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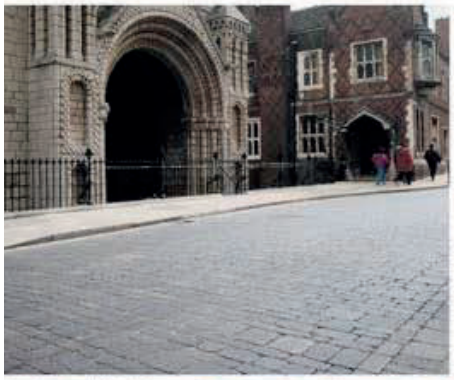
concrete block paving

GUIDE TO THE PROPERTIES, DESIGN, CONSTRUCTION, REINSTATEMENT AND MAINTENANCE OF CONCRETE BLOCK PAVEMENTS

EDITION 2



Interpave
THE PRECAST CONCRETE PAVING AND KERB ASSOCIATION

www.paving.org.uk

CONCRETE BLOCK PAVING

guide to the properties
design, construction, reinstatement and maintenance of concrete block pavements

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Addendum

With the publication of **BS 7533-101:2021** ***Pavements constructed with clay, concrete or natural stone paving units – Part 101: Code of practice for the structural design of pavements using modular paving units***, designers may wish to refer to that standard for the latest advice. Alternatively, the guidance provided by this Interpave document, with its long track record, remains valid.

In 2022, Interpave became a part of MPA Precast, part of the Mineral Products Association.

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1 PROPERTIES

The use of small stone elements to create a hard surface for roads or pavements is an ancient tradition that can be traced back to the royal processional roads of ancient Babylon, continuing in Greek and Roman times. Concrete block paving continues this tradition and was first introduced in Holland after the Second World War followed by other countries (notably Germany) and its introduction to the UK in the 1970s. Concrete block paving is a unique material, exhibiting important differences to other small element paving such as stone and clay, as well as to form-less materials such as asphalt and insitu concrete. It provides a hard surface which is good to look at, comfortable to walk on, extremely durable and easy to maintain. It adds a richness, com-plexity and human scale to any setting.

Blocks are fully engineered products manufactured in the factory to give consistency and accu-racy. The resulting interlocking characteristics of concrete block paving give it a distinct advan-tage over other forms of surface. Laid on a granular laying course and with an edge restraint, individual blocks interlock with each other to act together, distributing large point loads evenly. Concrete block paving can be used immediately after the laying procedures have been complet-ed and requires only minimal maintenance. Today, mechanical installation techniques allow large areas to be laid with a minimum of manpower saving both time and money.

Applications

Concrete block paving offers outstanding strength and durability, and is resistant to most chem-icals, making it suitable for a range of applications from ultra-heavy duty areas such as industri-al units, container stacking yards and airport pavements to lightly trafficked residential areas and hard landscaping projects. Block paving can also be used in conjunction with precast concrete flags, with coordinating sizes, to give variety combined with consistent surface characteristics.

Worn out road surfaces and other areas such as aircraft aprons, industrial hard-standings and car parks can be strengthened and reconditioned by an overlay of concrete block paving on a sand laying course. The new wearing surface uses the old pavement as the base course, providing it is structurally sound, and the design procedure is included in BS7533 2001. This cost-saving rehabilitation technique can be completed in sections with minimal disruption and has led to it being adopted extensively by airport operators such as BAA.

Reinstatement and Recycling

The structure of block paved areas allows sectional removal and reinstatement using the original blocks. The material's ability to accommodate reinstatement has been likened to 'unzipping' the surface without leaving evidence, in contrast to the patched or ribboned areas always appar-ent in an asphalt reinstatement. The re-use of concrete paving blocks contributes further to its impressive environmental credentials.

Colours, Finishes, Shapes and Sizes

Concrete block paving is available in a constantly expanding variety of shapes, sizes, colours and finishes and can be installed in numerous bonds and laying patterns, enabling it to delineate space or focus on specific features. Colours are formed from UV stable pigments which are an integral part of the block mix. Some blocks are multi-colour or brindle, formed from batches of two or more colours - such as black, red and buff - which are then blended together. Concrete block paving, often with an irregular or 'weathered' appearance, can match the look of stone setts, cobbles, clay bricks and other traditional surfaces while costing significantly less and pro-viding better slip resistance and a more accessible surface for all pedestrians. Full details of spe-cial products and finishes can be obtained from individual Interpave manufacturer Members.

Performance

The new European Standard BS EN 1338: 2003, *Concrete Paving Blocks - Requirements and Test Methods* has introduced a different approach to the old British Standard that will give specifiers and suppliers more confidence in the use of concrete paving blocks. Whereas the BS EN stipulates that the manufactured concrete must conform to a wider range of performance characteristics, determined on actual manufactured concrete paving block. Additionally, instead of having "one size fits all", all the performance characteristics are classified into classes, which the manufacturer must declare, so that the specifier and supplier has the relevant information need-ed to make informed selections.

Before any product is launched it is subjected to the rigours of 'Initial Type Testing' which demon-strates conformity to the BS EN for a product family. A family of product types is best described as paving blocks manufactured to give a similar surface using the same equipment, process and raw materials, e.g. a paving block manufactured with a natural river gravel will belong to the same surface family (same performance characteristics) as a paving block manufactured with crushed granite/limestone. Each manufacturer will declare their definitions of product families when asked.

The continuing conformance of the concrete block paving to the BS EN is supported by 'Routine Type Testing' and additional measures established under 'Factory Production Control'. The BS EN describes how the performance characteristics are to be assessed with detailed test meth-ods and procedures, as described below. These methods are to be used in all cases of dispute resolution. Other methods can be used routinely to check compliance with the BS EN provided correlation is established with the standard method.

Splitting Strength - is a measure of the ability of the concrete block paving to withstand load. It is determined under laboratory conditions applying a tensile splitting test. The concrete block paving is placed between two rigid bearers rounded to a radius of 75 ± 5 mm, after immersion in water for 24 hours, and a load uniformly applied at a rate which corresponds to an increase in stress of 0.05 ± 0.01 MPa/s until failure is reached. For each block the individual splitting strength in MPa is determined by calculation using the formula and a correction factor, and are recorded to check compliance with the BS EN. The number of blocks per sample will vary depending on previous production performance assessed statistically by attributes or variables.

Weathering Resistance - is a measure of the ability of the concrete paving block to withstand weathering where specific conditions exist such as frequent contact of the surfaces with de-icing salt under frost conditions. It can be assessed under laboratory conditions by measuring the amount of spalled material from a surface under the cycle of freezing/thawing action using a de-icing salt solution. Or, if no de-icing salt is used, then the measurement of the porosity by meas-uring the water absorption of the block should be used.

Abrasion Resistance - is a measure of the ability of the concrete paving block to withstand erosion caused by trafficking in service. It is assessed under laboratory conditions by abrading the surface of the block with a flow of a hard abrasive material while applying a known force. The resulting loss of material from the block surface is measured by determining the abraded width.

Slip/Skid Resistance - is a measure of the ability of the concrete block paving laid in service to withstand slipping for pedestrians and skidding for vehicles. The unpolished slip resistance value is determined using a “standard rubber” material attached to a Pendulum Friction Tester and tested under wet conditions. To determine the polished paver value (PPV) for all paving units BS 7932: 1998 should be used. This standard has formed the basis for the European Test Method DD ENV 12633:2003. This test method measures the slip resistance of the block paving after it has been synthetically trafficked (or polished) under laboratory conditions to replicate the performance of block paving during it’s life under traffic conditions. For more details please contact Interpave.

2 Structural Design

This section offers detailed guidance on structural design for various applications of concrete block paving. Generally, accepted design methods for concrete block pavements are based on the performance of asphalt pavements but using an equivalence factor to convert the surface to block paving. These methods can be considered as conservative, as research shows that interlock between the concrete blocks contributes to the structural performance of pavements.

Examples of uses of block paving

Thickness of Block mm	Typical application
50	Driveways, Patios, Pathways and Footways
60/65	Adopted highways and other roads <0.5 msa Cul-de-sacs, petrol forecourts, pedestrian areas subject to regular heavy traffic
80	Heavy duty pavements 0.5 to 12 msa
100	Very heavy duty pavements

Appropriate design methods for the pavement construction including sub-base, and where required, roadbase thicknesses are dependent upon traffic volumes, in millions of cumulative standard axles (msa):

- **up to 0.5 msa** - BS 7533-2: 2002, *Pavements constructed with clay, natural stone or concrete pavers, Part 2: Guide for the structural design of light duty pavements constructed of clay pavers or precast concrete paving blocks.*
- **0.5 to 12 msa** - BS 7533-1: 2001, *Pavements constructed with clay, natural stone or concrete pavers, Part 1: Guide for the structural design of heavy duty pavements constructed of clay pavers or precast concrete paving blocks.*
- **exceeding 12 msa** - Interpave publication: *The structural design of heavy duty pavements for ports and other industries* (which can be ordered on-line) or other appropriate design guides.

For aircraft pavements, the Civil Aviation Authority report: The use of pavers for aircraft pavements includes design methods for both new and overlay pavements derived from the specific loading characteristics of today's civil aircraft. The Ministry of Defence has also developed recommendations for concrete block pavements used by military aircraft. In addition to the above, design guidance for Overlay Resurfacing is also included in this section. Separate guidance is pro-vided for the design of permeable pavements at www.paving.org.uk.

Light Duty Pavements:

The British Standard BS 7533-2 provides guidance on the design of lightly trafficked pavements for all paved areas subject to the usual road spectrum of axles loads up to 11 000 kg. This applies to areas trafficked by up to 0.5 msa which includes cul-de-sacs, driveways, car parks, precincts, lightly trafficked roads, private and industrial vehicle parks, estate roads and paved areas.

STEP 1

The bearing strength of the subgrade should be obtained as this determines the overall thickness of the sub-base. The strength of the subgrade is described as the 'California Bearing Ratio' (CBR). The CBR of the underlying materials may be provided by a site investigation report. If there is no report or the CBR has not been obtained then it may be estimated using the follow-ing table:

Estimated CBR values for British soils

Type of subgrade	Plasticity index	CBR per cent
heavy clay	70	2
	60	2
	50	2
	40	3
silty clay	30	4
sandy clay	20	5
	10	5
silt		1
poorly graded sand		20
well graded sand		40
well graded sandy gravel		60

The following information has been extracted and summarised from BS 7533: Part 2. For sub-base design, the subgrade strength can be estimated using simple field tests (after initial compaction of the trimmed ground) to give the sub-base thickness:

Identification of materials and CBR values using a simple field test

Rock or soil		Simple field test	CBR
Type	**Condition**		
Rock	Hard	Requires mechanical pick for excavation	Above 5%
Sand Gravel	Compact	50mm square peg hard to drive in 150mm	>5%
Clay Sandy clay	Stiff	Cannot be moulded by fingers Need pick for excavation	5%-2%
Clay Sandy clay	Firm	Can be moulded by fingers Need spade for excavation	5%-2%
Sand Silty clay Clayey sand	Loose	Dry lumps easily broken down 50mm square peg driven in easily	2%
Silt Sandy clay Silty clay Clay	Soft	Can easily be moulded by fingers	<2%
Silt Sandy clay Silty clay Clay	Very soft	Exudes between fingers when squeezed	Seekspecialis-tadvice
NOTE 1 This table is based on the principles in BS 8103-1. NOTE 2 The CBR of the rock or soil is significantly affected by moisture content			

For loose, soft and very soft materials comprising sand, silt and clay, specialist advice should be sought. The above guidance applies where the water table is 300 mm or more below formation level. Specialist advice should be sought where this is less, standing water is present or there are any doubts about the ground conditions. Any soft spots should be dug out and replaced with good fill or sub-base material and fully compacted. On sites where the CBR varies from place to place then the lowest recorded value should be used.

STEP 2

The number of commercial vehicles using the area should be obtained. As a guide to typical applications and number of commercial vehicles per day (cv/d) the following table can be used.

Category	Maximum trafficking(msa)	cv/d	Typical applications
I	> 0.5		use BS 7533 -1
II	0.5	> 5 < 5	Adopted highways & other roads Car parks with occasional heavy traffic Footways overridden by vehicular traffic
IIIa		<1	Pedestrian areas with occasional vehicular traffic
IIIb		Nil	Car parks and footways
IV			Private drives, paths, patio

A typical design life of 20 years can be adopted for concrete block paving.

The volume of traffic to be carried by the pavement is expressed as 'standard axles'.

This theoretical figure is calculated by taking the number of commercial vehicles using the pave-ment during its design lifetime. Where channelised traffic in highways and roadways oc-curs, the traffic figure should be multiplied by 3. If the application of this factor results in a figure greater than 0.5 msa then BS 7533-1 should be used.

STEP 3

The construction thickness is determined based on the category of application and the CBR, and the thickness of each layer obtained from the following table.

Category	Sub-base thickness mm CBR					Roadbase mm	Laying Course mm	Paving thickness-minimum mm
	<2%	3%	4%	5%	>6%			
II	400	350	250	150	150	125	30	60
IIIa	350	300	225	150	150	0	30	50
	250	150	100	100	0	70	30	50
IIIb	300	250	175	100	100	0	30	50
IV	200	150	125	100	0	0	30	50

A DESIGN EXAMPLE

A driveway is to be constructed overlying firm clay with an estimated CBR value between 2 and 5. The category is IV and the construction thickness, using the lowest CBR value, is obtained from the above table, as follows:

Construction thicknesses -

Sub-base	200 mm
Laying Course	50 mm
Paving Blocks	50 mm

Heavy Duty Pavements

The procedure for the design of paving subject to highway loading conditions can be calculated from BS7533-1, on which the following guidance is based.

STEP 1

Establish the CBR of the subgrade. The saturated CBR value should be determined either by site investigation or, in the case of fine grained soils, from the plasticity index of the subgrade material. The degree of subgrade drainage must also be considered when deciding the appropriate CBR to be assumed.

Site investigation data should be analysed carefully and advice sought if in doubt. The equivalent equilibrium suction index CBR values may then be obtained from the following table, which is taken from BS7533-1.

Equilibrium suction index CBR

Type of soil	PI	High water table Construction conditions			Low water table Construction conditions		
		Poor	Average	Good	Poor	Average	Good
Heavy clay	70	1.5 to 2	2	2	1.5 to 2	2	2 to 2.5
	60	1.5 to 2	2	2 to 2.5	1.5 to 2	2	2 to 2.5
	50	1.5 to 2	2 to 2.5	2 to 2.5	2	2 to 2.5	2 to 2.5
	40	2 to 2.5	2.5 to 3	2.5 to 3	2.5	3	3 to 3.5
Silty clay	30	2.5 to 3.5	3 to 4	3.5 to 5	3 to 3.5	4	4 to 6
Sandy clay	20	2.5 to 4	4 to 5	4.5 to 7	3 to 4	5 to 6	6 to 8
	10	1.5 to 3.5	3 to 6	3.5 to 7	2.5 to 4	4.5 to 7	7 to >8
Silt	-	1	1	2	1	2	2
Poorly graded sand	-	20					
Well graded sand	-	40					
Sandy gravel	-	60					

The construction conditions referred to in the table above relate to the general conditions on site during the construction period. This factor has a significant effect on the assessment of the CBR value to be used. A high water table is one which is 300 mm or less below the formation level, while a low water table is 1 m or more below the formation level. ‘Good’ conditions are where the subgrade is protected promptly with an improvement layer or sub-base, while ‘Poor’ condi-tions are where little or no subgrade protection is provided.

The value used for the CBR should be based on the worst results obtained on site. If it is considered to be economical, a localised design can be introduced for the poorer areas or poor materials can be replaced.

STEP 2
Assess the number of commercial vehicles per day (cv/d) passing in each direction and determine the number of standard axles for the required design life from the following table.
Conversion of commercial vehicles per day (cv/d) to number of standard axles in millions of axles (msa)

Volume of traffic cv/d	Cumulative traffic (msa)			
	20 years design life		40 years design life	
	zero growth	2% growth	zero growth	2% growth
30	0.2	0.3	0.4	0.6
120	0.8	1	2	3
250	2	3	6	9
500	6	8	15*	22*
1000	16*	22*	*	*

This table applies to normal pavements on which commercial vehicles constitute less than 50% of the flow. In other cases, guidance should be sought from TRL1132**.

