www.marshalls.co.uk/wm

Permeable Paving Design Guide

Marshalls

Creating Better Spaces

Marshalls

Creating Better Spaces

Marshalls is the UK's leading hard landscaping manufacturer and we have been supplying some of the most prestigious landmarks in the UK with hard landscaping solutions since the 1890s.

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.

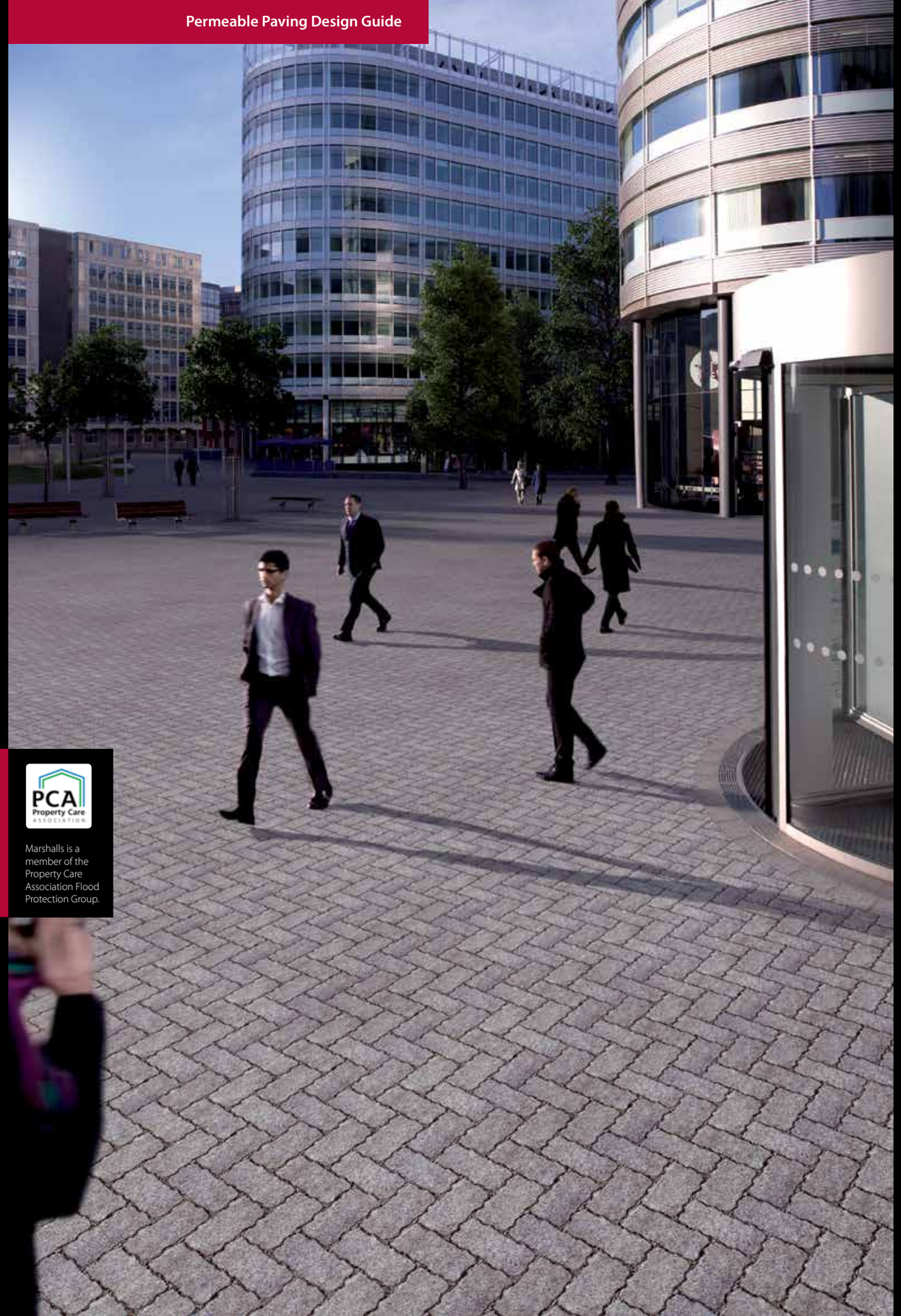
Above all, **our belief fuels the passion on which Marshalls is built.**

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.

Permeable Paving

www.marshalls.co.uk/commercial



Marshalls is a member of the Property Care Association Flood Protection Group.

Permeable Paving Design Guide

Contents

What's the issue? 06
What's the solution? 08
What's driving SuDs? 10
SuDS techniques 12
Marshalls Priora Permeable Paving 14
Driving Out Cost 18
Marshalls Services 22
Mythbusting 26
Marshalls Priora Product Pages 26
Types of Priora System 50
Designing a Priora System 52
Installing a Priora System 62
Machine Lay 68
Maintenance 70
Adoption 72
Glossary 74
Standard Details 78

Mary Dhonau (OBE)
MDA Community Flood Consultants

"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 year on year since 2007.

"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."

Permeable Paving
www.marshalls.co.uk/commercial

Why Choose Marshalls?

Marshalls plc is the UK's leading hard landscaping company. We have achieved this status through progressive product innovation and by demonstrating outstanding service levels to our customers. This privileged position will be sustained by continuous investment in our brand, our products, and our people.

This dedication to excellence is exemplified by Marshalls commitment to developing the most popular permeable paving system in the UK.

Marshalls experience and expertise can ensure that the right system is selected, detailed, delivered and installed to give total peace of mind.

Marshalls pledges that all of the products and systems featured in this book comply with relevant industry standards, are manufactured to the highest standards, are fit for purpose and are designed to optimise savings in installations and use.

Marshalls' purchasing policy sets out the standards and ethics by which we conduct our business and operate our management systems to manage our suppliers.

The majority of our products are manufactured in the UK; where products are sourced from outside the UK an ethical risk assessment is completed and an appropriate action plan agreed - multi-stakeholder independent social audits are part of our best practice. Marshalls is a member of both the Ethical Trading Initiative and UN Global Compact.

Marshalls accepts legal compliance as an absolute minimum standard to which we work and, where no legislation is in place, we use industry best practice. Legal compliance is monitored through our independently audited management systems. Our Board is ultimately responsible for ensuring the business operates in a socially responsible way, including compliance with relevant legislation.

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.

Ethical Trading Initiative
Respect for workers worldwide

Marshalls is a member of the Ethical Trading Initiative (ETI).

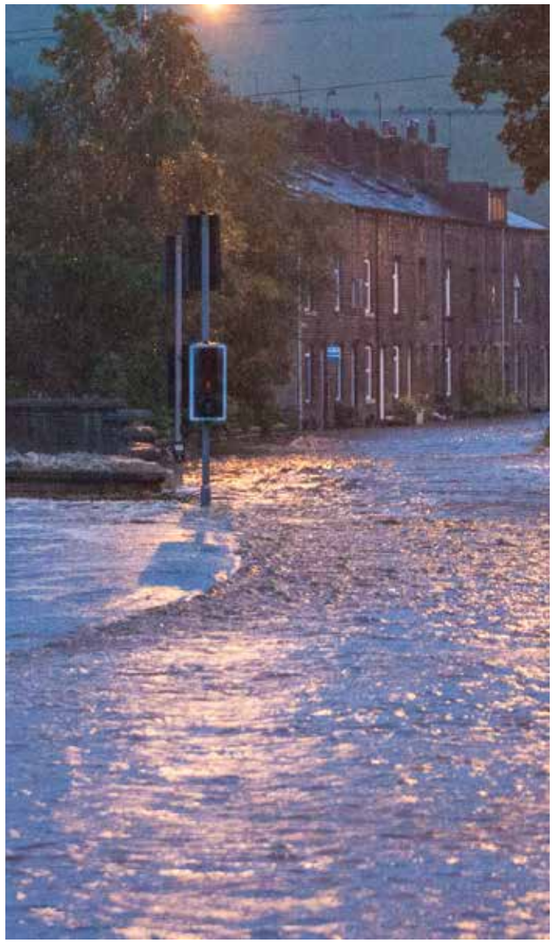
WE SUPPORT

OHS 69609 EMS 56194 FM 00004 IMR 72571

What's the issue?

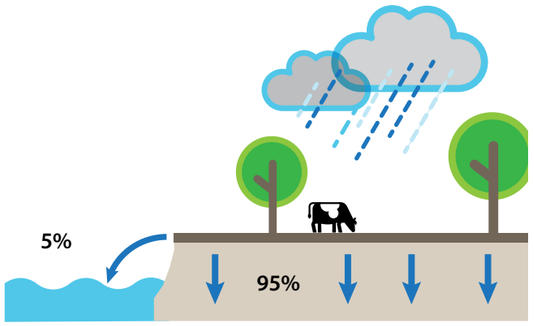
Many developed areas across the world are now entering a state of 'water stress' – not because there's less water available, but because we're mismanaging this essential resource.

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…



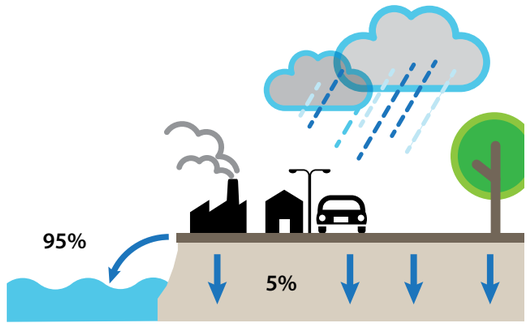
Of the 57,000 homes affected in the 2007 summer floods, over two thirds were the result of surface water run-off - not swollen rivers.

Countryside



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

Towns & Cities

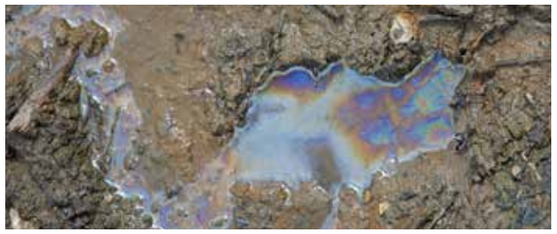


In developed areas, the majority of rainwater falls onto impermeable surfaces, where it is diverted away from its natural course into storm drains and waterways.

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.

The increased frequency and cost of rainfall related external flooding events, has rightly focussed public and government attention on the development of policies and associated guidance documents promoting the use of sustainable water management methodologies.

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.

What's the Solution?

Sustainable 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 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:

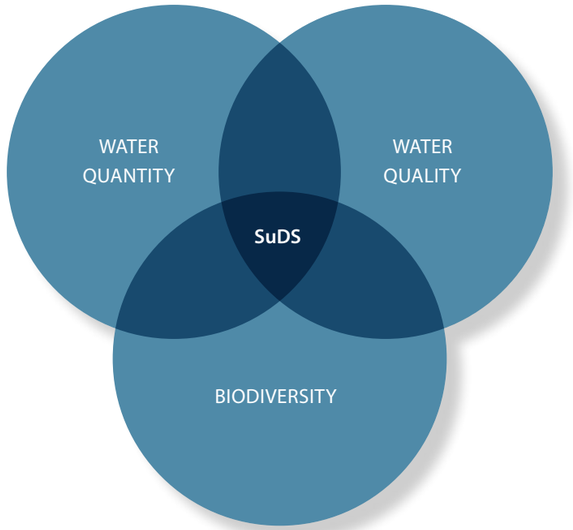
- **Water Quantity**
- **Water Quality**
- **Biodiversity**

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.

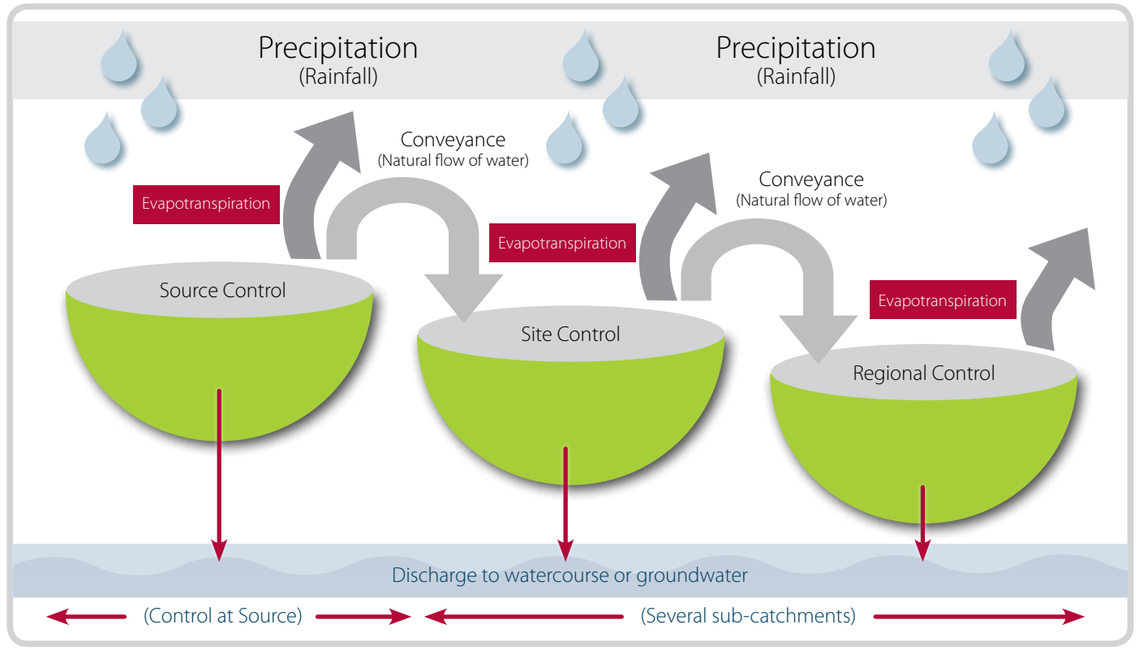
By considering these three factors during the design stage of a project, it is possible to create drainage systems that provide natural water quality treatment, encourage infiltration, reduce the impact of peak flows and minimise impact on the local habitats of both communities and wildlife.

The SuDS Triangle



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.

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.

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.

What's 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.

In 2010, following the release of the Flood and Water Management Act, various stakeholders involved in the flooding crisis were optimistic that the introduction of the National SuDS Standards would be a major legislative tool to drive uptake of SuDS. However, as the release of the standards was repeatedly delayed over a number of years, it became increasingly apparent that legislation wasn't going to be the tool which forced SuDS onto the agenda.

Regardless, the building industry began to take notice. SuDS solutions which proved to be effective, reasonably priced and easy to integrate into new developments started to grow in popularity. Developers, it seemed, started to ask, "why wouldn't we?", instead of "why would we?" when it came to surface water solutions.

This growing trend was supported in 2015 when the National SuDS Standards were (if not actually released as anticipated) finally integrated into planning regulations. SuDS Approval Bodies (SABs), which had been hastily put together within many local authorities to support the release of the standards, are now well placed to advise on how to incorporate SuDS into building schemes.

Approaches to SuDS integration currently vary from region to region, with some local authorities more enthusiastic than others – but what is clear is that as SuDS gain popularity, sensible and pragmatic guidance is essential. In addition to your local authority's planning documentation, there are also some excellent examples of independently produced guidance documents which will help you select the best SuDS approach for your scheme.

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

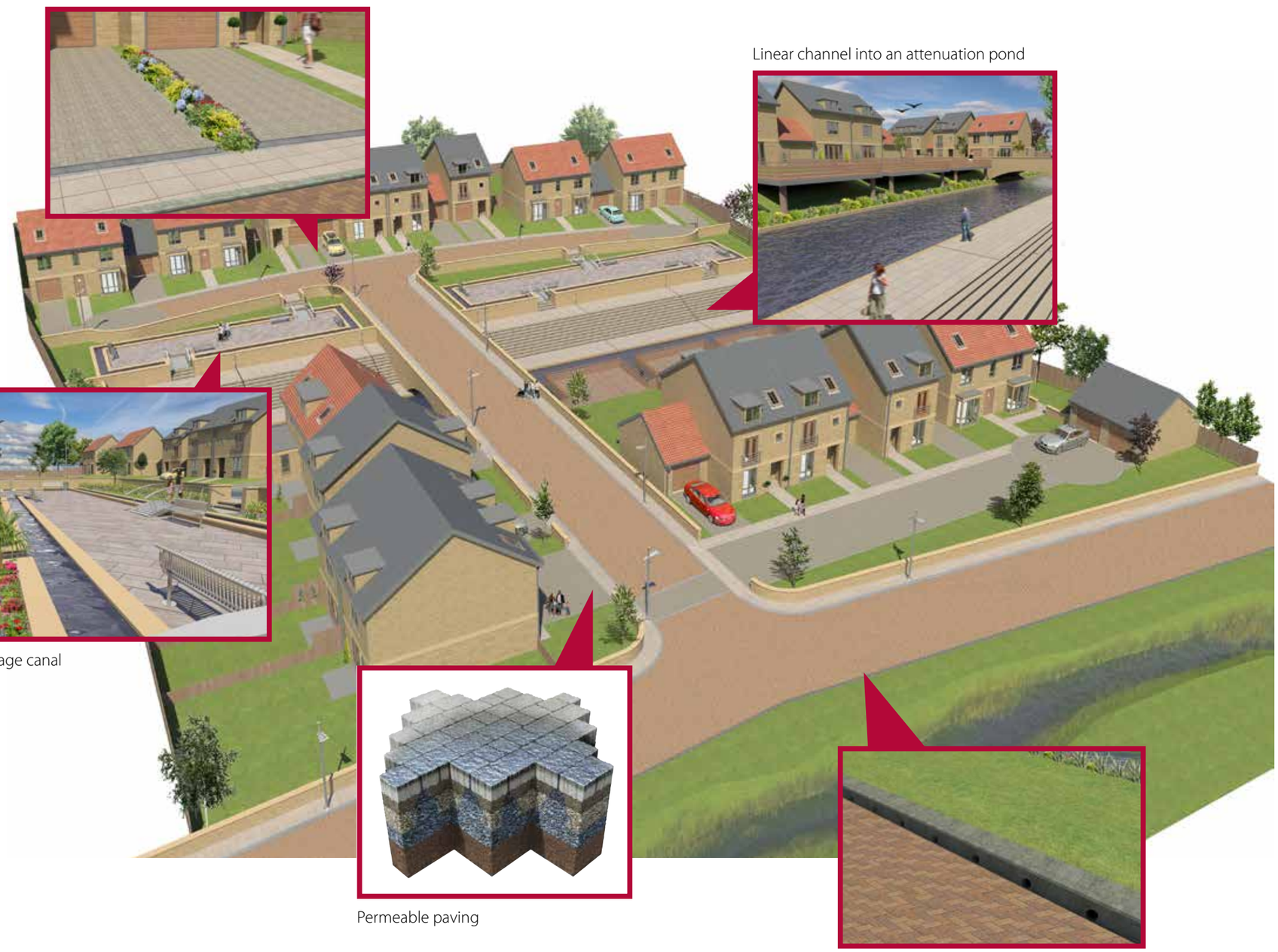
Filter drains – trenches filled with permeable material

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



Linear drainage directed to a tree pit

Linear channel into an attenuation pond

Open drainage canal

Permeable paving

Marshalls Beany combined kerb and drainage into a swale

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 sustainable building practises, 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 a practical SuDs solution.

