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Sustainable Urban Drainage System (SUDS)
SuDS systems are used to effectively manage surface and ground water, to mitigate flood risk and water course pollution, while maintaining natural flow regimes\textsuperscript{3}.

Californian Bearing Ratio (CBR)
A penetration test to establish the mechanical strength of sub-grades\textsuperscript{4}.

**GLOSSARY**

**Heat Island Effect**
Resulting from the urbanisation of areas due to the introduction of impermeable surfaces, which absorb solar radiation and emit heat energy more readily than those in undeveloped areas\textsuperscript{1}.

**Thermal Emittance**
The rate at which a surface radiates energy away from itself as compared to a blackbody operating at the same temperature, facilitating radiative cooling helping to keep surface temperature low\textsuperscript{1}.

**Albedo**
The ability of a surface to reflect solar radiation. It is recorded as a ratio between reflected solar radiation and total amount of radiation falling onto a surface. A higher albedo equates to more radiation reflected\textsuperscript{2}.
Our approach to construction encompasses innovative sustainable products, efficient building systems and practical solutions. We recognise the important role we have in promoting sustainable construction by optimising our products, their use and whole life performance. This document is one of a suite that identifies specific construction solutions that can help deliver a sustainable built environment. They explore the details of each system, its performance benefits, how it can be implemented in a project and then compares its environmental performance against alternative solutions.

This document introduces permeable concrete which contributes to creating a built environment which is long lasting, robust and efficient.

Typical Applications

Car parks, driveways, pavements and walkways, swimming pool decks, sports courts, hard shoulders, ground stabilisation for permeable blocks.
INTRODUCTION

Urbanisation of rural and lightly developed areas creates an increase in impermeable surfaces due to the construction of buildings and their supporting infrastructure. Increases in impermeable surfaces with traditional drainage systems, kerbs and gutters linked directly to surface drainage networks, can result in high instantaneous water flows that can overwhelm existing infrastructure leading to increased risks of flash flooding.

Systems integrating permeable surfaces can provide a solution to help manage surface water, through infiltration and attenuation to maintain natural water flows.

Permeable concrete can form an integral part of a SuDS\textsuperscript{3} solution, a key tenant of sustainable planning.
Location: Barkby Thorpe
Client: Roots Farm Shop
Year: 2012
Floor surface area: 190m²
Slab depth: 150mm
Volume: 28.5m³
ROOTS FARM SHOP
BARKBY THORPE

Roots Farm Shop opted for a permeable concrete paving solution over a traditional asphalt approach to cope with increasing popularity, flood risk and safety and health concerns.

A decision was made to extend and expand their car parking facilities due to a lack of existing space through increasing customer demand, however they were faced with a number of issues that could not be solved by traditional methods.

Increasing the impermeable area surrounding the shop and local farm buildings was seen to have the potential to exacerbate existing concerns and issues of flooding during periods of high rainfall. Permeable concrete offered the ability to increase the area of hard standing whilst maintaining pre-existing infiltration rates.

More importantly permeable concrete was seen as a solution to mitigate a significant safety and health concerns of ponding and during periods of low temperature ice, a risk to customers.

The extent of the area paved was around 190m², with the system constructed of 150mm of permeable concrete (28.5m³) over a 200mm permeable aggregate sub-base.

“We were having major issues with floods in our storage sheds and standing water in the car park, so we started looking at asphalting the area to fix this. When speaking to Tarmac they spoke about permeable concrete and the fact I could reduce the standing water and flooding, offering a better experience for my customers for no more work than just asphalting. We have since been hit with one of the worst winters on record, hail storms and floods, but my car park and yard are free from water, all due to my new concrete drainage system. My customers are happier and feel safe, I should have done this years ago.”

George Mount
Owner – Roots Farm Shop
Permeable concrete is a concrete paving solution with improved permeability characteristics compared to conventional permeable concretes.

Offering a porosity of up to 30%, an average flow rate of 36,000mm/hr/m² with compressive and flexural strengths of 10-20N/mm² and 1.5-3.0N/mm² respectively.

A permeable solution offers significant benefits over traditional solutions. The combination of trafficking surface and drainage system in a single element creates benefits in construction processes and in construction and environmental costs.
TAKE CONTROL OF RAINWATER

A permeable solution is typically constructed with three layers; permeable concrete as the surface layer, followed by a permeable aggregate sub-base over undisturbed soil. The dimensions and structure of each layer is dependent on application, prevailing site conditions and performance requirements.

Permeable concrete allows surface water to freely drain through the wearing surface to the underlying ground (or drainage system) with the ability to act as a reservoir during periods of high downfall. During these periods this characteristic can aid in delaying the discharge of surface water into water courses or drainage systems reducing the risk of overwhelming systems and causing flash flooding.