Particular care should be taken in the selection of the laying course material to be used for areas subjected to loading by heavy channelised traffic, particularly in areas of high rainfall. The minimum block thickness for roads carrying averages of more than 5 commercial vehicles per day should be 80 mm. In cases of lesser flows the block thickness may be 50 mm.

Notes:
* Volumes exceed the scope of BS 7533: Part 1
** TRL1132 - 1984. The Structural Design of Bituminous Roads.

Special Cases
In some cases unusual or particularly onerous loading effects or other conditions should be taken into account, e.g. the following:

a) Where channelised traffic is expected, the traffic figures should be multiplied by three before carrying out the design, to allow for the increase in the concentrated application of loads at a particular location on the pavement. Normal lane widths in a highway do not generally constitute channelised traffic but channelised traffic can develop on any road, e.g. on steep hills, approaches to traffic signals and pinch points within traffic calming measures.
b) Where speeds in excess of 30 mph (50 km/h) are expected, the cumulative traffic should be multiplied by two before carrying out the design to allow for dynamic loading effects.
c) Where both channelised traffic and speeds in excess of 30 mph (50 km/h) occur only the higher multiplier, i.e. three, should be applied.
d) Pavements constructed over frost-susceptible soils should have an overall thickness of non frost-susceptible material of not less than 450mm.

STEP 3

Use the following table to determine the thickness of the improvement layer and sub-base, **or** sub-base alone. The thicknesses are dependent upon the subgrade CBR value and trafficking. Using the combination of improvement layer with sub-base or sub-base only may result in a pavement design of equivalent structural performance.

	Foundation option	<2%	>2% -<3%	>3% -<4%	>4% -<5%	>5%- <10%	>10% -<15%	>15% -<30%
Untrafficked	Sub-base/improvement-layer	150/150	150/150	Sub-base alone				
	Sub-base		170	150	150	150	150	150
Up to 4 dwellings 2000m²or 100 sa	Sub-base/improvement-layer	150/210	150/180	150/150	Sub-base alone			
	Sub-base		250	190	160	150	150	150
Up to 20 dwellingsor 200 sa	Sub-base/improvement-layer	150/370	150/250	150/170	150/160	150/150	150/150	150/0
	Sub-base		310	240	210	180	150	150
Up to 50 dwellings 5000m²commercial or 500 sa	Sub-base/improvement-layer	150/470	150/340	150/250	150/220	150/200	150/150	150/0
	Sub-base		350	270	230	200	160	150
Up to 80 dwellings 8000m²orcommercial or 1000 sa	Sub-base/improvement-layer	150/600	150/450	150/350	150/300	150/250	150/180	150/0
	Sub-base		400	310	270	225	180	150
largedevelopment 5000m²	Sub-base/improvement-layer	200/600	200/450	150/450	150/350	150/300	150/250	150/150
	Sub-base		450	350	310	270	240	225

The number of standard axles in the table is based on traffic during the construction phase, i.e. those designed to impose directly on to the sub base during the construction period.

Sub base materials should be Type 1 granular materials as in the Specification for Highway Works. The use of Type 2 or inferior materials may lead to the pavement construction becoming excessively sensitive to moisture changes and water movements. Any soft or poorly compacted materials must be removed from the subgrade.

If the subgrade materials are susceptible to frost attack, the total pavement thickness of sub base, laying course sand and concrete blocks must not be less than 450 mm. The nominal compacted laying course thickness over a sub base of granular material should be 50 mm. When a bound roadbase is provided a thinner laying course may be used but in no place should the compacted thickness of sand laying material be less than 30 mm.

STEP 4

The thickness of roadbase required can be ascertained from the number of standard axles using the pavement in its design life and the type of roadbase employed from the following table:

Structural design for roadbase and surfacing

Design in millions of standard axles	Roadbase thickness (mm) CBM3	Dense bitumen macadam roadbase (mm)	Laying course thickness (mm)	blockthickness (mm)
0.5 to 1.5	130	130	30	50, 60, 65 or 80
>1.5 to 4	130	130	30	80
>4 to 8	180	155	30	80
>8 to 12	230	170	30	80

For pavements with msa's in the range of >1.5 to 8, it is permissible to reduce the blocks thickness if the road base thickness is increased to compensate. The following table gives guidance on the increase in road base necessary.

Alternative design for roadbase and surfacing

Design in millions of standard axles	Roadbase thickness (mm) CBM3	Dense bitumen macadam roadbase (mm)	Laying course thickness (mm)	blockthickness (mm)
>1.5 to 4	150	150	30	60
>1.5 to 4	145	145	30	65
>4 to 8	195	170	30	65

The materials used in the roadbase should be as specified in Clauses 906 or 1038 of the Specification for Highway Works. Other materials may be substituted and guidance may be found in BS7533 -1.

A DESIGN EXAMPLE

A housing development of 50 dwellings will be served by an access road, which will be trafficked by 120 commercial vehicles per day. The traffic is estimated to grow at 2% over 20 years. The road sub-base will be used for site access and the CBR of the subgrade value is between 4 and 5%. The speed limit for the road is 50 kph but traffic is channelised.

SUBGRADE CBR VALUE **Step 1**	Determine subgrade CBR **CBR value = 4 – 5%**
CUMULATIVE TRAFFIC **Step 2**	Assess the number of commercial vehicles/day (cv/d) passing in each direction and determine the number of standard axles for the required design life. cv/d = 120 growth will be 2% over 20 years therefore cumulative traffic = 1 msa but traffic is channelised therefore increase the cumulative traffic by a factor of 3 therefore **cumulative traffic = 3 msa**
SUB-BASE/IMPROVEMENT LAYER THICKNESS **Step 3**	Determine the thickness of the sub-base/improvement layer CBR value = 4 – 5% up to 50 dwellings therefore **sub-base/improvement layer = 150/220mm** or **sub-base only = 230mm**
ROADBASE AND BLOCK THICKNESS **Step 4**	Determine the roadbase and block thicknesses msa = 3 therefore **roadbase thickness = 130mm (CBM3)** or **= 130mm (DBM)** **laying course thickness = 30mm** **block thickness = 80mm**

Construction thicknesses -

Block paving	80 mm
Laying course	30 mm
Roadbase CBM 3 or DBM	130 mm
Sub-base / improvement layer or if sub-base only	150/220 mm 230mm

Ports and Other Very Heavy Duty Pavements

The Third Edition of the Interpave and British Ports Association *The structural design of heavy duty pavements for ports and other industries* can be used to design pavements surfaced with block paving. It was published in 1996 and, for the first time, a radically new way of analysing pavements is incorporated in the design method, which includes pavement design charts based on finite element analysis. This has allowed design to be based on the concept of Equivalent Single Load. Also, it has allowed the design of the whole pavement to be separated into design of the base and design of the foundation. In making this separation, no accuracy is lost and the design exercise has been greatly simplified, such that only one chart is now required for design. The resulting pavement should remain serviceable throughout its life. During the last 10 years, a good deal of experience has been gained in the use of Material Conversion Factors or Material Equivalence Factors so that they can now be used as a means of effectively swapping one mate-rial for another during the design process. This means that when a design has been produced using the chart, the designer can generate alternative design solutions using different materials and so investigate a full range of solutions.

The Third Edition of the Interpave and British Ports Association *The structural design of heavy duty pavements for ports and other industries* can be ordered on-line at www.paving.org.uk.

Pavements for Aircraft

Where concrete block paving is used by aircraft, design should follow the recommendations of the Civil Aviation Authority or Ministry of Defence on the use of pavers for aircraft pavements.

Pavement Overlays

In the Component Overlay Design Method given in BS 7533: Part 1, the condition of each course in an existing pavement is expressed as an equivalent thickness of a standard material. This allows the current condition of dilapidated materials to be assessed numerically. The standard material chosen is dense bitumen macadam (see Clause 903 of the Department of Transport Specification for Highway Works).

Once each type of material within the pavement is identified, a Material Conversion Factor (MCF) is assigned to that material. The true thickness of each course in the pavement is then multi-plied by the appropriate MCF to obtain the equivalent thickness of dense bitumen macadam.

In order to account for any degradation which may have taken place in each course of the pave-ment since construction, the equivalent thickness of each course is multiplied by two factors which account for the less than perfect condition of the material in the pavement. These two con-dition factors are CF1, to be applied to take account of cracking and spalling of the pavement materials, and CF2, to account for rutting and settlement. If the deterioration of the surface of the roadbase is a result of failure in the sub-base, the subgrade improvement layer or the subgrade, it may not be possible to overlay the existing pavement.

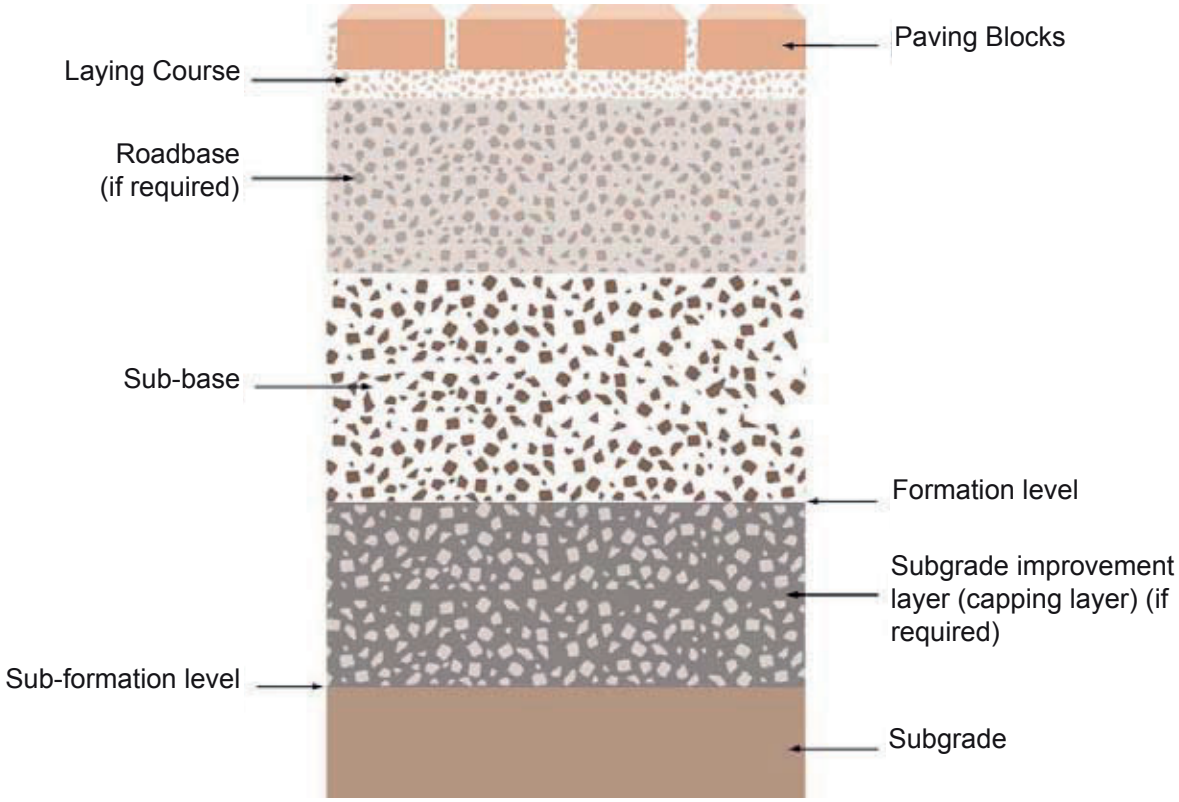
Once the existing pavement has been transformed into an equivalent thickness of dense bitumen macadam, a pavement is designed in accordance with the new pavement design method and that theoretical pavement is then transformed into an equivalent thickness of dense bitumen macadam using the material conversion factors. By comparing the equivalent thickness of dense bitumen macadam in the existing pavement with the equivalent thickness of dense bitu-men macadam required for the new pavement, a determination can be made as to whether the provision of a concrete block paving overlay will provide a satisfactory engineering solution. It may be that an additional course of material will have to be provided beneath the concrete block paving in order to bring the overlaid pavement to a satisfactory structural condition (see BS 7533: Part 1 for full details).

3 Detailing And Construction

This construction guidance is based upon information from the Specification for Highway Works, BS7533 : Part 3 - 1997, *Pavements constructed with clay, natural stone or concrete pavers* (please note that this standard is under revision and it is proposed to be re-published 2005), other relevant guides and hands-on best practice experience.

A block paved area should be able to accommodate the intended trafficking over its design life, without experiencing significant surface deformation. In order to achieve this the pavement must be correctly designed and properly constructed. Close attention to detailing will ensure an aes-thetically acceptable block surface able to transmit the applied loads to the structural elements of the pavement layers.

The correct level of compaction of each layer of the block pavement will prevent the formation of ruts throughout its life by maintaining the structural integrity of the surface course, and protect-ing the pavement layers and subgrade from becoming overstressed.

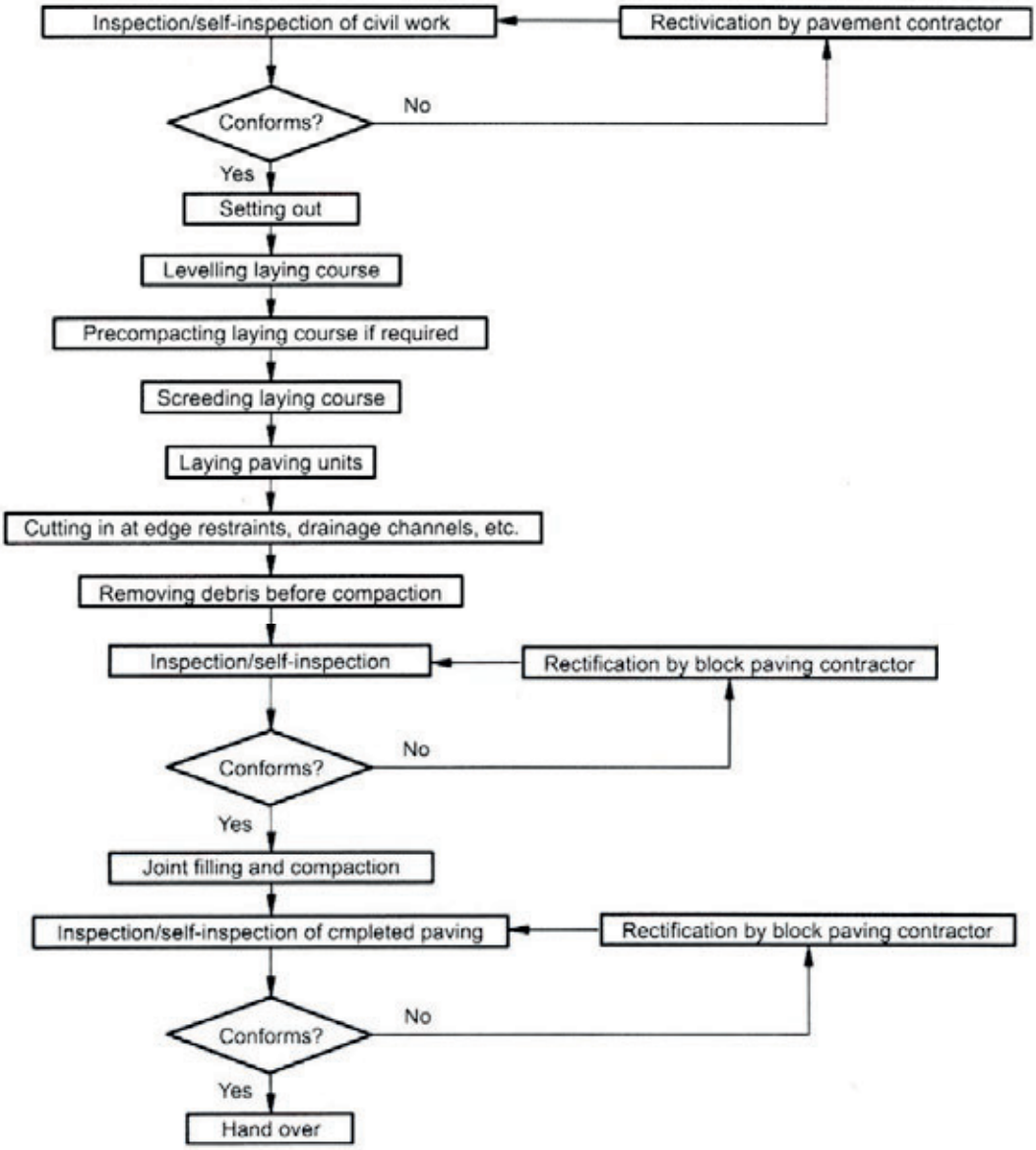


The main elements of a typical conventional concrete block paved pavement construction are shown in the cross-section above. The roadbase and capping layers are dependent on the level of trafficking and ground strength respectively, and may not be present in all pavements.

