Pervious Pavement Design Guidance

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California Department of Transportation
HQ Division of Design
https://dot.ca.gov/programs/design/hydraulics-stormwater/treatment-bmp-design-guidance

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List of Acronyms

AB	Aggregate Base
ASTM	American Society for Testing and Materials
ATPB	Asphalt Treated Permeable Base
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
Mr	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
OHSD	Office of Hydraulics and Stormwater 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

Section 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. The intent was to have consistent guidelines and standards, if a pervious pavement installation was ultimately chosen. A major concern related to pervious pavement is maintainability. Prior to implementing pervious pavement into a contract within Caltrans right of way, concurrence is needed from the Office of Hydraulics and Stormwater Design (OHSD)and the Division of Maintenance. Maintenance wants to be assured that a long term maintenance plan has been developed or a maintenance agreement has been formalized.

When considering pervious pavement for stormwater treatment, 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

This guidance was developed with the understanding that only those project examples listed in Categories A, B & C (listed as Low Risk) would be considered at this time. Categories D and E are currently not candidates for pervious pavement 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 Hydraulics and Storm Water Design (OHSD).

1.2 Definition

Pervious pavements allow stormwater to filter through voids in the pavement surface into an underlying rock 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 to promote stormwater infiltration and improve the quality of stormwater runoff. It is typically designed to capture rainfall on the pavement surface area, but may also accept run-on from adjacent impervious areas and other hardscapes (sidewalks), rooftops, or gutters. 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 a LID technique, the use of landscape and soil-based BMPs to treat storm water runoff is still considered first. Life cycle cost, site feasibility, and the overall water quality benefits need to be evaluated when determining which BMPs will be used.

Section 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 Infiltration Devices 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:

- Soil 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 vacuuming to maintain the hydraulic function.
- Pavements regularly receive winter sanding. Seal coating or repaving are not appropriate for pervious pavements.

Contaminated Soil or Groundwater Consideration:

Refer to the environmental document Initial Site Assessment for potential soil and groundwater issues that may affect the siting of Porous Pavement BMPs. Consult with the District Hazardous Waste Unit and NPDES coordinator on appropriate siting. If the project includes ADL soils that will be reused or are determined to be in the project location, the Caltrans Soil Management Agreement for Aerially Deposited Lead-Contaminated Soils and all associated regulations must be followed. Porous Pavement does not meet the definition of a “pavement structure” under the ADL agreement because it infiltrates water by design and does not provide an impermeable cap. The ADL agreement can be found at this link: https://dtsc.ca.gov/caltrans/

Also, consider the following criteria.

- Determine if pervious pavement is 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, unless it can be coupled with upstream practices to achieve 100% WQV.
- 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.
- 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.
- Avoid placing in areas where wind erosion could supply a significant amount of windblown sediment or where offsite sediment laden storm water cannot be eliminated. This may require additional surface cleaning efforts.
- Provide a concrete curb and/or a concrete curb and gutter for edge support. These barriers can also keep unwanted sediment off the pavement. See Figure 2-1 and 2-2.
- Place a PCC strip between pervious pavement and asphalt pavement. A modified Caltrans curb (Type A1 or B1) may be used. See Figure 2-3.
- 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 at the reservoir invert. An exception would be for use on a maintenance access road.
- Slope designs for the surface of the pervious pavement should be in accordance with the HDM. 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.
- Include typical surface drainage based on peak flow design with no planned attenuation by pervious pavement/reservoir.
- Consider designing the inlet grate openings for large pervious pavement areas that contain surface inlets in the interior, the resulting flow at the downstream end of these areas may resurface.
- 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 5.3.2 Site-Specific Determination of Feasibility of the PPDG https://dot.ca.gov/programs/design/manual-project-planning-design-guide

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. https://dot.ca.gov/programs/design/hydraulics-stormwater/treatment-bmp-design-guidance

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 infiltration 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 3.3.2 Part B of Caltrans Infiltration Basins Design Guidance. Both tests can be found at this site: https://dot.ca.gov/programs/engineering-services/california-test-methods

- CT 231 Method of Test for Relative Compaction of Untreated and Treated Soils and Aggregates Using Nuclear Gage - 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 is performed. One of the tests should be of the native soil condition. The PE should coordinate with Caltrans Geotechnical Services since there is considerable variation of subgrade soils.

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

The Geotechnical Services Office should include these additional test results in the Geotechnical Summary Report.

