Infiltration Systems

3.3 Pervious Pavement

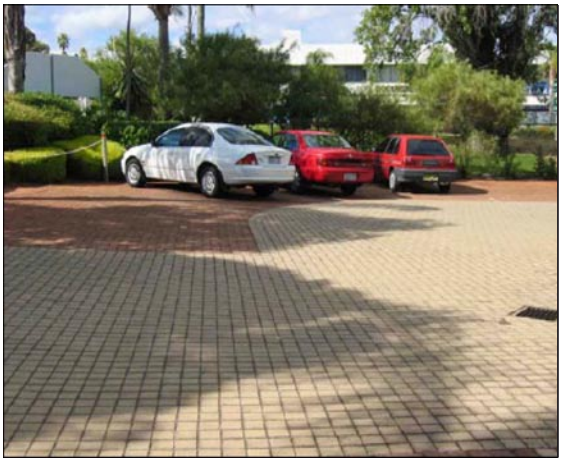

Figure 1. Pervious paving in a commercial carpark, Burswood. (Photograph: Department of Water 2006.)

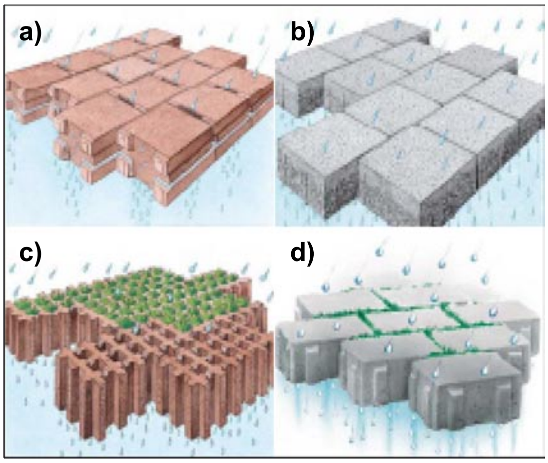

Figure 2. Types of permeable paving: a) pavers with canals b) porous pavers c) greened permeable pavers with small apertures d) greened permeable pavers with wide joints. (Dierkes et al. 2002.)

Background

Permeable/porous (collectively termed pervious) paving can be used as an alternative to traditional impervious hard surfaces, such as roads, carparks, footpaths and public squares. Bitumen, concrete and other hard surface areas (such as paving surrounding buildings) are typically impermeable and result in high runoff rates during a storm event. This runoff can be reduced by interspacing permeable material, such as lawn or pebbles, between widely spaced impermeable pavers, or by installing porous paving.

There are different types of porous pavements, including porous asphalt pavement, porous concrete pavement and modular interlocking concrete bricks with internal or external drainage cells. Porous pavement comprises a thick layer of highly porous material, for example an asphaltic layer of gap-graded coarse aggregate held together with bitumen, or a well-compacted mixture of graded sand and gravel (Argue 2004).

The porous pavement is typically laid on top of a high-void aggregate or gravel base layer, with a geotextile in between (Figure 3). The stormwater passes through the pore spaces of the pavement, through the geotextile and into the aggregate/gravel layer, which provides temporary storage as the water gradually infiltrates into the subsoil. Where the subsoil has low permeability, the water can be removed by providing a slow drainage outlet to the receiving stormwater system.

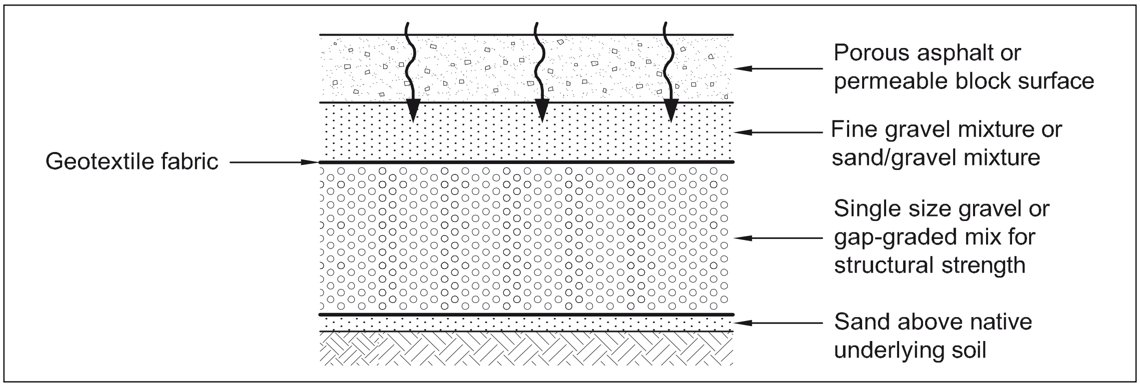

Figure 3. Schematic of a section through pervious pavement.