The Construction Process

The block laying procedure is set out below in a flow chart, as an aid.

Pavement Construction Procedure



Before commencement of the block laying, the preceding work i.e. base construction, edge restraints, features and penetrations within the pavement such as drainage channels, inspection pits, etc., should be checked to ensure they are in compliance with the contract requirements. Particular attention should be paid to the base levels and tolerances to ensure that, when the block layer is constructed, overall surface levels and tolerances are achievable.

Any non-conformances in the processing works must be corrected before the commencing of the block layer construction.

Preparation of Subgrade

Any soft spots should first be excavated and back-filled with well-compacted suitable material. The subgrade or original ground formation should then be prepared by trimming to level and compacting to a tolerance within +20 mm and -30 mm, in accordance with the Specification for Highway Works. For conventional block pavements (as opposed to permeable pavements) it may also be necessary to introduce drainage into the sub-grade to lower the water table and improve the bearing capacity of the sub-grade.

Preparation of Pavement Layers

Capping Layer

The construction of a capping layer is a method to improve the bearing capacity of a weak sub-grade. It may also be used with a suitable geotextile fabric, which prevents loss of capping mate-rial into a soft sub-grade. When a capping layer is included, the upper surface of this layer is often referred to as the 'formation'. The subgrade surface is then called the 'sub-formation'. The capping layer should be rolled to a tolerance within +20 mm and -30 mm, in accordance with the Specification for Highway Works.

Sub-base

A sub-base should be present in all pavements as it helps to spread the applied wheel loads. Generally, DTp Type 1 material is recommended for conventional concrete block pavements. It should be compacted in accordance with the Specification for Highway Works to a toler-ance within +20 mm and -15 mm. It should be dense and tightly compacted to avoid downward migra-tion of the laying course material.

Roadbase

A roadbase may be required in heavier duty pavements. It forms a major load-bearing layer with-in the pavement construction. The roadbase material should be one of the materials listed in the following table and laid in accordance with the Specification for Highway Works. It should be laid to a tighter surface tolerance than the sub-base, within +0 mm and -12 mm.

Roadbase Materials

Roadbase Material	Material Clause*	Compaction Clause*
Dense bitumen macadam	903	901
Hot rolled asphalt	904	901
Pavement quality concrete	1001 to 1034	1024 to 1025
Cement-bound materialcategory 1 (CBM 1)	1036	1035
Cement-bound materialcategory 2 (CBM 2)	1037	1035
Cement-bound materialcategory 3 (CBM 3)	1038	1035
Cement-bound materialcategory 4 (CBM 4)	1039	1035

*See the *Specification for Highway Works*

Preparation of Existing Bases as the Sub-layer (Overlay Resurfacing)

Where blocks are to be laid over existing roads or other paved areas, it may be necessary to correct levels of the existing pavement to ensure final surface tolerances are within +0 mm and -12 mm.

Level adjustment

Any excess material should be removed, for example using a planing process, to allow installation of the required laying course thickness. Where levels need to be built up, suitable material complying with the table above should be used, laid and compacted in accordance with the Specification for Highway Works. Care should be taken to ensure existing drainage will continue to function after any adjustments to levels.

Preparation of Restraints

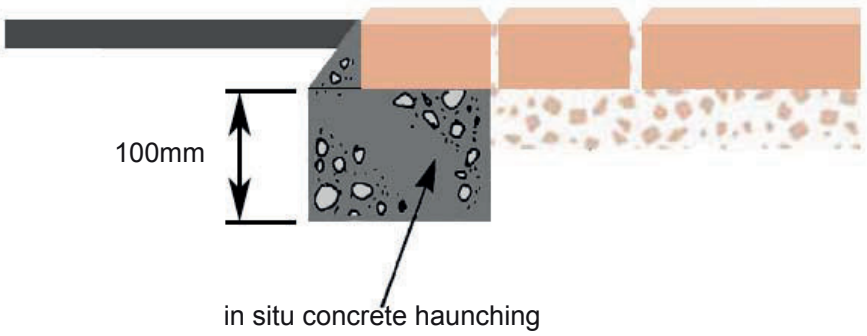
Edge Restraints

The paved area must be restrained at its edges to prevent movement, either of the whole paved area or individual blocks. Edge restraints resist lateral movement, prevent rotation of the blocks under load and restrict loss of laying course material at the boundaries.

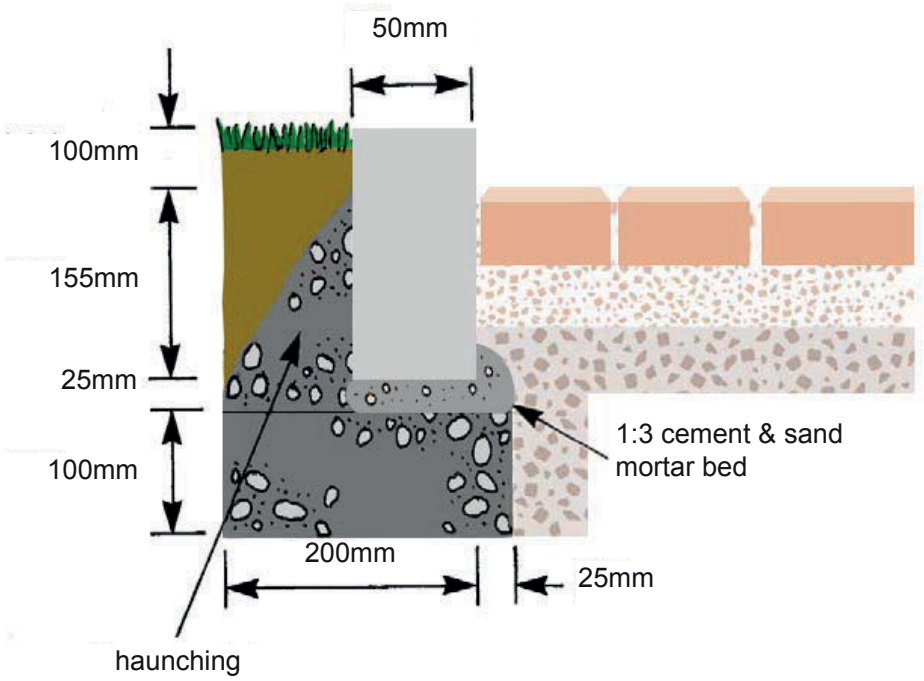
Edge restraints should be laid at all boundaries of the block paved area including where block paving abuts different flexible materials, such as bituminous bound material. They should be suitable for the relevant application and sufficiently robust to resist displacement if likely to be overrun by vehicles. It may be necessary to extend sub-layers to support the edge restraint together with any base and haunching. Compaction of pavement layers near edge restraints should be delayed until any concrete bed and haunching has gained sufficient strength to prevent movement of the edge restraint.

The following diagrams illustrate typical edge restraints for various situations:

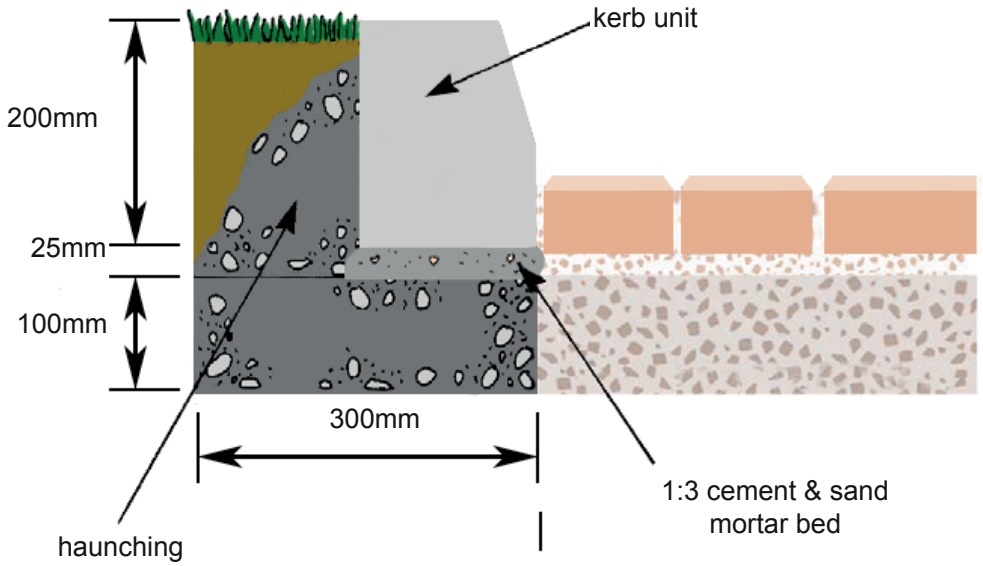
Domestic light traffic areas/adjacent to a building



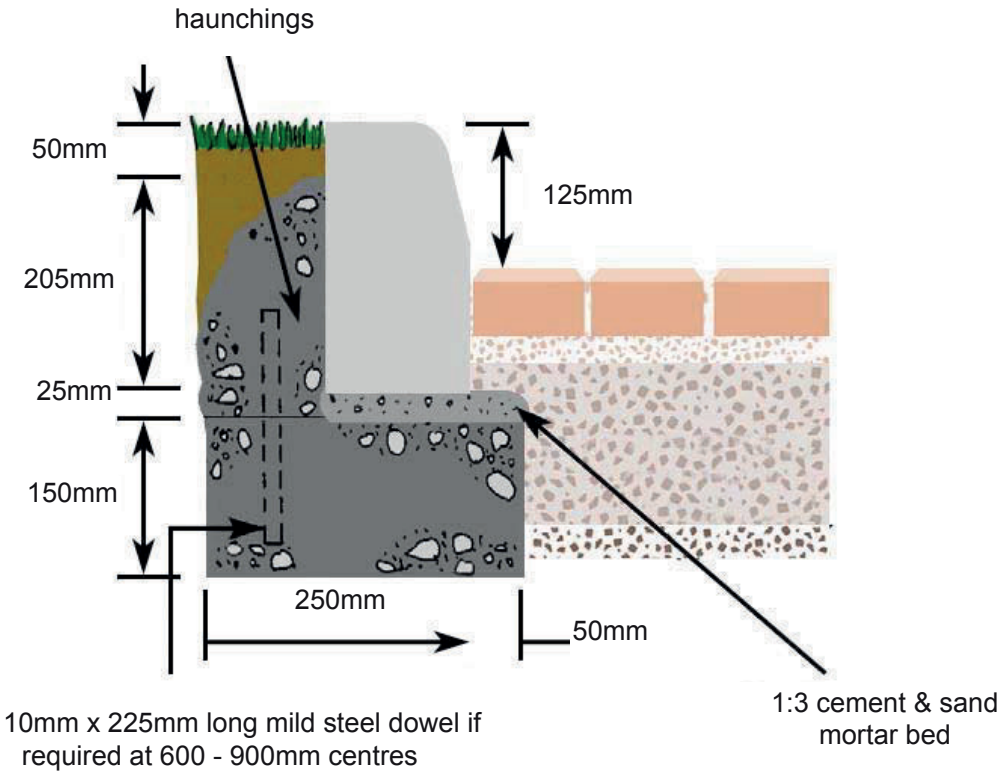
Light vehicle and pedestrian traffic



Estate roadways/car parking areas



Heavy industrial traffic



Temporary Restraints

For areas of pavement that cannot be completed for some time and may be subject to trafficking near the edge of the unfinished area, it may be necessary to construct temporary restraints to prevent movement of laid blocks. Temporary restraints should be constructed to resist lateral movement during full compaction of the paving and subsequent trafficking.

Preparation of the Block Paved Surface Course

Laying Course

The laying course material should be naturally occurring sand (from the quaternary geological series) or sea-dredged sand. It should not contain cement. Other materials including crushed rock fines may be used for category IV applications. The category of the sand and its grading should be in accordance with the following tables.

Laying Course Material Categories

Laying Course Category	**Application**
IA	Aircraft pavements Bus stations Pavements with severely channelised traffic
IB	Industrial pavements Loading bays
II	Adopted highways Roads Petrol station forecourts Pedestrianisation schemes with regular heavy traffic Car parks with some heavy vehicles Footways with frequent vehicle overrun
III	Pedestrianization projects receiving only occasionalheavy trafficcar parks receiving no heavy vehicles
IV	Private driveways Areas with only pedestrian traffic Footways with occasional vehicle overrun

The following table is based upon the new European Aggregate Standard BS EN 12620 and provides basic gradings.

Laying Course Material Grading

Sieve (mm)	% Passing	
8	100	100
6.3	95	100
4	85	99
0.5	30	70
0.063	0	See the following table

Site Category	IA	IB	II	III	IV
Passing 63micron (max) (f)	0.3%	0.5%	1.5%	3.0%	4.0%

As a guide to moisture content, after the material has been squeezed in the hand and the hand is opened the laying course material should bind together without showing free moisture on its surface. Where laying course material is stored on site it should be covered to reduce moisture loss due to evaporation, or saturation from rainfall.

If the laying course material becomes saturated after laying then it should be removed and replaced with laying course material in a condition suitable for the block laying operation. Alternatively, the laying course can be left in place until it dries sufficiently to allow block laying to proceed.

Drainage of Laying Course

It is desirable to drain the laying course material. Localised drainage may also be required where a physical barrier within the pavement surface could lead to water collecting in the laying course.

The size and spacing of the drainage outlets through the impermeable layer depend upon the size, shape and gradient of the underlying layer. A typical, minimum example is 30mm diameter holes at 1.0 m centres. The holes should be covered with a suitable filter fabric, extending at least 150 mm either side of the drainage hole, to prevent loss of laying course.

Laying Course Thickness

The laying course should have a nominal compacted thickness to achieve tolerance as shown in the following table.

Laying Course Thickness and Tolerance

Thickness mm	Tolerance
50	+15 -20
30	+10 -5

Laying Course Construction

The laying course material should be screeded and prepared using one of the following methods:

a) Pre-compaction of laying course: Spread the material in one layer and compact using a plate compactor making allowances for the reduction in thickness achieved during compaction and level the surface by screeding. A pre-compacted laying course is recommended for mechanically installing block paving. Contact Interpave Member companies for further details pertinent to their method of mechanical laying.

b) Uncompacted laying course: Spread the material loosely in a uniform layer and screed to the thickness required to give the target laying course thickness after the paving blocks have been laid and vibrated into place.

(c) Special Equipment: Lay and compact the laying course material with specialised equipment such as an asphalt paving machine or similar type of equipment.

When drainage of the laying course is required, it will be necessary to incorporate a geotextile filter to prevent sand migrating into drainage systems or into cracks in the underlying pavement layer. Where concrete block paving is laid in combination with small element paving flags the compacted sand thickness will be determined by the requirements of the flags.

Where screed rails have been used to assist in the line and level of the laying course screeding they should be carefully removed to avoid disturbing the screeded surface. Any depressions left by the screeding rails should be made good. If the prepared laying course is disturbed or damaged prior to block laying it should be corrected before block laying commences.

