Abstract

The City of Olympia has built a demonstration low impact development (LID) roadway that uses traditional pavement materials and infiltrates runoff under the roadway. Our transportation needs prompt extensive amounts of pavement with inadequate right-of-way area for onsite stormwater management. Current roadway designs conflict with the LID goal of dispersing and managing stormwater near its source. The Decatur Street LID Roadway Project is an innovative design that meets LID goals and manages its stormwater within the existing right-of-way.

Under-pavement infiltration is advantageous because traditional water quality treatment and pavement construction materials can be used. This accommodates traditional maintenance and life cycle cost expectations for the above-ground roadway features. Utilizing the entire roadway area for infiltration provides designs suitable for poorly drained soils and for use with various roadway widths.

This paper presents the design and construction aspects of the Decatur Street LID Roadway Project. The paper describes the three different stormwater management techniques utilized in the project. Roadway structural design is presented, including the use of geogrids for structural stability of the roadway over a subgrade of uncompacted soil. The bid prices, cost comparisons to traditional construction, and lessons learned are provided.

Introduction

The City of Olympia, Washington is actively pursuing the use of permeable pavements as a stormwater management tool. For example, the City routinely builds sidewalks out of pervious concrete and has allowed the use of porous asphalt in parking lots. Additionally, the City has built a major roadway reconstruction project with a traditional asphalt roadway draining to a pervious concrete bicycle lane. To date, we have not built porous asphalt roadways.
While porous or pervious asphalt appears to be a good LID roadway strategy, there are concerns about the durability of the porous asphalt, especially in hot weather and under heavy loads. Porous asphalt is harder to maintain than traditional roadways and stormwater facilities and cannot be chip sealed to extend the pavement life.

The stormwater functions of a porous asphalt roadway rely on the surface pores remaining free-draining. Olympia’s experience with large void pavement materials is that they clog easily with leaf litter and sediment and are difficult to clean. Currently the City does not own a high-powered vacuum street sweeper which could clean the pores of porous asphalt. There is a real concern that a porous asphalt roadway would clog before the end of its structural life and hence would cease to function for stormwater mitigation. While not overwhelming, these concerns are appreciable.

In response, the Decatur Street project is a side-by-side trial of a porous asphalt roadway and two traditional roadway sections that incorporate underground infiltrations systems. These infiltration systems may provide all the benefits of permeable pavements but with traditional pavement durability and maintenance. Short- and long-term performance of the three are being tracked and compared.

The goal of the project is for each of the street designs to meet the water quality treatment and flow control requirements of Washington State Department of Ecology’s 2005 Stormwater Manual for Western Washington within the existing roadway right-of-way. The Decatur Street project is funded in part by the Washington State Department of Ecology 2007 Low Impact Development – Stormwater Management Grant Program.

**Decatur Street - Three Stormwater Management Roadway Designs**

The three low impact development (LID) roadway designs for Decatur Street all utilize under-pavement infiltration. By using the roadway footprint to infiltrate the rainfall, the LID goal of managing and infiltrating rainfall as close to the source as possible is fulfilled. Each roadway section utilizes a different water quality treatment technique of catch basin filters, porous asphalt cleaning, and a rain garden. Each section of the roadway uses the same under-pavement infiltration system to meet flow control requirements.

Soils under the roadway are challenging. The under-pavement infiltration system is designed with an infiltration rate of 0.15 inches per hour. This design infiltration rate was determined from the soils at the site and the depth to the seasonally high groundwater elevation. Olympia typically has poorly infiltrating soils. If the Decatur Street under-pavement infiltration system proves to be effective in Olympia’s soils, it could be easily replicated in areas of better infiltrating soils. LID designs are easier to achieve in soils that infiltrate well.
The three roadway sections are reflected below in Figure 1.

A) Regular asphalt pavement overlying an under-pavement infiltration system with catch basin stormwater filtration units.

B) Porous asphalt pavement overlying an under-pavement infiltration system.

C) Regular asphalt pavement overlying an under-pavement infiltration system with a planter strip rain garden for stormwater treatment.

Each roadway section is about 200 feet long with the entire project encompassing a two block section of Decatur Street.

The adjacency of the roadway sections provides a good comparison between designs through the monitoring portion of the project. Details for each of the three roadway designs are presented in Figures 3, 4, and 5 on the following figures.
Figure 2. Section A - Asphalt with Catch Basin Filter

A graded road surface directs stormwater runoff to a catch basin filter. The filtered water is then piped to a perforated pipe running the length of the road surface. Water is released into the rock aggregate and percolates into the ground.

Catch Basins with Filtration
Two catch basins are fitted with cartridge filters to clean the runoff.

