The Marshalls Brand Manifesto

We are all influenced by our environments and the better our environment the better we can be.

Marshalls believe that we all need places that make us feel safer, happier and more sociable. Places to be ourselves, where we can live, play, create and grow. That belief drives us to be the best we can be.

To design and produce new products which are better than anything else available. To make them from the best materials we can source and to care about the impact that our company and its products have on our society.

Above all, our belief fuels the passion on which Marshalls is built.

To architects, town planners, civil engineers, builders merchants, paving installers and home owners, we pledge a passion to bring to life all that you can imagine. A passion that will enable you to breathe new life into those corners of the landscape where potential lies unfulfilled and unchallenged.

Our passion pervades everything we do. We use our expertise to create integrated landscapes which promote wellbeing to the benefit of everyone. So, whether it’s through fairly traded stone, providing products which alleviate flood risks, enabling our business partners to share in our success or creating innovative street furniture that protects us from attack, we proudly strive to make our world a better place. One stone, patio, pavement, town square or car park at a time.
We strive to create a better environment for everyone, and use our expertise and experience to create attractive, safe and sustainable spaces which promote well-being. Marshalls believe that flood alleviation products make an effective contribution to achieving this goal.

As we continue to develop the spaces around us, the need to protect our natural environment is stronger than ever before. We recognise that green, open spaces in which we can relax and enjoy our leisure time need to co-exist alongside hard landscaped areas. We constantly work to develop new products and technologies which provide real benefits to our environment in terms of both performance and aesthetics.

Mary Dhonau (OBE)
MDA Community Flood Consultants
Chair of the Flood Protection Association

“Climate change means that incidences of ‘extreme weather’ are becoming commonplace. Increasingly frequent bouts of heavy rainfall should be anticipated as the norm rather than the exception, and in conjunction with our increased rate of urban development, this means that risk of flooding is rapidly increasing all over the UK.

“The need to manage excess water run-off safely and effectively has never been more important. We must take responsibility for the sustainable development of our landscapes – failure to do so will create more and more of the floods which have devastated businesses and communities in 2012.

“Permeable paving is a great example of a SUDs solution which reduces flood risk in a cost effective manner while still providing the desired level of hard standing. Following the work Marshalls has done to improve and rationalise sub-base designs there is no longer any reason why permeable should not be the first choice for all hard standing requirements.”
What’s the issue?

Many developed areas across the world are now entering a state of ‘water stress’ – not because there’s less water available, but because we’re mismanaging this essential resource.

As we continue to develop over green land, we are fundamentally altering the way rainwater maintains our landscapes. Increased levels of impermeable hard standing areas (such as roads, roofs and paved surfaces) intercept and redirect surface water run-off before it has a chance to infiltrate naturally into the ground. This creates a number of problems, which are likely to get worse as global development continues…

Of the 57,000 homes affected in the 2007 summer floods, over two thirds were the result of surface water run-off - not swollen rivers.

Flooding

In the UK, surface water run-off is typically diverted into piped networks. The consequence of this is that when heavy rainstorms create high peak flow rates and high volumes of run-off, the piped networks become overloaded and at risk of creating an external flood.

Climate change means that the UK’s weather patterns are changing; we now encounter more frequent bursts of much heavier rainfall than ever before. The increased severity of these events, combined with inadequate piped drainage infrastructure, only serve to compound the levels of flooding now experienced.

Pollution

In addition to the risk of flooding, large volumes of surface water run-off can cause water quality problems. Surface water run-off from impermeable urban surfaces can potentially transport pollutants resulting in contamination of surrounding watercourses. Pollutants such as hydrocarbons, nitrates, phosphates and heavy metals can be contained within urban run-off.

Drought

An additional and often overlooked problem created by our increased urban development is that of increased drought risk. By diverting water away from its intended course, it is prevented from entering the water table (deep infiltration). Even after a heavy and prolonged period of rain, water is quickly channelled away from its natural path and prevented from soaking deep into the ground where it would naturally have maintained our aquifers, artificially creating a drought situation. This has the effect of choking our natural landscape by reducing the amount of groundwater available to maintain the lush, green spaces which would normally provide us with a wide variety of biodiversity benefits.

In completely natural environments, the majority of rainwater permeates naturally into the ground at source and only a small amount runs off into waterways.

In developed areas, the majority of rainwater falls onto impermeable surfaces, where it is diverted away from its natural course into storm drains and waterways.
What’s the Solution?

Sustainable Urban Drainage Systems (SUDs) provide an alternative approach to traditional piped systems. They mitigate many of the adverse impacts of storm water run-off on the environment in terms of both volume and pollutants.

SUDs

SUDs stands for Sustainable Urban Drainage System. Essentially, the term refers to a combination of drainage techniques which deal with surface water run-off in an environmentally friendly way. SUDs provide an alternative approach to traditional piped systems.

The SUDs philosophy is known as the SUDs Triangle and addresses three areas of concern:

- Water Quantity
- Water Quality
- Biodiversity

A successful SUDs design mimics natural processes to deal with excess water, providing control at (or adjacent to) the source:

- It should deal with Quantity by keeping surfaces clear of standing water, and releasing it into the ground or into traditional systems at a controlled rate.
- It should improve Quality by filtering pollutants from the water that flows through it.
- It should provide Biodiversity benefits by maintaining the local water table, helping to maintain lush, green spaces which encourage the growth of flora and fauna.

By considering these three factors during the design stage of a project, it is possible to create drainage systems that provide natural water quality treatment, encourage infiltration, reduce the impact of peak flows and minimise impact on the local habitats of both communities and wildlife.

SUDs Treatment Train

The SUDs treatment train follows a sequence of SUDs measures ensuring potentially contaminated surface water run-off passes through an appropriate series of SUDs measures before being discharged into the receiving watercourse.

Source Control

To facilitate control of run-off at (or adjacent to) the source, source control measures represent the most important element of the treatment train as they result in the highest removal rate of contaminants.

Source control measures are regarded as the most cost effective SUDs measure to implement as they manage smaller volumes of surface water run-off within a relatively small footprint of land, such as swales, filter strips, permeable paving and Grassguard.

Regional Control

Regional control SUDs facilities provide the final water quality improvement or ‘polishing’ of surface water run-off. Regional controls would include ponds and basins and typically receive flows from upstream SUDs measures. Regional controls can offer the opportunity to create landscaping features and habitats.

Site Control

To receive run-off from upstream catchments or source control measures, site control SUDs will typically discharge from a single point at a controlled flow rate. Site control SUDs are regarded as a medium ‘land take’ option - ie detention basins and ponds.
Legislation is driving SUDs

Whilst there is an acceptance that SUDs plays a vital role in creating sustainable landscapes, it is still a relatively new philosophy. As such, there is a need for clear guidance.

The Flood and Water Management Act 2010 is a major legislative step towards improving both flood risk management and the way we manage our water resources. The act seeks to define clearer roles, responsibilities and standards for the creation of sustainable drainage systems in line with proposed flood risk management strategies.

Whilst the act places responsibility for managing SUDs on Local Authorities' SUDs Advisory Boards, responsibility for the specification, design, implementation and maintenance of SUDs schemes remains shared between local government, designers, town planners, landowners, developers and even homeowners.

With so many stakeholders involved, decisions about new developments and increasingly essential water management systems cannot be taken without a complete understanding of surface water risks - and the most effective solutions.

Further Government planning advice is available within both Planning Advice Notes (PANs) and Scottish Planning Policy (SPP) documents.

A summary of relevant legislation and Guidance documents is contained within Appendix I.
Examples of SUDs Techniques

Utilising green areas to provide natural filtration is known as ‘soft SUDs’. Using man-made materials to achieve the same result is referred to as ‘hard SUDs’. The following is a list of soft SUDS techniques, and examples of how we can integrate soft and hard SUDs to achieve a practical and holistic solution.

Filter strips – wide gently sloping area of grass or dense vegetation that filters storm water run-off from impermeable areas
Swales – generally wide shallow grass lines channels intended to transport or store storm water run-off and allow infiltration
Infiltration Basin – surface depressions in the landscape intended to store storm water and allow infiltration
Wet ponds – used to store storm water run-off and are permanently wet and provide amenity features
Detention basins – used to store storm water run-off but are only wet following a storm event
Wetlands – shallow ponds with vegetation intended to reduce pollutants in storm water run-off
Filter drains – trenches filled with permeable material
Soakaways – buried storage point for storm water run-off where it will infiltrate into the ground
Green Roofs – planted roofs which slow and reduce the amount of run-off whilst also providing a host of biodiversity benefits
Rills – open surface channels which transport water cleanly and safely from one point to another (frequently employed as an aesthetic consideration)
Permeable Paving – hard surfaced areas which allow water to permeate through the surface and into the ground at source

Adopting wider use of these features will make a marked difference to our landscapes, improving habitats for wildlife and flora and reducing the risk of flooding. However, we cannot ignore the growing need for hardstanding. People need to drive and park vehicles, ride bikes, and push prams and wheelchairs comfortably and easily. We all enjoy aesthetically appealing public spaces which retain their clean, sleek looks with the minimum of maintenance. Even taking into account the growing awareness of green issues, we have to accept that we all want to go about our modern lives with the least amount of mess and difficulty; hard standing is here to stay.

So, the question is: how do we satisfy these modern requirements whilst mitigating the effects of water stress?
Traditional Pavements vs Permeable Pavements

Permeable paving is not a new concept, but it has started to gain wide acceptance with the construction industry only in recent years. It marries the requirement of durable and attractive hardstanding with all three elements of the SUDs triangle.

Traditional Paving

A traditional pavement construction includes integral cross falls which direct surface water into a drainage system, such as a road gully or linear drainage channel. This ensures that during a storm, rainwater is removed swiftly and efficiently – preventing unsafe, unhygienic and potentially damaging standing water from ponding on the surface. The problem with this type of drainage is what happens next. Rainwater continues to flow through the system into the main sewers, culverts and eventually streams and rivers. The time it takes for this journey is relatively short, and as the area of impermeable surfacing is increasing the extra burden placed on the river systems can have disastrous consequences. In other circumstances, where there is no opportunity to outfall to a water course, the storm water is frequently directed to a combined sewer where it will be treated (at great expense and environmental impact) despite it being fresh water.

Most importantly, to the untrained eye, there is no discernable difference between a traditional concrete block paved surface and a permeable pavement!

Permeable Paving

Permeable Paving combines hardstanding with SUDs and works in a very different way to a traditional pavement. It is designed to allow rainfall to percolate immediately through the surface near to where the raindrop lands – so surface ponding is completely eradicated without the need for an additional channel drainage system. The water flows into a specially prepared sub-base, where the voids between the stones which make up the structure act as a temporary reservoir. During a rainstorm, the water is collected in the sub-base (‘attenuated’) before it is released slowly either by natural infiltration into the ground beneath the pavement, into the main sewer at a controlled rate via a flow restrictor, or a combination of both.

