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understanding permeable paving

GUIDANCE FOR DESIGNERS, DEVELOPERS, PLANNERS AND LOCAL AUTHORITIES

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

Foreword

Methods of providing drainage and water supply solutions in the towns and cities of the UK are changing rapidly, and this latest information from Interpave shows just how much technology and attitudes have developed in recent years. It is now more than twenty years since the first concrete block paving systems for environmental protection were constructed on large developments. These systems have been shown to be very successful in protecting both water quality of small and vulnerable streams, and in reducing peak flood flows. Unfortunately they have only slowly been widely adopted.

SUDS started out being perceived as only 'soft' and 'green', and only for developments where open space was available. Engineering solutions are increasingly also required for the more densely built up parts of our cities – and concrete block permeable paving, which is both robust and adaptable, plays a critical role in this type of SUDS. However, a more recent change by government is the call for adaptable technology for drainage and the re-use of rainwater to be incorporated into all developments to reduce flooding and pollution, in line with the requirements of the European Water Framework Directive.

This timely new guidance document will help all those involved with the development process, including designers, developers, planners and building control officers, to understand all aspects of concrete block permeable paving. It deals with legal as well as practical issues. It explains the different systems and techniques available, and how they can be used to meet current requirements.

The authors are to be congratulated on producing a very readable and interesting document, and in the way it presents a diverse range of case studies. Now we have a guide to finding good examples of permeable paving around the country!

On behalf of SUDSnet, I look forward to future schemes which are better conceived and designed with the help of this new guide.

Professor Chris Jefferies
Principal Investigator, SUDSnet
UWTC at University of Abertay

Front cover photos:

Upper right – concrete block permeable paving used as a sustainable drainage technique and adopted by the local authority.

Upper left – permeable paving on front gardens will not require planning permission under new regulations.

Lower left – enhanced surface finishes are available with concrete block permeable paving, such as granite (shown here).

Introduction

This document is intended to help all those involved with the development process – including designers and developers, and planning, building control and adoption officers – understand concrete block permeable paving. It deals with legal 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. 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 detail and is considered to be the definitive design, construction and maintenance guidance.

The need for sustainable drainage

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) offers the solution.

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 clearly requires use of SUDS on all developments wherever possible and also encourages planners to take a central role in coordinating its acceptance by all. This requirement is supported by Building Regulations and other governmental guidance, including the *Manual for Streets* and *Code for Sustainable Homes*. But there has been some confusion over responsibilities and adoption limiting take-up of SUDS by developers, an issue which the government is now determined to address with the Defra water strategy *Future Water*, along with similar initiatives anticipated in Wales and Scotland.

Concrete block permeable paving (CBPP) is the most versatile SUDS technique, with important attenuation and pollution source control characteristics. CBPP is a deceptively simple concept, providing an attractive pavement surface suitable for trafficking that also acts as a drainage system. It has been in use throughout the UK, Europe and other parts of the world for decades, resulting in extensive information and experience. However, it is only now that this adaptable technology, along with other sustainable approaches to drainage, is being demanded by government on all developments to reduce flooding and pollution, in line with the requirements of the European Water Framework Directive.

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. 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.

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 current guidelines such as the *Manual for Streets*.

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**.

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:

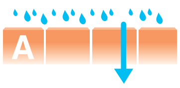
- Ground Water Table Level
- Pollution Prevention
- Discharge Consents
- Proximity to Buildings

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).

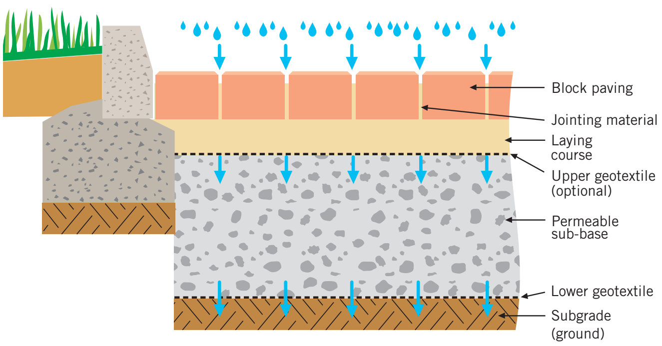
Systems

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.

