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understanding permeable paving

GUIDANCE FOR DESIGNERS, DEVELOPERS, PLANNERS AND LOCAL AUTHORITIES

EDITION 5

Interpave
THE PRECAST CONCRETE PAVING AND KERB ASSOCIATION
www.paving.org.uk

Introduction

This guide is intended to help all those involved with the development process – including designers and developers, and planning, building control and adoption officers – to understand concrete block permeable paving (CBPP) as an essential Sustainable Drainage System (SuDS) technique. It deals with regulatory as well as practical issues and explains the different systems and techniques available, and how they can be used to meet current demands. It considers statutory requirements, the planning process, overall design, long-term performance, costs and adoption issues.

This edition replaces several earlier Interpave publications and takes into account *The Flood and Water Management Act 2010* and a draft of *The National Standards for SuDS* available at the time of publication. Its sister publication *Permeable Pavements – Guide to the Design, Construction and Maintenance of Concrete Block Permeable Pavements*, available from **www.paving.org.uk**, offers far more technical detail and is considered to be the definitive design, construction and maintenance guidance for CBPP.

The need for sustainable drainage

The Environment Agency has estimated that over two thirds of the 57,000 homes affected by the 2007 summer floods were flooded not by swollen rivers but by surface water runoff or overloaded drainage systems. The government's *Foresight* report estimates that currently 80,000 properties are at very high risk from surface water flooding causing, on average, £270 million of damage every year. The continuing growth in urbanisation and ambitious government driven housing programmes, combined with more extreme weather events linked to climate change, will only exacerbate the problem. Clearly, a sustainable approach to all surface drainage is needed to deal with existing overloaded systems and to accommodate future growth. It is now well recognised that Sustainable Drainage Systems (SuDS) offer the solution, as reflected by the new legislation.

SuDS is a design philosophy which, when using a range of techniques in a sequence, is known as a management train. SuDS manages surface water by attenuation and filtration with the aim of replicating, as closely as possible, the natural drainage from a site before development.

The three pillars of SuDS are to:

- minimise water runoff QUANTITY
- improve water QUALITY
- provide AMENITY and biodiversity.

Governmental planning policy guidance throughout the UK has for some time encouraged use of SuDS on all developments wherever possible and guided planners to take a central role in coordinating its acceptance by all from the very first stages of development. This stance is supported by Building Regulations and various guidance documents, including the *Manual for Streets* and *Code for Sustainable Homes*. Also, permitted development rights have already been taken away from new or replacement paving around many existing buildings unless it is permeable or retains or infiltrates runoff on the property.

However, the principal legislation controlling surface water drainage in England and Wales will be *The Flood and Water Management Act 2010*, once it takes effect after completion and implementation of *National Standards for SuDS* (which remain in draft form at the time of publication). The Act takes on board several of the recommendations of the Pitt Review into the 2007 flooding events and *Future Water*, the government's water strategy for England. Essentially, it aims to replace conventional piped drainage for surface water management with SuDS and ensure that SuDS proposals happen on the ground – helping to avoid downstream flooding and reduce water-borne pollution.

Extensive areas of CBPP used at the Craigmillar redevelopment in Edinburgh – the first to be adopted in Scotland. A case study on this project can be downloaded from www.paving.org.uk

Similarly, in Scotland the *Water Environment (Controlled Activities) (Scotland) Regulations 2011* already require surface water drainage systems from new developments to discharge water to the environment through SuDS.

Interpave's role

CBPP is a unique sustainable drainage technology which is being championed by Interpave, representing all the major precast concrete paving manufacturers in the UK. Its block paving manufacturer members maintain the highest standards of quality control, product innovation and sustainability and are signatories to the British Precast Concrete Federation *Sustainability Charter*. Interpave has the expertise, international contacts and resources to develop technologies such as permeable paving to the benefit of the building industry as a whole. Interpave works closely with other organisations such as Defra, Environment Agency, the Scottish Environmental Protection Agency, CIRIA and SuDSnet in driving forward sustainable drainage solutions. Its manufacturing members continue to develop innovative concrete block permeable paving products and systems.

Permeable paving principles

In conventional pavements, rainwater is allowed to run across the surface to gulleys that collect and direct it into pipes, removing it as quickly as possible. This means that water with the pollutants contained in it are rapidly conveyed into overloaded drains, streams and rivers, leading to floods in extreme conditions.

In contrast, CBPP addresses both flooding and pollution issues, unlike attenuation tanks which only deal with flooding. It also has a dual role, acting as the drainage system as well as supporting traffic loads. CBPP allows water to pass through the surface – between each block – and into the underlying permeable sub-base where it is stored and released slowly, either into the ground, to the next SuDS management stage or to a drainage system. Unlike conventional road constructions, the permeable sub-base aggregate is specifically designed to accommodate water.

At the same time, many pollutants are substantially removed and treated within the CBPP itself, before water infiltrates to the subgrade (ground) or passes into the next stage of the management train. Increasingly, CBPP is being used at the head of the management train as a controlled source of clean water for harvesting, irrigation and amenity, forming an integral part of landscape designs.

Products

There is a growing choice of concrete blocks and flags available from Interpave manufacturers, designed specifically for permeable paving. Essentially they have the same impressive performance as conventional precast concrete paving products, including slip and skid resistance, durability and strength. Various shapes, styles, finishes and colours are available allowing real design freedom. Another Interpave publication – *Planning with Paving* – illustrates the versatility of precast concrete paving and kerbs, and how they can be used in the design of our external environment to meet the aims of the *National Planning Policy Framework* and current guidelines such as the *Manual for Streets*, both discussed in Interpave's *Planning with Paving* guide.

The difference with CBPP is enlarged joints created by larger than conventional spacer nibs on the sides of each unit. These joints are subsequently filled with a joint filling material specific to each product, which is an angular aggregate, not sand. This arrangement ensures that water will continue to pass through the joints over the long-term. It is fundamentally unlike pervious materials.

CBPP offers a major benefit in modern urban design, enabling accessible shared surfaces to be created without the need for cross falls, channels or gulleys, while still avoiding standing water.

For further information on specific block types, contact the relevant Interpave manufacturer via **www.paving.org.uk**.