The intent of performing these tests is to ensure that the pavement design has adequate stiffness and strength to carry the predicted traffic loads during the design life.. 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 Analysis and Typical Cross Sections

Table 2-1. Cost Analysis

PCP[1]	PAP[1]	PICP[1]
$ 15 to $40/sf	$ 11 to $38/sf	$36 to $53/sf
Pervious Concrete – $600/CY	HMA (OGFC) - $530/CY	Conc Pavers - $55/SF
Class 4 AB - $200/CY	ATPB- $280/CY	Sand Bedding- $300/CY
	Class 4 AB - $200/CY	Class 3 AB - $225/CY
		Class 4 AB - $200/CY

The costs described in Table 2-1 are for planning purposes only. All three types PCP, PAP, and PICP costs are based on 2023 data, and should be adjusted based on current construction cost trends and specific project thicknesses.

[1] Based on Caltrans Cost Data Base for each item, July 2023, assumed max depth of 4 feet for each.

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.

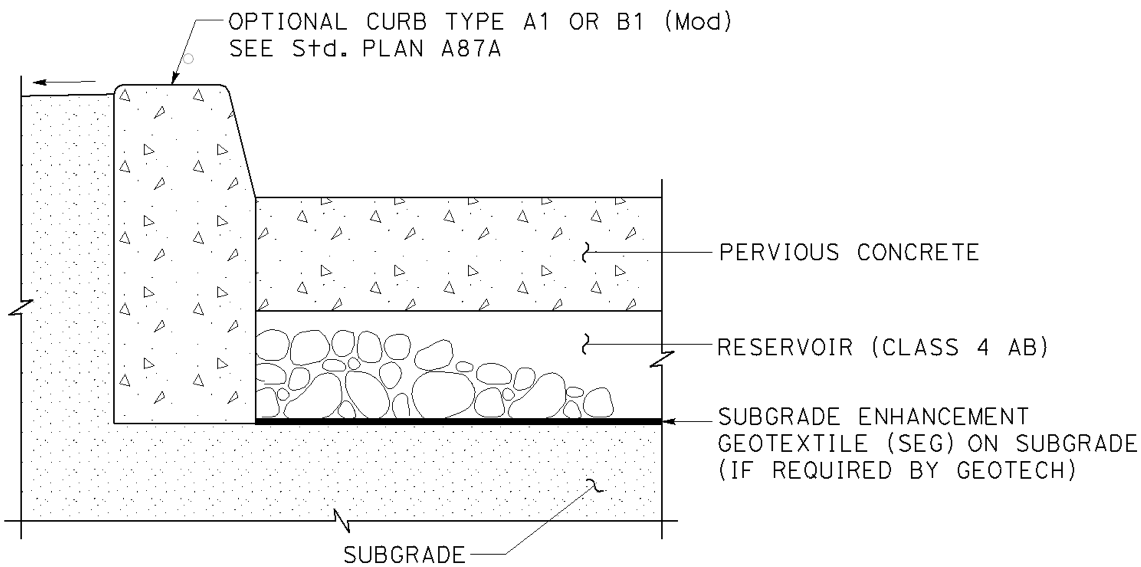

Figure 2-1. Pervious Concrete Pavement (PCP) Typical Section

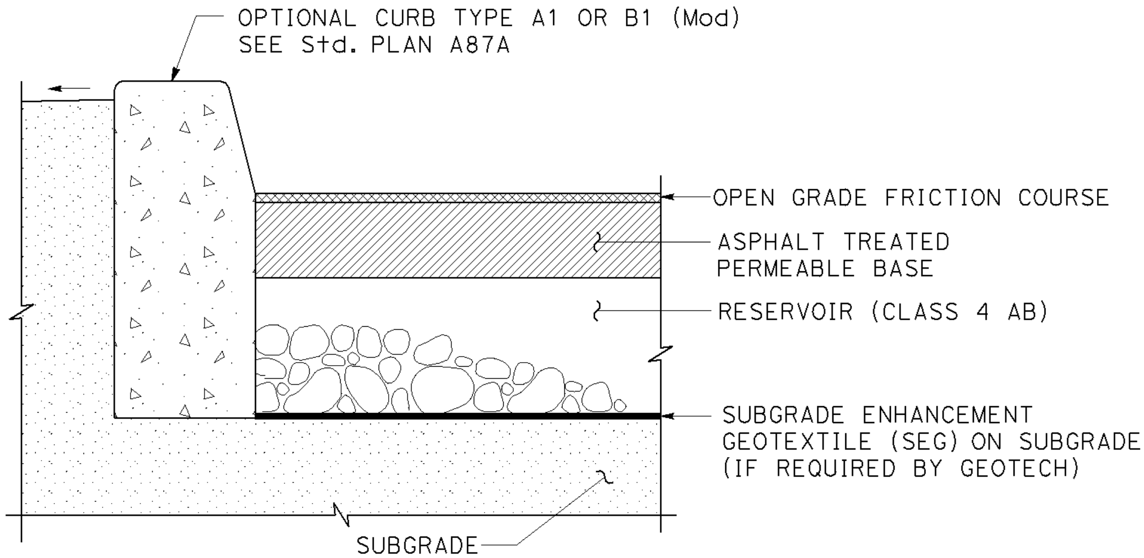

Figure 2-2. Pervious Asphalt Pavement (PAP) Typical Section

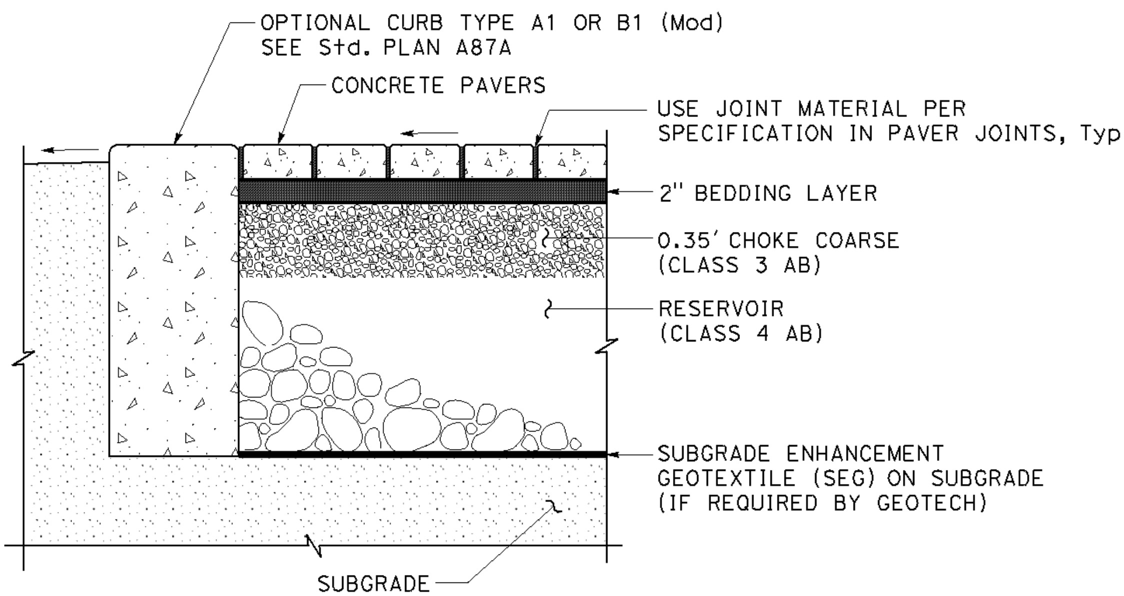

Figure 2-3. Permeable Interlocking Concrete Pavement (PICP) Typical Section

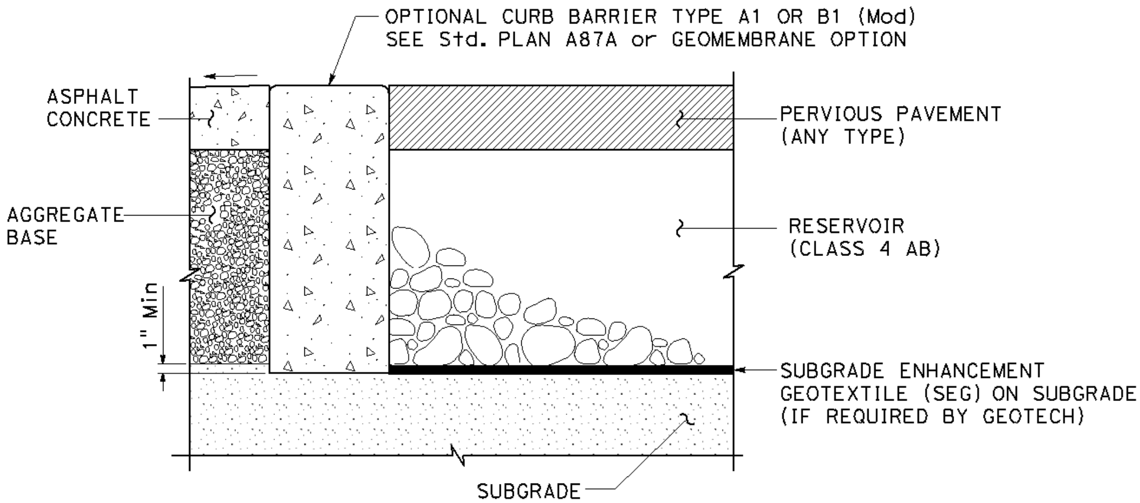

Figure 2-4. Barrier Between Pervious Pavement and Asphalt Concrete Pavement

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, maybe only a portion of a parking lot needs to have pervious pavement, such as the parking stall areas, to be in compliance with stormwater requirements. The impervious surface areas could be designed to slope onto the pervious pavement surfaces. See Figure 2-4 for a transition between pervious and impervious pavements.