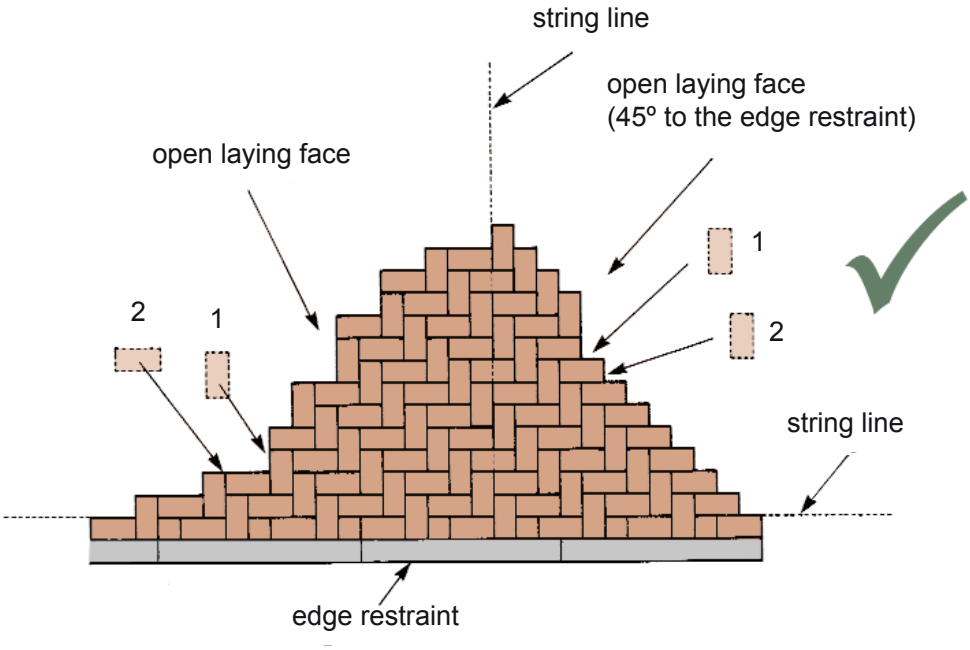
Construction of the Block Paving Layer

Blocks can be hand or machine laid. Block laying should normally start at a fixed edge restraint.

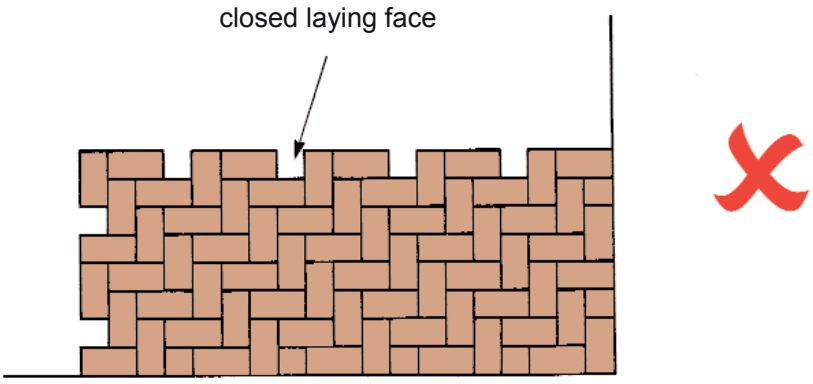
If this edge restraint is unlikely to be adequately straight or at 90° to the intended block bond, a string line temporary datum should be set up a short distance from the edge restraint and used to align the first “row” of blocks. A second string line at 90° to the first will ensure that the block bond does not “wander”. The area between the first string line and edge restraint can then be infilled with blocks, cut to fit as necessary.

It is advisable to continue to use string lines or other control methods during laying of the paved area. Manufacturing tolerances in the blocks and normal joint/laying tolerances may not aid per-fectly straight joint lines but using string lines and continuously adjusting blocks as they are laid will ensure acceptable alignment of the bond and joint spaces - providing that joints do not exceed the specified joint widths.

The blocks should be laid with joint widths between 2-5 mm, in the specified bond. The spacer nibs on some blocks are not designed to fix the joint width but rather to prevent damage to the blocks from face to face contact. For hand laying, the installer should work from blocks already placed, taking care not to disturb them. Full blocks should be laid first using an open laying face as shown:



A closed laying face, as shown below, should be avoided wherever possible as it can become impossible to lay blocks between the ‘castellations’ created as the paving of the area progresses.

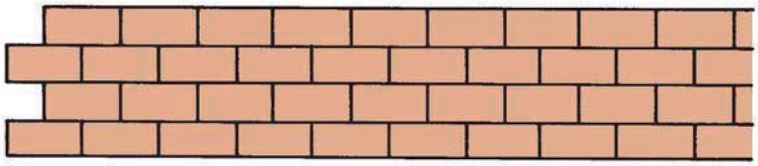


Block Laying Patterns

Precast concrete paving blocks are manufactured in an array of shapes, sizes and colours enabling the designer to create numerous patterns and designs.

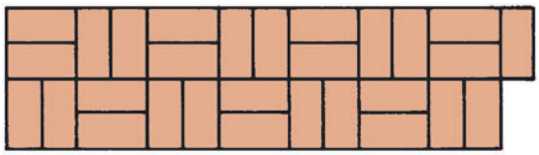
For pedestrian areas, the laying pattern is not as important to serviceability as in trafficable areas. For vehicular trafficked areas, the most effective laying pattern is herringbone bond. The orientation of her-ringbone bond in relation to the direction of vehicular areas does not affect the performance of the pavement. The herringbone pattern is usually set at 45° or 90° to the longest straight edge. Rectangular units may be used in stretcher bond but it is desirable that the stretcher bond is not 'in line' with the general flow of traffic.

Stretcher bond



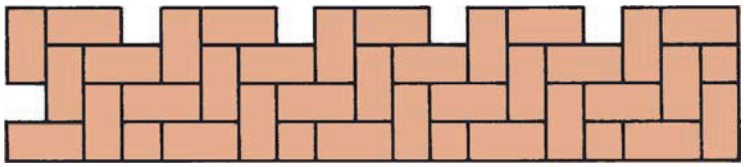
Stretcher bond is suited to pedestrian areas and very lightly trafficked areas not subject to regular turn-ing movements or frequent braking or acceleration. Block rows should be laid at right angles

Basket weave or Parquet

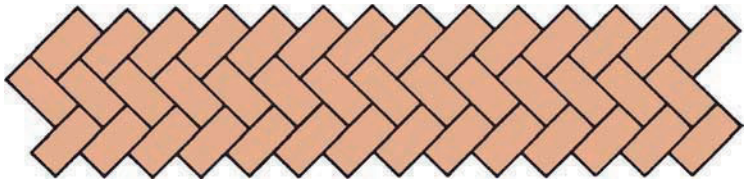


This pattern is suited to pedestrian areas only and should not be used for trafficked areas.

Herringbone at 90º to an edge



Herringbone at 45º to an edge



Herringbone patterns are suitable for all applications. Either 90° or 45° Herringbone pattern oriented to the longest straight edge should be used with vehicular areas. This reduces the incidence of creep and distributes wheel loads more evenly to the underlying pavement construction.

Coloured Blocks

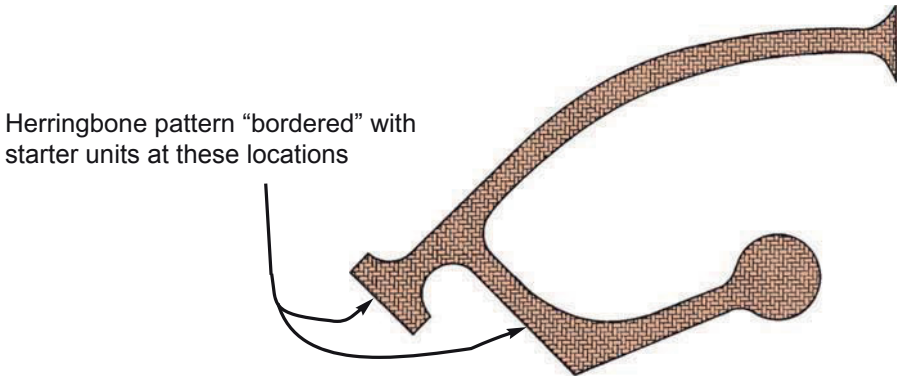
Coloured blocks can be used to form patterns in a pavement, either for aesthetic or more functional uses. Blocks can be used to create pictures and/or words, as well as chevron patterns on traffic islands, yellow no-parking lines and car parking bay delineation.

Proprietary Shapes or Systems

Interpave members' guidance should be sought on the suitability of proprietary shapes or systems for particular applications.

Other Design Considerations

Concrete block paving can accommodate areas of any shape or size and careful design can min-imise the need for block cutting. The orientation of the pattern in relation to the longest bound-aries of the paved area will determine how much cutting of blocks is necessary to complete paving of the area. A typical residential road layout provides a good example as shown:



Careful selection of the laying bond, the orientation of the bond and position of any breaks or changes in the bond can reduce the amount of block cutting and speed up the laying process.

Falls

After an initial period of operation a concrete block pavement surface can be regarded as virtually impermeable in trafficked areas. It therefore requires gradients for drainage of surface water, as for any surfacing material. Minimum crossfalls of 2.5% (1:40) and longitudinal falls of 1.25% (1:80) are recommended for carriageways. Where proprietary drainage systems are used the pavement should be laid with a minimum crossfall of 2.5% and the longitudinal fall as recommended by the drainage manufacturer. For other areas minimum 1% (1:100) longitudinal falls and 1.25% (1:80) crossfalls are recommended. To summarise:

- Carriageway Minimum Crossfall 2.5% (1:40)
- Carriageway Minimum Longitudinal Fall 1.25% (1:80)
- Other Areas Minimum Crossfall 1.25% (1:80)
- Other Areas Minimum Longitudinal Fall 1.0% (1:100)
- Carriageways with propriety drainage systems crossfalls 2.5% (1:40)

Mechanical Laying

Whilst the basic principles of mechanical laying of block paving do not differ greatly from hand laying, there are a number of points which should be considered when planning a machine laid project. Rectangular or proprietary shaped blocks, configured in an appropriate pattern, are packaged in 'clusters', typically 1 m^2, and installed by specialist block laying machines or equipment. Essentially, a hydraulically operated clamp is used to close the blocks together within the cluster, lift the cluster and place into position within the pavement. Please contact Interpave Member companies for details of block types suitable for mechanical laying and specific laying instructions for particular products.

Block Cutting

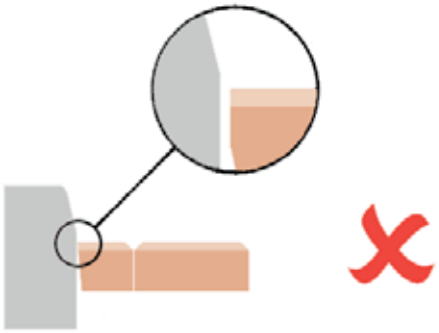
Before the end of the working day or the onset of inclement weather, the block paved area should be completed, as far as practicable, with the insertion of cut blocks, followed by the bedding operation, joint filling and compaction.

Blocks should be cut using a hydraulic or mechanical block splitter, saw or abrasive disc cutter, to an accuracy that ensures a joint width between 2-5 mm. Cut blocks may be used up to one third of their original length. Cut blocks smaller than a quarter of their original length should not be used. Cutting the blocks longitudinally should be avoided, as the resultant cut piece may be significantly weaker than a full-width block. It may not be possible to maintain a maximum 5 mm joint at all times when blocks are laid to a tight curved edge.

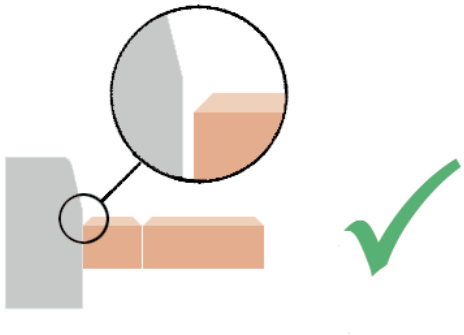
Edge Details

To avoid small infill pieces of blocks (which are almost inevitable when cutting shaped blocks) it is recommended that manufacturers' edge/end blocks be used to provide a straight line adjacent to all perimeters and that the infill between the edge blocks and the edge restraint is filled by using rectangular blocks, with any cutting being within this rectangular block area. Alternatively, blocks can be saw cut and chamfered, to give the appearance of a manufactured block and may be used directly against an edge restraints or against stretcher courses.

Wherever possible, avoid placing the cut face of a block against an adjacent edge restraint, as shown below:



Cut faces should be positioned against an adjacent block chamfer to reduce the visual intrusion of the square cut edge:

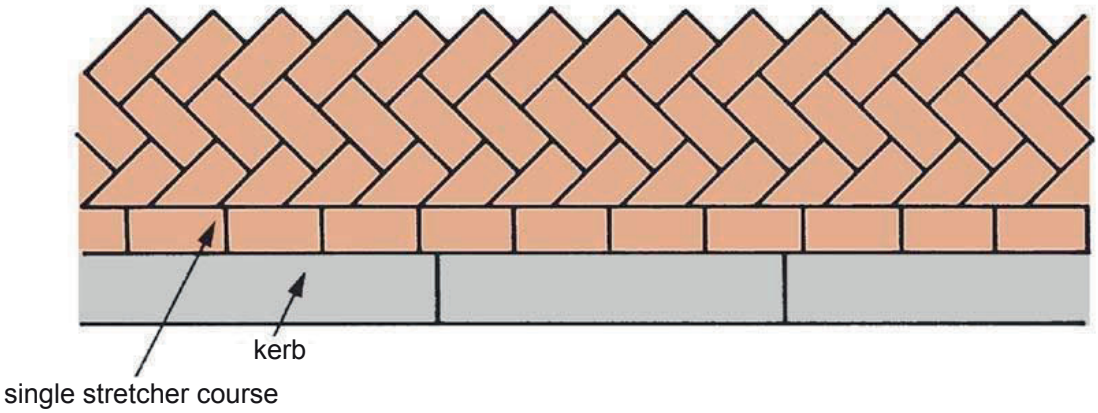


The above detail can be adopted as shown where the block pattern is square to the edge restraint. With curved edge restraints or where the block pattern is not square to the edge restraint a single stretcher course, double stretcher course or a header/soldier course can be introduced against the kerb or edge restraint. Cut faces of blocks can then be positioned against this course to reduce the visual impact of the cut, providing a neat finish and also making the marking of the cut block much easier.

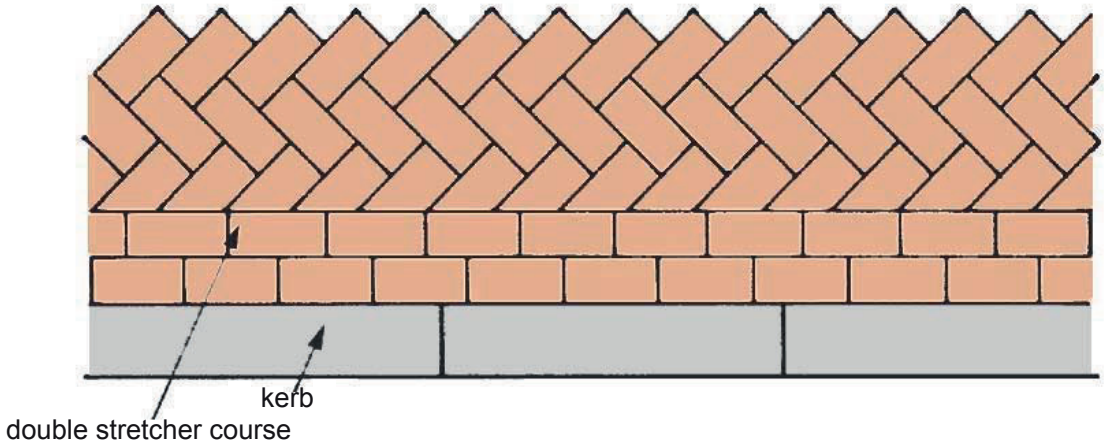
These details can be used with any bond, with a stretcher course of rectangular blocks used with either rectangular or shaped blocks. Alternatively blocks can be saw cut and chamfered.

