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- Concrete Block Permeable Paving as a key Sustainable Drainage System technique
- Principles, Design, Construction & Maintenance
- Comprehensive guidance for Designers, Developers, Planners & Local Authorities

UNDERSTANDING **PERMEABLE PAVING & SUDS**

www.paving.org.uk

Interpave
THE PRECAST CONCRETE PAVING AND KERB ASSOCIATION

Bridget Joyce Square, Australia Road, White City, London

Designed by Robert Bray Associates in association with McCloy Consulting

'Winner of Winners' at the 2017 Landscape Institute Awards, this community-driven SuDS landscape design introduces the innovative concept of concrete block permeable paving as a thin overlay for existing streets. Simply replacing the asphalt surface over the original road base, it removes rainwater straight from the surface without gulleys and provides attenuation and treatment before discharging to adjacent, well-planted basins. (Also shown on the front cover, right).

>> case study via **www.paving.org.uk**

Introduction

This guide is intended to help all those involved with the development process – particularly architects, urban designers, landscape architects, civil engineers and developers, as well as local authority planning, flood risk, building control and highways officers – to understand concrete block permeable paving (CBPP) as an essential Sustainable Drainage System (SuDS) technique.

Overview

All developments need paving, whether for pedestrians, vehicles or other uses. CBPP simply combines well-drained, safe and attractive surfaces for a wide range of applications with attenuation, storage, pollution treatment and conveyance of rainwater – by its very nature requiring no additional land-take.

Both construction and whole-of-life costs of CBPP have been shown to be lower than for conventional paving and drainage. As a multifunctional SuDS technique CBPP combines unique capabilities including source control and a gradual flow of clean water to other SuDS features or into the ground. In particular, it removes traffic pollution at source, avoiding damage to watercourses.

CBPP is established technology based on sound engineering principles, supported by research and experience, delivering consistently predictable performance. At the same time, it replicates natural drainage with dispersed water management near the surface, similar to vegetated SuDS. This unique combination means that CBPP is an essential component of any development, irrespective of the drainage regime. As well as with SuDS, CBPP can be used in isolation or with conventional piped drainage, and applied to new-build or existing developments. It has proven its effectiveness on all types of ground and topography, and has few limitations.

More than 25-years usage has proven CBPP to be robust, resilient and forgiving, with limited, straightforward maintenance requirements. CBPP is, however, different to conventional block paving and does require a full understanding of its characteristics, design, construction and long-term care – addressed here and in other Interpave guidance – to ensure long-term performance.

Scope

This guide deals with regulatory, urban planning, design and practical issues, explaining different systems and techniques, and how they can be used to meet current demands. This edition reflects the latest thinking based on experience from long-term usage of CBPP and reviews recent innovations and developments.

With continuing flooding around the UK and the current focus on climate change, there is now a growing move towards demanding SuDS through new national and local policies, together with enforcement of existing measures. CBPP will inevitably play a key role and all those involved with development need a full understanding of its capabilities and potential.

This edition replaces several previous Interpave publications and takes into account the latest guidance, including *The SuDS Manual* (CIRIA, 2015)[1] and the *Code of Practice for Surface Water Management for Development Sites* BS8582:2013[2]. In particular, *Permeable Pavements – Guide to the Design, Construction and Maintenance of Concrete Block Permeable Pavements, Edition 7* (Interpave, 2018 – www.paving.org.uk)[3], offers far more technical detail and is considered to be the definitive technical guidance for CBPP, informing British Standards.

Interpave has played a key role in developing CBPP since its introduction. As a unique sustainable drainage technology CBPP has been championed by Interpave, representing the major precast concrete paving manufacturers in the UK. Its 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 CBPP to the benefit of the construction industry as a whole. Interpave works closely with other organisations in driving forward sustainable drainage solutions. Its manufacturing members continue to develop innovative CBPP products and systems. Find out more at each manufacturer's website via the link below.

https://www.brettlandscaping.co.uk

https://www.aggregate.com

https://www.forterra.co.uk/formpave

https://www.marshalls.co.uk

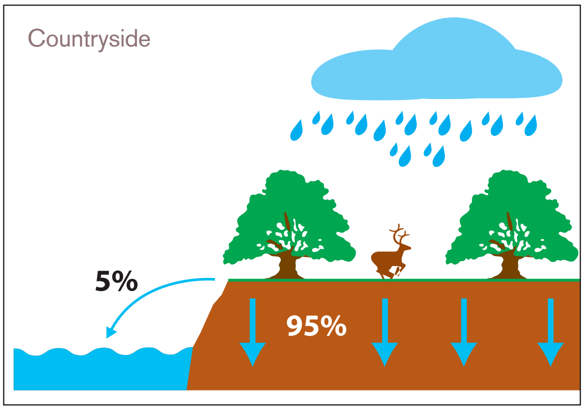
http://www.plaspave.co.uk

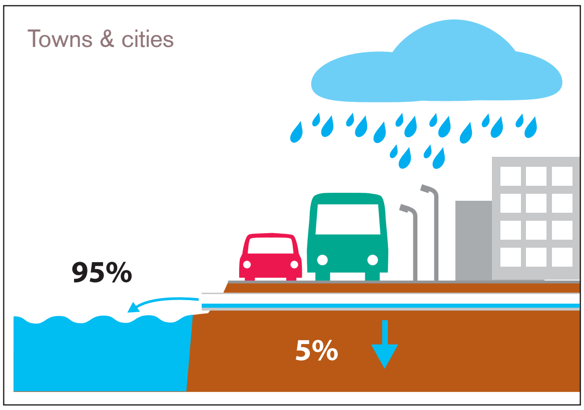
Sustainable Drainage Systems

Why do we need SuDS?

There is ample research to demonstrate the link between growing urbanisation and flooding, notably the Pitt Review into the summer 2007 floods. Here, over two thirds of the 57,000 homes affected were flooded, not by swollen rivers but by surface water runoff or surcharge from overloaded drainage systems. Subsequent flooding – notably throughout the Autumn and Winter of 2019/20 – provides a reminder of the growing personal and social, as well as financial costs of these increasingly frequent events.

Worryingly, research using detailed modelling shows that extreme summer rainfall may also become more frequent in the UK due to climate change. Today, few would disagree with the principle that SuDS and techniques such as CBPP are needed to help fight flooding and pollution – particularly with overloaded sewers, urbanisation and climate change. Now, there is also a growing realisation that SuDS can deliver far more, as an integral part of urban design through the planning system.





What are SuDS?