Benefits of a Concrete Block Permeable Paved System

**Quantity** – Helps to reduce the impact of storm water on the river systems by attenuation and infiltration thus reducing the risk of downstream flash flooding.

**Simplicity** – A form of source control – ie deals with the water where it lands. Source control is the preferred method of treatment from the SUDs hierarchy.

**Quality** – Improves the quality of the water in two ways:

- The stones within the sub-base act as a filter medium which remove heavy particles such as silt and heavy metals.
- Over time microbial organisms begin to cultivate in the pavement which break down hydrocarbon leaks such as exhaust fumes and sump oil drips.

...in addition to the existing benefits of a standard Concrete Block Pavement, including:

**Aesthetics** – The varied combinations of texture, form and colour provide rich visual appeal to a huge range of landscape projects.

**Strength** – In addition to the inherent strength of each unit, the interlocking design of the pavement dissipated loads evenly over the surface.

**Durability** – Resistant to frost damage and most chemicals, fuels and oils, CBP forms a hardwearing surface with an exceptionally long lifespan.

**Legislation** – Complies with current SUDs legislation and planning regulations.

**Cost** – Frequently less expensive than equivalent conventional impermeable surfaces plus drainage and storage.

**Practicality** – A low land take option. All new developments will require some form of hard landscaping; permeable paving combines hard landscaping with a SUDs drainage solution.
Marshalls Priora – Permeable Paving Made Easy

Marshalls Priora, the best selling permeable paving system in the UK, is an ideal SUDs solution. The designs of both the sub-base and the block itself have been continually developed over the past 10 years to provide a solution which delivers on all levels in terms of cost, performance and aesthetics.

It is important to acknowledge that a permeable pavement is a system and not just a paving block; the design of the sub-base is essential to the system’s performance, and allows the pavement to perform structurally (by supporting the load on the pavement) and hydraulically (by storing the required amount of run-off water).

Rainwater falls onto the surface...
Where it seeps immediately through the specially created voids between the blocks...
Into the specially designed sub-base...
Where it is stored...
Until it permeates into the ground...
...or is released into water courses at a controlled rate.

Each block features a series of six patented Priora nibs around its edge, which interlock on eight separate faces in three different directions. These nibs also create the voids through which water run-off percolates into the sub-base.

The system improves water Quality by filtering the water as it falls through the sub-base. It also provides Biodiversity benefits by replenishing the water table at source, which will maximise ecosystem services in the area.

A key factor in the way a block paved surface behaves is the way in which each block interlocks with its neighbours. Interlock helps to spread the load evenly across the area of the paved surface, improving surface stiffness and reducing pressure on the laying course immediately beneath the blocks.

There are three different kinds of interlock: horizontal, vertical and rotational.

**Vertical interlock** refers to the ability of each block to move against its neighbours on a vertical plane. If the sub-base has been designed and installed to our specifications, it is unlikely that this will be a factor in a Priora surface. However, the unique patented Priora nib improves vertical interlock by increasing the amount of ‘brick to brick’ contact. The 6mm aggregate between the blocks further improves vertical interlock by bridging the gap between blocks.

**Horizontal interlock** refers to the ability to move against its neighbours on a horizontal plane. In all CBP installations, horizontal interlock is maximised by the geometric shape of the block. The interlocking nature of the Priora nib reduces the ability of a block to move horizontally against its neighbours. This feature can also be enhanced by the laying pattern. A herringbone laying pattern has been proven to provide the best possible horizontal interlock which makes it the recommended style for heavy loading applications.

**Rotational interlock** refers to the ability of each block to rotate against its neighbours on a horizontal plane. This is where the unique patented Priora nib has a proven advantage; in laboratory tests at Newcastle’s Rolling Load Facility (NUROLF), Professor John Knapton discovered that the Priora nib maximises rotational interlock between blocks, and can therefore reduce pressure on the laying course by up to 40% compared to other surfacing options.

A Patented Nib Design For Superior Interlock

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**Professor John Knapton**
World Renowned Structural Engineer

“...it’s one of the few benefits of a paving that’s not just a marketing claim - it does actually have some good engineering behind it”
Smart Design Drives Out Cost

All areas of the construction sector are being subjected to ever-increasing levels of financial pressure. Marshalls believe that in order to make permeable paving the first choice for all hard standing requirements, we must strive to make the design and installation of these systems as cost effective as possible.

Marshalls has recently undertaken a major project with Professor John Knapton, one of the world’s leading structural engineers, to reinvestigate the design advice we offer our customers. We used a combination of laboratory testing, desktop analysis, Professor Knapton’s worldwide experience, and in-situ data from over 10 years of successfully installed Priora projects to arrive at a series of findings which now make a Priora system more cost effective than ever:

- **Nine New Design Models**, ranging from light domestic to a heavy duty ‘ports and docks’ option, eclipse the six offered by the British Standard. This means that our designs are more prescriptive than ever before, and ensures that the designs we create are less likely to be overspecified than the BS.

- **Rationalised Sub-Base Design** – by understanding the improved rotational interlock provided by the unique Priora nib, we can now reduce the depth of the majority of our designs while still providing the necessary level of structural integrity.

**New Marshalls Designs – Benefits:**

- **Environmental**: less energy used in excavation, less waste to dispose of and less imported aggregate all add up to reduce the carbon footprint of your project.

- **Practical**: In areas where excavation is limited (to avoid services, for example), our new designs frequently make a Priora surface a realistic option where it wasn’t before.

- **Financial**: Crucially, our new design models combined with our rationalised sub-base designs drive cost from the Priora structure, making permeable paving a more cost effective option than ever before.

**Build Up**: 80mm Block 50mm Laying Course 350mm Sub-base (OGCR) Total Depth = 480mm

**NEW Marshalls Design** 31% shallower than the BS

**Build Up**: 80mm Block Same as BS 50mm Laying Course Same as BS 200mm Sub-base (OGCR) 43% shallower than BS Total Depth = 330mm

*Example used: Cars & Light Vans (or equivalent), 5% CBR

**Priora Sub-Base Construction**

The aggregate installed beneath a Marshalls Priora surface is an essential element of the Marshalls Priora system. The aggregate must provide sufficient porosity to store water in the voids between the granular elements; it must also be of sufficient structural strength to withstand the loads to which the structure will be subjected.

Therefore, for the Marshalls Priora system to work effectively, we provide thorough aggregate specification to help source the correct material.

For detailed aggregate specification please see page 43, and for details of Marshalls Priora Aggregate, please see page 33.

**Jointing**

A traditional concrete block pavement would use sand to fill the joints between the blocks. A Marshalls Priora system requires a more open graded coarse material, which will allow water to easily pass through into the sub-base without clogging.

It should also be of an angular nature to maximise interlock within the aggregate and between the blocks to provide additional stability to the surface layer.

**Laying Course**

The large size of sub-base material aggregate creates an uneven surface when compacted and has an open textured surface. Therefore a laying course material is required, to provide a flatter platform onto which the blocks are laid. This should prevent any rocking or instability of the blocks inset.

Crucially, the laying course in a Marshalls Priora system should also provide maximum infiltration properties, allowing water to flow freely through the joints.

**Sub-Base**

In addition to providing structural stability, a sub-base must also provide sufficient hydraulic capacity to store water. This is achieved by using an aggregate with a high permeability.

Permeability is measured in terms of the aggregate/void ratio. We recommended the use of an aggregate with a void ratio of between 30% - 32%. In effect, this means that every 3m³ of aggregate can store approximately 1m³ of water.

**Full specification of suitable aggregate is set out in EN 13242: 2002**
Our permeable paving designs consider both the structural and hydraulic requirements for the pavement during its intended design life, using methodologies developed from a combination of lab testing, desktop analysis and market leading experience from 10 years of in-situ installations. In addition, we also provide recommendations for material specification and installation procedures, recommending the most cost effective solution at every stage.

Crucially, our team never loses sight of the requirement to create the most welcoming, visually appealing open spaces imaginable. They will use the wide range of textures, colours and sizes from the Priora portfolio, along with the full suite of Marshalls landscaping product range, to create the perfect landscape for your project.

**Benefits to you**
- Project-specific structural design
- Project-specific hydraulic calculations
- Potential cost savings
- Schedule of components
- Installation advice

**Marshalls Priora Design Service**

Marshalls offer a completely free, no obligation design service for the Priora range of permeable paving, making the entire process completely straightforward. Our fully qualified and experienced team utilises a proven system to provide comprehensive support for your project from concept to installation.

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**What do you need to provide?**

**Project brief:**
The information given in the project brief will allow Marshalls to produce the most accurate and cost effective solution for the project. This should include details of traffic loading/frequency, storm return periods to be attenuated, infiltration rates or allowable outflow rates, CBR data, and any significant ground conditions such as contaminated soil or a site investigation report.

**DWG drawings:**
The design team will use AutoCAD to determine the pavement area and catchment area. Providing an AutoCAD drawing will ensure that the most accurate assessment of areas can be made within any calculations and schedules provided.

**Level information:**
For Marshalls to complete an accurate design of a permeable pavement system we need to assess the levels in the area of the proposed pavement. The proposed levels will dictate the position of any outfalls and the distance between any baffles required. The available storage capacity of a permeable pavement will be affected by the longitudinal gradient. Assessing the gradient will allow Marshalls to specify the most cost effective solution. The required capacity of a permeable pavement is calculated by assessing the catchment area that will drain to the pavement, proposed levels allow us to make an accurate assessment of the drained area as well as the direction of flow within the pavement.

**Any specific deadline dates:**
When a design request is made through Marshalls design team we will require a deadline for our proposals. This allows us to programme our workload to suit your requirements. We will endeavour to hit any realistic deadline.

This valuable service is available to all of our customers completely free of charge. To discuss your specific requirements, or just to find out more, please contact our design team direct on:

**0845 302 0606**

or email:

**design.team@marshalls.co.uk**
Marshalls Services

Samples

Marshalls operate a comprehensive, free of charge samples service. Marshalls always recommend that samples are obtained to ascertain actual colours and textures; because our products are made with natural aggregates, slight variation from photographs should be anticipated.

Where multiple colours are a feature of the product more than one sample will be sent. For larger units such as flags, kerbs and drainage channels, a section or slip may be supplied to meet guidelines regarding manual handling.

To request samples of Marshalls products please call 08704 112233.