Edge Details

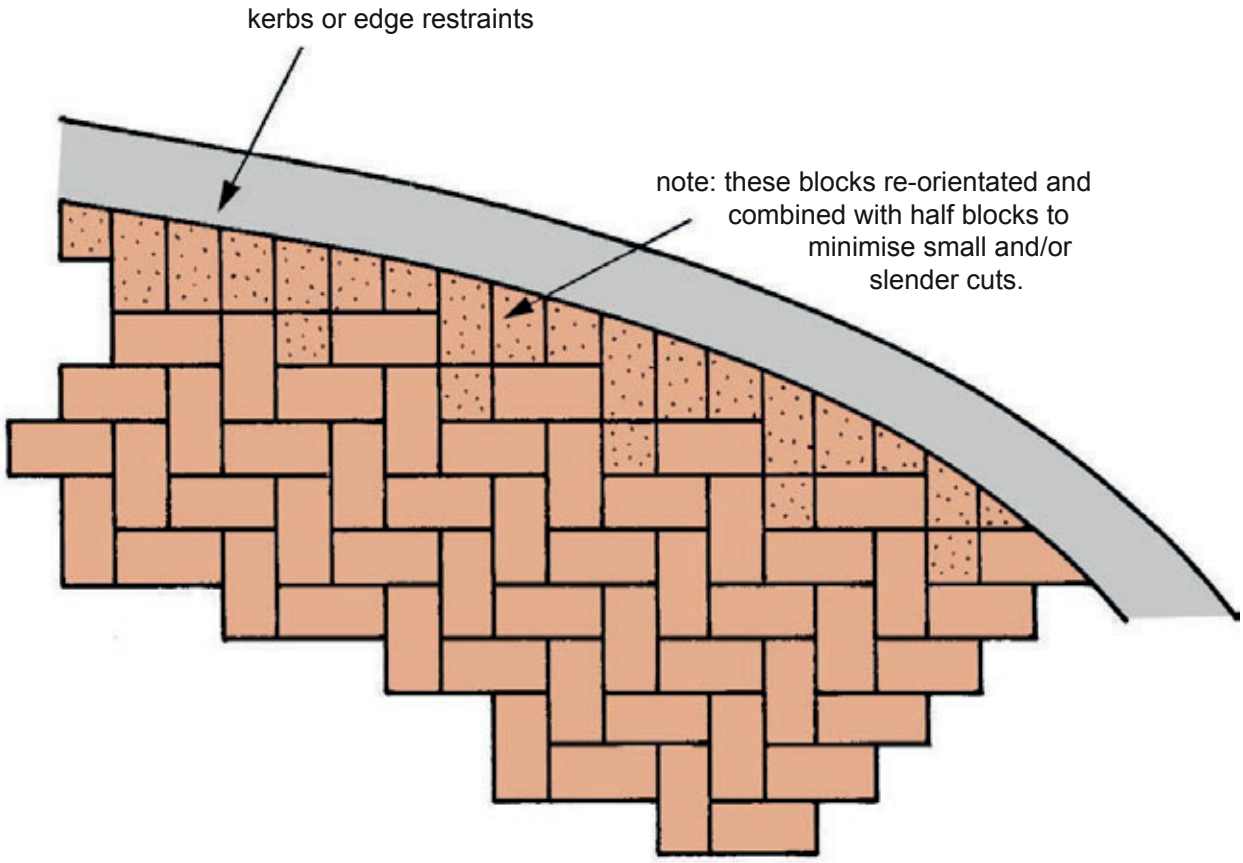
Single stretcher course



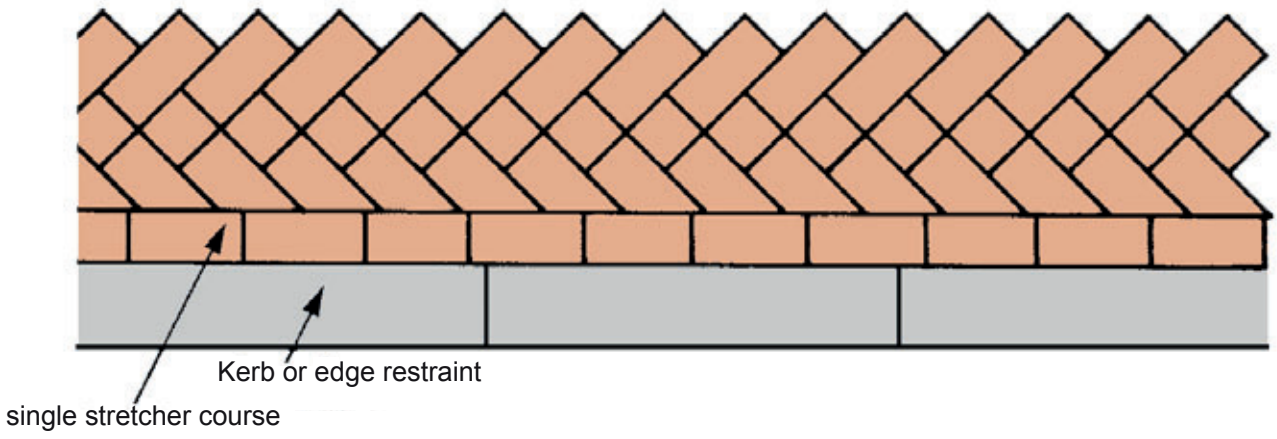
Double stretcher course



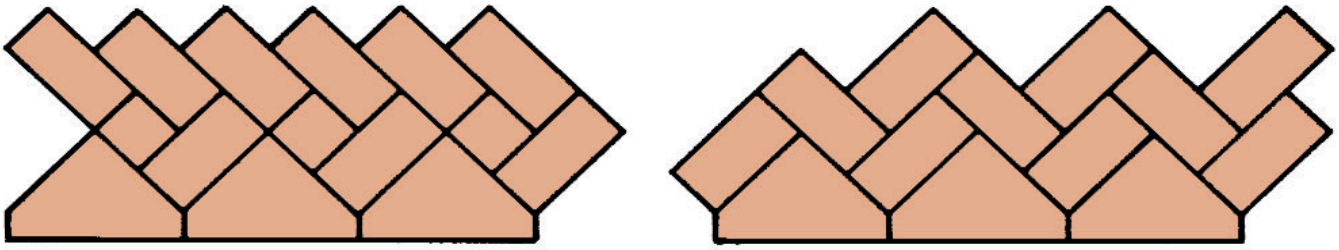
Soldier course



Cut/purpose made half blocks



Special fittings (mitre blocks)



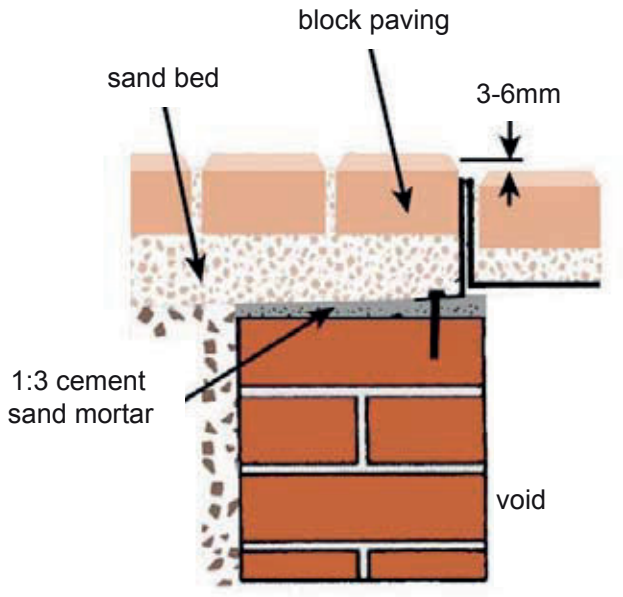
Special starter units to ease laying are available for use with rectangular blocks laid in a 45° herringbone pattern. These units may be used in rectangular areas, where the edge restraints are at 45° to the block pattern, but should not be used on radii.

For individual manufacturers' special shapes there may be specific starter, edge and end blocks available. Contact the Interpave Member companies for availability of these products.

Manhole Details

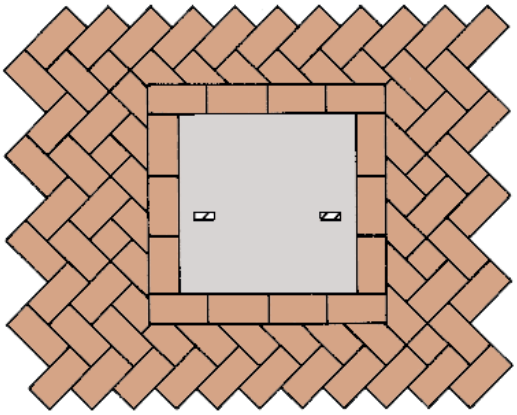
Ideally, manhole covers or gully frames with straight sides should be used to allow the block paving to directly abut the frame. A stretcher course at this point, around the manhole, avoids cut edges of blocks directly against the frame and ensures any cut edges are less intrusive. This stretcher course may be laid on a mortar bed where there is a possibility of bedding sand migrating beneath the manhole surround. After compaction the block surface level should be 3-6 mm above the manhole cover and frame to allow for any future settlement.

Frame bedded and haunched with concrete

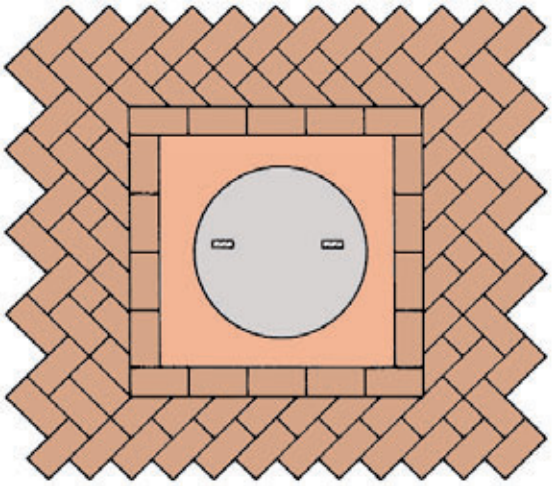


The typical manhole details shown below use block paving stretcher courses. They also illustrate the use of half blocks to “break the bond” and avoid the need for cut pieces of less than a quarter of a block in length.

Manhole detail (no concrete infill)



Manhole detail (concrete infill)



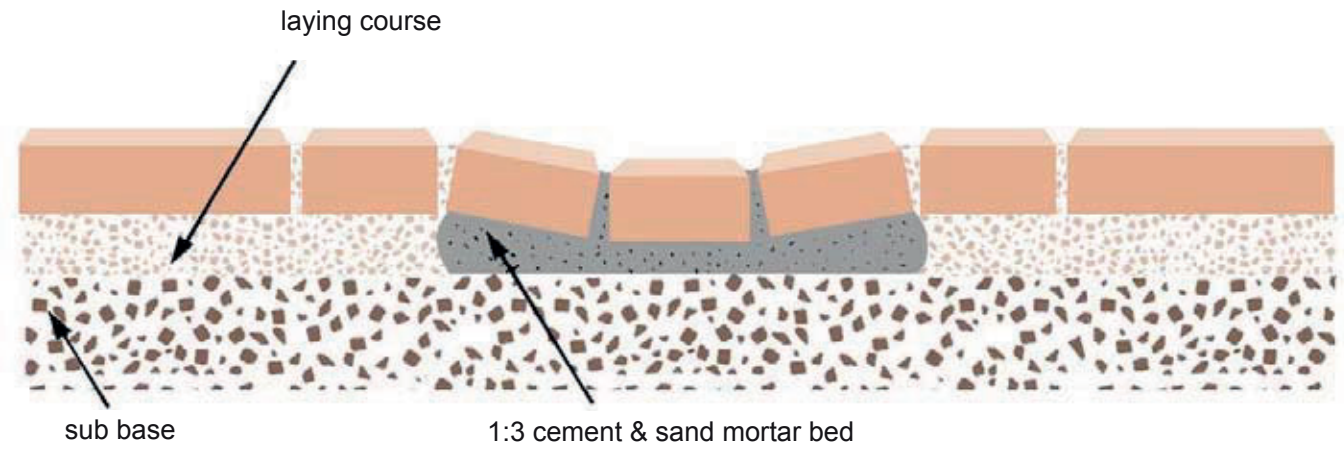
If a manhole cover or gully frame without straight sides is used, which will not allow the paving to directly abut the frame, then a surround of C35 air entrained concrete to BS EN 206-1 should be incorporated as shown. Careful selection of the raw materials for the concrete and/or the addition of suitable colour pigments can help reduce the visual impact of the concrete surround.

This concrete surround should be a minimum maximum of 100 mm wide and extend to the underside of the laying course or manhole frame flange. Where an infill exceeding 100 mm is required a stretcher course of blocks can be introduced to the concrete surround.

Drainage channels

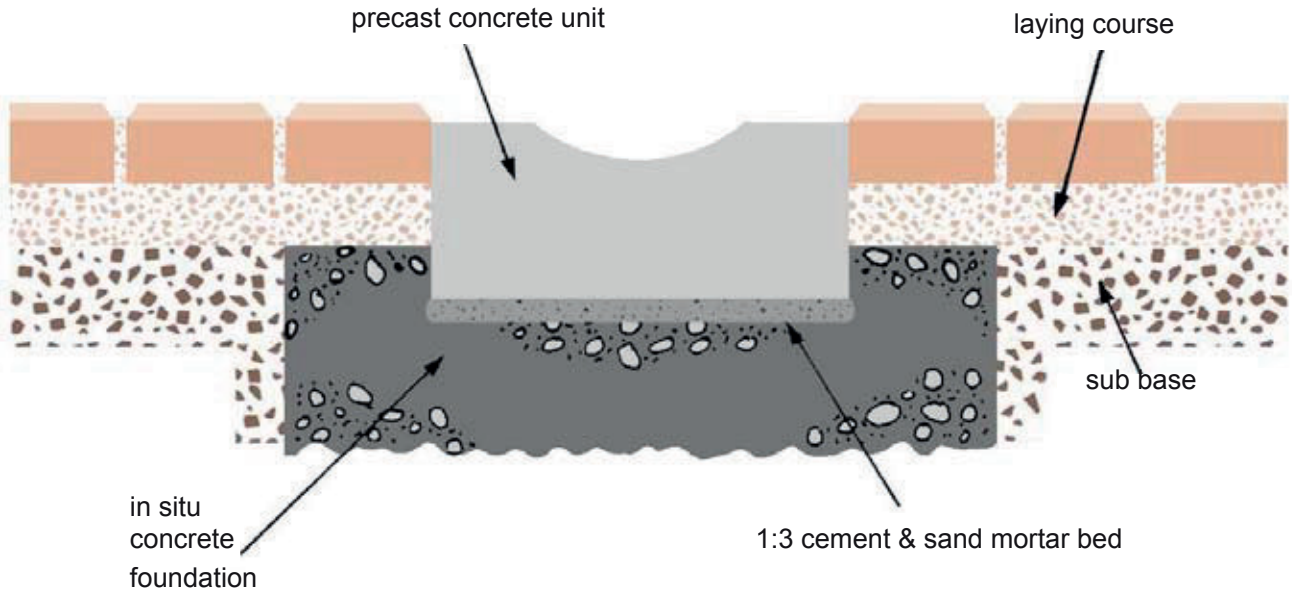
Drainage channels can be formed using rectangular paving blocks laid on a mortar bed to produce a dished channel, with a concrete foundation below if the paving is subject to vehicular traf-ficking. The compacted block surface level should be between 3 mm and 6 mm higher than sur-face drainage channels and outlets for pedestrian areas.

