CONCRETE PAVEMENT
CPTP
TECHNOLOGY PROGRAM

Daylighted Permeable Bases

This TechBrief discusses daylighted permeable bases for concrete pavements. Information is provided on the use, design, materials, construction, and maintenance of daylighted permeable bases, as well as their performance and costs.

TechBrief

The Concrete Pavement Technology Program (CPTP) is an integrated, national effort to improve the long-term performance and cost-effectiveness of concrete pavements. Managed by the Federal Highway Administration through partnerships with State highway agencies, industry, and academia, CPTP's primary goals are to reduce congestion, improve safety, lower costs, improve performance, and foster innovation. The program was designed to produce user-friendly software, procedures, methods, guidelines, and other tools for use in materials selection, mixture proportioning, and the design, construction, and rehabilitation of concrete pavements.

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U.S. Department of Transportation
Federal Highway Administration

INTRODUCTION

Subsurface drainage is a critical element in pavement design for pavements constructed in wet areas. Excessive subsurface moisture due to infiltration of rain water can lead to early failures of pavements as a result of a weakened foundation and loss of material below the concrete slab due to pumping. It is generally recommended that efforts be made to remove water out of the pavement as fast as possible or to incorporate foundation and pavement designs that reduce or eliminate the risk of damage to the pavement as a result of water infiltration into the pavement system. It is also generally recommended that subsurface drainage should be built only if the following are applicable:

1. There is a potential for moisture damage to the pavement.
2. There is medium to heavy truck traffic.
3. The subsurface drainage system can be properly designed and constructed.
4. There is a commitment to inspection and maintenance of the drainage system.

The two most popular methods of subsurface drainage are open-graded drainage layers (stabilized or nonstabilized) with edge drains and outlet pipes and daylighted permeable bases.

In the past (during the 1990s), the trend was to use drainage layers with very high permeability—on the order of 8,000 to 10,000 ft/day (2,438 to 3,048 m/day). The current practice is to use drainage layers that are less permeable (500 to 800 ft/day [152 to 244 m/day]) but more stable. There is no need to use drainage layers with very high permeability as the amount of water that infiltrates into a well-maintained concrete pavement is not high.

This TechBrief provides guidance on use of daylighted permeable bases for concrete pavements.

USE OF DAYLIGHTED PERMEABLE BASES

Daylighted permeable bases are well suited for roadways with flat grades (1 percent or less) and shallow ditches, where it is difficult to outlet drainage pipes at an adequate height above the ditch. Daylighted permeable bas-

es have been used for more than 20 years in the United States to remove infiltrated water from pavement structures (Fehsenfeld 1988; Christopher et al. 2006). In 1993, a survey of State highway agencies identified 3 States using treated daylighted permeable bases and 10 States using untreated daylighted permeable bases (Forsyth 1993). In the 15 years since, the use of permeable base drainage systems has continued, but the use of edge drains with permeable bases has often been encouraged over the use of daylighted permeable bases. This is unfortunate, because when appropriately used, designed, constructed, and maintained, daylighted permeable bases have the potential to perform just as well as edgedrained permeable bases, for about the same or even lower cost. Figure 1 shows a typical daylighted drainable base shoulder.

Depending on the thickness of the pavement structure and the depth of frost penetration in the region where the highway is constructed, water can freeze in a daylighted permeable base and inhibit outflow. This may also be true of pipe edge drains, depending on the depth at which they are placed.

MATERIALS

Two types of materials have been used for daylighted permeable bases. The first is an unstabilized large-sized stone, also called a rock base, typically constructed about 18 to 24 in. (457 to 610 mm) thick. The second type of material is a permeable base gradation such as would be used for an edge-drain system, either untreated or treated with asphalt or portland cement, and typically constructed about 4 to 6 in. (102 to 152 mm) thick. The permeability requirements and asphalt or cement content required to maintain long-term stability are the same for daylighted permeable bases as for edgedrained permeable bases.

A permeable daylighted base needs a suitable separator layer beneath it to prevent subgrade fines from migrating up into and clogging the base. This may be an appropriately graded untreated aggregate subbase, an appropriate geotextile fabric, or a layer of subgrade soil treated with sufficient lime or cement to achieve good long-term stability and resist erosion.