System A Layers
Asphalt
Aggregate Base Course
Geogrid
12" Drain Rock
Subgrade

Geogrid
The grid structure grips and stabilizes the rock in the aggregate base, effectively distributing weight from the road surface and vehicles, while using less rock aggregate base.

Perforated Pipe
The perforated pipe has small holes in the pipe that allow the water to trickle into the surrounding aggregate and down into the subsoil.

Figure 3. Section B - Porous Asphalt

A porous asphalt surface covers the entire road surface, allowing the stormwater to pass directly through the surface into the drain rock below the road. The stormwater is cleaned as it filters through the pore space in the asphalt. The asphalt needs periodic cleaning to remove these particles and pollutants.

Porous Asphalt
Specially engineered asphalt creates a porous surface which allows water to quickly pass directly through the road surface, while providing the strength and hardness required for heavy vehicles.

System B Layers
Porous Asphalt
2" Leveling Course
12" Drain Rock
Geogrid
Subgrade
Figure 4. Section C - Asphalt with Rain Garden Treatment

Roadway Drainage Design

All roadway sections have a design infiltration rate of 0.15 inch per hour. The native soils have a high percent of fine aggregate with some portions overlaying weakly cemented till. The depth to the shallow groundwater is minimal.

The drainage layer in permeable pavements needs to be designed for both short-duration and long-duration storm events. The Washington Department of Ecology Stormwater Manual requires flow control up to the 50-year event. For this project, long-duration event sizing was performed with the Western Washington Hydrologic Model (WWHM). The model uses 34 years of rainfall data with 1-hour time steps.

The long-duration WWHM drainage analysis generated the need for a drainage rock thickness of 12 inches. The short-duration analysis was performed using intensity duration frequency curves for Olympia. This analysis yielded a necessary drainage layer thickness of 7 inches. In general, soils with high infiltration rates are dictated by the storage needs of short-duration events, while lower infiltration rates are dictated by storage needs of long-duration events.
The water quality design flow rate needs to capture 91% of the average annual runoff. For the 200 feet of pavement for each section, a rate of 13.6 gallons per minute (gpm) is needed. Each stormwater filter used in the traditional pavement design can accommodate 7.5 gpm. Conversely, the porous asphalt roadway section is not sized for a treatment flow rate. Typically, porous asphalts are 15 to 20% void which results in sufficient infiltration capacity.

Little technical design guidance is available for rain gardens in this application. The rain garden area passes the runoff through at least 18 inches of soil/compost media. Standing water should drain within 24 hours of the conclusion of a storm event. The project’s design discharges water onto the surface of a swale. Compost/soil media is provided below the swale. The media is in a gravel envelope with perforated pipe used to capture the treated water. An overflow is located at the downstream end of the swale that directs excessive flows directly into the under-pavement infiltration system.

**Roadway Structural Design**

Decatur Street is classified as a major collector roadway with an expected average daily traffic (ADT) of between 3,000 to 14,000 vehicles. The equivalent single axial load (ESAL’s) for the expected life of the pavement is 2.4 million (Craig--units?).

The experimental pavement design is based on a 12 inch thick drainage layer topped with 6 inches of aggregate base coarse. Asphalt thickness is 4 inches. The roadway subgrade is assumed to be completely saturated and of very little support. In order for the section to meet design requirements, a geogrid was installed to help support the subgrade. Contech Earth Stabilization Solutions determined that the geogrid and roadway would continue to be stable with a subgrade support value as low as 1.2. Without the geogrid, the life of the pavement would be reduced to 500,000 ESAL’s, a reduction of 80%.

The geogrid compensates for the saturation of the subgrade material by the runoff stored in the drainage layer of the roadway section. Traditional pavement designs strive to keep moisture out of the subgrade, thereby maintaining the strength of the native material. Under-pavement infiltration systems weaken the subgrade necessitating the use of additional structural reinforcement.

The drainage layer contains a high percentage of voids (30 to 40% by volume). The native soils also contain a significant amount of voids and fine materials. There is the potential for the fines in the subgrade to migrate into the drainage layer. A geotextile allows water to move between the drainage layer and subgrade while preventing the fines from migrating back into the drainage layer. Additionally, the geogrid must be in contact with the drainage layer in order to resist loading forces. Given these constraints, the sequence of the pavement section is uncompacted native subgrade, a geotextile for separation, the geogrid, and the drainage layer.

**Cost Comparison to Traditional Roadway Projects**

It is difficult to compare costs between two entirely different approaches to stormwater management. Traditional stormwater facilities require land, the cost of which is highly variable
depending on zoning, availability and willingness of sellers. For the following analysis a variety of land acquisitions costs are assumed.