Traditional Paving

A traditional pavement construction includes integral cross falls which direct surface water into a drainage system, such as a road gulley 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.

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.

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

Marshalls Tegula Concrete Block Paving (CBP), Huddersfield University

Marshalls Mistral Priora Concrete Block Permeable Paving, Woodberry Down, London

Permeable Paving Design Guide

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:

a. *The stones within the sub-base act as a filter medium which remove heavy particles such as silt and heavy metals.*

b. *Over time microbial organisms begin to cultivate in the pavement which break down hydrocarbon leaks such as exhaust fumes and sump oil drips.*

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.

…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 dissipates 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.

Slip-Skid resistance – Excellent performance for pedestrian and vehicular traffic alike, due to the joint profile and surface finish.

Reinstatement – Underlying surfaces can be accessed by the removal of a small number of blocks, which can be easily replaced for immediate trafficking with no visible effect.

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 15 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…

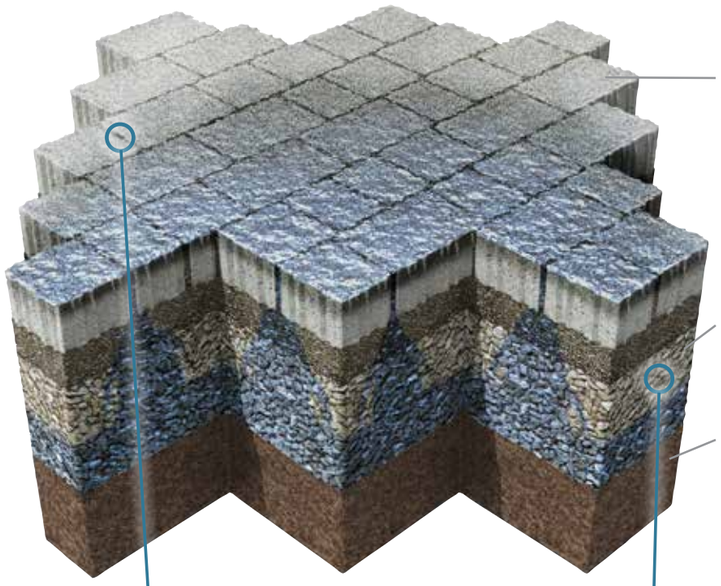
…where it seeps immediately through the specially created voids between the blocks…

…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.

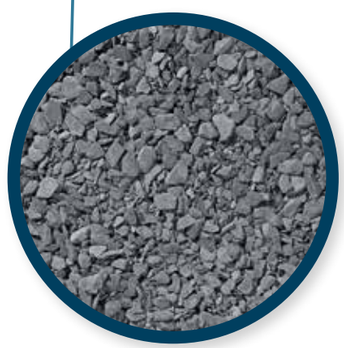


Marshalls Priora deals with water **Quantity** issues by eliminating pooling

The system improves water **Quality** by filtering the water as it falls through the sub-base.

It also provides **Bio-diversity** benefits by replenishing the water table at source, which will maximise ecosystem services in the area.

Each block features a number of carefully spaced, patented 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.



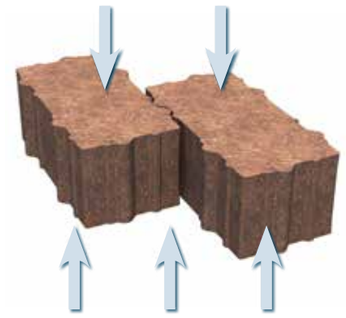
The sub-base is composed of two different grades of aggregate. These are specially selected to provide maximum internal friction (offering enhanced stability) whilst also providing a void ratio of over 32% (offering adequate water storage) (see page 21)

A Patented Nib Design For Superior Interlock

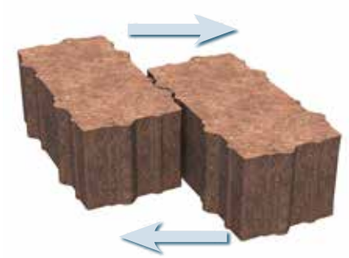
A key factor in the way a block paved surface behaves is the way in which each block interlocks with its neighbours. Interlock helps to spread the load evenly across the area of the paved surface, improving surface stiffness and reducing pressure on the laying course immediately beneath the blocks.

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

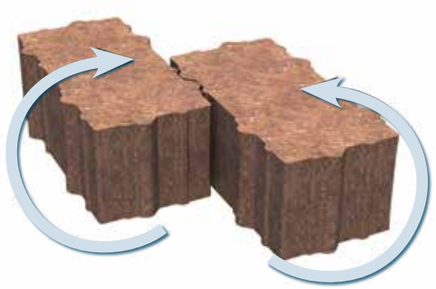
Vertical interlock refers to the ability of each block to move against its neighbours on a vertical plane. If the sub-base has been designed and installed to our specifications, it is unlikely that this will be a factor in a Priora surface. However, the unique patented Priora nib improves vertical interlock 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.



In 2015, to further test this "rotational interlock advantage", Marshalls developed a method for measuring rotational interlock in the field. This involves attaching a rig to an in-situ block and measuring the force required to rotate it out of its horizontal plane. The results corroborated Professor Knapton's hypothesis: in order to rotate a Priora bock to the same degree as a standard Keyblok unit, 40% more force is required.

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:

Eleven 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.

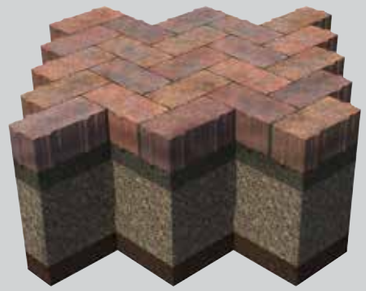
Practical: In areas where excavation is limited (to avoid services, for example), our new designs frequently make a Priora surface a realistic option where it wasn't before.

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.

British Standard Design*

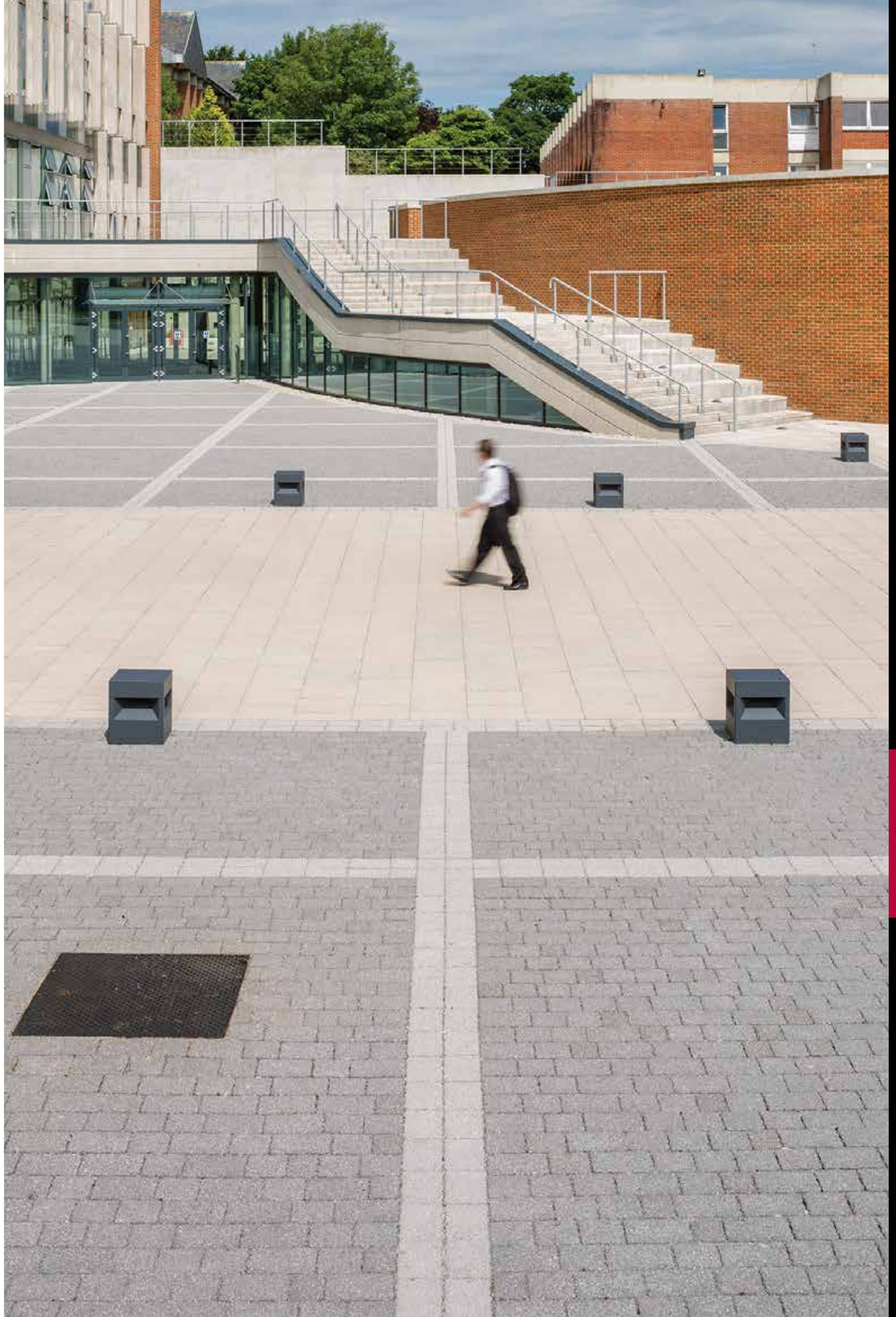
Build Up:
80mm Block
50mm Laying Course
350mm Sub-base (OGCR)
Total Depth = 480mm

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**



Water Quality

With flood events grabbing ever-increasing column inches, the primary purpose of most SuDS is currently to attenuate and hold back water. However, the ability of a well designed SuD to cleanse surface water as it passes through is a major benefit which should not be overlooked.

Marshalls testing with Abertay University in 2010 concluded that up to 94% of heavy metals are removed from effluent as it passes through the sub-base of a permeable pavement, and UK SuDS expert Bob Bray is regularly quoted as saying that permeable paving provides "a controlled flow of clean water".

However, confusion still surrounds water quality in permeable pavements.

- How does this cleaning process work?
- Now that Marshalls Priora sub-bases are shallower than the BS, does it make them less effective at removing pollutants?
- Can anything be done to maximise the cleansing potential of Marshalls sub-base designs?

In 2015 Marshalls undertook an ambitious testing programme with Coventry University to understand exactly how our Priora systems improve the water that flows through them.

"The project is the largest and most ambitious laboratory simulation of its kind in the world, and will set the standard for future water quantity and quality design"

– **Dr Stephen J Coupe,** Coventry University

Findings to date…

- *Structural depth has not been shown to be a detectable contributor to water cleansing. Therefore, Marshalls rationalised sub-base designs are as effective as the deeper (and more expensive) BS designs at cleansing water.*
- *Both the shallowest and deepest Marshalls Priora designs which include MT120 Filtration Textile produce the cleanest water of all the designs tested.*
- *Marshalls MT120 Filtration Textile performs better at cleaning chemical impurities from water than a leading competitor filtration layer.*

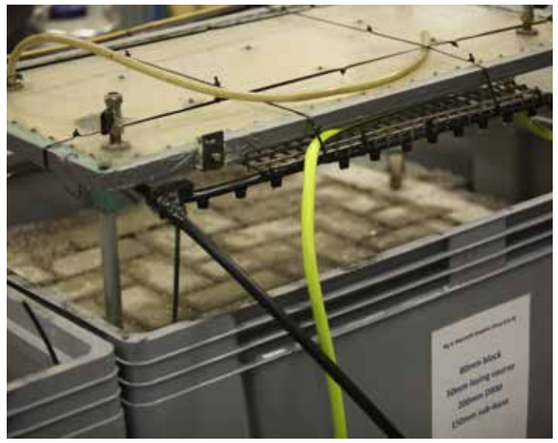
Coventry University

Dr Stephen J Coupe, BSc (Hons) PhD

Research Fellow in Environmental Science and Water Management

Dr Luis Angel Sañudo Fontaneda, MEng, MSc, PhD

Researcher in Civil Engineering and Water Management

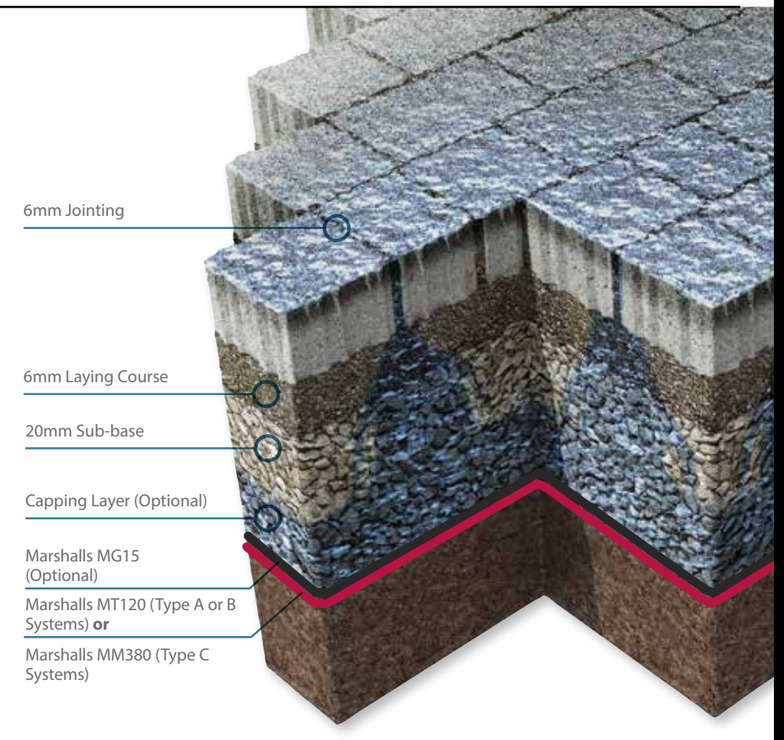


Priora Sub-Base Construction

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 59-61, and for details of Marshalls Priora Aggregate, please see page 49.



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.

Jointing Aggregate Specification: 6mm Open Graded Crushed Rock

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 in-situ.

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

Laying Course Aggregate Specification: 6mm Open Graded Crushed Rock

Sub-Base

In addition to providing structural stability (as it would in a traditional pavement), the sub-base of a Marshalls Priora system 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 recommend the use of an aggregate with a void ratio of between 30% - 32%. In effect this means that every $3m^3$ of aggregate can store approximately $1m^3$ of water

Sub-Base Aggregate Specification: 20mm Open Graded Crushed Rock

Capping Layer

A capping layer is required on weak ground to improve the bearing capacity of the pavement. Ground is considered "weak" when the CBR (California Bearing Ratio) is below 5%. Marshalls MG15 Grid can be used at the interface of the capping layer and the subgrade to confine the capping material and stabilise the structure, reducing the amount of capping material required. See page 59 for Capping Material specification. See page 46 for information on MG15 Grid.

6mm Aggregate

20mm Aggregate

Full specification of suitable aggregate is set out in EN 13242: 2002

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.