SuDS technology is well-established in the UK and other countries. SuDS manage surface water by attenuation and filtration with the aim of replicating, as closely as possible, greenfield (pre-development) conditions with natural losses and reduced discharge rates. As important as reducing flooding, they must also improve water quality and provide amenity and biodiversity through multifunctionality. SuDS are based on a design philosophy, using a range of techniques in a sequence known as a management train.

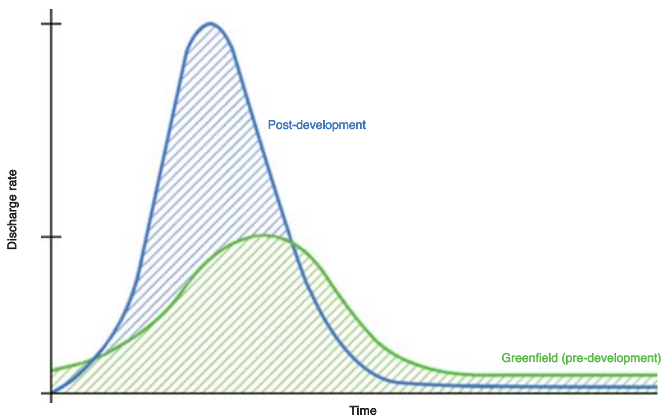
The 2018 Welsh National Standards[4] (discussed later) summarise current thinking: *'The SuDS approach mimics natural drainage, managing surface runoff at or close to the surface and as close to its source as practicable, controlling the flow (volume and rate of runoff) and providing a range of additional benefits. It contrasts with traditional drainage techniques, which are based on underground pipes to convey rainwater away from properties as quickly as possible'.*

This approach is also supported by the 2013 Code of Practice BS 8582. It seeks to integrate SuDS with urban design in delivering amenity and community value as well as enhancing landscape and townscape character. It also stresses the importance of linking surface water management and development planning from the very start to:

- maximise opportunities for using space in a multifunctional way
- enable water storage and conveyance zones to form part of the character of the development
- provide the greatest opportunity for the drainage system to deliver multiple planning and environmental benefits.

Drainage engineering then becomes simply a part of the design process – not the primary driver.

This holistic approach is being expanded with the concept of 'Integrated Water Management', considered as *'a collaborative approach to managing land and water that delivers co-ordinated management of water storage, supply, demand, wastewater, flood risk, water quality and the wider environment'* (CIRIA 2019)[5].



The impact of urbanisation on the quantity and rate of rainwater discharge. SuDS and CBPP replicate greenfield runoff.

How are SuDS implemented?

Although National Building Regulations and associated guidance do encourage use of SuDS, planning policies and dedicated water and flood legislation have a much wider influence on requirements for SuDS and CBPP, and are the primary drivers for their use.

England

The Government has abandoned dedicated requirements for SuDS on new developments using the 2010 Flood and Water Management Act, relying instead on national and local planning policies. According to the 2019 *National Planning Policy Framework*[6], 'major developments' (i.e. 10 dwellings or 0.5 hectares for residential; 1,000m^2 of floorspace or 1 hectare for non-residential, or more) should incorporate SuDS *'unless there is clear evidence that this would be inappropriate'*. They should also *'provide multifunctional benefits'* where possible.

These measures must be applied by local planning authorities (LPAs) through local policies and plans, as well as planning application decisions on major developments. 'Lead Local Flood Authorities' (LLFAs at county or unitary level) are now statutory consultees on surface water management for planning applications. LPAs must satisfy themselves of minimum operational standards and ensure that maintenance is provided for the lifetime of the development using planning conditions or other obligations such as Section 106 agreements.

Scotland

A different approach is taken in Scotland where the Water Environment (Controlled Activities) (Scotland) Regulations 2011 simply require surface water drainage systems from new developments to discharge water to the environment through SuDS.

Wales

Most recently, in 2019, the Welsh Government implemented Schedule 3 of the 2010 Flood and Water Management Act, including establishment of a SuDS Approving Body (SAB) within each local/unitary authority, alongside its lead local flood authority duty. SAB approval is required before construction of drainage systems on new and redeveloped sites (except single dwellings and less than 100 m^2) and the SAB will be required to adopt and maintain approved SuDS that serve more than one property.

Permitted Development

In addition to new developments, various permitted development rights, applying to new or replacement hard surfaces serving existing properties, have been amended to encourage SuDS. They apply to drives serving existing homes, as well as hard-standings and car parks serving industrial, warehouse, office and shop premises.

Effectively, these rights have been removed except for permeable paving or surfaces that drain water onto a permeable area within the curtilage of the property. Otherwise planning permission will be needed but generally refused, with policies encouraging SuDS applied. For example, the Draft London Plan (Policy SI13 C) states that: *'Development proposals for impermeable paving should be refused where appropriate, including on small surfaces such as front gardens and driveways'*.

>> detailed guidelines on permitted development via **www.paving.org.uk**

How much do SuDS cost?

Well-designed, multifunctional SuDS that operate on or near the surface have been demonstrated to cost less than conventional piped drainage. When comparing costs, it is essential to take into account the multifunctionality of SuDS, delivering more than just drainage alone. In terms of maintenance costs, the 2019 Welsh National Standards point out that: *'Surface based sustainable drainage components are visible in their operation and performance and are generally simpler and easier to operate, monitor and maintain.'*

The Lamb Drove SuDS Monitoring Project[7] (page 6) provides useful cost comparisons between similar developments, one using SuDS management trains including CBPP; the other, a conventional piped drainage system.

Lamb Drove SuDS Monitoring Project, Cambourne, Cambridgeshire

Designed by Royal HaskoningDHV with Robert Bray Associates

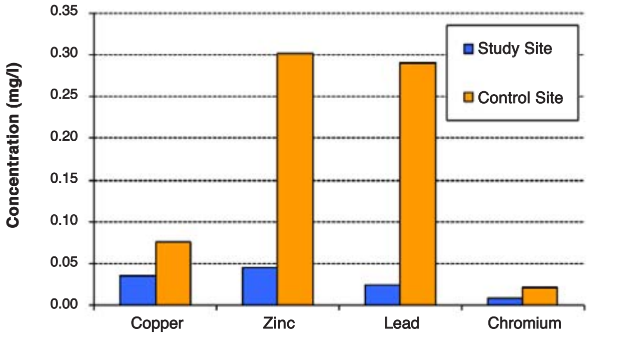
This scheme demonstrates the use of as many SuDS techniques as possible, including CBPP, used in combination to form effective management trains applied to a conventional housing layout. The Monitoring Project measured the performance of the SuDS over time, compared with that of a conventional piped drainage system on another nearby development, similar in size and density. The monitoring of pollutants, biodiversity and resident satisfaction is testament to the SuDS, with CBPP delivering a gradual flow of treated water to open SuDS features further down the management train.

