PERMEABLE PAVEMENT MATERIALS AND CONSTRUCTION

SPECIFICATION TO COMPLEMENT PERMCALC DESIGN SUGGESTIONS

Note: This specification is for general guidance only and is to complement the design suggestion(s) generated by Brett PermCalc and is only applicable for permeable pavements where Brett Landscaping and Building Products are specified and used.

1. Preparation of the Subgrade

The preparation of the subgrade of a permeable pavement is fundamentally no different from preparing the subgrade of a conventional impermeable pavement. The subgrade should be trimmed to level and compacted to a tolerance within +20 mm to -30 mm in accordance with the *'Specification for Highway Works'*.

1.1 Fill material

If fill is needed to build up levels for a System A (total infiltration into the subgrade) permeable pavement, then the fill material must have similar or superior properties to the existing subgrade, e.g. permeability, density and strength. Consideration must be given if it is proposed to use crushed concrete as fill material, as it is likely water that after water infiltrates though it and into the subgrade, it may have an elevated alkalinity, which may not be desirable or be allowed.

If fill is needed to build up levels for a System C (no infiltration into the subgrade), then the fill material must have similar or superior properties to the existing subgrade, e.g. strength.

1.2. System C

For System C pavements (no infiltration into the subgrade) it is recommended that the subgrade is trimmed with a nominal fall to allow water collected in the bottom of the pavement to drain towards the outlet points.

1.3. Subgrade geotextile

For System A pavements (full infiltration into the subgrade) a geotextile shall be installed between the sub-base and subgrade. The geotextile can be either a mono filament woven, non woven bonded or needle punched non-woven fabric. The geotextile shall be manufactured from a suitable polyethylene or polypropylene filament able to withstand naturally occurring chemical and microbial effects.

The production of the geotextile shall be in accordance with BS EN ISO 9001: 2008. The tensile properties of the material shall be verified in accordance with BS EN ISO 10319: 1996. The physical properties shall comply with Table 1.

The geotextile shall be protected from ultraviolet light whilst stored.

The geotextile shall be laid with a minimum overlap of 200mm.

Table 1

Characteristics	Standard	Woven Filter	Non Woven Filter
Weight	BS EN 965: 1995	≥ 200 g/m²	≥ 300 g/m²
Ultimate Tensile Strength Longitudinal Transverse	BS EN ISO 10319: 1996	 ≥30 kN/m ≥30 kN/m	 ≥15 kN/m ≥15 kN/m
Strain at Nominal Tensile Strength Longitudinal Transverse	BS EN ISO 10319: 1996	 ≤ 25% ≤ 25%	 ≤ 70% ≤ 70%
CBR Puncture	BS EN ISO 12236: 2006	≥3 kN	≥3 kN
Opening Size	BS EN ISO 12956: 1999	≥0.2 mm	≥0.1 mm
Water Permeability	BS EN ISO 11058: 1999	≥ 20 x 10^{-3} m/s	≥ 40 x 10^{-3} m/s

2. Capping Layer

A capping layer is required in all System C pavements.

The capping thickness can only be determined approximately during the design process because the condition of the subgrade will depend upon site drainage conditions, water table levels and recent weather conditions. The actual capping thickness may have to be determined by site trials.

The capping layer shall be installed in accordance with 'Specification for Highway Works' and the capping materials shall meet the requirements of either 6F1 or 6F2 of Table 6.1 of 'Specification for Highway Works – Series 600 – Earthworks'.

The surface texture of the capping is to be smooth and dense so not to damage the impermeable membrane. This can be achieved by blinding the fine aggregate and/or installing a geotextile over the cpping.

3. Impermeable Membrane

For light duty applications, a Category 1 impermeable membrane, of minimum 2000 gauge polythene with double taped overlapping joints shall be used. For heavier applications, a Category 2 impermeable membrane shall be used.

Category 2 impermeable membranes shall be manufactured from a durable robust material such as High Density Poly Ethylene (HDPE), Ethylene Propylene Diene Monomer (M-class) rubber (EPDM), polypropylene or similar approved material.