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

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
design.team@marshalls.co.uk

Project Support

Marshalls

Creating Better Spaces

BIM & Product innovation

Marshalls is an early adopter of Building Information Modelling (BIM) and has invested heavily in developing our people and skills to create the appropriate BIM objects and data that large commercial projects will soon demand. The company is in the process of building a BIM object library that will be unrivalled in the Landscape sector and currently collaborates with relevant industry bodies to develop the training strategies, product data and software that will drive BIM adoption across the industry.

CPD Presentations and Training

Marshalls Engineers and Project Consultants offer free of charge comprehensive and industry leading range of CPD (Continuous Professional Development) seminars to architects, engineers and contractors.

Marshalls CPD seminars cover a whole range of water management topics and solutions from permeable paving to linear and combined kerb and drainage systems.

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.

Web Assistance

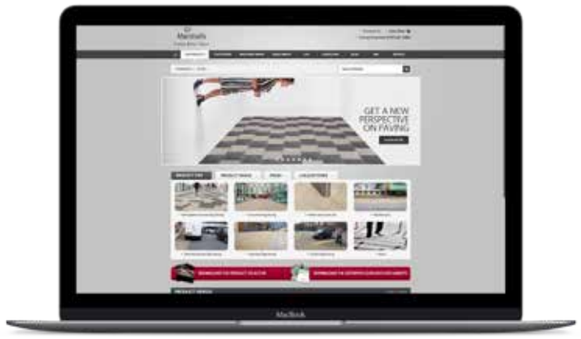
Marshalls website offers the best way to keep up to date with the full range of Marshalls products, services and research. It is an invaluable resource from which customers are free to download the following information:

- 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



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
- Specification Clauses

…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.

Marshalls

DESIGN SPACE

Design Space

A bespoke London work space to inspire landscape design professionals. Bookable spaces for meetings, brainstorm sessions, or simply quiet space to think and create. Fully kitted to explore materials, colours and textures, BIM Models, technical data and social media platforms all on screen.

Extra events are a regular programme of seminars, notable speakers, and CPD. Open Space for big ideas, Personal Space for quiet contemplation, Inner Space for imagination.

Mythbusting . . .

Are permeable pavements difficult and expensive to maintain?

No. No. After monitoring Priora installations for over 15 years, Marshalls now recommends a "reactive" maintenance regime; in other words, the system only needs attention if it stops working. Occasional sweeping is recommended to keep the pavement clear of moss, weeds and debris, but this is to maintain cosmetic appearance and is not necessary to maintain the functionality of the system. See page 70 for details.

Does permeable paving improve water quality?

Yes. Water which flows through the sub-base is cleansed by two processes - mechanical filtration and biological chemical breakdown. Marshalls has undertaken studies with both Abertay University and Coventry University to understand how their systems affect water quality. See page 20 for details.

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

No. An independent study demonstrated that even if the joints appear to be blocked, the system will still remove surface water. In addition, to test these findings, Marshalls conducted its own infiltration test on the most neglected Priora system in the UK - enter "Marshalls Priora Maintenance Test" into YouTube to see the evidence for yourself!

Are permeable pavements limited to light load or infrequent traffic applications?

No. Marshalls Priora has been successfully installed in a wide variety of loading applications, ranging from domestic driveways to port areas. Marshalls has now developed nine loading categories which mean that the designs we create are more prescriptive than ever, avoiding the risk of over-engineering a system.

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.

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 50 for information regarding Type A, B and C systems).*

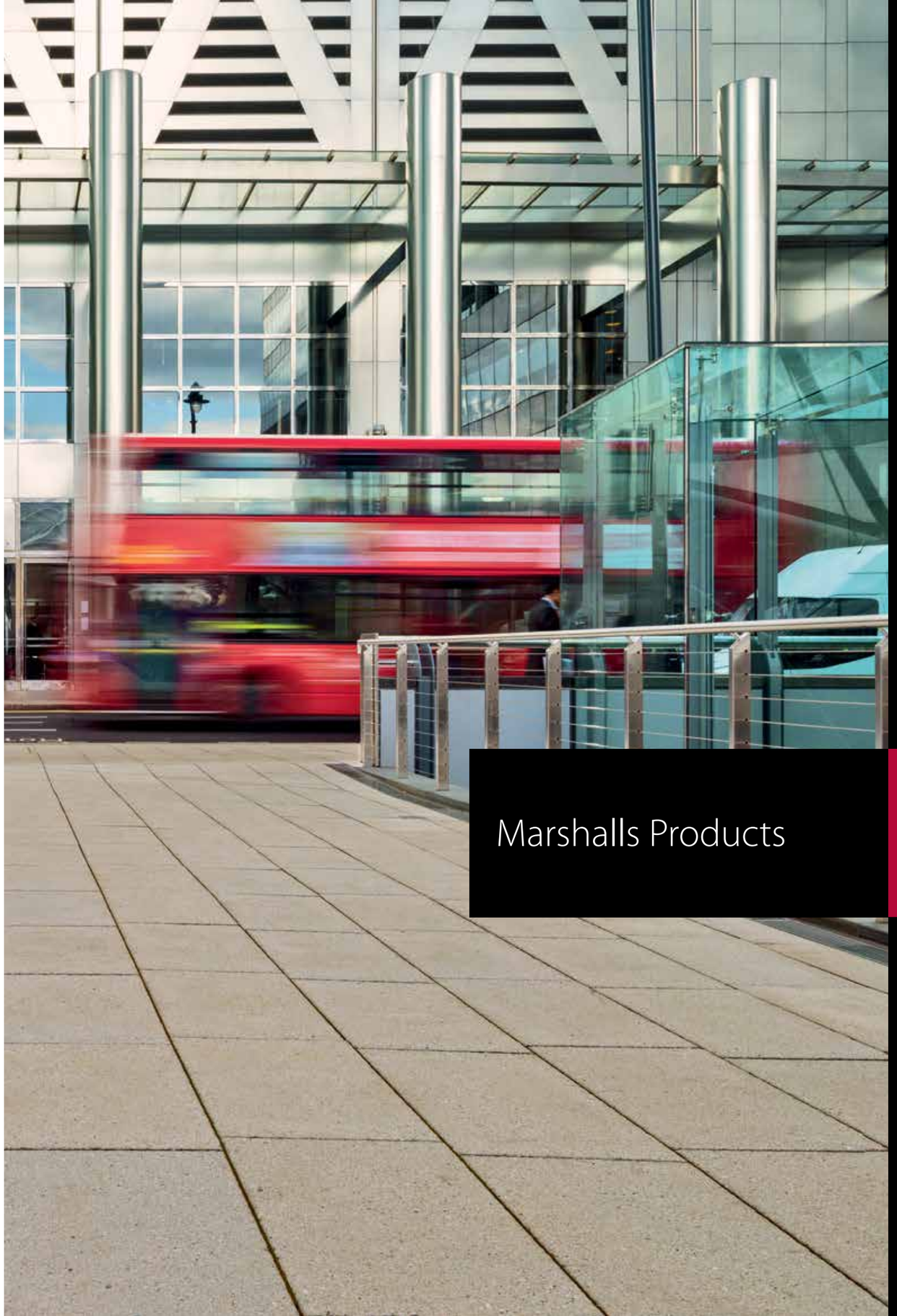
Does the 5m rule used in soakaway design apply to permeable paving?

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 Win*Des*®, porous car parks are one of the storage structures available.

Mistral Priora, Silver Grey, BRE Watford



Marshalls Products

Permeable Paving Design Guide
Permeable Paving
www.marshalls.co.uk/commercial

Conservation Priora, Silver Grey, Charcoal & Graphite

Conservation Priora

Permeable Flag Paving System

NO_x

Silver Grey

Charcoal

Graphite

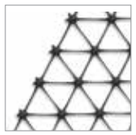
Priora, the UK's best-selling permeable paving block, is now available in large plan flag sizes! Based on Marshalls' most popular premium flag option, the combination of 3 sizes and 3 colours can be freely mixed and matched to allow truly creative laying patterns.

The exposed aggregate in the subtly textured surface offers a sleek, striking look for contemporary urban spaces. Conservation Priora is ideal for pedestrianised areas but has been engineered and tested to withstand occasional loads up to 7.5 tonne.

In addition, during field tests undertaken in 2014, we have proven that the patented Marshalls Priora nib provides the surface with 40% more interlock than our standard block. This means that specifying Marshalls Priora blocks will bring long-term benefits in relation to pavement longevity and maintenance requirements - regardless of the intrinsic hydraulic benefits.

NO_x *On request, this product can be manufactured using Noxer technology to improve the air quality in the area in which it is installed.*

For use with the Marshalls range of sub-base components:



MG15 Grid

MM380 Tanking Membrane

Priora Aggregate

MT120 Filtration Textile

NSSPlus
Q24 112 Q24 117
Q24 115 Q24 119

CO_2 per m^2

For the latest carbon value visit
www.marshalls.co.uk/commercial/carbon-calculator

Thickness (mm)	Plan Size (mm)	Unit Weight (Kg)	Pack size (m^2)	Pack Weight (Kg)	Silver Grey Item Code	Charcoal Item Code	Graphite Item Code
65	200x400	11.96	6.4	957	**FL7420100**	**FL7420200**	FL7420300
65	400x400	23.92	7.68	1,148	**FL7422100**	**FL7422200**	FL7422300
65	600x400	35.88	7.68	1,148	**FL7424100**	**FL7424200**	FL7424300

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

Plan Sizes

200 x 400 400 x 400 600 x 300

Numbers indicate the maximum loading category recommended for each unit.
Loading category descriptions can be found in Marshalls Permeable Paving Design Guide.

Permeable Paving Design Guide

La Linia Priora, All Colours, Example

La Linia Priora

Permeable Block Paving System

Light Granite

Mid Grey Granite

Grey Granite

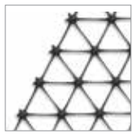
Anthracite Basalt

La Linia Priora is the latest version of the UK's most popular permeable paving system. Using high quality exposed aggregates across a broad range of integrated plan sizes, La Linia Priora is a subtly textured permeable paving range that can be employed to generate striking visual effects through both colour and shape. The collection of complementary units create 2 gauges with 3 sizes in each, allowing the designer creative freedom. Units can be laid as part of a multi-sized pattern or simply on their own – the patented Priora nibs have been carefully placed on each block to allow laying in ANY combination and in ANY orientation.

In addition, during field tests undertaken in 2014, we have proven that the patented Marshalls Priora nib provides the surface with 40% more interlock than our standard block. This means that specifying Marshalls Priora blocks will bring long-term benefits in relation to pavement longevity and maintenance requirements - regardless of the intrinsic hydraulic benefits.

NO_x *On request, this product can be manufactured using Noxer technology to improve the air quality in the area in which it is installed.*

For use with the Marshalls range of sub-base components:



MG15 Grid

MM380 Tanking Membrane

Priora Aggregate

MT120 Filtration Textile

NBS Plus

Q24 112 Q24 117
Q24 115 Q24 119

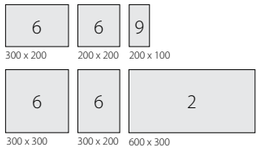
CO_2 per m^2

For the latest carbon value visit
www.marshalls.co.uk/commercial/carbon-calculator

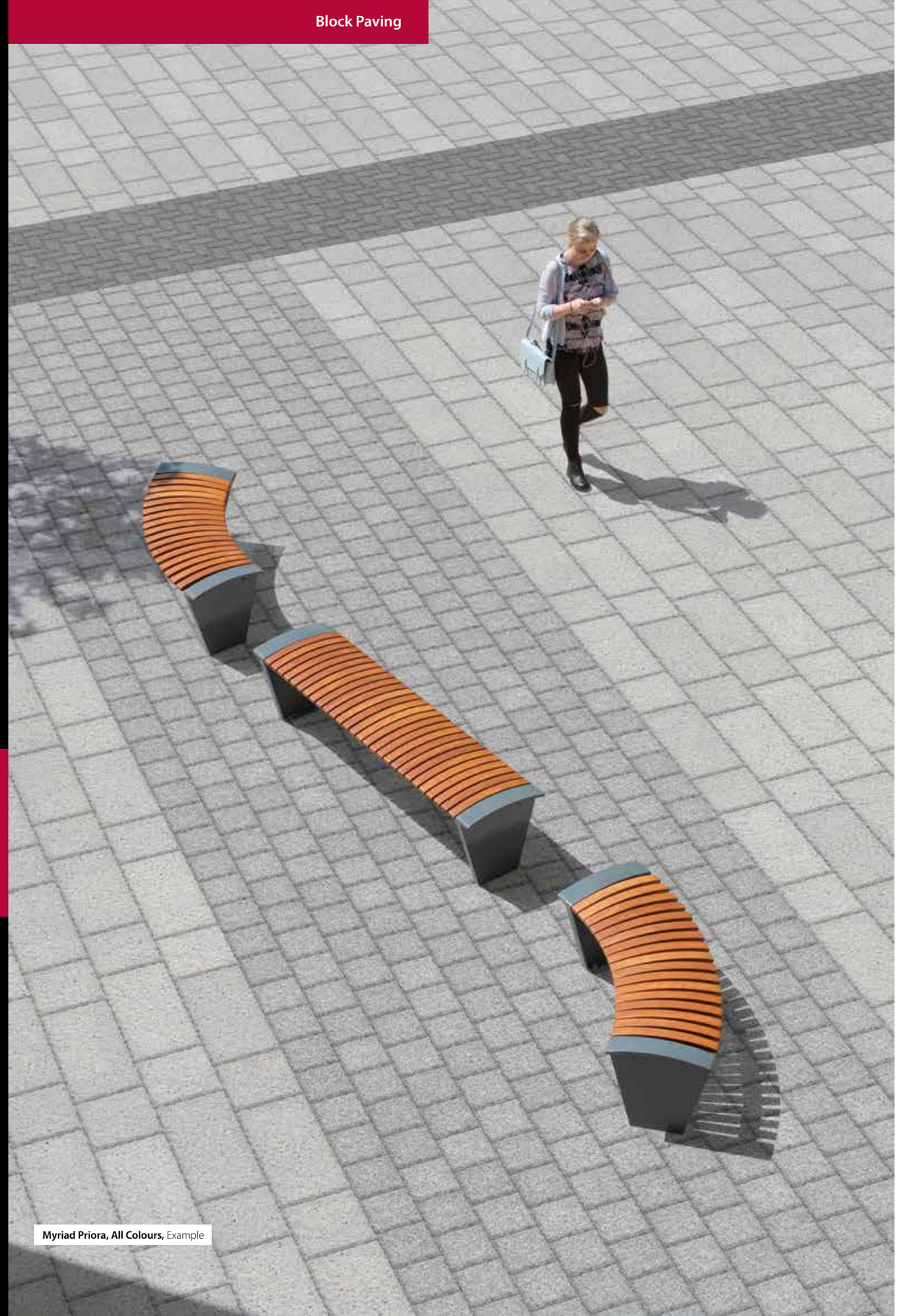
Thickness (mm)	Plan Size	Unit Weight (kg)	Pack Size (m^2)	Pack Weight (kg)	Grey Granite	Mid Grey Granite	Light Grey Granite	Anthracite Basalt
80	200x100	2.76	8.64	1222	SD1406200	SD1409200	SD1400200	SD1402200
80	200x200	7.2	7.2	1296	SD1406300	SD1409300	SD1400300	SD1402300
80	200x300	8.28	9.6	1355	SD1406400	SD1409400	SD1400400	SD1402400
80	300x300	12.42	7.56	1222	SD1406500	SD1409500	SD1400500	SD1402500
80	300x600	32	7.56	1361	SD1406600	SD1409600	SD1400600	SD1402600

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

Plan Sizes



Numbers indicate the maximum loading category recommended for each unit.
Loading category descriptions can be found in Marshalls Permeable Paving Design Guide.

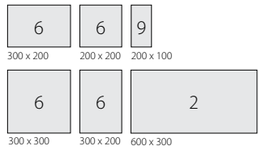


Myriad Priora, All Colours, Example

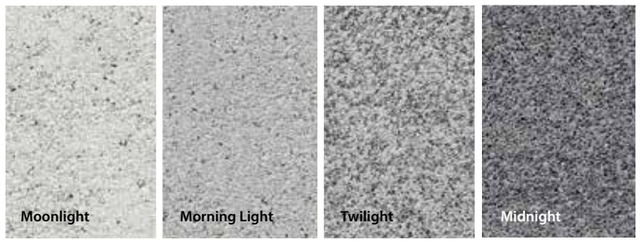
Thickness (mm)	Plan Size	Unit Weight (kg)	Pack Size (m²)	Pack Weight (kg)	Moonlight	Morning Light	Twilight	Midnight
80	200x100	3.7	7.56	1409	PV6636100	PV6634100	PV6632100	PV6630100
80	200x200	7.5	7.2	1342	PV6636200	PV6634200	PV6632200	PV6630200
80	200x300	11.2	7.2	1342	PV6636300	PV6634300	PV6632300	PV6630300
80	300x300	16.8	7.56	1409	PV6636700	PV6634700	PV6632700	PV6630700
80	300x600	33.6	7.56	1409	PV6636900	PV6634900	PV6632900	PV6630900

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

Plan Sizes



Numbers indicate the maximum loading category recommended for each unit.
Loading category descriptions can be found in Marshalls Permeable Paving Design Guide.



