



Pervious Pavement Draft Design Guidance

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California Department of Transportation
Division of Design
Office of Storm Water Management
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<http://www.dot.ca.gov/hq/oppd/stormwtr/>

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List of Acronyms

AB	Aggregate Base
ASTM	American Society for Testing and Materials
BMP	Best Management Practice
Caltrans	California Department of Transportation
CT	California Test
EPA	Environmental Protection Agency
HDM	Highway Design Manual
HMA	Hot Mixed Asphalt
LID	Low Impact Development
MEP	Maximum Extent Practical
MR	Modulus of Rupture
M_r	Resilient Modulus
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NRCS	National Resources Conservation Service
nSSP	Non-Standard Special Provision
O&M	Operations & Maintenance
OGAC	Open Graded Asphalt Concrete
OGFC	Open Graded Friction Course
OSWMD	Office of Storm Water Management - Design
PAP	Pervious Asphalt Pavement
PCC	Portland Cement Concrete
PCP	Pervious Concrete Pavement
PE	Project Engineer
PICP	Permeable Interlocking Concrete Pavement
PPDG	Project Planning and Design Guide
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
RWQCB	Regional Water Quality Control Board
SF	Square Feet
TI	Traffic Index
TMDL	Total Maximum Daily Load
VER	Version
WLA	Waste Load Allocation
WQV	Water Quality Volume

1. INTRODUCTION

1.1 Overview

This guidance considers Pervious Concrete Pavement (PCP), Pervious Asphalt Pavement (PAP) (also known nationally as Porous Asphalt Pavement), and Permeable Interlocking Concrete Pavement (PICP).

While pervious pavements have become very popular in the area of stormwater management, the true applicability to the highway environment is still unclear. Local agencies and regulators continue to ask Caltrans to consider pervious pavement on projects. However, until more information is determined related to safety, maintainability, constructability, and improved water quality benefit over other approved stormwater best management practices (BMPs) the inclusion of pervious pavement into Caltrans projects needs to be carefully considered.

This document was developed to provide general guidance on the design and applicability of pervious pavements for Caltrans projects. A project should first evaluate the other approved BMPs and compare them to determine if pervious pavement would be considered the preferred BMP. Use Table 1-1 to help determine which locations are suitable candidates for pervious pavement and consult with the District Stormwater Coordinator.

Table 1-1: Pervious Pavement Categories

Category	Examples	Loading	Speed	Risk
A	Landscaped areas, sidewalks and bike paths (with no vehicular access), miscellaneous pavement to accept run-on from adjacent impervious areas (e.g. roofs)	No vehicular loads	N/A	Low
B	Parking lots, park & ride areas, maintenance access roads, scenic overview areas, sidewalks and bike paths (with maintenance/vehicular access), maintenance vehicle pullout	Few heavy loads	Low speed (less than 30 mph)	Low
C	Rest areas, maintenance stations	Moderate heavy loads	Low speed	Low
D	Shoulders, some low volume roads, areas in front of noise barriers (beyond the traveled way)	Moderate heavy loads	High speed	Medium

E	Highways, weigh stations	High heavy loads	High speed	High
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This guidance was developed with the understanding that only project scope examples listed in Categories A, B & C (listed as Low Risk) would be considered. Categories D and E are currently not candidates for pervious pavement at this time on Caltrans facilities.

If the purpose of installing pervious pavement is not for NPDES permit compliance then variation from certain siting and design requirements may be allowed. Contact the Office of Storm Water Management – Design (OSWMD).

1.2 Definition

Pervious pavements allow stormwater to filter through voids in the pavement surface into an underlying stone reservoir where it is temporarily stored and infiltrated into the surrounding materials.

While pervious pavement designs may vary, they all have a similar structure, consisting of a surface pavement layer with an underlying reservoir layer.

Other terms such as ‘permeable pavement’ or ‘porous pavement’ are used in literature to describe what Caltrans has termed “pervious pavement.” Pervious pavements consist of a surface layer made of either asphalt or concrete (cast-in-place or interlocking concrete units).

1.3 Benefits

Benefits of pervious pavements include:

1. reducing the rate of runoff
2. filtering pollutants out of runoff
3. infiltrating runoff into the ground, and
4. maintaining the natural hydrologic function of the site

Pervious pavement is designed primarily for promoting stormwater infiltration and improving the quality of stormwater runoff. It is typically designed to capture rainfall from the pavement surface area, but may also accept run-on from adjacent impervious areas and other hardscapes (sidewalks) or rooftops. Another benefit of pervious pavement is the reduction of pollutants that enter stormwater runoff by reducing the amount of splash and spray that wash pollutants from the underside of vehicles. This would be considered a form of source control and a useful component of stormwater compliance. Pervious pavements infiltrate the water below the pavement surface and eliminate standing water issues. This will help to eliminate concerns of mosquito breeding. Some recent studies

have also found that pervious pavement can help reduce temperatures on and around pavements which helps reduce urban heat island effect.

Since pervious pavements function similarly to other infiltration devices treatment crediting should be documented in the same fashion.

1.4 Need Statement

The reduction of runoff and pollutants from Caltrans right of way is an important element of meeting the requirements of the Caltrans NPDES Permit. This can be achieved using pervious pavement by encouraging on-site infiltration of the Water Quality Volume (WQV) into a reservoir section and releasing it within a specified drawdown time through the underlying soils.

Caltrans projects also have a requirement to evaluate the downstream effects of added stormwater due to the increased impervious surface. Pervious pavement can be used to help mitigate impacts of the additional runoff through temporary storage and infiltration.

The Caltrans NPDES Permit has requirements to consider Low Impact Development (LID) principles on all projects. LID principles are sustainable practices that treat the stormwater onsite. Unlike some storm water management methods, which collect and convey stormwater runoff through storm drains, pipes, or other conveyances to a centralized stormwater facility, LID principles use site design and storm water management techniques to maintain the site's pre-project runoff rates and volumes by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to the source.

While pervious pavement would be considered to be an LID technique, Caltrans should still prioritize the use of landscape and soil-based BMPs to treat stormwater runoff as the first means to compliance. Life cycle cost, site feasibility, and the overall water quality benefits need to be evaluated when determining which BMPs will be used.

In general, for stormwater compliance, pervious pavement will only be considered after landscape and soil-based BMPs are determined to be infeasible.

2. SELECTION CRITERIA

2.1 Candidate Sites

After following the Project Planning and Design Guide (PPDG) and considering all of the approved treatment BMPs, the first step in considering pervious pavements for a project is to confirm that the location is appropriate and will be able to provide infiltration for the life of the pavement.

Since the primary means of stormwater treatment will be by infiltrating water, pervious pavement will act in a manner similar to other infiltration devices that are described in Appendix B.3 of the PPDG. Designers should reference this (specifically sections B.3.2 and B.3.3) when considering pervious pavement. Although there will be some differences in the design criteria such as lower allowable infiltration rates, the general concepts are applicable.

Hydrologic Soil Groups A and/or B shown on NRCS soil surveys would be considered as the best areas for considering infiltration BMPs. However, other soil types can be considered with the understanding that the design will still be driven by the determination of the infiltration rate, adhering to drawdown time requirements and meeting the minimum separation to groundwater.

In addition to using the siting criteria listed in Appendix B of the PPDG (see table B-2), pervious pavements should not be used where the following conditions exist:

- Landscaped and other pervious areas drain to the proposed pervious pavement. Debris and sediment from these areas could lead to clogging.
- Pavement placement will be in close proximity to structural foundations. Setbacks may be reduced where liners are used or the amount of pervious pavement is small. Consult with your Storm Water Coordinator, Structures representative, or Geotechnical staff.
- It is not feasible to perform routine and long term maintenance, such as vacuum sweeping to maintain the hydrologic function.
- Pavements regularly receive winter sanding. Seal coating or repaving are not appropriate for pervious pavements.
- Where vehicles will be parked or stored for an extended period of time.