Dished channel formed from blocks

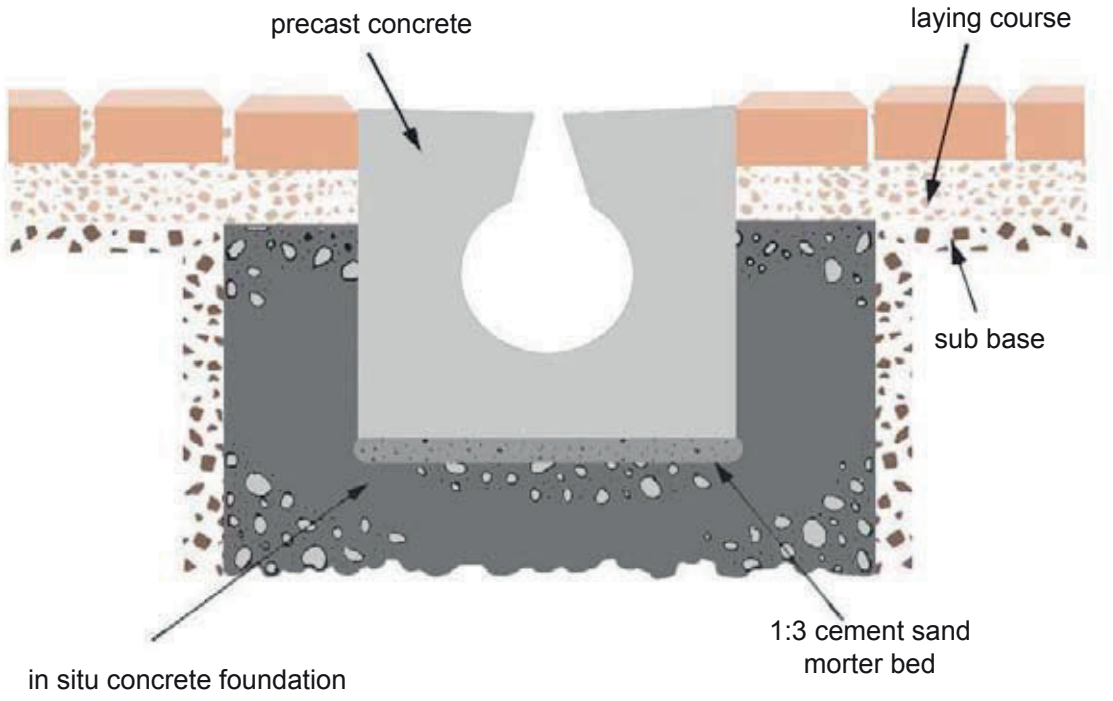


Proprietary drainage channels used within block paved areas should be treated as manholes and “picture framed” with stretcher or header courses to allow cut edges to abut a block chamfer. After compaction, the block surface level should be between 3 mm and 6 mm above the edge of the drainage unit to allow for any future settlement.

Dished concrete channel



Slotted drainage channel



Block Layer Compaction

The laying course material and blocks should be compacted using a vibrating plate compactor, as detailed in the following table. Some blocks may require a rubber or neoprene faced sole-plate to prevent damage to the block surfaces.

Vibrating Plate Compactor Requirements

Site category (see page 22)	**Plate Requirements**			
	Minimum Area (m^2)	Minimum Effective Force/ Unit Area (kN/m^2)	Vibration Frequency (Hz)	Minimum Mass kg
IA,IB and II	0.250.20	75	65-100	200
III and IV		60	75-100	80

The block paved area should be fully compacted as soon as possible after both full blocks and cut blocks have been laid, to achieve finished pavement tolerances of ± 6 mm from the design level after compaction. Adjacent blocks should not differ in level by more than 2 mm and, when measured with a 3 m straight edge, there should be no surface irregularity (i.e. depression or high point) greater than 10 mm. Ideally, at the cessation of the days work, compaction should be completed to within 1.0 m of an unrestrained edge.

Joint Filling

Before the commencement of the joint filling operation the block layer should be checked to ensure that it is in full compliance with the specification, including levels and tolerances, joint spaces and block alignment, and with any non-conformance corrected. Only after satisfactory corrections (if needed) have been made should the jointing operation commence.

Fine, dry (preferably kiln dried), free-flowing silica sand in accordance with the following table (based upon the new European Aggregate Standard, BS EN 12620 - fine category f2) should be brushed into the joints between the blocks, fully filling the joints. This operation is followed by two or more applications of the vibrating plate compactor. Additional sand should be added to top up the joint as necessary after compaction and during the early life of the pavement. The sand selected should not stain the surface of the paving.

Jointing Material Grading

Sieve (mm)	**% Passing**	
2	100	100
1	85	100
0.05	55	100
0.063(f)	0	2

Completion of the Work

Before the pavement is handed over a final inspection should be carried out to ensure that all work is in compliance with the contractual requirements and any non-compliance should be corrected.

Vacuum sweepers should not be used until the joints have silted up to avoid sand loss. Alternatively the jointing sand may be stabilised (to prevent sand loss) with a suitable joint sealant.

4 REINSTATEMENT

This section is intended to help with the opening up and rein-statement of conventional and permeable concrete block paving - for access to underground services or repairs to the pavement structure.

Unlike other pavement materials, with concrete block paving it is possible to complete reinstatement work with no visual evidence that a repair has been undertaken. This guide combines information from BS 7533-11: 2003, 'Code of practice for the opening, maintenance and reinstatement of pavements of concrete, clay and natural stone' with 'hands-on' experience to provide practical advice. Although sugges-tions on appropriate equipment are listed, these are not exhaustive and do not include personal protective equip-ment or other health and safety measures required by cur-rent legislation. All health and safety measures are the responsibility of those undertaking the work.

Special block removal/extractor tool

Block splitter

Equipment List:

- Hand shovels
- Crow-bar, hammer & bolster, pick-axe
- Large flat-bladed screw drivers or special block removal/ extractor tools (shown)
- Special paver alignment tool
- Wire brushes and/or stiff hand brushes
- Storage pallets
- Broom and hand brush
- Hand rammer (50 x 50mm timber or hammer shaft)
- Aluminium or notched wood screeding board with length to suit the area width
- Screed rails, 25, 30, 35 and 50mm thick (usually steel hollow section or bar)
- String line
- Steel float
- Rubber mallets
- Rubber coated sledge hammer or special paver hammer
- Replacement blocks - see later page
- hammer and bolster, block splitter (shown) or bench saw
- An appropriate plate compactor

General cleaning equipment

Remove the paving blocks:

Equipment Checklist

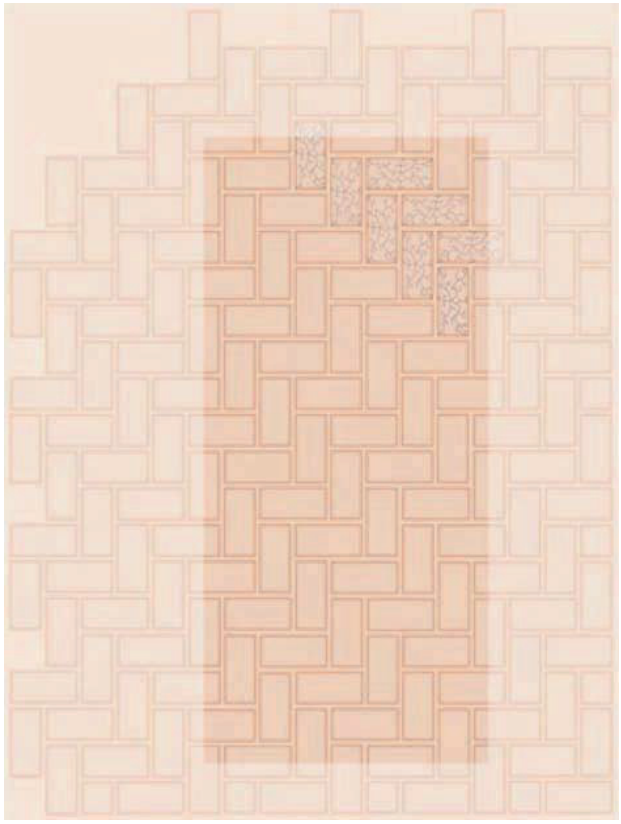
- *Crow-bar, hammer & bolster, pick-axe*
- *Large flat-balded screw drivers or special block removal/extractor tools*
- *Wire brushes and/or stiff hand brushes*
- *Strorage pallets*

1. Take up the blocks in the order shown on the next pages
   - *due to the interlock, it is usually necessary to break the first few blocks for easy removal of the remainder*

2. Clean the joint sand and detritus from the blocks before stacking or re-use

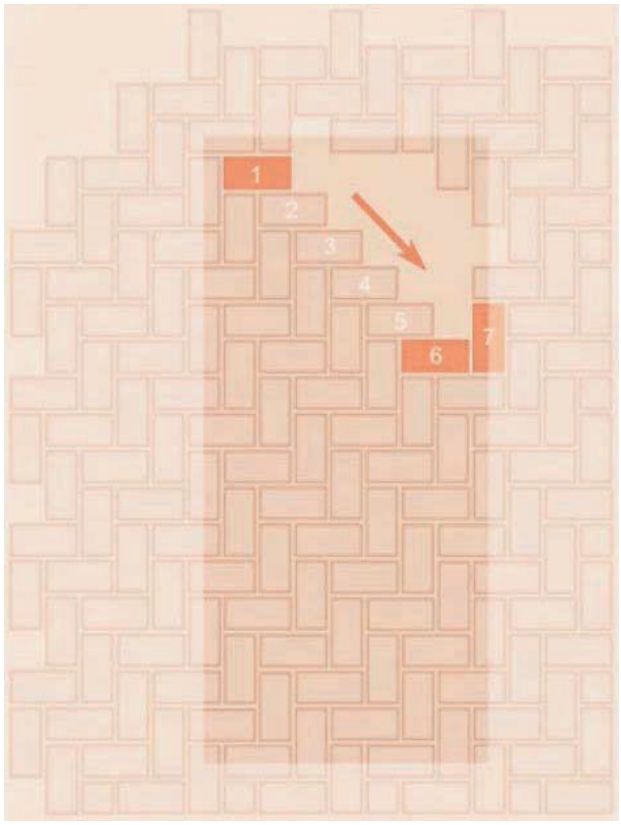
3. Stack damaged and undamaged block separately and at least 0.5m away from the excavation
   - *damaged blocks can be kept for re-use as cut blocks*

4. Stack and store blocks adjecent to where they were removed, or record and lable stacks, so that they can be re-laid in the same or nearby areas
   - *this will help ensure that they fit back in position*

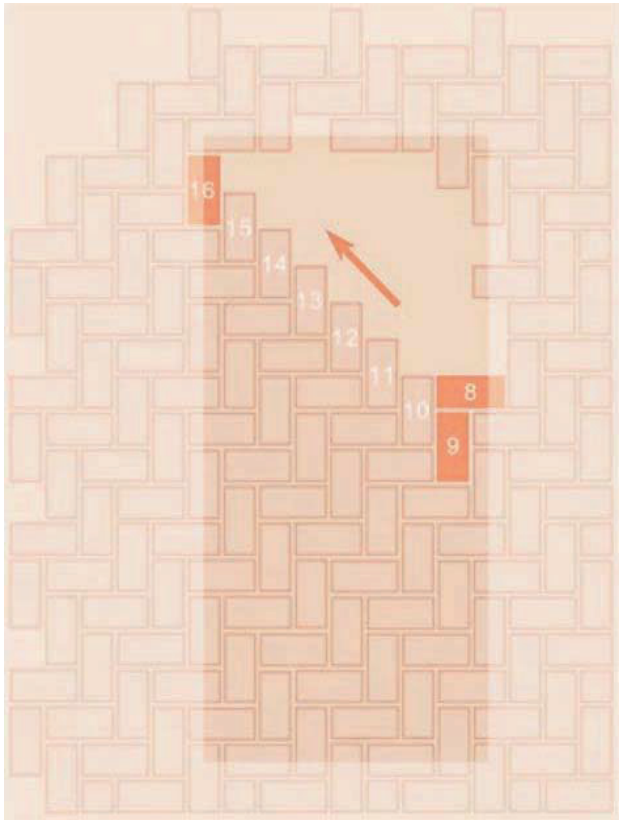


Take up the blocks in the order shown

Due to the interlock it is usually necessary to break these blocks first

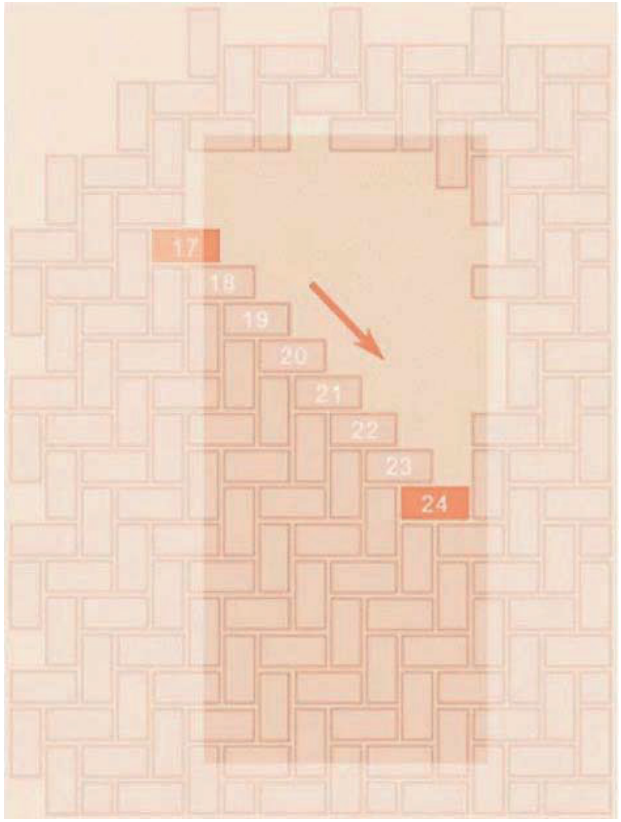


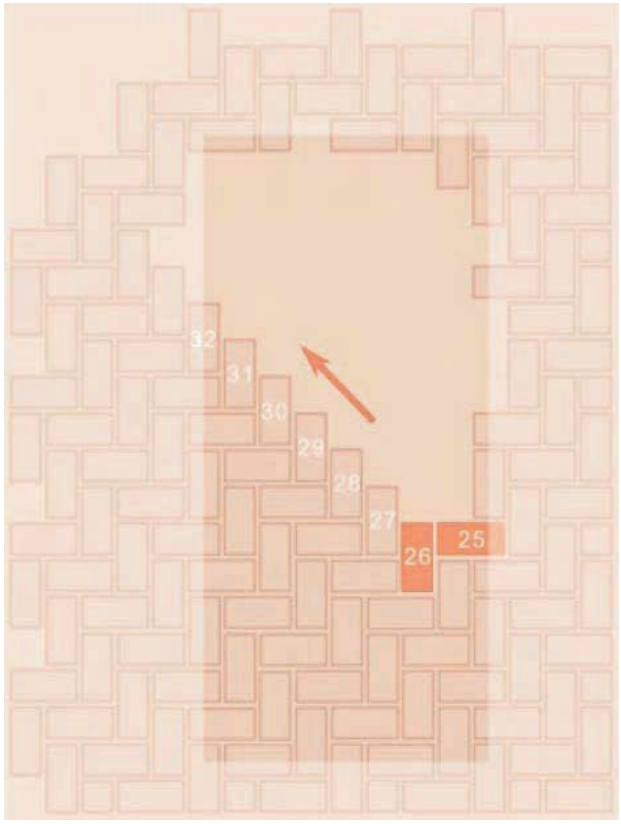
These blocks may need careful prising out with the aid of flat-bladed screw drivers or special block removal / extractor tools



Take up the blocks in the order shown

These blocks may need careful prising out with the aid of flat-bladed screw drivers or special block removal / extractor tools





