Edition 7 | August 2023

Understanding Permeable Paving

www.mpaprecast.org

Mineral Products Association

Concrete Block Permeable Paving

A fully-engineered and predictable alternative to conventional sealed paving for a wide range of applications, replicating rainwater management in nature.

- Suitable for new or retrofit applications enabling SuDS, trees and green infrastructure to reduce flooding and address climate change.
- No additional land-take for low-cost water storage and no gulleys with related pipework or risk to wildlife.
- Initial and whole-of-life costs shown to be lower than for conventional paving and drainage.
- Essential at the head of any SuDS scheme providing a gradual supply of clean water near the surface.
- Combining self-drained surfaces with rainwater attenuation, storage, pollution treatment and conveyance.
- Interception losses manage runoff during regular rainfall events.
- Integral water filtration of silt, pollutants and debris which remains on the surface.
- Providing optimal irrigation and essential gas exchange for new and existing trees meeting planning and other requirements.
- Working in synergy with trees and green infrastructure avoiding root disruption to the surface.
- Low-intervention, low carbon, no-heat retrofit installation.
- Long life with only limited, simple maintenance avoiding clogging problems.
- Straightforward access to below-ground services.
- Sustainable re-use of long-life blocks and their embodied carbon for 'invisible' reinstatement or new applications.
- A diversity of shapes, styles, finishes and colours for attractive and popular urban design.
- Safe, level surfaces with no puddles or potholes, for user comfort and safety.
- Cooling by solar reflectance with high albedo, evaporation and water movement, as well as enabling tree shade.
- Sustainable – in every sense.

"...the need to respond to climate change continues to grow in urgency, demanding far wider application of permeable surfaces throughout our towns and cities, reversing the sealing-up of urban areas and moving towards the 'sponge city' paradigm."

Introduction

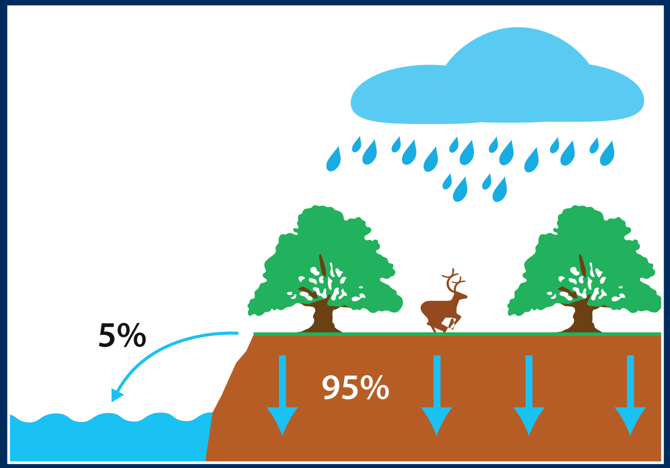
With more than 25 years' use on a wide range of project typologies, including adopted roads and even container terminals, concrete block permeable paving (CBPP) has proven to be a robust, resilient and adaptable technology. This long experience also gives a greater understanding of the capabilities of CBPP, revealing that it performs far better than originally anticipated with important potential for even more applications and innovations.

Over that time, the need to respond to climate change continues to grow in urgency, demanding far wider application of permeable surfaces – whether for new-build, renewal or replacement – reversing the sealing-up of urban areas and moving towards the 'sponge city' paradigm. This approach is recognised in recent government proposals for: mandatory sustainable drainage systems (SuDS) on new developments in England, action on surface water flooding from existing surfaces and enforcement of planning permitted development rules for 'unplanned paving'.

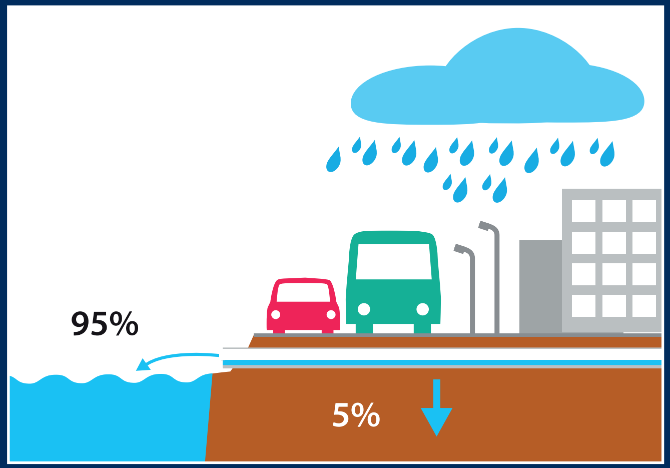
To address these challenges, not only is CBPP the responsible choice for multifunctional urban design and SuDS, but also in synergy with green infrastructure offering simple, passive solutions to help maintain urban trees, meeting National Planning Policy Framework requirements.

Interpave is now a part of MPA Precast. This guide replaces the MPA Precast (Interpave) '*Understanding Permeable Paving & SuDS*', Edition 6, and aims to enable all those involved with the development process to rediscover CBPP as an essential permeable surface with proven performance and new opportunities.

It also sets out to dispel unwarranted myths and challenge orthodoxies that continue to limit mainstream take-up of CBPP technology and its real potential. It offers planning, highways, flood risk and other authorities – as well as architects, urban designers, landscape architects, civil engineers and developers – responsible and nature-based solutions to address climate change in the public realm.



Countryside



Towns & Cities

Modular Paving Principles

To fully understand the real potential of CBPP, it's worth reminding ourselves of the unique characteristics and attributes of modular concrete paving generally. The use of segmental paving laid to create a hard surface for roads can be traced back over 6,000 years. Modular concrete paving continues this tradition today but in the modern form of paving blocks, flags and kerbs.

Consistent Performance

Essentially, concrete paving blocks from MPA Precast manufacturers are engineered products, produced under automated factory conditions using high strength, semi-dry concrete in a vibration/compression process. This ensures precise dimensional control and consistent performance characteristics making them slip/skid resistant, safe, strong, durable, reusable and sustainable.

These high-strength, interlocking units are installed with granular material filling joints and as a laying course, enabling miniscule movement between blocks and forming a 'flexible pavement'. In the case of conventional block paving (and unlike CBPP) this material is sand, resulting in an impermeable pavement.

The 'surface zone' of blocks and laying course can then be supported by various structural layers below to form the pavement construction. Generally, accepted design methods for concrete block paving are based on the performance of asphalt pavements but using an equivalence factor to convert the surface to block paving. These methods can be considered as conservative, as research shows that interlock between the blocks contributes to the structural performance of pavements.

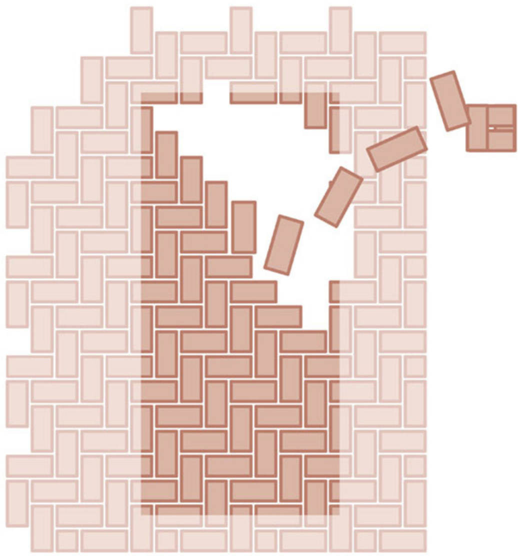
Similarly, horizontal interlock through tessellated block shapes and/or laying patterns (such as herringbone) resists traffic braking and turning forces. Decades of use internationally have demonstrated the suitability of concrete block paving for the most taxing paving applications.