Technical Support

Marshalls dedicated Technical Hotline Team is available at the end of the phone for any technical queries. They will be able to supply:

- Product Data Sheets
- COSHH Data Sheets
- SpecificationClauses

... or to answer any questions you may have prior to or during installation of Marshalls Products.

To contact our Technical Support Team, please call 08704 112233 or visit our website to use our new ‘live chat’ online support system.

Web Assistance

Marshalls website offers the best way to keep up to date with the full range of Marshalls products, services and research. It is an invaluable resource from which customers are free to download the following information:

- Product Information
- Technical Information
- Brochures
- NBS Plus Documents
- DWG Files
- Case Studies

The website also houses a vast library of more than 1,200 images - a combination of essential product shots and installed examples which will both inform and inspire.

The website is regularly updated with images, documents and videos, ensuring that it’s easy for Marshalls customers to get the information they need in the format they want.

Visit www.marshalls.co.uk

CPD Seminars

Marshalls provide a full range of CPD seminars (many of which are RIBA accredited) which cover a comprehensive range of landscaping topics. Our expert team share their knowledge and experience to ensure that our customers receive presentations featuring the most up to date thinking and the most respected opinion in the industry. These sessions can be delivered at your convenience in your offices (often over a buffet lunch).

To arrange a CPD, simply call 0845 302 3131 or book online.
Mythbusting . . .

**Are permeable pavements difficult and expensive to maintain?**

**No.** Maintenance of a permeable pavement isn’t a costly or complicated process. Visual inspections, especially after heavy storm events, should be carried out and the joints should be agitated using a brush or vacuum etc. Other than that the joints should be topped up with 6mm washed aggregate as appropriate.

**Does permeable paving improve water quality?**

**Yes.** Permeable paving is excellent at removing pollutants from surface water run-off. Pollutants are filtered and trapped by the aggregate laying course and sub-base which allows some pollutants to degrade over time. Marshalls, with Abertay University, carried out significant testing to measure water quality improvement within a permeable pavement.

**Won’t the joints clog up and stop water getting into the sub-base?**

**No.** Independent tests have demonstrated that even with absolutely no maintenance, after 10 years a permeable pavement will still maintain 20% of its original permeability. A newly installed Priora surface offers a minimum permeability rate of 14,295 litres per second per hectare; the reduced rate offered by an old, unmaintained permeable Priora surface is still more than enough to cope with any rainfall event. However, to maintain optimum performance, an infrequent maintenance regime (along with regular visual inspections) is recommended.

**Can Priora be used on sloping sites?**

**Yes.** The interlocking ability of the Priora block allows installation on sloping sites without the need for intermediate restraints. The slope will affect the amount of available storage within the sub-base and this should be taken into consideration during design. There are options including baffles and terracing which will increase the amount of available storage within the sub-base.

**Is permeable paving only effective on a limited number of ground conditions?**

**No.** Although a clay subgrade may not be suitable for a Type A or B system, using Priora may still provide the most beneficial solution for a site. A correctly designed Type C system will give a controlled outflow utilising the storage within the pavement, and it will still provide the same level of source control and treatment benefits as you would expect from a Type A or B system. (See page 34 for information regarding Type A, B and C systems).

**Does the 5m rule used in soakaway design apply to permeable paving?**

**No.** Permeable pavements use dispersed infiltration across a large area as opposed to standard soakaways. However, consideration should be taken when discharging a concentrated volume of run-off, such as roof water, into a permeable pavement.

**Can the hydraulic design be modelled in Micro Drainage?**

**Yes.** Within the source control section of Micro Drainage’s WinDes*, porous car parks are one of the storage structures available.

**Can services run through a CBPP?**

It is recommended that wherever possible service runs should be isolated from a permeable paving area. This will allow easier maintenance works without the need to disturb the permeable pavement. Containing service runs within conventional concrete block pavement footpaths or pedestrian crossing areas is particularly popular and can help to create a design feature within an area. The permeable paving can be designed to manage the run-off from these adjacent impermeable surfaces.
Mistral Priora
Permeable Paving System

- Permeable Textured Granite Aggregate Setts.
- 3 colour finishes.
- 3 plan sizes with patented interlocking nib design.
- The exposed granite aggregates of Mistral and the environmental benefits of Priora have been combined to create the permeable block paving of choice for modern developments and contemporary public spaces requiring a SUDS solution.
- Random course permeability: 17,693 litres/hec.tare.
- Suitable for use in light traffic applications.
- Typical applications: Civil, Retail, Commercial, Residential and Streetscapes.
- Compliant to BS EN 1338:2003.
- Bond Pattern: Random Course Only.
- To maintain the interlocking properties of the Priora nib design, products have been designed for specific bond patterns.

Colours
Precise colour and surface texture should be judged from actual materials rather than photographic representations.

![Colours](image)

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<th>Plan Size (mm)</th>
<th>Unit Weight (kg/m2)</th>
<th>Pack Size (m2)</th>
<th>Pack Weight (kg)</th>
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<th>Charcoal (Ref No.)</th>
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</table>

Mistral Priora, Silver Grey, Skinners Academy, North London

Mistral Priora with reference numbers indicated in bold black are available ex-stock. Mistral Priora with reference numbers indicated in light black are manufactured to order. Contact our sales office to discuss your requirements.
Tegula Priora

Permeable Paving Design Guide

Permeable Concrete Sets.
- 5 colour finishes.
- 3 plan sizes with patented interlocking nib design.
- Bringing together the aesthetics of Tegula and the environmental benefits of Priora, Tegula Priora provides versatility to complement conservation projects or enhance distinctive show piece schemes requiring a SUDS solution.

Permeability:
- Random Course – 17,693 litres/sec/hectare
- Herringbone – 14,295 litres/sec/hectare.

Suitable for use in any loading application – herringbone bond.

Typical applications: Civil, Retail, Commercial, Residential, Streetscapes and Adopted Highways.


Compliant to BS EN 1338:2003.

Bond Pattern: Random Course, Herringbone.

To maintain the interlocking properties of the Priora nib design, products have been designed for specific bond patterns. Large units are not interchangeable between patterns.

This product can be Machine Laid for safer, faster installation. See page 50 for more details.

Colours

Precise colour and surface texture should be judged from actual materials rather than photographic representations.

<table>
<thead>
<tr>
<th>Bond Pattern</th>
<th>Thickness (mm)</th>
<th>Plan</th>
<th>Unit Weight (kg)</th>
<th>Pack Weight (kg)</th>
<th>Powd</th>
<th>Powd</th>
<th>Powd</th>
<th>Powd</th>
<th>Powd</th>
<th>Powd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Course</td>
<td>60 Large</td>
<td>160 x 240</td>
<td>7.79</td>
<td>3.4</td>
<td>1347</td>
<td>PV6451200</td>
<td>PV6451750</td>
<td>PV6452000</td>
<td>PV6452500</td>
<td>PV6453000</td>
</tr>
<tr>
<td>Medium</td>
<td>160 x 160</td>
<td>6.5</td>
<td>3.0</td>
<td>1236</td>
<td>PV6451200</td>
<td>PV6451750</td>
<td>PV6452000</td>
<td>PV6452500</td>
<td>PV6453000</td>
<td>PV6453750</td>
</tr>
<tr>
<td>Small</td>
<td>160 x 120</td>
<td>5.25</td>
<td>2.6</td>
<td>1132</td>
<td>PV6451200</td>
<td>PV6451750</td>
<td>PV6452000</td>
<td>PV6452500</td>
<td>PV6453000</td>
<td>PV6453750</td>
</tr>
</tbody>
</table>

Herringbone

Olde Priora

Permeable Concrete Block Paving.
- 6 colour finishes.
- 200 x 100mm rectangular block with patented, interlocking nib design.
- Olde Priora is a sympathetically rusticated block, which carries all the inherent benefits of standard Priora. With subtle texturing, Olde Priora lends itself well to conservation areas.

Permeability: 18,750 litres/sec/hectare.

Suitable for use in any loading application – herringbone bond.

Typical applications: Retail and Commercial, Residential, Streetscapes and Adopted Highways.

Complementary Products: Keykerb, Priora, Marker Blocks.

Compliant to BS EN 1338: 2003.

Bond Pattern: Herringbone, Stretcher Course, Basketweave.

Colours

Precise colour and surface texture should be judged from actual materials rather than photographic representations.

<table>
<thead>
<tr>
<th>Bond Pattern</th>
<th>Thickness (mm)</th>
<th>Plan</th>
<th>Unit Weight (kg)</th>
<th>Pack Weight (kg)</th>
<th>Powd</th>
<th>Powd</th>
<th>Powd</th>
<th>Powd</th>
<th>Powd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random Course</td>
<td>60 Large</td>
<td>200 x 100</td>
<td>7.79</td>
<td>3.4</td>
<td>1347</td>
<td>PV6621200</td>
<td>PV6621750</td>
<td>PV6622000</td>
<td>PV6622500</td>
</tr>
<tr>
<td>Medium</td>
<td>160 x 160</td>
<td>6.5</td>
<td>3.0</td>
<td>1236</td>
<td>PV6621200</td>
<td>PV6621750</td>
<td>PV6622000</td>
<td>PV6622500</td>
<td>PV6623000</td>
</tr>
<tr>
<td>Small</td>
<td>160 x 120</td>
<td>5.25</td>
<td>2.6</td>
<td>1132</td>
<td>PV6621200</td>
<td>PV6621750</td>
<td>PV6622000</td>
<td>PV6622500</td>
<td>PV6623000</td>
</tr>
</tbody>
</table>

Olde Priora available in stock.

*Natural products are manufactured from aggregates sourced locally to the works and contain no pigmentation, therefore colour variation between products from different works is possible.

Tegula Priors with reference numbers indicated in bold black are available ex-stock. Tegula Priors with reference numbers indicated in light black are manufactured to order. Contact our sales office to discuss your requirements.

www.marshalls.co.uk/watermanagement
Priora
Permeable Paving System

- Permeable Concrete Block Paving.
- 9 colour finishes.
- Now available in 60mm and 80mm block thicknesses.
- 200 x 100mm rectangular block with patented, interlocking nib design.
- Priora, Marshalls original permeable block paving, adds hydraulic capability to the outstanding performance characteristics of Keyblok. The Priora nib profile creates voids at the joint to allow surface water to pass through the pavement at source.
- Permeability: 18,750 litres/hectare.
- Suitable for use in any loading application – herringbone bond.
- Typical applications: Ports, Service Yards, Residential, Streetscapes and Adopted Highways.
- Complementary Products: Keyblok and Keykerb.
- Compliant to BS EN 1338: 2003.
- Bond Pattern: Herringbone, Stretcher Course, Basketweave.
- This product can be Machine Laid for safer, faster installation. See page 50 for more details.

Colours
Precise colour and surface texture should be judged from actual materials rather than photographic representations.