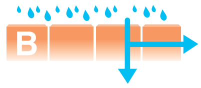
System A – Full Infiltration



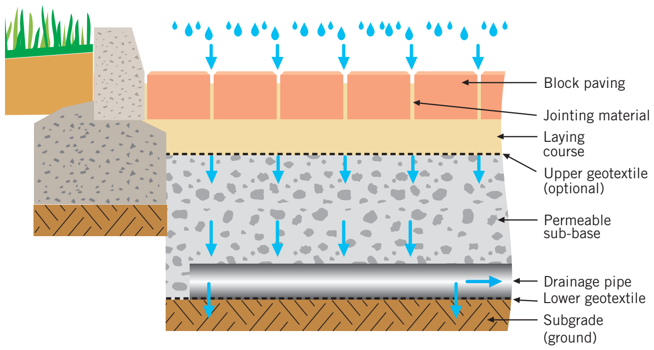
– suitable for existing subgrade (ground) with good permeability, System A allows all the water falling onto the pavement to infiltrate down through the constructed layers below and eventually into the subgrade (ground). Some retention of the water will occur temporarily in the permeable sub-base layer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



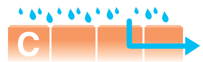
System B – Partial Infiltration



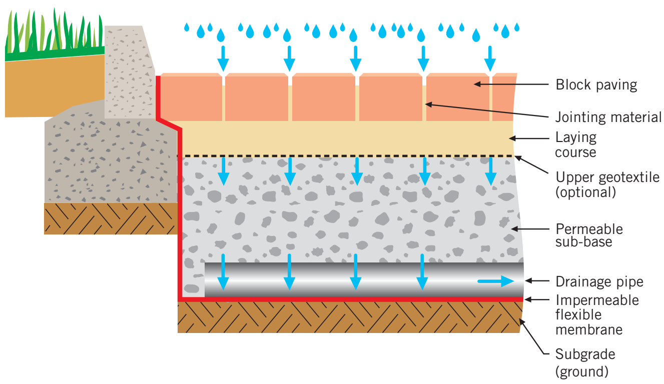
– used where the existing subgrade (ground) may not be capable of absorbing all the water. A fixed amount of water is allowed to infiltrate – which, in practice, often represents a large percentage of the rainfall. Outlet pipes are connected to the permeable sub-base and allow the excess water to be 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, 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. 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 performance & benefits

There are three well-known pillars of SUDS which CBPP successfully achieves:

- Quantity – management of rainwater and avoidance of flooding
- Quality – removal and treatment of diffuse pollution from runoff
- Amenity – improvement of the external environment.

In addition, CBPP offers a range of other unique benefits and opportunities.

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, unlike 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.

Pollution Prevention Guideline PPG 3 (Environment Agency, 2006) recognises the benefits of CBPP in removing pollution from runoff. It states that: 'Techniques that control pollution close to the source, such as permeable surfaces…, can offer a suitable means of treatment for runoff from low risk areas such as roofs, car parks, and non-operational areas'. The capabilities of CBPP in handling pollution are summarised in the table (above right). Oil separators are not required when CBPP is used. Permeable pavements are actually more effective at removing a wider range of pollutants from runoff than oil separators.

Amenity – improving the environment

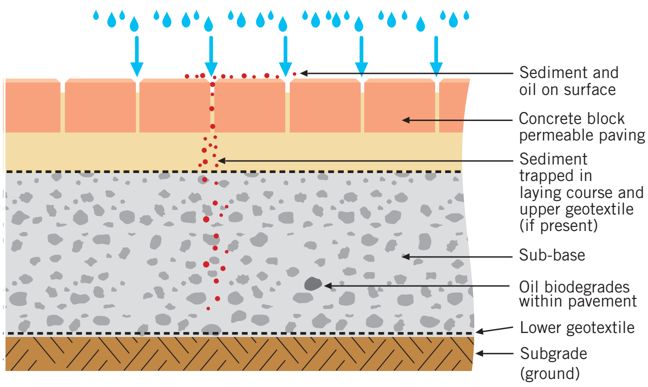
CBPP is used on projects ranging from footpaths to container terminals, with the reassurance of proven engineering design solutions for every type of application. In addition to the visual design possibilities discussed earlier, CBPP offers two fundamental benefits compared with conventional surfacing:

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)	

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

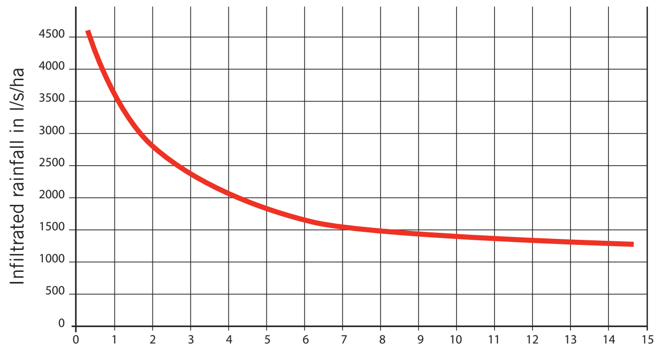
As a result, CBPP meets current accessibility requirements for the whole community – unlike loose materials such as gravel, suggested in some guidance on permeable paving but specifically excluded by accessibility rules, such as Building Regulation Part M. Particular benefits include eliminating 'ponding', 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.

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. Recommended maintenance is minimal – no more extensive than that for conventional block paving and less than for conventional gulley and pipe drainage. Also, any problems with CBPP become apparent on the surface with a visual inspection, unlike the below-ground inspections needed for pipe drainage.