Also, consider the following criteria.

- Determine if pervious pavement is truly the most cost effective BMP during the feasibility process (e.g., the life cycle cost of an infiltration trench may be lower

even if it would entail more design work to facilitate the trench fitting within the site).

- Determine that the infiltration rate will facilitate treating 100% of the WQV from the added impervious area. Only infiltrating a portion of the WQV using pervious pavement may not be worth the added cost.
- Design pervious pavement such that surface flow will not cause ponding, flooding and/or erosion.
- Typical drainage design is still necessary to address the Caltrans HDM design storm event.
- Try to avoid placement in fill areas. If a small amount of new fill is required or over excavation of reservoir layer occurs during construction, consider using additional reservoir material instead of adding compacted soil.
- Check with the District Hazardous Waste Unit to evaluate for potential soil or groundwater contamination within the project area.
- Avoid placing in areas where wind erosion could supply a significant amount of windblown sediment or where offsite sediment laden stormwater cannot be eliminated, due to additional surface cleaning requirements.
- Consider installing a secondary stormwater drainage system (see Figure 2-1 and 2-2) to reduce clogging in areas with expected minimal sediment loading or if the pavement receives run-on from an adjacent impervious area. This material would typically be the same as the reservoir, which is Class 4 AB. Maintenance should be involved in the design process to get their concurrence for these situations.
- Provide concrete curb or concrete curb and gutter for edge support. This barrier can also keep unwanted sediment off the pavement. See Figure 2-3 and 2-4.
- Consider placing a PCC strip between pervious pavement and asphalt pavement. See Figure 2-5. Extend strip down below the bottom of the asphalt section to prevent water migration degradation of the asphalt pavement section. Additionally, consider placing an impermeable barrier 10-mil polypropylene barrier between the pervious pavement and asphalt pavement sections. The 10-mil barrier can be placed with or without the PCC strip.
- Try to keep the reservoir invert slope flat to enable even distribution and infiltration of stormwater for parking lot type applications. Do not exceed 2% slope of reservoir invert. An exception is using pervious pavement for an access roadway into an infiltration basin. Refer to Appendix 3 for more exceptions.
- Slope designs for the surface of the pervious pavement should be in accordance with the HDM. Flat top slopes are discouraged because during rain events that exceed the WQV, the pavement will pond. No maximum slope is set but the designer must realize the cost impacts to the design for the increased reservoir material. Typically, any slope greater than 5% is considered not feasible. An exception is using pervious pavement for an access roadway into an infiltration basin.
- In frost conditions extend the filter bed below the frost line to reduce the freezing potential of the reservoir layer. Determine the maximum depth of ground freezing

in the area of the project. The minimum depth for the pavement surface to the invert of the reservoir should be 65% of the ground freezing depth.

2.2 Feasibility Analysis

To initially assess the feasibility of using pervious pavement, follow Section 2.4.2.1 Site-Specific Determination of Feasibility of the PPDG ([click on this web link to download](#)).

In addition, perform a Feasibility Analysis as described in Section 3 of the Caltrans Infiltration Basins Design Guidance as pervious pavement will function similarly to an infiltration device. This can be found under the infiltration tab at the following website. ([click on this web link to go to website](#)).

A site investigation is critical to evaluate whether pervious pavements are an appropriate BMP for a site. The site investigation should be conducted with appropriate staff to be able to consider hydrology and hydraulic design, soil permeability, pavement thickness design, and environmental regulations.

The minimum acceptable infiltration rate when designing the reservoir section may be less than a typical infiltration device due to the large surface area being used for infiltration. Because of this design criterion, no lower limit of infiltration rate has been set.

Coordinate with Geotechnical staff to determine the necessary number of permeability test locations. Discuss the applicability of performing tests every ¼ acre of pervious pavement as a general estimate.

If the invert of the reservoir is designed with multiple invert elevations, construct an impermeable barrier between the tiers. This will keep the WQV from migrating. Consider conducting separate test sites for each tier.

In order to control over compacting the subgrade soil surface (below the reservoir layer) during construction, the following design method is prescribed:

Perform additional tests for each test site during the Geotechnical Investigation for Soil Lithology and Select Chemical Testing outlined in Section 3.3.1 Part B of Caltrans Infiltration Basins Design Guidance:

- [CT 231](#) (Method of Test for Relative Compaction of Untreated and Treated Soils and Aggregates by the Area Concept Utilizing Nuclear Gages) should be conducted at the invert elevation of the reservoir section to obtain compaction of the “native soil.”
- [CT 220](#) (Method of Test for Permeability of Soils) will be used in the lab. Typically, three tests should be performed at different compactions. Soil samples

must be representative of the invert soils of the reservoir layer and taken from the location where CT 231 performed. One of the tests should be of the native soil condition. The PE may need to coordinate with Caltrans Pavement Program, Geotechnical Services, and Construction to determine an upper compaction limit. Compaction limits are typically between 88 and 94%.

Additional soil classification and testing requirements for pavements can be found in HDM Topic 614.

Include these additional test results in the geotechnical summary report.

The intent of performing these tests is to provide compaction limits to the contractor. A site is acceptable only if the reservoir layer can be designed to infiltrate the WQV in the appropriate drawdown time using the upper compaction limit used in CT 220. The upper limit of compaction will set the minimum acceptable subgrade permeability rate used to design the reservoir layer. The lower compaction limit is typically the “native soil” condition. If the native soil compaction is less than 88%, contact the Pavement Program. The agreed upon compaction limits are then specified in the contract documents. These will give the contractor a performance based specification that will help determine the construction methods and equipment to be used.

A minimum compaction range of 4% should be specified. If this cannot be accomplished, consult with Construction. An example would be if the lower limit is set at 89% (native soil) then the minimum upper limit would be 93%. Use average results when the site has multiple test locations. If the site has multiple invert elevations, consider designing each separately. The PE should use discretion when infiltration rates vary significantly at the site.

Always strive to maximize the compaction range. For example, if the design permeability requirements can be met with 95% compaction, then increase the upper compaction limit to allow the contractor the greatest flexibility during construction. However, it will be up to the PE to determine the final compaction range, based on costs associated with the reservoir layer thickness requirement.

Key information related to the soils, as outlined above, should be documented in the Storm Water Data Report.

2.3 Cost Analysis and Typical Cross Sections

Table 2-1: Cost Analysis

PCP ¹	PAP ²	PICP ¹
\$ 2.00 to \$6.50/sf	\$ 4.80 to \$6.00/sf	\$5.00 to \$10.00/sf

¹ Based on Virginia Department of Conservation and Recreation (DCR) Stormwater Design Specification No. 7, Permeable Pavement Ver. 1.6, September 30, 2009

² Based on Caltrans HQ Pavement Program 2012 data

The costs described in Table 2-1 are for planning purposes only . PCP and PICP costs are based on 2009 data and PAP 2012 and should be adjusted based on current construction cost trends.

During PS&E develop cost based on actual bid price data, or by contacting local Associated General Contractors chapter and requesting unit costs to assure that current local costs are reflected in the engineer's estimate. The costs listed in Table 2-1 include the reservoir and vary due to the total pavement area, site access, pavement configuration, and installation methods. As part of the BMP feasibility process outlined in Section 2.4.2.1 of the PPDG, the PE should compare different BMP types. When comparing costs keep in mind there may be additional savings in pervious pavement because there is an opportunity to reduce drainage items. This should be included in the cost comparison.