Modern Methods of Paving

Adopting the principles of 'modern methods of construction', including mechanised installation, concrete block paving delivers fast, low-cost installation using weather-independent, 'dry' construction methods. There are no curing, hot-work or noxious fume problems and only small plant and equipment is needed, with noise and disturbance minimised.

A wide choice of block shapes, styles (including small-element flags), colours, textures (including natural aggregates) and finishes add a richness, diversity, visual interest and human scale to the urban realm. With an extremely long lifespan, blocks can be taken up and re-used without processing for low-intervention repairs, changing demands and layouts, or completely new schemes – saving carbon, meeting 'circular' economy' criteria and adding to sustainability credentials.

These principles generally apply to CBPP products as well.



Installation in action
Modular concrete paving products are long-life and can easily be taken up and re-used saving costs and carbon.

Permeable Paving Principles

Concrete Block Permeable Paving (CBPP) enhances this technology as an inherently permeable surface and well-established, multi-functional SuDS technique. It simply combines self-drained, safe and attractive surfaces for a wide range of applications with attenuation, storage, pollution treatment and conveyance of rainwater runoff. CBPP provides a controlled flow of clean water available to green infrastructure, landscape design and safe use within other, open SuDS features – linked to other multifunctional benefits.

The difference with CBPP is angular aggregate (2/6.3mm) – not sand – used to fill enlarged joints usually generated by spacer nibs and as a laying course. Conventional block paving does use sand for joints or laying course, and is therefore not permeable. This permeable 'surface zone' is the key to CBPP performance. It is supported by various layers below: generally, coarse-graded aggregate (typically 4/20mm) with voids (typically 30%), enabling water attenuation and storage, as well as structural support.

New Approaches and Techniques

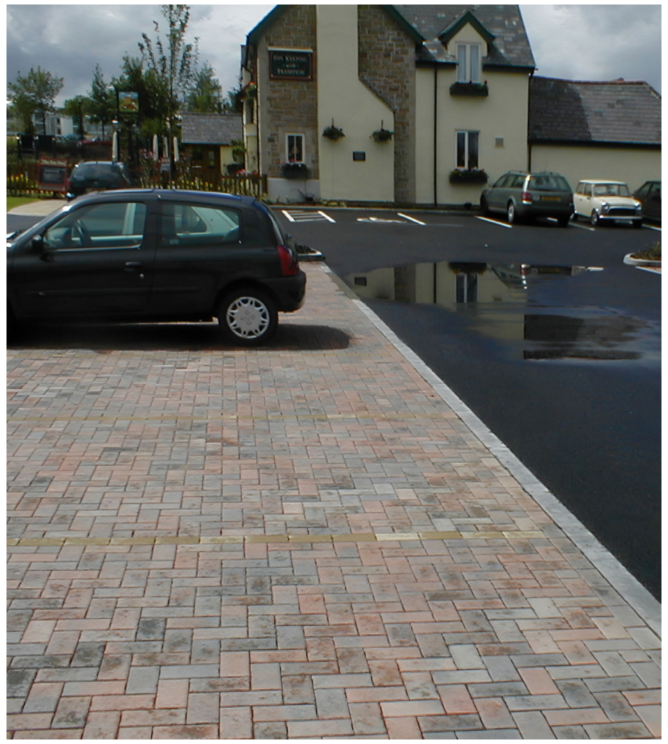
Increasingly, however, alternative structural layers are being used to create exciting opportunities for urban trees and green infrastructure, provide additional water storage, accommodate statutory services or meet other requirements. They include: structural soils, preparatory tree pits, geocellular systems and impermeable sub-bases. Also, retrofit permeable surface zone overlays, utilising existing road-bases (and their embodied carbon), offer particularly effective street renewal and regeneration solutions.

Permeable, Pervious or Porous?

'*The SuDS Manual*' identifies concrete block permeable paving as the most commonly used of *Pervious Pavement SuDS* typologies. Pervious Pavements are essentially sub-divided into *Porous* (infiltrating water across the whole surface via pores in the material) and *Permeable* (infiltrating water through joints between impermeable units). Confusion between typologies has resulted in misleading myths. For example, CBPP does not: clog, have low strength or poor durability, require frequent maintenance or suitability only for light-duty applications.

CBPP is unlike – and not to be confused with – porous materials and other forms of pervious pavements, which cannot deliver its long-term performance and multifunctional benefits.

How does CBPP work?



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

> **There is now sufficient long-term experience in the UK to endorse the minimal maintenance requirements of CBPP".**

Image below | Rainwater passes straight off CBPP through permeable joints between blocks.
Image top right | CBPP avoids the ponding experienced with conventional sealed paving.

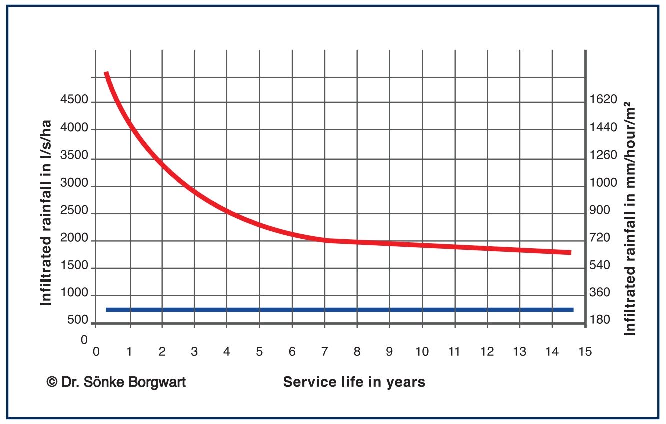
In contrast, rainwater drains straight off each block in CBPP, through the joints and laying course, as a permeable surface with dispersed drainage. CBPP attenuates and temporarily stores water during rainfall, cleaning, conveying and releasing it gradually over time. Essentially, it addresses flooding and water quality issues together, unlike attenuation tanks which only address flooding.

It is also truly multi-purpose, acting as the drainage system as well as a hard surface supporting traffic loads and offering numerous other additional benefits. 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 Performance & Benefits

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 shown red in the graph).



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 in the graph).

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 now recommended by MPA Precast. 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.

Cutting Carbon

The precast paving sector has been actively reducing carbon emissions. An assessment by MPA Precast suggests that the average carbon footprint of precast concrete paving products has already dropped by 27% since 2017. MPA Precast now assesses that the embodied carbon of concrete block paving can be 44% lower than equivalent asphalt paving alternatives over a 60-year service period.

In addition, CBPP offers significant embodied carbon benefits compared to traditional piped drainage, as it eliminates the need for gullies and other underground components.

2020

Martlesham Park & Ride (case study via www.mpaprecast.org) has delivered problem-free performance over 17 years. Recent field tests show that the CBPP still provides infiltration rates that would cope with any likely UK rainfall event, despite minimal maintenance. Extensive mature tree roots have continued to grow within the permeable pavement sub-base with no visible signs of CBPP rutting or lifting.