Overall, both capital and maintenance costs – and therefore whole-of-life costs – associated with the Lamb Drove SuDS Monitoring Project were much lower than those for the conventional piped drainage system Control Site. The Monitoring Report noted capital cost savings of £314 per home and also suggested 20-25% lower maintenance costs than traditional drainage on the Control Site. Having said that, further potential cost savings were also noted, particularly for projects designed to integrate SuDS from the start (rather than the conventional layout with SuDS added, at Lamb Drove).

The Monitoring Report also confirms the robustness of the CBPP to limited maintenance and its infiltration capacity to cope with the highest recorded rainfall intensity at the Study Site.

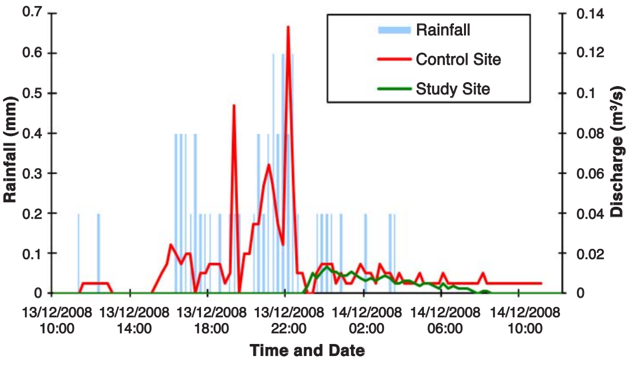
>> case study via **www.paving.org.uk**

Monitoring Results – Water Quality



courtesy of Royal HaskoningDHV

Monitoring Results – Discharge



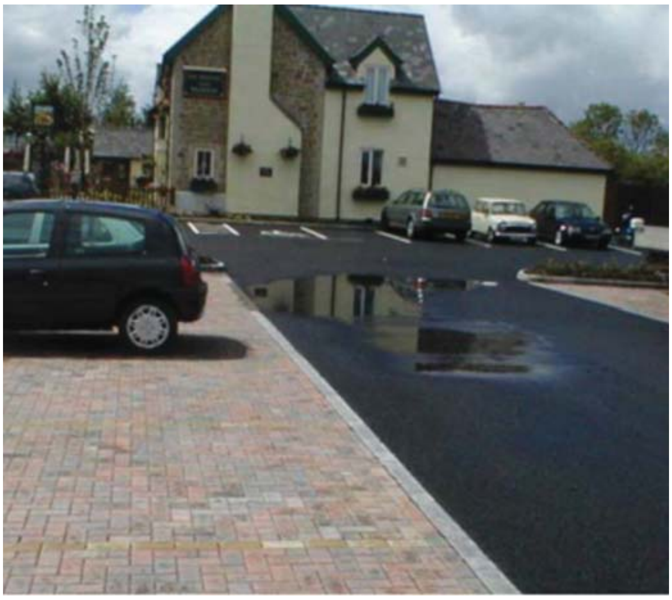
courtesy of Royal HaskoningDHV

Permeable Paving Principles

What is CBPP?

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, rainwater drains straight off the surface of CBPP through the joints. CBPP attenuates and temporarily stores water during rainfall, cleaning, conveying and releasing it gradually over time. Essentially, it addresses flooding and water quality issues together, unlike attenuation tanks which only address flooding. It serves a dual purpose, acting as the drainage system as well as a hard surface supporting traffic loads. In fact, CBPP goes further in satisfying a diversity of requirements and providing multifunctional SuDS, in line with the Code of Practice BS 8582 which looks for permeable surfaces and surface-based conveyance in SuDS wherever possible.



CBPP avoids ponding, unlike conventional sealed paving (above). Rainwater passes straight off CBPP through permeable joints between blocks (below).

How does CBPP work?

CBPP allows water to pass through the surface – between each block – and into voids within the underlying coarse grade aggregate, permeable sub-base where it is stored and released slowly, into the ground, to the next SuDS management stage or to a piped drainage system. Unlike conventional road constructions, the CBPP construction materials are 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 (i.e. existing underlying ground) or passes into the next stage of the management train.

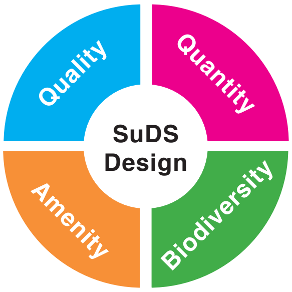
CBPP Products

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*[8] – illustrates the versatility of precast concrete paving and kerbs. It focuses on their use in the design of our external environment to meet the aims of the National Planning Policy Framework and guidelines such as the *Manual for Streets*[9] and the *National Design Guide*[10].

The difference with CBPP is enlarged joints, created by spacer nibs on the sides of each unit. These joints are subsequently filled with a joint filling material which is an angular aggregate, not sand. This arrangement ensures that water will continue to pass through the joints over the long-term and is fundamentally unlike pervious paving materials. Further information on specific block types from relevant Interpave manufacturers can be found via members' websites (see page 3).

Permeable Paving and SuDS

CBPP is unique as a SuDS technique in combining proven engineering design solutions with water management replicating nature near the surface. It provides a particularly useful source control technique at the head of a management train and achieves all four well-known pillars of SuDS:



At the same time, it offers attractive, durable and safe hard surfaces suitable for a wide range of applications. In addition to its key role in the SuDS management train, CBPP can equally be used in isolation or as a stand-alone SuDS technique to improve conventional drainage systems.

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. Within CBPP, 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.

CBPP provides diffuse dispersion, enabling effective water treatment, unlike soakaways which concentrate pollutant loads.

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 equivalent to double its own area from roof drainage or adjacent impermeable surfaces, as well as rain falling on the CBPP itself.

Amenity & Biodiversity – improving the environment

As a result of its unique capabilities, CBPP offers designers the exciting potential of a gradual supply of clean, treated water for safe, open SuDS features downstream. 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).

Hazeley School, Milton Keynes

Designed by Robert Bray Associates

At the pioneering Hazeley School in Milton Keynes, a terraced sequence of permeable paving car parks provides effective pollutant removal for water serving two ponds for wildlife - notably the 'protected' great crested newts indigenous to the site. In addition, the ponds offer a valuable teaching and learning resource for the school. Other sections of concrete block permeable paving with a storage 'box' below, on level areas used for play, collect rainfall runoff from adjacent hard games surfaces and roofs. Here, the water, already filtered by the CBPP, is UV-light treated and pumped to a header tank for toilet flushing in the school buildings.