Permeable paving performance & benefits

Permeable paving and SuDS

CBPP provides a particularly useful source control technique at the head of a management train and achieves the three well-known pillars of SuDS:

- Quantity
- Quality
- Amenity

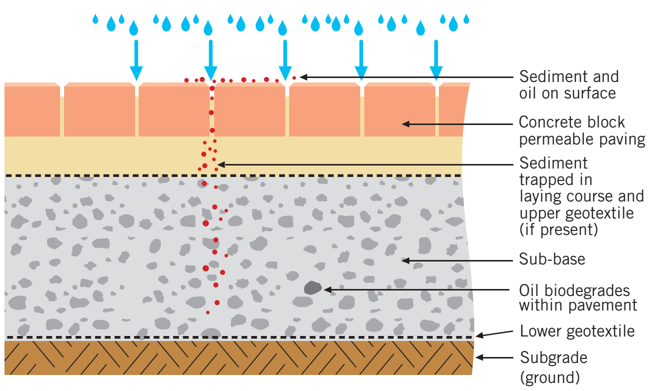
At the same time, it offers attractive, durable and safe hard surfaces suitable for a wide range of applications.

Quantity – rainwater management

CBPP deals with surface water close to where rainfall hits the ground. This is known as 'source control' and is fundamental to the SuDS philosophy. It also reduces the peak rate, total volume and frequency of runoff and helps to replicate green-field runoff characteristics from development sites. A study by H. R. Wallingford (Kellagher and Lauchlin 2003) confirms that CBPP is one of the most space-efficient SuDS components available, as it does not require any additional land take. In fact, it can handle runoff from roof drainage and adjacent impermeable surfaces, as well as rain falling on the CBPP itself, as discussed later.

Quality – handling pollution

CBPP is very effective at removing pollution from runoff, so improving water quality, unlike attenuation tanks or conventional drainage systems which effectively concentrate pollutants and flush them directly into drains, watercourses and groundwater. The pollutants may either remain on the surface or be flushed into the underlying pavement layers, where many are filtered and trapped, or degrade over time.



Permeable pavements provide diffuse dispersion, enabling effective water treatment, and are unlike soakaways which concentrate pollutant loads. This characteristic is recognised by the Scottish Environmental Protection Agency which considers permeable pavements as having two 'treatment stages' and *"accepts that oil interceptors are not required on permeable car parking areas which have an engineered sub-base…"*.

The capabilities of permeable pavements used in isolation without the need for oil interceptors are also recognised in *PPG 3 Pollution Prevention Guidelines' (2006)* which says: *"You might not need an oil separator if you use 'sustainable drainage systems' (SUDS)...Techniques that control pollution close to the source, such as permeable surfaces or infiltration trenches, can offer a suitable means of treatment for run-off from low risk areas such as roofs, car parks, and non-operational areas."*

Percentage Removal of Pollutants	
Total suspended solids	60-95%
Hydrocarbons	70-90%
Total phosphorus	50-80%
Total nitrogen	65-80%
Heavy metals	60-95%
(source: CIRIA C609, 2004)	

Water Quality Treatment Potential	
Removal of total suspended solids	High
Removal of heavy metals	High
Removal of nutrients (phosphorus, nitrogen)	High
Removal of bacteria	High
Treatment of suspended sediments & dissolved pollutants	High
(source: CIRIA C697, 2007)	

Amenity – improving the environment

As a result of its unique capabilities, concrete block permeable paving offers designers the exciting potential of a gradual supply of clean, treated water. This can be integrated with landscape design, including sculptural outlets and natural water features for education, adventure and play, as well as to promote biodiversity. The treated water can also be used for irrigation and harvesting (for example, toilet flushing).

An Interpave case study explores several school and housing schemes by Robert Bray Associates which demonstrate these approaches. In addition, the Lamb Drove SuDS monitoring project in Cambourne records the water quality benefits of permeable paving used at the head of a management train and its impact on biodiversity.

CBPP at this housing scheme in Stamford supplies clean water to landscape features.

Durable, attractive & safe surfaces

CBPP is used on projects ranging from footpaths to container terminals, with the reassurance of proven engineering design solutions for every type of application. In addition to the visual design possibilities discussed earlier, CBPP offers two fundamental benefits compared with conventional surfacing:

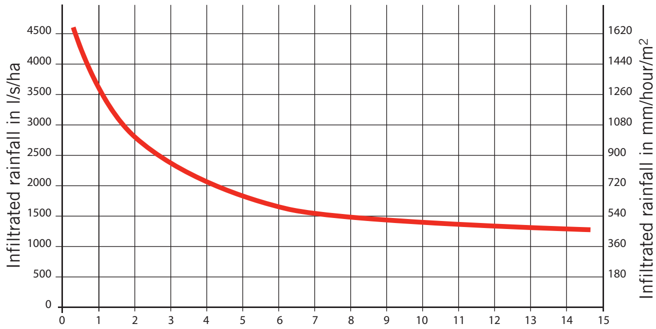
- completely level, well-drained, firm and slip-resistance surfaces
- an absence of channels, gulleys and other interruptions.

As a result, CBPP meets current accessibility requirements for the whole community – unlike loose materials such as gravel, suggested in some guidance on permeable paving but specifically excluded by accessibility rules, such as Building Regulation Part M. Particular benefits include eliminating 'ponding', reducing the risk of ice forming on the surface and no rain splashing from standing water. These aspects are particularly important for accessible shared surfaces, eliminating the need for cross falls, channels or gulleys.

This capability for completely level pavements is helpful in other applications as well, for example level car parking areas for supermarkets, making it easier to control trolleys, in container yards to meet specific operational requirements or areas used by forklift trucks. From an ecological perspective, CBPP also avoids the "death traps" which open gulleys present to wildlife and provides sustenance to nearby trees and plants.

Service life and maintenance

CBPP technology has proven itself over decades of successful use around the world. One issue that is well-understood is the performance of the block paved surface. The infiltration rate of CBPP will decrease due to the build-up of detritus in the jointing material, then stabilise with age – as summarised in the graph below.



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American and German experience recommends that the design infiltration rate through the surface should be 10% of the initial rate, to take into account the effect of clogging over a 20-year design life without maintenance. Even after allowing for clogging, studies have shown that the long-term infiltration capability of permeable pavements will normally substantially exceed UK hydrological requirements. The typical rainfall rate in the UK is 75mm/hour. The percolation rate through joints of newly laid CBPP is 4000mm/hour, so even allowing for the reduction to just 10% discussed above, there is still a large factor of safety.

Maintenance is minimal – no more extensive than that for conventional block paving and less than for conventional gulley and pipe drainage. There is now sufficient long-term experience with CBPP in the UK to endorse the minimal maintenance requirements of CBPP. For example, Oxfordshire County Council has taken a positive and pragmatic approach to adopting streets and other areas using concrete block permeable paving for some 15 years. Examples there (discussed in an Interpave case study) demonstrate the continuing performance of CBPP with no maintenance over 5 years.