Another use of the curb shown in Figure 2-4 would be for an existing pavement section that is retrofitted to use a pervious pavement. Retrofits can be considered when the existing pavement is sloped towards the proposed pervious pavement.

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.

Section 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. 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.

OHSD developed a Reservoir Design Tool to size the reservoir layer https://design.onramp.dot.ca.gov/pervious-pavement using equations from several referenced Caltrans design guidance documents and methodology outlined below. The depth of the reservoir layer based on OHSDs Reservoir Design Tool can be compared to the depth developed by the Pavement Program (see Section 4). The final reservoir layer will be the larger of the two designs. (Note: A pervious pavement design example has been developed and is included in the tool.)

Table 3-1 has been developed as a means to evaluate the reservoir depth based on infiltration rates and Water Quality Depth.

Information required prior to using Table 3-1:

- WQ Depth = Water Quality Depth from Basin Sizer
- k_c = infiltration rate used to set the upper compaction limit of site area discussed in Section 2.2

Design factors used in Table 3-1:

- The entire pavement area is pervious.
- The table values use a void ratio of 0.3 and a drawdown time of 72 hours. See equations below.
- Values for K_{min} have been calculated for WQ depths (half inch increments) and Reservoir Depths (0.1 foot increments)
- The WQ depths shown are within the range of values found in California based on the 85th percentile 24-hour storm event. Typical values are between 0.5 to 1.5 inches.
- The final reservoir depth should be rounded up to the nearest 0.1 feet.
- Interpolating the values between the rows is acceptable.

The following methodology outlines the steps needed to use Table 3-1.

Step 1: Determine the reservoir depth based on WQV requirements:

d = WQ Depth / 0.30

Where:

d = depth of the reservoir layer (ft)
WQ Depth (ft) (calculated by *Basin Sizer* (in))
0.30 = void ratio of reservoir layer

Use Table 3-1 to find the reservoir depth associated with the WQ Depth.

Step 2: Determine the infiltration rate based on the reservoir depth (calculated in Step 1) and the drawdown time.

k = d / t x C x SF x 0.30

Where:

k = minimum infiltration rate based on depth of reservoir (in/hr)
d = depth of the reservoir layer (ft) (from Step 1)
t = drawdown time (typically 72 hours)
C = conversion factor (12 to convert from inches to ft)
SF = safety factor of 1.0
0.30 = void ratio of reservoir layer

Use Table 3-1 to find the minimum infiltration rate associated with the reservoir depth (from Step 1) and drawdown time.

Step 3: Determine k_c (infiltration rate used to set the upper compaction limit of site area discussed in Section 2.2). If k_c is not available, determine the project's Hydrologic Soil Group(s) shown on NRCS soil surveys. Once the soil type(s) has been determined use typical infiltration rates associated with the HSG.

Step 4: Compare the infiltration rates determined in Steps 2 and 3. Verify that the infiltration rate from Step 3 is greater than Step 2. This condition means that the WQ depth (WQV per square foot) can infiltrate into the soil within the given drawdown time. When the infiltration rate cannot drain the WQ Depth in the specified drawdown time, the site should be eliminated.

Step 5: Determine the reservoir depth based on the pavement structural design requirements in Section 4.3.5.

Step 6: Compare Step 1 (rounded up to the next half tenth of a foot, 0.05 ft) and Step 5. The final reservoir layer will be the greater of these compared depths.

Table 3-1. Hydrology Reservoir Design for Small Storm Events

Void Ratio	Drawdown Time (hrs)	K_{min} to Drain Reservoir Depth in Drawdown Time (in/hr)	HSG Class	WQ depth (in)	Reservoir Depth (ft)
0.3	72	0.007	D	0.5	0.14
0.3	72	0.010	D	0.72	0.20
0.3	72	0.014	D	1	0.28
0.3	72	0.015	D	1.08	0.30
0.3	72	0.020	D	1.44	0.40
0.3	72	0.021	D	1.5	0.42
0.3	72	0.025	D	1.8	0.50
0.3	72	0.028	D	2	0.56
0.3	72	0.030	D	2.16	0.60
0.3	72	0.035	D	2.5	0.69
0.3	72	0.035	D	2.52	0.70
0.3	72	0.040	D	2.88	0.80
0.3	72	0.042	D	3	0.83
0.3	72	0.045	D	3.24	0.90
0.3	72	0.049	D	3.5	0.97

Note: If PICP is the surface, the reservoir Depth indicated may be reduced by 0.11 ft before rounding.