Protecting the Environment

Pollution is present and can build up on all hard surfaces used by vehicles (including EVs), 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, microplastics, 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, during high rainfall they may surcharge directly into watercourses without treatment. Worryingly, dedicated 'surface water' and highway drainage generally passes directly to watercourses or groundwater without any effective treatment. Used widely throughout suburban areas, this practice continues on new developments today.

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 and stores runoff during storms for later, gradual release to other drainage, reducing polluted surcharging from sewers into watercourses.

With CBPP, pollutants may either remain on the surface together with silt or filtered and trapped in lower permeable layers, particularly metals and total suspended solids (TSS), where some degrade over time, such as hydrocarbons. It is also well-established that oil separators are not required with CBPP. Indeed, CBPP is more effective at removing a wider range of pollutants from runoff than oil separators.

Extensive use of CBPP as a multifunctional source control within our streetscapes presents an obvious solution to pollution as well as flooding – particularly in conjunction with green infrastructure – whether retro-fitted in place of existing impermeable paving or designed-in to new developments.

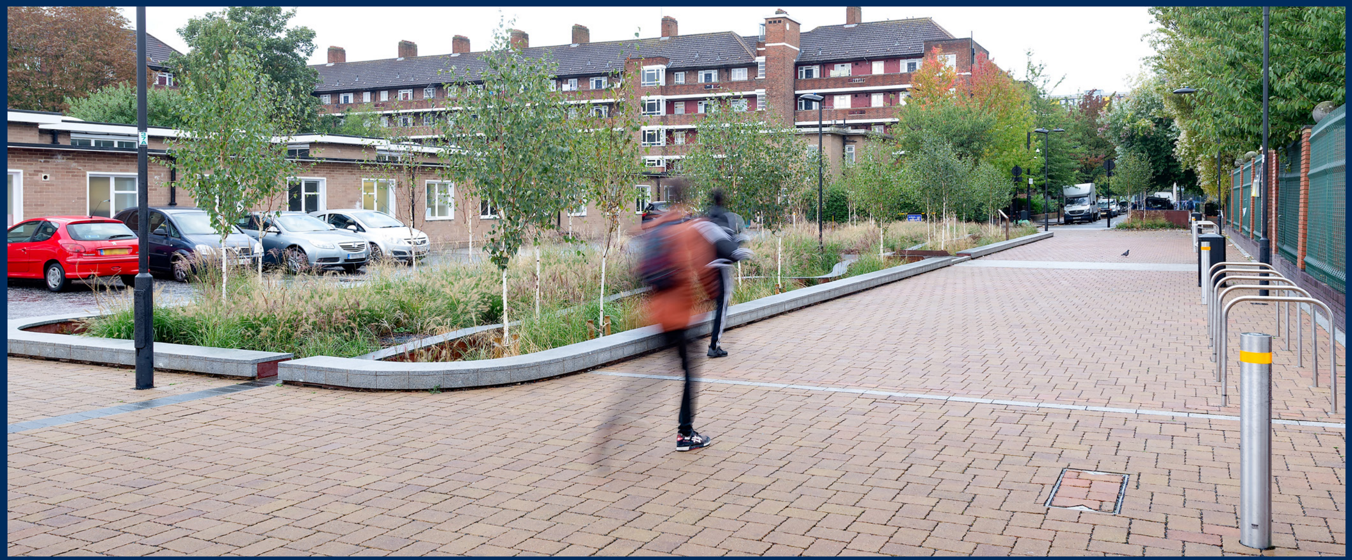


Image | At Bridget Joyce Square, London, a typical, adopted asphalt street and adjacent parking areas were transformed for community use with CBPP overlay shared surfaces and tree-planted raingarden basins – an exemplar for future urban landscapes. Photos: Robert Bray Associates.

Improving the Public Realm

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 public realm advantages and design possibilities of modular concrete paving generally (discussed earlier), CBPP offers additional fundamental benefits compared with conventional impermeable surfacing.

It meets current accessibility requirements for the whole community – unlike loose materials such as gravel, suggested in some guidance for permeable paving but specifically excluded by accessibility requirements. CBPP can be laid level and still avoid puddles, or adapt to slopes, all without the need for drainage gulleys. It eliminates 'ponding', reducing the risk of ice forming on the surface, and rain splashing from standing water.

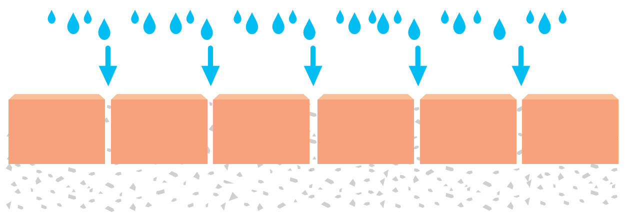
These aspects are particularly important for accessible shared surfaces, eliminating the need for cross falls, channels or gulleys. The capability for completely level pavements is helpful in other applications as well, for example car parking areas for supermarkets, making it easier to control trolleys, in container yards to meet specific operational requirements or areas used by forklift trucks.

CBPP also has potential to reduce urban heat island effects with evaporation and transfer of heat through movement of water within the paving, as well as enhanced solar reflectance (albedo) of concrete block paving. Most importantly, CBPP works in synergy with green infrastructure (discussed later), providing irrigation and exchange of oxygen and carbon dioxide for trees and planting that provide shade, air pollution removal and wellbeing.

By its very nature, CBPP requires no additional land-take for water storage or management, and no gulleys – death traps for wildlife – with related pipework. Both construction and whole-of-life costs of CBPP have been shown to be lower than for conventional paving and drainage, and it requires only limited, straightforward maintenance without clogging problems.

Image | Regeneration of White Hart Lane, London (case study via www.mpaprecast.org) is an exemplar of 'Healthy Streets' principles making a busy street more liveable, as well as SuDS and the protection and addition of trees – all enabled by CBPP. Photos: Robert Bray Associates.

CBPP Profiles

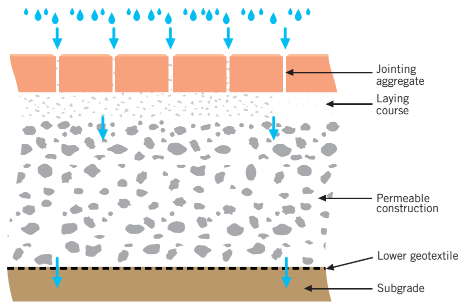


The key to CBPP is its permeable surface zone of high-strength concrete blocks with angular aggregate (2/6.3mm) used to fill enlarged joints and as a laying course.

It allows water to pass between the blocks while filtering out silt with many pollutants and preventing ingress of debris, retained on the surface where it can easily be removed. This unique permeable surface works in conjunction with various construction profiles and differentiates the technology from other types of pervious paving. In most CBPP constructed to date, water then passes into voids (approx. 30% by volume) within an underlying coarse grade aggregate (CGA) permeable sub-base. Here it is stored and released slowly, using the following alternative three Systems.