Storage of water in the system can also have a beneficial effect in reducing the heat island effect.

During periods of rising temperatures and intense rainfall, water stored within the system evaporates creating a cooling effect reducing surface temperatures.

This action is complemented by the albedo of permeable concrete. Naturally lighter in colour than traditional surfacing materials, permeable concrete offers a higher albedo, absorbing less solar radiation and emitting less heat energy, contributing to a reduced heat island effect.
PERMEABLE CONCRETE SYSTEMS

There are three typical best practice systems\(^5\) that can be employed in the construction of a permeable solution. All of these systems can be easily adapted to create a permeable concrete based solution and are described as follows:

**SYSTEM A**

**Full Infiltration**

Allows all water falling onto the surface to infiltrate through the constructed layers to the underlying ground enabling natural drainage flows to be maintained.

A full infiltration system is only viable if the existing ground offers suitable levels of permeability.

Typical formation of a full infiltration system utilising permeable concrete
SYSTEM B

Partial Infiltration

For use in locations where the underlying ground offers some level of permeability and infiltration, but cannot manage flows expected from the drained area.

Within the sub-base layer outlet pipes are required to be installed that allow any excess water that cannot penetrate into the existing ground to be drained.

Typical formation of a partial infiltration system utilising permeable concrete

SYSTEM C

Full Attenuation

Where the existing ground does not permit any infiltration, surface water is required to be attenuated within the system and discharged off site.

The system requires the installation of an impermeable membrane above the sub-grade and the provision of outlet pipes within the sub-base to remove all water.

Typical formation of a full attenuation system utilising permeable concrete
PERMEABLE CONCRETE DESIGN CONSIDERATIONS

A permeable paving solution is required to be tailored to a specific application due to performance requirements and site conditions.

The following characteristics require close consideration during design and should be considered alongside and in conjunction with existing standards and guidance that dictate and aid the design process\textsuperscript{5}. 
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<th>DESIGN CHARACTERISTIC</th>
<th>CONSIDERATION</th>
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<tr>
<td>Sub-grade permeability</td>
<td>Permeability of existing sub-grade plays an important role in dictating the viability of a permeable solution, where infiltration rates dictate the system that can be employed; A, B or C. Permeability testing should be carried out on site at paving formation levels in order to enable a suitable design to be selected.</td>
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<tr>
<td>Water table level</td>
<td>It is important for all permeable solutions that the existing water table level is established and particularly for those incorporating an attenuation layer. A high underlying water table level can reduce storage capacities of attenuation layers due to a reduction in available layer depth. In areas with high water tables increases in levels can negate the filtering effect as the distance to the water course is reduced.</td>
</tr>
<tr>
<td>Discharge consents</td>
<td>When new or renovated systems are to be installed it is necessary to contact the local authority to determine if discharge consent is required. Consents are dependent and based on the likelihood of contaminants being present in discharged water.</td>
</tr>
<tr>
<td>Traffic loading</td>
<td>To create an accurate and cost effective design loadings are required to be determined, incorrect specification of loadings can result in premature system failure or poor performance. Traffic loading is typically based upon the category of loading, such as domestic parking or commercial, from which a standard axle loading can be determined to enable detailed design. Permeable concrete has been designed to withstand a maximum payload of 7.5 tonnes and should not be used for highly trafficked applications.</td>
</tr>
<tr>
<td>Water storage capacity</td>
<td>The capacity of the system is required to be designed in line with the rainfall return periods for that location. When decisions are made regarding capacity this should be undertaken in combination with structural design to ensure an effective and durable solution.</td>
</tr>
</tbody>
</table>
Permeable concrete has existed for more than 60 years, but recent improvements and growing interest in sustainable construction have allowed it to become a more viable option.

Permeable concrete is one of the most advanced concrete solutions and is the result of innovation focused on the compaction of concrete.

**REDUCTION OF SURFACE RUNOFF**

A permeable concrete based permeable solution enables surface water to freely drain through the material reducing run off and the risk of flooding. Its higher permeability facilitates a high flow rate reducing risks of clogging enabling a long service life requiring little maintenance.

**REDUCTION OF THE HEAT ISLAND EFFECT**

The light colour and reduced density of permeable concrete compared to asphalt and conventional concrete results in a positive effect on the heat island effect.

Concrete has a higher albedo than traditional asphalt, 35% to 40% compared to 5% to 10% of light reflected respectively. This results in a surface that reflects more solar energy rather than storing and emitting it as heat energy, which contributes to increasing temperatures.

Additionally in warm weather any stored water can evaporate creating a cooling effect.
HYDRAULICALLY BOUND MATERIAL

In applications where increased traffic loadings are expected or significant soil remedial is required, hydraulically bound materials can be required to provide the requisite strength.