Brindle Burnt Ochre Bracken Charcoal Natural Red Marigold Buff

White Colourtop

<table>
<thead>
<tr>
<th>Thickness (mm)</th>
<th>Plan</th>
<th>Size</th>
<th>Unit Weight (kg)</th>
<th>Park Size per sqm</th>
<th>Brindle (Ref No)</th>
<th>Bracken (Ref No)</th>
<th>Charcoal (Ref No)</th>
<th>Natural (Ref No)</th>
<th>Red (Ref No)</th>
<th>Marigold (Ref No)</th>
<th>Buff (Ref No)</th>
<th>White Colourtop (Ref No)</th>
<th>Black Colourtop (Ref No)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand Lay 60</td>
<td>200</td>
<td>100</td>
<td>3.4</td>
<td>8.08</td>
<td>PV6501750</td>
<td>PV6502000</td>
<td>PV6502250</td>
<td>PV6500500</td>
<td>PV6500250</td>
<td>PV6501500</td>
<td>PV6500750</td>
<td>PV6501200</td>
<td>PV6501400</td>
</tr>
<tr>
<td>Machine Lay 45 degree</td>
<td>200</td>
<td>100</td>
<td>3.4</td>
<td>7.68</td>
<td>PV6531760</td>
<td>PV6532010</td>
<td>PV6532260</td>
<td>PV6530510</td>
<td>PV6530260</td>
<td>PV6531510</td>
<td>PV6531010</td>
<td>PV6530760</td>
<td>PV6531400</td>
</tr>
</tbody>
</table>

Prices with reference numbers indicated in bold black are available ex-stock.
Prices with reference numbers indicated in light italic are manufactured to order. Contact our sales office to discuss your requirements.
*Natural products are manufactured from aggregates sourced locally to the works and contain no pigmentation, therefore colour variation between products from different works is possible.
M380 Tanking Membrane
For Type C Priora Permeable Pavements

- Impermeable polymer-blend membrane
- Essential for tanking the sub-base of every Type C permeable system
- Manufactured in ‘Marshalls Red’ for easy identification on site
- Double folded to minimise pack size
- 380 microns - THINNER than alternative membranes, providing a lighter, easy to roll out product
- STRONGER than alternative membranes, providing better puncture resistance and less chance of tanking failure
- 80m² roll size – LARGER AREA than alternative membranes means less jointing is required
- Range of ancillary items available:
  - Marshalls Tanking Tape – for the waterproof jointing of Marshalls M380 Membranes
  - 110mm and 160mm flexible top hat units – to create neat, secure pipe outfalls
  - Marshalls M380 Tanking Membrane can be welded for complete impermeability on projects where leakage is not acceptable. Contact Marshalls Technical Services on 08704 113344 for more details.

Marshalls Priora Aggregates

Marshalls have partnered with carefully selected quarries from all over the UK to source the correct specification of aggregates for Priora permeable systems.

- See full aggregate specification on page 43 of the Marshalls permeable paving design guide
- Both 20mm sub-base aggregate and 6mm laying course/jointing aggregate available nationally
- Graded to provide a void ratio of at least 32% and up to 40%
- Complies with BS 7533-1:2009
- Infiltration Rate of 70,000 litres/second/hectare
- Internal angle of friction has been tested to ensure constructability and structural stability, going further than the British Standard to ensure optimal performance
- Reduce the carbon footprint of your job by using a local quarry
  * colour, texture and shape of aggregate will vary dependent on quarry location

To order, please contact our Technical Advisory Service on 08704 112233, who will put you in touch with your nearest recommended supplier.

NB: You will need your Priora Fastquote number to achieve preferential Marshalls Priora Aggregate rates.

Technical Specification

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value or Statement</th>
<th>Units</th>
<th>Compliance Criteria</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>20</td>
<td>m</td>
<td>±0% / ±10%</td>
<td>EN 1848-2</td>
</tr>
<tr>
<td>Width</td>
<td>4</td>
<td>m</td>
<td>±0% / ±10%</td>
<td>EN 1848-2</td>
</tr>
<tr>
<td>Thickness</td>
<td>0.38</td>
<td>mm</td>
<td>±0% / ±10%</td>
<td>EN 1849-2</td>
</tr>
<tr>
<td>Mass</td>
<td>395</td>
<td>g/m²</td>
<td>±0% / ±10%</td>
<td>EN 1849-2</td>
</tr>
<tr>
<td>Resistance to impact</td>
<td>30</td>
<td>N/mm²</td>
<td>±0% / ±50%</td>
<td>EN 12691</td>
</tr>
<tr>
<td>Resistance to tearing</td>
<td>1695</td>
<td>N</td>
<td>±50% / ±50%</td>
<td>EN 12310-1</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>24.2</td>
<td>N/mm²</td>
<td>±50% / ±50%</td>
<td>EN 12311-1</td>
</tr>
</tbody>
</table>

All Marshalls Membrane Products and Ancillaries are available ex-stock

Dimensions

<table>
<thead>
<tr>
<th>Dimensions</th>
<th>Product Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>M380 Tanking Membrane (roll) 20m x 4m (80m²)</td>
<td>DYPV9701000</td>
</tr>
<tr>
<td>Top Hat including Clip 110mm</td>
<td>DYPV9701100</td>
</tr>
<tr>
<td>Top Hat including Clip 160mm</td>
<td>DYPV9701200</td>
</tr>
</tbody>
</table>

All Marshalls Membrane Products and Ancillaries are available ex-stock

6mm Marshalls Priora laying course aggregate

20mm Marshalls Priora sub-base aggregate

6mm Marshalls Priora laying course / jointing aggregate
Types of Permeable Paved Systems

A Priora permeable system can be installed onto the vast majority of ground types in the UK. However, there are three different types of permeable system, which differ largely in the way that the attenuated water is released.

Type A
In this type of system the rain water percolates through the joints between the blocks, then through the bedding layer and into the sub-base material where it is temporarily stored within the voids between the individual stones. The water then slowly infiltrates into the underlying ground and will eventually find its way through the bedrock into the river systems. This means that 100% of the surface water run-off is dealt with on site.

Type A systems can only be used where the underlying ground conditions have sufficient permeability (infiltration rate) and where adding water to the subgrade will not adversely affect the bearing capacity of the ground.

Type B
This type of system is more suited to ground conditions where some permeability exists, but the infiltration rate is so slow that the calculated depth of the sub-base becomes very deep and therefore prohibitively expensive. In a Type B system the water enters the pavement as in Type A, and some of the water will infiltrate into the underlying ground, but some will exit the system by means of a restricted outfall pipe into a storm water sewer or further attenuation system.

Type C
This type of system is suited to ground conditions where the infiltration rate is very low. It is likely in these cases that the subgrade material would be weakened by the addition of rainwater and should be protected by Marshalls 380 Tanking Membrane. In a Type C system the water enters the pavement as in Type A and B systems but will exit by means of a restricted outfall pipe (or flow control device) into a storm water sewer or further attenuation system.

Which type of system is right for me?

The type of system which is suitable for your site will be dependent on a number of factors, such as ground conditions and Environment Agency or local authority planning restrictions.

Type A systems are the ideal SUDs solution because they offer the designer Zero Discharge. This type of system is suited to silt or sand based soils with reasonably high infiltration rates.

However, in some cases the ground conditions will dictate that no infiltration will be possible and therefore a Type C system will be the only option for the designer. The ground may be:

i. Mainly clay which would form an impervious barrier.
ii. Sealed, contaminated ground.
iii. Above a known protected aquifer.

As a guide to selection of the correct type of system the table, below, is an extract from Interpave’s Guide to the Design, Construction and Maintenance of Concrete Block Permeable Pavements.

<table>
<thead>
<tr>
<th>Permeability of subgrade (m/s)</th>
<th>System A Total Infiltration</th>
<th>System B Partial Infiltration</th>
<th>System C No Infiltration</th>
</tr>
</thead>
<tbody>
<tr>
<td>better than $10^{-6}$</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>between $10^{-6}$ &amp; $10^{-8}$</td>
<td>❌</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>worse than $10^{-8}$</td>
<td>❌</td>
<td>❌</td>
<td>✔</td>
</tr>
<tr>
<td>High ground water table</td>
<td>❌</td>
<td>❌</td>
<td>✔</td>
</tr>
<tr>
<td>(within 1000mm of finished formation)</td>
<td>❌</td>
<td>❌</td>
<td>✔</td>
</tr>
<tr>
<td>Pollutants present in subgrade</td>
<td>❌</td>
<td>❌</td>
<td>✔</td>
</tr>
</tbody>
</table>

What type of soil do I have?

The two soil related variables within a permeable paving design are the permeability and the bearing capacity. In some cases this information can be obtained from the soil investigation which is carried out on a site prior to development.

In the case of permeability the report would usually state an infiltration rate in metres per second. For example, silty clay soils would normally provide an infiltration rate of approximately $10^{-9}$ or $10^{-8}$ m/s.

The measurement of the grounds bearing capacity (ie the ground’s ability to withstand loads without displacement) can also be found within the soil report. It would usually be stated as either a CBR (California Bearing Ratio) or as an undrained shear strength, Cu.
Structural Design for Priora Pavements

Permeable Paving Structural Design Philosophy

Priora pavements contravene many of the traditionally accepted principles of pavement design. In particular, one of the objectives of a conventional pavement is to create an impermeable surface so that moisture ingress cannot weaken components of the pavement or the underlying subgrade. Many highway pavement specifications are predicated upon the requirement to keep the specified materials dry.

The deliberate cascading of water through highway construction materials requires a radical approach to the selection of material thickness and properties. This impacts two areas of design. Firstly, an alternative approach is required for the assessment of loading. Secondly, material properties need to be selected taking into account the flow of water vertically downwards and the retention of water within the material. This means that the traditional structurally beneficial effects of fine materials will have to be foregone and an alternative methodology will be required to ensure stability, strength and durability.

Traditionally, highway pavement loading has been assessed in terms of the number of 8000kg Equivalent Standard Axles (ESAs) that a pavement will be required to withstand throughout its life. The loads applied to a pavement usually differ significantly from 8000kg, but research has shown that axles of other load values can be equivalenced to standard ones. The Fourth Power Law is often used to equivalence a given axle load to a standard axle. In the case of permeable pavements, an alternative approach is required: one that assesses loading in terms of the maximum load that a pavement can be expected to withstand.

The reason for this alternative approach is that Priora pavements are designed on the basis of ultimate limit state analysis up to the standard axle load, and thereafter by serviceability limit state analysis.

The research work carried out by Marshalls at NUROLF (Newcastle University’s Rolling Load Facility) was used as the basis for this design approach. A paper detailing this work is available from Marshalls Technical Department.

