumulating and creating a “bathtub” effect. This indicates that the precipitation is effectively infiltrating into the subsoils.
- The ponding depths are generally lower than the reported rainfall depths. This also indicates that the precipitation infiltrating through the porous pavement and into the stone detention bed is effectively infiltrating into the subsoils without allowing the precipitation to accumulate in the stone detention bed.
## Table 2: Rawson Commons
**Ecocreto™ Porous Pavement/Stone Detention Bed Monitoring Results**

<table>
<thead>
<tr>
<th>Rainfall Date</th>
<th>Rainfall Depth* (inches)</th>
<th>SE Port</th>
<th>SW Port</th>
<th>Center Port</th>
<th>NW Port</th>
<th>NE Port</th>
<th>Overflow M.H. Observations</th>
</tr>
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<tbody>
<tr>
<td>05/11/06</td>
<td>1.0”</td>
<td>0.02’ (0.24”)</td>
<td>0.03’ (0.36”)</td>
<td>0</td>
<td>0.13’ (1.56”)</td>
<td>0.08’ (0.96”)</td>
<td>No flow</td>
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<tr>
<td>05/12/06</td>
<td>0.75”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.08’ (0.96”)</td>
<td>0.02’ (0.24”)</td>
<td>No flow</td>
</tr>
<tr>
<td>05/25/06</td>
<td>1.0”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.02’ (0.24”)</td>
<td>No flow</td>
</tr>
<tr>
<td>05/31/06</td>
<td>1.1”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.05’ (0.60”)</td>
<td>No flow</td>
</tr>
<tr>
<td>06/19/06</td>
<td>1.39”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.04’ (0.48”)</td>
<td>No flow</td>
</tr>
<tr>
<td>07/09/06</td>
<td>2.76”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.06’ (0.72”)</td>
<td>No flow</td>
</tr>
<tr>
<td>07/20/06</td>
<td>1.04”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.01’ (0.12”)</td>
<td>0.05’ (0.60”)</td>
<td>No flow</td>
</tr>
<tr>
<td>08/24/06</td>
<td>0.53”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.03’ (0.36”)</td>
<td>0.04’ (0.48”)</td>
<td>No flow</td>
</tr>
<tr>
<td>09/12/06</td>
<td>0.56”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.03’ (0.36”)</td>
<td>0</td>
<td>No flow</td>
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<tr>
<td>11/10/06</td>
<td>0.72”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.05’ (0.60”)</td>
<td>0.02’ (0.24”)</td>
<td>No flow</td>
</tr>
<tr>
<td>11/29/06</td>
<td>0.72”</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.08’ (0.96”)</td>
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<td>0.21’ (2.52”)</td>
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<tr>
<td>03/22/07</td>
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<td>0</td>
<td>0</td>
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<td>0</td>
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</tr>
<tr>
<td>04/03/07</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0.06’ (0.72”)</td>
<td>0.12’ (1.44”)</td>
<td>No flow</td>
</tr>
<tr>
<td>04/25/07</td>
<td>0.51”</td>
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<td>0</td>
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<td>06/06/07</td>
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*Based on reported rainfall depths at Mitchell International Field, Milwaukee, Wisconsin
Monitoring of the discharge manhole for the overflow piping indicated that there was no discharge from the overflow piping for any of the rainfall events. This indicates that all the precipitation infiltrating through the porous concrete pavement into the stone detention bed is efficiently infiltrating into the subsoils. Based on the rainfall depths for the events monitored, it is estimated that the system provided approximately 124,175 cubic feet or 928,800 gallons of groundwater recharge over the duration of the monitoring period.

CONCLUSION

Today’s regulatory climate pertaining to storm water management presents many challenges to developers and site designers. Storm water management regulations can have significant impacts on development projects in terms of space, grades and costs: especially for smaller, infill developments. Conventional storm water management techniques such as surface detention basins are often not feasible given these impacts, and innovative, non-conventional storm water practices are sometimes required to improve the feasibility of a development. One such storm water management practice is the use of porous concrete pavement with an underlying stone detention bed.

The use of porous concrete pavement can provide a durable, cost effective pavement system for development projects while providing an effective means of managing storm water. Porous concrete pavement systems can increase the cost effectiveness of a development project by eliminating the need for additional land that would be needed for conventional storm water management measures, such as surface detention basins, and by increasing the area of buildable land on a given project site. The use of porous concrete pavement systems can also provide the added environmental benefits of reducing the potential for downstream sewer surcharging and flooding, reducing downstream pollutant loading and providing for increased groundwater recharge.

While not necessarily feasible or cost effective for all development sites, porous concrete pavement systems provide developers and site designers another tool to address storm water management requirements imposed by the various storm water management regulations promulgated at the state, county and local levels.

ACKNOWLEDGEMENTS

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REFERENCES

Wisconsin Department of Natural Resources; Chapter NR 151 – Runoff Management; September 2002
Milwaukee Metropolitan Sewerage District; Chapter 13 – Surface Water and Storm Water; January 1, 2002

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