



DPC: 25 / 30483651 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000

Fax: +44 (0)20 8996 7400

www.bsigroup.com

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Part 103: Design and installation of permeable pavements constructed with concrete paving blocks and flags, natural stone slabs and setts and clay pavers – Guide

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Responsible Editorial Project Manager: **Mary Groom**

Direct tel:

E-mail: mary.groom@bsigroup.com

Introduction

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BS 7533-103:2025

Pavements constructed with clay, concrete or natural stone paving units – Part 103: Design and installation of permeable pavements constructed with concrete paving blocks and flags, natural stone slabs and setts and clay pavers – Guide

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Foreword

Publishing information

This part of BS 7533 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on XX Month 2025. It was prepared by Technical Committee B/507, *Paving units and kerbs*. A list of organizations represented on this committee can be obtained on request to the committee manager.

Supersession

This part of BS 7533 supersedes BS 7533-13:2009, which is withdrawn.

Relationship with other publications

BS 7533 is published in the following parts:

- Part 101: *Code of practice for the structural design of pavements using modular paving units*; and
- Part 102: *Installation of pavements using modular paving units – Code of practice*.

Information about this document

This is a full revision of the document, and introduces the following principal changes:

- [list items]
- [list items]

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As a guide, this part of BS 7533 takes the form of guidance and advisory recommendations. It is not to be quoted as if it were a specification or a code of practice.

Presentational conventions

The guidance in this document is presented in roman (i.e. upright) type. Any recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Additional commentary, explanation and general informative material is presented in smaller italic type.

Where words have alternative spellings, the preferred spelling of the *Shorter Oxford English Dictionary* is used (e.g. “organization” rather than “organisation”).

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DRAFT

1 Scope

This part of BS 7533 gives guidance on the design of permeable pavements surfaced with:

- concrete paving blocks manufactured in accordance with BS EN 1338;
- concrete paving flags manufactured in accordance with BS EN 1339;
- natural stone slabs manufactured in accordance with BS EN 1341;
- natural stone setts manufactured in accordance with BS EN 1342;
- clay pavers manufactured in accordance with BS EN 1344; and
- other modular paving units, including porcelain.

It applies to areas subject to pedestrian and vehicular loading, with axle loads up to 11 000 kg and a cumulative design traffic of up to 30 million standard axles (msa).

NOTE Attention is drawn to the Road Vehicles (Construction and Use) Regulations 1986 [1], which specifies the pedestrian and vehicular loading requirements.

This part of BS 7533 specifically excludes design traffic above the specified maximum and areas of higher vehicle loading such as aircraft pavements and those in ports and specialized industrial areas. Although permeable pavements are often used effectively in conjunction with tree pits and tree root protection systems, the design and construction of tree root protection and tree pits is a specialist application and is not covered in this British Standard.

Design for impermeable surface with a water stored within the pavement foundation layers, commonly known as a reservoir foundation below, is not covered by this British Standard.

This British Standard applies to the design and installation of permeable pavements formed from pavers bedded on and jointed with graded granular permeable aggregates and permeable mortar where there is a full depth permeable base and/or sub-base construction below. Following this guidance provides a sustainable drainage system (SuDS) component.

A surface constructed with a permeable laying course and permeable jointing material, bound or unbound, where the underlying pavement construction is impermeable (for example, an existing or new impermeable road base or similar) can be used to provide a surface drainage function or degree of surface water control in some scenarios and is covered in Annex C. This configuration, sometimes referred to as “permeable paving overlay”, in and of itself, does not constitute a SuDS component.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions, or limits the application, of this document¹⁾. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 8582, *Code of practice for surface water management for development sites*

BS 8661, *Geotextiles – Guidance for specification for basic separation and filtration functions*

BS EN ISO 10318-1, *Geosynthetics – Part 1: Vocabulary*

¹⁾ Documents that are referred to solely in an informative manner are listed in the Bibliography.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in BS EN ISO 10318-1, BS 8582 and BS 8661 and the following apply.

3.1 attenuation

reduction in volume and rate of surface water discharge from a site

3.2 base

one or more layers of material placed above the sub-base that constitutes the main structural element of a pavement on which the laying course is placed

[SOURCE: BS 7533-101:2021, 3.1.1]

3.3 capping

layer of foundation material placed immediately above the formation

NOTE The capping is the lowest layer of the foundation (it might not always be present).