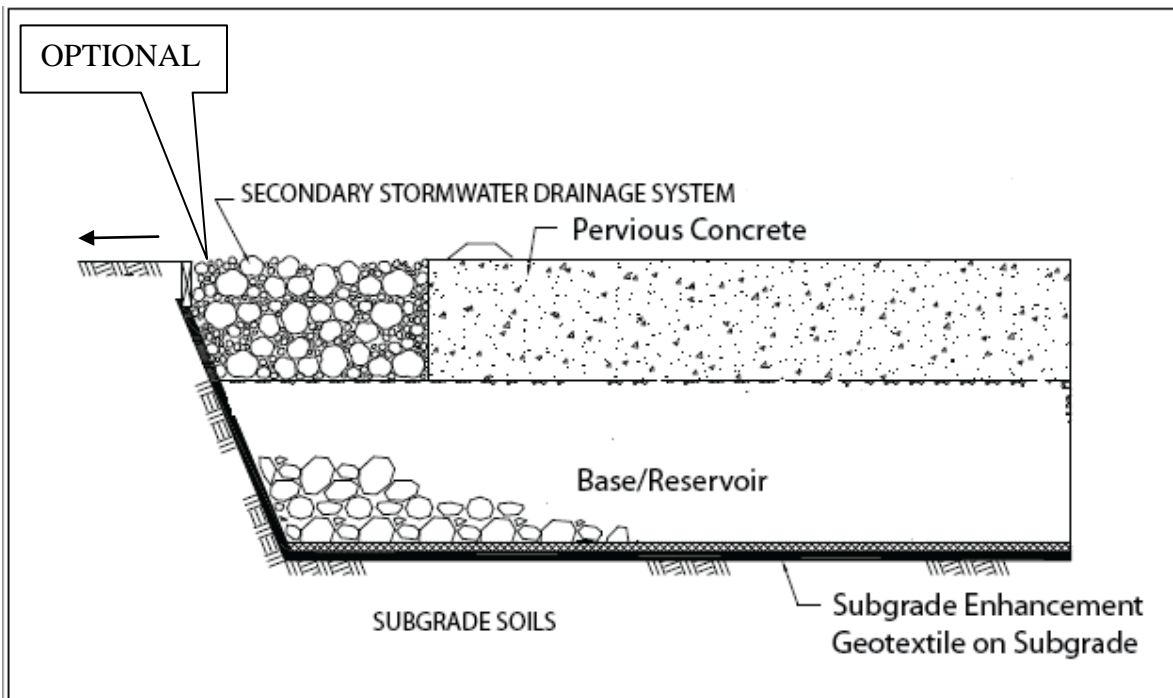


Figure 2-1 - Typical PCP Section

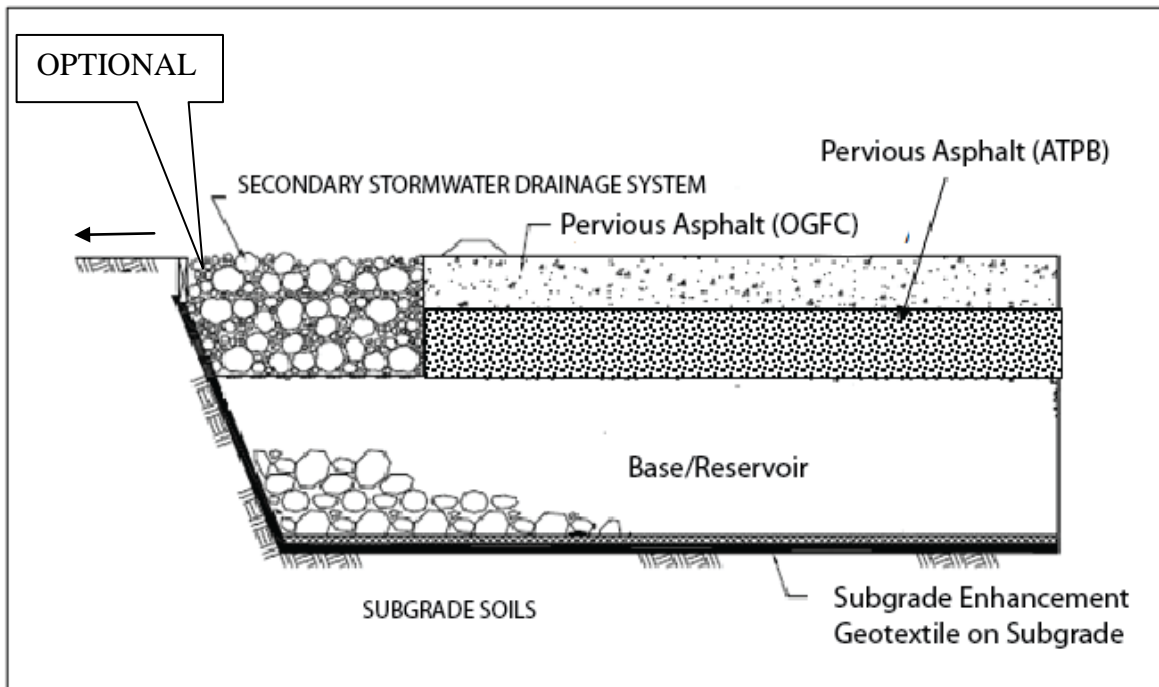


Figure 2-2 - Typical PAP Cross Section

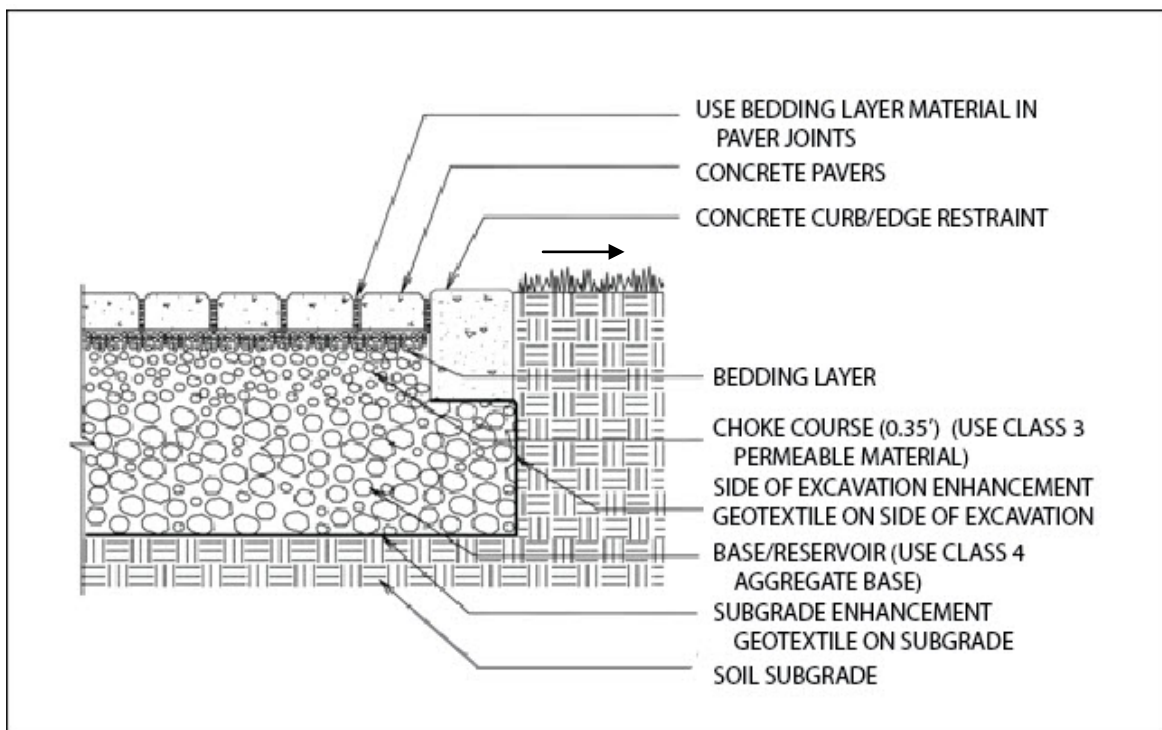


Figure 2-3 - Typical PICP Cross Section

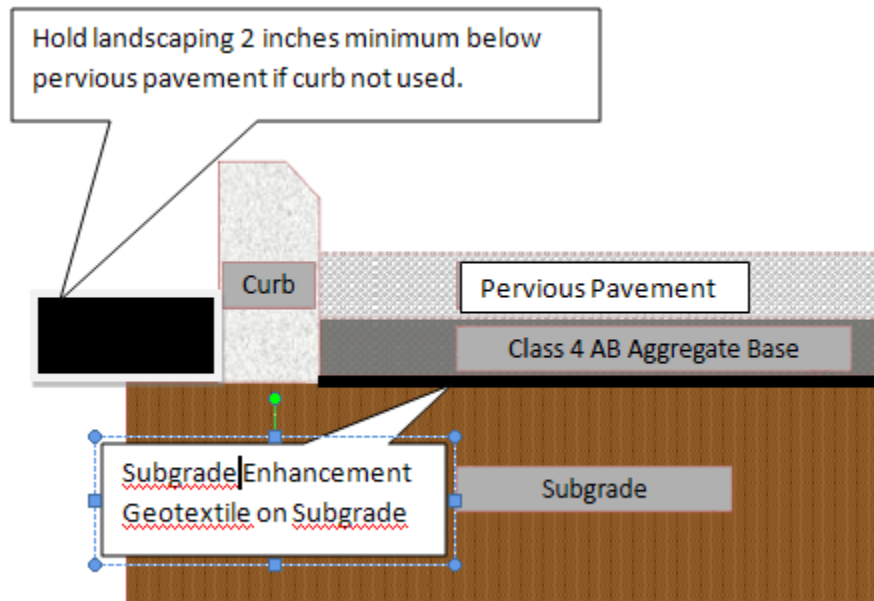


Figure 2-4- Typical Pervious Pavement with Adjacent Curb/Landscaping

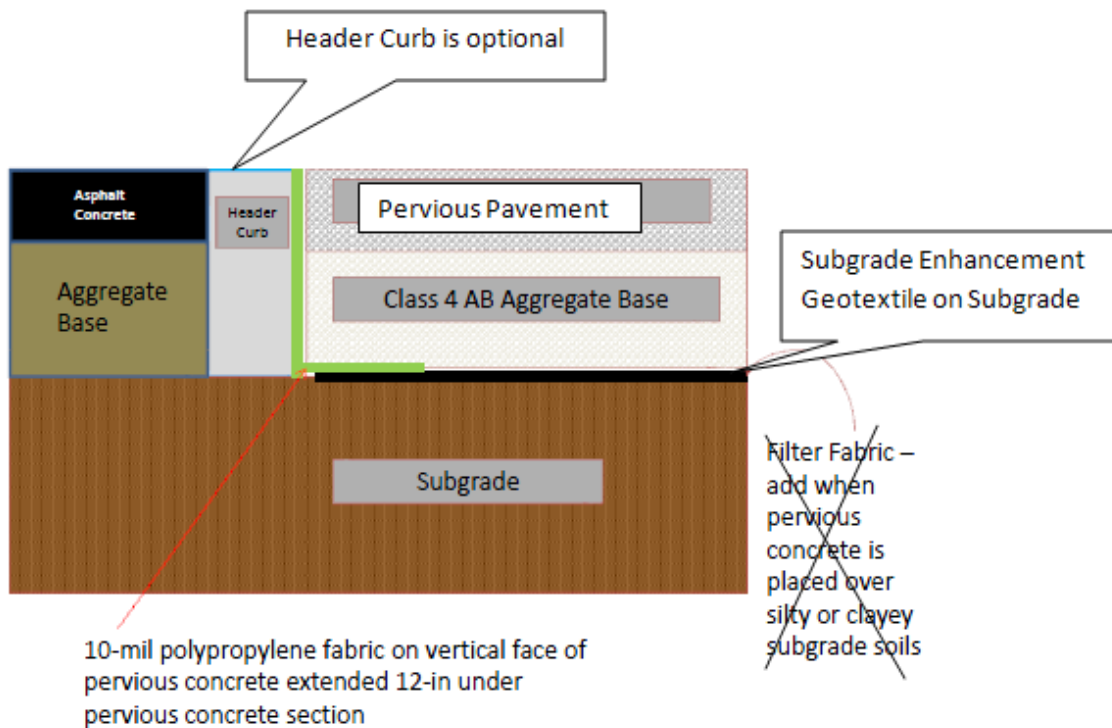


Figure 2-5- Barrier Between Pervious and AC Pavements

2.4 Other Design Considerations

There are other considerations that could be made as part of the design process that may reduce costs, while acting similar to pervious pavement and still comply with regulatory treatment requirements.

For example, in Figure 2-1 - Typical PCP Section the secondary stormwater drainage system acts as a conduit to the reservoir layer. The pavement could be designed as a typical impervious pavement, such as asphalt or PCC, instead of a pervious pavement. This would eliminate costs for the pavement and long term maintenance. Keep in mind; this would require the ability to grade the facility to the secondary drainage system.

Another consideration would be to determine if the site would be able to function using pervious pavement in portions of the facility instead of the entire area. This has been seen in parking lots where pervious pavement was only used in the parking stalls and not in the driving lanes. In such a case, the drive lane should be sloped to drain water onto the pervious pavement in the parking stalls.

There may be times where a pervious pavement layer may be placed on native soil and a reservoir is not needed to achieve the desired results, such as a sidewalk.

Engineers are encouraged to use ingenuity while designing infiltration type devices. Always consider different combinations of materials, infiltration techniques and siting alternatives while trying to achieve the desired results in the most cost effective manner.

