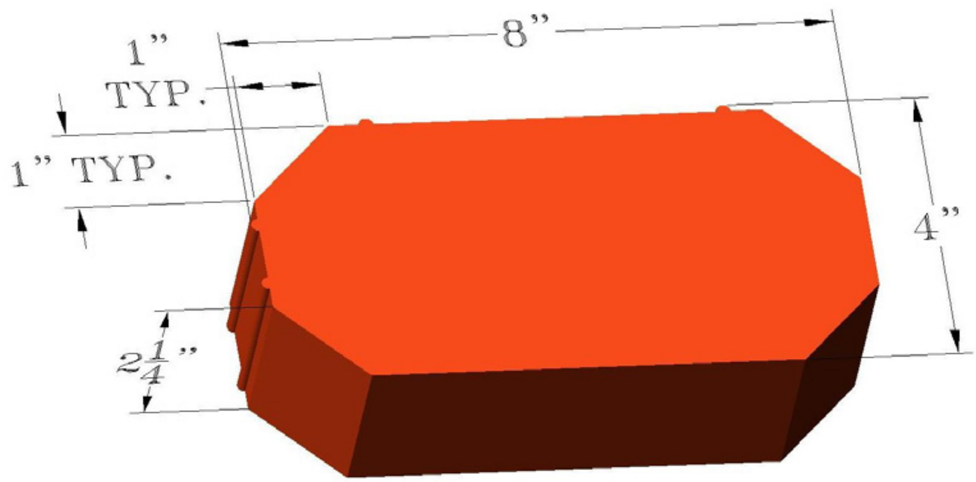
Introduction: Clay permeable pavers are designed to reduce and/or eliminate stormwater runoff through infiltration, thereby reducing volume flows, improving water quality, and recharging groundwater. Clay permeable pavers are ideal for walkways, patios, courtyards, driveways, pedestrian malls, plazas, parks, and many other applications. Clay permeable pavers are an environmentally friendly solution for stormwater runoff.

General Shale Permeable Pavers: General Shale produces a Clipped Corner permeable paver which is a solid paver with a 1" chamfer on all corners; illustrated below.



Clipped Corner Permeable Paver

Water Quantity: Permeable pavers reduce and/or eliminate stormwater runoff. This section covers the determination of the infiltration capacity of a clay permeable paver system.

The infiltration rate for permeable pavers is the product of the fraction of voids and the infiltration rate of the filler material. Sand meeting the gradation requirements of ASTM C33 has an infiltration rate of 8 inches/hour (Georgia Stormwater Management Manual, Section 3.3.8). Brick dust has an infiltration rate of 3 inches/hour (Bennett and Tinsely, 2007). If the fines (particles passing a #100 sieve) are removed from the brick dust, the gradation of the brick dust will be similar to C33 sand, and the infiltration rate will be 8 inches/hour. Table 1 gives the percent voids and infiltration rates and for various constructions.

Table 1: Permeable paver infiltration rates

Paver	% Void	Surface Infiltration Rate (inches/hour)	
		ASTM C 33 Sand	Brick Dust
Clipped Corner	11	0.88	0.33

The ability of clay permeable pavers to handle a storm of given duration is the infiltration rate multiplied by the duration of the storm. This determines the amount of rainfall the permeable pavers can accommodate. Table 2 gives rainfall amounts for different duration storms.

Table 2: Permeable paver infiltration rates

Paver	Rainfall amount (inches)			
	Storm Duration			
	1 hr	2 hr	6 hr	24 hr
ASTM C 33 Sand				
Clipped Corner	0.9	1.8	5.4	21.6
Brick Dust				
Clipped Corner	0.3	0.7	2.0	8.0

The rainfall capacity for clay permeable pavers can be compared to different design storms to determine the capability of the pavers to handle the runoff from the storm. Rainfall amounts can be obtained from NOAA's National Weather Service, hdsc.nws.noaa.gov/hdsc/pfds/index.html. Table 3 gives rainfall amounts for various cities, storm durations, and storm return periods. The rainfall intensity is obtained as the rainfall amount divided by the storm duration.