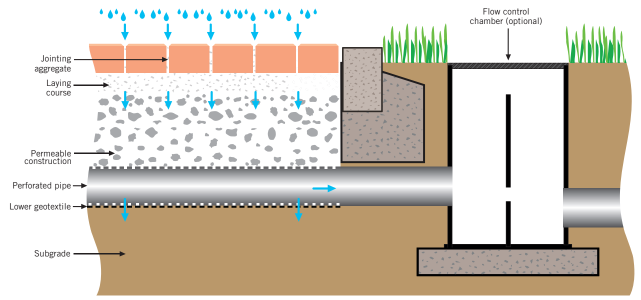
Full Infiltration (System A)

Suitable for existing subgrade with good permeability, System A allows all the water falling onto the pavement to infiltrate down through the constructed layers and eventually into the subgrade. Some attenuation will occur in the CGA layer before it eventually passes through. No water is discharged into conventional drainage systems, completely eliminating the need for pipes.



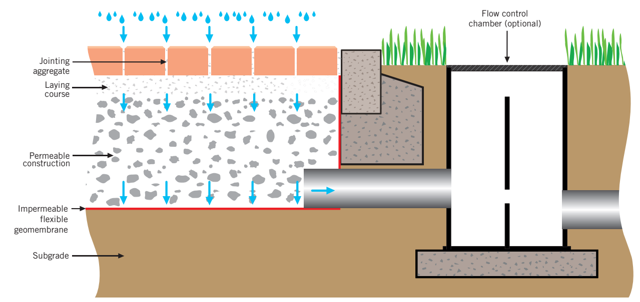
Partial Infiltration (System B)

Where the existing subgrade may not be capable of absorbing all the water, outlet pipes drain the CGA of excess water into other elements, such as swales, ponds, watercourses or sewers. This is one way of achieving the requirement to reduce the volume and rate of runoff, and will most likely remove the need for any long-term storage. An orifice plate flow control on each outlet pipe can increase water retention time and infiltration, and protect downstream devices.



No Infiltration (System C)

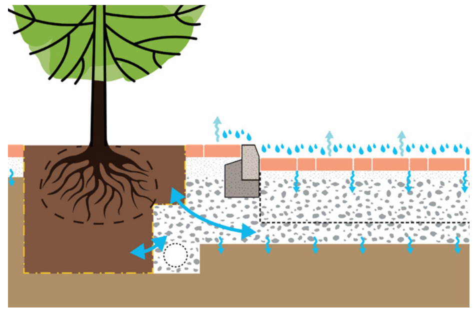
This system is used where the subgrade is poor or contaminated (to avoid pollution being washed down to groundwater), where infiltration would present a down-slope risk or where treated water is to be re-used as an asset. All the water is captured using an impermeable, flexible membrane placed on top of the subgrade and up the sides of the permeable sub-base to effectively form a storage tank. Outlet pipes through the membrane transfer the collected water and orifice plate flow controls ensure that designed storage/discharge rates are achieved.



Tree Pits

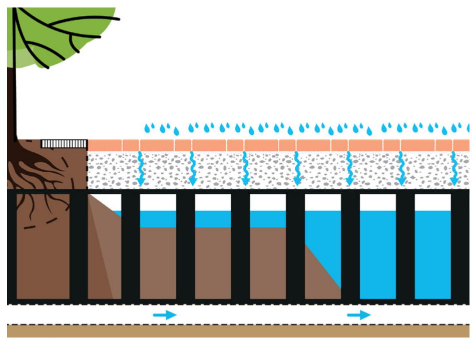
CBPP can be used over and around standard tree pits, enabling irrigation and simple gas (oxygen/carbon dioxide) exchange essential to trees, without additional reservoirs or pipes. It also avoids root disruption common with other paving and can be used close to trees. The current Code of Practice for accessibility in the external environment, BS 8300-1:2018, recommends permeable paving rather than tree grilles.

However, alternative structural layers are increasingly being used to cater for trees and green infrastructure, provide additional storage, accommodate statutory services or meet other requirements. The ability of CBPP to remove silt is particularly important to protect many of these alternative structural layer systems from clogging.



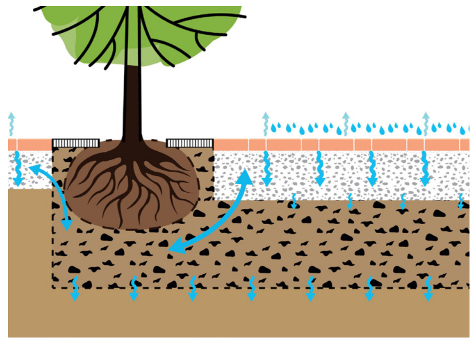
Geocellular Systems

Proprietary permeable sub-base replacement systems usually consist of plastic units forming a cellular raft to replace the CGA sub-base, designed to support anticipated traffic loadings. With over 90% void volume, they can provide additional water storage or reduce pavement thickness, or accommodate tree soils. They are also useful to form inlets and outlets from the permeable constructions



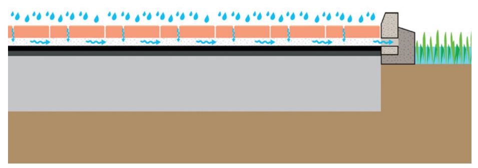
Structural Soils

Structural soils, such as the 'Stockholm System', have been developed using crushed stone compacted to form a load-bearing base. Then, selected soils – some incorporating biochar – are introduced into voids enabling tree root growth. CBPP, usually with a CGA aeration layer below, provides water and gas exchange so that aeration wells, gulleys or other devices, and their maintenance, are unnecessary.



Permeable Paving Overlays

The permeable surface zone can simply be applied as an overlay to impermeable constructions to collect, clean and convey water laterally to raingardens, trees, SuDS features or sewers. As low-intervention renewal and improvement works, utilising existing impermeable road-bases (and their embodied carbon), this approach delivers low-cost retrofit SuDS.



Permeable Paving Techniques

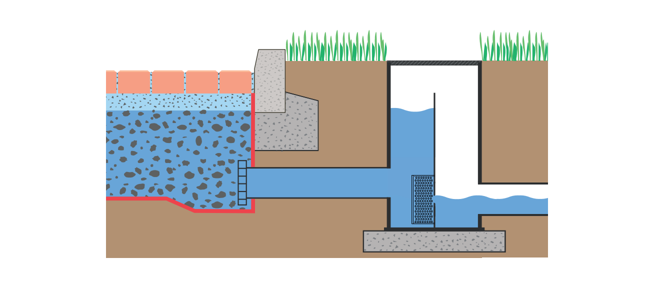
All Drainage Regimes

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 up to twice its own area.

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.

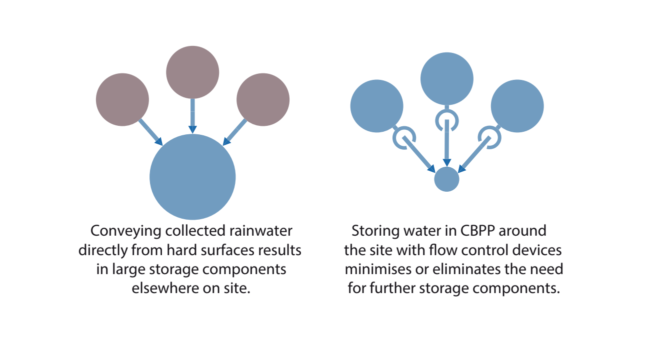
Outlet Flow Controls

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. 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.