>> case study via **www.paving.org.uk**

Permeable Paving Characteristics and Benefits

Protecting the Environment with CBPP

Pollution is present and can build up on all hard surfaces used by vehicles (including electric), from motorways to driveways. This major problem results from tyre or brake wear, oil or fuel leaks, dust from the atmosphere and other sources. Rainfall washes this diffuse pollution off the surface, carrying trace metals, hydrocarbons and – potentially – more than 300 different pollutants.

Of course, conventional drainage systems using road gulleys and pipes do not remove pollution or attenuate water flows. In fact, conventional drainage, as well as attenuation tanks, effectively concentrate these pollutants, which are flushed directly through the drainage system during rainfall.

Although the 'combined' (foul and surface water) sewers found in our older urban centres convey these pollutants to treatment plants, their presence during times of high rainfall means that they may surcharge directly into watercourses without being treated. However, dedicated 'surface water' and highway drainage is even more worrying, as it generally passes directly to watercourses or groundwater without any effective treatment. It has been used widely throughout our more recent suburban areas and continues on new developments today.

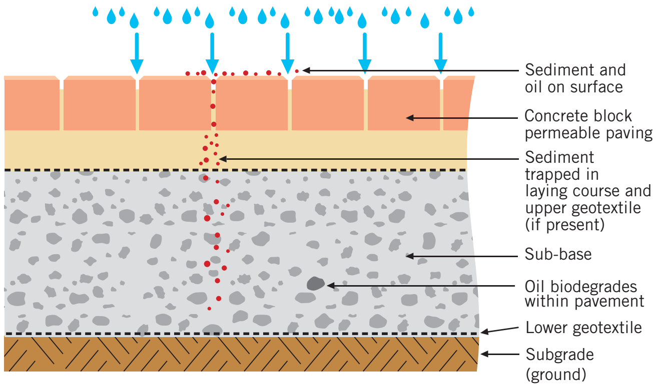
The long- and short-term damage caused by pollutants in surface water drainage to the biodiversity and health of our rivers and streams is highlighted in a December 2019 report by the Greater London Authority, concluding that *'London's roads are harming London's rivers'*. This report proposes research into the addition of SuDS features to manage runoff pollution from the most damaging roads.

There is a wealth of research available from around the world showing that CBPP is particularly effective at removing the main pollutants of concern – i.e. total suspended solids, hydrocarbons and metals. It also attenuates runoff during storms for later, gradual release to other drainage.

Extensive use of CBPP as a multifunctional source control within our streetscapes presents an obvious solution to this growing problem – whether retro-fitted in place of existing paving or designed-in to new developments.

With CBPP, the pollutants may either remain on the surface (particularly with zero gradients) or may be flushed into the underlying pavement layers where many are filtered and trapped, such as metals and total suspended solids (TSS), or degrade over time, such as hydrocarbons. It is also well-established that oil separators are not required when CBPP is used.

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)	

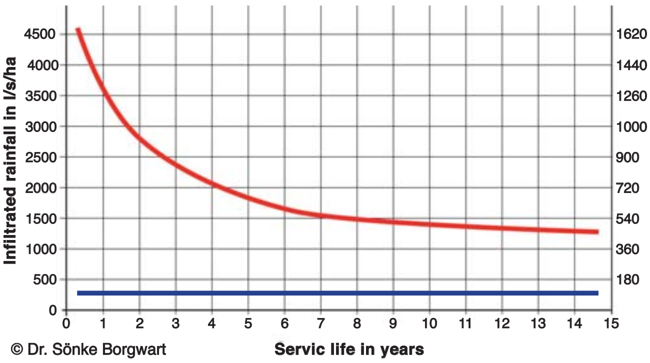


Indeed, CBPP is more effective at removing a wider range of pollutants from runoff than oil separators (CIRIA, 2004). If additional treatment is required for higher risk areas, vegetated SuDS methods such as swales or wetlands can also be used, as these also treat a wider range of pollutants.

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

Long Term Rainwater Management

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.



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 (for example, an extreme storm of 100mm/hour as shown blue, above).

Maintenance is minimal – no more extensive than for conventional block paving and less than for gulley and piped drainage. There is now sufficient long-term experience in the UK to endorse the minimal maintenance requirements of CBPP. 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. Maintenance is discussed further on page 17.

CBPP Applications and Accessibility

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.

Benefits of Precast Concrete Paving

- Attractive and delivering distinctive local character
- Helping to deliver ‘Manual for Streets’ and other guidance
- Capability for clear differentiation between distinct areas
- Accessible to all with consistent slip and skid resistance
- Durable and maintainable with reliable product supply
- High albedo (heat reflectance) reducing urban heating
- Higher light reflectance for safety and reduced lighting
- Sustainable – in every sense.

A diversity of shapes, styles, finishes and colours for contemporary design.

Extra Benefits of CBPP

- Reducing, attenuating and treating rainwater near the surface
- Direct infiltration to the ground or conveyance to SuDS or sewers
- Multifunctional SuDS meeting current requirements
- Low cost storage using flow controls without additional land-take
- Established technology with decades of proven performance
- Cool pavements with evaporation and high albedo
- Safe, level, puddle-free, shared surfaces for all.

A gradual supply of clean water for landscape, biodiversity and harvesting.

Permeable Paving System Selection

One of the key criteria in selecting a CBPP system is the permeability of the existing subgrade (i.e. existing underlying 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 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:

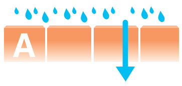
- Groundwater Table Level
- Pollution Prevention
- Discharge Consents
- Proximity to Buildings

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).

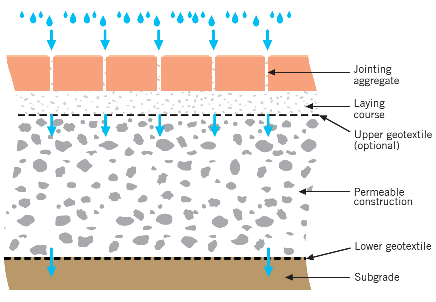
System annotation

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* 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.