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Initial and whole life costs

Independent research, commissioned by Interpave and carried out by specialist consultants Scott Wilson (Interpave, 2006), provides the most up-to-date and 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.

Permeable paving law

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.

In England, a series of Planning Policy Statements (PPS) apply. At the core is PPS1 – *Delivering Sustainable Development* which requires regional planning authorities and LPAs to promote the sustainable use of water resources and the use of SUDS. Also, PPS25 – *Development and Flood Risk* includes as key planning objectives: 'reducing flood risk to and from new development through location, layout and design, incorporating sustainable drainage systems' and 'using opportunities offered by new development to reduce the causes and impacts of flooding making the most of SUDS.'

PPS25 requires LPAs to give priority to SUDS when determining planning applications and places responsibilities on developers to incorporate SUDS to reduce flood risks. It also requires both regional and local planning authorities to: 'further the use of SUDS by:

- incorporating favourable policies within Regional Spatial Strategies;
- adopting policies for incorporating SUDS requirements in Local Development Documents;
- encouraging developers to utilise SUDS wherever practicable in the design of development, if necessary through the use of appropriate planning conditions or by planning agreements;
- developing joint strategies with sewerage undertakers and the Environment Agency to further encourage the use of SUDS as an aid to mitigating the rate and volume of surface water flows; and
- promoting the use of SUDS to achieve wider benefits such as sustainable development, water quality, biodiversity and local amenity'.

Apart from flood risk, the role of SUDS to improve water quality is recognised in PPS 23 – *Planning and Pollution Control*. This requires LPAs to encourage developers to: 'incorporate into their proposals SUDS that are able to absorb at source, the runoff from various types of development, including car parks, buildings, paved areas and roads, or to store water for non-drinking water use or enabling it to be released more slowly. This will help to reduce the impact of diffuse pollution from that runoff and flooding, as well as providing a contribution to local amenity and biodiversity'.

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.

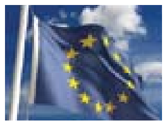
In Scotland, comprehensive advice covering all aspects of SUDS is contained within a single Planning Advice Note (PAN) 61 – *Planning and Sustainable Urban Drainage Systems*. This clearly requires planners to have: 'a central co-ordinating role in getting SUDS accepted as an integral part of the development 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.

Additional steps may also be appropriate, such as 'Section 106' (of the Town and Country Planning Act 1990) agreements between LPAs and developers. As PPS23 points out: 'Properly used, Section 106 Agreements can be used to offset the subsequent environmental impact of a proposed development. Measures which it might be possible to consider for Section 106 Agreements include the technical vetting and funding for provision and management of SUDS for a development'. It may also be the case that direct government action is taken to address implementation issues, for example through the Water Strategy.

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.

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.

Water strategy for England

The new strategy *Future Water*, launched by the Environment Minister in February 2008, includes several proposals that have a major impact on CBPP. Along with other SUDS techniques, there has been some confusion over responsibilities and adoption, limiting take-up of permeable paving by developers – an issue which the government is now determined to address with a consultation process. Interpave supports the principles set out in *Future Water* and is actively involved with Defra as part of this consultation adding its expertise on CBPP to ensure a clear and viable outcome.

Future Water proposes that surface water management plans will be required to co-ordinate activity, clarifying responsibilities for SUDS and their adoption by local authorities, in line with the planning policies discussed earlier. It also calls into question the automatic right to connect surface water drainage for new developments to the public sewer, strengthening pressure to use alternative on-site solutions such as CBPP. Major changes for domestic paving are proposed as well which will – for the first time – require planning permission for paving to front gardens of existing, as well as new, homes, unless 'the surface is porous'. It can also be expected that, generally, permission will not be granted if permeable paving is a viable alternative. Finally, the 2008 *Pitt Review* looks in detail at the 2007 Summer flooding and puts forward specific proposals in a number of areas, including planning and development. It endorses many of the *Future Water* proposals - going even further in some cases – and highlights the role that permeable paving can play in avoiding flooding.

Building regulations

Building Regulations strictly only apply to buildings and their immediate curtilage, so that planning policy has a much wider influence.

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 *(such as CBPP System A)*
(b) watercourse or where that is not reasonably practicable
(c) a sewer.

Unfortunately, this approach ignores one of the major strengths of CBPP Systems B or C to both attenuate water flows and remove pollutants before discharging into watercourses or sewers (where System A is not possible). This approach also conflicts with the planning guidelines discussed earlier.

In Scotland, at first sight the 2008 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. However, the *Technical Handbook* lists various methods of dealing with surface water drainage – including SUDS, but also sewers and watercourses – without any preferential hierarchy. Again, it is left for the planning system to demand CBPP and sustainable drainage.

These regulations should at least correspond with government policy reflected in planning guidance – a point stressed in PPS25 and promoted by Interpave to government. In the meantime, Building Control Officers can actively encourage CBPP in support of their planning colleagues to ensure that local sustainability policies are implemented consistently and correctly on the ground.