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Brett Landscaping operate to the highest levels of independent certification:
- BS EN ISO 9001 Quality Management System
- BS EN ISO 14001 Environmental Management System
- OHSAS 18001 Health and Safety Management System

In addition, when designing projects under BREEAM we are also holders of BES 6001 Responsible Sourcing of Construction Products (Very Good)
All of these can help significantly when designing for sustainability.

The membrane shall be resistant to puncture, the stresses and strains associated with multi-axle movement and environmental stress cracking. The membrane shall be unaffected by potential pollutants such as alkaline or acidic groundwater.

The membrane shall be able to withstand the additional loads applied during construction and to resist punching stresses caused by loading or sharp points of contact with the aggregate throughout the design life of the pavement.

All joints between adjacent layers, pavement penetrations and discharge outlets shall be watertight. In the case of Category 2 membranes, welded joints shall be tested to ensure the integrity of the system.

The impermeable membrane shall be installed and, in the case of Category 2 membranes, tested by competent personnel in accordance with the membrane manufacturers recommendations.

4. Sub-base Aggregates

The sub-base may be comprised of the Coarse Graded Aggregate (CGA) only or CGA overlaid with Hydraulically Bound Coarse Graded Aggregate (HBCGA).

(PermCalc will automatically determine the makeup and thicknesses of the pavement layers.)

The sub-base aggregate shall comply with the requirements of 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*, as follows:-

- The aggregate shall be a crushed Type 4/20 (4 mm minimum and 20 mm maximum particle size)
- The voids ratio of the sub-base aggregate shall be at least 30%.
- Aggregate Particle Shape: Preferably a hard crushed rock. The aggregate must have sufficient internal stability to perform both during installation and in the long term.
- Physical properties shall comply with BS EN 13242: 2002 – Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction.

4.1 Particle Size Distribution

The CGA shall comply with the grading values given in the Table 2.

Table 2

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

4.2 Physical Properties

In order to be able to sustain the effects of traffic under both dry and wet conditions, the CGA shall meet the physical requirements shown in the Table 3.

Table 3

Properties	Category to BS 13242 or BS 12620
Grading	4/20 Gc 85 - 15, GTc 20/17.5
Fines content	f_4
Shape	FI_{20}
Resistance to fragmentation	LA_{30}*
Durability: Water absorption to BS EN 1097-6:2000 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 air-cooled blast furnace slag	 $AS_{0.2}$ $AS_{1.0}$
Total sulpher: - aggregates other than air-cooled blast furnace slag 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 disintigration in accordance with BS EN 13242:2002,6.4.2.2 V_5
Leaching of contaminants	Blast-furnace slag and other recycled materials should meet the requirements of the Environment Agency 'Waste Acceptance Criteria' for inert waste when tested in accordance with BS EN 12457-3
*The durability of aggregates depends on the nature of the source. In some instances a lower value of LA may need to be specified based on local experience.	

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4.3 Hydraulically Bound Coarse Graded Aggregate (HBCGA).

For more heavily trafficked permeable pavements (load categories 3, 4, 5 or 6), to strengthen and stiffen the pavement, the sub base will require the inclusion of a HBCGA layer. (This HBCGA layer can be partially or totally substituted with Dense Bitumen Macadam (DBM))

In addition to the requirements for the CGA sub base, above, the HBCGA shall comply with BS EN 14227-1:2004. *'Hydraulically bound mixtures – Specifications – Part 1: Cement bound granular mixtures.'*

- Minimum cement content by mass = 3%.
- Strength Class = $C_{5/6}$ (As defined in Table 2 of BS EN 14227-1:2004.)
- Minimum permeability = 20,000 mm/hour.

5. Sub-base construction

The permeable CGA sub-base shall be laid in 100 – 150 mm layers and compacted to ensure that the maximum density is achieved for the particular material type and grading without crushing the individual particles or reducing the void ratio below the design value. The surface level tolerance shall be within +20 mm to –15mm of the design levels.

Care shall be taken to avoid segregation of the aggregate, but if this occurs, remedial corrective action must be taken to ensure that the completed sub-base has evenly distributed aggregate particle sizes.