Optimising Site Levels with CBPP

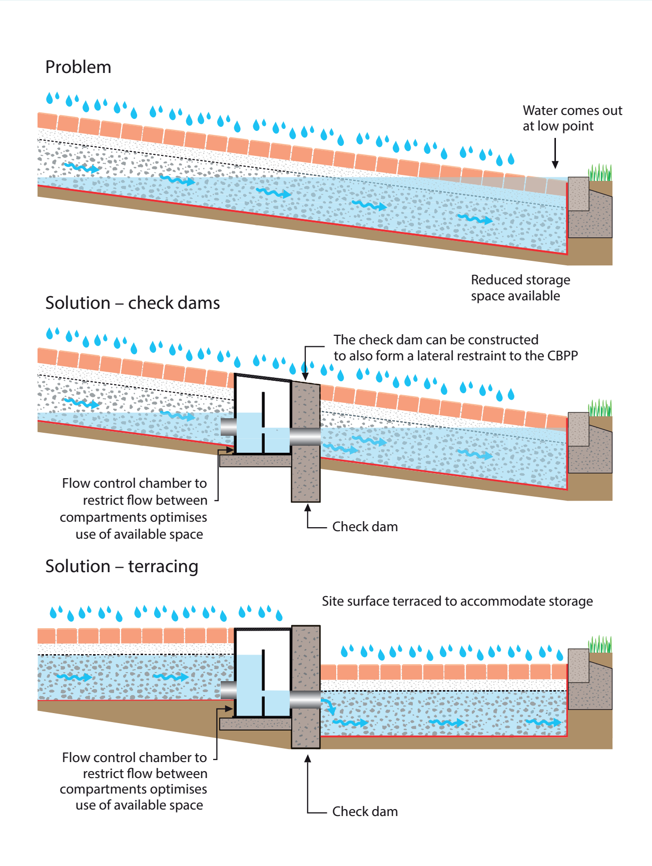
Unlike impermeable paving, the surface of CBPP can be completely flat, avoiding ponding. This means that CBPP surfaces are independent of cross-falls, channels, gulleys and other impediments to accessibility. Therefore, designers have complete freedom to introduce level changes for other reasons unrelated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

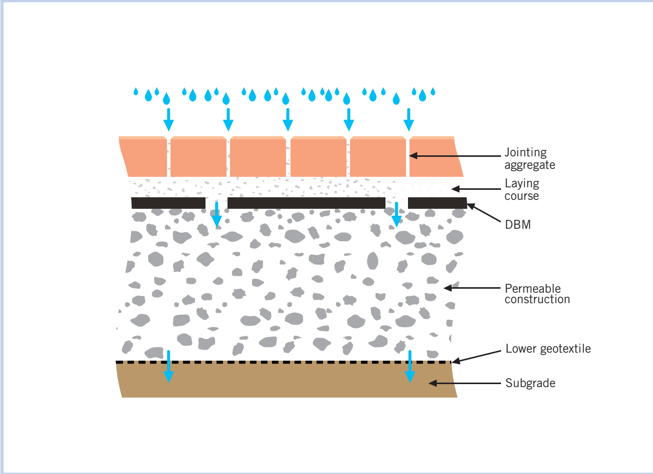
To some extent, the CBPP surface can be considered independently of pavement base and existing ground levels. Care is needed to ensure that the water in the permeable sub-base does not simply overflow at the lowest point, or the available storage will be reduced.

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 capacity and 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.



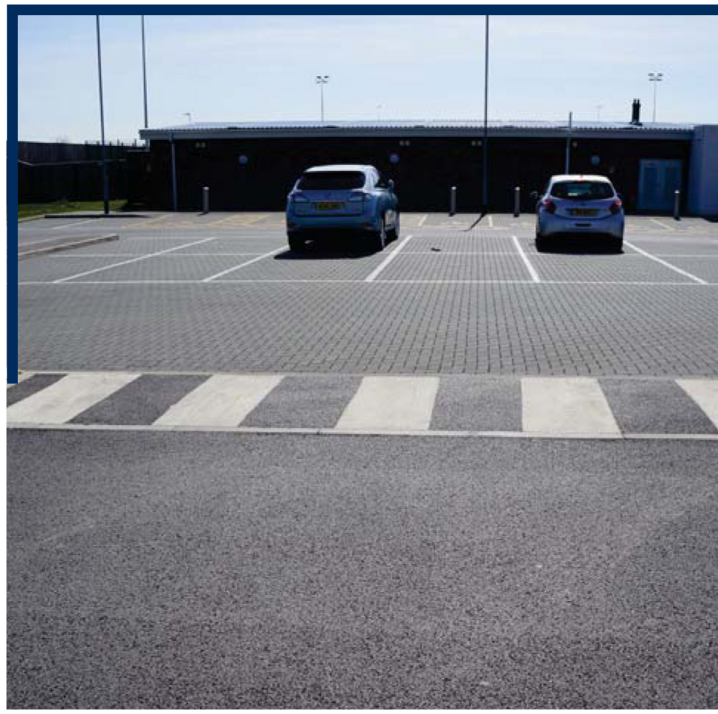


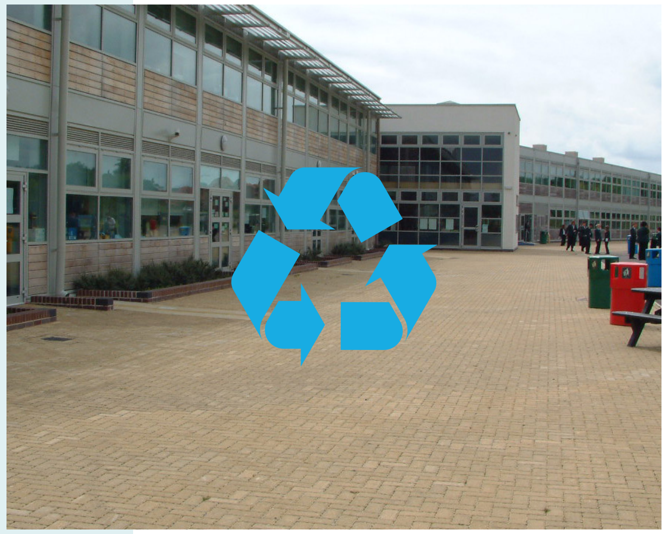
Cored Protective Layer

A popular method of providing a temporary surface for construction traffic while protecting the permeable sub-base from contamination is the DBM layer. The Dense Bitumen Macadam (DBM – also known as Asphalt Concrete) layer forms part of the pavement structure and 75mm holes are cored or punched prior to installation of the surface zone blocks and laying course. Typically, holes form an orthogonal grid of 750mm but they can be deployed strategically to retain water in the laying course with overflows – for example to optimise tree irrigation.

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 right.





Water Harvesting with CBPP

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

Permeable Paving Techniques continued...

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 left, 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 project shown right and on page 15 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.

> **"Where ground conditions preclude complete infiltration CBPP discharges a delayed, gradual flow of clean water".**

Parkside Civic Centre and Library, Bromsgrove.
Photo: Robert Bray Associates.

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.

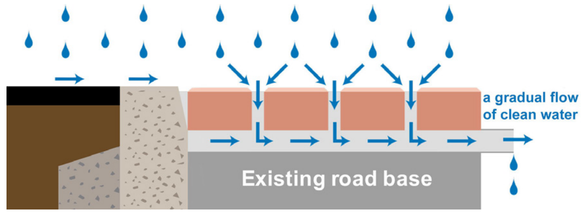
Case study via www.mpaprecast.org. Photos: Robert Bray Associates.