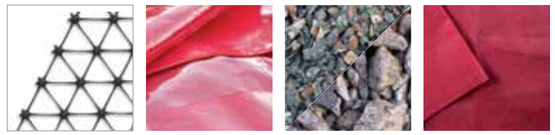
Myriad Priora

Permeable Block Paving System

The new Myriad Priora range offers multi-gauge, multi-size and multi-colour design options to landscape architects who require proven SuDS performance without compromising on striking aesthetics. The wide range of plan sizes and gauges can be mixed and matched or used individually to create a vast array of laying patterns, which are further enhanced by the complementary and sophisticated colourways featuring strikingly textured surfaces. The patented Priora nibs have been carefully placed on each block to allow laying in ANY combination and in ANY orientation.

In addition, during field tests undertaken in 2014, we have proven that the patented Marshalls Priora nib provides the surface with 40% more interlock than our standard block. This means that specifying Marshalls Priora blocks will bring long-term benefits in relation to pavement longevity and maintenance requirements - regardless of the intrinsic hydraulic benefits.

For use with the Marshalls range of sub-base components:



MG15 Grid | MM380 Tanking Membrane | Priora Aggregate | MT120 Filtration Textile

NBS Plus
Q24 115 Q24 119
Q24 117

CO_2 per m^2

For the latest carbon value visit
www.marshalls.co.uk/commercial/carbon-calculator

Installation	Thickness (mm)	Plan Size (mm)	Unit Weight (kg)	Pack Size (m^2)	Pack Weight (kg)	Silver Grey Item Code	Charcoal Item Code	Harvest Buff Item Code
Random Course	80	160 x 240	7.0	6.72	1246	**PV5726300**	**PV5728300**	PV5721500
		160 x 160	4.7	7.17	1168	**PV5726400**	PV5728400	
		160 x 120	3.5	6.72	1086	**PV5726350**	PV5728350	
Herringbone*	80	160 x 240	7.0	6.72	1246	**PV5739300**		

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.

*Where a herringbone laying pattern is specified, it is essential to order Herringbone Mistral Priora units which feature correctly placed nibs to ensure that full interlock is achieved. Attempts to lay standard large Mistral Priora units in a herringbone pattern will result in clashing nibs, wide joints and ultimately an unstable surface.

Plan Sizes

240 x 160 160 x 160 120 x 160

Numbers indicate the maximum loading category recommended for each unit.
Loading category descriptions can be found in Marshalls Permeable Paving Design Guide.


Charcoal


Harvest Buff


Silver Grey

Mistral Priora

Permeable Paving System

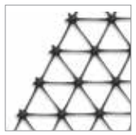
NO_x

A striking, contemporary surface option which offers excellent drainage without the need for drainage channels. The exposed granite aggregate in the textured surface catches the light to lend a sophisticated edge to modern urban landscapes. The patented Priora nib featured on the edge of each block ensures that the pavement provides maximum structural integrity as well as unsurpassed SuDS performance.

In addition, during field tests undertaken in 2014, we have proven that the patented Marshalls Priora nib provides the surface with 40% more interlock than our standard block. This means that specifying Marshalls Priora blocks will bring long-term benefits in relation to pavement longevity and maintenance requirements - regardless of the intrinsic hydraulic benefits.

NO_x *On request, this product can be manufactured using Noxer technology to improve the air quality in the area in which it is installed.*

For use with the Marshalls range of sub-base components:


MG15 Grid


MM380 Tanking Membrane

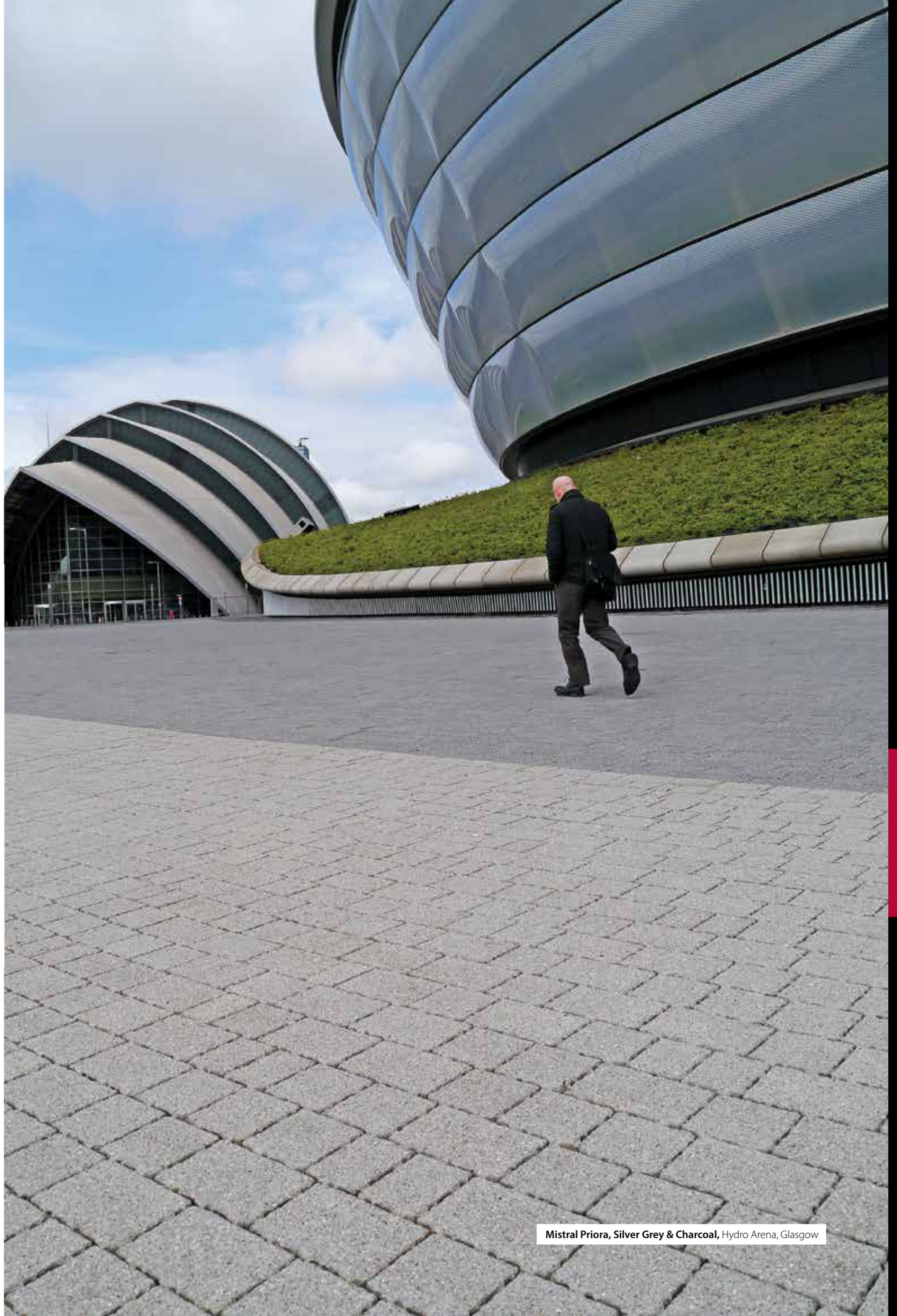

Priora Aggregate


MT120 Filtration Textile

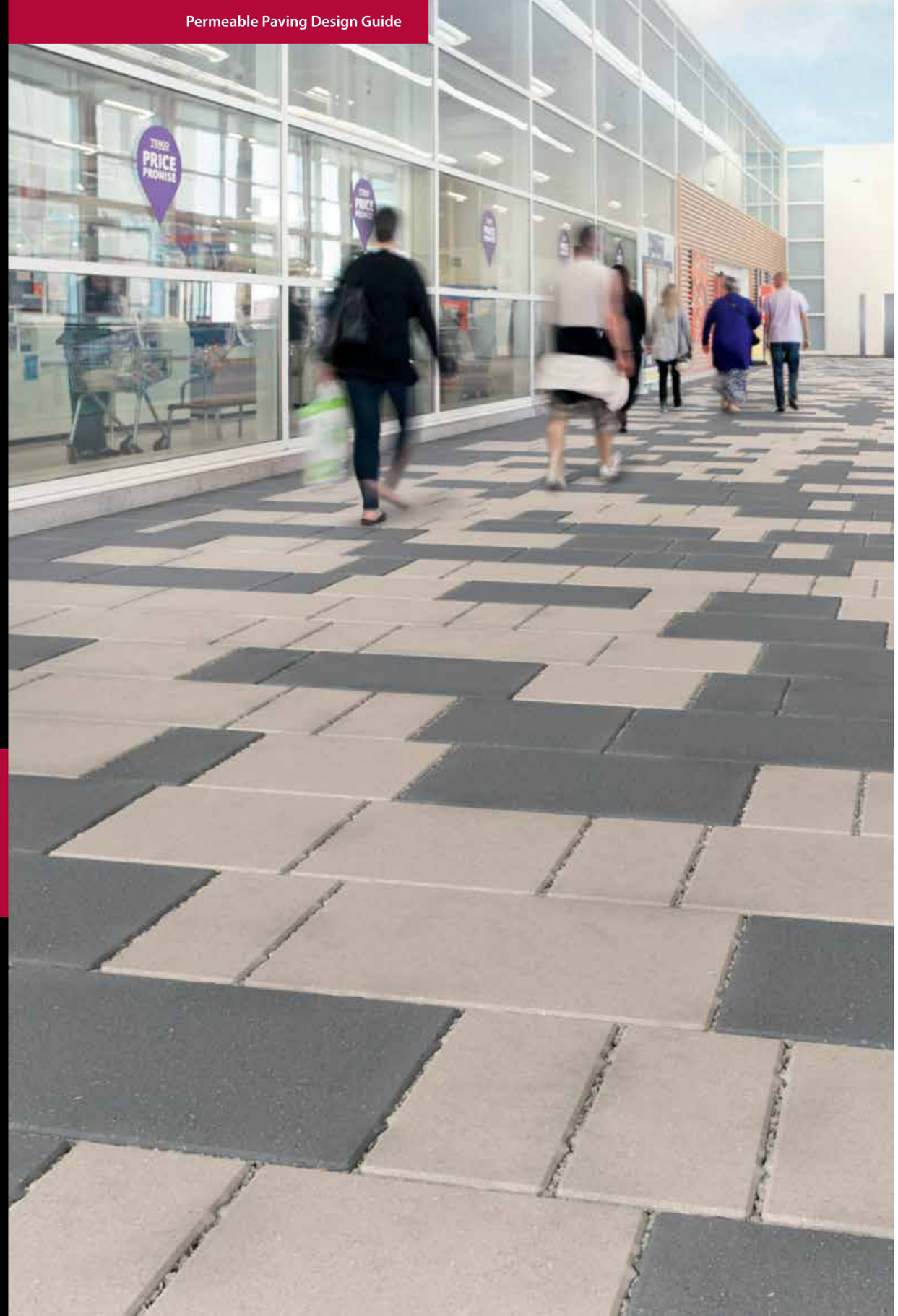
SSSPlus
Q24 115

kg
CO_2 per m^2

For the latest carbon value visit www.marshalls.co.uk/commercial/carbon-calculator


Mistral Priora, Silver Grey & Charcoal, Hydro Arena, Glasgow

Permeable Paving Design Guide
Permeable Paving
www.marshalls.co.uk/commercial



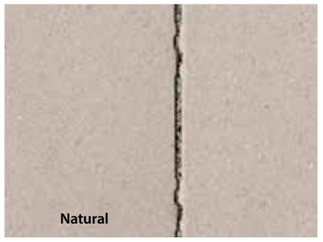
Thickness (mm)	Plan Size (mm)	Pack Size (m^2 approx)	Unit Weight (kg approx)	Pack Weight (kg approx)	Natural Item Code	Charcoal Item Code
65	200 x 400	6.4	11.96	957	**FL7440100**	**FL7440300**
65	400 x 400	7.68	23.92	1148	**FL7442100**	**FL7442300**
65	600 x 400	7.68	35.88	1148	**FL7444100**	**FL7444300**

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

Plan Sizes

200 x 400 400 x 400 600 x 300

Numbers indicate the maximum loading category recommended for each unit.
Loading category descriptions can be found in Marshalls Permeable Paving Design Guide.



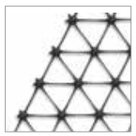
Priora Flag

Permeable Flag Paving System

NO_x

NO_x *On request, this product can be manufactured using Noxer technology to improve the air quality in the area in which it is installed. .*

For use with the Marshalls range of sub-base components:


MG15 Grid


MM380 Tanking Membrane


Priora Aggregate


MT120 Filtration Textile

NBSPlus
Q24 115 Q24 119
Q24 117

CO_2 per m^2

For the latest carbon value visit
www.marshalls.co.uk/commercial/carbon-calculator

Priora, the UK's best-selling permeable paving block, is now available in large plan flag sizes! Priora Flag offers designers real creative freedom, as the 3 sizes can be laid freely in either single size or multi-size random course patterns. The 2 complementary colours can be used either on their own, or mixed together to further extend the creative possibilities.

Priora Flag is ideal for pedestrianised areas but has been engineered and tested to withstand occasional loads upto 7.5 tonne.

In addition, during field tests undertaken in 2014, we have proven that the patented Marshalls Priora nib provides the surface with 40% more interlock than our standard block. This means that specifying Marshalls Priora will bring long-term benefits in relation to pavement longevity and maintenance requirements - regardless of the intrinsic hydraulic benefits.

Tegula Priora, Harvest, Swindon

Installation	Thickness (mm)	Plan Size (mm)	Unit Weight (kg)	Pack Size (m^2)	Pack Weight (kg)	Traditional Item Code	Burnt Ochre Item Code	Pennant Grey Item Code	Red/ Charcoal Item Code	Harvest Item Code
Random Course	60	160 x 240	5.3	9.6	1323	**PV3751160**		**PV3755160**		**PV3754160**
		160 x 160	3.5	8.96	1236	**PV3751200**		**PV3755200**		**PV3754200**
		160 x 120	2.7	9.6	1323	**PV3751230**		**PV3755230**		**PV3754230**
Random Course	80	160 x 240	7.0	7.68	1444	**PV6451160**	**PV6453160**	**PV6455160**	**PV6452160**	**PV6454160**
		160 x 160	4.7	7.16	1347	**PV6451200**	PV6453200	**PV6455200**	PV6452200	**PV6454200**
		160 x 120	3.5	7.68	1444	**PV6451230**	PV6453230	**PV6455230**	PV6452230	**PV6454230**
Herringbone*	80	160 x 240	7.0	7.68	1444	**PV6461160**	**PV6463160**	**PV6465160**	PV6462160	**PV6464160**

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

*Where a herringbone laying pattern is specified, it is essential to order Herringbone Tegula Priora units which feature correctly placed nibs to ensure that full interlock is achieved. Attempts to lay standard large Tegula Priora units in a herringbone pattern will result in clashing nibs, wide joints and ultimately an unstable surface.

Plan Sizes

Numbers indicate the maximum loading category recommended for each unit.
Loading category descriptions can be found in Marshalls Permeable Paving Design Guide.

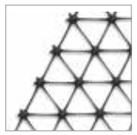
Tegula Priora

Permeable Paving System

A lightly weathered, multi-size, SuDS-compliant surfacing solution, ideal for use in rural, rustic projects. The traditional sizes create a classically British aesthetic that suits civic and residential developments alike. Each unit features the unique, patented Priora nib which ensures that surface water drains straight into the specially prepared sub-base, leaving the paved area clean, safe and puddle-free.

In addition, during field tests undertaken in 2014, we have proven that the patented Marshalls Priora nib provides the surface with 40% more interlock than our standard block. This means that specifying Marshalls Priora blocks will bring long-term benefits in relation to pavement longevity and maintenance requirements - regardless of the intrinsic hydraulic benefits.

For use with the Marshalls range of sub-base components:


MG15 Grid


MM380 Tanking Membrane


Priora Aggregate


MT120 Filtration Textile

NBS Plus
Q24 115

CO_2 per m^2

For the latest carbon value visit www.marshalls.co.uk/commercial/carbon-calculator

Olde Priora, Bracken & Brindle, Sherborne Road, Crewe

Olde Priora

Permeable Paving System

NO_x


Brindle


Burnt Ochre


Bracken


Charcoal

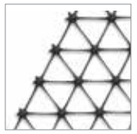

Natural*

A lightly weathered concrete block unit which marries the tried and trusted SuDS performance of Priora with a more rustic aesthetic. The softer visual impression provided by the lightly worn edges of the blocks works particularly well in countryside settings. Olde Priora's popular block size allow a variety of laying patterns which support all loading requirements from light domestic use right up to heavy duty industrial.

In addition, during field tests undertaken in 2014, we have proven that the patented Marshalls Priora nib provides the surface with 40% more interlock than our standard block. This means that specifying Marshalls Priora blocks will bring long-term benefits in relation to pavement longevity and maintenance requirements - regardless of the intrinsic hydraulic benefits.