Additional information:

The elevation of the invert of the reservoir layer:

- should be no greater than ft below the original ground surface (as costs increase greatly with the depth and the potential need for shoring)
- must provide the required minimum 10 foot groundwater separation (otherwise consultation with Regional Water Quality Control Board may be required)

The licensed engineer performing the drainage design should document any additional reservoir storage capacity above the minimum required WQ depth. The added storage can provide additional benefits to minimize downstream effects. This information should be documented in the Storm Water Data Report and drainage report. Some projects may be able to store the design storm event at minimal additional costs, which may provide savings in the cost of the underground storm drain system (e.g., pipes, and drainage inlets).

There are occasions when only a portion of the pavement area is designed to be pervious pavement such as in a parking lot where it may be desired to place the pervious pavement in the parking stall areas only.

Follow these steps for this type of application:

Step 1: Calculate the WQV

WQV = WQ Depth x C x A

Where:

WQV = Water Quality Volume (ft^3)

WQ Depth (ft) (calculated by *Basin Sizer* (in))

C = runoff coefficient [2]

A = the tributary area (ft^2)

Step 2: Calculate the excavated volume for the reservoir layer:

EV = WQV / 0.30

Where:

EV = excavated volume (ft^3)

WQV = Water Quality Volume (ft^3)

0.30 = porosity of reservoir layer

Step 3: Calculate the invert area based on desired depth to fit site conditions:

A_{inv} = EV / D

Where:

A_{inv} = area of invert (ft^2)

EV = excavated volume (ft^3), and

D = depth of the reservoir layer (ft)

Step 4: Calculate the width to fit site conditions:

W = A_{inv} / L

Where:

A_{inv} = adjusted area of invert (ft^2)

L = length of pervious pavement (ft)

W = width of pervious pavement (ft)

Step 5: Calculate the minimum invert area and verify it is less than the invert area calculated in Step 3. If not, adjust reservoir depth, width, and length in Steps 3 and 4.

$A_{inv\ min}$ = C x SF x 0.30 x WQV / (k_c x t)

Where:

C = conversion factor (12 to convert from inches to ft)

SF = safety factor of 1.0

0.30 = void ratio of reservoir layer

WQV = Water Quality Volume (ft^3)

[2] C value will vary based on treatment area, this example uses 1 (slightly conservative for the partial pervious pavement design)

k_c = infiltration rate used to set the upper compaction limit of site area discussed in Section 2.2

t = drawdown time (typically 72 hours)

3.3 Material Specifications

Caltrans Pavement Program has developed non-standard specifications nSSPs for pervious pavement bases (i.e., reservoir layer), PCP, PAP, and PICP

Until adopted as standard, these specifications must go through Caltrans OHSD for approval to be used on any project within Caltrans right-of-way. Follow the sponsor request and concurrence process (http://www.dot.ca.gov/hq/oppd/stormwtr/nssp.htm).

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

- Maintenance Pavement Program,
- OHSD Geotechnical,
- District Storm Water Design and Storm Water Coordinator, and
- Maintenance

Each function plays a role in the success of the pervious pavement implementation. It is the PEs 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 OHSD 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 any recommended compaction numbers.

Section 4

Pavement Structural Design

4.1 Materials and Mix Design

Caltrans Pavement Program developed specifications for pervious pavement on the OHSD website.

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 613.4, specifically Table 613.4A.

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 from this guidance must be discussed with the OHSD and headquarters Pavement Program, 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 Resilient Modulus (M_r) of soil in accordance with HDM Topic 614 and other applicable discussions for concrete and asphalt pavements. The Resilient Modulus (M_r) is used in Caltrans CalME flexible pavement design method to determine thicknesses for reservoir and surface layers for PAP and PICP. Consult District Materials Engineer if soil meets Subgrade Type 3 on Table 623.1A of the HDM (USCS CH with Plasticity Index – PI >12 or M_r is less than6) for suitability of site for pervious pavement and possible design modifications. There is a comparison table in

Chapter 630 of the HDM Table 633.1B of USCS, M_r, and R-Value to roughly estimate between them.

Place a subgrade enhancement geotextile fabric between the subgrade soil and the bottom of the reservoir layer, only if recommended by Caltrans Geotechnical Services. A fabric may help reduce fine materials from migrating into the reservoir. Do not increase the M_r in the design calculations (HDM Index 614.5 does not apply to pervious pavement).