3. DESIGN CRITERIA

3.1 Structural Design

The pervious pavement surface and reservoir layer must be designed to support the maximum traffic load. The structural design process will vary according to the type of pavement section selected. In addition, the reservoir layer must be able to temporarily store the WQV. When determining the overall thickness of the pavement structure, it must satisfy both the Pavement Structural Design in Section 4 and the Reservoir Layer Design in Section 3.2.

The structural design of pervious pavement considers four main site elements:

- total traffic
- in-situ soil strength
- environmental elements (i.e., pollutants), and
- pavement section (pervious layer, bedding layer, reservoir layer, and fabric) design

3.2 Reservoir Layer Design

The reservoir layer design should be performed in consultation with the licensed engineer performing the field investigation and the design of the pavement thickness. Use the WQV to design the reservoir layer of the pervious pavement section. To determine the WQV refer to the PPDG Section 2.4.2.2 - Treatment BMP Use and Placement Considerations.

The reservoir layer thickness for WQV storage must be compared with the reservoir layer thickness designed for the traffic loading and in-situ soil strength requirements. Once the reservoir layer thickness has been determined using the criteria in Section 2.2, the PE compares the depth determined in Section 4. The final reservoir layer will be the maximum depth of either design. If the reservoir layer thickness required for the traffic loading and soil strength is used as the final design, the licensed engineer performing the drainage design should document the additional reservoir storage capacity above the minimum required WQV. The added storage can provide additional benefits to minimize downstream effects. This information should be documented in the in the Storm Water Data Report and drainage report.