Table 3: Rainfall amounts

City	Rainfall (inches)															
	1 hour storm				2 hour storm				6 hour storm				24 hour storm			
	1 yr	2 yr	5 yr	10 yr	1 yr	2 yr	5 yr	10 yr	1 yr	2 yr	5 yr	10 yr	1 yr	2 yr	5 yr	10 yr
Atlanta, GA	1.6	2.0	2.4	2.6	1.9	2.3	2.8	3.2	2.4	2.9	3.7	4.2	3.4	3.8	4.9	5.7
Charlotte, NC	1.4	1.6	2.0	2.4	1.7	2.0	2.5	3.0	2.3	2.8	3.4	3.9	3.0	3.5	4.5	5.0
Chicago, IL	1.2	1.5	1.8	2.0	1.5	1.7	2.1	2.4	1.8	2.1	2.6	3.0	2.4	2.8	3.5	4.0
Cincinnati, OH	1.1	1.3	1.7	2.0	1.4	1.6	2.1	2.3	1.8	2.2	2.7	3.2	2.6	3.0	3.7	4.2
Dallas, TX	1.5	1.9	2.4	2.8	1.7	2.1	2.8	3.3	2.5	3.0	3.9	4.5	3.0	3.7	5.0	6.0
Indianapolis, IN	1.2	1.4	1.7	2.0	1.5	1.7	2.2	2.3	1.9	2.3	2.7	3.2	2.6	2.9	3.7	4.3
Nashville, TN	1.3	1.5	2.0	2.2	1.6	1.9	2.4	2.8	2.2	2.5	3.2	3.7	3.0	3.6	4.5	4.9
Orlando, FL	2.0	2.2	2.7	3.0	2.2	2.7	3.4	3.8	2.9	3.4	4.4	5.2	3.8	4.6	6.2	7.4
Pittsburgh, PA	1.0	1.1	1.5	1.7	1.2	1.4	1.8	2.2	1.7	1.8	2.5	2.8	2.3	2.7	3.4	3.9
St. Louis, MO	1.3	1.6	2.0	2.3	1.7	1.9	2.4	2.8	2.3	2.7	3.2	3.7	2.9	3.5	4.4	5.0
Washington DC	1.4	1.8	2.3	2.7	1.7	2.1	2.8	3.3	2.3	2.8	3.5	4.2	3.0	3.5	4.7	5.7

Any excess infiltration capacity of the permeable pavers can be used to handle runoff from other impermeable areas. During rare, infrequent storms, there can be runoff from clay permeable pavement surfaces. The runoff coefficient for permeable pavements is approximately 0.3 for the Rational Method.

The infiltration rate of the underlying soil is typically less than that of the paver system. Therefore, a storage area is needed underneath the pavers to store water until it can infiltrate into the ground. Typically, this storage area is #57 crushed stone or similar. The storage capacity is the product of the depth of the stone times the void space of the stone. A conservative value of the void space for #57 stone is 0.30.

The required thickness of the underlying stone is obtained as:

$$t = \frac{(i - i_{soil})T_D}{n}$$

where t is the required thickness of the stone (inches), i is the intensity of the storm (inches/hour), i_{soil} is the infiltration rate of the underlying soil (inches per hour), T_D is the duration of the storm, and n is the void space of the stone. The intensity of the storm is determined as the rainfall amount divided by the duration of the storm.

$$i = \frac{\text{Rainfall Amount}}{\text{Storm Duration}}$$

The time for the water to infiltrate the soil should also be checked using the equation:

$$T_i = \frac{i}{i_{soil}} T_D$$

where T_i is the time for the water to infiltrate the soil. If the time for the water to infiltrate the soil is greater than 24 hours, a drainage system, such as perforated pipes, should be considered.

It is important to prevent sediment from entering the base and pavement surface during construction, as this will reduce permeability of the system. There should not be excessive compaction of the underlying soil, as this will reduce the soil permeability. Over time, the accumulation of fines will result in a reduction of the infiltration rate of the paver system. Higher infiltration rates can easily be restored through vacuuming the surface, as most of the fines accumulate near the surface. A recommended maintenance plan is semiannual vacuuming.