4.3.3 Reservoir Layer

The reservoir layer is a reservoir for the storage of storm water and it is the structural support for the surfacing, when needed. Use Class 4 AB for reservoir layer.

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

- Pervious Asphalt

  For pervious asphalt design the reservoir thickness based on procedures for new pavement in HDM Topic 633. Required structural base layer depth should be requested from the District Materials Engineer (ME) who will calculate it using the CalME software. Class 4 AB is one of the possible material types in the CalME program.

  Once you have the required structural thickness from the District ME and can determine the Reservoir layer required for the WQV.
- Pervious Concrete

  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 M_r is less than 14 (R-value less than 25).
- Permeable Interlocking Concrete Pavement

  For PICP, determine the subbase thickness using the following steps:

  – (1) Determine the lifetime 18,000 lb. equivalent single axle loads or Traffic Index (TI) on the pavement.

  – (2) Determine the M_r of the subgrade in a saturated condition.

  – (3) Find the Caltrans Water Quality Planning Tool on http://svctenvims.dot.ca.gov/wqpt/wqpt.aspx

  Turn on map layer named 'Monthly Precipitation' by checking the appropriate box on the left of the screen. Using the California map located on the right side of the screen zoom into the project site area or use the Postmile Lookup tool located at the upper right hand corner of the screen. Once the site is located click on the nearest monthly precipitation icon (blue rain drop) nearest to the project site and a box marked 'Monthly Precipitation' should appear. This box presents a chart with the number of days per month and days of annual rainfall over 0.1 inches and 0.5 inches.

– (4) Find the number of approximate wet days per year, days the reservoir has standing water in it.

  This number depends on the soil infiltration rate (Section 2). If the soil infiltration rate is 0.05 inches per hour or greater, use the annual number of days per year over 0.5 inches of rainfall. Apply that number to the top row on Table 4.1 labeled 'Number of Wet Days per Year.' The 0.05 inches per hour infiltration rate means that 0.5 inches of rainfall will be infiltrated in well less than 24 hours. This approach provides a safety factor for long-term subgrade clogging.

  If the subgrade infiltration rate is less than 0.05 inches per hour, then select the annual days for rainfall over 0.1 inches at the bottom of the chart shown on the Caltrans Water Quality Planning Tool and apply value to the top row of Table 4.1, 'Number of Wet Days per Year.'

  If there is runoff contributed to the PICP from adjacent surfaces, then add that depth to the rainfall depth and estimate the number of days required to infiltrate this water with the soil infiltration rate. Use this value as the number of wet days.

– (5) Determine the Class 4 AB thickness from Table 4-1 or using Equation 4-1. Under the appropriate column heading with the selected number days, find the applicable M_r or R-value modulus for the soil subgrade. If M_r fall between two values provided on the chart, use the lower M_r for selecting the thickness of the Class 4 AB. Note: Resilient Modulus (M_r)in psi = 1155 + 555 x R-value. R-values are rounded down to the nearest whole number.

  With the selected M_r follow that column downwards until it intersects with the row indicating the Traffic Index or ESALs. Select the Class 4 AB thickness in inches where the column and row intersects.

Table 4-1. PICP Class 4 AB thickness chart

Number of Wet Days per Year	10 or less				11 to 30			
M_r of Subgrade, MPa (R-value)	24 (4)	36 (7)	48 (9)	60 (13)	24 (4)	36 (7)	48 (10)	60 (13)
Lifetime ESALs (Traffic Index)	Minimum Class 4 AB Thickness (in) 1 in. Allowable Rut Depth							
50,000 (6.3)	6.0	→	→	→	→	→		
100,000 (6.8)	8.5	6.0	6.0	6.0	10.5	6.0	6.0	6.0
200,000 (7.4)	12.5	8.5	6.0	6.0	14.5	10.0	6.5	6.0
300,000 (7.8)	15.0	10.5	7.0	6.0	17.0	12.5	8.5	6.0
400,000 (8.1)	17.0	12.0	8.5	6.0	19.0	14.0	10.0	7.0
500,000 (8.3)	18.0	13.5	9.5	6.5	20.0	15.0	11.0	8.0
600,000 (8.5)	19.0	14.5	10.5	7.0	21.0	16.0	12.0	9.0
700,000 (8.6)	20.0	15.0	11.0	8.0	22.0	17.0	13.0	10.0
800,000 (8.8)	20.5	16.0	12.0	8.5	22.5	17.5	13.5	10.5
900,000 (8.9)	21.0	16.5	12.5	9.0	23.5	18.0	14.0	11.0
1,000,000 (9.0)	22.0	17.0	13.0	9.5	24.0	19.0	14.5	11.5