Retrofit CBPP Techniques

Apart from new developments, various techniques can transform worn-out paving and deliver SuDS, green infrastructure and healthy streets. There is a compelling case to apply CBPP in place of impermeable surfaces for street renewal, as well as regeneration and upgrade projects. In addition to full profile CBPP, other techniques can be used in existing urban settings enabling low-intervention, low carbon, no-heat, retrofit installation and providing long-life with minimal maintenance and low whole-of-life cost, while minimising excavation and avoiding statutory services.

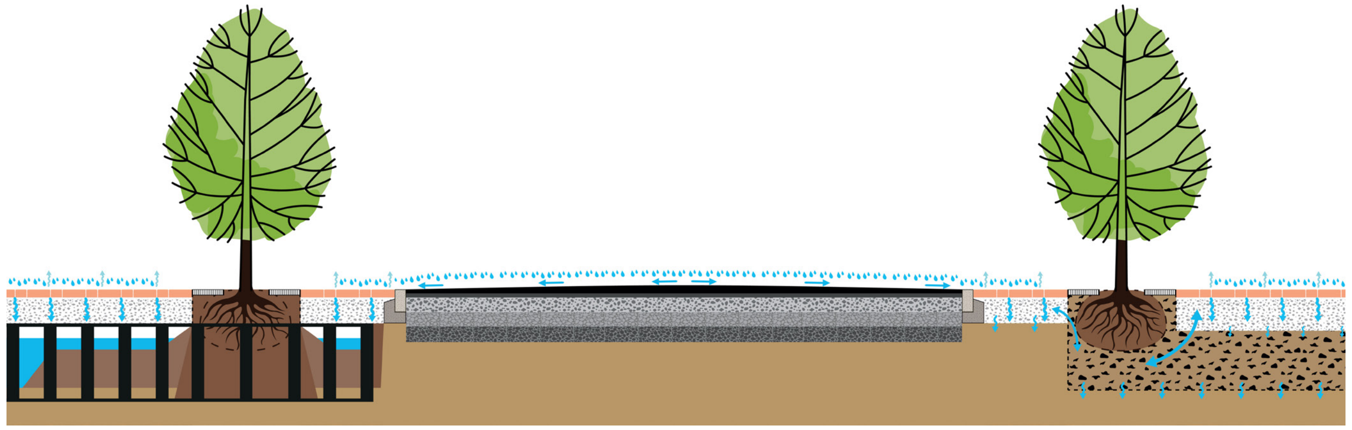
Overlays with CBPP

CBPP Overlay is a deceptively simple but innovative approach, maximising re-use of the existing road-base and its embodied carbon. The CBPP surface zone simply replaces planed-off old asphalt or another road surface, applied to the original structural road base. In many cases, this can simply run kerb-to-kerb to form a shared surface, level with the footway and flush kerb top, and can optimise the original drainage regime – but below the surface.



The same blocks and 2/6.3mm grit bedding layer and jointing material as for permeable pavements generally are used. Water is attenuated, treated and conveyed within the laying course, which is key to this technology, enabling filtration of silt and retention/treatment of pollutants without clogging.

A gradual flow of clean water can then be released near the surface, meeting SuDS requirements and irrigating green infrastructure, for example in rain gardens where water can also be stored, or passing into sewers. The CBPP surface zone overlay collects, cleans and stores up to 20mm of everyday rainfall, representing up to 95% of rainfall events and the 'first flush' of silt and pollution from the surface.



Partial Replacement with CBPP

An alternative approach to introducing SuDS and trees to existing streets is the partial replacement of existing impermeable paving with CBPP to one or both sides, avoiding statutory services and demarcating on-street parking areas.

Here, the existing road profile directs water from the impermeable carriageway and also footways onto the CBPP (which can accept twice its own area of runoff). Water storage for SuDS and/or sustenance for trees and green infrastructure is achieved with modular geocellular systems (shown left, above) or structural soil profiles (shown right) below the CBPP, and/or raingardens.

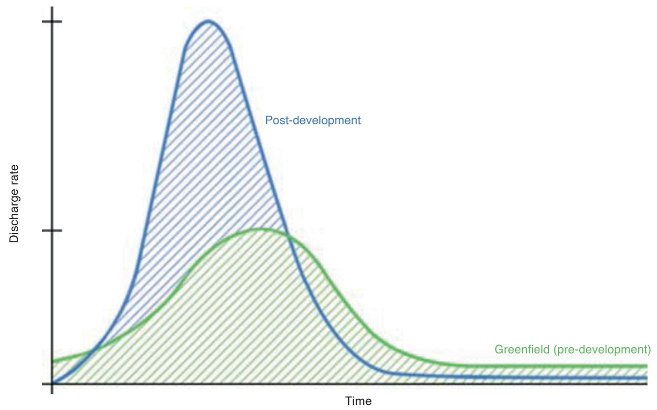
At Bridget Joyce Square, London (case study via www.mpaprecast.org) winner of the 2017 Landscape Institute Awards top prize, a typical adopted asphalt street and adjacent parking areas were transformed for community use with CBPP overlay shared surfaces. Water is cleaned, attenuated and conveyed to tree-planted basins that provide water storage for SuDS to reduce overloading existing drains, as well as for irrigation. The permeable paving continues to perform well and no problems reported during extreme summer storms. Photo: Robert Bray Associates.

Two different profile examples of typical street enhancements in Hammersmith & Fulham, London (case study via www.mpaprecast.org), characterised by low-intervention CBPP on-street parking. As well as delivering SuDS and irrigation for trees, the puddle-free CBPP retains litter, silt and pollutants on the surface for removal with straightforward cleaning.

CBPP for SuDS

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.

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

The Costs of SuDS

Well-designed, multifunctional SuDS that operate on or near the surface – including CBPP – have been demonstrated (for example at Lamb Drove, opposite) to cost less than conventional piped drainage. When comparing costs, it is essential to take into account the multifunctionality of SuDS, delivering far more than just drainage alone. Similarly, the cost of impermeable paving should include piped drainage, gulleys and water storage tanks or basins – plus their maintenance – when compared with that of CBPP.

CBPP – the Key to SuDS

CBPP is unique as a SuDS technique in combining proven engineering designs with nature-based solutions, replicating natural water management near the surface. Replacing the impermeable surfaces that cause the runoff issues that SuDS seek to address, it not only provides a particularly useful source control technique at the head of a management train – fundamental to the SuDS philosophy – but also helps achieve all four well-known pillars of SuDS: Quantity...Quality...Amenity...Biodiversity.

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 urban and landscape design, and is of major importance to street trees and green infrastructure.

The mandatory Welsh National Standards for SuDs 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*'.

The Code of Practice BS 8582: 2013 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.

The Lamb Drove SuDS Monitoring Project discussed opposite.

The Lamb Drove SuDS Monitoring Project

Site Plan courtesy of Robert Bray Associates.

Lamb Drove (case study via www.mpaprecast.org) was highlighted in Defra's January 2023 report announcing mandatory SuDS for England (see Page 20) as an exemplar of the government's 'SuDS approach'. It explores the use of CBPP as a key SuDS component and provides important cost comparisons between similar developments.