Similar conclusions have been reached by other practitioners and the Lamb Drove SuDS monitoring project report concluded that: *"The permeable pavement infiltration study specifically illustrates the robustness of the performance of this feature to limited maintenance. The infiltration capacity of the permeable pavement is able to adequately cope with the highest recorded rainfall intensity at the Study Site."*

Oxfordshire CC has been adopting streets and other areas using CBPP for some 15 years.

It is also important to remember that any problems with CBPP would become apparent on the surface with a visual inspection, unlike the complex below-ground inspections needed for pipe drainage.

Initial and whole life costs

At the time of publication, there is some debate about comparing the costs of SuDS with those of conventional drainage systems. It is essential to apply a like-for-like, comprehensive cost comparison, examining all attributes of the drainage systems and components needed to achieve common aims: for example, removal of pollution which might require additional measures for conventional systems. The Lamb Drove SuDS monitoring project report represents the most comprehensive research and demonstrates that the SuDS scheme with CBPP resulted in capital and maintenance costs – and therefore whole life costs - that were much lower than for conventional drainage.

Monitoring of the Cambourne project highlights the robust performance and minimal maintenance needs of CBPP.

Independent research, commissioned by Interpave and carried out by specialist consultants Scott Wilson provides comprehensive cost guidance for paving designers. It considered over 250 different scenarios and compared concrete block permeable pavements with conventional block paving, asphalt and in situ concrete. By taking into account drainage requirements, the economic advantages of concrete block permeable pavements – both in terms of initial construction cost and whole life costs – have been clearly demonstrated. For example, on housing estate roads, initial costs for all three CBPP systems are lower than other materials including asphalt, except for the very poorest ground conditions, while whole life costs are the lowest. The complete Scott Wilson reports, as well as a summary document, are available from: **www.paving.org.uk**.

Benefits of Concrete Block Permeable Paving

- providing a structural pavement while allowing rainwater to infiltrate into the pavement construction for temporary storage
- playing an important part in removing a wide range of pollutants from water passing through
- allowing treated water to infiltrate to the ground, be harvested for re-use or released to a water course, the next SuDS management stage or other drainage system
- suitable for a wide variety of residential, commercial and industrial applications
- optimising land use by combining two functions in one construction: structural paving combined with the storage and attenuation of surface water
- handling rainwater from roof drainage and impervious pavements as well as the permeable paving itself.

Concrete block permeable paving, combined with conventional block paving, is used throughout this major regeneration project in Craigmillar, Edinburgh.

Permeable paving law

Water framework directive

The European Water Framework Directive requires that surface water discharges are managed so that their impact on the receiving environment is mitigated. The objective is to protect the aquatic environment and control pollution from diffuse sources such as urban drainage – a key aspect that effectively precludes use of the traditional approach to drainage. The Directive is, of course, a major driver for the British government initiatives described here.

Planning policy

Different national guidelines apply around the UK to influence local planning authorities (LPAs) both in formulating their local policies and in determining individual planning applications for development whether at 'outline' or 'detailed' stages.

The National Planning Policy Framework (NPPF) came into force in March 2012. It applies to England and replaces the numerous 'Planning Policy Statements' and other policy documents. It must be taken into account in the preparation of local and neighbourhood plans, and is a material consideration in planning decisions.

One of its core Planning Principles is always to secure high quality design and a good standard of amenity and contribute to conserving and enhancing the natural environment and reducing pollution. These principles align with the central aims of SuDS and with use of CBPP, as discussed earlier. NPPF also requires local plans to use opportunities offered by new development to reduce the causes and impacts of flooding. Furthermore, when determining planning applications, local planning authorities should ensure flood risk is not increased elsewhere. Both of these requirements will be satisfied with local policies for the use of SuDS and CBPP.

In Wales, Technical Advice Note (TAN) 15 – *Development and Flood Risk* – takes a similar stance but goes further requiring: 'early consultation with the relevant drainage authority to achieve the best possible outcome and ensure that any systems can be subsequently adopted by the relevant body. Developers will need to give good reason why SuDS could not be implemented.
If a conventional drainage system does not improve the status quo or has a negative impact then this can be a valid reason for refusal' of planning applications.

In Scotland, comprehensive advice covering all aspects of SuDS is contained within a single Planning Advice Note (PAN) 61 – *Planning and Sustainable Urban Drainage Systems*. This clearly requires planners to have: 'a central co-ordinating role in getting SuDS accepted as an integral part of the development process. Planning policy should set the framework in structure and local plans and in master-planning exercises. In implementing SuDS on the ground, planners have a key role through the development control process, from pre-application discussions through to decisions, in bringing together the parties and guiding them to solutions which can make a significant contribution to sustainable development.'

Planning implementation

Despite all these clear national policies, there are still risks that – despite early plans for their inclusion – CBPP could fall by the wayside during development, perhaps as part of a misguided cost-cutting exercise. To resist this, CBPP should be required as a specific planning condition and this is encouraged in the various guidelines. Such an approach results in a far more robust framework for enforcement than simply relying on approved external works drawings, often overlooked towards the end of construction.

Taking responsibility

Taking on board the intent of planning policy around the UK, it is clear that planners have a responsibility to demand CBPP and other SuDS techniques wherever possible in developments of all types. Planners should play a central coordinating role at all stages and take the necessary steps to ensure that this requirement is carried through to site implementation.

Retrofitting paving & permitted development

Current planning 'Permitted Development' rules aim to apply SuDS techniques to paving around existing homes (in England and Scotland) and industrial, warehouse, office and shop premises (currently in England only). They take away permitted development rights from most new or replacement paving unless it is permeable or drains water onto a permeable area on the property. Both English and Scottish governments refer to a guide on permeable paving from the Department of Communities and Local Government and this, in turn, refers to the Interpave website and guidance.

Interpave's *Permitted Paving* guide provides more detail on these important measures and how to interpret them, so that they can be correctly applied on the ground. It also provides surveyors, conveyancing lawyers, designers, contractors, landscapers and other professionals with the information they need to advise their clients correctly, avoiding issues of planning enforcement and complications with property sales.

A separate Interpave website is available for homeowners, showcasing the huge variety of concrete paving products available, illustrated in a domestic context. Here, *Paving for Rain – Responsible Rainwater Management around the Home* provides straightforward, practical information and design/construction guidance for homeowners, designers and contractors.

All Interpave's guidance documents are available to download from **www.paving.org.uk**

Flood & Water Management Act and National Standards

The Flood and Water Management Act 2010 includes far-reaching requirements for SuDS on future construction work carried out in England and Wales. It applies to construction work that creates a building or other structure, including *"anything that covers land"* that will affect the ability of land to absorb rainwater. In other words new buildings, roads and other paving could well be affected – as well as alterations that have drainage implications. The Act may apply to work that does not need planning permission, or indeed Building Regulations compliance, although applications for approval can be made with planning applications.