DESIGN AND CONSTRUCTION

A daylighted permeable base is simpler to construct than a permeable base with edge drains and outlets. The daylighted base/subbase interface should have a cross slope of 3 percent to remove water effectively from the pavement structure. After the base material is spread across the prepared subbase or separator layer, it is compacted with a steel-wheeled roller and trimmed as needed. Once the base is compacted, it needs to be protected from damage or contamination prior to the paving of the concrete surface. For a cement-treated base, adequate time for curing must be provided before the concrete slab is placed.

Figure 1. Daylighted permeable base on US 50 in Kansas (Gisi, Brennan, and Luedders 2004).

The bottom of the exposed edge of the daylighted base should be at least 6 in. (152 mm) above the 10-year-storm flow line of the ditch to prevent water from backing up into the daylighted base during or after a heavy rainfall.

MAINTENANCE

Daylighted permeable bases require periodic maintenance to keep the exposed edge clear of soil, vegetation,

and debris. Typical maintenance activities include weeding and manual removal of debris. A water hose may be used to flush material out from the edge of the base, but a high-pressure water hose should not be used as this can damage the base and undermine the subbase. Occasional grading of the exposed edge of the daylighted base may be necessary to remove such material. An annual visual inspection is recommended to assess the need for maintenance work (ARA-ERES 2004).

PERFORMANCE AND COSTS

While daylighted permeable bases are sometimes perceived as being less effective than permeable bases with edge drains at removing water from a pavement structure (FHWA 1992), various studies have shown that when properly designed, constructed, and maintained, daylighted permeable bases are just as effective as edgedrained permeable bases (Gisi et al. 2004; Yu et al. 1998).

Based on the results of a survey of concrete paving contractors, Hoerner et al. (2004) estimated that the cost of a concrete pavement with a 6-in. (152-mm) permeable base layer (untreated, asphalt-treated, or cement-treated) with edge drains will typically be between 100 percent and 120 percent of the cost of the same pavement with no drainage layer and no edge drains, while the cost of a concrete pavement with a daylighted permeable base (asphalt-treated or cement-treated) will typically be between 90 percent and 120 percent of the cost of the same pavement with no drainage layer and no edge drains. Compared to edge-drain systems, daylighted bases offer potential savings in eliminating the materials, equipment, and time needed for installation of edge drains, outlets, and headwalls. On the other hand, use of a daylighted base entails a higher cost for the permeable base material because of the greater quantity needed to extend the base to the side slope.

STATE EXPERIENCE

Several States have been using daylighted bases for years. The Missouri Department of Transportation (DOT) has been using a thick (currently 18 in. [457 mm]), unbound, fairly dense-graded rock base since 1994. When available, it has been the preferred base type for nearly all new concrete pavement projects and has been incorporated in several thousand lane-miles of new concrete pavements. Thin courses of permeable bases are not to be relied upon to provide permanent drainage when daylighted. The specification for the daylighted base is not restrictive, and the end product is easily constructed and stable. Although not studied comprehensively, there is no record of drainage-related pavement failures in Missouri on this base type. The Missouri specification (2009; Section 303) for the drainable rock base is summarized below:

> The rock base shall be 18 inches (450 mm) thick and may be placed in one lift…. No particle dimension shall exceed approximately 6 inches (150 mm) less than the placed lift thickness. There shall be some material with particle dimensions exceeding approximately 50 percent of the lift thickness…. Class C Excavation in rock cuts shall be performed to allow placement of the specified base thickness.
>
> The final surface [of the base] shall be of a uniform texture and grade suitable for paving. The top 2 inches (50 mm) of the rock base shall consist of either 2-inch (50 mm) maximum rock particles…, a 2-inch (50 mm) maximum size granular type material having a plasticity index not to exceed 10 and a gradation such that at least 50 percent of the material will be retained on the No. 4 (4.75 mm) sieve or a gradation meeting Type 5 aggregate…. There shall be no exposed rock exceeding the 2-inch (50 mm) size in the final surface that would interfere with final preparation of the base for paving.

Daylighted permeable bases have been used in several districts in Virginia. They are used when undercut is necessary to mitigate the presence of poor subgrade materials. In the Richmond District, for example, typically the base is 24 in. (600 mm) thick. The bottom 18 in. (450 mm) are filled with Virginia DOT (2007) Open-Graded Coarse Aggregate No. 1, and the top 6 in. (150 mm) are filled with Virginia DOT No. 21B Dense-Graded Aggregate (see table 1).