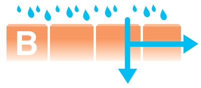
System A – Full Infiltration



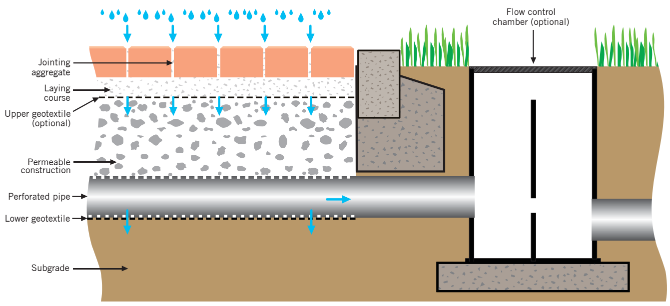
Suitable for existing subgrade with good permeability, System A allows all the water falling onto the pavement to infiltrate down through the constructed layers below and eventually into the subgrade . Some retention of the water will occur temporarily in the permeable sub-base layer allowing for initial 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.



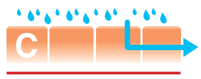
System B – Partial Infiltration



For use where the existing subgrade 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. An orifice plate flow control on the outlet pipe can increase water retention time and thus maximise potential infiltration.

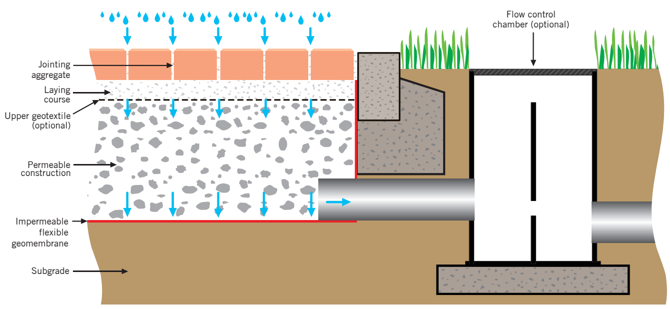


System C – No Infiltration



Where the existing subgrade permeability is poor or contains pollutants; or where infiltrated water may present a downslope risk; 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 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. An orifice plate flow control on the outlet pipe can ensure that designed discharge rates are achieved. System C is particularly suitable for contaminated sites, as it prevents pollutants from being washed further down into the subgrade where they could reach groundwater.



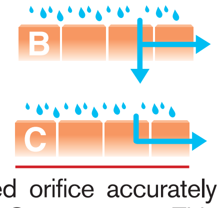
Permeable Paving Techniques

All Drainage Regimes

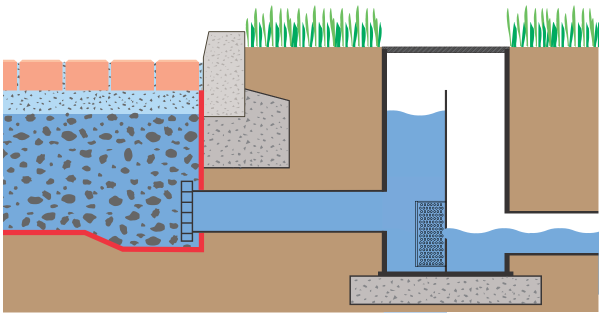
Fundamentally, CBPP enhances any type of surface water drainage. It captures the rainwater that falls upon it (which is immediately removed from the surface) and can also handle runoff from roofs and other impermeable surfaces.

In its simplest form, it attenuates and treats this water before infiltrating gradually into the ground, where conditions allow. Alternatively, where ground conditions preclude complete infiltration and following natural losses (such as evaporation), CBPP discharges a delayed, gradual flow of clean water. This can discharge at the head of a SuDS management train or to a conventional drain system or watercourse, improving water quality and reducing downstream flooding in all cases.

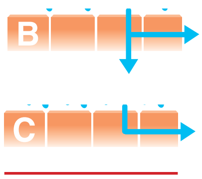
Outlet Flow Controls



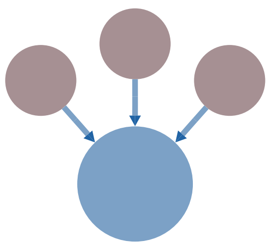
CBPP's capability to attenuate water flow during rainfall for gradual discharge is well known. However, this principle has been transformed by use of straightforward outlet flow controls – generally in chambers accessible for observation and adjustment if needed – with a calculated orifice accurately limiting outlet flows from System B and C pavements. This allows straightforward compliance to be demonstrated, notably as part of the SuDS design approval process.



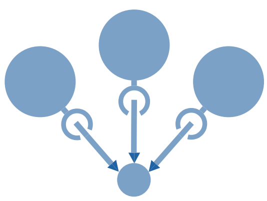
Storage Compartmentation



There are several advantages in considering areas of CBPP as distinct compartments within a sub-catchment, with flow control devices fitted to the pavement outlet pipes. They provide demonstrable water volumes of storage deployed around a development site, requiring no additional land take. CBPP is therefore not just a collection, attenuation and conveyance mechanism, but also provides storage that will reduce – or completely negate – the need to provide other storage on a development.

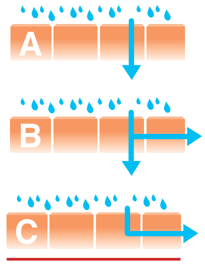


Conveying collected rainwater directly from hard surfaces results in large storage components elsewhere on site.



Storing water in CBPP around the site with flow control devices minimises or eliminates the need for further storage components.

Optimising site levels with CBPP



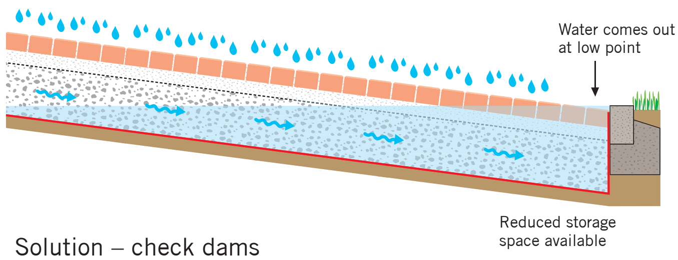
Unlike impermeable paving, the surface of CBPP can be completely flat, avoiding ponding. This means that CBPP surfaces are independent of cross-falls, channels, gulleys and other impediments to accessibility. Therefore, designers have complete freedom to introduce level changes for other reasons unrelated to drainage, for example to suit site topography.