At the time of publication, a draft of *The National Standards for SuDS* is under consideration which will prescribe exemptions from the Act, once finalised and taking effect. Then, applicable construction works cannot start until drainage systems have been approved by 'SuDS Approving Bodies' (SABs) – generally county councils or unitary authorities – in line with the Standards. The right to connect surface water drainage systems to public sewers (under Section 106 of the 1991 Water Industry Act) will be restricted to those approved under the new regime, i.e. appropriate SuDS. SABs will be obliged to adopt all approved drainage systems except those on single properties and public highways. Road drainage will be adopted by Highways Authorities with design, construction and maintenance in line with the new Standards.

Interpave has published its response (available from **www.paving.org.uk**) to the consultation on the draft of *The National Standards for SuDS*, raising a number of areas of concern. Government has also acknowledged that more comprehensive guidance will be needed. In the case of CBPP, detailed guidance is already available with Interpave's *Permeable Pavements – Guide to the Design, Construction and Maintenance of Concrete Block Permeable Pavements*. This guidance is based on decades of experience both here and abroad, and should provide the substantial basis for relevant detailed requirements applied by SABs.

Water Environment Regulations

In Scotland, the *Water Environment (Controlled Activities) (Scotland) Regulations 2011* already require surface water drainage systems from new developments to discharge water to the environment through SuDS and all reasonable steps to be taken to ensure protection of the water environment. The only exceptions being single dwellings and direct discharge to coastal waters.

Building Regulations

Building Regulations strictly only apply to buildings and their immediate curtilage, so that planning policy and the new water and flood legislation above have a much wider influence on requirements for SuDS and CBPP and are the primary drivers.

For both England and Wales, Part H and *Approved Document H – Drainage and waste disposal* – apply. Regulation H3(3) requires rainwater from roofs and paved areas around the building to discharge to one of the following, listed in order of priority:

(a) soakaway or other infiltration system

(b) watercourse or where that is not reasonably practicable

(c) a sewer.

Unfortunately, this approach does not acknowledge one of the major strengths of CBPP to both attenuate water flows and remove pollutants before discharging into watercourses or sewers, where ground conditions preclude infiltration from the CBPP.

In Scotland, at first sight the 2011 Scottish Building Standards appear much stronger. Mandatory Standard 3.6 requires that *"every building, and hard surface within the curtilage of a building, must be designed and constructed with a surface water drainage system that will… have facilities for the separation and removal of… pollutants"* – an ideal application for CBPP, particularly where land is at a premium. While the Technical Handbooks discuss SuDS at some length, other methods of dealing with surface water (sewers and watercourses) are also available for use, with no preferential hierarchy.

Other requirements

The current *Code for Sustainable Homes* (Category 4 – Surface Water Run-off, which will be revised when the *National Standards for SuDS* come into force) sets mandatory criteria for both peak rate and volume of run-off from a project. These criteria do not apply where there is no increase in man-made impermeable area with development, which could be the case with some CBPP schemes. CBPP can form an essential part of SuDS management trains to meet the mandatory requirements. One credit is available for ensuring that there is no discharge from the development for rainfall depths up to 5mm and a second credit for an appropriate level of treatment from all hard surfaces to minimise pollution – both of which CBPP can provide.

Elsewhere in the Code, one credit is available for external water harvesting for irrigation, for example using CBPP, whilst the same technique applied to toilet flushing and washing machines could contribute to further credits for reducing potable water use. As we have seen, CBPP can have beneficial effects on ecology – by providing a controlled supply of treated water into the landscape – which is also recognised in the Code with credits. A similar approach to all the above criteria is taken with BREEAM 2011 – the Building Research Establishment's Environmental Assessment Method – a widely used assessment tool for various other building types.

Further guidelines from government and other organisations encourage use of SuDS and CBPP. For example, the *Manual for Streets* says: 'The use of SuDS is seen as a primary objective by the Government and should be applied wherever practical and technically feasible.'

Permeable paving systems

System selection

One of the key criteria in selecting a CBPP system is the permeability of the existing subgrade (ground), which is established from tests on site.

More information can be found in the Interpave Permeable Pavements Guide, which also recommends appropriate pavement systems for a range of subgrade (ground) conditions. It also discusses a number of other factors that need to be considered when choosing which is the most appropriate system for a site, including:

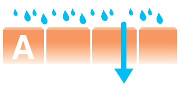
- Ground Water Table Level
- Pollution Prevention
- Discharge Consents
- Proximity to Buildings

Finally, different techniques for the application of CBPP to meet specific project requirements, discussed later, are suited to particular Systems (as identified using the symbols that follow).

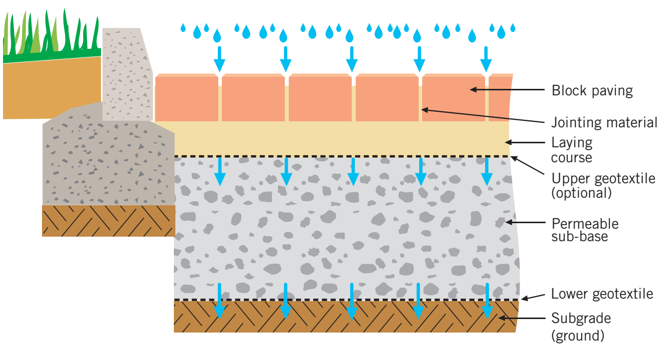
System annotation

There are three different CBPP systems, described as Systems A, B and C in all Interpave guidance. These systems were initially identified by Interpave and their designations have now been adopted in British Standards, *The SuDS Manual* (CIRIA 2007) and elsewhere. There is no difference between the surface appearance of the different Systems but each has unique characteristics making it suitable for particular site conditions.

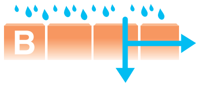
System A – Full Infiltration



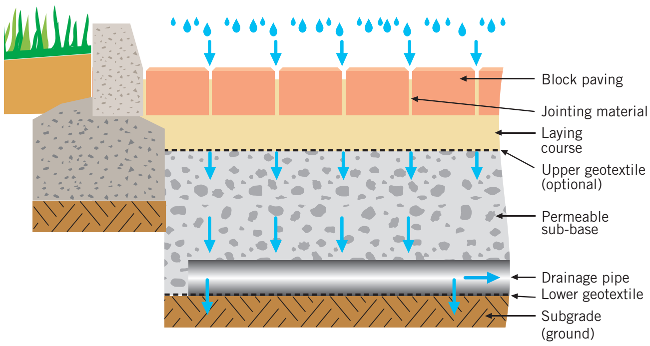
– suitable for existing subgrade (ground) with good permeability, System A allows all the water falling onto the pavement to infiltrate down through the constructed layers below and eventually into the subgrade (ground). Some retention of the water will occur temporarily in the permeable sub-base layer allowing for initial storage before it eventually passes through. No water is discharged into conventional drainage systems, completely eliminating the need for pipes and gulleys, and making it a particularly economic solution.