Performance efficiency

Pervious pavements can remove sediments and some nutrients, heavy metals and hydrocarbons from polluted stormwater via the processes of adsorption, filtering and biological decomposition.

A field study by Brattebo and Booth (2003) of four different types of porous paving installed in a parking area found no oil, fuel or lead in the water infiltrated through the paving, even though these pollutants were present in the direct surface runoff from the impermeable asphalt control sample.

Field studies have also shown pervious pavement to be very effective at retaining dissolved metals (Dierkes et al. 2002).

Rankin and Ball (2004) found that the impervious area on a road surface reduced from 45% to 5% when pervious pavements were used. Subsequent monitoring found that surface runoff water quality improved and there was no increase in groundwater contaminants.

Cost

Summary costs for pervious paving are presented in Table 1. These costs are inclusive of excavation and profiling and installation of gravel, sand and geofabric liners.

Fletcher et al. (2004) reported that the typical annual maintenance costs of permeable paving in California (when converted from US dollars) were approximately $9 700/ha.

Table 1. Pervious Paving Installation Costs (Boral 2003 cited in Taylor 2005)

Pervious Paving Method	Construction Cost
Porous paving allowing infiltration	$111/m^2
Porous paving over sealed sub-grade allowing water collection	$119/m^2
Augmentation with porous paving (i.e. mixing porous with normal pavers)	$98/m^2
Porous paving with asphalt	$67/m^2
Porous paving with concrete slab	$90/m^2

Design considerations

As with other infiltration systems, designing pervious pavement systems requires consideration of the site conditions and potential contamination of the receiving groundwater environment. A detailed discussion of these considerations is provided in the Design Considerations section of the Infiltration Basins and Trenches BMP.

There are some specific considerations for the design of pervious pavement. Some pervious pavement systems have a high failure rate that is attributed to poor design, clogging by fine sediment and excess traffic use (USEPA 1999).

Pervious pavement systems are not suitable for areas with slopes greater than 5% or high wind erosion rates (USEPA 1999). Soils that feature a rising water table, saline conditions, dispersive clay or low hydraulic conductivity are not suitable for pervious pavement.

Pervious pavement systems require regular vacuum sweeping to prevent clogging by fine sediment and maintain porosity (Water and Rivers Commission 1998). Alternatively, sediment traps and vegetation filter strips can be used to prevent sediment entering the system (Coombes 2003). Excessive vehicle traffic is also a common cause of failure. Pervious pavement should be used for low volume parking and roads with light vehicle use (USEPA 1999). To prevent pervious pavement from being clogged with sediment/litter during road and housing/building construction, temporary bunding or sediment controls need to be installed. See Section 2.1.1 'Land development and construction sites' of Chapter 7 for information about site management practices.

Design guidelines

The following method for calculation is based on Argue (2004). The equations are applicable where the overall value of the hydraulic conductivity for the product and its underlying sub-structure is known. This method should be applied with caution to the sizing of infiltration systems where shallow groundwater is present. This approach does not consider the impacts of shallow groundwater in its calculation, which may reduce infiltration capacity. Detailed modelling of shallow water table situations is recommended. Designers should take into account the maximum groundwater level, and hence the minimum infiltration potential, in determining their flood detention design. However, designers should also consider maximum infiltration opportunities to achieve aquifer recharge when the groundwater table is below its maximum level (refer to the Design Considerations section of the Infiltration Basins and Trenches BMP for further discussion).

The required infiltration capacity of a soil surface, vegetated area or pervious pavement for a selected design storm event (with zero overflow) is calculated by:

$$Q_{peak} = k_h A_{\text{inf}}$$

Where:

Q_{peak} = peak design runoff rate from the contributing catchment (m^3/s)

k_h = design hydraulic conductivity (m/s)

A_{inf} = surface area available for infiltration (m^2)

Hence:

$$\frac{CiA}{1000 \times 60^2} = k_h A_{\text{inf}}$$

Where:

C = runoff coefficient as defined in Institution of Engineers Australia (2001)

i = probabilistic rainfall intensity (mm/hr)

A = total defined catchment area (m^2), i.e. the area of the treatment surface plus the surrounding contributing catchment area

This equation applies where the infiltration surface is located within the total defined catchment area (A), as shown in Figure 4, the paving is uniformly porous and the overall value of the hydraulic conductivity for the product and its underlying sub-structure is known. However, for permeable paving where part of the pavement area is impervious (for example, area taken up by lattice work) and this has not been accounted for in the overall value of the hydraulic conductivity, a blockage factor must be applied. The blockage factor accounts for the surface area of the pavement that is not contributing to infiltration (as shown in Figure 5).

Hence:

$$\frac{CiA}{1000 \times 60^2} = k_h (1-\psi) A_{\inf}$$

Where:

Ψ = infiltration surface blockage factor

Note: this equation applies where the infiltration surface is located within the total defined catchment area (A).