How to Design a Priora Sub-Base

1. Calculate sub-base composition based on loading requirements
   - Establish traffic loading from Table II, page 38
2. Calculate sub-base composition based on hydraulic requirements
   - Determine site location and storm return period
   - Determine Priora sub-base depths and specification from Table III, page 38
   - Establish what Type of Priora pavement (Type A, B or C) from soil infiltration data Table I, page 35
   - Determine subgrade strength and requirement for subgrade improvement via a capping layer from Table V, page 40
   - Determine hydraulic design parameters for site location and storm return period allowing for the effects of climate change
   - Consider site traffic
3. Having calculated two different designs for both structural and hydraulic requirements, your final Priora Design will be the higher of the two results.
The structural depth and specification of the sub-base is then determined from the table below:

<table>
<thead>
<tr>
<th>Load Category</th>
<th>Traffic Type</th>
<th>Anticipated Axle Load (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Domestic (GVW=2,000kg)</td>
<td>1000</td>
</tr>
<tr>
<td>2</td>
<td>Cars &amp; Light Vans (GVW=3,500kg)</td>
<td>2000</td>
</tr>
<tr>
<td>3</td>
<td>Light Commercial (GVW 7,500 kg)</td>
<td>2000</td>
</tr>
<tr>
<td>4</td>
<td>Emergency large goods vehicles only (100 Standard axles)</td>
<td>8000</td>
</tr>
<tr>
<td>5</td>
<td>One large goods vehicle per week (0.015msa)</td>
<td>8000</td>
</tr>
<tr>
<td>6</td>
<td>Ten large goods vehicle per week (0.15msa)</td>
<td>8000</td>
</tr>
<tr>
<td>7</td>
<td>100 large goods vehicles per week (1.5msa)</td>
<td>8000</td>
</tr>
<tr>
<td>8</td>
<td>1,000 large goods vehicles per week (15msa)</td>
<td>8000</td>
</tr>
<tr>
<td>9</td>
<td>Heavy Duty Pavements for Ports or similar</td>
<td>DOA</td>
</tr>
</tbody>
</table>

Stage Three - Determination of Subgrade Strength and the Requirement for a Capping Layer

The specification of a permeable pavement depends upon the properties of the subgrade, the ground directly beneath the pavement. Strength and permeability of the subgrade are interrelated - a wet subgrade is usually a weak subgrade.

The following tests are recommended on the soil samples, especially if the soil has clay content. These assist in evaluating the soil’s suitability for supporting traffic in a saturated condition while exfiltrating.

<table>
<thead>
<tr>
<th>USCS - Soil Classification</th>
<th>Shearing strength when compacted</th>
<th>Compressibility</th>
<th>Typical CBR range</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW-well graded gravels</td>
<td>Excellent</td>
<td>Negligible</td>
<td>30 to 80</td>
</tr>
<tr>
<td>GP-poorly graded gravels</td>
<td>Good</td>
<td>Negligible</td>
<td>20 to 60</td>
</tr>
<tr>
<td>GM-silty gravels</td>
<td>Good</td>
<td>Negligible</td>
<td>20 to 60</td>
</tr>
<tr>
<td>GC-clayey gravels</td>
<td>Good to fair</td>
<td>Very low</td>
<td>20 to 40</td>
</tr>
<tr>
<td>SW-well graded sands</td>
<td>Excellent</td>
<td>Negligible</td>
<td>10 to 40</td>
</tr>
<tr>
<td>SP-poorly graded sands</td>
<td>Good</td>
<td>Very low</td>
<td>10 to 40</td>
</tr>
<tr>
<td>SM-silty sands</td>
<td>Good</td>
<td>Low</td>
<td>10 to 40</td>
</tr>
<tr>
<td>SC-clayey sands</td>
<td>Good to fair</td>
<td>Low</td>
<td>5 to 20</td>
</tr>
<tr>
<td>ML-inorganic silts of low plasticity</td>
<td>Fair</td>
<td>Medium</td>
<td>2 to 15</td>
</tr>
<tr>
<td>CL-inorganic clays of low plasticity</td>
<td>Fair</td>
<td>Medium</td>
<td>2 to 5</td>
</tr>
<tr>
<td>OL-inorganic silts of low plasticity</td>
<td>Poor</td>
<td>Medium</td>
<td>2 to 5</td>
</tr>
<tr>
<td>MH-inorganic silts of high plasticity</td>
<td>Fair to poor</td>
<td>High</td>
<td>2 to 10</td>
</tr>
<tr>
<td>CH-inorganic clays of high plasticity</td>
<td>Poor</td>
<td>High</td>
<td>2 to 5</td>
</tr>
</tbody>
</table>

If the subgrade CBR is 5% or greater, the sub-base can be installed without any capping layer. In poorer ground conditions, a capping layer should be used as shown in the table on the following page. A distinction is made between Types A, B or C systems when considering the capping layer depth, as the material used for the capping layer will be different.
The choice of capping layer material will vary with the type of Priora pavement. For Type C systems, the capping layer is often but not always placed below the impermeable membrane. Guidance on the choice of material is given later in this guide.

### Table of Capping Layer Thickness

<table>
<thead>
<tr>
<th>Subgrade CBR Value</th>
<th>Capping Layer Thickness Type A &amp; B Systems (mm)</th>
<th>Capping Layer Thickness Type C Systems (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>4%</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>3%</td>
<td>125</td>
<td>225</td>
</tr>
<tr>
<td>2%</td>
<td>175</td>
<td>350</td>
</tr>
<tr>
<td>1%</td>
<td>300</td>
<td>600</td>
</tr>
</tbody>
</table>

The choice of capping layer material will vary with the type of Priora pavement. For Type C systems, the capping layer is often but not always placed below the impermeable membrane. Guidance on the choice of material is given later in this guide.

### Structural Design for Priora Pavements

#### Stage Four - Consideration of the Impact of Site Construction Traffic

Where a Priora pavement is required to carry site or construction traffic prior to completion, consideration must be given to avoiding contamination of the sub-base. Measures should be taken to avoid this such as:

- Consider the construction process during design and identify areas and routes for construction traffic that avoid the Priora sub-base areas.
- Where this is not possible, construct the Priora sub-base and then cover it with a sacrificial layer of geotextile and hardcore (100mm thick). This can be removed prior to the installation of the laying course and blocks.
- For a Type C system, construct a normal capping layer and use this as the temporary road surface. Construct the permeable pavement over it towards the end of construction.
- Construct the permeable sub-base and then cover it with an impermeable layer of a minimum of 80mm Dense Bitumen Macadam (DBM). Use this as the temporary road surface. Guidance on the specification of this material is given on page 45.

---

### Hydraulic Design for Priora Pavements

Hydraulic requirements are frequently calculated using modelling software such as Micro Drainage’s WinDes® (www.microdrainage.co.uk). These packages will take into account a wide range of rainfall frequencies and intensities as well as the topography of the site. The following provides the methodology behind arriving at a hydraulic calculation.

The volume of water entering a Priora pavement is often greater than the water percolating into the subgrade or being slowly discharged to a secondary system. As such a degree of surface water storage will be required. The volume of water storage within a Priora pavement sub-base is calculated on the basis of:

**Water In − Water Out = Storage Volume Required**

The volume of water storage can be calculated using the Wallingford procedure and software packages are available to quickly and efficiently calculate for a variety of storm durations. The following tables can be used as a guide only to the sizing of the sub-base; they are conservative indications and more accurate (shallower) solutions can be calculated. The following is assumed in these tables:

1. The Priora sub-base has a void ratio of 32%
2. Discharge rate for types B and C systems are limited to 5 l/s/ha
3. The Priora pavement has no impermeable area draining into it
4. The site is level with no falls within the pavement

<table>
<thead>
<tr>
<th>Sub-base Depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MS-60</strong></td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>20</td>
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<tr>
<td>19</td>
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<tr>
<td>14</td>
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<tr>
<td>14</td>
</tr>
<tr>
<td>14</td>
</tr>
</tbody>
</table>

MS-60 is the anticipated rainfall for a storm of 60-minute duration that is likely to occur once in 5 years. “r” is the ratio of a 60-minute to a 2 day rainfall depth for a 1 in 5 year storm return period.
Worked Design Example

In this example, we will assume that the project is an estate access road which will be subject to occasional, infrequent heavy loading from vehicles such as dust carts or delivery wagons. The subgrade has a CBR value of 3%.

1. Calculate sub-base composition based on loading requirements

Traffic loading is assumed as one HGV (dust cart) per week which is loading category 5. See Table II, page 38

2. Calculate sub-base composition based on hydraulic requirements

Storm return period — 1 in 100 years (plus 30% for climate change). Site location — Greater Manchester

Subgrade permeability – 1.0 x 10⁻⁹ m/s

A Type C system will be chosen as the soil permeability is low; an impermeable membrane will be located below the pavement

The DBM and OGCR thicknesses are:
- 70mm DBM
- 150mm Open Graded Crushed Rock

And the proposed construction is:
- 80mm Priora
- 50mm Bedding Layer
- 70mm DBM
- 150mm Open Graded Crushed Rock

A capping layer depth of 225mm is taken from Table V, page 40

Due to ground conditions, the site trafficking on top of the DBM layer will be an acceptable option and will avoid contamination of the sub-base and capping layers

Refer to Table VI, page 41

Select 180mm

The depth of the Priora system will be 180mm, as this is the higher of the two models.

As we have a Type C system, the capping layer would generally be located below the impermeable membrane and a "type 1" material used. However, the hydraulic requirement called for a greater depth than the 150mm open graded crushed rock sub-base, the same open graded crushed rock material would be used as the capping layer and it would be located above the impermeable membrane.

Assuming that the 150mm sub-base is not sufficient from hydraulic considerations and the storage depth needs to be increased, say to 170mm, the construction now becomes:

<table>
<thead>
<tr>
<th>Sub-base Material</th>
<th>Specified Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subgrade</td>
<td>330mm Type 1 Capping Layer (350mm – 20mm)</td>
</tr>
<tr>
<td>50mm Bedding Layer</td>
<td>80mm Priora</td>
</tr>
<tr>
<td>70mm DBM</td>
<td>170mm Open Graded Crushed Rock (150mm + 20mm)</td>
</tr>
<tr>
<td>Impermeable Membrane</td>
<td>300mm</td>
</tr>
</tbody>
</table>

Materials

Subgrade Improvement/Capping layer

A subgrade improvement (capping layer) will be required to improve the bearing capacity of weak ground. Consideration towards the use of sub-base reinforcement such as geogrids or confinement systems to reduce capping depths should be given; they may also prevent migration of the capping layer in to the formation. Alternatively subgrade improvement techniques, such as lime or cement stabilisation, can be used.