3.4 channelized traffic

traffic where the vehicle track width and the traffic lane width are virtually the same

NOTE Normal lane widths in a highway do not constitute channelized traffic.

3.5 commercial vehicle

vehicle over 3.5 tonnes gross vehicle weight

3.6 competent person

person, suitably trained and qualified by knowledge and practical experience, and provided with the necessary instructions, to enable the required task(s) to be carried out correctly

3.7 conventional pavement

pavement that does not specifically allow water to pass through its layers into the sub-base

3.8 drainage

natural or artificial removal of a surface's water and sub-surface water from an area with excess water

3.9 fin drain

geocomposite material placed vertically to collect and drain surface or groundwater

NOTE The fin drain is attached continuously to a pipe at the bottom that collects and conveys water from the geocomposite.

3.10 formation

interface between the subgrade and the pavement foundation

3.11 foundation

lower pavement layers comprising the sub-base and capping (if used) which provide support to the upper pavement layers

[SOURCE: BS 7533-101:2021, 3.1.16]

3.12 geocomposite

manufactured, assembled material using at least one geosynthetic product among the components

3.13 geogrid

planar, polymeric structure consisting of a regular open network of integrally connected, tensile elements, which can be linked by extrusion, bonding or interlacing, whose openings are larger than the constituents

3.14 geotextiles

3.14.1 geotextile

proprietary fabric that allows water to flow through and reduced migration of particulates between construction layers

3.14.2 nonwoven geotextile

geotextile made of directionally or randomly orientated fibres, filaments or other elements, mechanically and/or thermally and/or chemically bonded

3.14.3 woven geotextile

geotextile produced by interlacing, usually at right angles, two or more sets of yarns, filaments, tapes or other elements

3.15 half empty time

time it takes to reduce the volume of water in a reservoir pavement to half its maximum capacity

3.16 impermeable membrane

membrane which prevents the passage of water

3.17 jointing material

material used to fill the joint in modular paving

NOTE The jointing material can be either bound or unbound.

3.18 laying course

layer of material on which paving units are installed

NOTE The laying course can be bound or unbound.

3.19 paver/paving unit

clay paver or a concrete block paver or paving slab or a natural stone slab or sett

3.20 permeability

ability of a material to allow water to pass through it and hence the extent to which voids in a material are connected

3.21 permeable modular surface

surface made up of paving units jointing and laying course material forming the wearing course and its aesthetic and allowing the passage of water through the surface as part of a permeable pavement, or to a suitable alternative outlet when used as a surface drainage function

3.22 permeable pavement

pavement designed to allow water to pass from the surface to a lower level via the units, joints or formed gaps between the paving units and where the water is stored or attenuated within its base and/or sub-base

3.23 porosity

percentage of the bulk volume of a rock or soil that is occupied by voids

3.24 reservoir pavement

pavement (foundation layer) designed to retain water within its structure

3.25 separation with filtration

condition where presence of soils with $\geq 15\%$ fines and passage of water is a design factor

3.26 standard axle

axle carrying a load of 80 kN or 8 200 kg

3.27 sub-base

one or more foundation layers of material placed immediately above the subgrade or capping layer

3.28 subgrade

upper part of the soil, natural or constructed, that supports the loads transmitted by the overlying pavement foundation

3.29 subgrade improvement layer

layer of granular or treated material at the top of the subgrade to provide an improved load bearing capability of the subgrade

4 General design criteria

4.1 Basis of design

A permeable pavement is an effective means of providing a structural pavement suitable for pedestrians and vehicular traffic while also allowing water to pass straight through the surface into the pavement construction for temporary storage, storm attenuation and dispersal to the ground or collection. Permeable modular surface design for the conveyance of water to an outlet is covered in Annex C. This is not in and of itself a SuDS component.

A permeable pavement needs to be able to capture the specified amount of water to be retained and then discharge it in a controlled manner through the subgrade or drainage system. At the same time, the pavement has to be able to withstand the loadings imposed by vehicles. The design of the pavement is approached by determining the sub-base thickness required to meet both the hydraulic factors and the loading factors. The greater sub-base thickness identified for either of these factors is adopted.

When determining the preferred construction type, account should be taken of the need to access buried services and the future availability of materials for reinstatement works. The safety implications of constructing permeable paving which requires mechanical excavation over shallow or vulnerable buried services should be assessed.

If an acceptable permeable pavement design is not possible or practicable, an alternative pavement design and/or installation method should be selected.