System B – Partial Infiltration

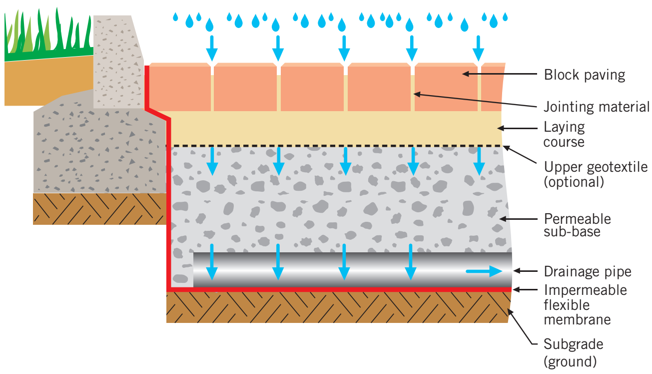


– used where the existing subgrade (ground) may not be capable of absorbing all the water. A fixed amount of water is allowed to infiltrate – which, in practice, often represents a large percentage of the rainfall. Outlet pipes are connected to the permeable sub-base and allow the excess water to be drained to other drainage devices, such as swales, ponds, watercourses or sewers. This is one way of achieving the requirement for reducing the volume and rate of runoff and will most likely remove the need for any long term storage.



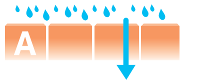
System C – No Infiltration

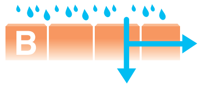
– where the existing subgrade (ground) permeability is poor or contains pollutants, or where treated water will be harvested for re-use, irrigation or amenity, System C allows for the complete capture of the water. It uses an impermeable, flexible membrane placed on top of the subgrade (ground) level and up the sides of the permeable sub-base to effectively form a storage tank. Outlet pipes are constructed through the impermeable membrane to transmit the water to other drainage devices, such as swales, ponds, watercourses or sewers or for re-use. Importantly, the outlet pipes are designed to restrict flow so that water is temporarily stored within the pavement and discharge slowed. System C is particularly suitable for contaminated sites, as it prevents pollutants from being washed further down into the subgrade (ground) where they could reach groundwater.



Permeable paving techniques

Stand alone CBPP



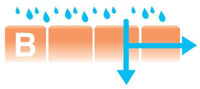


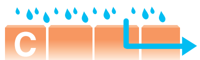
While CBPP is popular as part of a management train comprising various SuDS techniques it can equally be used in isolation or as a stand-alone sustainable drainage technique to improve conventional drainage systems.

In its simplest form, CBPP can allow all the water to infiltrate into the ground below, where ground conditions allow, following temporary storage and pollution treatment.

Alternatively, where ground conditions preclude complete infiltration, CBPP can play an essential role in slowing down and cleaning up runoff before discharge into conventional drain systems or watercourses, so improving water quality and reducing flood risks.

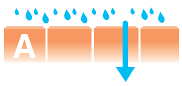
CBPP as part of a SuDS management train

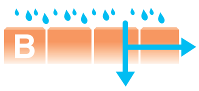




CBPP is well-recognised as an important Sustainable Drainage System (SuDS) technique. CBPP is particularly effective at the head of a SuDS management train, where it can also accept runoff from roofs and impermeable paving, as it can mitigate pollution events before the water passes to more sensitive parts of the train or other environments. This is not the case with attenuation tanks. The Lamb Drove SuDS monitoring project demonstrates use of CBPP at the head of a management train incorporating several SuDS techniques.

Optimising site levels with CBPP





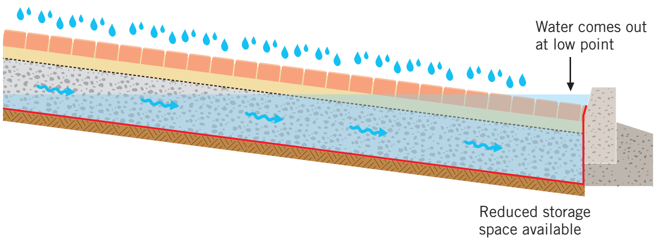
Unlike impermeable paving, the surface of CBPP can be completely flat, as water passes straight into the gaps between blocks, avoiding ponding. This means that CBPP surfaces are independent of cross-falls, channels, gulleys and other impediments to accessibility. This characteristic is particularly helpful for container yards and forklift truck use, as ponding is eliminated even with the differential settlement commonly encountered with such applications. Also, designers have complete freedom to introduce level changes for other reasons unrelated to drainage, for example to suit site topography.

The maximum gradient of the pavement surface itself should be about 5% (1 in 20) to prevent water flowing over the surface rather than into the paving joints.

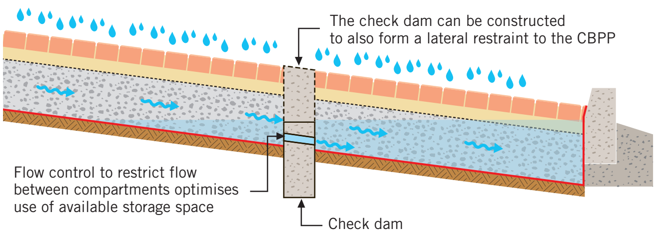
To some extent, the CBPP surface can be considered independently of pavement base and existing ground levels. When constructing CBPP on sloping sites care is needed to ensure that the water in the permeable sub-base does not simply run to and collect or overflow at the lowest point, or the available storage will be reduced. There are four potential solutions:

- Install dams within the permeable sub-base with flow controls to ensure the water does not flow to the lowest level and discharge from the surface.
- Terrace the site to give flat areas of permeable paving that have separated permeable sub-base storage areas.
- Use high capacity geocellular storage at the bottom of the slope to increase storage capacity.
- Increase the permeable sub-base thickness to allow for reduced storage capacity at the top of the slope.