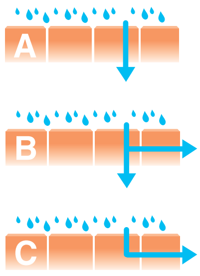
Other requirements

The *Code for Sustainable Homes* includes a mandatory requirement to ensure that peak run-off rates and annual volumes of run-off post development will be no greater than the previous conditions for the site, effectively requiring SUDS solutions. CBPP used in isolation can also help achieve this, particularly in urban locations. In addition, the Code allows one credit where specific levels of attenuation are achieved with hard surface run-off. Also, one credit is available for external water harvesting for irrigation – for example using CBPP – whilst the same technique applied to toilet flushing (as demonstrated in the case study on page 16) could contribute to further credits for reducing potable water use. As we have seen, CBPP can have beneficial effects on biodiversity which are also recognized in the Code. A similar approach to all the above criteria is taken with BREEAM 2008 – *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 techniques

Stand alone CBPP

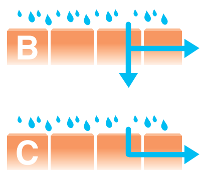


While CBPP is popular as part of a management train comprising various SUDS techniques it can equally be used in isolation or as a stand-alone sustainable drainage technique to improve conventional drainage systems.

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.

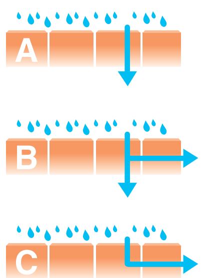
Alternatively, where ground conditions preclude complete infiltration, CBPP can play an essential role in slowing down and cleaning up runoff before discharge into conventional drain systems or watercourses, so improving water quality and reducing flood risks. It is unfortunate that this important capability is not currently recognised in guidelines such as Building Regulations *Approved Document H*.

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. Most SUDS techniques are ‘soft’ landscaping features such as swales, wetlands and ponds but CBPP is the most efficient with no additional land-take. Detailed information on SUDS design and techniques – including CBPP – is available in *The SUDS Manual* (CIRIA 2007) and other CIRIA guidance.

Optimising site levels with CBPP



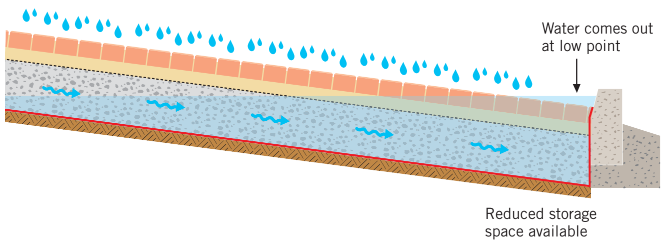
Unlike impermeable paving, the surface of CBPP can be completely flat, as water passes straight into the gaps between blocks, avoiding ponding. This means that CBPP surfaces are independent of cross-falls, channels, gulleys and other impediments to accessibility. This characteristic is particularly helpful 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 should be about 5% (1 in 20) to prevent water flowing over the surface rather than into the paving joints.

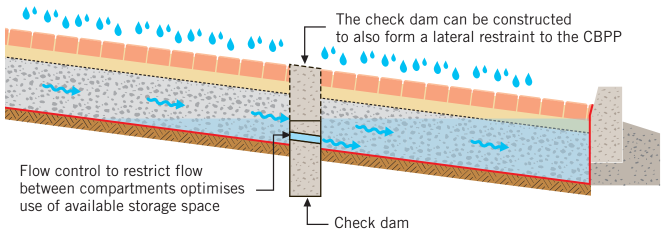
To some extent, the CBPP surface can be considered independently of pavement base and existing ground levels. When constructing CBPP on sloping sites care is needed to ensure that the water in the permeable sub-base does not simply run to and collect or overflow at the lowest point, or the available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

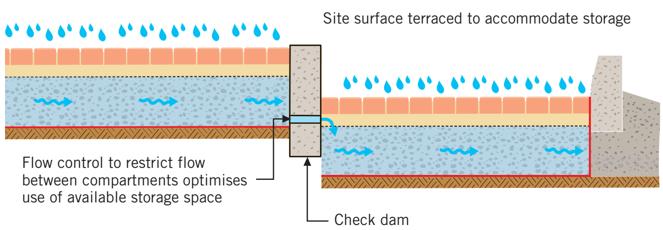
Problem



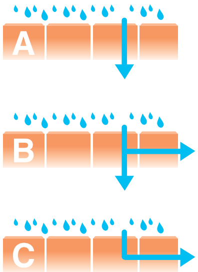
Solution – check dams



Solution – terracing

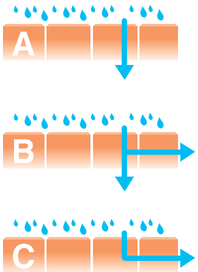


Combining CBPP and impermeable surfaces



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

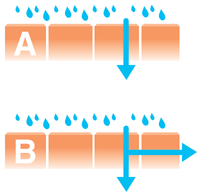


There are a number of permeable sub-base replacement systems on the market that can be incorporated into CBPP. They usually consist of a series of lattice plastic, cellular units, connected together to form a raft structure that replaces some or all of the permeable sub-base, depending upon the anticipated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