The contractor bid prices for the Decatur Street project ranged from $383,000 to $632,000 with an average bid of $506,000. The original City Engineer’s estimate for the project was $409,000. These bids encompass only the roadway portion of the work, curb to curb including the rain garden and the under-pavement infiltration system. Sidewalks are not included. The project is approximately 600 feet long.

The cost per foot of roadway is:

- Original estimate = $680/ft
- Low bidder = $640/ft
- Average bid = $843/ft

The following costs were estimated for the same roadway project built with traditional pavement and stormwater management. Land purchase and stormwater pond construction would be needed.

**Table 1: Estimated Cost of an Equivalent Traditional Roadway Construction.**

<table>
<thead>
<tr>
<th>Roadway cost, $/foot</th>
<th>Estimated construction cost, $</th>
<th>Cost of land, $/Acre</th>
<th>Cost of land, $/square foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>571</td>
<td>343,000</td>
<td>200,000</td>
<td>4.60</td>
</tr>
<tr>
<td>680</td>
<td>409,000</td>
<td>461,000</td>
<td>10.60</td>
</tr>
<tr>
<td>825</td>
<td>495,000</td>
<td>800,000</td>
<td>18.36</td>
</tr>
</tbody>
</table>

All costs given do not include engineering and contingencies. Total project costs are significantly higher due to these factors.

As can be seen, there is a great deal of potential variation in project costs depending on the bidding environment and the cost of land. The cost of land varies significantly with the zoning and the cost to develop the parcel to its highest and best use. Unfortunately, roadway reconstruction projects in Olympia are commonly major thoroughfares within fully developed areas. These roadways have high density or commercial zoning adjacent to them. Land is often not available for stormwater ponds and what is available is expensive. A recent appraisal of a potential stormwater pond property on a commercial corridor estimated the value of the land at between $10 to $15 per square foot.

We find that if land is relatively inexpensive, traditional roadway and stormwater designs are less costly. However, if land is expensive, permeable pavement projects are less costly.

The above cost comparisons are for the initial construction of the roadway and stormwater management system. In order to perform a thorough cost evaluation between different roadway designs, a complete life cycle cost analysis should be completed. However, since the life expectancy of porous asphalt and the under-pavement infiltration systems is currently unknown, life cycle cost analysis falls apart.
It is evident that under-pavement infiltration systems utilizing treatment filters and porous pavement will have higher ongoing maintenance costs than a traditional pavement and stormwater pond design. Additionally, stormwater ponds do not depreciate to zero. While an under-pavement infiltration will slowly lose its effectiveness and eventually have to be totally rebuilt, a stormwater pond can be effectively rehabilitated with the relatively simple removal of sediment. The stormwater pond never loses its ability to store runoff and thus always has value.

**Lessons Learned**

Evaluation and monitoring of the Decatur Street LID roadway design will begin in fall 2008. At this time the project is complete. While we feel that the project will adequately test the alternative stormwater management techniques, we do not feel that the design is highly efficient.

The design requires moving water underground against the natural slope of the roadway. This requires that a deeper than needed drainage layer be installed. An improved design would infiltrate the runoff from one section of roadway under the pavement of the immediately down gradient section of roadway. In this way, water would only need to be moved down gradient. In long roadways, the initial section of roadway would not have an under-pavement infiltration system. The last section would need either a traditional pond or some other form of stormwater management. This more efficient layout will be considered in future projects.

Under-pavement infiltration systems require deeper excavation and under-pavement sections than do traditional roadway designs. The extra depth of the roadway system can conflict with utilities under the pavement. The Decatur Street project required relocation of a water main. If the under-pavement infiltration systems are adopted as a standard, the depth of utilities should be increased. Another concern with the under-pavement infiltration system is the potential need to repair existing utilities under the drainage layer. Repairs could be completed through the geogrid and geotextile, but only with additional excavation, care, and cost.

A three-year monitoring plan will be implemented to measure the performance of the Decatur Street LID demonstration project. Monitoring for stormwater pollutants (total suspended solids, dissolved metals, and nutrients) will be conducted from sampling ports integrated into the street section design. The monitoring will evaluate samples before and after each treatment method in order to determine the effectiveness of the various systems. Water level monitoring will be performed in the drainage layer to determine the site infiltration rate. In turn, the infiltration rate will be used to determine if the design is meeting the flow control requirements for the stormwater manual and its LID design.

More information and the results of the performance monitoring of the Decatur Street project will be posted on the City of Olympia web site as they become available: [http://www.olympiawa.gov/cityutilities/stormwater/scienceandinnovations/porouspavement.htm](http://www.olympiawa.gov/cityutilities/stormwater/scienceandinnovations/porouspavement.htm)