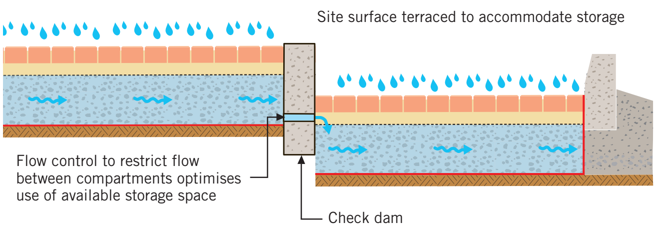
Problem



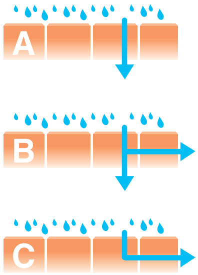
Solution – check dams



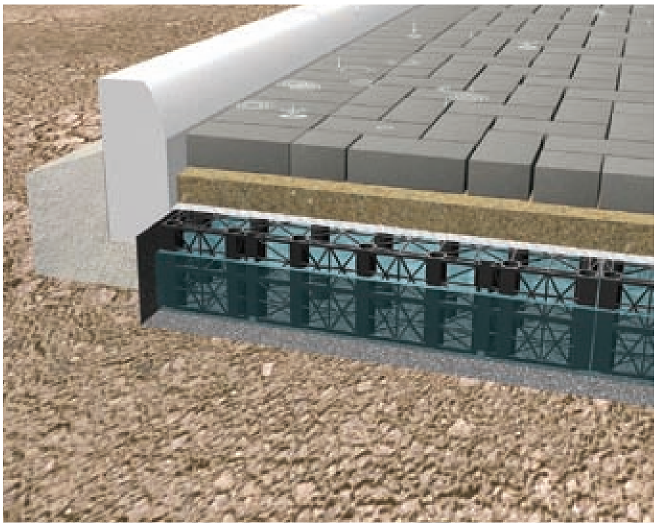
Solution – terracing



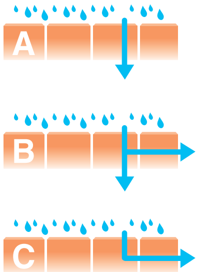
Combining CBPP and impermeable surfaces



Generally the traffic loading pavement thickness required is greater than the water storage pavement thickness required, resulting in “spare” water storage capacity within the pavement. Without exceeding the pavement depth determined for the traffic loading, it is possible to utilise this “spare” water storage capacity to drain roofs or other adjacent impermeable surfaces.



CBPP sub-base alternatives



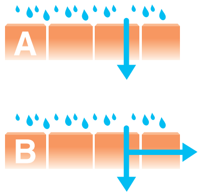
There are a number of permeable sub-base replacement systems on the market that can be incorporated into CBPP. They usually consist of a series of lattice plastic, cellular units, connected together to form a raft structure that replaces some or all of the permeable sub-base, depending upon the anticipated traffic loading.

The water storage capacity is higher than with conventional granular systems, resulting in 30-40% reduction in the pavement thickness. This can lead to a shallower excavation and reduced material disposal to landfill which, in turn, makes them particularly economical for ‘brown field’ and contaminated sites. The design of these systems is more specialised than conventional permeable pavements and advice should be sought from the suppliers/manufacturers of these systems. They are also useful to form inlets to or outlets from the permeable sub-base, as they can be placed at a much shallower depth below trafficked areas than most pipes, as well as storage for water harvesting.

Water harvesting with CBPP

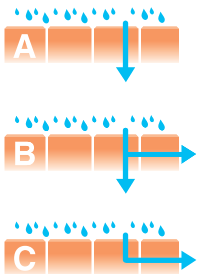
Rainwater harvesting is a system where runoff from roofs and hard surfaces is collected and used in or around buildings. The water can be used for a range of non-potable uses such as toilet flushing and watering gardens. The runoff used for harvesting needs to be free of debris and sediments. Filtration and storage with CBPP is an efficient means of achieving this requirement, as well as removing pollutants. An impressive example is Hazeley School, featured in Interpave’s *Permeable Paving for Amenity* case study.

Sustenance for planting



As CBPP allows the same pattern of run-off transfer to the ground as natural vegetation, it allows water to reach tree and shrub roots, despite providing a hard surface above. In fact, some tree protection systems incorporate permeable paving as an integral component.

Retrofitting CBPP



While CBPP is growing rapidly in popularity for new projects of all types, it can also be retrofitted to existing projects, for example during refurbishment work or as part of a planned operation to reduce stormwater runoff and improve quality. In fact, the requirements for sustainable drainage techniques such as CBPP, contained in the planning policies discussed earlier, apply equally to development of existing areas and buildings. A case study on retrofitting CBPP is included in Interpave’s *Permeable Paving Projects* document.

Implementation

Planning for CBPP

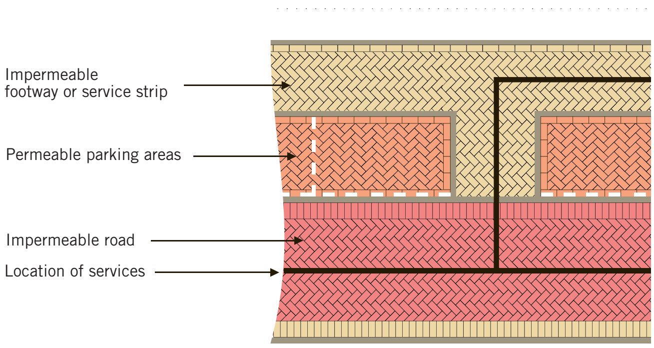
CBPP is an established mainstream technology, supported by a wealth of experience – but there are differences compared with conventional impermeable paving, the implications of which must be fully understood by all involved. Therefore, full liaison and discussion between all stakeholders is essential from the earliest stage – before a planning application – and must include those responsible for long-term maintenance, including adoption officers and the SuDS Approving Body (SAB).

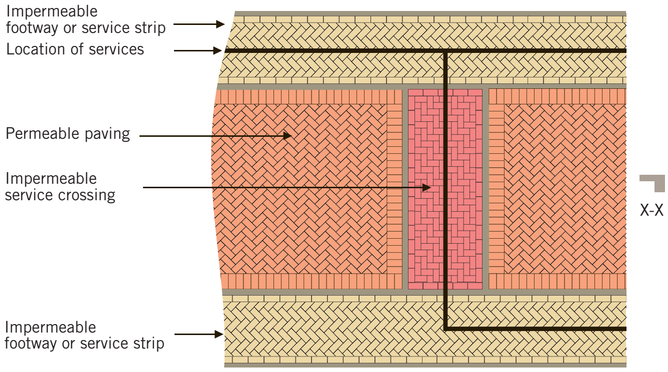
CBPP layout design

Experience has shown that thoughtful handling of services is key to the long-term success of CBPP projects. It is not necessary to design all paved areas as permeable: as we have seen, CBPP can cope with runoff from adjacent impermeable surfaces, including roofs. With careful layout design, services and utilities can be located within conventional impermeable areas, service corridors or verges, avoiding the CBPP, negating the need to excavate and removing the risk of disturbing the CBPP to access these services.