NO_x *On request, this product can be manufactured using Noxer technology to improve the air quality in the area in which it is installed.*

For use with the Marshalls range of sub-base components:


MG15 Grid


MM380 Tanking Membrane


Priora Aggregate


MT120 Filtration Textile

NSS Plus
Q24 115

CO_2 per m^2

For the latest carbon value visit
www.marshalls.co.uk/commercial/carbon-calculator

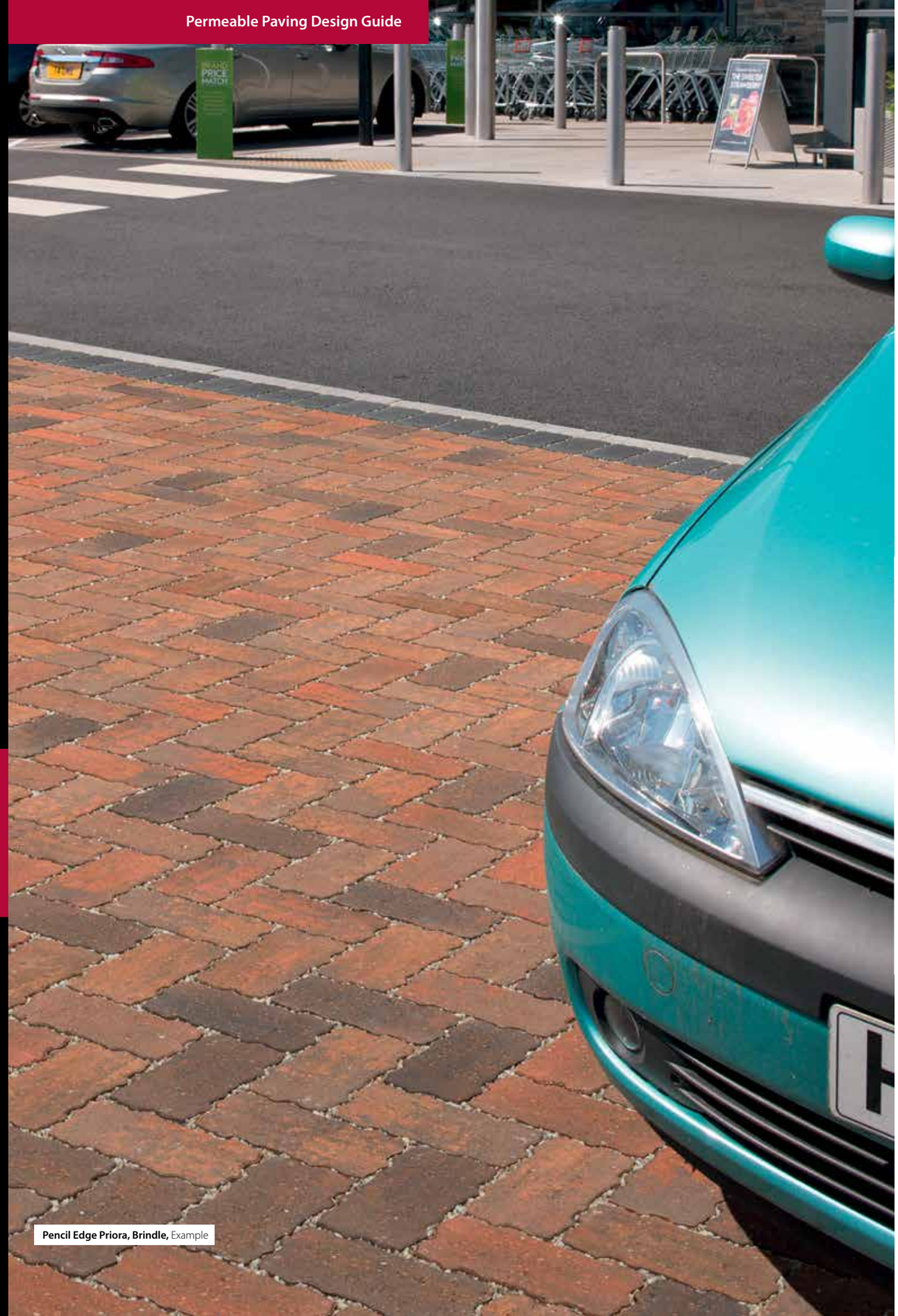
Thickness (mm)	Plan Size (mm)	Unit Weight (kg)	Pack Size (m^2)	Pack Weight (kg)	Brindle Item Code	Burnt Ochre Item Code	Bracken Item Code	Charcoal Item Code	Natural Item Code
80	200 x 100	3.4	7.92	1347	PV6521750	PV6522000	PV6522250	PV6520500	PV6520250

Olde Priora with reference numbers indicated in light black 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.

Plan Sizes

9
200 x 100

Numbers indicate the maximum loading category recommended for each unit.
Loading category descriptions can be found in Marshalls Permeable Paving Design Guide.



Pencil Edge Priora, Brindle, Example

Thickness (mm)	Plan Size (mm)	Unit Weight (kg approx)	Pack Size (m^2 approx)	Pack Weight (kg approx)	Brindle Item Code	Burnt Ochre Item Code	Bracken Item Code	Charcoal Item Code	Natural Item Code	Red Item Code	Buff Item Code
80	200 x 100	3.4	6.16	1040	**PV6571750**	PV6572000	PV6572250	**PV6570500**	PV6570250	PV6571500	PV6570750

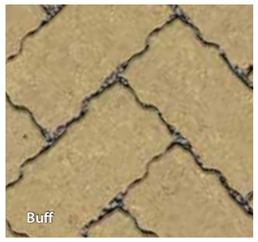
Pencil Priora Edge with reference numbers indicated in **bold** black are available ex-stock.
Pencil Priora Edge with reference numbers indicated in light black are manufactured to order. Contact our sales office to discuss your requirements.
*Natural products are manufactured from aggregates sourced locally to the works and contain no pigmentation, therefore colour variation between products from different works is possible.

Plan Sizes

9
200 x 100

Numbers indicate the maximum loading category recommended for each unit.
Loading category descriptions can be found in Marshalls Permeable Paving Design Guide.


Brindle


Buff


Charcoal


Burnt Ochre


Red


Natural*


Bracken

Pencil Edge Priora

Permeable Paving System

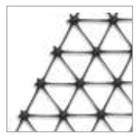
NO_x

This Priora variety has been developed to minimise vibration and surface noise for wheeled traffic, making it ideal for car parks and cycleways. The chamfer on the edge of the block has been eradicated to provide a smooth, flat surface while still featuring the patented Priora nib.

In addition, during field tests undertaken in 2014, we have proven that the patented Marshalls Priora nib provides the surface with 40% more interlock than our standard block. This means that specifying Marshalls Priora blocks will bring long-term benefits in relation to pavement longevity and maintenance requirements - regardless of the intrinsic hydraulic benefits.

NO_x *On request, this product can be manufactured using Noxer technology to improve the air quality in the area in which it is installed.*

For use with the Marshalls range of sub-base components:


MG15 Grid


MM380 Tanking Membrane


Priora Aggregate


MT120 Filtration Textile

NBS Plus
Q24 115

kg
CO_2 per m^2

For the latest carbon value visit
www.marshalls.co.uk/commercial/carbon-calculator

Permeable Paving
www.marshalls.co.uk/commercial

Priora, Charcoal, Cowbridge

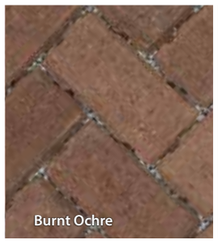
Priora

Permeable Paving System

MACHINE LAY

NO_x

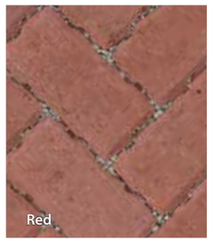

Brindle


Burnt Ochre


Bracken

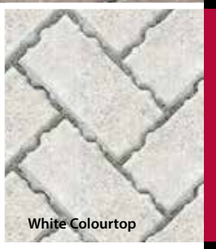

Charcoal


Natural*


Red


Marigold


Buff


White Colourtop

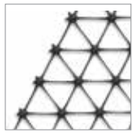
The best-selling permeable paving system in the UK marries superb SuDS performance with a hard wearing, heavy load bearing, attractive block paved surface. Already used in a vast range of applications from industrial to residential, Priora offers a classic aesthetic for all requirements whilst simultaneously helping to alleviate the triple threat of flood, drought and pollution. The unique, patented nib on the edge of each block has been proven in extensive testing over more than 14 years.

In addition, during field tests undertaken in 2014, we have proven that the patented Marshalls Priora nib provides the surface with 40% more interlock than our standard block. This means that specifying Marshalls Priora blocks will bring long-term benefits in relation to pavement longevity and maintenance requirements - regardless of the intrinsic hydraulic benefits.

This product is available in special machine lay formation packs. This makes automated installation easy, saving time and improving health and safety on large jobs.

NO_x *On request, this product can be manufactured using Noxer technology to improve the air quality in the area in which it is installed.*

For use with the Marshalls range of sub-base components:


MG15 Grid


MM380 Tanking Membrane


Priora Aggregate


MT120 Filtration Textile

NSS Plus
Q24 115

kg
CO_2 per m^2

For the latest carbon value visit www.marshalls.co.uk/commercial/carbon-calculator

Installation	Thickness (mm)	Plan Size (mm)	Unit Weight (kg)	Pack Size (m^2)	Pack Weight (kg)	Brindle Item Code	Burnt Ochre Item Code	Bracken Item Code	Charcoal Item Code	Natural Item Code	Red Item Code	Marigold Item Code	Buff Item Code	White Colourtop Item Code	Yellow Colourtop Item Code
	60	200 x 100	3.4	8.08	1080	**PV3801750**	**PV3802000**	**PV3802250**	**PV3800500**	**PV3800250**	**PV3801500**		**PV3800750**		
	60	200 x 100	3.4	4	493									PV3814200	
	80	200 x 100	3.4	6.16	1040	**PV6501750**	**PV6502000**	**PV6502250**	**PV6500500**	**PV6500250**	**PV6501500**		**PV6500750**		
	80	200 x 100	3.4	4	675									**PV6514200**	PV6514300
45 degree ML	80	200 x 100	3.4	7.68	1310		PV6532000	PV6532250	PV6530500		PV6531500	PV6531000	PV6530750		
90 degree ML	80	200 x 100	3.4	7.92	1510						PV6531510	PV6531010	PV6530760		
Half Blocks ML	80	100 x 100	1.7	4.62	880			PV6542250			PV6541500	PV6541000	PV6540750		

Priora with reference numbers indicated in bold black are available ex-stock.
Priora with reference numbers indicated in light black 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.

Plan Sizes

9
200 x 100

Numbers indicate the maximum loading category recommended for each unit.
Loading category descriptions can be found in Marshalls Permeable Paving Design Guide.

Permeable Paving Design Guide
Permeable Paving
www.marshalls.co.uk/commercial

MG15 Grid

MG15 Grid Installation

Technical Specification

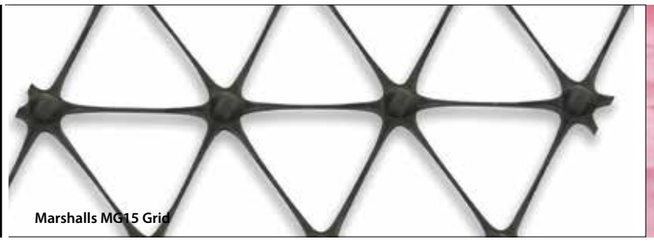
Property	Value
Rib Shape	Rectangular
Aperture Shape	Triangular
Open Area Aspect Ratio	>85%
Junction Efficiency	>90%
Resistance of Chemical Degradation	96%
Resistance to Weathering	98%
Resistance to Oxidisation	90%

	Dimensions	Item Code
MG15 Grid (roll)	50m x 4m (200m²)	**PV9701400**

Marshalls MG15 Grid is available ex-stock

MG15 Grid

For stabilising the sub-base of a Priora permeable pavement



Marshalls MG15 Grid

A special grade of GeoGrid that has been developed with the UK's market leading grid supplier to provide additional stability to the sub-base of a Priora permeable pavement. Installed directly over the sub-grade, the voids in MG15 Grid are the ideal size and shape to interlock with Priora aggregate, confining movement and improving the CBR of the ground by 1% - which can, in some conditions, reduce the depth of the sub-base, saving time and money.

NSSPlus
Q24 117
Q24 119

MM380 Tanking Membrane Installation, Leeds

MM380 Tanking Membrane

"Top Hat" Outfall

MM380 Tanking Membrane

MM380 Tanking Membrane

For Type C Priora Permeable Pavements

Technical Specification

Characteristic	Value or Statement	Units	Compliance Criteria	Test Method
Length	20	m	-0% / +10%	EN 1848-2
Width	4	m	+/- 2.5%	EN 1848-2
Thickness	0.38	mm	+/- 10%	EN 1849-2
Mass	395	g/m²	+/- 12%	EN 1849-2
Resistance to impact	30	mm/diameter	>MLV	EN 12691
Resistance to tearing	185 185	N	MDV	EN 12310-1
Tensile strength	24.2 20.7	N/50mm	MDV	EN 12311-1

	Dimensions	Item Code
MM380 Tanking Membrane (roll)	20m x 4m (80m²)	**DYPV9701000**
Top Hat including Clip	110mm	**DYPV9701100**
Top Hat including Clip	160mm	**DYPV9701200**
Jointing Tape (roll)	15m x 100mm	**DYPV9701300**

All Marshalls Membrane Products and Ancillaries are available ex-stock

An impermeable tanking membrane that has been developed exclusively for use within Type C (non-infiltration) Priora permeable pavements. While thinner and lighter than most commonly used alternatives, MM380 demonstrates superior strength and puncture resistance, which ensures that angular Priora aggregate will not compromise the integrity of your watertight system.

NSSPlus
Q24 119


MT120 Filtration Textile Installation


6mm Marshalls Priora laying course aggregate

MT120 Filtration Textile

To both improve water quality and provide a seperation layer within a Priora system


MT120 Filtration Textile

Marshalls' unique grade of Geotextile material can be included in Priora sub-bases to maximise water cleansing performance. Supplied in practical parking-bay sized rolls, MT120 is easy to roll out and cut allowing for fast installation.

Install directly above the subgrade on all Type A (infiltration) and Type B (partial infiltration) systems to prevent aggregate migration. In all systems an upper layer can also be installed directly beneath the laying course in order to maximise water quality.

	Dimensions	Item Code
MT120 Textile	5.4m x 100m (540m²)	**PV9702500**

Technical Specification

Characteristic	Value	Units	Test Method
Length	100	m	For Guidance
Width	5.4	m	For Guidance
Roll Weight	65	kg	For Guidance
Thickness	1.0	mm	BS EN ISO 12956
Static Puncture Strength (CBR)	1800	N	BS EN ISO 12236
Tensile Elongation	45	%	BS EN ISO 10319
Mass per unit area	120	GSM	BS EN ISO 9864
Water flow	120	l/sm²	BS EN ISO 11058
Air Permeability	719	l/sm²	ISO 9237:1995

MT120 Filtration Textile is available ex-stock

NBSPlus
Q24 115 Q24 119
Q24 117


6mm Marshalls Priora laying course/jointing aggregate•


20mm Marshalls Priora sub-base aggregate*

Priora Aggregates

To provide the ideal sub-base for Priora permeable pavements

In a Priora permeable system, what's underneath the surface is as important as the blocks themselves. Marshalls' nationally sourced, carefully specified grade of aggregate has been selected because of its superior void ratio and maximum internal angle of friction – which ensures that your permeable pavement will perform both structurally and hydraulically. Sourced from quarries all over the UK to minimise the carbon footprint of your job. 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.

NBSPlus
Q24 10 Q25 125
Q24 112 Q25 220
Q24 113 Q25 315
Q25 120

*Please note that because aggregate is sourced from a national network of suppliers, the colour and texture may differ from the aggregate in the image shown here.

Types of Permeable Paved Systems

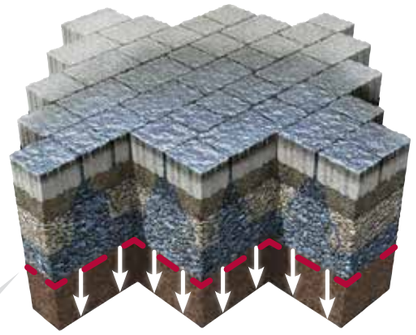
A Priora permeable system can be installed onto the vast majority of ground types in the UK. However, there are three different types of permeable system, which differ largely in the way that the attenuated water is released.

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.

Zero Discharge

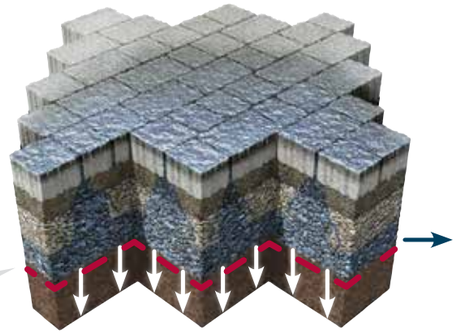


New Marshalls MT120 Filtration Textile
– see page 48 for details

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.

Some Discharge

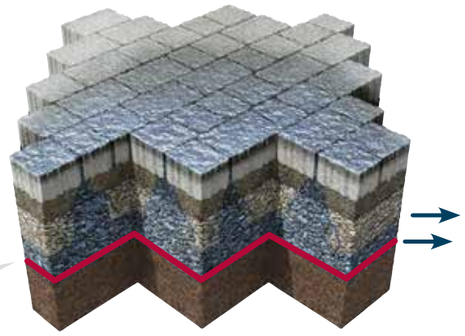


New Marshalls MT120 Filtration Textile
– see page 48 for details

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 MM380 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.

Total Discharge



New Marshalls MM380 Tanking Membrane
– see page 47 for details

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.