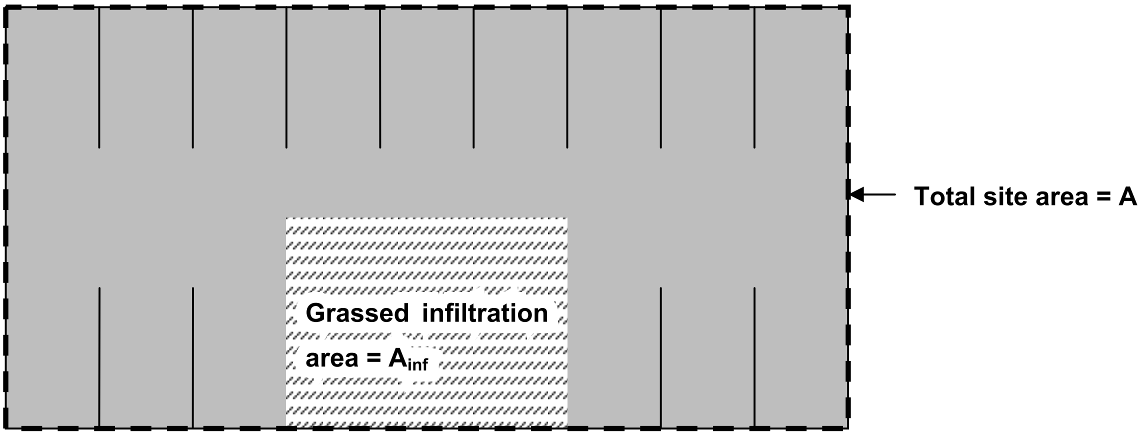

Figure 4. Example definition of a catchment area where the infiltration surface is located within the defined site area.

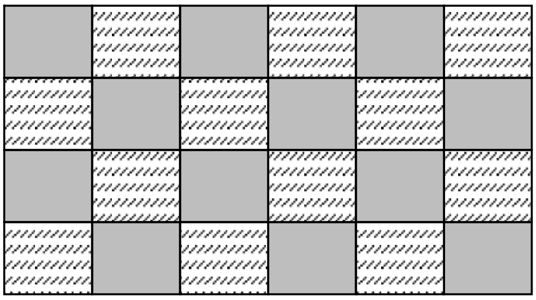

Figure 5. A blockage factor of 0.5 would need to be applied to account for the impervious concrete pavers interspaced with grass squares in this illustration of permeable paving.

Where the infiltration surface is external to the impervious area from which it is receiving runoff (as shown in Figure 6), Q_{peak} passing to the infiltration surface must also take into account the rainfall input to the surface itself.

Hence, total peak inflow:

$$Q_{peak} = \frac{CiA}{1000 \times 60^2} + \frac{A_{\inf} i}{1000 \times 60^2} \qquad [\mathrm{m^3/s}]$$

The flow capacity of the pervious area:

$$Q_{\inf} = (1-\psi) A_{\inf} k_h \qquad [\mathrm{m^3/s}]$$

To determine the required area of the pervious surface:

$$\frac{CiA}{1000 \times 60^2} + \frac{A_{\inf} i}{1000 \times 60^2} = (1-\psi) A_{\inf} k_h$$

$$A_{\inf} = \frac{CiA}{1000 \times 60^2 \left[(1-\psi) k_h - \dfrac{i}{1000 \times 60^2} \right]} \qquad [\mathrm{m}^2]$$

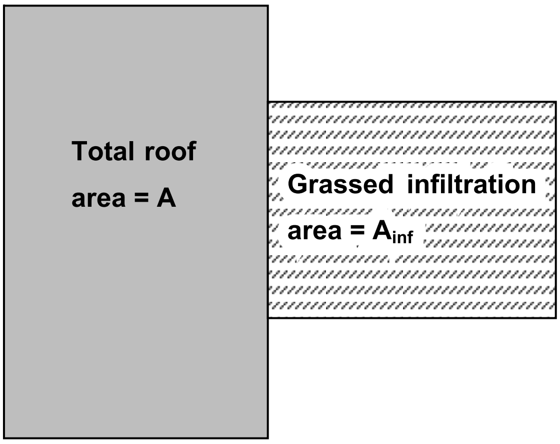

Figure 6. Example definition of a catchment area where the infiltration surface is located external to the defined site area.

Note that in the previous equations, if the soil hydraulic conductivity has been determined by small test pits and boreholes, k_h should be multiplied by the moderation factor U (see Table 3 in the Infiltration Basins and Trenches BMP). Where the long-term or life span hydraulic conductivity is used (as described below), U = 1 may be applied.