The permeable sub-base shall not be used as a temporary access road for general site traffic or as a hard standing storage area.

The aggregates are relatively self compacting and heavy vibrating compaction is not usually required. Satisfactory results may be achievable by rolling without vibration. Site trials are to be undertaken to determine the appropriate construction methodology.

For HBCGA setting, times will vary dependent upon many factors including the ambient temperature and winds. Compaction of the HBCGA shall be completed before on onset of setting. Advice shall be sought from the HBCGA supplier.

HBCGA shall be constructed in accordance *Volume 1 Specification for Highway Works – Series 800*. The HBCGA shall not be laid during rain and shall be protected from rain and surface water run-off after completion of the rolling process.

5.1 Asphalt Concrete (AC) /Dense Bitumen Macadam (DBM)

Note: Dense Bitumen Macadam (DBM) is now referred to as asphalt concrete (AC)

IIf a temporary access is required an AC (DBM) layer shall be installed that will remain in-situ throughout the service life of the pavement.

PermCalc will determine the AC (DBM) thickness and if necessary make adjustments to the other pavement layers.

For load categories 1 and 2 an AC (DBM) layer is in addition to the CGA.

For load categories 3, 4, 5 and 6 an AC (DBM) layer can substitute some, or all, of the HBCGA layer but the minimum thickness of the remaining HBCGA layer must not be less than 125mm.

As the AC (DBM) has no water storage capability PermCalc will check that the remaining permeable layers has sufficient water storage capacity, and if necessary increase the sub-base depth.

The asphalt concrete should be AC 32 dense 40/60 designed base as defined in BS EN 13108-1:2006 Bituminous mixtures. Material specifications Asphalt Concrete.

The asphalt concrete layer should be installed in accordance with BS 594987 Asphalt for roads and other paved areas. Specification for transport, laying, compaction and type testing protocols.

When laying AC (DBM) over a CGA sub-base it will be necessary to use a tracked asphalt paving machine, otherwise there is a danger of rutting and damaging the surface profile of the CGA as a wheeled asphalt paver may become embedded in the CGA.

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6. Block Paving Laying Course and Jointing Aggregate

The laying course and jointing aggregate shall comply with the requirements of a material of type 2/6.3 Gc 80/20 according to BS EN 13242: 2002. *'Aggregates for unbound and hydraulically bound materials for use in civil engineering works and road construction'* with a Particle Size Distribution as shown in Table 4.

Table 4

(BS EN 993 - 1: 1995) Sieve size mm	Percentage Passing %
14	100
10	98 - 100
6.3	80 - 99
2.0	0 - 20
1.0	0 - 5

The compatibility of the sub-base and laying course aggregates shall be assessed to ensure that the laying course aggregates particles fit into the voids of the sub-base aggregate without excessive migration into the sub-base.

This can be assessed visually and by applying the following criteria to the grading envelope for aggregates proposed to be used:

- D_{15} sub-base/ D_{85} laying course ≤ 5
- Where D_{15} sub-base - size of particles at 15% passing
- Where D_{85} laying course - size of particles at 85% passing

7. Permeable Concrete Block Paving

The block paving shall be manufactured and tested by Brett Landscaping and Building Products to *BS EN 1338: 2003 Concrete paving blocks requirements and test methods.*

Suitable permeable paving blocks available from Brett are given in Table 5:

Table 5

Product/colours	Available in Machine lay format	Thickness	Joint space - measured at the widest point
Omega Flow Autumn Gold Brindle Burnt Oak Charcoal	yes	80 or 60 mm	6 - 10 mm
Alpha Flow Autumn Gold Brindle Burnt Oak	no	80 or 60 mm	8 - 11 mm
Beta Flow	no	80 or 60 mm	8 - 11 mm
Grass Flow Natural Brown	yes	80 mm	2 -5 mm measured at the normal joint position, not at the void

Once the product has been selected, PermCalc will calculate the minimum thickness of block suitable for the traffic category selected.