4.2 Design considerations

4.2.1 General

Design for pavements is in two parts: structural to support the traffic load and hydraulic to manage the surface water effectively. These are determined separately (see Figure 1).

Surface water drainage proposals should fully explore the surface water hierarchy and provide evidence to support alignment with requirements valid in the place of installation and local flood risk strategies and policies before connection to a sewer is undertaken.

Figure 1 – Permeable pavement hydraulic design procedure

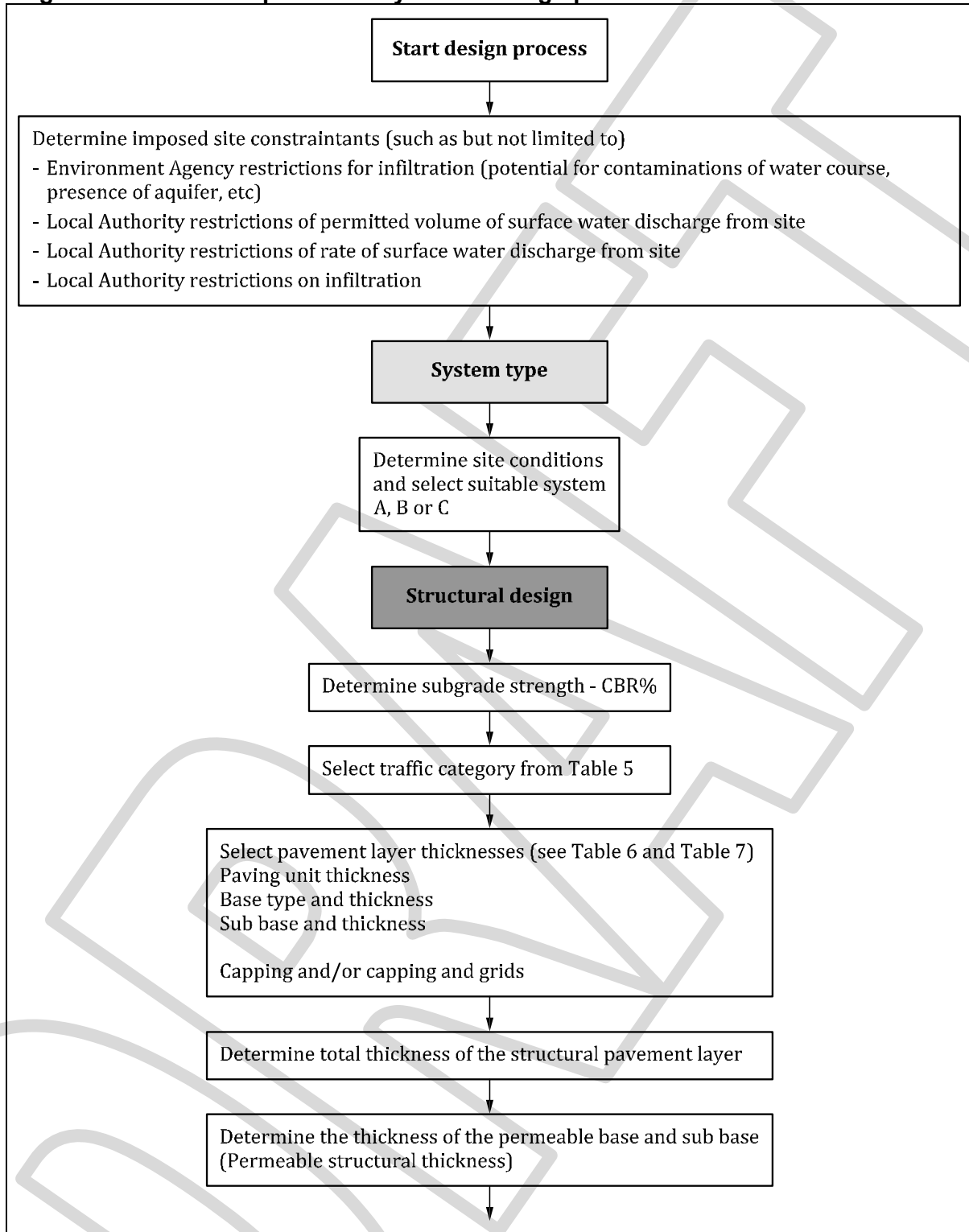
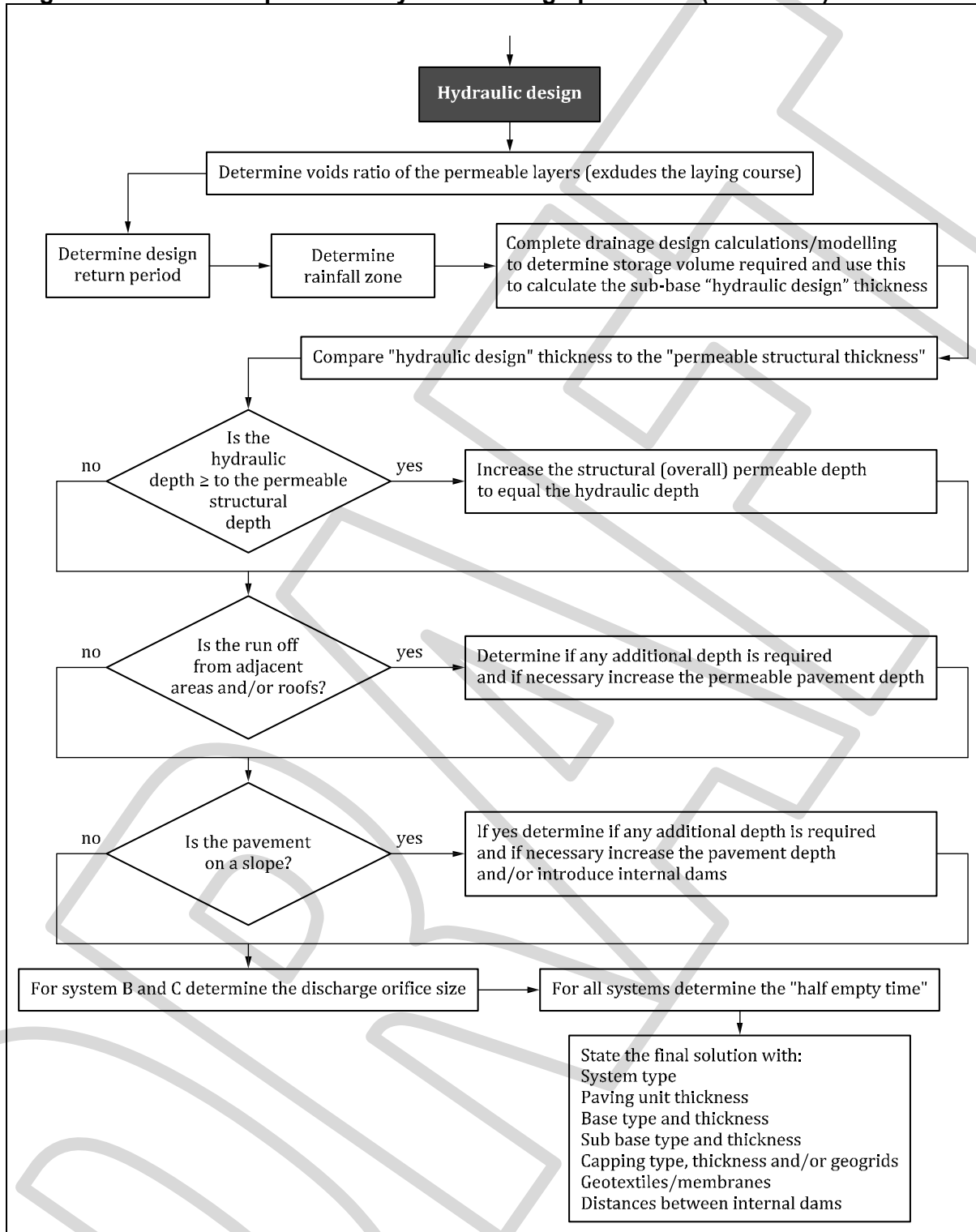