Type B systems are the middle ground for infiltration rates that are quite low (ie the half drain time is between 24 and 48 hours). In these cases the rain water from a previous storm may still be clearing through the system as the next storm begins and so an outfall is added to the system to reduce the drain time.

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 I

		System A Total Infiltration	**System B** Partial Infiltration	**System C** No Infiltration
Permeability of subgrade (m/s)	better than 10^{-6}	✔	✔	✔
	between 10^{-6} & 10^{-8}	✘	✔	✔
	worse than 10^{-8}	✘	✘	✔
High ground water table (within 1000mm of finished formation)		✘	✘	✔
Pollutants present in subgrade		✘	✘	✔

What type of soil do I have?

The two soil related variables within a permeable paving design are the permeablility 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.

A BRE Digest 365 soil test will determine the permeability of the soil.

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.

Finite element analysis desktop study

Full scale testing at NUROLF

How to Design a Priora Sub-Base

Worked example on page 58

1. Calculate sub-base composition based on **loading** requirements

Establish traffic loading from Table II, page 54

Determine Priora sub-base depths and specification from Table III, page 54

Determine subgrade strength and requirement for subgrade improvement via a capping layer from Table V, page 56

Consider site traffic

2. Calculate sub-base composition based on **hydraulic** requirements

Determine site location and storm return period

Establish what Type of Priora pavement (Type A, B or C) from soil infiltration data Table I, page 50

Determine hydraulic design parameters for site location and storm return period allowing for the effects of climate change

Determine depth of Priora sub-base from Table VI, page 57

3. Having calculated two different designs for both structural and hydraulic requirements, your final Priora Design will be the higher of the two results.

Structural Design for Priora Pavements

Stage One – Determination of Traffic Loading Category

Levels of traffic loading need to be assessed so that the pavement can be placed into one of nine load categories as shown in the table below:

Table II

Load Category	Traffic Type	Anticipated Axle Load (kg)
1	Domestic (GVW=2,000kg)	1000
2	Cars & Light Vans (GVW=3,500kg)	2000
3	Light Commercial (GVW 7,500 kg)	2000
4	Emergency large goods vehicles only (100 Standard axles)	8000
5	One large goods vehicle per week (0.015msa)	8000
6	Ten large goods vehicle per week (0.15msa)	8000
7	100 large goods vehicles per week (1.5msa)	8000
8	1.5 to 4 msa	8000
9	4 to 8 msa	8000
10	1,000 large goods vehicles per week (15msa)	8000
11	Heavy Duty Pavements for Ports or similar	DOA

Stage Two – Determination of Sub-Base Depth

The structural depth and specification of the sub-base is then determined from the table below:

Table III

Load Category	DBM Thickness (mm)	Alternative HBM Thickness (mm)	OGCR Sub-base Thickness (mm)
1	--	--	150
2	--	--	200
3	--	--	275
4	--	--	300
5	70	100	150
6	90	125	150
7	115	175	150
8	200	275	150
9	200	275	150
10	200	275	150
11	DOA	DOA	150

Structural Design for Priora Pavements

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 a 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.

1. Soil classification
2. Moisture content in percent.
3. Soaked CBR

The table below, using the Unified Soil Classification System (USCS), shows typical ranges of Californian Bearing Ratio (CBR) that can be expected although CBR values should be established using soil investigation techniques.

Table IV

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

If the subgrade CBR is 5% or greater, the sub-base can be installed without any capping layers. 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.

Structural Design for Priora Pavements

Table of Capping Layer Thickness

Table V

Subgrade CBR Value	Capping Layer Thickness Type A & B Systems (mm)		Capping Layer Thickness Type C Systems (mm)			
	Open Graded Crushed Rock		Open Graded Crushed Rock or MOT Type 1		Capping Material	
	Without MG15 Grid	With MG15 Grid	Without MG15 Grid	With MG15 Grid	Without MG15 Grid	With MG15 Grid
5%	--	--	--	--	--	--
4%	100	--	100	--	150	--
3%	125	100	125	100	225	150
2%	175	125	175	125	350	225
1%	300	175	300	175	600	350

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 on page 59.

Marshalls MG15 Grid confines individual elements of Priora aggregate, which stabilises the pavement structure. Placing the MG15 Grid at the interface of the subgrade and the capping layer has the effect of improving the CBR by 1%. This can reduce the depth of the structure which either provides a financial saving, or in places where excavation depths are limited, can make a permeable pavement a viable option where it wasn't previously. Note that hydraulic considerations should still be taken into account.

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 61.

Hydraulic Design for Priora Pavements

Hydraulic requirements are frequently calculated using modelling software such as Micro Drainage's Win*Des*® (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 VI

Sub-base Depth (mm)				
M5-60	r	1 in 30 year storm	1 in 100 year storm	1 in 100 year storm + 30%
20	0.4	120	160	210
20	0.3	140	190	250
20	0.2	180	250	330
19	0.4	110	150	200
19	0.3	130	180	230
19	0.2	170	240	310
18	0.4	100	140	180
18	0.3	120	170	220
18	0.2	160	220	290
17	0.4	100	130	170
17	0.3	110	160	210
17	0.2	150	210	270
16	0.4	100	120	160
16	0.3	100	150	200
16	0.2	140	200	260
15	0.4	100	110	140
15	0.3	100	140	180
15	0.2	120	180	230
14	0.4	100	100	130
14	0.3	100	130	170
14	0.2	110	170	220

M5-60 is the anticipated rainfall for a storm of 60-minute duration that is likely to occur once in 5 years.
"r" is the ration 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	2. Calculate sub-base composition based on hydraulic requirements
Traffic loading is assumed as one HGV (dust cart) per week which is loading category 5. See Table II, page 54	Storm return period -- 1 in 100 years (plus 30% for climate change). Site location – Greater Manchester
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	Subgrade permeability – 1.0 x 10-9 m/s A Type C system will be chosen as the soil permeability is low; MM380 Tanking Membrane will be located below the pavement
A capping layer depth of 225mm is taken from Table V, page 56	From the Wallingford Procedure document for a site in Manchester M5-60 = 18mm, r = 0.4
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 57 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. If 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:

80mm Priora

50mm Bedding Layer

70mm DBM

170mm Open Graded Crushed Rock (150mm + 20mm)

Impermeable Membrane

330mm Type 1 Capping Layer (350mm – 20mm)

Subgrade

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.

MM380 Tanking Membrane

Marshalls MM380 Tanking Membraneis manufactured from a unique polymer blend to create the ideal material for tanking a non-infiltration ("Type C") permeable pavement. It is stronger than the market leading impermeable membrane. It is also thinner and lighter, making it easier to transport, handle and roll out. It comes double folded to minimise storage requirements.

Should you require specialist advice regarding, for example, gas permeability or radon barriers, please speak to you local Marshalls engineer who will work up an appropriate solution according to your specific requirements.

nb: Marshalls has not tested any other impermeable membrane option within its sub-base designs. Using an alternative impermeable membrane will invalidate the Marshalls design warranty.

MG15 Grid

Marshalls MG15 Gridhas been developed with the UK's market leader to provide optimal performance within a Priora sub-base. The apertures on the grid are the optimal size for 20mm Priora aggregate to interlock with, and the rectangular profile of the ribs maximise interlock with the broken faces of the Priora aggregate.

The Marshalls team will be happy to provide designs both with and without MG15 Grid, and discuss options with you to ensure that you receive the best installation advice for your project.

nb: Marshalls has not tested any other geogrid option within its sub-base designs. Using an alternative geogrid will invalidate the Marshalls design warranty.

MT120 Filtration Textile

Marshalls MT120 Filtration Textile has been developed to both maximise the cleansing properties of the Priora system and to provide a separation layer preventing aggregate migration between sub-base components. It should be installed directly above the subgrade in all Type A (infiltration) and & Type B (partial infiltration) systems, and when specified it can also be included directly below the laying course in all system types in order to improve the quality of water that flows through it.

nb: Marshalls has not tested any other geotextile option within its sub-base designs. Using an alternative geotextile will invalidate the Marshalls Design Warranty.

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 should 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.

Materials

Providing the above criteria are met, the OGCR or OGCG sub-base material will have a porosity of at least 0.32 and offer a storage capacity in its voids typically of 30% to 40%. A 40% void space means that the volume of the OGCR or OGCG sub-base will need to be 2.5 times the volume of the water stored. The infiltration rate through 20mm graded crushed rock sub-base is over 70,000 litres/hectare/sec and this should be compared with the required value of 180 litres/hectare/sec.

In addition, the material should meet the grading requirements as shown in Table VII.

Due to the relationship between the grading curve of the OGCR or OGCG sub-base material and the laying course material, a geotextile between these layers may not necessarily be required.

As the OGCR is also a structural element of the pavement the stone itself must be able to withstand the loadings over the life of the pavement, to enable this there are minimum physical properties the aggregates should reach (Table VIII).

OGCR and OGCG Sub-base Gradings

Table VII

Grading Requirements	
Recommended BS EN 12620 aggregate grading (mm)	4/20
Recommended BS EN 12620 grading / tolerance category	Gc80/20 GTc20/15

Table VIII

Grading Details	
Sieve size (mm)	Percentage by mass passing ISO 565 sieve
31.5	98 to 100
20	90 to 99
14	
10	25 to 70
6.3	
4	0 to15
3.15	
2	0 to 5

OGCR and OGCG Physical Properties

Table IX

Properties	Category to BS EN 13242 or BS 12620
Grading	4/20 (preferred) or 4/40, Gc 85-15, GTc 20/17.5
Fines Content	f4
Shape	FI_{20}
Resistance to Fragmentation	LA_{30}
Internal Angle of Friction	40˚
Durability: Water absorption to BS EN 1097-6:2000+A1:2005, Clause 7 – for WA>2% - Magnesium sulphate soundness.	$WA_{24}2$ MS_{18}
Resistance to wear	$M_{DE}20$
Acid Soluble sulphate content: -aggregates other than air cooled blast furnace slag and -air cooled blast furnace slag	$AS_{0.2}$ $AS_{0.1}$
Total Sulphur: -aggregates other than air cooled blast furnace slag and -air cooled blast furnace slag	≤1% by mass ≤2% by mass
Volume stability of blast furnace and steel slags: air cooled blast furnace slag -steel slag	Free from dicalcium silicate and iron disintegration in accordance with BS EN 13242:2002+A1:2007, 6.4.2.2. V_5
Leaching of contaminants	Blast furnace slag and other recycled materials should meet the requirements of the Environment Agency "Waste Acceptance Criteria" A) for inert waste when tested in accordance with BS EN 12457-3
A) Guidance on waste acceptance criteria for inert waste is given in the Environment Agency's Guidance for waste destined for disposal in landfills	

Should an alternative sub-base material be proposed, the material should at least achieve if not exceed the performance requirements of the OGCR or OGCG discussed above and any restrictions imposed by the Environment Agency or relevant party. It will be the responsibility of the proposer to prove the suitability of the alternative material and provide any necessary confirmations.

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 BSEN 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.

Aggregates 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

Sieve size (mm)	Percentage Passing %
40	100
31.5	98-100
20	90-99
10	25-70
4	0-15
2	0-5

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 mm^2.

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.

The Priora Laying Course should be graded as below:

Table XI

Laying Course Grading	
Recommended BS EN 12620 aggregate grading (mm)	2/6.3
Recommended BS EN 12620 grading / tolerance category	Gc80/20

Table XII

Grading Details	
Sieve size (mm)	Percentage by mass passing ISO 565 sieve
31.5	
20	
14	100
10	98 to 100
6.3	80 to 99
4	
2	0 to 20
1	0 to 5
0.063	0 to 2

BS 7533-13:2009 states that only the grading of the laying course should be tested, as it is not possible to test to the same physical properties of the sub-base aggregate but the source material of the 2-6.3mm should achieve the same values.

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, Olde Priora, Pencil Edge Priora, La Linia Priora, Myriad Priora, Conservation Priora and Priora Flag concrete block or flag paving of 60mm, 65mm and 80mm nominal thickness, are manufactured in accordance with BS EN1338: 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**

Marshalls recommend that all installers produce site specific health and safety Risk Assessment and Method Statement for all projects.

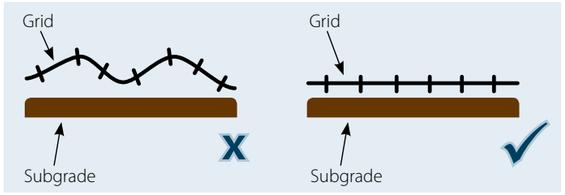
Installation

1. Excavation

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

2. MG15 GridInstallation (if required)

Roll out Marshalls MG15 Grid onto the subgrade, overlapping ends and edges by 30cm. Care should be taken to ensure that the Grid is NOT UNDER COMPRESSION when laid. If possible, put the Grid UNDER TENSION (peg it out and pull it taught) as it is laid.It



may be useful to weigh down ends and edges of MG15 Gridto prevent it from rolling back up. Cut away excess with a sharp knife or scissors.

MG15 Grid Maintenance: It may occasionally be necessary to perform repairs to MG15 Grid, or remove a section to access services etc. In these instances:

Excavate the sub-base material to an area of 50cm around the edge of the area to be removed. Cut away the required area of MG15 Grid, following the line of the ribs. Replace the subgrade to the correct level beneath the cutaway section. Apply a section of MG15 Grid large enough to cover the removed section and also provide a 30cm overlap all the way around. Ensure that the replacement section is not under compression. Carefully replace the sub-base aggregate

3. 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 MM380 Tanking Membraneshould be placed at the invert of the capping layer.

Marshalls MM380 Membrane: As a rule of thumb, order a quantity of MM380 Tanking Membraneequivalent to the surface area of the job plus 30% (to account for overlaps, wastage and cuts). Rolls of MM380 should be rolled out and unfolded over the required area, overlapped by 30cm, and jointed using Marshalls Jointing Tape. In situations where leakage is unacceptable (for example, on contaminated ground), welding of the joints can be arranged. Please speak to your Marshalls engineer who can put you in touch with a local welding crew. One piece "top hat" units should be installed around outfalls to prevent leakages – installation instructions are provided with each unit.

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 1m^2 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.

Priora Permeable Pavement Installation

4. 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 blinding 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.

5. 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.

6. 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.

7. Install DBM Layer (if required)

A DBM (Dense Bitumen Macadam) layer is sometimes included in the pavement design to provide additional structural support. This is usually wet poured on site, and once set, punctured or drilled at regular intervals to ensure that water can permeate the layer.

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.

See page 61 for puncturing specification.

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.

8. Install MT120 Filtration Textile (if required)

Independent testing at Coventry University demonstrates that Marshalls MT120 Filtration Textile maximises the water cleansing properties of a Priora system, improving water quality by in excess of 7%. On sites where water quality is paramount the inclusion of MT120 will provide maximum cleansing.

To install, roll out the textile on top of the previous subgrade layer (either DBM or sub-base aggregate) prior to installing the laying course aggregate. Edges should be overlapped by 300mm. No jointing is required. Care should be taken to remove wrinkles from the laid textile, and to ensure that the laid textile is not under tension when the laying course aggregate is installed.

Priora Permeable Pavement Installation

9. 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 blocks in-situ.

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.

10.1 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.

Compaction

Compaction should be undertaken with a plate vibrator, conforming to the requirements of Annex F of BS 7533-3:2005+A1:2009.

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.

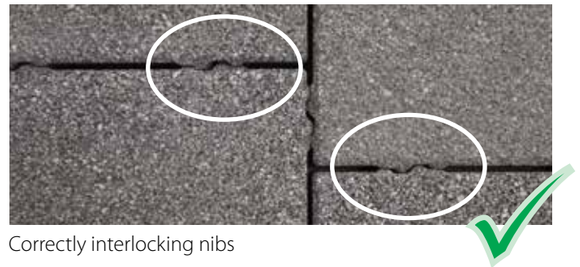
Blocks should be cut such that the resultant joint width remains within the 2 – 6mm tolerance. When laying to tight curves it may not always be possible to maintain a maximum 6mm joint, in which case, cut or special shaped units may have to be considered.

10.2 Install Conservation Priora or Priora Flag

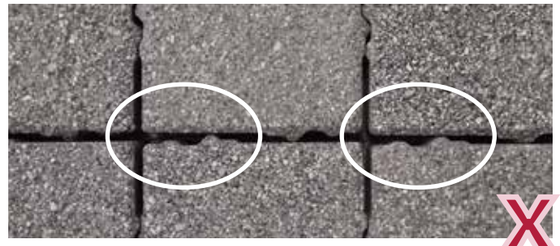
Laying flag sized Priora units largely follows the same process as laying Priora blocks. However, there are three key points which the installer must consider:

1. **Lifting:** the large (600x400mm) flags weigh over 35kg, as with all manual handling a specific risk assessment should be conducted prior to any lifting. Vacuum lifters can be used with this product should their requirement be identified by the risk assessment. Advice on these can be sought from lifting equipment specialists.
2. **Nib placement:** It is ESSENTIAL that the nibs on Priora flags are aligned. If they're not, the surface may not perform and the correct laying pattern will not be achieved.

Note that correct nib placement will always result in a staggered edge to the paving design.