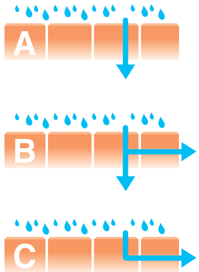
Rainwater harvesting is a system where runoff from roofs and hard surfaces is collected and used in or around buildings. The water can be used for a range of non-potable uses such as toilet flushing and watering gardens. The runoff used for harvesting needs to be free of debris and sediments. Filtration and storage with CBPP is an efficient means of achieving this requirement.

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 discussed on page 18.

Implementation

Planning for CBPP

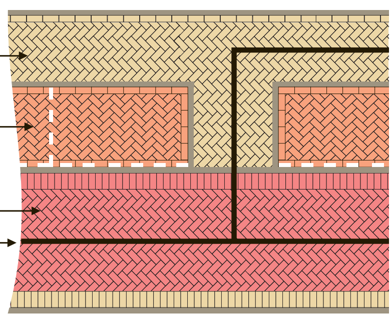
CBPP is an established mainstream technology, supported by a wealth of experience - but there are differences compared with conventional impermeable paving, the implications of which must be fully understood by all involved. Therefore, full liaison and discussion between all stakeholders is essential from the earliest stage – before a planning application – and must include those responsible for long-term maintenance, including adoption officers. Planners should also embrace their key role as SUDS coordinators, as required by governmental planning policy.

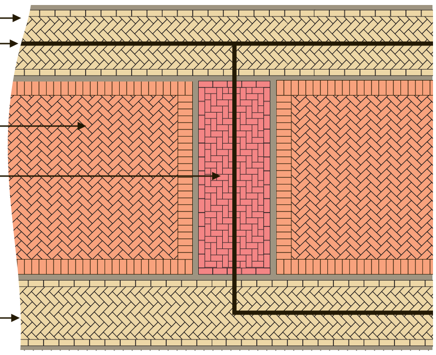
CBPP layout design

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.

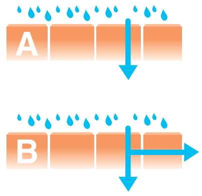
This approach can also form a key part of the overall layout design both visually and technically, allowing designers to use their imaginations and realise the aspirations of the *Manual for Streets*. For example, an impermeable central carriageway might be employed to contain services, visually differentiated 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.

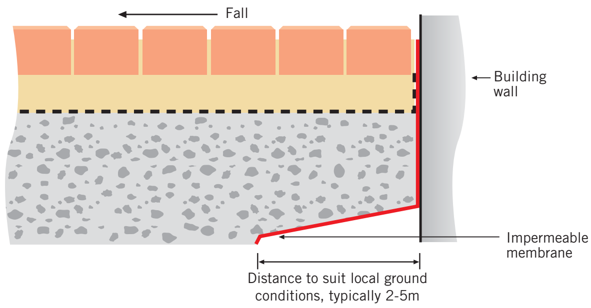




CBPP close to buildings

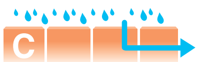


Building Regulations *Approved Document H* currently states that: ‘Infiltration devices should not be built: within 5m of a building or road… Infiltration devices include soakaways, swales, infiltration basins and filter drains’. In contrast, infiltrating CBPP may be used close to buildings as it allows 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. It 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.

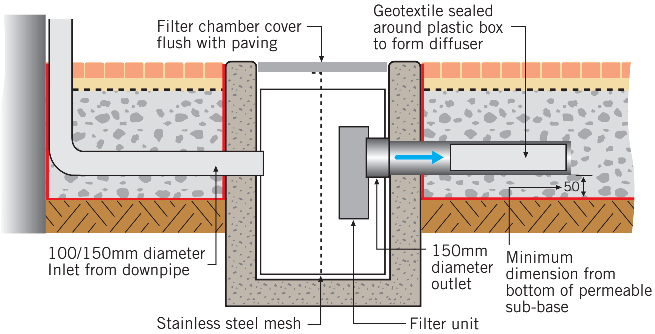
As with any drainage system, there are three key overriding, principles when designing with CBPP to ensure that:

- 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.

