Allston Way PICP Case Study – Berkeley, California

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Abstract:

The City of Berkeley, California recently completed the rehabilitation of a section of Allston Way in the downtown core. The City was interested in evaluating the effectiveness of permeable pavements for stormwater management. A suitability matrix including 10 evaluation criteria was used to assess the suitability installing PICP for 9 candidate projects. Allston Way was selected with the highest ranking of the candidates. The existing pavement, which had reached the end of its service life, was excavated to the subgrade level and a permeable subbase and base followed by permeable interlocking concrete pavers was installed. This paper provides and outline of the PICP candidate selection process and suitablity matrix, pavement design including use of geocell confinement and unique treatment to improve tree growth adjacent to the roadway, life-cycle cost comparison with conventional alterative pavements, effectiveness of stormwater management and lessons learned from the construction of the roadway.

Key Words: PICP; suitability; life-cycle; geocell; lessons learned; effectiveness

1. Introduction

The City of Berkeley, California recently completed the rehabilitation of a section of Allston Way in the downtown core. In keeping with the progressive image of the City and to assist in reducing stormwater runoff and improving stormwater runoff quality, the rehabilitation including the installation of permeable interlocking concrete pavement (PICP).

While the use of permeable pavements may have significant benefits in terms of stormwater management, their application is not be suitable for all situations. In order to be successful, consideration must be given to site specific conditions, design, construction and maintenance details. The following stepwise process is recommended for evaluating the suitability and opportunity for permeable pavement and identifying key factors that may influence design and effectiveness.

Step 1 - Evaluate acceptability. The first step in determining the suitability of a project for permeable pavement is to determine if they are permitted by national and local regulations for the project location.

Step 2 - Evaluate opportunities and drivers. The next step is to evaluate whether the project provides the opportunity for any of the following general considerations:

- Incentives (financial, environmental benefits, sustainability achievement, etc.);
- Desire or regulatory requirements to reduce the volume of stormwater runoff, reduce peak runoff flowrates, improve the quality of stormwater runoff, and/or and address other related run-off issues such as effluent temperature; and
- Potential for reduction in future stormwater management costs by modifying pavement design for stormwater management.

Step 3 - Evaluate benefits, risks, and technical design factors. If the analysis in Step 1 and 2 indicates that the use of a permeable pavement may be suitable for a particular project, additional specific considerations should be analyzed to evaluate the anticipated benefits and risks associated with its use.

2. Suitablity Design Matrix

To determine the suitability of a project for a permeable pavement, the key factors specific to the project should be considered. Based on their importance in overall decision making, these factors can be divided into primary, secondary, and other considerations which may impact the decision to use a permeable pavement for a particular project. Primary considerations (i.e., fatal flaws or major design challenges) are those that would have an overriding influence on the decision to move forward with the project. Secondary considerations are those that have a lesser influence and usually are taken into account as part of the design process when there are no overriding considerations. These factors may diminish the performance or acceptability of permeable pavements or may require additional design provisions (and associated costs) to avoid risks. Other considerations may have some influence on the decision to include permeable pavements for a particular project. The primary considerations should generally be weighted the highest to reflect their importance in moving forward with the project, while secondary and other considerations are useful to prioritize between sites and informed design, but are not generally fatal flaws.

A. Primary Considerations

- Significant longitudinal grades (>5 percent)
- Geotechnical risks
- Groundwater contamination risk
- Presence of utilities
- Slow/turning movement of heavy loads

B. Secondary Considerations

- Stringent receiving water quality standards
- Low soil infiltration rates
- Target design volumes and runoff rates
- Complexity of geometric conditions (super elevation, number of lanes, etc.)
- Risk of flooding
- Mandates for stormwater quality control
- Mandates for drainage and peak flow control
- Maintenance protocols
- Presence of recreational paths
- Potential for sediment loading

C. Other Considerations

- Depth of water table
- Impact of unknown site conditions
- Risk of accidental chemical spill

This list of considerations was developed for the City of Berkeley. This is not an exhaustive list, but rather reflects typical needs and expectations. Other constraints and project-specific considerations should be added or deleted as necessary. Permeable Pavement Feasibility Decision Matrix

To assist in evaluating the suitability of projects for the use of permeable pavements, a project suitability matrix (template) was developed. The matrix includes the considerations outlined above with appropriate weighting factors for each group. Within each group, the individual consideration items also are given weighting factors. Each factor should be assessed using specific criteria of the owner's needs and expectations for the project. Once the factor is rated, the total scores are summed on a scale of 0 to 100. If the score totals less than 65, the project is not considered a good candidate for permeable pavements. Between 65 and 75, the project can be considered for permeable pavements. Scores over 75 indicate that the project is well suited for permeable pavements.