Capping Layer Material

Where the CBR for the subgrade is less than 5% then a capping layer will be required. The material should be of a suitable quality to create a firm working surface so that the overlying materials can be installed correctly. The capping materials should, as a minimum, meet the requirements of 6F5 of Table 6/5 of Highways Agency Specification for Highways Works – Series 600 – Earthworks. On site recycled material can be used provided that it meets the specification for 6F5. Our guideline capping layer depths have been calculated by using the same material as the sub-base.

Priora Aggregate Specification

Sub-base Material

Open graded materials are required to allow storage of the surface water within the pavement construction.

The Open Graded Crushed Rock (OGCR) or Open Graded Crushed Gravel (OGCG) sub-base should have a porosity of at least 0.32 to allow void space for water storage. The structural strength of the materials should be adequate for the loads to which it will be subjected. The OGCR or OGCG sub-base should be in accordance with BS 7533-13:2009, Pavements constructed with clay, natural stone or concrete pavers – Guide for the design of permeable pavements constructed with concrete paving blocks and flags, natural stone slabs and setts and clay pavers.

In the case of natural aggregate, the OGCR or OGCG sub-base shall comprise coarse graded crushed rock or gravel meeting the following requirements:

- The flakiness index, shell content and mechanical properties should be as set out in BS EN13242: 2002 for coarse graded crushed rock or gravel.

OGCR and OGCG Sub-base Gradings

<table>
<thead>
<tr>
<th>Table VII</th>
<th>Grading Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recommended BS EN 12620 aggregate grading (mm)</td>
<td>4/20</td>
</tr>
<tr>
<td>Recommended BS EN 12620 grading / tolerance category</td>
<td>GC80/20, 0TC80/15</td>
</tr>
</tbody>
</table>

Table VIII

<table>
<thead>
<tr>
<th>Grading Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sieve size (mm)</td>
</tr>
<tr>
<td>31.5</td>
</tr>
<tr>
<td>20</td>
</tr>
<tr>
<td>14</td>
</tr>
<tr>
<td>10</td>
</tr>
<tr>
<td>6.3</td>
</tr>
<tr>
<td>4</td>
</tr>
<tr>
<td>3.15</td>
</tr>
<tr>
<td>2</td>
</tr>
</tbody>
</table>
OGCR and OGCG Physical Properties

Table IX

<table>
<thead>
<tr>
<th>Properties</th>
<th>Category to BS EN 13242 or BS 12620</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grading</td>
<td>4/20 (preferred) or 4/40, Gc 85-15, Gc 20-87-7.5</td>
</tr>
<tr>
<td>Fines Content</td>
<td>f4</td>
</tr>
<tr>
<td>Shape</td>
<td>f10</td>
</tr>
<tr>
<td>Resistance to Fragmentation</td>
<td>LA4</td>
</tr>
<tr>
<td>Internal Angle of Friction</td>
<td>40°</td>
</tr>
<tr>
<td>Grading</td>
<td>85-15</td>
</tr>
<tr>
<td>GTc</td>
<td>20/17.5</td>
</tr>
<tr>
<td>Fines Content</td>
<td>f10</td>
</tr>
<tr>
<td>Shape</td>
<td>f10</td>
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<tr>
<td>Resistance to Fragmentation</td>
<td>LA4</td>
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<td>Internal Angle of Friction</td>
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<tr>
<td>Grading</td>
<td>85-15</td>
</tr>
<tr>
<td>GTc</td>
<td>20/17.5</td>
</tr>
</tbody>
</table>

Table IX: Properties Category to BS EN 13242 or BS 12620

Cement Stabilised Open Graded Crushed Rock

Open-graded road base material may be stabilised with cement prior to placing. The use of cement will reduce the storage capacity of the road base, but stabilisation may be necessary to increase its structural capacity. This will allow the Priora pavement to receive more heavily trafficked pavements and use within heavy-duty applications.

The bound material should comply with the requirements given in BS EN 14227-1:2004 – Hydraulically bound mixtures – Specifications – Part 1: Cement bound granular mixtures.

To maintain high void space, only enough cement to coat the aggregate is required and care should be taken not to fill the voids with excess paste. The minimum amount of Portland cement required is 3% by mass. The water-cement ratio should be controlled to make a paste to coat the aggregate.

Aggregate shall be naturally occurring crushed rock material with an absorption value no greater than 2%. The materials shall retain all of their strength when saturated and the grading shall fall within the following range:

Table X

<table>
<thead>
<tr>
<th>Sieve size (mm)</th>
<th>Percentage Passing %</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>31.5</td>
<td>98-100</td>
</tr>
<tr>
<td>20</td>
<td>90-99</td>
</tr>
<tr>
<td>10</td>
<td>25-70</td>
</tr>
<tr>
<td>4</td>
<td>0-15</td>
</tr>
<tr>
<td>2</td>
<td>0-5</td>
</tr>
</tbody>
</table>

Table X: Sieve size (mm) Percentage Passing %

Material strength should meet Strength Class C5/6 (As defined in Table 2 of BS EN 14227-1:2004.)

The material permeability should be in the region of 20,000mm/hr and the Elastic Modulus should be in the region of 10,000N mm2.

DBM

The DBM (Dense Base Macadam) can be installed within the design where additional structural support or temporary running surface is required for site traffic over the recently laid 20mm Priora sub-base aggregate.

The material should be a 0/32mm size dense base as given in BS4987-1:2005, Coated macadam (asphalt concrete) for roads and other paved areas – Part 1: Specification for constituent materials and for mixtures, clause 5.2. Typically the binder will be a 50 pen according to clause 4.7 of BS4987-1:2005 but can vary dependent on loading conditions.

Priora Laying Course Aggregate Specification

The large size of sub-base material aggregate creates an uneven surface when compacted and has an open textured surface. The laying course material provides a flatter platform onto which the blocks are laid, to prevent any rocking or instability of the blocks in-situ.

Priora Laying Course Aggregate Specification

The Priora Laying Course should be graded as below:

Table XI

<table>
<thead>
<tr>
<th>Laying Course Grading</th>
<th>Recommended BS EN 132620 aggregate grading (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2/40</td>
</tr>
<tr>
<td></td>
<td>2/60</td>
</tr>
<tr>
<td></td>
<td>Gc80/20</td>
</tr>
</tbody>
</table>

Table XI: Laying Course Grading

Material strength should meet Strength Class C5/6 (As defined in Table 2 of BS EN 14227-1:2004.) The material permeability should be in the region of 20,000mm/hr and the Elastic Modulus should be in the region of 10,000N mm2.
Priora Permeable Pavement Installation

Guidelines for the flexible installation of Marshalls Priora
Concrete Block Paving

Scope
These guidelines cover the construction of modular permeable pavements using Marshalls Priora, Tegula Priora, Mistral Priora and Olde Priora concrete block paving and are in accordance with Interpave’s (The Precast Concrete Paving and Kerb Association) document Permeable Pavements; Guide to the Design, Construction and Maintenance of Concrete Block Permeable Pavements (Edition Five, Dec. 2007).

Products Included
Marshalls Priora, Tegula Priora, Mistral Priora and Olde Priora concrete block paving of 60mm and 80mm nominal thickness, are manufactured in accordance with BS EN 1338: 2003 Concrete paving blocks – Requirements and test methods.

Health and Safety Information
All relevant health and safety information, including COSHH data sheets can be obtained from Marshalls Advisory Services. For more information please email: advisory.services@marshalls.co.uk
Or telephone: 0845 30 20 606

Installation
1. Excavation
Once the area for the CBPP has been cleared it will require excavation down to the invert of the pavement design.

2. Lay Capping Layer (if required)
If the site has a CBR of 5% or less then you will require a capping layer. There are two options for this:

Non-Infiltration: If you are constructing a non-infiltration system then you can use an impermeable capping layer like MOT Type 1. This will reduce construction depth marginally but mainly decrease cost. You can use permeable sub-base as a capping layer and this will increase the storage capacity of the system. If using a permeable sub-base the impermeable membrane should be placed at the invert of the capping layer.

Infiltration: If you are constructing an infiltration system the capping layer should be the same as the 20mm OGCR permeable sub-base as detailed in the materials section.

All materials should be compacted in layers not exceeding 150mm in thickness or twice the nominal maximum aggregate size. All conventional rollers can be used for compaction but these should not be vibrating. This avoids over compaction as it is important to retain a void ratio of 32%. As all sites and materials differ it is recommended that a trial be conducted. Installers should aim to achieve a tolerance of ±20mm to -30mm from specified levels when installing the capping layer.

For example, create a 1m² 150mm deep excavation lined with an impermeable membrane, fill with sub-base aggregate and compact. The filled cavity should now take 48 litres of water.

3. Construct any edge restraints and baffles
Edge restraints should be sufficiently robust to resist the lateral displacement from imposed loadings placed upon the pavement. The edge restraint may take the form of associated fittings, walls or buildings or be formed from precast concrete, clay or natural stone kerb systems, either existing or newly constructed features. The restraint must provide a consistent vertical face to a level below the laying course material.

Where an impermeable membrane is being used the surface of any concrete haunching must be smoothed off to prevent any puncturing of the membrane. Modular edge restraints systems should be laid onto a suitable base of sufficient strength to withstand vehicular over-run. Units may be mortared to the suitable base and incorporate either a mortar joint, or narrow gap of trowel width.

The surface course of the pavement should not be vibrated until such time as the edge restraint has gained sufficient strength to resist the lateral imposed loads.

Where mortar bedding and jointing is adopted, consideration should be given to the provision of movement joints at regular intervals.

Where an intermittent restraint may be required, the edge restraint’s base material may be laid directly onto the open-graded sub-base material. Should any concern exist about the restraint bedding material compromising the voidage of the open-graded sub-base material, a suitable lining material can be used, separating the two materials.

There are several examples of edge restraint construction within the standard construction details which can be found at the end of this section.

Baffles are constructed when there is a significant surface fall across the CBPP. These should be constructed in concrete and in non-infiltration systems, a pipe should be placed at the invert of the sub-base through the concrete to allow the water to flow towards the outfall. A standard construction detail can be found at the end of this section (TS-0525).

Due to certain ground conditions, infiltration may not always be an option therefore an impermeable membrane is required. The water within the sub-base should be removed via a fin drain or a network of perforated pipes laid to falls.

The water should then flow through a suitable outflow pipe. The size of the pipe will be dependent on the site topography and the volume to be drained. Directly beneath the impermeable membrane, dependent on the site conditions, a sand bedding layer may be included to achieve greater flatness and reduce any potential puncturing of the membrane. Any sharp or protruding features at formation level that may promote the puncturing of the membrane should be removed and the remaining area made good.

