BELGARD
PAVES THE WAY™

PERMEABLE PAVERS ON SLOPED SURFACES

Belgard Permeable Pavers are a versatile and resilient stormwater control measure which can be employed on most projects. Permeable pavers are most efficient when laid relatively flat (0% to 2%) but can be designed for a range of slopes up to approximately 15%. As the slope increases, the design of the permeable pavement system must be adjusted accordingly to maximize stormwater benefits and minimize subgrade degradation and erosion. This Technical Note provides guidance for using Belgard permeable pavers on sloped conditions ranging from 0% to 15%.

TECHNICAL GUIDANCE

The American Society of Civil Engineers has published Design Standard 68-18 Permeable Interlocking Concrete Pavement (ASCE 68-18) and provides some guidance on sloped permeable paver systems:

Table 3.1. Factors in Determining the Suitability for Use of Permeable Pavement Systems

Site Grades	A pavement with steeply sloped surfaces and subgrade (e.g., >5%) may be less effective at promoting infiltration and water storage than a level pavement system (e.g., <2%). Significant longitudinal grades may require additional design features, such as intermittently spaced berms, check dams, walls, or baffles in the subbase that create a stepped or terraced system with level sections. These features can promote infiltration to achieve design goals and prevent water from exiting the pavement surface at the low-elevation end of the system.

Table 3.2. PICP System Design Assessment Steps

Pavement Surface	Determine the effect of surface slope of the pavement on the ability of the pavement to infiltrate water.
Subgrade Slope	Minimize subgrade slopes for infiltration designs. Consider berms, check dams, walls, and weir structures in the pavement for steeply sloped sites. Use flatter subgrade slopes where possible.

Section 4.5.2 Slopes

Permeable pavements can be installed for sloped surfaces. The design of sloped surfaces should consider decreased constructability, decreased surface infiltration, and compliance with allowable pavement slopes for roads, parking lots, and other facilities. Subgrades and/or subbases can be designed with flat or sloped bottoms that do not need to match the surface slopes. Terracing of the subgrade with flat bottoms on each terrace helps reduce the overall stone depth and maximize infiltration. Subgrades and/or subbases can also be bermed and piped to control downslope flows and encourage infiltration through using check dams. These check dams may be required on subgrade slopes exceeding 2%, and they are recommended for slopes exceeding 5%.

The design for sloped systems should ensure that water is not able to surge from below and exit the surface of the pavement. The pavement structural design for sloped systems should ensure that the full structural section is present above the top of the check dam elevation, or that the check dams provide an equal amount of structural support for the pavement. Overflows for larger storm events should also be accounted for in the check dam design.

While ASCE does not set a maximum slope for permeable paver systems, once the slope exceeds 12% additional design considerations may be needed above what is provided in this document.

RESEARCH PAPER

Hydraulic Characterization and Design of Permeable Interlocking Concrete Pavement, Kevern, et. al.

The study performed in 2015 at the University of Missouri Kansas City (UMKC) examined the effects of slope on permeable paver systems. The research focused on both vertical infiltration rate measured in conformance with ASTM C1781 Standard Test Method for Surface Infiltration Rate of Permeable Unit Pavement Systems, and horizonal infiltration which was setup to mimic stormwater run-on. The laboratory experiments also varied the slope from 0% to 10% and looked at manufactured joint widths of 6 mm, 10 mm, and 12.5 mm. Table 3 on the next summarizes the vertical infiltration findings:

Table 3. ASTM C1781 Experimental and Calibrated Vertical Infiltration						
Infiltration Values per PICP Spacing, in/hr.						
PAVEMENT SLOPE	6 MM	6 MM CALIBRATED	10 MM	10 MM CALIBRATED	12.5 MM	12.5 MM CALIBRATED
0 %	1077	369	1505	502	2012	671
1 %	1088	363	1558	519	2345	782
2 %	1226	409	1628	543	2532	844
5 %	1140	380	1514	505	2505	835
10 %	1115	372	1495	498	2439	813

The laboratory surface infiltration rates were calibrated using in-situ ASTM C1781 test results from a nearby installation because the laboratory results were too high; the variation is contributed to the lack of compaction within the laboratory setting vs. in-situ conditions.

As shown by the table, the calibrated 10 mm surface infiltration rate at 0% surface slope is 502 in/hr. and 498 in/hr. at surface slope 10%. The vertical infiltration rate is essentially the same.