Initially, 8 potential candidates were screened for their suitability of the permeable pavement demonstration project. The screening matrix was applied and the results of the analysis indicated rating values ranging from 47 to 73 with none of the sections deemed as strong candidates. On review of potential other candidates, a section of Allston Way in the downtown area was selected with an overall rating of 81.

3. Pavement Design

3.1 Site Characterization

The pavement area that was surfaced with permeable pavers was approximately 2,707 m^2. In addition to the permeable pavement, there were three areas that sloped towards the pavement and were contributing run-on of water to the permeable pavement. These included:

Contributing Area	Surface Texture	Surface Area (m^2)
Park area to the north	Grass	2,705
Park area to the north	Hard surfaced walkways	904
Sidewal to the south	Concrete walkway	625

3.2 Traffic

A limited traffic study was completed to support the structural design for the permeable pavement. Traffic counts were completed for three 24 hours periods. In addition to total traffic volume, the traffic data was classified into AASHTO Classes 4 through 13. The annual average daily traffic (two directions) for the three days was 4,836 out of which approximately 3.9 percent were heavy vehicles, i.e. AASHTO Classes 3 through 13. The traffic distribution was then multiplied by the typical vehicle ESAL factor to determine the number of ESALs per year and by the number of years in the design period to determine the total design ESALs for the roadway.

3.3 Structural Design

The following additonal parameters were selected for the pavement structural design:

Subgrade Type	=	Lean Clay with Sand
Subgrade Permeabilty	=	1.65 cm/hr
Subgrade R-Value	=	5
Permeable Paver Surface Infiltration Rate	=	15 cm/hr
Initial Serviceability	=	4.2
Terminal Serviceability	=	2.8
Reliability	=	80 percent
Standard Error	=	0.44
Paver + Bedding Layer Coefficient	=	0.3
ASTM No. 57 Base Layer Coefficient	=	0.09
ASTM No. 2 Subbase Layer Coefficient	=	0.06
20 Year Service Life Design ESALs	=	370,673
30 Year Service Life Design ESALs	=	556,010

Based on the parameters above, the structural design for the permeable pavement was:

<u>20 Year Service Life Structural Design</u>

8 cm	Permeable Paving Stones
5 cm	ASTM No. 8 or ASTM No. 9 Bedding Stone
10 cm	ASTM No. 57 Base
70 cm	ASTM No. 2 Subbase

30 Year Service Life Structural Design

8 cm	Permeable Paving Stones
5 cm	ASTM No. 8 or ASTM No. 9 Bedding Stone
10 cm	ASTM No. 57 Base
80 cm	ASTM No. 2 Subbase

3.4 Water Volumes

The pavement areas outlined in the Site Characterization section above were used to calculate the stormwater volumes for the permeable pavement system. Table 1 provides the expected water volumes for storm return periods ranging from 2 to 100 years.

Table 1. Expected water volumes for various storm return periods.

Return Period	Rainfall (cm)	Volume (m^3)	Contributing Area Run-on (m^3)	Total Water Volume (m^3)
2	5.8	158.2	132.3	290.4
5	7.4	196.7	180.9	377.6
10	8.4	223.5	216.2	439.7
25	9.7	262.7	269.4	532.1
50	10.9	293.0	311.5	604.5
100	11.9	323.2	354.3	677.5

3.5 Subsurface Drainage Details

Based on the longitudinal and transverse slope of the pavement, subsurface berms were used to control the volume of water flow within the pavement structure and promote water infiltration into the subgrade. The following subsurface drainage pipe design parameters were selected:

Pavement average transverse slope	=	2 percent
Maximum distance to an underdrain pipe	=	7.3 m
Drainage area per pipe	=	1,354 m^2
Pipe diameter	=	10 cm
Distance from pipe to bottom of subbase	=	0 cm
Pipe slope	=	2 percent
Roughness coefficient of the pipe	=	0.024

3.6 Hydrologic Design

Based on the analysis input parameters above both the 20 and 30 year pavement service life cross sections are sufficient to accommodate the 10 year storm return period with the majority of the water volume reaching the pavement infiltrating into the subgrade (95 percent). The remainer of the water volume was expected to run off the pavement onto adjacent surfaces or be channeled by the underdrains to the City storm drainage system.

4. Life-Cycle Cost

The U.S. Federal Highway Administration (FHWA) describes LCCA as “an analysis technique that builds on the well-founded principles of economic analysis to evaluate the over-all-long-term economic efficiency between competing alternative investment options.” The comparison of life-cycle costs has become standard to not only compare different pavement types, but also evaluate different feasible rehabilitation plans over the service life of a pavement.

Municipal pavements are typically designed for an initial service life of between 15 and 25 years. At the end of the service life, some form of rehabilitation action such as removal and resetting of interlocking concrete blocks or a mill and overlay for flexible pavements is completed.The actual service life of both the initial pavement construction and rehabilitation treatment is dependent on a variety of factors including type and composition of

the traffic, timeliness of maintenance treatments, and environmental factors such as temperature and precipitation.

In order to develop comparative cost estimates to determine the whole life cost of the different pavement types, it is necessary to know the timing, type and quantities of repairs and their service life. The service life of a pavement is defined as the time between initial construction and the time when the pavement reaches a minimum acceptable level of service. Life-cycle costing is a technique that quantifies all of the costs necessary to construct and maintain a pavement over a set analysis period, typically between 25 and 50 years. Future costs are discounted to today's dollars by using a discount rate which takes inflation and interest rates in account to determine the net present value of future costs. By comparing the total life-cycle cost of two or more pavement options, it is possible to make informed decisions as to the best pavement alternative for a particular application.

A detailed life-cycle cost analysis was completed for the Allston Way pavement in comparison to a conventional flexible pavement. This included the initial cost for the construction, maintenance and rehabilitation costs over the life of the pavements, expected long-term performance, residual and salvage values.

The life-cycle analysis comparing potential options for Allston Way show that a flexible pavement to have the lowest total present worth cost. Permeable and conventional interlocking concrete pavement were found to be almost the same (less than 2 percent difference). However, the analysis did not take into account the benefits associated with permeable pavements such as a reducing stormwater runoff volume, reducing stormwater runoff peak flows, reducing surface ponding, reducing stormwater pollutant load, decreased downstream erosion and increase groundwater recharge. If these factors were taken into account, the permeable pavement would have the lowest total present worth cost.

5. Pavement Construction

The Allston Way permeable pavement was constructed in the summer/fall of 2014. The existing pavement was excavated with the curbs and sidewalks retained for the new pavement. Several utilities were updated or relocated. The City arborist required treatment of the exposed tree roots which included the use of cellular confinement techniques. The plastic cells extended approximately 5 ft from the curb and included backfill consisting of ASTM No. 57 stone mixes with loose soil from the site (Photograph 1).