Correctly interlocking nibs



No interlock between some nibs - incorrectly laid

3. **Medium (400x400mm) Flag alignment:**
   the medium (square) flag can be laid in two orientations. To ensure correct placement:

   a. In RANDOM COURSE surfaces: always start an installation with a SMALL or LARGE unit. As long as the installer ensures that the Priora nibs interlock on all subsequent flags, the correct orientation of the medium flags will be obvious.

   b. In SINGLE MEDIUM PLAN SIZE surfaces: lay two medium size flags next to each other and examine the nib placement. Ensure that both flags are oriented in the same way, and then butt the flags together ensuring that the nibs achieve full interlock. Ensure that the straight edge is in the required direction.

The Benefits of a Mechanical Installation

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

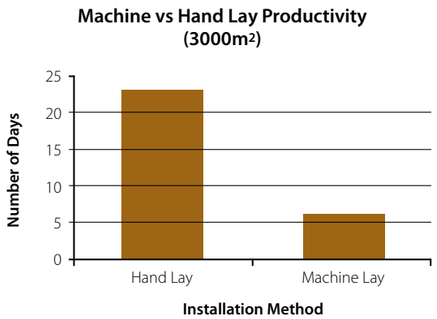
Marshalls Machine Lay automates all of the processes involved in a Marshalls Priora installation:

- **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:

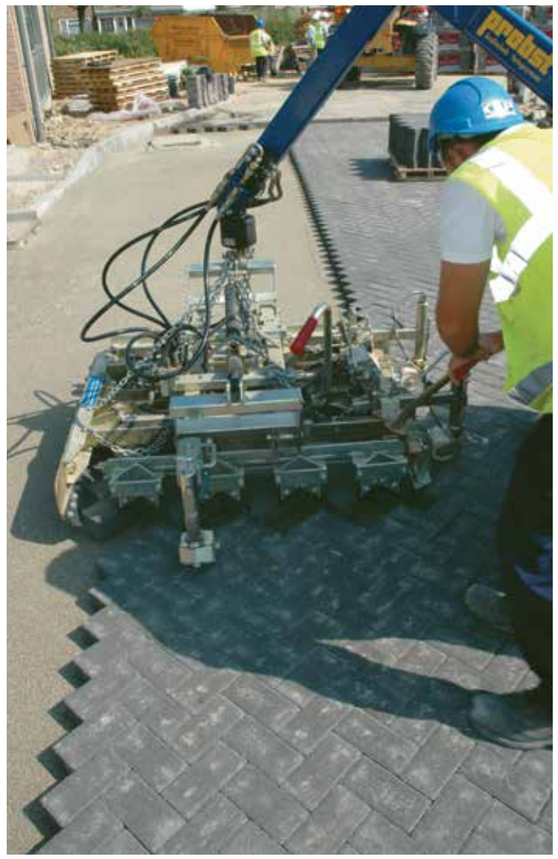
A six man team, over an eight hour day, might anticipate installing approximately 250m² (incorporating screed, installation, compaction and filling joints).

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



Marshalls Priora ML blocks are manufactured in unique machine-in-stallable layers within the pack and are installed on-site by a powered ride-on machine.


Installation of Marshalls ML Products



The Machine Lay Installation Process

- Reduces manual installation
- Reduces manual sweeping
- Assists in speeding up the overall installation programme

1. Laying Course

- Plant attachments or adapted plant, installs the 6mmm 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.

A Guide To Maintenance

Marshalls Priora: Maintenance

Maintaining your Marshalls Priora Permeable Paving System is easy: simply ensure that the voids between the blocks don't get blocked and prevent water from flowing through the surface and into the sub-base.

However, it's important to remember that even if the voids do appear to be blocked, it's unlikely to stop the system working. This is because the voids on a Marshalls Priora surface are far wider than they need to be – so blocked voids are likely to only slow the flow of water, not stop it completely.

A Marshalls Priora surface made of 200mmx100mm blocks provides infiltration rates in excess of 18,000 litres per second per hectare (l/s/h). The average rainfall event in the UK provides flow at approximately 180 l/s/h. Independent research in 2006 by Soenke Borgwardt concluded that after 10 years, with absolutely zero maintenance, a permeable pavement might be reduced to 10% of its original permeability. In Priora's case, this would be 1,800 l/s/h – still TEN TIMES more permeable than it needs to be!

See for yourself!

Visit YouTube and search for "Marshalls Priora Maintenance Test" to see a real time infiltration test on an unmaintained Priora system!

Notes on Maintaining Conservation Priora or Priora Flag

Flag sized Priora surfaces feature fewer voids per square metre, rendering the surface less permeable than standard Priora CBP. However, even the largest sized Priora Flag units (600x400mm), laid in a single plan sized laying pattern, allow rainwater to infiltrate at a rate of 5,296 litres per second per hectare – which is more than permeable enough to cope with any realistic UK rainfall event.

Maintenance should therefore be exactly the same as for Standard Priora CBP.

5 simple steps to maintain a Marshalls Priora surface in optimum condition:

- **NEVER dump sand, cement, soil or other loose material directly onto a Marshalls Priora surface. This could block the joints or even fall into the sub-base.** *If you do need to store any loose material on a Marshalls Priora surface, make sure you put down a tarpaulin or impenetrable sheet first.*
- **Every twelve months or so, undertake a visual inspection to check that the voids aren't blocked with dirt or other debris.** *This is usually best undertaken after a period of heavy rainfall. If any voids are blocked, ponding on the surface will be apparent.*
- **If you notice ponding, the joints in that area are blocked. To clear them, either sweep the joints with a stiff brush or vacuum the contaminated aggregate out and replace it.** *If using an automatic suction brush, angle the brushes at 30° to avoid aggregate migration.*
- **Any vegetation growing in the joints can be removed manually, or treated with a Glyphosate-based weedkiller.** *Glyphosate will be neutralised upon contact with the ground, so it will be safe to plant in the area soon after treatment*
- **For winter maintenance, pure (white) rock salt is an effective and readily available de-icer. However, avoid using salts which contain an additional abrasive such as sand or grit.** *For heavy ice, should an abrasive be required, mix pure (white) rock salt with 6mm Priora jointing aggregate. This can be brushed safely back into the joints once thawed. (nb – Use of chlorides is highly unlikely to increase chloride levels in the local ground).*

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 stacked for reuse, a suitable surfacing material - 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.

Manual block lifter in action

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.

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.

Marshalls are committed to working with local authorities to alleviate any concerns they may have regarding adoption.

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.

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 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
Is 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 Pre-cast Concrete Federation. Interpave works closely with Defra, the Environment Agency, Scottish EPA, CIRIA and SuDSnet driving forward sustainable drainage solutions.

The SuDS Manual - C753

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.

England and Wales

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 unitary 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.

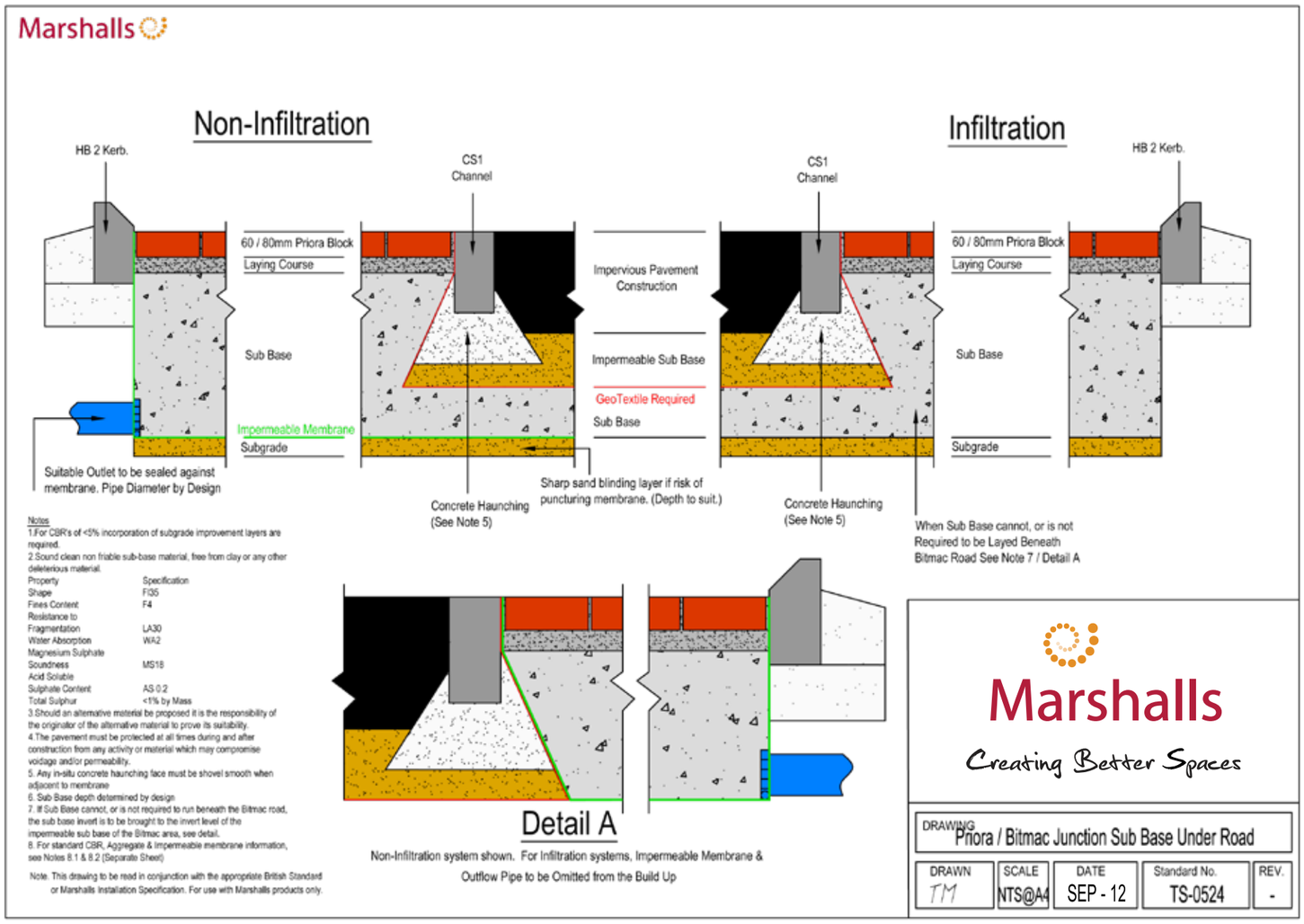
Planning Advice Note (PAN) 61: Planning and Sustainable Drainage Systems

Good practice advice for planners and the development industry complementing the Sustainable Drainage Systems Design Manual for Scotland and Northern Ireland.

Building Regulations – Scotland

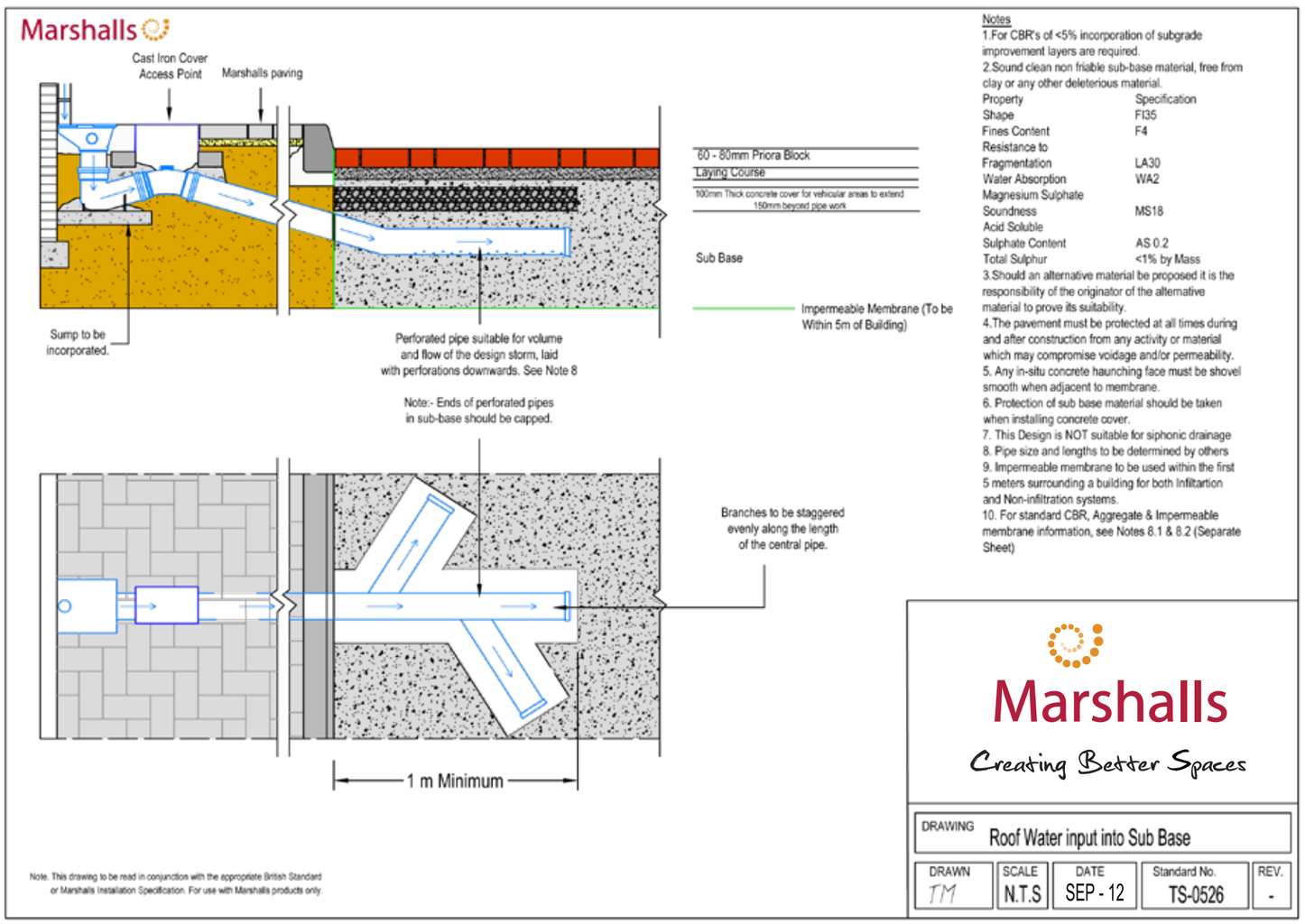
In Scotland, the 2008 Scottish Building Standards are applicable. Mandatory Standard 3.6 requires that 'every building, and hard surface within the curtilage of a building, must be designed and constructed with a surface water drainage system that will... 'have facilities for the separation and removal 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

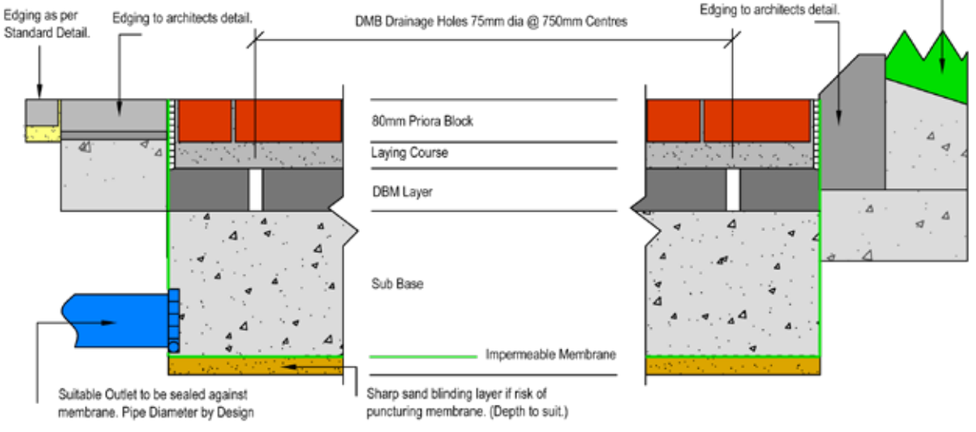
Not syphonic - only suitable for smaller roofs. Contact our design team for more details.



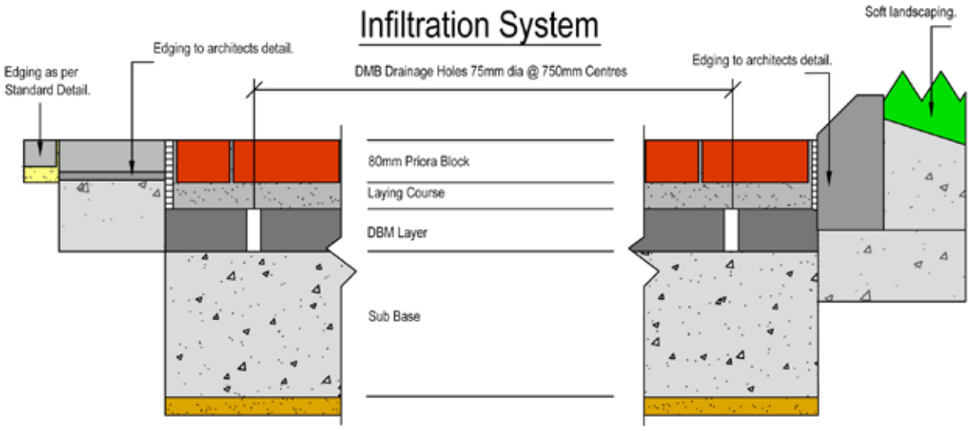
Standard Detail for Heavy Duty Paving

Marshalls

Non-Infiltration System



Infiltration System



Note. This drawing to be read in conjunction with the appropriate British Standard or Marshalls Installation Specification. For use with Marshalls products only.