4. Construct Outfall (if required)
There are a number outfalls that can be installed into a permeable pavement; these should be positioned at the low point of the sub-base construction. Some examples of outfall constructions can be found in the standard details section.

5. Install Sub-base Material
The sub-base will consist of 20mm OGCR as detailed in the materials section and will be laid in the same manner as the capping layer section. Installers should aim to achieve a tolerance of +/- 20mm from specified levels when installing the sub-base layer.

6. Install DBM Layer (if required)
The DBM (Dense Base Macadam) can be installed within the design where additional structural support or temporary running surface is required for site traffic over the recently laid 20mm Priora sub-base aggregate.

The material should be a 0/32mm size dense base as given in BS4987- 1:2005 Coated macadam (asphalt concrete) for roads and other paved areas – Part 1: Specification for constituent materials and for mixtures, clause 5.2. The binder penetration will be specified in our design documents.

Installation considerations
It is important to ensure the site tipped DBM is correctly protected and sheeted from adverse weather, to guarantee correct material laying temperature is maintained.

On larger areas, generally machine laid by tracked mini (7 tonne) or midi (14 tonne) paving machine, subject to laying width or output requirement, material normally supplied to paving machine hopper by 9 tonne front tip dumpers.

Disturbance to the 20mm aggregate can be kept to a minimum by ensuring both paving machine and dumper keep to one laying track. Dumpers must avoid crossing this laying path or excessive wheel turning, which can cause aggregate rutting.

Any disturbance to the 20mm stone can easily be raked and re-levelled by labour or rake hands as the surfacing progresses.

Installers should aim to achieve a tolerance of +/- 20mm from specified levels when installing the DBM layer.
Surface Preparation

After the DBM has served its use as a temporary site access or storage area and site access has finished, the DBM surface must be thoroughly cleaned of all contamination by sweeper or pressure cleaning.

Once this has been completed and the existing surface is clean, connection between the 6mm bedding aggregate and the Priora 20mm sub-base is achieved by either core cutting or drilling 75mm diameter holes at 750mm centres through the compacted DBM layer; these are then carefully filled with the Priora 6mm bedding stone.

In the event of any delay between the holes being cut through the DBM and being filled with 6mm aggregate a temporary stopper or bung should be inserted to prevent any possibility of debris entering or clogging the new connections.

7. Screed Laying Course

The large size of sub-base material aggregate creates an uneven surface when compacted and has an open textured surface. The laying course material provides a flatter platform onto which the blocks are laid, to prevent any rocking or instability of the adjacent prepared laying course material.

The laying course material provides a flatter platform onto which the blocks are laid, to prevent any rocking or instability of the affected area and the surrounding laying course. When screeding rails are removed on completion of the installation of the laying course, the affected area should be filled and rescreeded with corresponding laying course material and manually compacted. Care should be taken as not to disturb adjacent prepared laying course material.

Final compacted target thickness for the laying course should be 50mm.

Tolerances for laying course material are +/- 20mm. However, due to the nature of the open-graded material, it will not compact and reduce in thickness in the same manner as a sharp sand laying course. Therefore, it is important to ensure the initial placing and screeding of the open-graded laying course is as accurate as possible.

It may prove advantageous to trial a small area of open-graded material to ascertain the characteristics of the material under compaction to ensure accurate levels are achieved.

Should any disturbance of the screeded laying course material occur prior to the placement of the blocks, the affected area should be rescreeded to ensure consistency between the affected area and the surrounding laying course. When screeding rails are removed on completion of the installation of the laying course, the affected area should be filled and rescreeded with corresponding laying course material and manually compacted. Care should be taken as not to disturb adjacent prepared laying course material.

8. Install Priora Blocks

Laying

Paving units should be laid on the laying course material so that the final level is within the permitted surface tolerance.

String lines should be utilised as often as required. This is necessary to ensure the bond pattern is maintained and straight lines are achieved in the finished paving. The manufacturing tolerances of the paving units, profile of the site, and frequency of string lines used should be taken into consideration during laying. These factors may have a bearing on the straightness of line achievable.

Paving units should be laid such that the joint profile interlocks with its neighbouring units. Joint widths may be varied slightly in order to achieve straight lines or maintain bond.

When hand laying block paving, the blocks should be mixed simultaneously from a minimum of three packs, taking vertically from each slice offered by the pack. This is necessary to ensure an even distribution of both the colours and any manufacturing tolerances offered by the blocks.

Lay whole paving units first, followed by cut units around obstacles or at edges. No paving unit should be cut down to less than one quarter of its original size to prevent looseness or dislodgement at a later date.

Where it appears that only a small section of block will fit, the “inboard cutting” technique should be adopted. The use of a larger or full unit against the edge restraint, allows a smaller unit to be placed in the resulting space.

Where slopes, gradients or ramps are being constructed, placement of the paving units should commence at the lowest point (ie - the bottom of the slope, working upwards).

Where there is a risk of lateral movement of the paving units due to the gradient encountered, the provision of additional intermediate restraint should be considered.

Prior to final compaction of the surface, joints should be filled with the same grading of material as that used for the laying course. All joints should remain full of jointing material at all times, with periodic checking and replacing carried out where necessary.

Cutting

Cutting may be carried out using a diamond tipped power saw, a block-splitting guillotine, or hammer and bolster. It must however be noted that the aesthetic finish achieved will depend greatly upon the choice of cutting mechanism and the skill of the installer.

Cut blocks should be inserted prior to completion of the working period.

Blocks should be cut such that the resultant joint width remains within the 2 – 6mm tolerance. When laying to tight curves it may not always be possible to maintain a maximum 6mm joint, in which case, cut or special shaped units may have to be considered.
The construction industry is increasingly demanding the use of automated handling and installation methods to deliver safe working practices and to assist in delivering projects on time and on budget.

Marshalls has recognised this demand and has fully committed to lead the industry in the development of Machine Lay paving solutions incorporating both product and plant.

Automated methods of Marshalls Priora installation can now deliver new levels of speed, efficiency and quality when compared with traditional installation methods - particularly on larger areas.

Driving Out Cost

Marshalls Machine Lay automates all of the processes involved in a Marshalls Priora installation:

- Installation of the 6mm aggregate laying course
- Installation of the Marshalls Priora block
- Compaction
- Joint filling

This greatly reduces the construction time of the project. For example:

A six man team, over an eight hour day, might anticipate installing approximately 250m² (incorporating screed, installation, compaction and filling joints).

An experienced machine lay installer, automating all of these processes, can install between three or four times more in the same period.

The Benefits of a Mechanical Installation

<table>
<thead>
<tr>
<th>Number of Days</th>
<th>25</th>
<th>20</th>
<th>15</th>
<th>10</th>
<th>5</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation Method</td>
<td>Hand Lay</td>
<td>Machine Lay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Installation of Marshalls ML Products**

1. Laying Course
   - Plant attachments or adapted plant, installs the 6mm aggregate laying course to the required depth and levels
   - Reduces manual effort
   - Reduces labour requirement
   - Assists in speeding up the overall installation programme

2. Installation of Marshalls ML Products
   - Marshalls Machine Lay (ML) products are supplied to site ready packed in the required laying formation
   - Layers of product are grabbed by the installation machine and placed on the laying course
   - Reduces manual installation
   - Reduces labour requirement
   - Assists in speeding up the overall installation programme

3. Compaction
   - Single or multi-plate compactors are used to bed the product in to the laying course
   - Reduces vibration transfer to the installer
   - Reduces labour requirement
   - Assists in speeding up the overall installation programme

4. Jointing
   - 6mm jointing aggregate is applied over the installed surface using one tonne aggregate bags
   - 6mm jointing aggregate is then brushed into the joints using site plant with brush attachments

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Marshalls Priora ML blocks are manufactured in unique machine-installable layers within the pack and are installed on-site by a powered ride-on machine.
A Guide To Maintenance

To ensure the performance of the Priora permeable paving, Marshalls recommend the following maintenance be carried out as shown.

- Maintenance of the pavement is carried out to ensure the infiltration of the paving is not compromised. The following guidelines are offered as an initial regime, but may be either increased or decreased depending on the local environment of the pavement and any external contributing factors.
  - A visual inspection of the paving should be carried out on a regular basis. This will confirm the effectiveness of the agitation maintenance due to variations between sites and allow any refinement of the regular agitation activity if necessary.
  - The paving should be agitated (i.e., brushed, vacuumed, etc.) at least twice a year. This is to ensure no vegetation of any sort is allowed to grow and develop in the joints. Ideally, this activity should be carried out in the spring and autumn seasons.
  - The paving should be inspected after any heavy precipitation to ensure no displacement of any organic matter onto the surface of the pavement.
  - For winter maintenance, the controlled use of de-icing may be used without causing significant detrimental effects on the performance of the permeable pavements. When used carefully, the use of these chlorides will not result in an increase in the chloride levels in the local ground.
  - Where non-infiltration systems have been employed, the inspection of the outfalls should be undertaken initially on a twice-yearly basis.
  - Weed growth – when sedimentation occurs in areas of permeable paving then there is the potential for weed growth, which will typically occur where there are overhanging trees or soft landscaping slopes down on to the paving or in areas which do not receive over run from vehicles particularly frequently. Weeds can be removed from the surface through the application of weed killers. Glyphosate based weed killers are the most common for general purpose use, they are most effective on grasses and perennial weeds with non-woody stems. Weeds should be sprayed when they are actively growing so that the Glyphosate will go down to the root and kill the weed completely.

Glyphosate will be neutralised upon contact with the ground, which makes it safe to plant in the area soon after treatment. It is available ready mixed or as a concentrate.

Glyphosate-based weed killers include: Roundup, Tumbleweed and B&Q Complete.

Depending on the type and amount of usage the permeable pavement has been exposed to, the laying course material may require either cleaning or replacing after a 25 to 30 year period. This would be evident if the infiltration rate of the paving becomes prolonged, allowing ponding to develop. Should this occur, the uplifting and cleaning of the laying course (or replacing, depending on the costings of the activity) may be considered. The laying course material, jointing and Priora blocks can be re-used, minimising costs.

Please contact our Technical Advisory Service on 08704 112233 for more details.

A Guide To Accessing Services

During the design stage of the project consideration should be given to the placement and location of underground utilities. This is intended to minimise the need to carry out any excavation work within the main permeable pavement construction.

Should a situation arise where access is required, Marshalls would suggest the following approach to the works.