Take up the blocks in the order shown

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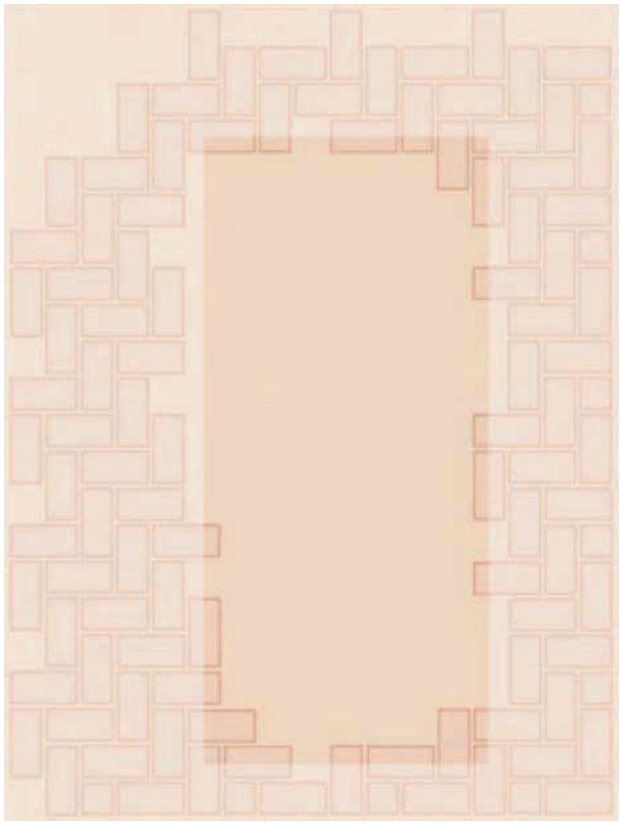


Continue in this way untill the required area has been opened up

Remove laying course:

Equipment Checklist

- *Hand shovels*

Shovel up and dispose of the laying course material, which must not be re-used

Repair/Reinstate the lower pavement layers:

1. Carry out the required work to services or lower pavement layers

2. Reinstate to give a finished level so that the laying course will be the correct thickness

•*Although BS 7533-11: 2003 suggests that reinstatement should have a cambered surface with blocks slightly proud slightly proud of the existing for future settlement, experience shows this to be unnecessary if material selection, constuction and compaction are all carried out correctly*

Placing the new laying course:

Equipment Checklist

- *Broom and hand brush*
- *Hand shovel*
- *Hand rammer (50 x 50mm timber or hammer shaft)*

1. Carefully remove debris, old laying course and jointing material from the surface of the surrounding blocks and side-walls of the blocks adjacent to the repair

2. Ensure that remaining blocks are fully supported on the laying course with some level existing laying course exposed in front

3. Select the correct laying course material grading and thickness shown in the tables on the following pages for either conventional or permeable block paving

4. Place and spread the correct laying course material (see pages 22-23)

5. Compact (hand ram) the new laying course material against the existing to ensure there are no voids where they meet. This does not apply to permeable pavement laying course material which can not be compacted

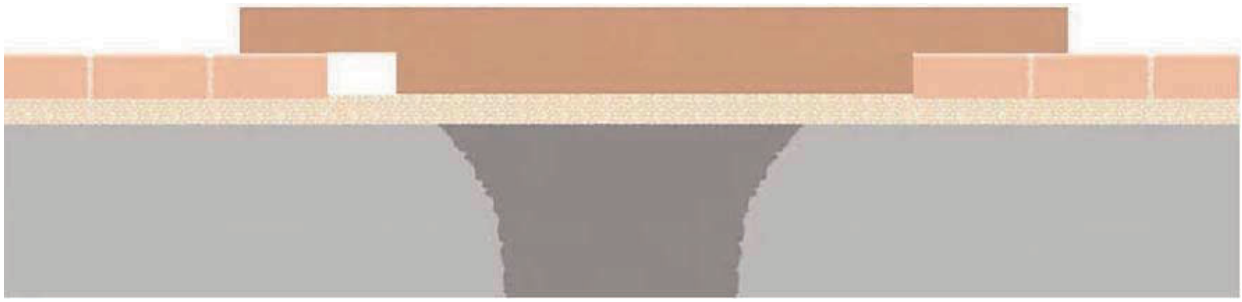
Screed the laying course: - for areas up to 3.0m wide

Equipment Checklist

- *Aluminium or notched wood screeding board with length to suit the area width*
- *Steel float*

1. Screed the laying course to approximately 5mm above the underside of the adjacent blocks using a notched screeding board running on top of the existing blocks as shown

- *Although BS 7533-11: 2003 suggests that reinstatement should have a cambered surface with blocks slightly proud slightly proud of the existing for future settlement, experience shows this to be unnecessary if material selection, constuction and compaction are all carried out correctly*



2. Use a rectangular steel float to hand screed areas that can not be screeded with the board

- *For areas of any width, it is advisable to undertake a small trial of laying course screeding, block laying and compaction to ensure the right thickness of laying course material for the reinstated blocks to be at the same level as the surrounding blocks. If necessary make adjustments to the screed before proceeding with any more work*

Screed the laying course: - for areas up to 3.0m wide

Equipment Checklist

- *Aluminium or notched wood screeding board with length to suit the area width*
- *Screed rails, 25, 30, 35 and 50mm thick (usually steel hollow section or bar)*
- *String line*
- *Steel float*

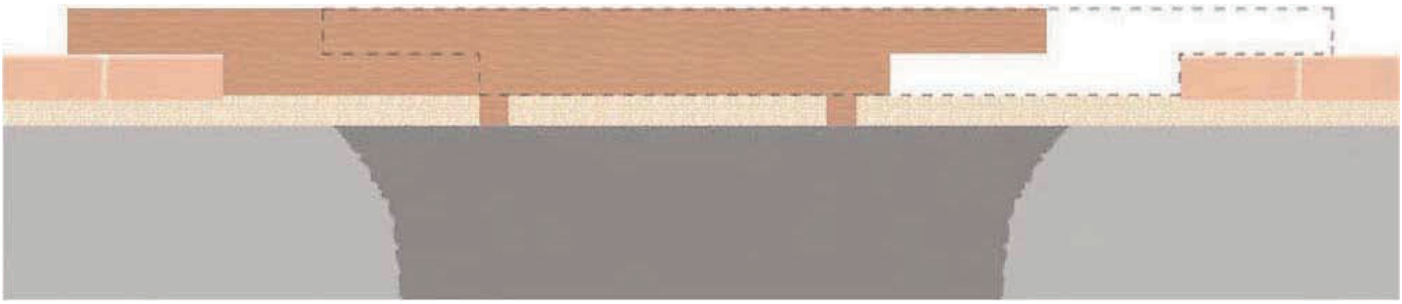
1. Place temporary screed rails at a maximum of 3.0m centres to form a screeding datum wit in the areas to be reinstated

2. Check the rail levels by placing a block on top of each rail and pulling a string line from each side of the existing pavement across the top of the block. Ensure that the block is approximately 5mm above the string line (to allow for compaction of the laying course)

- *Although BS 7533-11: 2003 suggests that reinstatement should have a cambered surface with blocks slightly proud slightly proud of the existing for future settlement, experience shows this to be unnecessary if material selection, constuction and compaction are all carried out correctly*

3. If necessary, adjust the level of the screed rail • *If it needs to be lower, replace within a thinner rail*
- *If it needs to be higher, pack underneath with sand laying course material or use a thicker rail*

4. pack laying course material into any voids under the temporary screed rail to ensure that it does not deflect during screeding

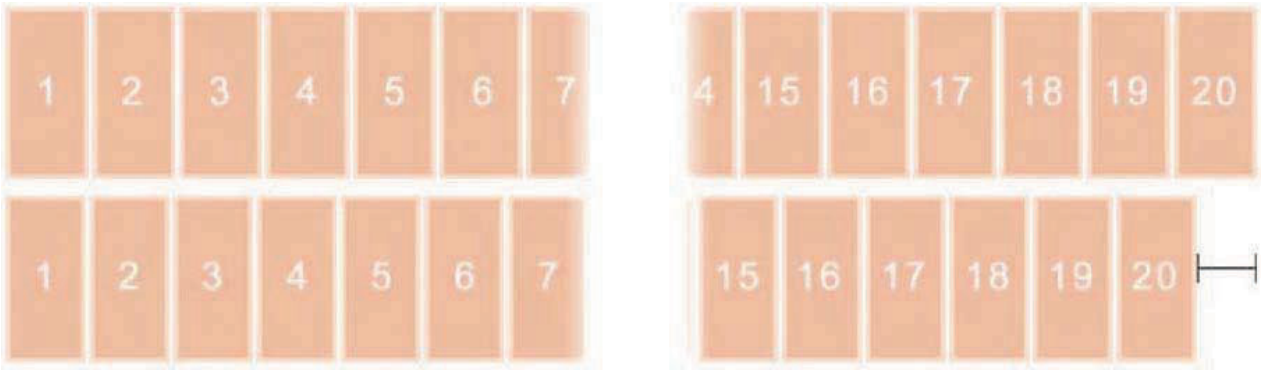


5. Screed as described on previous page

6. Remove temporary screed rails and replace with laying course material, then hand screed/float

Select replacement blocks:

Any replacement blocks should be evenly distributed over the whole area and not place together. If a significant quantity of new replacement blocks is required then size compatibility with existing blocks is essential to ensurethat they can be reinstalled successfully. this is necessary due to size tolerances that are allowable under the manufacturing standard BS 6717: 2001.



Size compatibility between existing and new blocks can be checked by laying out 20 existing and 20 new replacement blocks side by side, ensuring that they are pushed tight to eachother.

If the cumulative length of the replacement blocks is the same or shorter, this would indicate that these blocks are smaller and should fit easily into the reinstated area. If the length of the replacement blocks is longer, this would indicate that these blocks are larger and this may cause difficulties with fitting these blocks into the reinstatement.

- *if difficulties are encountered, it may be necessary to saw-cut a thin (2-3mm) slice off some blocks to allow them to fit*
- *for shaped blocks, it is permissible to reduce the size by saw-cutting into halves (along length or width) and fixing these back together using a high strength epoxy resin suitable for concrete*

Lay the blocks:

Equipment Checklist

- *String line*
- *Rubber mallets*
- *Rubber coated sledge hammer or special paver hammer*
- *Large flat-bladed drivers or special paver alignment tools*
- *Replacement blocks - see previous page*

1. Check that the existing blocks around the perimeter of the reinstatement have not moved or crept. If necessary, adjust or remove. Sweep clean the surface of the pavement around the area to be re-laid

- *avoid detritus, laying and joining material from getting into joints, as this will detrimentally effect block fitting and adjustment of alignment or joint spaces*

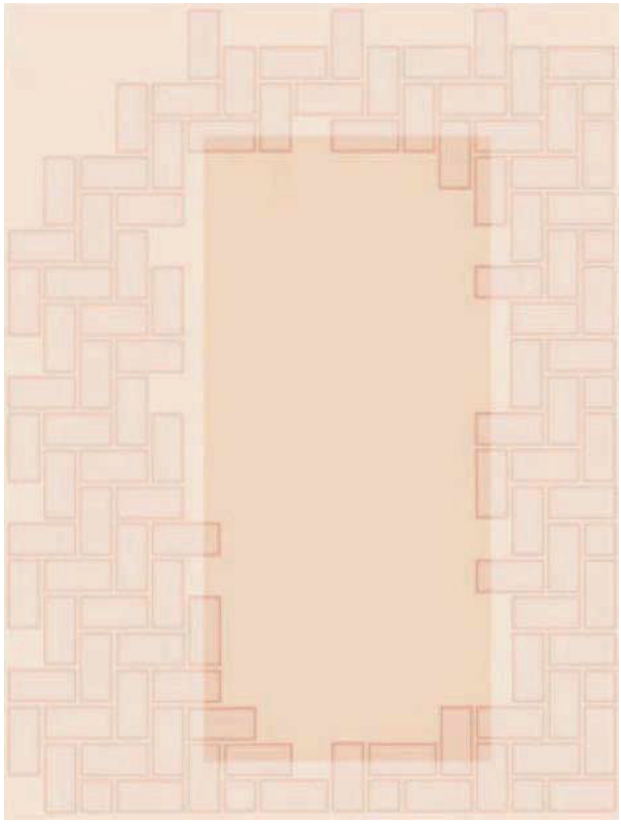
2. Place blocks in the required pattern (in the order shown in the drawings that follow) with a joint space in the range of 2 to 5mm, without disturbance to the bedding sand

- *Re-use undamaged blocks previously removed from this area. If it is necessary to use new replacement blocks, then distribute them equally within the area during laying*
- *Ensure that all blocks have had all traces of laying and jointing material and detritus removed from them*

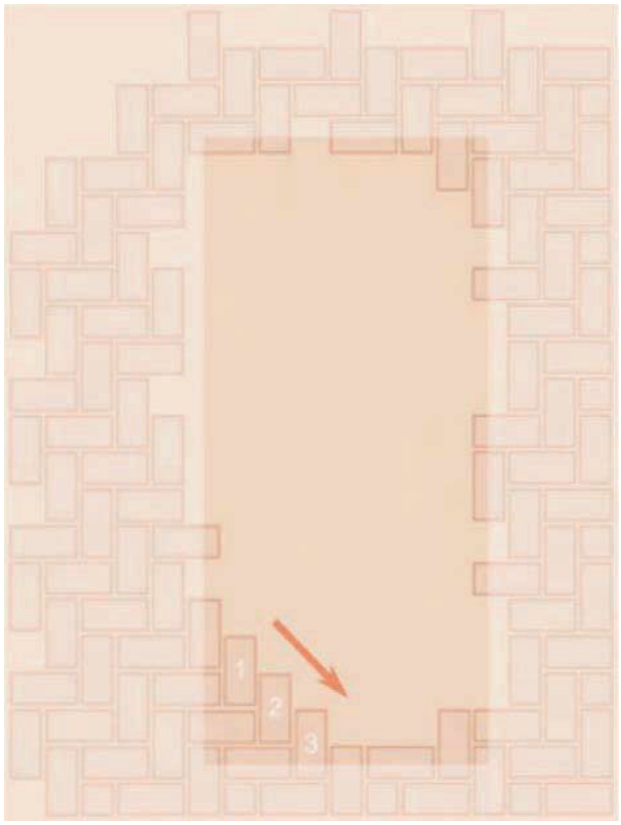
3. Continuously monitor the alignment of the pattern, viewing from approximately 5mm away and checking the alignment to the existing pavement in two directions at 90° to each other

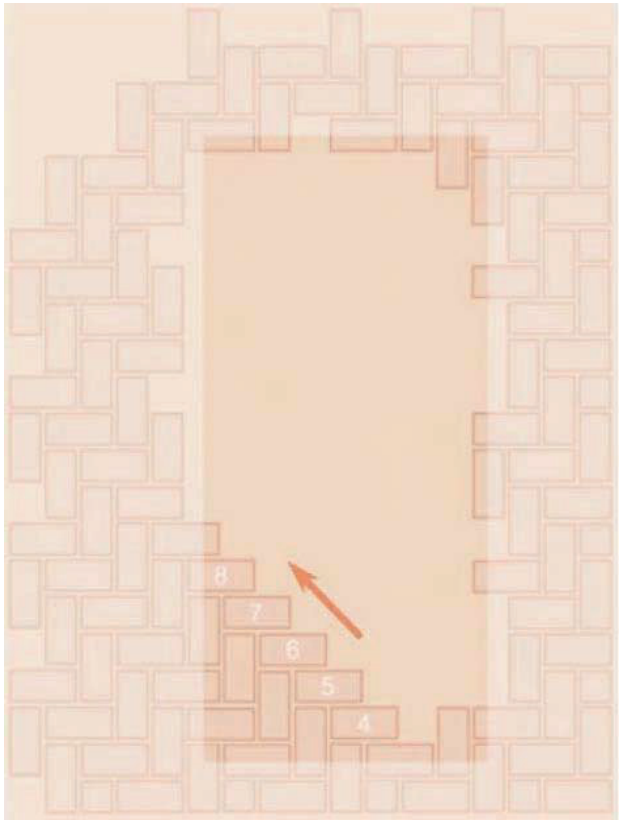
- *For large areas use string lines to assist in this alignment*