The Lamb Drove SuDS Monitoring Project (case study via www.mpaprecast.org) provides useful cost comparisons between similar developments. Overall, both capital and maintenance costs – and therefore whole-of-life costs – associated with the SuDS development were much lower than those for the conventional piped drainage system.

Completed in 2006, Lamb Drove is a 35-homes development on a 1-hectare site in Cambourne, Cambridgeshire, with a conventional layout but still delivering SuDS. It was compared with a similar, neighbouring development using piped drainage.

Lamb Drove demonstrates various techniques to collect, clean, convey and infiltrate, or store and release water at greenfield runoff rates (2 l/s/hectare) from developments to watercourses or sewers. The design is considered as two discrete sub-catchments, each with a micro-catchment of CBPP paved roads – all managed by flow control chambers. This enables full storage within landscape features and permeable paving, while roof-water discharges directly to green space.

Lamb Drove is an integrated SuDS system with predictable performance and is still operating successfully today. The monitoring report highlights lower capital costs – saving £314 per property at the time – and lower maintenance costs, with potential for further improvements and savings. It identifies that the scheme successfully attenuates surface water flows and significantly reduces peak flows, with reductions in concentrations of pollutants and other water quality indicators, and with an increase in wildlife species and diversity.

The report also confirms that with only minimal maintenance: *'The permeable pavement infiltration study specifically illustrates the robustness of the performance of this feature to limited maintenance. The infiltration capacity of the permeable pavement is able to adequately cope with the highest recorded rainfall intensity at the Study Site'.*

Overall, both capital and maintenance costs – and therefore whole-of-life costs – associated with the SuDS development were much lower than those for the conventional piped drainage system.

Regulatory Implementation of SuDS

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 unitary authority and publication of mandatory National Standards. A different approach is taken in Scotland where dedicated regulations simply require surface water drainage systems from new developments to discharge water to the environment through SuDS.

But the provisions of the 2010 Flood and Water management Act were not implemented at the time in England under Schedule 3 of the Act, relying instead on planning policies for flood protection.

Mandatory SuDS on Developments

Under mounting pressure and recognising that the planning-based system has not worked, government is now moving towards implementing Schedule 3 in England to make SuDS mandatory, announced in a review from Defra in January. Public consultation later this year will help to shape the new approach, with implementation expected during 2024. To demonstrate the government's 'SuDS approach', Defra's report cited one project in particular as an exemplar: Lamb Drove (discussed on page 19).

National SuDS Standards and other related changes will be applied to England and SABs will be set up within unitary authorities or county councils. SAB approval will be required before construction of drainage systems on new and redeveloped sites (except single buildings or permitted development, under 100 square metres), or connection to public sewers. This is an important step forward, not just in the fight against flooding but also in enabling the numerous multifunctional benefits of well-designed SuDS to be realised, particularly in response to climate change.

Action on Existing Surfaces

The welcome move towards wider use of permeable surfaces will also help to reverse the "sealing-up" our towns and cities, highlighted in a November 2022 National Infrastructure Commission (NIC) report on reducing flooding from surface water. The NIC is an executive agency of the Treasury and provides government with impartial, expert advice on major long term infrastructure challenges including water, drainage and flood risk management. It recommends urgent action to move away from impermeable surfaces, both for new developments and in existing settings.

The NIC report highlights that, currently, around 325,000 properties in England are in areas at the highest risk (with more than 60 per cent chance of surface water flooding) in the next 30 years and that, without action, up to 295,000 more properties could also be put at risk. The report aims to ensure that: *'We should not let surface water flooding continue as a stealth threat. We have the means to address it – what's largely required is impetus for a range of bodies to act, and better coordination between them'.*

Permitted Paving Enforcement

The NIC also recognises that, by 2055, some 50,000-65,000 properties may be put in areas at high risk due to "unplanned" increases in impermeable surfaces, such as front gardens being paved over, which increase the volumes of water entering drainage. 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 (see the 'Permitted Paving' guide via www.mpaprecast.org). Although planning permitted development rights for replacement or new paving around existing homes and some commercial properties have been removed for impermeable surfaces for some time, enforcement and compliance have been limited.

So, the NIC now recommend a review of options for managing unplanned increases in impermeable surfaces and potential policy changes to prevent it adding to the problem. In addition, some water companies already apply "area-based charging" to commercial properties where impermeable paving drains to sewers and Ofwat is encouraging trials with residential customers as well.

Clearly, we should soon see a much wider application of permeable surfaces – notably CBPP – reversing the sealing-up of urban areas.

Riverside Court, Stamford

Site Plan and photos courtesy of Robert Bray Associates.

CBPP can help deliver SuDS on high-density urban developments, as well. At this 104-units per hectare town-centre housing scheme in Stamford, most public areas between buildings are CBPP which also accepts runoff from other hard areas and roofs. Stored, treated water then passes from the paving directly into planted rills and canals, which add interest and much-needed greenery to the courtyard environment, before passing into the nearby river.

CBPP for Trees and Climate Change

Probably the most exciting recent developments result from recognition of the synergy between CBPP and trees. New techniques optimise the key characteristic of CBPP to replicate natural permeable surfaces with diffuse rainwater infiltration and retention, plus free air movement.

The Need for Trees

Planting new and protecting existing trees are now recognised as central to making our towns and cities liveable and responding to climate change. Trees help deliver carbon sequestration, biodiversity and SuDS, as well as enabling urban cooling through shading and evapotranspiration, biodiversity and biophilia (well-being). Research shows that they also reduce noise, air pollution, stormwater pollution, wind-chill cooling in winter and even crime.

Straightforward Spatial Solutions

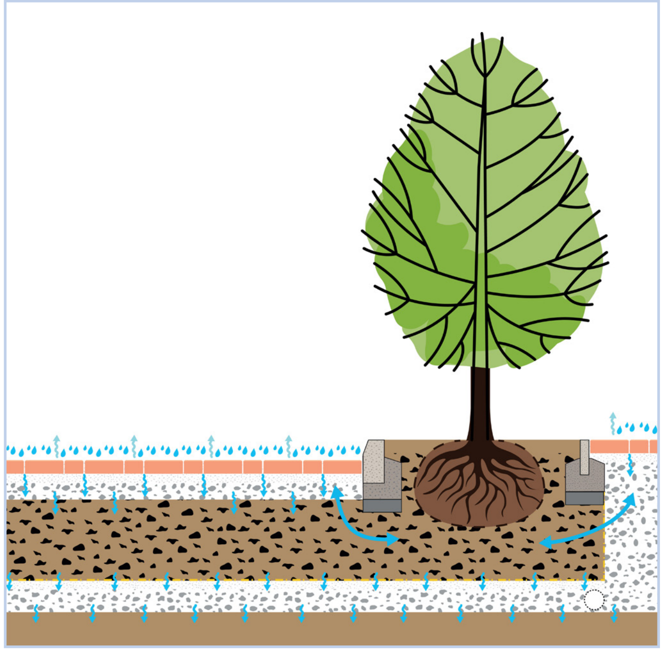
However, measures need to be put in place to nurture and allow trees to mature – generally for decades – so that they can actually deliver their real potential. Increasingly, street trees are becoming a requirement in developments and regeneration. For example, the National Planning Policy Framework (July 2021) for England says: *'Planning policies and decisions should ensure that new streets are tree-lined and that opportunities are taken to incorporate trees elsewhere in developments…with appropriate measures … to secure the long-term maintenance of newly-planted trees, and that existing trees are retained wherever possible'.*

Local authorities will be seeking practical, spatial solutions for maintenance and sustenance. CBPP offers unique opportunities to collect, attenuate and treat rainwater runoff, removing pollutants for a gradual supply of clean water irrigating green infrastructure. Unlike conventional impermeable paving, CBPP allows the same pattern of run-off transfer to the ground as natural vegetation. It can provide irrigation with scope for stormwater storage and maximises rainwater capture away from sheltering tree canopies for conveyance to tree roots – essential in summer.