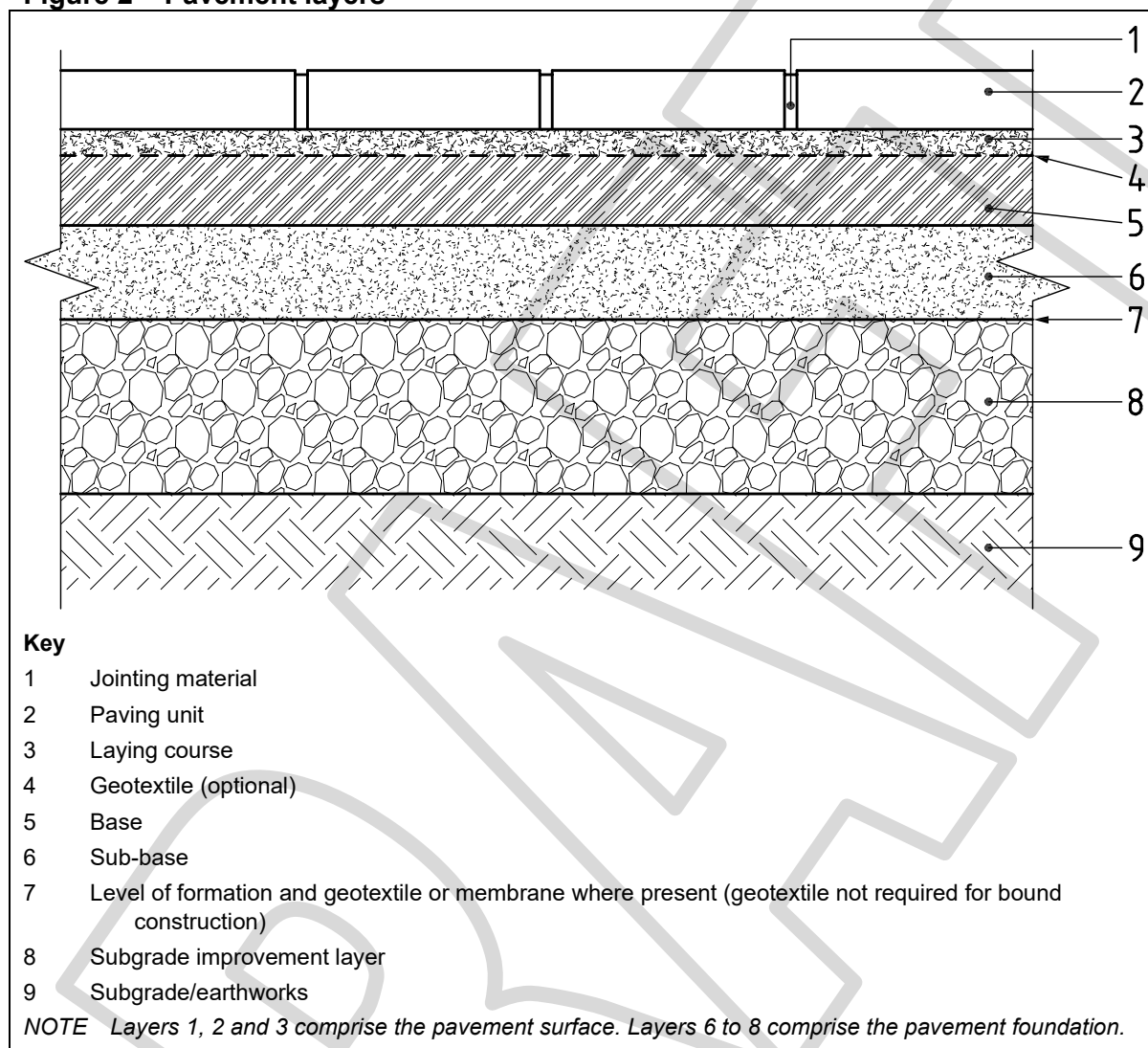
Figure 1 – Permeable pavement hydraulic design procedure (continued)