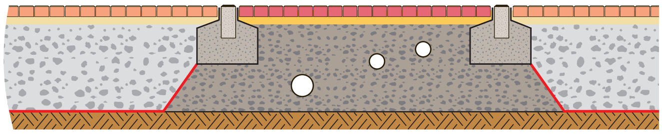
This approach can also form a key part of the overall layout design both visually and technically, allowing designers to use their imaginations and realise the aspirations of the *Manual for Streets*. For example, an impermeable central carriageway might be employed to contain services, visually differentiated from CBPP parking bays. Alternatively, impermeable service crossings could also be used as pedestrian ways, clearly differentiated from CBPP intended for vehicles.

As with any drainage system, overflow routes to cater for extreme events should be planned. Design of CBPP must take into account the overland flow routes of water when the design capacity is exceeded. Although resulting in flooding of some areas of the site, flows should be routed to prevent flooding of buildings for events that exceed design capacity.

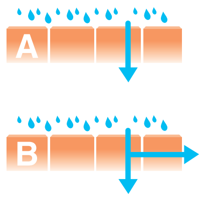




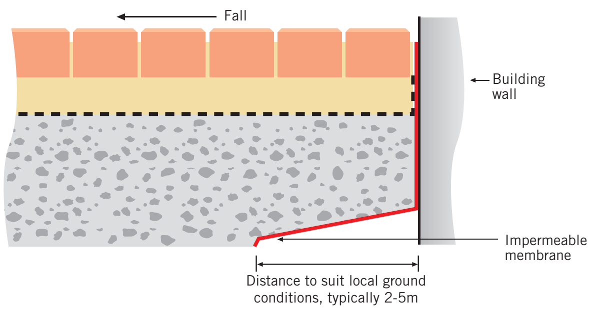
Section X-X



CBPP close to buildings



Building Regulations *Approved Document H* currently states that: *"Infiltration devices should not be built: within 5m of a building or road… Infiltration devices include soakaways, swales, infiltration basins and filter drains"*. In contrast, infiltrating CBPP may be used close to buildings as it allows dispersed, rather than 'point' infiltration similar to natural vegetation. So, the guidance in Approved Document H need not apply, as has been clarified by the government. A typical abutment detail is shown below.



However, if a concentrated outflow (such as a roof drainage outlet) is used within the CBPP, this should be at a sufficient distance to ensure the stability of the building is not affected. On many sites, even when the flow from roofs is considered, the ratio of area drained to the area of infiltration for CBPP is much less than that from a traditional soakaway (between 3:1 and 6:1 for a permeable pavement compared to 30:1 and 300:1 for a traditional soakaway). Therefore, water flows from the base of CBPP are much less concentrated.

This issue does not arise with System C – No Infiltration CBPP.

Engineering design of CBPP

The definitive, up-to-date guidance can be found in Interpave's *Permeable Pavements – Guide to the Design, Construction and Maintenance of Concrete Block Permeable Pavements,* available from **www.paving.org.uk**, incorporating the latest design methodology. Parts of it also form the basis of BS 7533-13:2009, *Guide for the design of permeable pavements constructed with concrete paving blocks and flags, natural stone slabs and setts and clay pavers*. The Interpave guidance recognises European and British Standards and encourages the use of pavement construction materials that are widely available. It also aims to encourage the development of innovative products and materials, which should not only help meet the objectives of SuDS and the requirements of the European Water Framework Directive but also anticipate future changes.

CBPP must be designed to:

- support the traffic loads
- manage surface water effectively (with sufficient storage).

Therefore, two sets of calculations are required for the engineering design and the greatest thickness of permeable sub-base resulting from either calculation is applied as the design thickness. One of the positive features of CBPP is that the materials used below the surface course to detain or channel water are the very same materials which impart strength to the pavement and thereby allow permeable pavements to sustain traffic loads. As we have seen, the traffic loading pavement thickness required is generally greater than that for water storage, resulting in "spare" water storage capacity within the pavement available for runoff from roofs and impermeable surfaces.

It is important to understand that CBPP infiltrates water into the ground at much shallower depths than traditional soakaways and therefore infiltration tests should be carried out at the estimated subgrade (ground) level of the pavement. When the construction program requires roads to be installed early for site access, the upper layer of the permeable sub-base can be substituted with impermeable dense bitumen macadam (DBM) as part of the pavement design. The DBM provides a permanent road that is used in the construction stage, preventing the permeable sub-base material becoming contaminated. Then, prior to completion of the block layer, the DBM surface is punctured with sufficient holes to allow drainage into the sub-base.

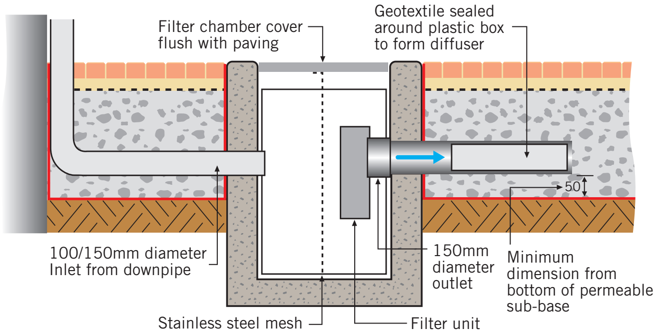
As with any drainage system, there are three key overriding, principles when designing with CBPP to ensure that:

- people and property on the site are protected from flooding
- the impact of the development does not exacerbate flood risk at any other point in the catchment of receiving watercourses
- overland flows are managed to ensure buildings are not flooded in extreme events where the design is exceeded.

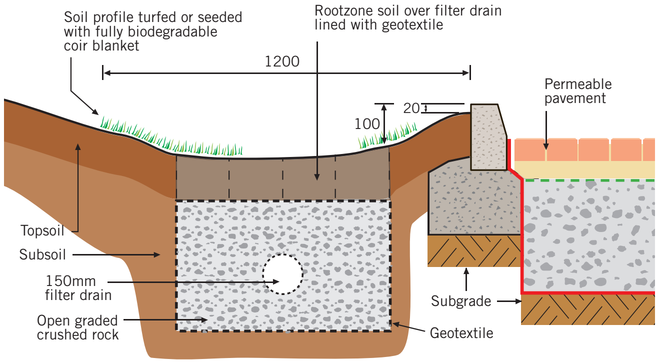
Drainage design software can be used to design systems that include CBPP. This allows performance of the whole drainage system and the impact of the permeable pavement to be modelled and tested to satisfy all the required design criteria.