Compliance to BS EN 14227-1:2004 - Hydraulically bound mixtures – Specifications – Part 1: Cement bound granular mixtures is needed, with typical strength and permeability characteristics of 5-6N/mm² and 20,000mm/hour/m² respectively, permeable concrete can comprehensively satisfy these requirements.

COMPRESSIVE STRENGTH

Typical compressive strengths of permeable concrete range between 10 and 20N/mm², with final strength closely related to void ratio and homogeneity.

To ensure the best results permeable concrete should be placed adhering to the recommendations and guidance of Tarmac’s technical team, however final quality and performance, as with all paving solutions, is dependent on the skill of those placing the material.
COMPATIBLE WITH PERMEABLE BLOCK PAVING

Permeable block paving is a popular alternative to impermeable surfaces, however in circumstances where the underlying soil is of low strength or the system is subject to large loads additional works are required to ensure structural performance.

Typically Dense Bitumen Macadams (DBM) or Cement Stabilised Coarse Graded Aggregates (CSCGA) are required to provide strength, however as impermeable materials they are required to be cored to provide permeability.

Permeable concrete is a viable alternative as it is able to satisfy structural performance requirements whilst offering desired permeability without any additional works.
MAINTAINING WATER QUALITY

Permeable paving solutions offer the rapid removal of surface water and have a positive effect on water quality.

Permeable systems are effective at removing pollutants through a number of stages; initial larger particles are stopped at the surface reducing penetration to underlying sub-grades, while finer materials such as hydrocarbons and heavy metals penetrate the top surface but are trapped as they percolate into supporting layers.

Trapped organic materials breakdown over time reducing the amount and volume of contaminants that reach discharge water courses.

The integration of a geotextile membrane can improve the effectiveness of pollutant removal and provide a barrier to any unwanted organic growth.
The design of a permeable concrete solution is required to take into consideration site and location specific conditions, such as the strength of underlying ground and weather conditions it is expected to endure.

An indicative design has been created to provide a base for the development of specific designs once site conditions have been ascertained.

This sample system† has been based on:

Key design criteria (shown opposite) which are required to be verified for the location in which the system is to be constructed;

A 30 year return period with a 20% climate change factor for summer and winter storm durations from 15 minutes to 7 days, with ground conditions enabling full infiltration.

* The base system has been designed by GHW Consulting Engineers Ltd, www.ghwconsulting.co.uk
<table>
<thead>
<tr>
<th>KEY DESIGN CRITERIA</th>
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<tr>
<td><strong>Permeable concrete (150mm)</strong></td>
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<tr>
<td><strong>Permeable Aggregate Sub-base (200mm)</strong></td>
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<tr>
<td><strong>Geotextile membrane</strong></td>
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<tr>
<td><strong>Soil Permeability</strong></td>
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<td><strong>CBR Ratio</strong></td>
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<td><strong>Loading</strong></td>
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<td><strong>Footpath construction</strong></td>
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SUSTAINABILITY

The specification and installation of permeable paving solutions in place of traditional impermeable paving enables further environmental improvements to be delivered.

RESOURCE DEPLETION

Concrete is an inherently flexible material with regards to its on site placement and also its constituents. It is possible to adapt mix designs to incorporate recycled and secondary aggregates to reduce its impact on virgin and finite materials. Further to this a permeable solution can reduce and remove the need for ancillary on site drainage systems, minimising the consumption of resources.

EMBODIED ENERGY

Opting for a permeable concrete surfacing solution in place of traditional asphalt solutions enables reductions in embodied energy to be made. The production process for traditional asphalt demands high temperatures in production to facilitate mixing and to ensure sufficient residual temperature remains to maintain flexibility for installation, this energy demand is removed with concrete solutions.
RECYCLING

The concrete industry has taken significant steps to improve its performance in terms of material reuse, reducing the depletion of abiotic resources, increasing energy efficiency and reducing carbon emissions. Significant improvements have already been achieved compared to the industry’s 1990 baseline. With respect to material reuse and the depletion of abiotic resources, concrete readily utilises recycled and secondary materials along with cement replacements. This has enabled the industry to be a net user of waste, using 47 times more waste than it generates, and concrete itself is also 100% recyclable.

BES 6001

Tarmac has achieved an ‘Excellent’ rating for all its production sites and products. The independent third-party scheme assesses responsible sourcing policies and practices throughout the supply chain.

ISO 14001

Tarmac is fully accredited with ISO 14001, having implemented Environmental Management Systems throughout our business, maintaining our commitment to reducing our environmental impact.