4.2.2 Structure of a pavement

A pavement should comprise as many of the layers shown in Figure 2 as are specified by the designer.

Figure 2 – Pavement layers



4.3 Determine imposed site constraints and site conditions

The site constraints should be assessed by a competent person with reference to geotechnical and environmental site investigations and risk assessments. Factors to be assessed include:

- a) infiltration rates (see 4.4);
- b) groundwater source protection zones;
- c) depth to groundwater;
- d) presence of mobile contamination;
- e) presence of geotechnical hazards;
- f) proximity to buildings and potential impact on foundations (low risk with infiltration from permeable pavements and infiltration from shallow systems is allowable within 5 m of buildings);

- g) allowable discharge rates from the site; and
- h) adoption organization requirements.

Further advice on the geotechnical and contaminated land risk that can be affected by using infiltration systems is provided in the CIRIA SuDS manual [2].

4.4 Infiltration tests

4.4.1 General

Permeable pavements allow water to infiltrate at shallow depth. Most of the time there is little or no free water in the sub-base because for small rainfall events up to 5 mm the water soaks into the paving units, jointing, laying course and foundation materials before evaporating. Only in large rainfall events does water accumulate in the sub-base and soak into the ground. The ground below the sub-base is likely to be partially saturated when most infiltration occurs. The head of water would be shallow and, in most cases, less than 300 mm depth. For this reason, large and deep infiltration tests are not appropriate for determining the infiltration rate below permeable pavements.

Infiltration test methods suitable for permeable pavement are described in BS 8582; however, the following tests are also appropriate.

- a) Single or double ring infiltrometer tests in accordance with BS EN ISO 22282-5. These should be completed in the base of shallow excavations (that are stable and safe to allow the work to be undertaken).
- b) Permeameter test in borehole in accordance with ASTM D5126.
- c) Tests at shallow depth with a maximum depth of water typically of 300 mm.

Earthworks to decrease or increase ground levels (commonly referred to as cut and fill) might result in the ground level being reduced by a significant amount prior to construction of a permeable pavement. The depth to formation at site investigation stage might preclude infiltrometer tests. In this case either permeameter tests or a permeability test in a borehole is acceptable (see BS EN ISO 22282-2). The ground around the well should be pre-saturated and the results analysed as a test in the unsaturated zone. These can be undertaken to any reasonably expected depth for an infiltration device.

The risk of smearing lower permeability materials around the surface of the borehole which could affect the test result should be assessed and, if necessary, the sides of the borehole cleaned with a wire brush or similar.

The test results should be accompanied by a ground model developed by a competent person that includes a sufficient number of exploratory holes with soil or rock descriptions of the ground into which the water is expected to soak (these descriptions should be in accordance with BS EN ISO 14688-1 or BS EN ISO 14689). The borehole records should identify the thickness of soil and rock strata and estimate the historical high groundwater level. The boreholes should be of sufficient depth to establish that a minimum of 2 m of permeable soil exists below the formation level of the permeable pavement and that there is a minimum of 1 m between the formation and the historical high groundwater mark.

A sufficient number of infiltrometer or permeameter tests should be completed to provide an indication of the likely variability due to the macro structure of the ground (fissures, etc). As a guide, the number of tests in Table 1 is suggested.

Table 1 – Number of infiltration tests required

Area of permeable pavement	No of tests
Single driveway to a single house (2.5 m by 5 m) or developments up to 3 houses	1 per single driveway
Single driveways (2.5 m by 5 m) in a housing development > 3 houses < 30 houses	1 for every 5 single driveways (minimum of 3)
Single driveways (2.5 m by 5 m) in a housing development > 30 houses	1 for every 10 single driveways
Rows of parking bays in car parks or alongside roads	1 for every five parking bays (minimum of 3)
Large areas of continuous permeable paving such as car parks	1 every 200 m ² (minimum of 3)

On larger sites with variable geology, a sufficient number of tests to characterize different strata would be needed. In that case the minimum number of tests applies to each strata.

If there is no obvious macro structure that allows higher rates of flow, the minimum results should be used as the design infiltration rate.

If there is macro structure, the mean value can be used as the design infiltration rate.

An infiltration test report prepared by a competent person should be provided which confirms through the infiltration testing and/or ground model that the proposed location is suitable for the proposed infiltration from a permeable pavement and an infiltration rate should be recommended (and the stratum to which it applies and the level, if appropriate, clearly stated).

4.4.2 Units for permeability and infiltration rates

The SI unit for reporting soil permeability is m/s. Therefore, soil infiltration rates are usually also reported in m/s. There is a general understanding within the industry of what constitutes a high or low value quoted in these units.

The infiltration rate of rainwater into the top surface of a pervious pavement is often compared to rainfall intensity. Rainfall intensity is reported in mm/h and therefore the infiltration of water into the pervious surface is reported in these units.

4.5 Retrofitting

When retrofitting permeable paving into existing streets it should preferably only be used to manage water falling on it and from immediately adjacent areas of carriageway. The cross and long falls should be suitable to prevent water running onto the pavement and channelling along the kerb edge, which causes premature blockage. If water from upstream catchments is to be managed by permeable pavements it should not be allowed to run onto the pavement as channelized flow along the kerb edge and the additional impermeable area should be minimized. Combining the permeable pavement with an upstream rain garden is one way of managing up stream flow effectively (the rain garden manages the water initially and the permeable pavement provides an overflow route and extra storage without loss of parking spaces). See Annex C for information on the use of products and systems over an impermeable structure. This configuration of permeable surface overlay is not deemed to be a permeable pavement for drainage purposes but can in some scenarios provide useful surface drainage options, conveying water to a suitable drainage outfall or other storage facility.