"CBPP works in synergy with trees, replicating natural permeable surfaces with diffuse rainwater infiltration and retention plus free air movement".

CBPP and Trees in Synergy

Urban trees and paving have traditionally been seen as in conflict. But this is not the case with CBPP. It enables air to reach roots and poisonous CO_2 to escape. The favourable environment created for tree roots avoids pavement surface disruption and facilitates natural growth into lower levels for stability and longevity. CBPP can be used within new-build, or regeneration schemes with new tree planting and also for 'rescuing' mature trees.



It can be used over standard tree pits, proprietary tree planters, 'Stockholm System' or other structural soil installations, enabling irrigation and simple gas exchange essential to trees – without additional reservoirs or pipes. Alternatively, a CBPP overlay can simply discharge horizontally into a raingarden or bioretention planter, perhaps with overflow into an existing, adapted gulley. The raingarden stores water during heavy rain for SuDS, retains soil moisture during dry weather and provides additional water quality 'polishing', as well as irrigation.

'The SuDS Manual' recognises the synergy between CBPP and trees, and it is the preferred surfacing option around trees, rather than tree grilles, according to BS8300-1 (2018).

Tottenham, London

In Tottenham, London (case study via www.mpaprecast.org) a new Pocket Park incorporates small element flag CBPP helping to sustain mature and new trees, and other green infrastructure. Photos: Robert Bray Associates.

Implementation

Standards and Guidance

The industry-recognised, definitive guidance on all aspects of CBPP is the MPA Precast (Interpave) *'Guide to the design construction and maintenance of concrete block permeable pavements'.* First published in 2003, the Guide is based on research and experience internationally, and substantially informs the BS 7533-13:2009 *'Guide for the design of permeable pavements…'* and also relevant sections of *'The SuDS Manual'*.

The current Guide Edition 7 (2018) – available via www.mpaprecast.org – supersedes both BS7533-13 and The SuDS Manual 2015. It includes design information for the latest Traffic Categories and important, simplified guidance on long-term maintenance based on decades of experience. A new Edition 8, incorporating the latest applications and techniques discussed here, is anticipated in 2024.

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.

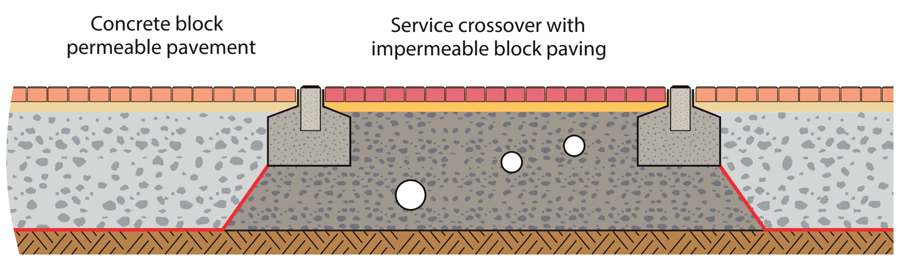
Project design should take into consideration the characteristics of CBPP to enable its efficient use. For example, scheme layouts and building positions should be informed by seeking level CBPP to maximise water storage.

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 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.

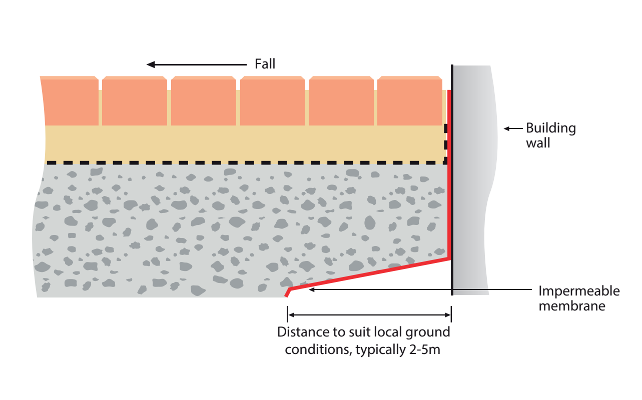
This approach can also form a key part of the overall layout design both visually and technically. For example, an impermeable central carriageway might be employed to contain services, visually differentiated from CBPP parking bays. Alternatively, impermeable service crossings could also be used as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



Cross section through impermeable paving service corridor.

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 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 MPA Precast's (Interpave) Guide and also its dedicated Detailing Permeable Paving & SuDS 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 the MPA Precast (Interpave) Guide, incorporating the latest design methodology.

This 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 MPA Precast's (Interpave) 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 criteria.

Constructing CBPP

Comprehensive guidance on specification and construction of complete permeable pavements is available in the MPA Precast Guide. The concrete block layer should be constructed in accordance with the BS 7533:Part 3:2005 +A1:2009 Code of Practice 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 MPA Precast (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 MPA Precast (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 MPA Precast (Interpave) guidance. One effective method is to use a protective Dense Bitumen Macadam (DBM – also known as Asphalt Concrete) layer during site works, subsequently punched through to allow drainage just before completion, as discussed earlier. This layer also contributes to the structural design.

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

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. 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 s hould be avoided. The The MPA Precast (Interpave) Guide provides the latest maintenance and remedial guidance based on 25 years experience.

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.

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 20,000,000m² 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 below) and other major developments in Oxfordshire.

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.

Most importantly, wider use and adoption of CBPP enables developers and local authorities to meet mandatory requirements for SuDS in developments as well as action to replace impermeable surfaces in existing settings, resulting from the 2022 National Infrastructure Commission report on reducing surface water flooding.

This 1:20 gradient CBPP residential street in Sheffield (case study via www.mpaprecast.org) has been adopted and has been problem-free during extreme rainfall. Sheffield has entered into a long-term contract for highway maintenance, including CBPP with agreed costings informed by current MPA Precast maintenance guidelines.

At the start of this document, the urgent need to respond to climate change with far wider application of permeable surfaces throughout our towns and cities, reversing the sealing-up of urban areas, was highlighted. This will require change and MPA Precast welcomes dialogue with all those involved in the development process to help achieve it.

www.mpaprecast.org | precast@mineralproducts.org

Acknowledgements

MPA Precast would like to thank the following for their help in producing this document:

Bob Bray, Robert Bray Associates

Roger Nowell, Sheffield City Council

Written by **Chris Hodson** for MPA Precast.

MPA Precast is the trade association for precast concrete manufacturers and members of the supply chain.

MPA Precast is affiliated to the Mineral Products Association, the trade association for the aggregates, asphalt, cement, concrete, dimension stone, lime, mortar and silica sand industries.

www.mpaprecast.org

MPA Precast
The Old Rectory, Main Street
Glenfield, Leicestershire LE3 8DG

Tel
0116 232 5170

Email
precast@mineralproducts.org

Web
www.mpaprecast.org