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

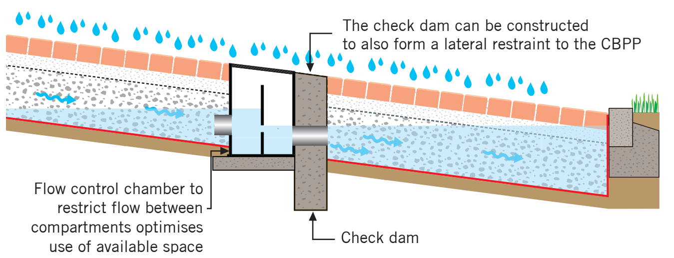
- Install check dams within the permeable sub-base to hold water, either for infiltration or, with flow controls, on its passage to the wider drainage network, avoiding discharge from the surface.
- Terrace the site to give flat areas of permeable paving that have separated permeable sub-base storage areas.
- Use high capacity geocellular storage at the bottom of the slope to increase storage capacityand prevent siltation of the storage structure.
- Increase the permeable sub-base thickness to allow for reduced storage capacity at the top of the slope.

The successful implementation of CBPP on sloping sites has been well-demonstrated in practice, even under extreme weather conditions: see case study on page 18.

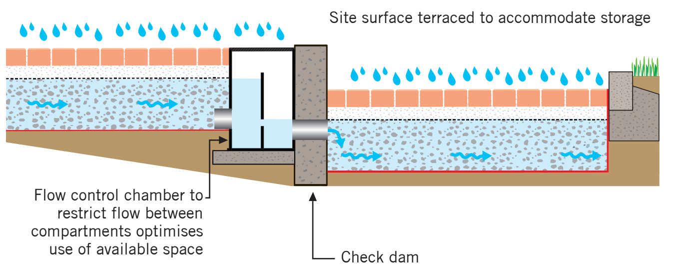
Problem



Solution – check dams

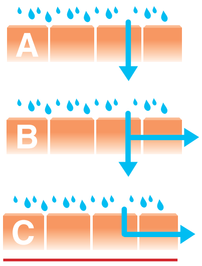


Solution – terracing



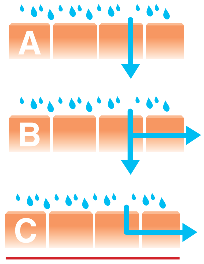
Combining CBPP and impermeable surfaces

Generally, the traffic loading pavement thickness required in paving design 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 up to twice the area of the CBPP, as shown below.

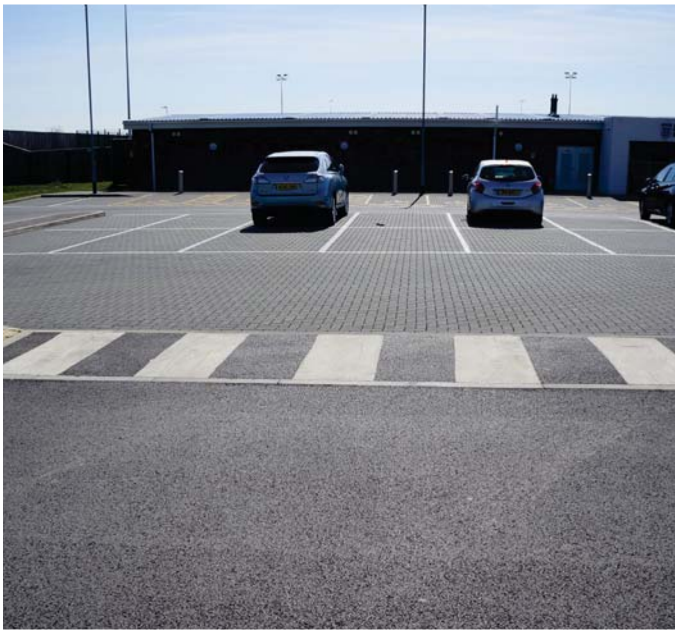


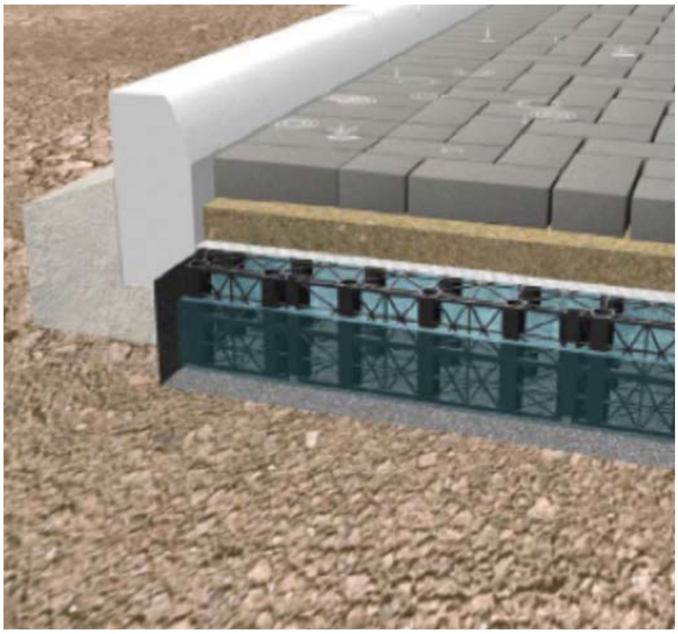
CBPP sub-base alternatives

Permeable sub-base replacement systems can be incorporated into CBPP. They usually consist of a series of lattice plastic, cellular units, connected together to form a raft that replaces the permeable sub-base, as shown below, depending upon the anticipated traffic loading.



They may enable a reduced pavement thickness for water storage and are also useful to form inlets to or outlets from the permeable sub-base, as well as storage for water harvesting.



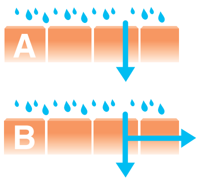


Cool Pavements

CBPP can also provide 'Cool Pavements', helping to reduce the urban heat island effect, with evaporation of rainwater from the surface and within the paving. This enhances the high albedo – or heat reflectance – offered by concrete block or flag paving generally, compared with asphalt.

Sustenance for planting

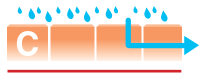
As CBPP allows the same pattern of run-off transfer to the ground as natural vegetation, it allows water to reach tree and shrub roots, despite providing a hard surface above. In fact, some tree protection systems incorporate permeable paving as an integral component.



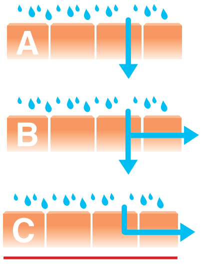
The current Code of Practice for accessibility in the external environment, BS 8300-1:2018[11], states that: *'Tree grilles should be avoided. Smooth or paved permeable surfaces should be used wherever practicable'*.