Table 4-1. PICP Class 4 AB thickness chart (continued)

Number of Wet Days per Year	31 to 50				51 to 90				91 or more			
M_r of Subgrade, MPa (R-value)	24 (4)	36 (7)	48 (9)	60 (13)	24 (4)	36 (7)	48 (9)	60 (13)	24 (4)	36 (7)	48 (9)	60 (13)
Lifetime ESALs (Traffic Index)	Minimum Class 4 AB Thickness (in) 1 in. Allowable Rut Depth											
50,000 (6.3)	7.0	6.0	6.0	6.0	8.5	6.0	6.0	6.0	9.0	6.0	6.0	6.0
100,000 (6.8)	11.5	7.0	6.0	6.0	13.0	8.5	6.0	6.0	13.5	9.5	6.0	6.0
200,000 (7.4)	16.0	11.5	7.5	6.0	17.0	13.0	8.5	6.0	18.0	13.5	9.5	6.0
300,000 (7.8)	18.0	13.5	9.5	6.5	20.0	15.0	11.0	8.0	20.5	16.0	11.5	8.5
400,000 (8.1)	20.0	15.0	11.0	8.0	21.5	16.5	12.5	9.5	22.0	17.5	13.0	10.0
500,000 (8.3)	21.0	16.5	12.0	9.0	23.0	18.0	13.5	10.5	23.5	18.5	14.0	11.0
600,000 (8.5)	22.0	17.5	13.0	10.0	24.0	19.0	14.5	11.0	24.5	19.5	15.0	12.0
700,000 (8.6)	23.0	18.0	14.0	11.0	25.0	19.5	15.0	12.0	25.5	20.5	16.0	12.5
800,000 (8.8)	24.0	19.0	14.5	11.5	25.5	20.0	16.0	12.5	26.5	21.0	16.5	13.5
900,000 (8.9)	24.5	19.5	15.0	12.0	26.0	21.0	16.5	13.0	27.0	21.5	17.0	14.0
1,000,000 (9.0)	25.0	20.0	15.5	12.5	27.0	21.5	17.0	13.5	27.5	22.0	17.5	14.5

Equation 4-1:

$$T_{AB4} = \frac{325.9 \log ESAL + 325.9 \log M_r - 373.3(\log M_r)^2 + 7.8\sqrt{d_w} + 62.5 * \log d_w - 1346}{304.8}$$

Where:
T_{AB4} = Thickness of the Class 4 AB (ft) (round up to next 0.05 ft; use 0.50 ft min)
ESAL = Equivalent single axel loading over the life of the pavement (1,000,000 Max)
M_r = Resilient modulus determined under AASHTO T307 (MPa)
d_w = Number of wet days per year as determined above (min 1)

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.

The minimum thickness 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 and consult the District Materials Engineer to provide minimum thicknesses.
  - The typical thicknesses are 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) consult District Materials Engineer.

- 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 2 inch bedding layer between 0.35 feet Class 3 ABcourse 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. 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 0.08 ft (1 inch) 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.

Verify the reservoir layer thickness is adequate for the required water storage volume.

4.4 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 2 inch thick bedding layer over a 0.35 foot thick Class 3 permeable material and no reservoir layer

4.5 Category B

- **Maintenance vehicle pull out**

MVP must be outside shoulder area. If Unified Soil Classification is CL, CH, OH, or OL or M_r is less than 14 (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 and gore areas**

Follow HDM 304 - Side Slopes.

Safety slope option (1:10 or flatter):

- 0.10 foot OGFC over 0.35 feet ATPB on 0.50 feet Class 4 AB
- 0.45 foot pervious concrete on 0.50 foot Class 2 or Class 4 AB.
- 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.

- **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

- **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

- **Parking area for passenger vehicles including trafficked area**

Option 1

Design per procedures in HDM Topic 633. Use TI values from HDM Table 613.4B for all auto parking areas.

Option 2

0.50 foot pervious concrete on 0.50 foot Class 4 AB. If M_r is less than 14 (R-value is less than 25), add 0.20 foot base.

Option 3

PICP on 0.35 foot Class 3 permeable material. Determine Class 4 AB minimum thickness by the procedure in section 4.3.3.

4.6 Category C

- **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.

Option 2

0.70 foot pervious concrete on 0.70 foot Class 4 AB.

Option 3

PICP on 0.35 foot Class 3 permeable material. Determine Class 4 AB minimum thickness by the procedure in section 4.3.3.