4.6 Selection of pavement system

4.6.1 General

When determining which type of permeable pavement to apply, consultation should be made with organizations such as the Environment Agency and the relevant Local Authority to understand any constraints that might be applicable in relation to any limitations regarding surface water discharge or infiltration. This can influence the system(s) which are suitable.

Table 2 gives guidance on appropriate pavement systems for a range of subgrade conditions, while Table 3 gives guidance on soil classification.

Table 2 – Guidance on selection of a pavement system

Ground characteristics	System A: Total infiltration	System B: Partial infiltration	System C: No infiltration
Permeability of subgrade defined by hydraulic conductivity, k (m/s):			
1×10^{-6} to 1×10^{-3}	✓	✓	✓
1×10^{-8} to 1×10^{-6}	✗	✓	✓
1×10^{-10} to 1×10^{-8}	✗	✗ ^{A)}	✓
Highest expected water level within 1 000 mm of formation level	✗	✗	✓
Pollutants present in subgrade	✗	✗	✓
Ground conditions such that infiltration of water is not recommended (e.g. solution features, old mine workings, etc.)	✗	✗	✓

NOTE For instances where water storage cannot be accommodated, see Annex C for alternative surface drainage options.

^{A)} Partial infiltration systems may be used in soils with permeability less than 10^{-8} m/s but the infiltration of water is not allowed for in the storage design. This helps with the provision of interception.

Table 3 – Soil classification guide

Soil classification	Typical range for hydraulic conductivity, k m/s	Typical range of CBR values when read in conjunction with Table 2	Plasticity index
Heavy clay	10^{-10} to 10^{-8}	2 to 5	40 to 70
Silty clay	10^{-9} to 10^{-8}	3 to 6	30
Sandy clay	10^{-9} to 10^{-6}	5 to 20	10 to 20
Poorly graded sand	5×10^{-7} to 5×10^{-6}	10 to 40	—
Well graded sand	5×10^{-6} to 10^{-4}	10 to 40	—
Well graded sandy gravel	10^{-5} to 10^{-3}	30 to 80	—

For System A and System B, the highest recorded groundwater level should be not greater than 1 000 mm below the level of formation for either Systems A or B. This is to allow filtration of pollutants in the soil below the pavement and also to prevent groundwater rising and reducing the available storage in the sub-base.

4.6.2 Hydraulic conductivity, permeability and infiltration rate

The hydraulic conductivity, k , of a soil or aggregate is a measure of how fast a fluid can flow through a fully saturated porous material under a hydraulic gradient. It also commonly referred to as the permeability or coefficient of permeability, but the correct term in respect of water flow within the materials in permeable pavements is hydraulic conductivity.

Hydraulic conductivity is a function of the material and the fluid (in this case, water) and has units of m/s.

Permeability is an intrinsic property of the material and does not depend on the fluid being moved. It has units of m^2 .

The relationship between saturated water flow and the properties of a porous material is defined by Darcy's Law.

Infiltration rate is a measure of how fast water flows into the surface of a soil or the top of the permeable pavement. In this case, the materials are only partially saturated and the relationship between soil properties and flow is far more complex. For this reason, an empirical constant, the infiltration rate, is used to define how fast water enters the surface. The infiltration rate is measured using infiltration tests on the soil or the pavement surface.

Where water is free draining vertically in an unsaturated soil with a reasonably steady flow system it is reasonable to assume a unit hydraulic gradient. Under these conditions the infiltration rate is equivalent to the hydraulic conductivity.

4.6.3 System A: total infiltration

System A (see Figure 3) allows all water falling onto the pavement to infiltrate down through the joints or voids between the paving units passing through the constructed layers below and eventually into the subgrade. Some retention of the water occurs temporarily in the sub-base layer allowing for initial storage before it eventually passes through into the ground. System A offers a solution with zero discharge to sewage systems or water courses, i.e. no additional water is discharged, eliminating the need for associated traditional drainage systems such as gulleys and associated pipe work. In some situations, overflows might be needed to provide support drainage in exceedance conditions.