Clay permeable pavers contribute to LEED® SS Credit 6.1: Stormwater Design: Quantity Control. One point can be earned in this category. If the existing imperviousness is less than or equal to 50%, one point is earned if a stormwater management plan is implemented that prevents the post-development peak discharge rate and quantity from exceeding the pre-development peak discharge rate and quantity for the one- and two-year 24-hour design storms. If the existing imperviousness is greater than 50%, one point is earned if a stormwater management plan is implemented that results in a 25% decrease in the volume of stormwater runoff from the two-year 24-hour design storm. Clay permeable pavers will contribute in either case to reducing the stormwater runoff and helping to earn this LEED® credit.

Example: Design a clay permeable paver system for Charlotte, North Carolina to handle a 10-year 6-hour storm. Assume the infiltration rate of the underlying soil has been determined to be 0.3 inches/hour. Use Clipped Corner clay pavers with sand filler.

Solution: From Table 2, the Clipped Corner clay pavers with sand filler can accommodate 5.4 inches of rain in 6 hours. From Table 3, the rainfall amount of the design storm is 3.9 inches. The pavers are sufficient to handle the design storm.

An underlying stone layer is required due to the low infiltration rate of the soil. The intensity of the storm is determined as:

$$i = \frac{\text{Rainfall Amount}}{\text{Storm Duration}} = \frac{3.9in}{6hr} = 0.65\ in/hr$$

The layer will use #57 stone with a thickness determined as:

$$t = \frac{(i - i_{soil})T_D}{n} = \frac{(0.65in/hr - 0.3in/hr)6hr}{0.30} = 7\ inches$$

The time for the water to infiltrate the soil is:

$$T_i = \frac{i}{i_{soil}} T_D = \frac{0.65in/hr}{0.3in/hr} 6hr = 13\ hours$$

Since T_i, 13 hours, is less than 24 hours, no supplemental drainage system is required.

Since the infiltration rate of the pavers is greater than the storm intensity, the system can handle runoff from adjacent areas. This would require a thicker stone layer. If the stone layer were designed to handle the infiltration rate of the paver system of 5.4 inches of rain in 6 hours, the stone would have to be 12 inches thick.

The pavers are also checked for their capability to handle a 2 year 24 hour storm. The permeable pavers can handle 21.6 inches of rain in 24 hours. This greatly exceeds the amount of rain in a 2 year 24 hour storm of 3.5 inches. If brick dust were used instead of the sand, the permeable paver system would still be able to handle 8.0 inches of rain in 24 hours, which is over twice the amount of rain in a 2 year 24 hour storm. Thus, the permeable pavers meet the requirements for a LEED® credit, and even can be used to handle runoff from adjacent impervious areas.

Water Quality: Clay permeable pavers contribute to the water quality. Surface water runoff contains a range of contaminants including oils, organic matter, heavy metals and toxic materials. Permeable pavers have a high removal of both soluble and particulate pollutants, as the pollutants become trapped, absorbed or broken down in the underlying soil layers. LEED® gives 1 point credit under category SS 6.2 for using a Best Management Practice (BMP), of which permeable pavers is one. Permeable pavers are considered to be a nonstructural measure, which is often preferred as it helps to recharge the groundwater.

Heat-Island Effect: Clay permeable pavers contribute to the reduction of heat-island effects. LEED® gives 1 point credit under category SS 7.1 for providing paving materials with a Solar Reflectance Index (SRI) of at least 29. Although the SRI of clay permeable pavers has not been measured, the Lawrence Livermore Cool Roof database gives a SRI of 36 for red clay tile roofs, and a similar value is expected for clay tile pavers. For comparison, new asphalt has an SRI of 0. Clay permeable pavers will contribute to reduction of the non-roof heat island effect.

Conclusion: General Shale clay permeable pavers provide many benefits, and are ideal for walkways, patios, courtyards, driveways, pedestrian malls, plazas, parks, and many other applications. Contact your General Shale representative for more information.

Disclaimer: The information included herein is intended to provide general guidance and suggestions for the design and construction of clay permeable pavements. Recommendations are guidelines only and all local regulations need to be followed. These guidelines are not intended to replace the judgment or expertise of professional engineers or landscape architects, who should be consulted in the design and construction of clay permeable pavements.

References:

Bennett, R.M., and Tinsely, A. (2007). *Brick Dust Gradation and Permeability*, The University of Tennessee.

Georgia Stormwater Management Manual (2001). http://www.georgiastormwater.com/