When the underlying soil infiltration rate cannot drain the WQV in the specified drawdown time, the site should be eliminated. An underdrain system should not be considered as an option, unless otherwise coordinated with OSWMD.

OSWMD developed a tool to size the reservoir layer ([click on this web link to download](#)) using equations from several referenced Caltrans design guidance documents. The reservoir layer depths developed by the Pavement Program (see Appendix 3) for the

different categories shown in Table 1.1 are included in the tool for comparison. The final reservoir layer will be the larger of the two designs. A pervious pavement design example has been developed and is included in the tool.

3.3 Material Specifications

Caltrans Pavement Program has developed non-standard specifications for pervious aggregate base, PCP, and PICP ([click on this web link to download](#)). These specifications are currently under evaluation for constructability prior to adopting as standard specifications.

Until adopted as standard, these specifications must go through Caltrans OSWMD for approval to be used on any project within Caltrans right-of-way. Follow the sponsor request and concurrence process ([click on this web link for details](#)).

The PE must submit documentation related to the design of the pervious pavement when requesting nSSP concurrence from OSWMD. Prior to submitting the Request Memo, the PE needs to coordinate with the following Caltrans functional groups:

- Pervious Pavement,
- Hydrology and Hydraulics (Drainage – Design),
- Geotechnical,
- Design (District/Regional Design Storm Water Coordinator), and
- Maintenance

Each function plays a role in the success of the pervious pavement implementation. It is the PE's responsibility to coordinate with these units and incorporate the nSSPs into the project. Maintenance concurrence will be through the approval of the PS&E SWDR.

PEs submittal package to OSWMD must include:

- Request Memo with narrative explaining coordination process including
 - Category and Example in Table 1-1
- Project Plans (all sheets related to the pervious pavement design, incl. shed areas)
- Engineering Estimate (only include pervious pavement items)
- nSSPs

- Pervious Pavement Design Tool Calculations
 - Include basis of infiltration rate used to design the reservoir layer, and
 - Include basis of upper and lower compaction limits used in the specification

4. PAVEMENT STRUCTURAL DESIGN

4.1 *Materials and Mix Design*

Caltrans Pavement Program developed specifications for pervious pavement ([click on this web link to download](#)).

4.2 *Traffic*

No traffic (neither light nor heavy) is considered for Category A facilities. For Category B and C facilities, follow the Traffic Index (TI) Guidance in HDM Index 613.5(4), specifically Table 613.5B.

4.3 *Design Method*

4.3.1 General

The thickness design of pervious pavements does not follow all of the standard Caltrans design methods in the HDM. In the past, such designs had to follow the design exception requirements from Headquarters. In lieu of obtaining design exceptions, use the following design methodology of this guide for pervious pavements. Variations for this guidance must be discussed with the OSWMD and design exceptions may apply.

The pavement structural designs found in this guide are based on the 20 year pavement design life requirement for roadside facilities in HDM Topic 612.

4.3.2 Subgrade Preparation

Unlike traditional pavements where a major design focus is to keep water away from the subgrade soil layer, pervious pavements introduce surface water to the subgrade soils.

The pervious pavement section should be placed in an excavated area and not on embankment. If embankment material is required to design the area, it should be minimal. It is recommended to use the reservoir layer material as the fill material where needed. Consider using barriers when using embankment materials on sides. Place a detail in the project plans to show this condition.

Determine the soil classification and/or R-Value of soil in accordance with HDM Topic 614 and other applicable discussions for concrete and asphalt pavements. The R-value is used to determine thicknesses for reservoir and surface layers for asphalt pervious pavement and PICP. Consult District Materials Engineer if soil meets Subgrade Type 3 on Table 623.1A of the HDM (USCS CH with plasticity index > 12 or R-value is less than 10) for suitability of site for pervious pavement and possible design modifications.

Place a subgrade enhancement geotextile (nonwoven fabric) between the subgrade soil and the reservoir. A nonwoven fabric helps reduce fines migration into the reservoir. A specification has been developed ([click on this web link to download](#)). Extend the geotextile along the sides of the excavated soil to prevent piping of fines into the reservoir layer. Do not increase the R-value in the design calculations (HDM Index 614.5 does not apply to pervious pavement).

4.3.3 Reservoir Layer

The pavement reservoir layer is used as a reservoir for the storage of stormwater in pervious pavements and it is the structural support for the surfacing when needed. Use Class 4 AB for reservoir layer. To meet Caltrans new NPDES Permit requirements, the reservoir layer thickness will be designed to store the WQV. The reservoir layer can be designed to store other storm events to meet project requirements. Document this information in the SWDR and the drainage report.

When an aggregate base layer is needed, the minimum thickness for all types of pervious pavement is 0.5 ft. for constructability.

For PICP, place 0.35 ft Class 3 permeable material over the Class 4 AB; the Class 3 permeable material can be calculated as part of the reservoir layer. Calculate the Class 4 AB thickness as $2TI/3 + R^2/300 - R/5 - 2.2$ in feet where TI is traffic index and R is the measured R-value.

For PAP design the reservoir thickness based on procedures for new pavement in HDM Topic 633. Use Gf of 1.0 for Class 4 AB.

For pervious concrete use the following minimum thicknesses for the Class 4 AB layer:

- Zero for Category A (non-auto locations)
- 0.50 feet for Category B auto areas
- 0.70 feet for Category B truck areas
- 0.70 feet for Category C truck areas

Add 0.20 ft of Class 4 AB where the R-value is less than 25.

4.3.4 Surface Layer

Surfaces for pervious pavement must be durable and maintainable. Three options are currently provided in this guide:

- Pervious Asphalt
- Pervious Concrete
- Permeable Interlocking Concrete Pavers

Any of these options can be used where pervious pavement is determined to be suitable and the appropriate bases and soil treatments are included. For PICP, place the bedding layer on top of the base permeable material to provide level foundation for the pavers.

The minimum thickness of and other surface layer requirements are as follows. Refer to Appendix 3 Usage Notes for Pervious Pavement nSSPs for further discussion.

- Pervious Asphalt
 - Consists of two surface layers: asphalt treated permeable base (ATPB) and Open Graded Friction Course (OGFC).
 - Do not use or specify tack coats or prime coats.
 - Design thickness of ATPB based on procedures for new pavement in HDM Topic 633 using the following values and minimums for situations with vehicular traffic.
 - Measured R-Value
 - ATPB – Use Gf of 1.4. Minimum thickness: 0.25 feet.
 - Place 0.10-foot OGFC on top of the ATPB. Do not deduct thickness from ATPB or reservoir for the OGFC. OGFC is a nonstructural wearing course which protects the ATPB and can be replaced as the surface wears out.
 - When no vehicular traffic is planned (Category A) use the minimum thicknesses for ATPB and OGFC above.
- Pervious Concrete
 - Use the following minimum thicknesses for the concrete layer for 20 year pavement design life:
 - 0.35 feet for all Category A (non-auto locations)
 - 0.45 to 0.50 feet for Category B auto areas.
 - 0.70 feet for Category C truck areas (TI < 9).
 - 0.80 feet for bus stop pads and TI 9 to 10.
 - When a project is designed for a TI greater than 10 contact the Office of Concrete Pavement and Pavement Foundations for additional input.
 - Dowel bars and tie bars are not used for pervious concrete.
- Permeable Interlocking Concrete Pavement
 - The minimum thickness of the pavers for PICP subject to vehicular traffic is 3 1/8 inches. 2 3/8 inch thick pavers may be used in pedestrian areas. Concrete pavers must conform to ASTM C936.
 - Place 0.15 foot bedding layer between 0.35 feet Class 3 permeable material course and pavers.
 - Do not use PICP where TI > 9 at this time.
 - Concrete curb or curb and gutter are typically used at the pavement edges and at transitions to other pavements. The curb acts as a guide for the bedding and paver placement and assists in interlock of the pavers.