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 case study on page 8 provides an example. 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.



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 redevelopment of existing areas and buildings.

CBPP Overlay

The Bridget Joyce Square project (discussed on page 2) demonstrates an innovative approach to retrofitted CBPP, simply applied as an overlay replacing an asphalt road surface over the original concrete road base. The same blocks and 2-6mm grit bedding layer and jointing material as used in permeable pavements generally are installed. Water is attenuated (to some extent), treated and conveyed within the paving. A gradual flow of clean water can then be released, either to adjacent SuDS features (such as raingardens) or, potentially, to existing road drainage (protecting downstream watercourses).

Permeable Sub-base Extension

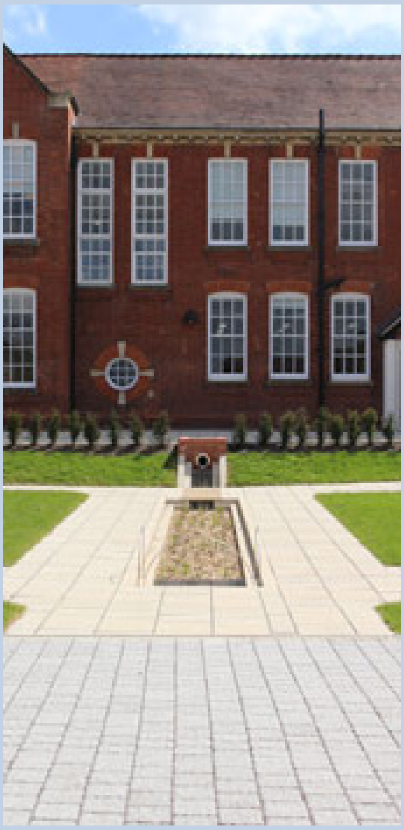
SuDS designers continue to innovate with CBPP, making the most of its capabilities to maximise performance and minimise costs. In the example shown below, the permeable sub-base of a car park extends below impermeable access roads and also an adjacent, artificial sports surface providing additional storage and adding to multifunctionality.

Optimising Infiltration

Flow controls on CBPP outlets (discussed earlier) can also be applied to optimise the time that water remains in the pavement. This technique, used in the example below, maximises infiltration potential into less permeable soils (in System B) and removal of pollutants, fulfilling a major benefit of CBPP – a controlled flow of clean water within the landscape.

Parkside Civic Centre and Library, Bromsgrove

Designed by Robert Bray Associates



The location on generally free-draining sandy soil suggested fully infiltrating SuDS, although complicated by several site factors. Accessible and useable permeable paving and landscaping, together with a series of flow control chambers to ensure full infiltration potential, define the comprehensive SuDS solution. The infiltration rate for the site, together with the storage provided within the pavement profiles, almost meets the 1 in 100 year return period including a 30% allowance for climate change.

Parking to the north of the access road is on contaminated ground and so required a liner beneath the CBPP to protect it. Water is collected, cleaned and stored in the pavement, with each compartment having a flow control chamber, then conveyed to perforated pipes and stone trenches elsewhere on the site where infiltration can be achieved.

>> case study via **www.paving.org.uk**

Implementation

Urban Design with CBPP and SuDS

The Government's approach to SuDS implementation using the planning system in England is a clarion call for architects, master-planners and other designers to take the lead in developing multifunctional SuDS with CBPP as an integral part of place shaping. This is reinforced by the Integrated Water Management (IWM) approach discussed on page 4 (CIRIA 2019)[5]. The government's 2019 *National Design Guide*[10] also expects that: *'Well-designed places have sustainable drainage systems to manage surface water, flood risk and significant changes in rainfall'.*

With good design as a priority, drainage engineering becomes a supporting function, not an end in itself.

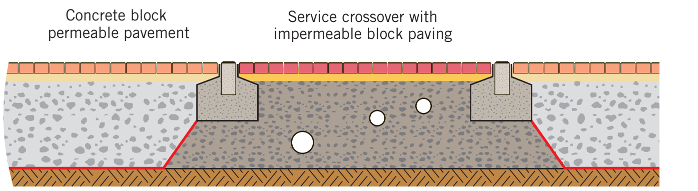
This approach is supported by the Code of Practice BS 8582:2013, as well as the *National Design Guide,* IWM guidance and other national and local design guidelines. They seek to integrate SuDS with urban design in delivering amenity and community value, enhancing landscape and townscape character. The importance of linking surface water management and urban design from the very start is essential.

Of course, safe and attractive hard surfaces are needed in any development. With CBPP, they offer the potential for multifunctionality and integration with the SuDS management train as well, delivering a gradual supply of clean water which innovative designers can exploit.

CBPP and Services

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. 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. 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.



Cross section through impermeable paving service corridor, also shown below.

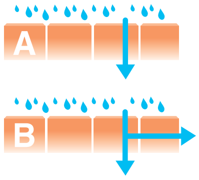
Planning for CBPP

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.

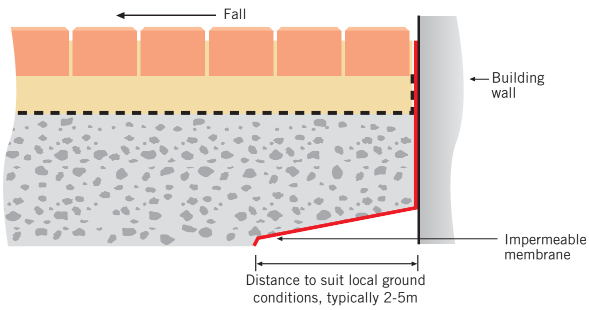
Project design should take into consideration the characteristics of CBPP to enable its efficient use. For example, scheme layouts and building positions should be informed by seeking level CBPP to maximise water storage.

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.

CBPP Close to Buildings



Building Regulations *Approved Document H*[12] 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 a lawn or flower bed. So, the guidance in Approved Document H need not apply, as has been clarified by the government. This issue does not arise at all with System C, non-infiltrating CBPP.



Typical building abutment detail.

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.

Detailing CBPP

Various typical details covering particular situations are included in Interpave's Guide and also its dedicated *Detailing Permeable Paving & SuDS*[13] guidance, application of which should ensure long-term performance.

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.

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, Edition 7*, (Interpave, 2018)[3] available from www.paving.org.uk, incorporating the latest design methodology.

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 climate change impacts.

CBPP must be designed to:

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

Therefore, two sets of calculations are required and the greatest thickness of permeable sub-base resulting from either the structural or hydraulic 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.

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.