In some cases the top size for the No. 1 gradation has been increased from 4 in. (100 mm) to 6 in.

Table 1. Aggregate Gradations Used in Richmond, Virginia, Daylighted Permeable Bases

Aggregate		Gradations					
Open-Graded Coarse Aggregate No. 1	Sieve Size	4 in.	3½ in.	2½ in.	1½ in.	¾ in.	
	% Passing (by weight)	Min. 100	90–100	25–60	Max. 15	Max. 5	
Dense-Graded Aggregate No. 21B	Sieve Size	2 in.	1 in.	⅜ in.	No. 10	No. 40	No. 200
	% Passing (by weight)	100	85–95	50–69	20–36	9–19	4–7

(150 mm), typically due to ready availability and lower price of the larger size. The entire base is daylighted on both sides of the roadway. This system provides the necessary permeability and foundation stability. It has been successful on many projects, most recently under continuously reinforced concrete pavement (11 in. [275 mm] thick) on Route 288, which was built around 2002.

The Kentucky and Idaho DOTs have also used thick large-rock bases with success. Another variation of daylighted base design employs a thinner, stabilized permeable aggregate layer. The Kansas DOT built this type in experimental sections in the late 1990s (Gisi et al. 2004). The DOT found that a daylighted 4-in. (102-mm) asphalt- or cement-stabilized drainable base could perform as well as a permeable base with an edge-drain system. However, the DOT cautions that the winter freeze condition can affect the outflow of water from the daylighted base, and this may not be desirable in harsh freeze environments.

RECOMMENDATIONS

Daylighted permeable bases are well suited for use on highways with flat grades and shallow ditches, where it would be difficult to outlet a pipe edge-drain system at an adequate height above the water flow line of the ditch. However, a daylighted permeable base may not be well suited for climates where the depth of frost penetration in winter exceeds the combined thickness of the base and overlying concrete slab, since the effectiveness of the permeable base will be reduced by water freezing in it.

Daylighted permeable bases may be constructed with a thick layer—18 to 24 in. (457 to 610 mm)—of large-sized stone or with a typical base course thickness of 4 to 6 in. (102 to 152 mm) of untreated, asphalt-treated, or cement-treated open-graded aggregate. The permeability requirements and asphalt or cement content needed are the same as for permeable bases used with edge-drain systems.

A daylighted permeable base should be sloped at 3 percent toward the side ditch, with the bottom of its exposed edge at least 6 in. (152 mm) above the 10-year-storm flow line of the ditch to prevent water from backing up into the base.

Daylighted permeable bases should be inspected visually once a year and maintained as needed by weeding, manual removal of debris, flushing with low-pressure water, and grading of the exposed edge to remove soil, vegetation, and other contaminants.

When properly used, designed, constructed, and maintained, a daylighted permeable base can perform as well as an edgedrained permeable base, at an equal or possibly lower cost.

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THE CONCRETE PAVEMENT TECHNOLOGY PROGRAM

The Concrete Pavement Technology Program (CPTP) is a national program of research, development, and technology transfer that operates within the Federal Highway Administration (FHWA) Office of Pavement Technology.

The CPTP includes some 30 research and demonstration projects, each of which is delivering products for improved design, construction, repair, and rehabilitation of concrete pavements.

The focus areas for the CPTP include advanced designs, optimized concrete materials, improved construction processes, rapid repair and rehabilitation, and user satisfaction. The CPTP continues to produce implementable products that result in safer, smoother, quieter, and longer lasting concrete pavements. Longer lasting pavements, in turn, contribute to FHWA's success in the areas of safety, congestion mitigation, and environmental stewardship and streamlining.

Technology transfer of products resulting from the CPTP is being accomplished under CPTP Task 65. This 5-year activity was initiated in September 2003 and is overseen by an Executive Expert Task Group (ETG) that includes State department of transportation (DOT) chief engineers and representatives from industry and academia.

An Engineering ETG, made up of pavement and materials engineers from State DOTs, FHWA field offices, plus representatives from industry and academia, reviews the technical aspects of CPTP products.

These products include:

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The delivery of CPTP products, in workshops and other formats, is tailored to meet the needs of each State DOT and its related industry groups. For more information, please contact:

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