4.3.5 Minimum Pavement Structures

The following designs are the minimum needed for structural adequacy and/or constructability. These designs will need to be checked against what is needed

hydraulically with the thicker design prevailing. Class 4 AB (reservoir layer) thicknesses are structural minima and any thickness greater is permissible. Thicker Class 4 AB will be required in cases that the pervious pavement is adjacent to a thick section non-pervious pavement or if there is a high hydraulic storage requirement. The bottom of the Class 4 AB should be 0.05 ft lower than adjacent non-permeable pavement structure. Category A, B & C are based on Table 1-1 of the Pervious Pavement Design Guidance.

Individual project needs may require thicker sections. Please consult your District Materials Engineer for final recommendations.

Category A

- *Pedestrian and bike pathways, occasional light vehicle can be permitted, and sidewalks except at driveways*

Option 1

0.20 feet OGFC over 0.50 feet AB Class 4

Option 2

0.35 foot pervious concrete on native soil

Option 3

PICP on native soil with a minimum 0.15 foot thick bedding layer over a 0.35 foot thick Class 3 permeable material and no reservoir layer

Category B

- *Maintenance vehicle pull out*

MVP must be outside shoulder area. If Unified Soil Classification is CL, CH, OH, or OL or R-value is less than 25 add 0.20 foot Class 4 aggregate base to values below. The grading plane of subgrade material should be sloped away from shoulder at 2 percent or more.

Option 1

0.10 foot OGFC over 0.35 feet ATPB on 0.50 feet Class 4 AB.

Option 2

0.45 foot pervious concrete on 0.50 foot Class 4 AB.

Option 3

PICP placed on 0.35ft Class 3 permeable material over 0.50 ft Class 4 AB..

- *Recovery zone outside shoulder area and Gore area*

Follow HDM 304 - Side Slopes.

Safety slope option (1:10 or flatter):

1. 0.10 foot OGFC over 0.35 feet ATPB on 0.50 feet Class 4 AB
2. 0.45 foot pervious concrete on 0.50 foot Class 2 or Class 4 AB.
3. PICP placed on 0.35ft Class 3 permeable material over 0.50 ft Class 4 AB.

Safety slope options (>1:10):

1. 0.10 foot OGFC over 0.25' ATPB.
2. 0.35 foot pervious concrete.
3. PICP not recommended

Grading plane of subgrade material and Class 2 AB should be sloped away from shoulder at 2 percent or more. Color treatment for pervious pavement is recommended to minimize intentional trafficking.

4. Driveway or Sidewalk at driveway

Option 1

0.10 foot OGFC over 0.40 feet ATPB on 0.70 foot Class 4 AB

Option 2

0.50 foot pervious concrete on 0.70 foot Class 4 AB

Option 3

PICP on 0.35 Class 3 permeable material over 0.70 foot Class 4 AB

5. Maintenance access road

Option 1

0.10 foot OGFC over 0.40 feet ATPB on 0.70 foot Class 4 AB

Option 2

0.50 foot pervious concrete on 0.70 foot Class 4 AB

Option 3

PICP on 0.35 foot Class 3 permeable material over 0.70 foot Class 4 AB reservoir layer

6. Parking area for passenger vehicles including trafficked area

Option 1

Design per procedures in HDM Topic 633. Use $G_f=0$ for OGFC, $G_f=1.4$ for ATPB, and $G_f=1.0$ for Class 4 AB. Use TI values from HDM Table 613.5B for all auto parking areas.

Option 2

0.50 foot pervious concrete on 0.50 foot Class 4 AB. If R-value is less than 25 add 0.20 foot base.

Option 3

PICP on 0.35 Class 3 permeable material over 0.50 foot Class 4 AB . If R-value is less than 15 add 0.20 foot base.

Category C

7. *Parking area for heavy vehicles (e.g. rest area on highway with AADTT > 3000)*

$TI \leq 9$ (See Note)

Option 1

Design per procedures in HDM Topic 633. Use $G_f=0$ for OGFC, $G_f=1.4$ for ATPB, and $G_f=1.0$ for Class 4 AB.

Option 2

0.70 foot pervious concrete on 0.70 foot Class 4 AB.

Option 3

PICP on 0.35 foot choke course over 2.00 foot Class 4 AB

$TI \geq 9.5$

Use a non-pervious paving material. Utilize current procedures in HDM to design.

8. *Bus Stop Pads*

0.80 foot pervious concrete on 0.70 foot Class 4 AB.

Note:

In trafficked area that gets more than 2000 trucks per day, average, use a non-pervious paving material. Water from non pervious area may flow to pervious area. Grading plane of subgrade below Class 4 AB must be below AB of adjacent pavement. Class 4 AB may be placed under non pervious pavement. Slope of grading plane of subgrade material should be zero percent. Place a polypropylene fabric on vertical interface between base of non-pervious pavement and the pervious structural section.

REFERENCES

REFERENCES

Highway Design Manual (HDM), Current Edition, California Department of Transportation.

Infiltration Basins Design Guidance, dated February 2011, California Department of Transportation, Division of Design, Office of Storm Water Management.

Infiltration Trenches Design Guidance, dated September 2011, California Department of Transportation, Division of Design, Office of Storm Water Management

Low Impact Best Management Practice (BMP) Information Sheet. 2008. Weston, MA: Charles River Watershed Association.

Permeable Interlocking Concrete Pavements, Fourth Edition 2011, Interlocking Concrete Pavement Institute, Herndon, Virginia.

Project Planning and Design Guide (PPDG), July 2010, California Department of Transportation (CTSW-RT-1.0-254.03).

Research Report – Laboratory Testing and Modeling for Structural Performance of Fully Permeable Pavements Under Heavy Traffic: Final Report, dated November 30, 2010, U.C. Davis, Department of Civil and Environmental Engineering (CTSW-RT-10-249.04).

VA DCR Stormwater Design Specification No. 7, Permeable Pavement Ver. 1.6, dated September 30, 2009, Department of Conservation and Recreation, Richmond, Virginia.

APPENDIX

1. CONSTRUCTION CONSIDERATIONS

When preparing to construct each type of pervious pavement, evaluate how the construction of the overall project could affect the ultimate performance of the pavement. Be sure to review and install the selected type of pervious pavement in accordance with current industry standards.

Protect the pervious pavement from adjacent stormwater runoff areas. This is especially critical if the adjacent areas are unpaved. These areas could introduce sediment-laden stormwater to flow onto the pavement, potentially clogging the surface and filling the voids in the reservoir. Temporary stormwater controls should remain in place until all disturbed areas that could reach the pervious pavement are stabilized.

If the pervious pavement is required to be constructed before completion of the project (building and fire codes commonly require hard surfaces to be in place before structures are constructed), the pervious pavement should be protected in place. Consider placing a geotextile fabric on the surface to protect the pavement from construction debris and vehicles. The fabric may require stabilization with a thin layer of clean aggregate over it to prevent wrinkling when trafficked by vehicles.

1.1 Preparation and Placement

Refer to the specifications ([click on this web link to download](#)) and Usage Notes for Pervious Pavement nSSPs & Recommended Minimum Pavement Structures (see Appendix 3) developed by the Caltrans Pavement Program for pervious pavement applications .