Notes
1.For CBR's of <5% incorporation of subgrade improvement layers are required.
2.Sound clean non friable sub-base material, free from clay or any other deleterious material.

Property	Specification
Shape	FI35
Fines Content	F4
Resistance to Fragmentation	LA30
Water Absorption	WA2
Magnesium Sulphate Soundness	MS18
Acid Soluble Sulphate Content	AS 0.2
Total Sulphur	<1% by Mass

3.Should an alternative material be proposed it is the responsibility of the originator of the alternative material to prove its suitability.
4.The pavement must be protected at all times during and after construction from any activity or material which may compromise voidage and/or permeability.
5. Any in-situ concrete haunching face must be shovel smooth when adjacent to membrane
6. Sub Base depth determined by design
7. CSOGCR can be used as an alternative to a DBM layer. Depth determined by design.
8. For standard CBR, Aggregate & Impermeable membrane information, see Notes 8.1 & 8.2 (Separate Sheet)

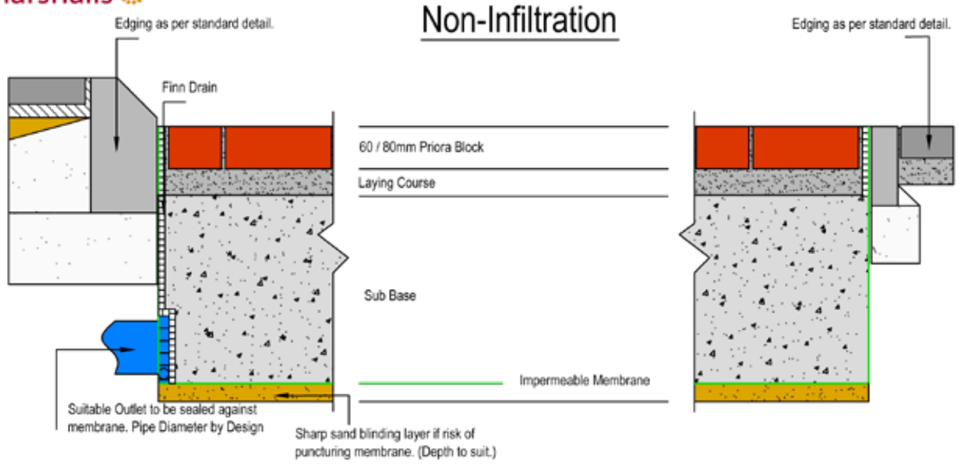
Marshalls
Creating Better Spaces

DRAWING	Priora Heavy Duty Paving System			
DRAWN	SCALE	DATE	Standard No.	REV.
TM	1:10@A4	SEP - 12	TS-0523	

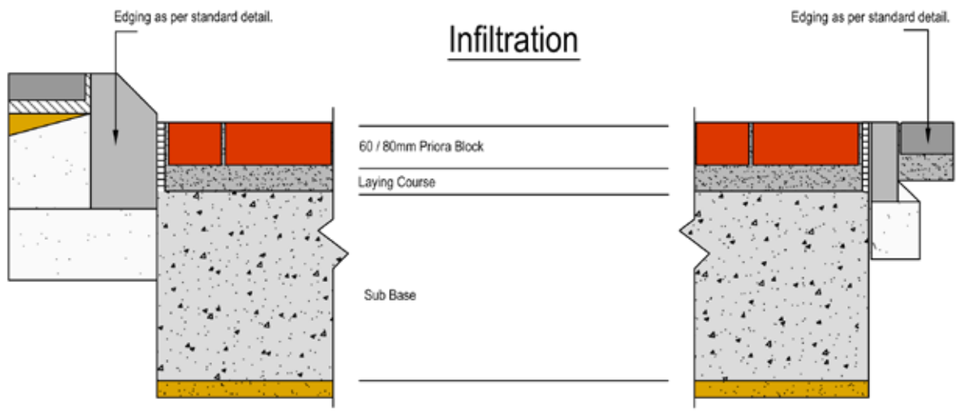
Standard Detail for Non-Infiltration & Infiltration

Marshalls

Non-Infiltration



Infiltration



Note. This drawing to be read in conjunction with the appropriate British Standard or Marshalls Installation Specification. For use with Marshalls products only.

Notes
1.For CBR's of <5% incorporation of subgrade improvement layers are required.
2.Sound clean non friable sub-base material, free from clay or any other deleterious material.

Property	Specification
Shape	FI35
Fines Content	F4
Resistance to Fragmentation	LA30
Water Absorption	WA2
Magnesium Sulphate Soundness	MS18
Acid Soluble Sulphate Content	AS 0.2
Total Sulphur	<1% by Mass

3.Should an alternative material be proposed it is the responsibility of the originator of the alternative material to prove its suitability.
4.The pavement must be protected at all times during and after construction from any activity or material which may compromise voidage and/or permeability.
5. Any in-situ concrete haunching face must be shovel smooth when adjacent to membrane
6. Sub Base depth to be determined by design
7. For standard CBR, Aggregate & Impermeable membrane information, see Notes 8.1 & 8.2 (Separate Sheet)

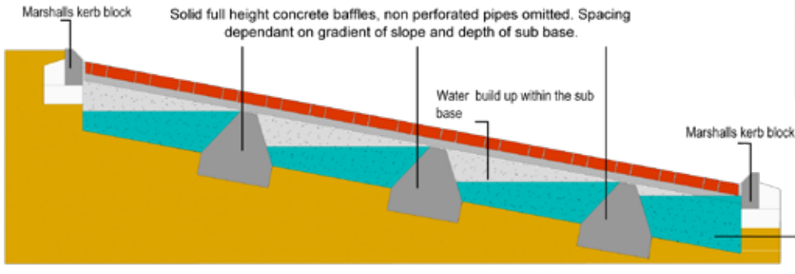
Marshalls
Creating Better Spaces

DRAWING	Priora Permeable Paving System			
DRAWN	SCALE	DATE	Standard No.	REV.
TM	1:10@A4	SEP - 12	TS-0522	-

Standard Detail for Priora on a Sloping Site (Baffles)

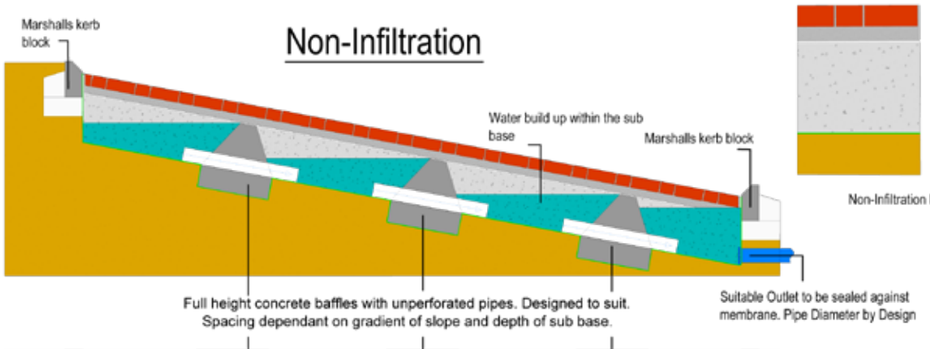
Marshalls

Infiltration

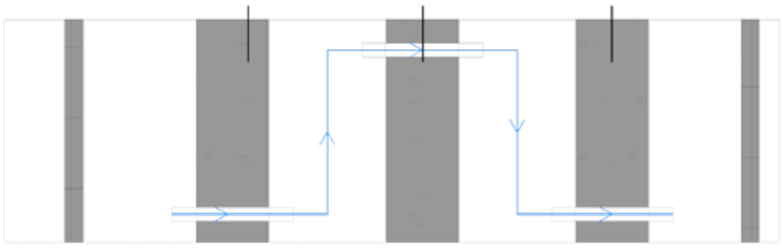


Infiltration Build Up Detail

Non-Infiltration



Non-Infiltration Build Up Detail



Note. This drawing to be read in conjunction with the appropriate British Standard or Marshalls Installation Specification. For use with Marshalls products only.

Notes
1.For CBR's of <5% incorporation of subgrade improvement layers are required.
2.Sound clean non friable sub-base material, free from clay or any other deleterious material.

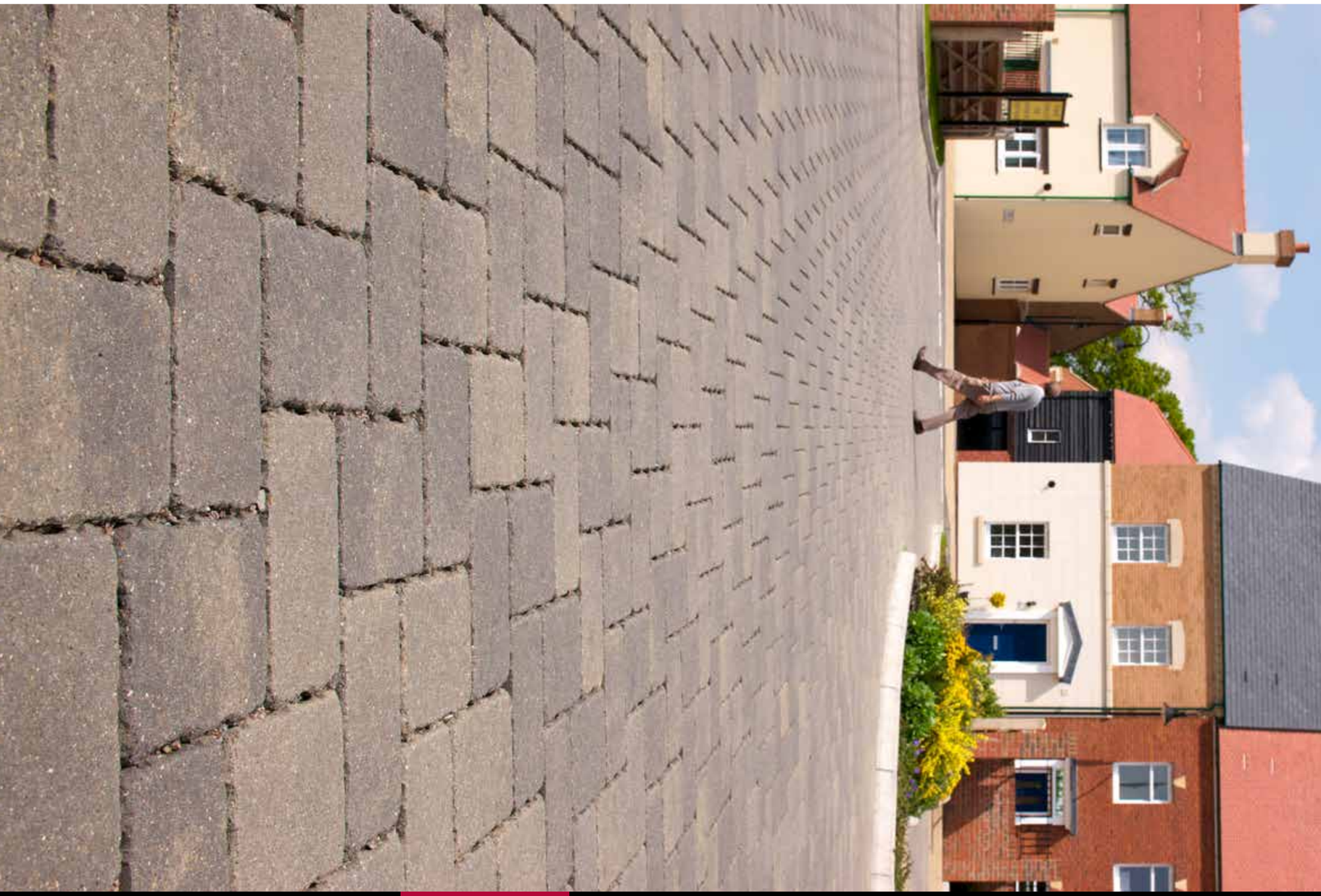
Property	Specification
Shape	FI35
Fines Content	F4
Resistance to Fragmentation	LA30
Water Absorption	WA2
Magnesium Sulphate Soundness	MS18
Acid Soluble Sulphate Content	AS 0.2
Total Sulphur	<1% by Mass

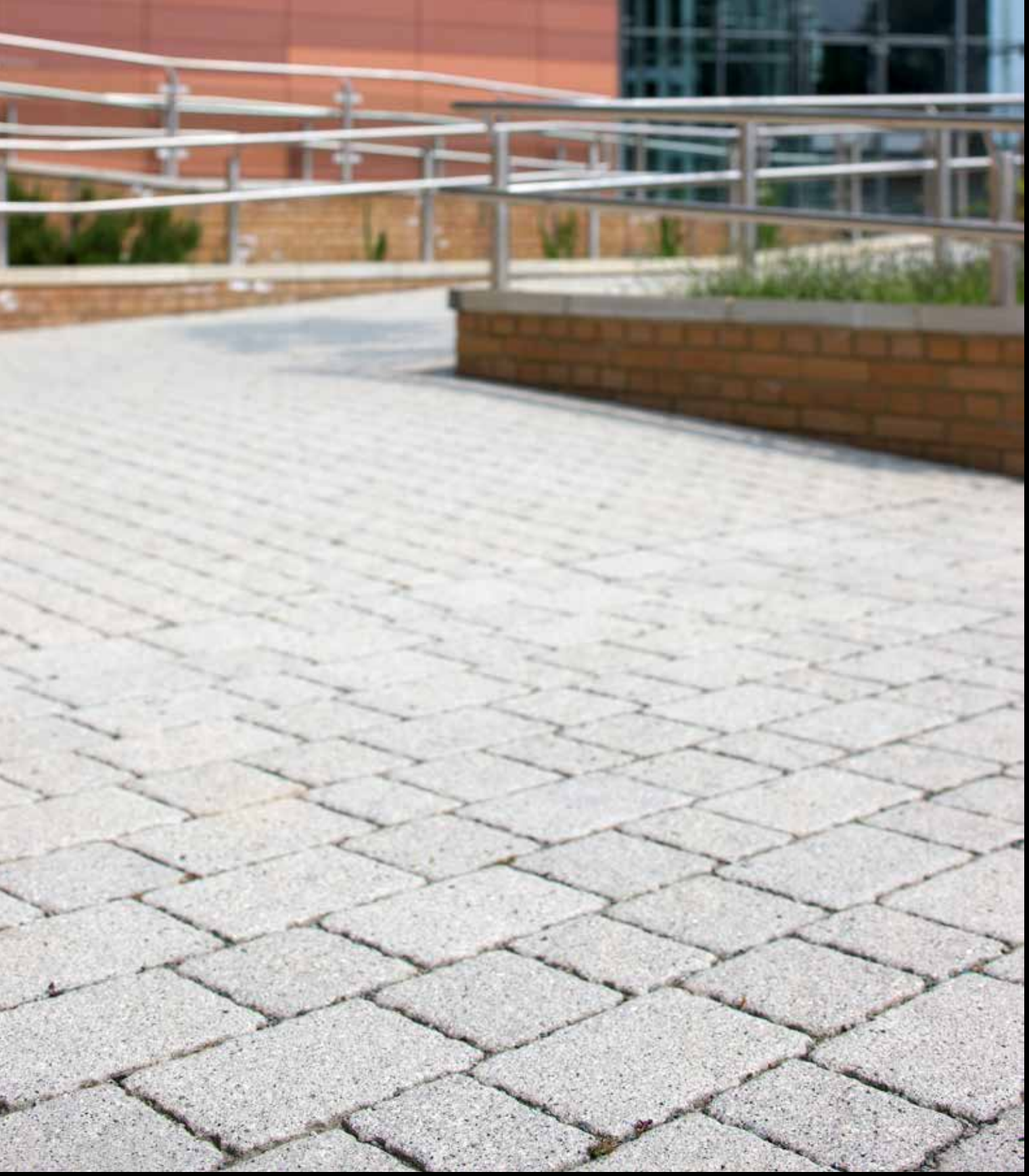
3.Should an alternative material be proposed it is the responsibility of the originator of the alternative material to prove its suitability.
4.The pavement must be protected at all times during and after construction from any activity or material which may compromise voidage and/or permeability.
5. Any in-situ concrete haunching face must be shovel smooth when adjacent to membrane
6. Sub Base depth to be determined by design
7. When constructing Infiltration systems, the following components are to be omitted:
Impermeable Membrane
Outflow Pipe.
Baffles are not to be solid and not inculde orifice in the form of a non perforated pipe.
8. Consideration to stepping base at baffles to increase volume may be given.
9. For standard CBR, Aggregate & Impermeable membrane information, see Notes 8.1 & 8.2 (Separate Sheet)

Marshalls
Creating Better Spaces

DRAWING Priora Permeable Paving System on Sloping Sites

DRAWN	SCALE	DATE	Standard No.	REV.
TM	NTS	SEP - 12	TS-0525	-





Marshalls

Creating Better Spaces

Landscape House, Premier Way,
Lowfields Business Park,
Elland HX5 9HT
Tel: 0370 241 4725
www.marshalls.co.uk/wm

Registered Office:
Marshalls plc,
Landscape House, Premier Way,
Lowfields Business Park,
Elland, HX5 9HT

DMD_36550