‡ Tarmac concrete products offer the ability to conform with a wide-ranging number of assessment criteria in both BREEAM and LEED. For more information contact Tarmac sustainability team.

* Our BES 6001 certificate number for our readymix concrete products is BES 559207.
SUSTAINABILITY ASSESSMENT SCHEMES

Concrete can play an extended role in enabling an efficient building to be created and can contribute in a number of assessment schemes and help achieve a range of credits.

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<thead>
<tr>
<th>BREEAM†</th>
<th>LEED</th>
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<tr>
<td><strong>Man 03: Responsible Construction Practices</strong>&lt;br&gt;Tarmac’s Carbon Calculator has the capability to determine and provide data relating to the CO₂ arising from production and delivery of our products.</td>
<td><strong>MR Credit 2: Construction waste management</strong>&lt;br&gt;Construction and demolition waste is encouraged to be diverted away from landfill or incineration, concrete is an inherently reusable material that is 100% recyclable.</td>
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<tr>
<td><strong>Mat 03: Responsible sourcing of materials</strong>&lt;br&gt;Concrete is primarily constituted of locally available materials, all concrete products produced by Tarmac are BES 6001 accredited to an ‘Excellent’ standard</td>
<td><strong>MR Credit 4: Recycled content</strong>&lt;br&gt;Concrete is a versatile material whose design can be readily adapted to enable the use of recycled, secondary or replacement materials.</td>
</tr>
<tr>
<td><strong>Wst 02: Recycled Aggregates</strong>&lt;br&gt;Concrete is a versatile material whose design can be readily adapted to enable the use of recycled, secondary or replacement materials.</td>
<td><strong>MR Credit 5: Regional materials</strong>&lt;br&gt;Concrete is one of the few materials that is produced locally to where it is used; it can typically be supplied from within 10 miles of any given site.</td>
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<tr>
<td><strong>Pol 03: Surface water run off</strong>&lt;br&gt;Permeable concrete can mitigate increases in surface run off by maintaining the infiltration level of the undisturbed ground or improving infiltration when replacing impermeable solutions. Additional contributions can be made by reducing water course pollution risks through the filtering action of a permeable concrete solution.</td>
<td><strong>SS Credit 6.1: Storm water Design – Quantity Control</strong>&lt;br&gt;Permeable concrete has the ability to reduce and filter polluting materials that can be present in vehicular paved areas.</td>
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</table>
Using this ‘whole life’ thinking we have engaged with our stakeholders to develop our sustainability strategy. The strategy defines the main sustainability themes and our key priorities, those issues which are most important to our business and our stakeholders. It sets out our commitments to transform our business under four main themes: People, Planet, Performance and Solutions.

Building on progress already made, we have set ambitious 2020 milestone targets for each of our key priorities. These ambitious targets have been set to take us beyond incremental improvement programmes to business transforming solutions.

Sustainability is about securing long-term success for our business, customers and communities by improving the environmental, social and economic performance of our products and solutions through their life-cycle. This means considering not only the goods we purchase, our operations and logistics but also the performance of our products in use and their reuse and recycling at the end of their life. By doing this, we can understand and take action to minimise any negative aspects, while maximising the many positive sustainability benefits our business and products bring.

**OUR SUSTAINABILITY STRATEGY**

Sustainability is about securing long-term success for our business, customers and communities by improving the environmental, social and economic performance of our products and solutions through their life-cycle. This means considering not only the goods we purchase, our operations and logistics but also the performance of our products in use and their reuse and recycling at the end of their life. By doing this, we can understand and take action to minimise any negative aspects, while maximising the many positive sustainability benefits our business and products bring.

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**FOUR THEMES**

Twelve key priorities
Twelve commitments
Twelve 2020 milestones
Forty four other performance targets

Our 2020 milestones are supported by a range of other performance targets. This hierarchy helps make it easier to build understanding, drive improvement and enables us to report progress in a meaningful and measurable way.
REFERENCES

1. United States Environmental Protection Agency
   Reducing Urban Heat Islands: Compendium of Strategies, Urban Heat Island Basics

2. American Concrete Pavement Association
   ALBEDO: A Measure of Pavement Surface Reflectance

3. Environment Agency

4. BS 1377-9: 1990, Soils for civil engineering purposes – Part 9 In-situ tests

5. CIRIA
   The SUDS Manual, 2007


7. Atkins Product Development Report for Tarmac
   Surface Water Management Technical Report, 2009 (details on request)

8. Concrete Industry Sustainability Performance Report
   4th Report: 2010 performance data

9. Green Spec
   http://www.greenspec.co.uk/greening-of-concrete.php

10. ISO 14001: Environmental Management

11. Green Book Live
    http://www.greenbooklive.com/search/scheme.jsp?id=153

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