The following applies to preparation and placement of the reservoir and pervious pavement materials

1.1.1 Subgrade

- A compaction range has been predetermined. The lower end has been set by Caltrans Pavement Program and the upper limit by Design with Construction concurrence. The intent of the range is to allow the Contractor to excavate the material while maintaining the soil permeability of the site to an acceptable rate.
- If area to be paved with pervious pavement exceeds the upper limit of relative compaction, the contractor must remove over compacted material and recompact to between the specified limits, preferably to the lower limit.
- If fill material is required underneath the reservoir layer to meet the finished grade, it should consist of additional reservoir material and not compacted soil. No fill materials should be allowed on sides of the pervious pavement and/or the reservoir layers unless properly designed. Some type of barrier may be necessary.

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It is in the best interest of the contractor to do the following to maintain the soil permeability during construction:

- Protect the site area from construction equipment that could reduce insitu permeability.
- Keep all traffic off the subgrade during construction to the maximum extent practical.
- Avoid using equipment with narrow tires.

1.1.2 Reservoir

- Exercise care to avoid damage to the geotextile during placement of the aggregate for the reservoir.
- The PICP Class 3 permeable material over the top of the reservoir material will stabilize the surface for the paving equipment. The purpose is to fill some of the surface voids created when using larger rock in the reservoir layer and help lock up the aggregate. Some of the large rocks may be visible after the Class 3 permeable material has been placed and compacted.

1.1.3 Pervious Asphalt

- Do not apply tack coat prior to placement of OGFC
- Do not apply prime coat prior to placement of ATPB

1.1.4 Pervious Concrete

- The water content of pervious concrete mix can have a dominant impact on performance and should be strictly controlled.
- Laboratory testing should be performed to estimate field unconfined compressive strength based on relationship between voids and unconfined compressive strength.
- The curing should happen within a time period so that the surface does not dry out. This is critical and there should be NO exceptions. If this is not enforced, the pervious concrete structural capacity will be significantly diminished and early deterioration of the pervious concrete is expected.
- The curing membrane should extend far enough beyond the edge of the paved area to enable adequate securing of the edges. The edges must be held down to prevent air circulating under the membrane and removing curing moisture. The weights used to hold the edges down can be boards held down with sand bags or sand bags alone. Unconfined soil is not allowed because it could contaminate the pervious concrete and reservoir layers. Stapling the curing membrane to wooden forms has been successful. Care must be taken to not pierce the membrane.
- Securing the curing membrane is essential. The contractor should designate staff to visit the site on a daily basis at a minimum, including weekends and holidays, to verify the membrane is secure. If the pervious concrete is not covered for the full 7 calendar days, the pervious concrete structural capacity will be diminished and the

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pavement may begin to ravel shortly after installation. The only exception to interrupting the covering during the 7 calendar day curing period is constructing the joints.

- Saw cut material should be removed by sweeping and vacuuming. While the pavement is uncovered for saw cutting, the exposed area should be kept wet with a continuous supply of water.
- National Ready Mixed Concrete Association (NRMCA) certified personnel are required. The installation and curing of pervious concrete is different from conventional PCC. The following are critical items that should be inspected, checked, and/or considered during construction of a pervious concrete project:
 - Unit weight is critical in the mix design for pervious concrete.
 - Hydration stabilizers are recommended for the mix.
 - Pervious concrete mixtures cannot be pumped.
 - The wind velocity should be checked prior to placing pervious concrete, similar to conventional PCC.
 - Placement must be continuous.
 - Spreading and strike-off must be rapid.
 - Do not use bull floats, darbies, or trowels except for edging or small touchup areas.
 - Edge forms are recommended.
 - Loose sand or dirt to hold curing plastic sheeting in place is not allowed.
 - The pervious concrete should appear moist during the 7 calendar day curing period.
 - Drying shrinkage of pervious concrete develops sooner, but is much less than conventional concrete.
 - Air entrainment of the cement paste is required in areas where the pavement may become susceptible to freeze thaw conditions.

1.1.5 Permeable Interlocking Concrete Pavement

- The reservoir layer consists of Caltrans Class 4 AB and varies in thickness depending on traffic and water storage requirements. The PE will determine the thickness of the reservoir layer. The SSP includes compaction requirements.
- Curbs are typically cast on the compacted reservoir layer. If curbs are cast on top of the reservoir, water will be able to flow underneath the curb. If needed a deeper curb may be cast to completely separate the reservoir from the adjoining soil or impervious pavement base.
- Concrete pavers are placed manually or with the assistance of machines to accelerate construction time.
- Cut pavers should be no less than 1/3 of a whole paver at edges around protrusions in the pavement.

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- After all of the pavers are placed, the joints are filled with small, washed stones, No. 89 (3/8 inch max) or 9 (No. 4 sieve max) aggregates. Pavers with joints less than ¼ inches will use No. 89 or No. 9 aggregate per Caltrans nSSP Section 40-9.
- Once an area has the joints filled, the surface is swept clean and the pavers are compacted twice with minimum 5,000 lbf plate compactor.
- The SSP provides tolerances on joint straightness and height above curbs after compaction.
- Once compaction is complete, joints may require some refilling of aggregates.
- After sweeping the surface clean, it is ready to accept traffic.
- Maintenance should inspect the surface within 3 to 6 months of the completion of the original contract to determine if the surface requires additional repairs. If repairs are required a separate contract may be necessary.
- Personnel holding a PICP Installer Technician Course certificate are required. The installation of PICP is different from regular interlocking concrete pavements with sand joints and a dense-graded base.
- The following are critical items that should be inspected, checked, and/or considered during construction of a PICP project.
 - Concrete Pavers meet ASTM C936 standards per manufacturer's test results
 - Class 3 permeable material consisting of maximum 1 inch stone size.
 - Elevations, slope, laying pattern, joint widths, and placement/compaction need to meet drawings and specifications
 - No cut paver is less than 1/3 of a whole paver
 - All pavers within 6 feet of the laying face must be fully compacted at the completion of each day
 - Surface tolerance of compacted pavers complies with SSP requirements.
 - Surface swept clean at finish
 - Elevations and slope(s) conform to drawings
 - Transitions to other paved areas separated with edge restraints
 - Surface protected from adjacent construction activities and potential sediment laden water
 - Adjacent vegetation stabilized to prevent erosion onto pavement surface

2. MAINTENANCE GUIDELINES

2.1 Maintenance

Maintenance requirements are for Caltrans or other entity through a Maintenance Agreement. It's often in the best interest of local governments or agencies to care for the facility via a Maintenance Agreement if proposed pervious pavement will require specialized care, or equipment. Early communication between Caltrans and local partners can help define respective needs, abilities and limitations.

The primary goal of pervious pavement maintenance is to prevent the pavement surface, reservoir, and/or underlying soil (infiltration bed) from being clogged with sediments. To keep the system clean throughout the year and prolong the pervious pavement life span, the pavement surface should be inspected, tested as described below, and, if necessary, vacuumed twice a year. These systems have the potential of pushing the sediments further down into the pervious layer, and can also damage the pervious pavement.

Although the mechanical brooms used by Caltrans have a vacuum action, fine mineral and organic material is collected and tends to clog the surface of the pavement and reduce its permeability. Consequently, the mechanical broom equipment used will probably not significantly prevent clogging of permeable pavements. It is recommended that low-pressure cleaning/vacuuming equipment be used annually to clean the pavement surface.

The annual maintenance schedule for pervious pavement was determined from a study performed by the U.S. EPA³, which suggests vacuum sweeping twice per year. The cost of vacuum sweeping is about \$400 to \$500 per year per half acre in total⁴.