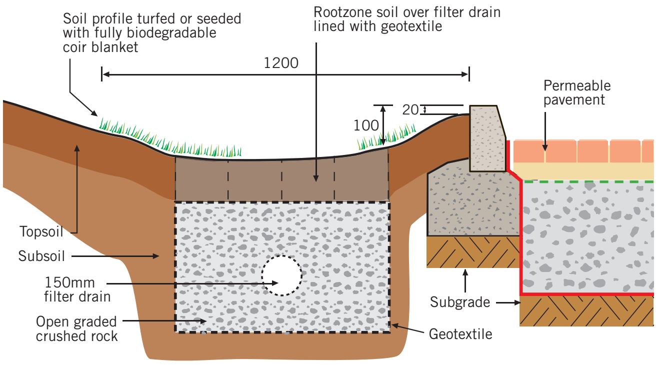
Drainage design software can be used to design systems that include CBPP. This allows performance of the whole drainage system and the impact of the permeable pavement to be modelled and tested to satisfy all the required design criteria.

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.

Maintaining CBPP

As discussed earlier, evidence to date suggests that infiltration rates always remain significantly higher than rainfall intensity, so – even without maintenance – there should be sufficient infiltration to accommodate rainfall events. Some manufacturers do recommend sweeping twice a year as a precaution against clogging, but should be no greater than is normally undertaken on conventional paving and experience suggests that this is rarely carried out on many sites where CBPP is still working. And, of course, 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.

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.

Adopting CBPP

As we saw earlier, the new Defra water strategy for England – *Future Water* – seeks to address adoption authority concerns with SUDS generally, and a similar approach is anticipated in Wales and Scotland. These concerns stem from many SUDS techniques still being regarded as unconventional drainage devices or landscaping features, with particular maintenance issues and some uncertainty over long-term performance. This is not the case with CBPP which 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.

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. Existing legislation, such as Section 38 of the Highways Act, 1980 and Section 106 of the Town and Country Planning Act, 1990, is being used successfully for adoption of CBPP. Some adoption authorities apply "commuted sums" to SUDS techniques, recognising that they fall outside the highway area, present greater risks or require a higher level of maintenance than normal. None of these apply to CBPP and there is a strong case not to use any commuted sums.

While maintenance requirements are minimal, basic programmes should be put in place for CBPP – whether for local authorities' own staff or for outside management companies appointed by local authorities – 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 (all available from Interpave via **www.paving.org.uk**) – just as conventional highway construction – adopting authorities can have confidence in the long-term performance and life span of CBPP and consider it an essential, mainstream technology.

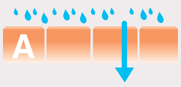
Case Studies

The following pages cover a variety of actual projects to demonstrate the practicalities of using CBPP. Where appropriate, the particular system (see page 5) and technique (see page 10) used for each project is identified, along with other key information. The aim of this section is to show CBPP as an established technology able to meet a wide range of demands while satisfying today's requirements for sustainable drainage. It is also intended to stimulate innovation with designers finding new uses for this versatile technology.

More detailed information on these and other projects can be found on the Interpave web resource **www.paving.org.uk** together with comprehensive information on concrete block permeable paving and precast concrete paving generally.

Hoylake Park and Ride, Wirral

Designed by: Wirral Borough Council



Subgrade (ground) conditions: good permeability

Particular constraints: potential flooding issues for the local area, linked to restrictions on discharge into the existing drainage system

Total area of CBPP: 1,756m^2

Constructed in: 2006

Techniques: CBPP used in isolation

Special interest: the CBPP also handles runoff from adjacent impermeable areas.

This 137-space car park was constructed next to Hoylake station as part of a package of transport improvements associated with the 2006 Open Golf Championship. Taking into account restrictions on discharge into the existing drainage system, investigations showed that using impermeable surfaces with piped drainage would increase the risk of flooding in the local area after medium rainfall. Instead, the 4,217m^2 area comprises impermeable roadways draining onto CBPP car parking areas which reduce, attenuate and clean up runoff, replicating natural infiltration to the ground and watercourse.

Case Studies

Hazeley School, Milton Keynes

SUDS Consultant: Robert Bray Associates
Architects: Architecture MK

Subgrade (ground) conditions: poor permeability – heavy clay

Particular constraints: the site is a natural habitat for Great Crested Newts – a "Protected Species" under national and European legislation