- The initial trench width for excavating should be related to the depth of the sub-base material. For example, the width of the utility should be considered, plus a degree of working space. The utility installer will decide this. In addition to this figure, the overall width should be determined by the depth of the open graded material plus 20%.
- When removing the first block a suitable location, such as at the perimeter of the installation or where a unit exists with a larger joint width surrounding it, should be considered. Next, as much jointing material should be cleared as possible to reduce the additional integrity being offered by this material.
- Once a block has become suitably loosened, a block lifter should be used to remove it. Due to the superior interlock provided by the patented Priora nib, it may be necessary to hold the lifted block in an elevated position, whilst a second person taps the adjacent blocks with a suitable lump hammer or rubber mallet. This may be repeated for the first few units during removal.
- Once the desired area of paving has been removed and carefully staked for reuse, a suitable surfacing material (i.e., membrane, wooden boards, etc.) should be placed on the surrounding paving for the laying course and sub-base materials to be separately stockpiled.

Once the utility work is complete, the pavement should be reconstructed as per Marshalls Installation Guide.

If the pavement construction contains any waterproof membranes or geotextiles, these should be sliced, folded back and weighed down during the opening of the pavement.

Upon reinstatement, these should be folded back into their original position and be overlaid with a new corresponding material (overlap dimension to be determined between the utility contractor and the membrane/geotextile manufacturer; consideration to bonding/welding the reinstated material should be given depending on site conditions) which has been cut to an appropriate size, before continuing with the next layer of construction.
Adoption

While some authorities still seem to be cautious about adopting CBPP, more and more now appreciate that permeable paving offers the most convenient and cost effective SUDs solution. The UK is beginning to catch up with other areas in Europe, particularly Germany, where CBPP has been used as a standard highway construction for many years.

In addition to the thorough desktop analysis undertaken by Professor John Knapton and in-situ testing at NUROLF, Marshalls have amassed a vast range of practical, hands-on experience since Priora’s launch in 2002. We sell more CBPP than any other UK supplier; our engineers and technical support teams are able to share over a decade’s knowledge from successfully installed systems, so our customers can be confident that the advice we offer is valid and proven.

Common concerns about CBPP seem to regard its longevity, the level of required maintenance, and the use of a different sub-base aggregate. The ‘Mythbusting’ section of this design guide deals with these misconceptions. The Flood and Water Management Act 2010 will further help to guide authorities through the adoption process, alleviating concerns that they may have. 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.

Currently, some local authorities require ‘commuted sums’ for CBPP, because the perception is that they pose a higher risk of failure and require more maintenance than a traditional drainage system. This is simply not the case; a correctly installed permeable pavement is at least equally as stable and requires less maintenance than a conventional CBP surface plus its necessary traditional drainage system. The Flood and Water Management Act 2010 will clarify these commuted sums once the SABs (SUDs Advisory Boards) have been appointed.

Marshalls are committed to working with local authorities to alleviate any concerns they may have regarding adoption. Further guidance will be available in the National SUDs Specification / Standard.

SUDs Glossary

**Attenuation**
Attenuation is the process of storing water and slowly discharging it in a controlled manner.

**Capping Layer**
The capping layer is positioned below the sub-base to act as a subgrade improvement layer for CBRs <5%. The depth and type of material will depend on the CBR and type of system proposed.

**Catchment Area**
The total contributing area draining to the pavement, this will include the pavements own area and possibly run-off from roofs, linear drainage channels/gullies, surrounding impermeable surfaces etc.

**Cap Volume**
Within Micro Drainage the Cap Volume is a level (not a volume) measured at the top of the sub-base material. This allows the software to determine the amount of storage within a permeable pavement. The Flood warning risk level is often set at the Cap Volume.

**CBPP**
Concrete Block Permeable Paving.

**California Bearing Ratio (CBR)**
CBR is a penetration test used to determine the strength of soils in pavement design. The CBR is expressed as a percentage and it determines the depth of capping material required.

**Climate Change**
A factor of safety applied to the design. Allowing for expected rainfall fluctuation within climatic changes during the pavement’s design life.

**Flow Control Device**
A mechanism used at the outlet to limit the flow from a permeable pavement for Type C (tanked) systems.

**Geotextile**
A permeable fabric which is generally woven or non-woven.

**Geomembrane**
An impermeable membrane wrapped around the pavement for Type C systems.

**Greenfield run-off rates**
This refers to the typical run-off rate expected from a site in its undeveloped state. Often quantified as 5 l/s/ha although it will vary depending on soil classification and geographical location.

**Infiltration Rate**
The speed at which water can drain into the ground. The rate of infiltration is typically measured in m/sec and is often determined using the BRE Digest 365 guide to Soakaway design. It is critical for Type A systems, it should be a minimum of 1 x 10^-6 m/sec.

**Interception Storage**
It is accepted that CBPP will provide up to 5mm of interception storage i.e. no surface water will be discharged from the pavement or infiltrate into the ground from the first 5mm of rainfall.

**M5-60 Rainfall**
A 1 in 5 year storm of 60-minute duration. It is measured in millimetres and is specific to the site’s geographical location.

**OGCR**
Open Graded Crushed Rock sub-base material used for Priora.

**Porosity**
The measure of voids within the specified sub-base material once compacted. Used to determine the available storage volume within a permeable pavement. The 4/20 Open Graded Crushed Rock recommended by Marshalls gives approximately 32% voids, so 0.32 porosity.

**Rainfall Ratio r**
The ratio of a 60 minute : 2 day rainfall event on a 1 in 5 year return period. This figure is specific to the geographical location of the site.

**SUDs approval body (SAB)**
A SAB will be responsible for approving, adopting and maintaining drainage plans and SUDs schemes that meet the National Standards for sustainable drainage.

**Source Control**
The term used for drainage solutions which manage surface water run-off within the site through attenuation.

**Storm Return Period**
The expected frequency a storm will occur. For example, a 1 in 100 year storm refers to a storm that would occur (on average), once every 100 years.

**Sustainable Urban Drainage Systems (SUDs)**
This is a concept that considers long term environmental and social factors within water management design. It encourages a development to mimic natural drainage. The SUDs triangle which considers quality, quantity and amenity / biodiversity is crucial for any SUDs design.

**Water Table**
The level below which the ground is saturated with water.
Appendix I

Legislation and Guidance Notes

General

Water Framework Directive
A European Union directive that commits European Union member states to achieve good qualitative and quantitative status of all water bodies (including marine waters up to a kilometre from shore) by 2015.

The directive defines ‘surface water status’ as the general expression of the status of a body of surface water, determined by the poorer of its ecological status and its chemical status.

BS7533:13:2009
Pavements constructed with clay, natural stone or concrete pavers. Guide for the structural design of permeable pavements.

Interpave 6th Edition
Interpave is an organisation that represents most of the major pre-cast concrete paving manufacturers in the UK who are all signatories to the Sustainability Charter of the British Precast Concrete Federation. Interpave works closely with Defra, the Environment Agency, Scottish EPA, CIRIA and SUDsnet driving forward sustainable drainage solutions.

The SUDs Manual - C697
Technical guidance on SUDs techniques and treatment for roads.

BREEAM 2008 – the Building Research Establishment’s Environmental Assessment Method
An assessment tool widely used for various building types. This allows various credits to be gained against a list of criteria. Credits can be scored through the use of SUDs in a number of areas.

Code for Sustainable Homes
The Code for Sustainable Homes includes a mandatory requirement to ensure that peak run-off rates and annual volumes of run-off post development are no greater than the previous conditions for the site. Permeable paving can help to achieve this, particularly in urban locations where space is at a premium. The Code gives one credit where specific levels of attenuation are achieved with hard surface run-off.

England and Wales

National SUDs Standards
The National Standards set out the requirements for the design, construction, operation and maintenance of SUDs. Following the Flood and Water Management Act 2010 a SUDs approving body (SAB) will assume responsibility for adopting and maintaining SUDs serving more than one property.

The National Standards define the criteria that must be met to satisfy the SAB on the functionality of the SUDs they intend to adopt.

The National Standards are part of Governmental policy for the construction of drainage for new developments and redevelopments.

Flood and Water management Act 2010
This act became law in April 2011. It requires the use of SUDs in almost all new developments and redevelopments applying to surface water drainage from all new buildings and roads in England and Wales.

SUDs will replace conventional piped drainage for surface water management wherever practical.

Local authorities will assume responsibility for adopting and maintaining SUDs. Drainage plans must be approved through the SUDs Approving Body (SAB), appointed by local statutory authorities/councils.

Planning Policy Statements
• PPS1 – Advises local planning authorities on the delivery of sustainable development through the planning system. The current version was introduced in February 2005.
• PPS3 – Housing. Outlines the strategic housing policy of the government, which was “to ensure that everyone has the opportunity of living in a decent home, which they can afford, in a community where they want to live.” The policy was developed in response to the Barker Review, and it replaced Planning Policy Guidance 3: Housing, which had been published in March 2000.
• PPS9 - Biodiversity and Geological Conservation. Contains advice on planning policies for the protection of biodiversity and geological conservation through the planning system. The current version was introduced in August 2005.
• PPS25 – Document to set out policy on development and flood risk. PPS25 was published in December 2006 and has been supplemented with a Practice Guide in June 2008.

The Building Regulations – England and Wales
In England and Wales, Part H and Approved Document H – drainage and waste disposal apply. Part H requires developers to consider Sustainable Drainage Systems (SUDs) above traditional drainage solutions. Soakaways and infiltration systems, which are SUDs, are given priority. Revisions to Approved document H are expected.

Technical Advice Note (TAN) 15 – Development and Flood Risk
TAN 15 is similar to PPS 23 but adds to it by 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 reasons why sustainable drainage systems cannot be used.

Scotland and Northern Ireland

Water Environment (Controlled Activities) (Scotland) Act 2005
It is a general requirement for new developments with surface water drainage systems discharging to the water environment that such discharges will pass through SUDs. All reasonable steps must be taken to ensure protection of the water environment.

Controlled Activities Regulations (CAR)
Provide regulation under General Binding Rules (GBRs) 10 and 11 for SUDs.

Scottish Planning Policy (SPP) 7: Planning and Flooding
A guidance document to prevent further development that would have a significant probability of being affected by flooding or which would increase the probability of flooding elsewhere.

Planning Advice Note (PAN) 61: Planning and Sustainable Urban Drainage Systems
Good practice advice for planners and the development industry complementing the Sustainable Urban Drainage Systems Design Manual for Scotland and Northern Ireland.

Building Regulations – Scotland
In Scotland, the 2008 Scottish Building Standards are applicable. 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 permeable paving as the hard landscaped area also serves as a sustainable drainage system.
Priora Bitmac Junction Sub-Base Under Road

Roof Water Input into Sub-Base
Standard Detail for Heavy Duty Paving

Standard Detail for Non-Infiltration & Infiltration
Standard Detail for Priora on a Sloping Site (Baffles)