The study also introduced horizontal flow (run-on) and measured the surface infiltration rate using the laboratory equipment. Table 6 below summarizes the horizontal infiltration findings:

Table 6. Infiltration Rate at Overflow per Section Area per Group, cfs/section area		
SLOPE	45° HERRINGBONE PATERN	AVERAGE STRAIGHT HERRINGBONE
Flow Rate (cfs)		
0.00 %	0.016	0.021
1.00 %	0.015	0.022
2.00 %	0.015	0.017
5.00 %	0.014	0.016
10.00 %	0.014	0.015

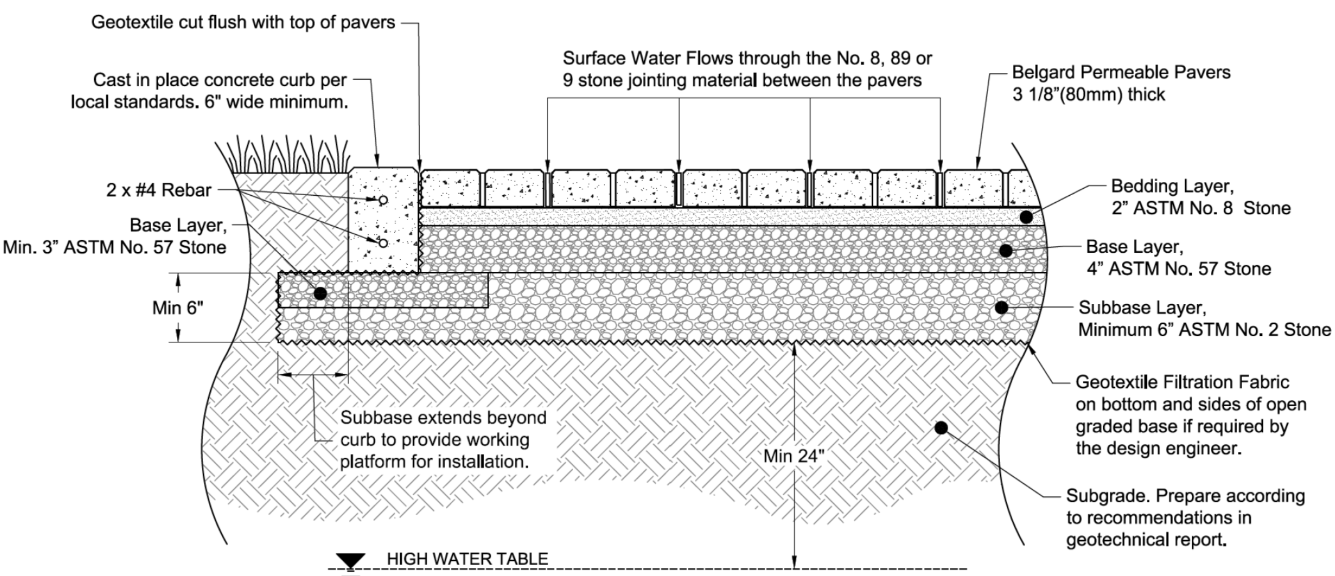
As shown by the UMKC study, the horizontal surface infiltration flow rate decreased approximately 12.5% from a 0.00% slope as compared with a 10% slope. Based on the above research, slope does not have an appreciable effect on the vertical and horizontal inflitration of permeable paver systems.

SLOPE CONDITIONS

Through years of design assistance, Belgard has developed the guidance below based on our design experience, feedback from contractors and owners, and available research. We have broken the permeable paver slopes into four categories as described below:

Surface Slope 0% to 2%

Most efficient for meeting stormwater storage requirements. Flow dams may be used to increase system efficiency but may not be necessary.



Technical Note

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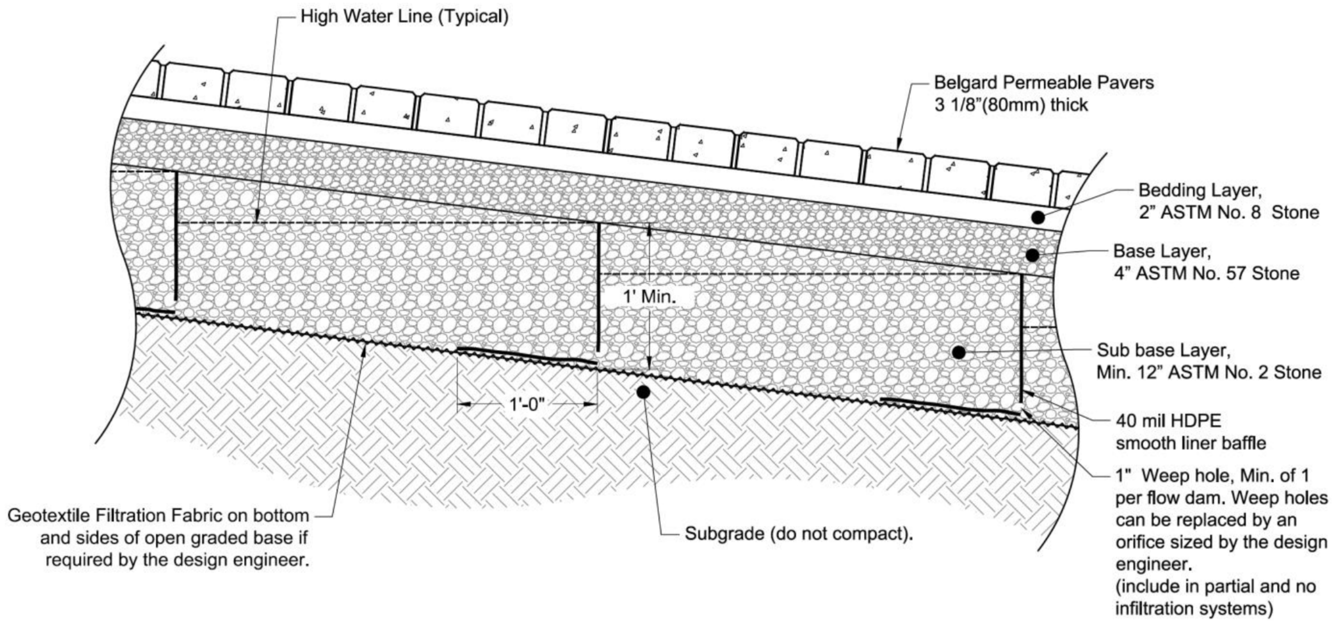
Surface Slope 3% to 5%