7.1 Physical Properties

Physical properties shall be measured in accordance with BS EN 1338:2003, as follows:

7.1.1 Dimensions

The dimensional deviations shall apply:

Table 6

Block thickness mm	Length mm	Width mm	Thickness mm
80	±2	±2	±3
The difference between any two measurements of the thickness of a single block shall be ≤ 3 mm			

7.1.2 Strength

Characteristic Tensile Splitting strength (T) shall not be less than 3.6 MPa. None of the individual results shall be less than 2.9 MPa nor have a failure load less than 250 N/mm.

7.1.3 Abrasion Resistance

The abrasion index shall be class 4.

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7.1.4 The Unpolished Slip Resistance Value
The unpolished slip resistance value shall be above 75

7.1.5 Freeze/Thaw Resistance
Class 3.

7.1.6 Total water absorption
Class 2.

7.1.7 Appearance
All block paving shall be sound and free from cracks or other defects, which would interfere with proper placing or impair the strength following correct construction.

8. Block Layer Installation
The block layer is to be installed in accordance with *BS 7533 - 3: 2005 A1: 2009, 'Code of practice for laying precast concrete paving blocks and clay pavers for flexible pavements* and shall follow the process set out in the flow chart, Annex A, figure A1.

8.1 Precautions
The works shall be undertaken in such a way that contaminants such as soil and mud are prevented from entering the sub-base and pavement surface both during and after construction.

Keep muddy construction equipment away from the construction area. Install silt fences, staged excavation and temporary drainage swales which divert runoff away from the area if appropriate.

The block layer installation shall only commence if all the preceding work is completed and compliant. Any non compliances shall be corrected before proceeding.

8.2 Block Pavement Compliance Criteria
The block paving surfacing shall comply with the following criteria:

- Laying Course thickness after compaction 50 mm ±20 mm
- Joint space width - see Table 5
- Variation in block to block height (lipping) 2 mm
- Surface smoothness - not applicable to a permeable pavement,
- Height of blocks against edge restraints, drainage pits/channels etc plus 5 mm

8.3 Upper Geotextile
If an upper geotextile is required between the CGA or HBCGA sub-base and the laying course, it shall comply with Table 1. The sub-base shall be blinded with laying course aggregate to fill any surface voids and create a smooth surface prior to installing the geotextile.

The overlap between adjacent strips of geotextile shall be at least 200 mm. No vehicles shall be allowed to traffic the geotextile.

8.4 Edge Restraints
Adequate edge restraints shall be installed along the exposed perimeter of block paving and to drainage items and other penetrations within the pavement.

These edge restraints shall be completed before the block laying proceeds and shall be in the form of concrete kerbs, adjacent structures or other suitable restraint as shown on the drawings. The face of the edge restraint, where it abuts block paving, shall be vertical, with a smooth surface to ensure a consistent joint space between edge restraint and the first row of block paving.

Pavement penetrations such as drainage pits shall be set parallel/ 90° to the laying pattern.

All edge restraints and other structures within the paved area, such as service pits/manholes etc, shall be set at the correct level and grade in relation to the sub-base to ensure that surface of the block paving shall be 5 mm above these structures without the laying course thickness exceeding 50 mm ± 20 mm.

All edge restraints shall be of structural grade concrete and located to ensure that no movement occurs during the compaction of sub-base and block paving operations.

8.5 Placement and Spreading Laying Course Material
When either machine laying or hand laying block paving on a CGA or HBCGA sub-base, with no upper geotextile, the laying course aggregate shall be pre-compacted to ensure that the surface of the sub-base is fully blinded by the laying course aggregate.

The Contractor may use an approved mechanical spreader (e.g. excavator dragging a screed, proprietary screeding system or an asphalt paver) to spread and screed the laying course.

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8.6 Screeding

Laying course aggregate shall be laid to achieve a thickness of 50mm ±20mm thick after compaction. Under no circumstances shall the thickness of the laying course exceed 70 mm.

At locations of gradient changes in the pavement, the laying course shall be profiled to give a smooth transition in the block paved surface.

Vehicular traffic, other than those involved in this operation, shall not be permitted on the prepared laying course.

Depressions left in the laying course by screed rails, or where survey points have been exposed, shall be carefully reinstated.