Constructed in: various phases since 2005

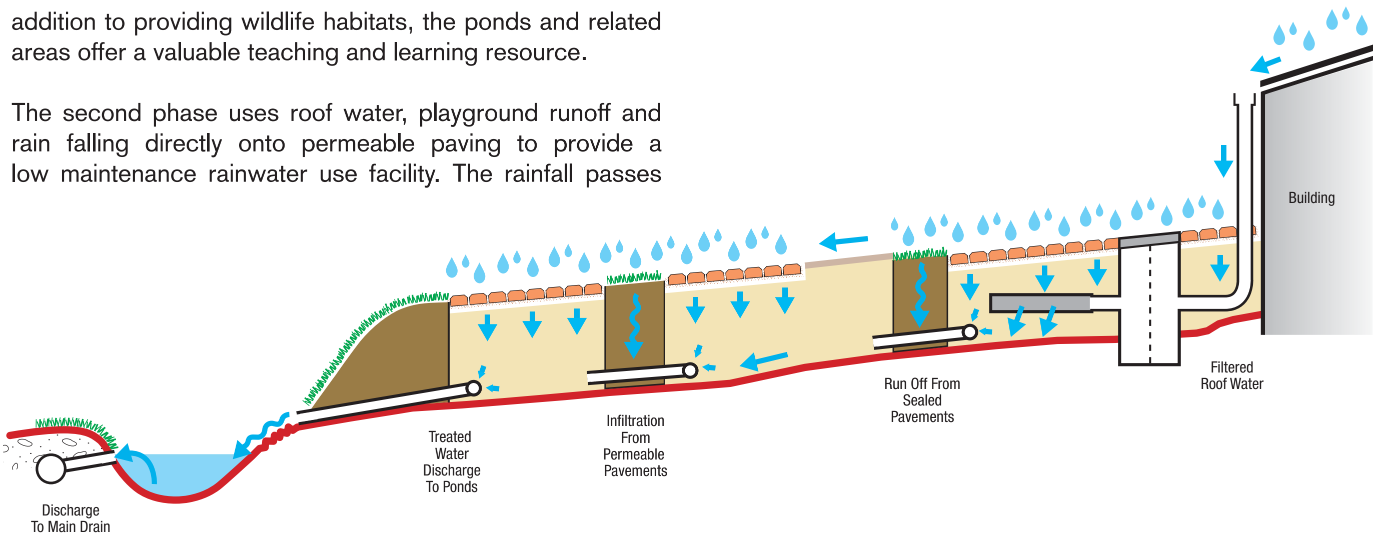
Techniques: terraced CBPP on sloping ground, CBPP used adjacent to buildings, runoff from roofs and impervious surfaces handled, and harvesting for toilet flushing

Special interest: encouraging biodiversity by eliminating gratings and gulley pots where wildlife can be trapped in lethal toxic liquors.

Hazeley School provides impressive examples of CBPP taking an holistic approach to achieve several sustainable aims. It consists of two distinct phases, firstly footpaths, car parking, cycle racks and other paved areas, terraced down land sloping away from the school building. These areas are surfaced in both impermeable asphalt and CBPP with runoff from the asphalt draining onto the permeable pavement. Water from all the roofs of the substantial school buildings also discharges into the CBPP. To deal with steep surface gradients on this sloping site the parking areas were terraced.

These areas became separate "compartments" within the CBPP and were linked, via a flow control device, to allow the stored water to flow from each higher compartment to the next lower compartment. This is repeated so that water progressively moves down the hill from compartment to compartment providing a controlled flow and the opportunity for extensive treatment of pollutants. At the bottom of the terrace of compartments, water discharges into two separate retention basins (ponds) and in significant rain events the water can overflow into the conventional storm sewer. In addition to providing wildlife habitats, the ponds and related areas offer a valuable teaching and learning resource.

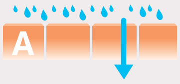
The second phase uses roof water, playground runoff and rain falling directly onto permeable paving to provide a low maintenance rainwater use facility. The rainfall passes through the CBPP joints and laying course directly into a geocellular storage box, with a waterproof polypropylene geomembrane to the sides and base – forming a water storage facility which can overflow at the edges into the adjacent CBPP. A pump chamber delivers cleaned rainwater to a header tank for toilet flushing in the school buildings. The system offers a number of cost and maintenance benefits, as well as an effective sustainable water resource management solution.



Case Studies

Martlesham Park and Ride, Suffolk

Designed by: Suffolk County Council Environment and Transport Architects and Landscape Designers: Mouchel



Subgrade (ground) conditions: good permeability

Particular constraints: the site is part of a designated 'Special Landscape Area' and also part of a 'County Wildlife Site' with mature trees requiring sustenance

Total area of CBPP: 14,000m^2

Constructed in: 2003

Techniques: CBPP used in isolation

Special interest: the car parking layout was designed to accommodate existing mature trees.

The Park and Ride facility at Martlesham was one of Suffolk County Council's top priority transport schemes and the third park and ride to be built serving Ipswich, offering sustainable transport alternatives to the car. The site occupies a total of 3.2ha and has space for 530 cars. The key challenge for the project was to mitigate the adverse environmental and landscape effects of the development by incorporating CBPP and other SUDS techniques into the overall design to reflect the sustainability credentials of the Park and Ride concept.

Bristol Business Park, Stoke Gifford, Bristol

Designed by: Arup

Subgrade (ground) conditions: poor permeability – stiff to hard clays

Particular constraints: the site is within the catchment of a small watercourse which frequently floods an adjacent road. It was therefore important to minimise discharge during heavy rain. The local authority's planning policy requires SUDS on all new developments.

Total area of CBPP: 6,000m^2

Constructed in: 2003

Techniques: CBPP at the head of a full SUDS management train

Special interest: a protective dense bitumen macadam (DBM) layer formed part of the design for site access, subsequently punched through to allow drainage just before installation of the block paving.