Use flow dams to slow flow and increase storage capacity. Subgrade is parallel to the pavement surface.

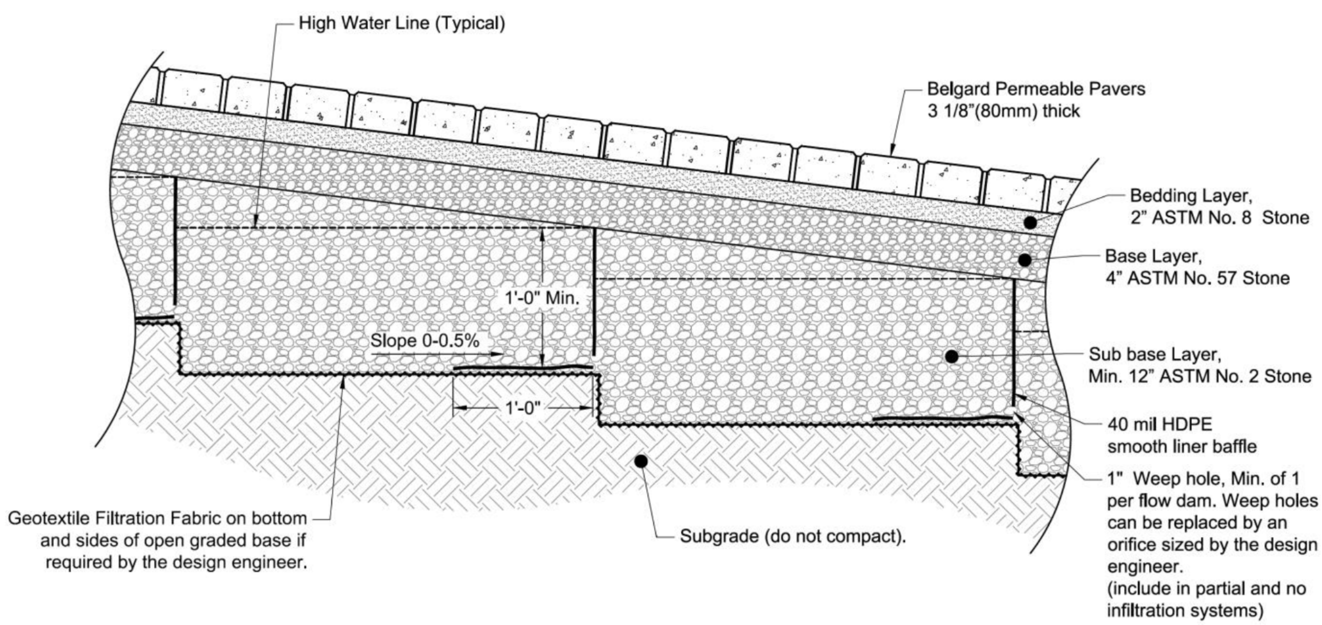


Surface Slope 5% to 10%

Use flow dams to slow flow and increase storage capacity. Subgrade can be either stepped or parallel to the pavement surface. Laying pattern may be placed on a 45-degree angle to the direction of travel which promotes infiltration and retards surface flow.

Surface Slope > 10%

Use flow dams to slow flow and increase storage capacity. Subgrade can be either stepped or parallel to the pavement surface. If subgrade is parallel, a geotextile must be used to reduce erosion/scour of the subgrade. Laying pattern must be placed on a 45-degree angle to the direction of travel which promotes infiltration and retards surface flow.



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