Detailing CBPP

Various typical details covering particular situations are included in the Interpave guidance, application of which should ensure long-term performance: for example the roof drainage outlet shown here.



As with conventional block paving, the correct edge restraint is essential and precast concrete kerbs offer an ideal solution, including heavier duty applications where other materials such as plastic kerbs are not robust enough. It is particularly important that soft landscaping be designed so that it does not cause soil and mulch to be washed onto the permeable pavement and cause clogging, so reducing efficiency. This is also essential during construction before the block joints have been filled. Steps such as the following edge detail are particularly useful.



Constructing CBPP

Comprehensive guidance on specification and construction of complete permeable pavements is available in the Interpave guidance. The concrete block layer should be constructed in accordance with BS 7533 : Part 3: 2005, *Code of practice for laying precast concrete paving blocks and clay pavers for flexible pavements*, and machine laying techniques can be used for greater efficiency.

It is important to understand that permeable sub-base materials differ from those typically used in conventional impermeable pavements. As they lack fines, there is potential for segregation during the transportation and construction process. Care should be taken to avoid segregation but, if it occurs, remedial, corrective action must be taken. The nature and grading of the permeable sub-base will vary between different sources and it is often best to undertake site trials to determine the appropriate construction methodology. More information is provided in the Interpave guidance.

A particularly important precaution with CBPP is to prevent and divert impermeable contaminants such as soil and mud from entering the base and paving surface both during and after construction, so that the pavement remains permeable throughout its design life. Simple practices such as keeping muddy construction equipment well away from the area, installing silt fences, staged excavation and temporary drainage swales which divert runoff away from the area should be considered. Other solutions to facilitate site access are detailed in the Interpave guidance.

Permeable pavement construction materials must be kept clean during the construction phase. This can be inconvenient when the construction method requires that the roads be installed early and can be used for site access. Various solutions are included in the Interpave guidance. As discussed earlier, one effective method is to use a protective dense bitumen macadam (DBM) layer during site works, subsequently punched through to allow drainage just before completion.

Extensive areas of concrete block permeable paving for bus parking areas installed in 2000 at the World Exposition, Hanover.

Maintaining CBPP

As discussed on page 5, there is ample research that infiltration rates always remain significantly higher than rainfall intensity, so – even without maintenance – there should be sufficient infiltration to accommodate rainfall events. There is also extensive experience of CBPP in use within the UK (for example in Oxfordshire over 15 years) with many examples in place for more than 5 years without maintenance, which do not exhibit any problems. This is reinforced by the Lamb Drove SuDS monitoring project report (referred to in the Defra consultation on the National Standards for SuDS) which concluded that: *"The permeable pavement infiltration study specifically illustrates the robustness of the performance of this feature to limited maintenance."*

There is therefore a growing consensus that - apart from cosmetic cleaning – maintenance such as mechanical sweeping of CBPP and refilling of joints with the correct aggregate need only be carried out at intervals of 5 years or so, subject to more regular visual inspection or manufacturer's recommendations to the contrary.

And, of course, with CBPP the maintenance required for conventional piped drainage is eliminated. With these conventional systems, regular cleaning of gulleys, oil separators and other equipment is notorious for being omitted and this lack of maintenance is often implicated in causing localised flooding during extreme weather events. Problems are also difficult to identify, requiring CCTV inspection, whereas CBPP is easily assessed visually.

CBPP will be used throughout the 3,300 homes Great Western Park and other major developments in Oxfordshire.

Most importantly, soil and other fine materials must be prevented from contaminating the CBPP surface in the first place, as discussed previously. As with conventional concrete block pavements, any depressions, rutting and cracked or broken blocks – considered to be detrimental to the structural performance of the paving or a hazard to users – will require appropriate corrective action.

One common misconception with CBPP is the effect of cold weather. Frost heave is not a problem, as water drains through the pavement before there is time for it to freeze. Permeable pavements have been used successfully in particularly cold climates. In the unlikely event that freezing did occur, it would not develop in a uniform manner and this allows the water displaced by the expanding ice to move within the open graded permeable sub-base, thus limiting the heave effects on the pavement. One of the most comprehensive studies undertaken in the USA failed to find any examples of a permeable pavement in a cold climate that had failed due to frost damage.

While maintenance requirements are minimal, basic programmes should be put in place for CBPP – whether for local authorities' and SAB's own staff or for outside management companies appointed by them – for inspection every six months for the first 2 years. "As constructed" drawings should be provided so that areas of CBPP can be identified in future and the area designated a "Road of special engineering importance" to protect the CBPP from abuse during later works. By applying standardised details, specifications and guidance – just as conventional highway construction, and available in Interpave's *Permeable Pavement Design and Construction Information*) – adopting authorities can have confidence in the long-term performance and life span of CBPP and consider it an essential, mainstream technology.

Adopting CBPP

While most SuDS techniques fall outside the immediate highway area, CBPP simply provides a sustainable alternative to conventional paving with piped drainage – but on the same footprint. So, at adoption it will itself become the highway and it is appropriate for it to be treated similarly to conventional highways and associated drainage: this is recognised in the *Flood and Water Management Act*. Existing legislation, such as Section 38 of the Highways Act, 1980 and Section 106 of the Town and Country Planning Act, 1990, has been used successfully for some years with adoption of CBPP.

Some adoption authorities have been applying "commuted sums" to SuDS techniques, anticipating higher level of maintenance than with conventional systems. As discussed earlier there is extensive evidence to demonstrate that this does not apply to CBPP and there is a strong case not to use any commuted sums. It is important to remember that CBPP uses established engineering technology and has predictable performance proven over decades in the UK and abroad. For example, in Germany – where over 20,000,000m^2 of permeable pavements are installed annually – it is treated as standard highway construction.

Once the *National Standards for SuDS* take effect, the *Flood and Water Management Act* will require SABs to adopt approved SuDS schemes, except for individual properties and highways. Where CBPP is used on highways, it will be adopted by the local highway authority but must still meet National Standards requirements. Other areas of CBPP will be adopted by the SAB. As a well-established and proven SuDS technique (which is included in the *SuDS Manual*, endorsed by extensive experience and supported by comprehensive information from Interpave), there is no justification for SABs or highway authorities to refuse adoption of correctly designed and constructed concrete block permeable paving.

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