The design of pervious paving should consider the reduction in permeability of the pervious surface over time due to sediment accumulation and clogging. Laboratory testing found that the permeability decreased to around 30-50% of the original ‘new’ product value after a period of approximately 30 modelled years (Argue 2004). Over the lifespan of the paving, it is anticipated the permeability reduces to approximately 20% (Argue 2004). Therefore, the design of pervious infiltration systems should adopt a hydraulic conductivity equal to 20% of the ‘new’ value to ensure acceptable lifespan performance. The lifespan of a pervious paving system will depend on the ratio of impervious to pervious area of the contributing catchment surface, and the catchment characteristics, e.g. the amount of trees and sediment in the catchment. Partial blockage over time of a permeable paving system adjacent to an impervious catchment is illustrated in Figure 7.

The lifespan of vegetated porous surfaces is around five times the lifespan of pervious pavement. Further design information, including estimated lifespans of pervious paving systems under different conditions, is provided Argue (2004).

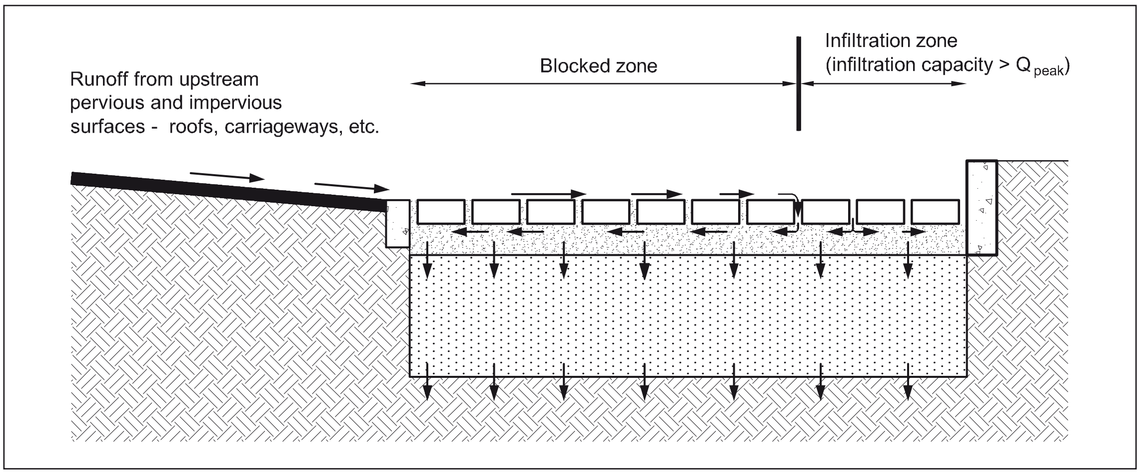

Figure 7. Partial blockage over time of a permeable paving system adjacent to an impervious catchment.

Maintenance

Maintenance of pervious pavement systems requires regular inspection and cleaning to maintain porosity, repair of potholes and cracks and replacement of clogged areas (Water and Rivers Commission 1998).

Regular vacuum sweeping can improve the efficiency of the system. It is recommended that cleaning be undertaken every 3 months (Coombes 2003). Overseas experience in the use of pervious paving has shown that complete clogging can occur between five and ten years after installation, so cleaning of the paving is essential (Dierkes et al. 2002).

A maintenance schedule similar to conventional road surfaces, involving retaining the pavers and replacing part of the underlying sand to remove contaminants, is also recommended for concrete grid, ceramic and plastic modular blocks (Coombes 2003).

Worked example

Assess the use of a reinforced turf courtyard to infiltrate runoff from a 200 m^2 adjacent bitumen carpark.

- carpark impervious surface area, A = 200 m^2
- blockage factor for the reinforced turf product selected, $\Psi = 0.1$
- hydraulic conductivity of the 'new' reinforced turf, $k_h = 2.5 \times 10^{-4}$ m/s
- the 'lifespan' hydraulic conductivity = 20% of the 'new' value, i.e. lifespan $k_h = 5 \times 10^{-5}$ m/s
- site time of concentration, t_c site= 5 minutes
- ARI = 2 years
- runoff coefficient for a 2 year ARI event, $C_2 = 0.765$ (see Worked Example section of the Infiltration Basins and Trenches BMP for calculation of C)

Based on t_c = 5 minutes and ARI = 2 years, the rainfall intensity i_2 = 78.0 mm/hr (from Rainfall Intensity – Frequency – Duration curves for Perth, available from the Bureau of Meteorology).

The required area of the courtyard is estimated as:

$$A_{\inf} = \frac{CiA}{1000 \times 60^2 \left[(1-\psi)k_h - \dfrac{i}{1000 \times 60^2} \right]}$$

$$A_{\inf} = \frac{0.765 \times 78.0 \times 200}{1000 \times 60^2 \left[(1-0.1)(5 \times 10^{-5}) - \dfrac{78.0}{1000 \times 60^2} \right]}$$

$A_{inf} = 142\ m^2$

References and further reading

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