Located to the north of Bristol, 1km away from the M4/M32 motorway junction, Bristol Business Park is a phased office development. Car parking areas in Phase 3 are a combination of impermeable concrete block paving and CBPP. Both roof drainage and the impermeable paving drain to the CBPP, which discharges into swales. In turn, the swales and drainage from earlier phases discharge through a wet detention pond via a hydrobrake control feature into the off-site watercourse. Observations during and after heavy and prolonged storms revealed only negligible flows into swales, demonstrating the attenuation of the CBPP.

Case Studies

Adoption in Oxfordshire

Oxfordshire County Council

Particular constraints: many of the CBPP projects in the county are located on level areas close to rivers and flood plains with relatively high water table

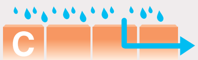
Special interest: a consistent policy of encouraging and adopting CBPP and SUDS generally. Use of impermeably paved service corridors and crossings.

Oxfordshire CC has been leading the way with a positive and pragmatic approach to adopting streets and other areas using CBPP and other SUDS techniques. Oxfordshire's interest in SUDS goes back some 10 years but behind its enthusiasm went the requirement that schemes would have to be adoptable and must not put a burden on the maintenance budget once it was adopted.

As a result, extensive experience has been built up of using CBPP, notably with techniques such as the handling of services within areas of impermeable paving.

The Dings Home Zone, Bristol

Drainage Design: Interpave Member



Particular constraints: the existing combined sewer system in the area was already working at full capacity and the drainage authority did not want to increase flow into these sewers

Constructed in: 2005

Techniques: retrofitted CBPP used for attenuation and treatment before discharge to watercourse

Special interest: retrofitted CBPP adopted by a local authority. The CBPP avoids barriers to mobility – such as channels, kerbs and gulleys – in shared surfaces within this Home Zone.

Bristol City Council has been at the forefront of developing Home Zones for some time and this example is one of the first retrofitted permeable paving schemes in the UK which was also adopted as a 'highway' by the local authority. The Dings Home Zone was developed in partnership with the charity Sustrans – along with other stakeholders – which led the community involvement process whereby residents are involved at each stage of the design of the new streets. A Sustrans spokesman said: 'The initial phase of the project has been awarded a Bristol Civic Society Environmental Award, which is a great credit to the work undertaken by the local community, Bristol City Council, and other stakeholders whose input has been invaluable and helped shape this scheme'.

Case Studies

Superstore, Exeter

Engineers: White Young Green
Drainage Design: Interpave Member

Subgrade (ground) conditions: rock

Particular constraints: a discharge restriction into a sewer was applied by the Environment Agency demanding additional storage on site

Constructed in: 2006

Techniques: optimisation of gradients to create additional storage within the CBPP and elimination of conventional drain run excavation within rock

Special interest: CBPP avoided the need to excavate into rock for conventional drainage runs and storage facilities.

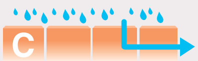
In this situation, the use of an impermeable conventional pavement with drainage gulleys, pipe connections and petrol interceptors would have been prohibitive due to the time, cost and unpredictability of excavation in rock.

The scheme involved an extension to an existing superstore car park. The new parking area joined the existing car park at a gradient of approximately 1:50. Due to the slope of the site and the discharge restriction imposed, the usual hydraulic design depth was not adequate for the entire site. Therefore a system was designed so that the lower edge of the car park had additional sub-base material for water storage. To achieve this end, the sub-grade gradient was slackened to 1:125 whilst keeping the CBPP surface at 1:50, making it visually consistent.

Sixfields Development, Northampton

Designers: Halcrow

Subgrade (ground) conditions: Polluted brownfield site with clay capping



Particular constraints: no discharge permitted to subgrade (ground)

Total area of CBPP: 52,000m^2

Constructed in: 2005

Techniques: CBPP used to attenuate and treat runoff to watercourses

Special interest: the largest CBPP project started in Europe during 2005. Also adopted by the local authority.

The Northampton Brownfield Initiative, a collaboration between English Partnerships and Northampton Borough Council, is transforming various sites to create new homes and leisure facilities. At Sixfields a 2,235 car and coach park with access roads forms an essential part of this development. It was constructed over old gravel pits previously filled with household waste and capped off with a clay capping layer many metres thick. In order to minimise future settlement it was necessary to reduce the clay capping layer to half a metre thick and apply high-energy ground compaction techniques. One of the strengths of CBPP is its ability to accommodate differential settlement anticipated in situations such as this.

Because the capping layer had been reduced the CBPP could not allow any water to infiltrate into the existing ground. CBPP used for parking areas and roads allows for the complete capture of all water, as well as attenuation and treatment within the pavement, before discharge into drainage ditches or directly into the River Nene. Due to the pollution removal characteristics of CBPP it was not necessary to provide oil separators. The CBPP roads are being adopted by the local authority.

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