TI≥9.5

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

- **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 surface paving material. Water from non-pervious area may flow to pervious area. Grading plane of subgrade below Class 4 AB must be below Class 2 or 3 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 curb between dense graded structural section and the pervious structural section. (Figure 2-4)

Section 5

References

Development and HVS Validation of Design Tables for Permeable Interlocking Concrete Pavement, UCPRC-Research Report-2014-04, UC Davis, Department of Civil and Environmental Engineering.

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

Infiltration Basins Design Guidance, dated December 2020, California Department of Transportation, Division of Design, Office of Hydraulics and Stormwater Design.

Infiltration Trenches Design Guidance, dated December 2020, California Department of Transportation, Division of Design, Office of Hydraulics and Stormwater Design

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), June 2023, California Department of Transportation.

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 A: 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.

A.1 Preparation and Placement

Refer to the specificationshttps://design.onramp.dot.ca.gov/pervious-pavement 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

A.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.
- 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.

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.

A.1.2 Reservoir

- The reservoir layer consists of Caltrans Class 4 AB and varies in thickness depending on traffic and water storage requirements.
- Exercise care to avoid damage to the geotextile during placement of the aggregate for the reservoir.

A.1.3 Pervious Asphalt

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

A.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 pavement may begin to ravel shortly after installation.
- Saw cut material should be removed (water should not be of sufficient force or direction so as to wash the saw cutting debris in to the open voids) by sweeping and vacuuming.
- 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.

A.1.5 Permeable Interlocking Concrete Pavement

- 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.
- Curbs are typically cast on the compacted reservoir layer. If curbs are cast on top of the reservoir, water will flow underneath the curb. If needed, a polypropylene fabric can be used 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.
- After all of the pavers are placed, the joints are filled with small, washed stones, No. 8, No. 89 or 9 aggregates. Pavers with joints less than ¼ inches will use No. 89 or No. 9 aggregate.
- 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 specification 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 nSSP 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.

Appendix B: Maintenance Guidelines

B.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 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 vacuumed.

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 regenerative air vacuum equipment be used annually to clean the pavement surface.

If pervious pavement is installed for stormwater management, Caltrans is obligated 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. The test result can be compared to the original ASTM C1701 test result completed when the pavement was installed as a comparison. This test can be used to determine and schedule maintenance. PICP surface infiltration can be tested using ASTM C1781 Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems. This test method is very similar to ASTM C1701 and results from the two tests are comparable.

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.

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 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.

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.
- 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 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.
- 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 regenerative air vacuum equipment (no brooms or water spray) at least once 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.
- Verify performance of pervious pavement per ASTM C1701 or C1781 as noted above when pavement has been vacuumed by high performance equipment and still determined to be clogged.

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

- 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 high performance vacuum equipment. Test sections by pouring water from a five gallon bucket to ensure infiltration in areas where surface clogging was identified.
- 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.
- Inspect inlets, pretreatment BMPs and any flow diversion structures for sediment buildup and structural damage. Perform standard maintenance procedures.

Where Caltrans will be maintaining the pervious pavement maintenance crews are encouraged to determine the most effective strategy of cleaning pervious pavement especially how many times the pavement will be swept a year due to the variability of each site. Pervious pavement should only be considered if there is an effective vacuuming program. At the early stages of planning (PID and PAED) it is the responsibility of District Maintenance to determine if vacuuming equipment is already owned or will be purchased, or procured through a service contract, and accounted for in their Maintenance budget. If the equipment is going to be provided through a service contract, make sure the equipment is available in area they will be used. Currently Caltrans does not have the required type of equipment in their inventories.

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.

Appendix C: Usage Notes for Pervious Pavement nSSPs & Recommended Minimum Pavement Structures

C.1 Usage Notes for Pervious Pavement nSSPs and Std. Specs.

Use these specifications and specification modifications when pervious pavement is desired.

Section 19 (Earthwork)

Use for subbase under Class 4 AB areas with 90% compaction as being outside 95% relative compaction requirement. No modification to existing standard specifications is required.

Base

Section 26 (Aggregate Base)

1 nSSP

nSSP_26-1 Pervious Pavement Bases- Creates Class 3 and 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 M_r is less than 14 (R-value of 25) or more otherwise use 8 inches as minimums. Class 3 AB is used in choker course layer for PICP.

Section 29 (Asphalt Treated Permeable Base)

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

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

40-8 - Pervious Concrete Pavement - Sets paving requirements for PCP; requires that 90-7 also is used in special provisions.

40-9 - Permeable Interlocking Concrete Pavement - defines materials and placement requirements for PICP and will normally have Class 3 AB and Class 4 AB under it.

Section 90

1 nSSP

90-7 - Creates pervious concrete.