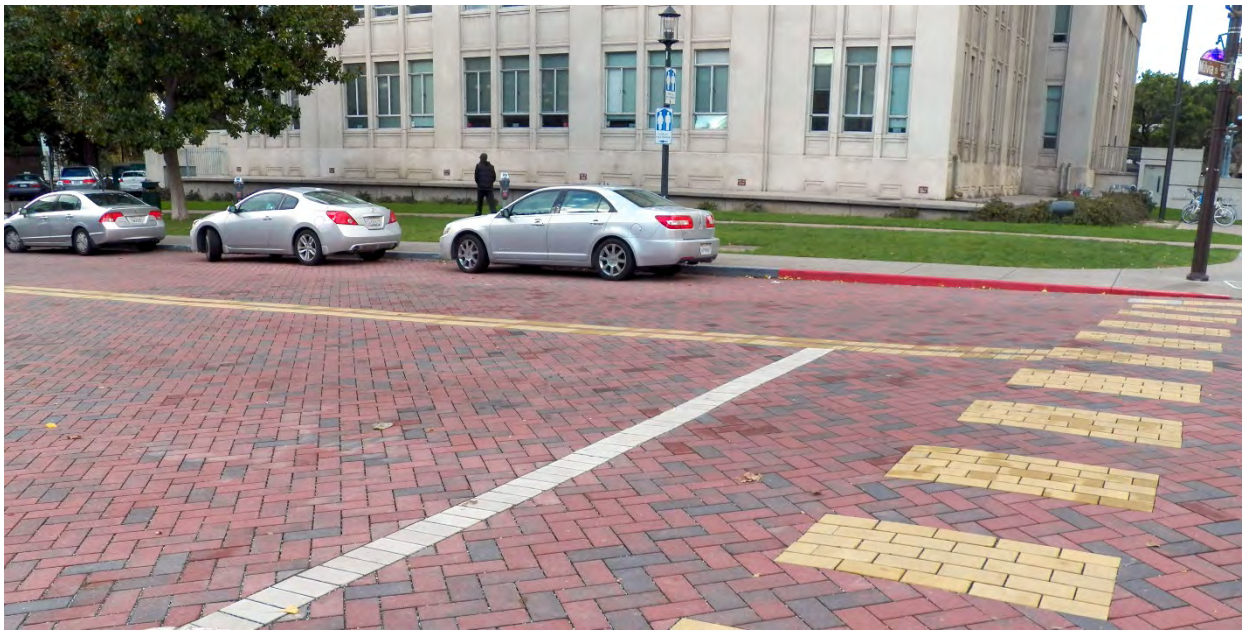
Photograph 1. Cellular confinement around the tree roots.

There were some conflicts with relatively shallow gas lines which were subsequently encased in concrete (Photograph 2). The utilities were located within the pavement structure.



Photograph 2. Utility casing within the pavement.

Construction was successfully completed with the roadway open to traffic in the late fall of 2014 (Photograph 3).



Photograph 3. Completed pavement.

6. Pavement Monitoring Program

The pavement condition and hydrologic performance has been monitored post-construction. This includes pavement surface condition inspections, noise monitoring and sampling and testing for water samples obtained from a downstream sampling station. To date, there have been a few pavers with corner cracks primarily at cut locations adjacent to utility covers. There has been some subsidence of the joint aggregate which was expected and the aggregate was replaced as a part of the 6 month planned repairs as a part of the original contract. Settlements have occurred at locations where the underground utilities were located close to the pavement surface. This was expected due to the difficulty of achieving adequate compaction of the base/subbase close to the utilities.

Noise monitoring indicates that the On-Board Sound Intensity (OBSI) noise levels are similar to the adjacent asphalt concrete surfaced pavement.

7. Maintenance and Utility Cut Restoration

Maintenance guidelines and a utility cut restoration manual were developed for the Allston Way permeable pavement. The objective of the manual is to provide operation and maintenance guidance to ensure that their permeable pavements function properly by providing stormwater infiltration and structural support for the anticipated traffic loading.

This document provides a background on the need for pavement preservation as well as specific performance criteria for the cost-effective maintenance of permeable pavements. It also provides recommendations for an annual monitoring program and maintenance plan detailed guidance for maintenance. The utility cut restoration manual provides guidance for the removal of the permeable pavers, excavation to access the utility and restoration of the pavement base/subbase and surface. The manual provides materials, labor and equipment needs and a step by step process to complete the operation.

8. Conclusions

The construction of a demonstration municipal roadway permeable interlocking concrete pavement for Allston Way in Berkeley, California provided the opportunity to demonstrate the ability to install a permeable pavement as a retrofit to an existing conventional non-permeable pavement. The suitability decision matrix tool developed for the project permitted the logical review of the suitability of the use of a permeable pavement in the municipal environment. The unexpected presence of some utilities found after the on-set of construction were a challenge that had to be overcome during construction. To date, the permeable pavement is performing extremely well with no water observed at the monitoring/sampling locations with all rainwater being infiltrated into the underlying subgrade.

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