If pervious pavement is installed for stormwater management, Caltrans is obliged to keep it functioning effectively as designed. This requires a Caltrans staff commitment to verify performance. To determine whether the pervious pavement is functioning, it should be tested when Maintenance determines there may be a problem with infiltration using ASTM C1701 Standard Test Method for Infiltration Rate of In Place Pervious Concrete. A minimum tested infiltration rate of 10 inches per hour indicates that the system is approaching a near-clogged condition. This test can be used to determine and schedule maintenance. The best indicator if the pavement is working is inspecting after a rain event.

Control of sediment is important to maintain the permeability of pervious pavements. Sediment control measures should be installed, and maintained to prevent sediment deposition on the pervious pavement surface. Planted areas adjacent to pervious pavement

³ Storm Water Technology Fact Sheet for Porous Pavement. 1999. Washington, DC: U.S. Environmental Protection Agency, Office of Water. (EPA 832-F-99-023)

⁴ Low Impact Best Management Practice (BMP) Information Sheet. 2008. Weston, MA: Charles River Watershed Association

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should be well maintained to prevent soil washout onto the pavement. Curbs can be used to mitigate potential washouts on the pervious pavement. If any washout does occur it should be cleaned off the pavement immediately to prevent further clogging of the pores. Furthermore, if any eroded areas are observed within the vegetated areas, they should be replanted and/or stabilized at once. Planted areas should be inspected on a semiannual basis. All trash and other litter that is observed during these inspections should be removed.

Superficial dirt does not necessarily clog the pavement voids. However, dirt that is ground in repeatedly by tires can lead to clogging. Therefore, trucks or other heavy vehicles should be prevented from tracking or spilling dirt onto the pavement. In addition, all construction or hazardous materials carriers should be prohibited from entering a pervious pavement area.

Immediately after large storm events, the surface of the pervious pavements should be inspected for ponding, as this is an indication that the pervious pavement may be clogged. Clogging typically occurs near the pavement surface. If the surface is slow draining, high performance vacuum equipment may restore the permeability and should be tried first. For PICP, the jointing aggregate and dirt can be removed with high-powered vacuum equipment and the openings re-filled with clean aggregate. A last resort option is to replace the pervious pavement while leaving the reservoir layer intact.

Where Maintenance determines a spill has occurred that may have environmental consequences the spill should be contained to limit the contaminated area of the pervious pavement section. Repairs should be done in a timely manner to remove the contamination completely.

PAP and PCP are repaired with like material and consideration should be given to the effect of the pavement repair on the overall permeability of the pervious pavement. Do not apply seal coats to pervious pavements. Any required repair of drainage structures should be done promptly to ensure continued proper functioning of the system. For PICP, damaged paving units can be replaced with whole units after leveling and compacting the reservoir layer and leveling the bedding layer. When reinstated, the pavers with filled joints should be ½ inch higher than the surrounding undisturbed pavers and the reinstated pavers compacted until their surface is level with the undisturbed surfaces.

Post a sign at pervious pavement sites to alert grounds keeping and Maintenance personnel to

- keep silt and debris from entering onto the pervious pavements
- not seal the pavement, and
- not use sand or other abrasives for snow or ice conditions because they reduce permeability.

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- observe the pavement surface for signs of sediment or organic debris accumulation and remove at early stages by vacuuming.
- use high performance, regenerative air vacuum equipment to clean surface regularly and not mechanical broom type.

Note that pervious pavements are less likely to ice since snowmelt immediately drains downward into the pavement rather than remaining on the surface. In addition, these signs can include some educational information regarding the advantages of pervious pavements.

The following maintenance issues should be part of the maintenance program.

- Check for standing water on the pavement surface after storms. Inspect after at least one major storm event per year.
- Repair ruts or deformations in pavement exceeding ½ inch.
- Pervious concrete may generate loose gravel over time. The loose gravel on the surface from raveling should be vacuumed. Schedule a vacuum sweeper (no brooms or water spray) at least twice a year. A typical hand held push broom is allowed to sweep small areas of loose gravel.
- Random cracks should not be sealed.
- Under no circumstance should the pavement surface ever be seal coated.
- Scuffing can occur on pervious concrete and pervious asphalt, and does not require maintenance.
- Maintain vegetation around pavement to filter runoff.
- How to deal with spills and repairs.

The following are suggested annual maintenance inspection points for pervious pavements:

- The drawdown rate should be measured at the observation well for, typically, three to four days (i.e., use the designed drawdown time) following a storm event equivalent to the designed storm event. Design shall provide Maintenance with the designed drawdown time including the design storm event depth of the reservoir layer. If standing water is still observed in the well, this may be a sign that clogging is a problem. Maintenance should contact Design to determine a feasible solution.
- Inspect the surface of the pervious pavement for evidence of sediment deposition, organic debris, staining or ponding that may indicate surface clogging. If any signs of clogging are noted, use hand brooms (for small areas), vacuum sweeper, or pressure washer vacuuming depending on the amount of deposited material. Test sections by pouring water from a five gallon bucket to ensure infiltration.
- Inspect the structural integrity of the pavement surface, looking for signs of surface deterioration, such as slumping, cracking, or spalling. Replace or repair affected areas.

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- Inspect inlets, pretreatment BMPs and any flow diversion structures for sediment buildup and structural damage. Perform standard maintenance procedures.
- If installed inspect the condition of the observation well and make sure it is still capped.

Striping of PAP and PCP typically takes twice the amount of paint as conventional PCC. Striping is generally improved with the use of a primer prior to placement of the actual colored striping.

3. USAGE NOTES FOR PERVIOUS PAVEMENT nSSPs & RECOMMENDED MINIMUM PAVEMENT STRUCTURES

3.1 Usage Notes for Pervious Pavement nSSPs

Use these specifications and specification modifications when pervious pavement is desired. Currently only Pervious Concrete Pavement and Permeable Interlocking Concrete Pavement are available for use. Pervious Asphalt Pavement is under development by Pavement Program, Office of Asphalt Pavement, Peter Vacura, Chief.

Subgrade

Section 19

2 SSPs

19-5.03B - Removes areas under pervious pavement from 95% relative compaction requirement.

19-5.03C - Sets compaction limits for areas under pervious pavement.

Use as many of these as deemed appropriate according to the permeability of the underlying soil as determined during design investigations.

Base

Section 26 (Aggregate Base)

1 nSSP

nSSP_26 - Creates Class 4 AB

Use Class 4 AB when a reservoir layer is required or if the pavement will be loaded by any heavy vehicles. Class 4 AB is probably not required under bike paths or pedestrian paths for structural support. Where required use 6 inches over soil with R-value of 25 or more otherwise use 8 inches as minimums.

Section 29 (Asphalt Treated Permeable Base)

Use ATPB as structural layer for asphalt pervious systems. No modification to existing standard specifications is required.

Section 68

1 SSP

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SSP 68-5 (Permeable Material Blanket)

Use between PICP and Class 4 AB. Edit SSP to use Class 3 permeable material and remove references to filter fabric.

Asphalt Surfaces

Section 39 (Open Graded Friction Course)

Use OGFC as the non-structural wearing course for asphalt pervious systems. No modification to existing standard specifications is required.

Concrete and Concrete Paver Surfaces

Section 40

2 nSSPs

40-9 - Pervious Concrete Pavement - Sets paving requirements for PCP; requires that 90-7 also is used in special provisions.

40-10 - Permeable Interlocking Concrete Pavement - defines materials and placement requirements for PICP and will normally have Class 4 AB under it.

Section 90

1 nSSP

90-7 - Creates pervious concrete.