Pedestrian traffic shall be limited to personnel required in the laying course screeding operation and those involved in the setting up of block paving laying string lines.

Any laying course that is disturbed or adversely affected shall be rectified.

8.7 Laying of Block Paving

The strongest laying pattern is herringbone. Omega Flow and Alpha Flow can be laid in herringbone pattern. Grass Flow is laid in stretcher bond.

Lay the block paving in a pattern as shown on the drawings. Once the laying pattern has been established, it shall continue without interruption over the entire pavement surface. Cutting of block paving will not be permitted except along the outer pavement boundaries and adjacent to drains, manholes etc.

Only plant and equipment necessary for the construction of the block paving layer shall be permitted to traverse the pavement during block layer installation.

Block paving shall be placed to achieve the appropriate joints widths (see Table 5) between adjacent blocks and or edge restraints.

The block paving alignment shall be checked and adjustments shall be made as necessary to achieve correct alignment and compliant joint widths.

The laying of block paving shall follow an order, which maintains an open working face and does not trap blocks.

To achieve compliant joint spacing and avoid problems of not being able to fit paving without breaks or cuts within the pavement surface, the installer should implement work practices to compensate for paver dimensional variability that is allowed for in the relevant manufacturing standard. This practice is particularly important for dimensionally large projects.

These practices could be liaising with Brett Landscaping and Building Products to ensure that paving size variability is minimised, setting out 'alignment grids to suit the larger pavers', not immediately joint filling areas that may have to be adjusted to enable pavers to fit with compliant joints.

8.8 Cutting Block Paving

It may be necessary to cut block paving to fit against edge restraints and any pavement penetrations.

Blocks shall be cut either with a block guillotine or powered diamond blade circular saw.

Saw cutting shall only be undertaken with saws with water dust suppression, with the operative wearing appropriate Personnel Projective Equipment (PPE) in accordance the Interpave Guidance Cutting Paving. (See www.paving.org.uk)

Small slender cuts and pieces less than 25% of a full block shall be avoided. It is permissible to compromise the pattern to avoid small cut pieces.

8.9 Initial Compaction

After laying the blocks, the blocks shall be bedded by not less than two passes of a suitable plate compactor. The use of steel drum rollers shall not be permitted.

Typically the compactor shall be a vibrating flat plate compactor with a mass of not less than 350 kg, generating a centrifugal force in the range of 30 to 40 kN a frequency in the range of 65 to 100 Hz. The compacter shall not damage the block paving. It is permissible to fit protective mats to the underside of the compactor. It is also permissible to link two or more compactors together to increase the efficiency of the compaction operation.

Compaction shall proceed as closely as possible following laying and prior to the acceptance of any traffic other than that necessary for the laying operation.

Compaction shall not be attempted within 1 m (approx) of the laying face. Compaction shall continue until lipping between adjoining units has been minimised and in any case shall not exceed 2 mm.

Any blocks which are damaged after the compaction process, shall be immediately removed and replaced.

8.10 Inspection Prior to Joint Filling

Prior to the commencement of the joint filling operation, the block paving shall be inspected to ensure compliance to the specification so far. Any non compliance shall be corrected before the commencement of the joint filling operation.

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8.11 Filling Joints

As soon as practical after compaction and inspection, and after confirming that the work so far is in accordance with the specification, the jointing operation shall proceed.

The jointing aggregate shall be spread to fill the joints. The jointing aggregate shall be compacted into the joints by not less than two passes of the plate vibrator and the procedure shall be repeated until the joints are filled to the bottom level of the chamfers.

No traffic other than pavement laying plant and equipment shall be permitted to use the pavement until all joints have been completely filled and compacted.

All work to within 1m of the laying face shall be left fully compacted and joints filled and compacted at completion of each day's laying.

8.12 Excess Jointing Aggregate

Excess jointing aggregate shall be removed prior to handing over each section of the pavement.

9. Inspection Prior to Hand Over

Prior to hand over, the pavement shall be inspected to ensure compliance to the specification. Any non compliance shall be corrected before handing over.

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