Having said that, Edition 7 of Interpave's Guide includes revised, thinner (and lower cost) structural design thicknesses related to updated traffic categories. Designers may decide to increase CBPP thickness in order to accommodate more water.

It is important to understand that CBPP infiltrates water into the ground at much shallower depths than traditional soakaways. Therefore, infiltration tests should be carried out at the estimated subgrade of the pavement and this should then be protected from compaction.

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

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 +A1:2009, *Code of practice for laying precast concrete paving blocks and clay pavers for flexible pavements*[14] and machine laying techniques can be used for greater efficiency.

Machine laying of concrete paving units offers a particularly efficient solution for permeable as well as conventional block paving.

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 Guide.

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. One effective method is to use a protective asphalt concrete (formerly known as DBM) layer during site works, subsequently punched through to allow drainage just before completion. This layer also contributes to the structural design.

Maintaining CBPP

Routine maintenance should be no more onerous than for impervious paving but with CBPP all the maintenance required for conventional below-ground gulley and pipe drainage is eliminated. Correct design, detailing and construction – as well as a full understanding of CBPP to avoid inappropriate actions in use – are key to long-term performance. In particular:

- prevent soil and mud from entering the base and surface both during and after construction
- ensure that joints are completely filled and topped-up at construction completion
- avoid soil and mulch being washed from landscaping onto the CBPP
- prevent aggressive mechanical brushing/suction of the surface.

Over time, detritus and silt collects in the upper part of the joint material, although studies have shown that long-term infiltration capability will generally substantially exceed UK hydrological requirements (see page 10). Performance is also not significantly affected by moss or weeds in the joints, or by leaves collecting on the surface.

Generally, any localised problems will be revealed on the surface by ponding (permeability issues) or damaged or displaced paving units (structural issues). In the absence of these indications, no remedial action is necessary. Current routine maintenance regimes for other paving can generally be applied to CBPP, although aggressive mechanical brushing which might dislodge jointing material should be avoided. The Interpave Guide provides straightforward maintenance and remedial information.

Cold Weather

'Frost heave' is not a problem as water drains through the pavement before there is time for it to freeze, and CBPP has been used successfully in particularly cold climates. There is less risk of sheet ice forming on CBPP compared to normal pavements because puddles do not form on the surface, although hoar frosts can occur more frequently. CBPP can be salted in the same way as other pavements. If grit is used, then the granules should be sufficiently large not to clog up the joints between paving units.

Reinstatement

Where possible, underground services should be located outside CBPP to avoid the need for disturbance to gain access, or located within service corridors. However, there may be situations where this is not possible, such as sewers located below CBPP because they cannot run with other services and, as a result, future excavation may be unavoidable. Localised structural failures of the pavement may also require reinstatement.

Unlike other pavement materials, with CBPP (as well as conventional block paving) reinstatement work can be carried out with no visual evidence that a repair has been undertaken, re-using the paving blocks. Reinstatement techniques for both types are discussed in detail in Interpave's *Concrete Block Paving* guide[15].

Adopting CBPP

In terms of adoption, CBPP differs from other SuDS techniques, as public highways are already the responsibility of the highway authority and other communal paving within properties is generally maintained by management companies or their owners. This status quo is recognised in *Sewers for Adoption 8* and, unlike other SuDS features, CBPP will not generally be adopted by local drainage authorities or SABs. Although multifunctional, the primary function of CBPP is considered to be paving rather than drainage.

Unlike conventional road construction, storing water in permeable pavement construction is not an issue, as all the materials are specifically designed for this. Correctly designed concrete block permeable pavements can also support heavy trafficking and loadings. CBPP is established engineering technology and has predictable performance proven over decades in the UK and around the world – notably Germany since the mid-1980s, where over 20,000,000m^2 of permeable pavements have been installed annually and treated as standard highway construction.

There is also extensive experience of CBPP adoption in the UK, using Section 38 of the Highways Act, 1980 and Section 106 of the Town and Country Planning Act, 1990. For example, Oxfordshire County Council has taken a positive and pragmatic approach to adopting streets and other areas using SuDS – particularly with CBPP – for around 20 years. CBPP is being used extensively, and adopted, throughout the 3,300 homes at Great Western Park (shown here) and other major developments in Oxfordshire.

>> case study via **www.paving.org.uk**

There is therefore no justification for highway authorities or other organisations to resist taking over correctly designed and constructed CBPP as an asset for the long term. Indeed, CBPP can help highways authorities meet their obligations under the requirement of the Public Services (Social Value) Act 2012 to *'have regard to environmental well-being in connection with public services contracts'* by helping to prevent downstream flooding and pollution. This is particularly pertinent to resolving the issue of traffic pollutants discharging from highways into our streams and rivers (discussed on page 9). In addition, any outdated bureaucratic limitations to optimising the potential of adopted CBPP as part of efficient SuDS management trains – for example, resistance to connectivity of CBPP driveways to highways – need to be addressed.

Sheffield City Council - Adopting CBPP for SuDS

Sheffield has been at the forefront of SuDS for some time and the City Council encourages the use of SuDS, including CBPP, wherever possible. Interpave is currently working with Sheffield, preparing guidance on development design integrated with SuDS, intended to be adopted as a 'Supplementary Planning Document' through the Local Plan. Sheffield has also entered into a long-term contract for highway maintenance, including CBPP with agreed costings informed by the current Interpave maintenance and remedial guidelines.

Various projects incorporating CBPP and SuDS have already been completed in Sheffield, including the Olympic Legacy Park and privately maintained parking areas (shown on pages 13 and 14). Residential streets are being adopted, including Top Road, a 1:20 gradient access (shown here) to a new hillside development amongst existing housing. Here, System A infiltrating CBPP incorporates check-dams (or baffles), dividing the paving into sub-catchments and ensuring that water is retained for local infiltration. This CBPP performed entirely as designed, without issues, during the extreme weather and flooding elsewhere in Sheffield of 7th November 2019.

>> case study via **www.paving.org.uk**

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Interpave

THE PRECAST CONCRETE PAVING AND KERB ASSOCIATION

www.paving.org.uk

The Old Rectory, Main Street, Glenfield, Leicester LE3 8DG United Kingdom
e: info@paving.org.uk t: 0116 232 5170

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mpa British Precast

t: 0116 232 5170
f: 0116 232 5197
e: info@britishprecast.org
www.britishprecast.org

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THE ASSOCIATION OF PAVING CONTRACTORS

t: 0116 232 5191
f: 0116 232 5197
e: info@interlay.org.uk
www.interlay.org.uk