4. Adjust alignment of the blocks to ensure they fit together, with the aid of the appropiate alignment tools

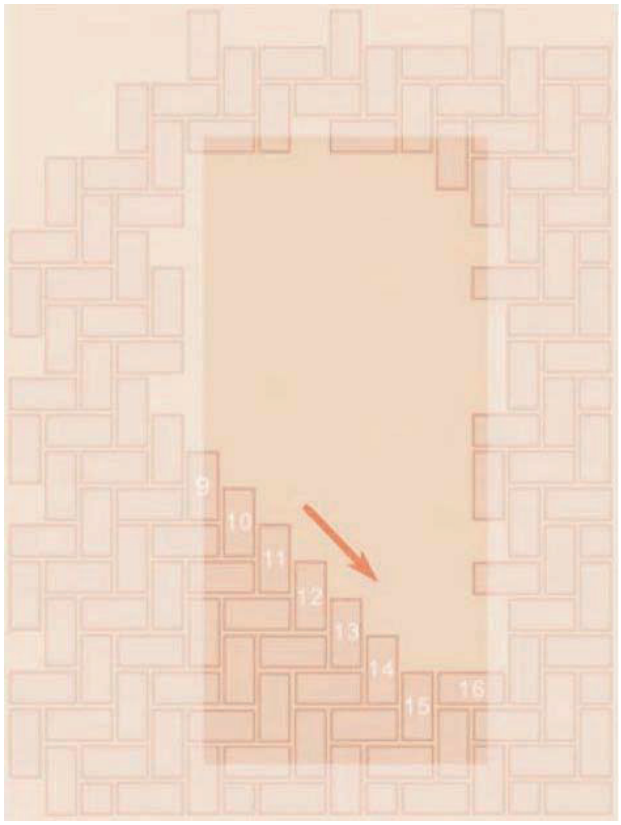


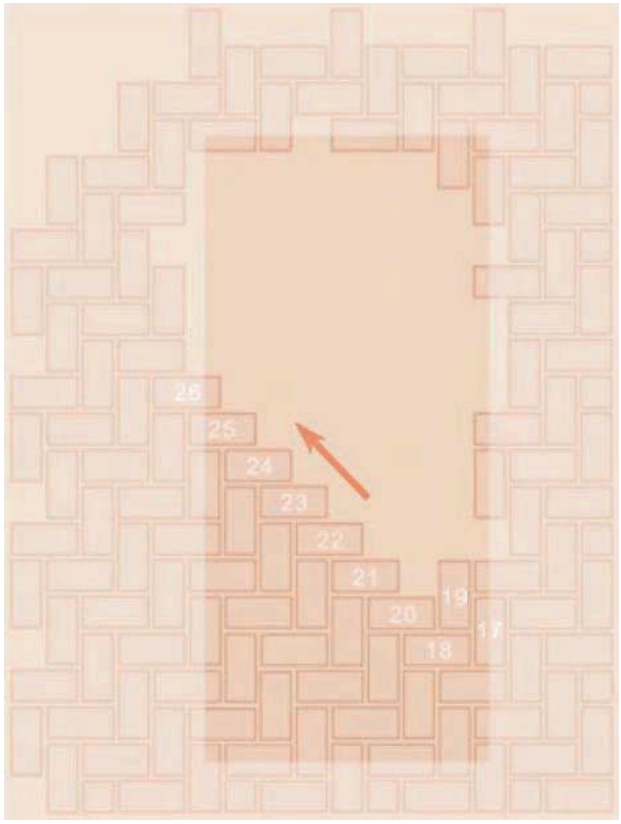
Relay the blocks in the order shown



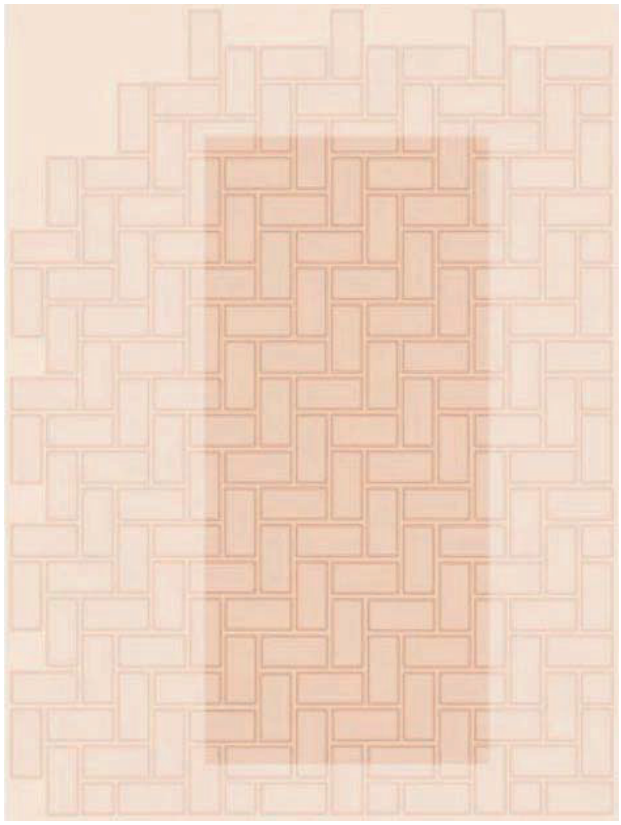


Relay the blocks in the order shown





Relay the blocks in the order shown



Continue to relay back and fore to complete the area

Block splitter

Cutting Blocks:

Equipment Checklist

- *Hammer and bolster*
- *Hydraulic block splitter or bench saw*

When necessary, blocks should be cut so that, when laid, the cuts align and the joint space is between 2 and 5mm. Cut blocks smaller than one quarter of their original length should not be used. Special edge blocks or half blocks and reorientation of blocks within the pattern should be used to minimise the need for small cut blocks. Do not use in-fill mortar or concrete.

Compacting the laying course:

Equipment Checklist

- *The appropriate plate compactor, (see pages 35 and 22)*

1. Compact the laying course by running the plate compactor over the laid blocks at least twice
2. Around the perimeter of the reinstatement, ensure that the compactor traverses half on the existing and half on the newly laid blocks

Check joint widths and block heights:

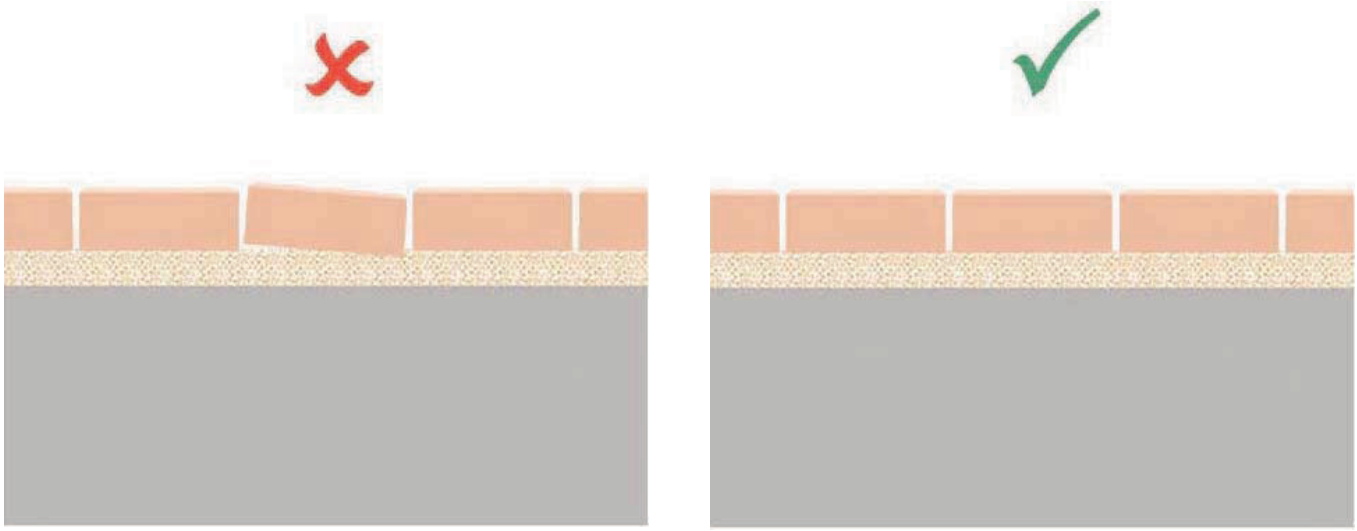
Equipment Checklist

- *Large flat-bladed screw drivers or special paver alignment tool*
- *Special block extractor tool*

1. Check block alignment and joint widths which should be in range of 2 to 5mm, adjust with alignment tools if necessary

2. Check for broken and damaged blocks and replace if necessary

3. Check for any protruding blocks and adjust the height as necessary by removing and correcting the level of the laying course. If the laying course has been disturbed, re-compact after replacing the block(s)



Fill block joints:

Equipment Checklist

• The appropriate plate compactor, selected in accordance with the requirements of BS 7533: Part 3, Annex F, selected from the previous tables

1. Only proceed with joint filling if the blocks, alignment, joint width and block heights have been checked and are acceptable. If not, make all necessary corrections first

2. Select the correct joint filling material grading (see page 36)

3. Place and sweep the joint filling material into joints

4. Compact the joint filling material by running the plate compactor over the laid blocks at least twice

5. Around the perimeter of the reinstatement, ensure that the compactor traverses half on the existing and half on the newly laid blocks

Final check:

Equipment Checklist

• General cleaning equipment

Check alignment, joint width and block height are all Ok and correct if necessary. Remove debris and sweep the area clean

At the end of each day's work all blocks laid shall be fully joint sanded and compact

This completes the reinstatement procedure which should leave no visible evidence that a repair has been undertaken.

5 CLEANINGMAINTENANCE ANDSEALING

The following notes are intended for general guidance on the cleaning and maintenance of pre-cast concrete paving and are not intended to be exhaustive.

Any surfacing material may suffer from staining or marking, due to general trafficking or contamination from other sources. There may also be some vegetation growing in joints or on the paving itself in shaded areas or areas subject to long periods of dampness.

Regular maintenance and good cleaning practice will enhance the overall appearance of the paving.

Health and Safety advice:

Some of the cleaning methods described involve the use of chemicals which must be used correctly and strictly in accordance with the suppliers/manufacturers' recommendation. The following precautions should also be noted:

- Appropriate protective clothing such as gloves, goggles, ear defenders, boots and overalls should be worn.
- Adequate ventilation is required in confined spaces when using chemicals.
- When using flammable materials, cigarettes, naked flames and other sources of ignition should be avoided.
- When diluting acid based cleaners, ALWAYS add acid to water and not water to cleaner.
- Any clothing which is contaminated with chemicals should be disposed of safely.
- Care must be taken not to damage, contaminate or stain any adjoining material.
- Personnel operating in the area of the cleaning must be protected from any hazard created by the cleaning. (Risk Assessments and COSHH)

It is particularly important with all cleaning methods that trials should be carried out on a small, preferably inconspicuous area, to determine the effect of the treatment before commencing work on a larger area.

Cleaning of paving:

General dirt and detritus:

To remove general dirt and detritus, regular brushing is recommended. If the colour of the paving becomes masked it may be re-established by scrubbing with soap and warm water, either by hand or by using an industrial cleaner.

Ensure all the soap has been thoroughly washed from the surface on completion of the cleaning and carefully channelled in the resulting run-off to either drainage points or containers where it can be safely disposed of.

If a power hose is used then care must be taken to avoid the removal of the jointing material (sand or mortar). After completion the pavement should be inspected and the joining material replaced as required.

Moss, lichens and algae:

Moss, lichens and algae should not grow on concrete unless the area is heavily shaded, is under trees or is not adequately drained. If such growth does occur and is considered undesirable then the area should be treated with a proprietary cleaner suitable for the purpose, used in accordance with the manufacturer's instructions. Some treatments leave a residue to discourage the regrowth of the moss and algae, but this will only be of limited value if the surrounding conditions leave the paving damp and in shade.

Rust stains:

Action must be taken to eliminate the sources of staining. To remove the rust stain, the surface should be wetted and the affected area treated with an acid based concrete cleaner (no stronger than an equivalent 5% Hydrochloric acid solution or similar). However acid cleaners attacks concrete. It may leave a slightly roughened surface or leach out some of the pigment from the concrete, so care must be taken when using acid based cleaners. After application of the cleaner any residue should be washed off the surface of the concrete with copious quantities of water to avoid staining. Care should be taken to dispose of the run-off safely. All manufacturers instructions must be strictly followed and after cleaning is completed, any chemical residue should be disposed of carefully.

Oil stains:

Oil penetrates readily into concrete, but it should not stain if any spillage is removed promptly with an absorbent material e.g. paper towels or cloth. Do not wipe as this will drive the oil into the concrete and spread the contamination over a larger area.

If the stain persists, a cleaner suitable for the purpose should be used in accordance with the manufacturers' instructions.

Alternatively the surface can be scrubbed with a strong detergent and the residue washed away with hot water. However, care must be taken as this method might also result in the leaching out of some pigment from the concrete product and discolouration due to surface abrasion of the concrete.

Bitumen stains:

Bitumen does not penetrate concrete readily. The bitumen should be left until it has cooled. It can then be removed using a paint scraper or similar mechanical device. If it is particularly resistant, the use of ice to make the bitumen even more brittle may be required, prior to scrap-ing it from the paving. Any residue should be removed with an abrasive powder and finally the whole area rinsed with clean water.

Certain proprietary cleaning agents are available to remove bitumen, but these should first be tested on an inconspicuous area of the paving.

Chewing gum:

Chewing gum is one of the most difficult substances to remove from any surface. Newly discarded gum can be scraped off using a scraper. Hardened gum can be removed by chiselling it off the surface of the paving, using a hot water/steam cleaner or by chemical means.

There are contract cleaning companies who specialise in this type of cleaning, and it is recommended that they be contacted directly for further details.

Scuff marks from vehicle tyres:

These can normally be removed by steam cleaning or by scrubbing the area with hot water and a strong detergent.

Graffiti and paint stains:

Both paint and graffiti are difficult to remove. Fresh wet paint should be soaked up with an absorbent material without wiping the paint, as this will spread the stain. It should then be treated with a suitable solvent, for the paint involved, and the area washed with a concentrated deter-gent, taking care with the disposal of the run-off material. Most paint strippers are Sulphuric Acid based and attack the concrete.

Dried paint should be scraped off as far as possible and an appropriate paint remover applied, used in accordance with the manufacturer's instructions. Paint manufacturers may be able to give more detailed advice on the removal of graffiti and it may be necessary to consult them if there are large areas of vandalism.

Epoxy and polyester stains:

Areas of solidified epoxy or polyester resin can be removed by carefully burning off with a blowtorch. Care must be taken not to inhale any fumes given off or to overheat the concrete sufficient to cause explosive fracture of the coarse aggregate.

If black stains remain after burning, this can be removed by scrubbing with soap and water.

For larger areas, grit blasting may also have to be considered. This will not affect the durability of the material but may affect the micro-texture of the surface. It is advisable to test a small area before any large scale operation is undertaken.

Smoke, fire and tobacco stains:

Normally these stains can be removed by scrubbing with soap and water. Where stains persist a mixture of scouring powder and household bleach can be used. When using bleach, it is important the bleach is washed from the area once cleaning is completed and the run-off disposed of carefully. Bleach is detrimental to plant life so care should be taken to protect adjacent lawns and borders.

Beverage stains:

These can normally be removed by scrubbing with hot soapy water. If the stain is persistent, apply mild bleach solution and then rinse the area with clean water, taking care to dispose of the run-off safely.

Initial maintenance of non mortared joints:

Refilling joints:

Jointing material may be lost from paving joints in early life during both dry and wet weather.

In dry weather dry jointing material on the surface of the joint can be lost before it can consolidate.

Particularly on steep slopes, the material can be washed from the surface of the joints during heavy rain in its early life. It is therefore important to inspect areas of new paving regularly in their early life and top up joints if necessary.

Sweeping:

Until joints have become stabilised (naturally or chemically) the paving should only be brushed by hand. Mechanical sweepers, (see following section) and in particular sweepers with high suction forces should not be used in the early life of the pavement. If they are used, there is a real risk of loss of jointing material from between the paving units. This is particually important for permeable pavements that have enlarged joints or voids.

Sealants:

Any form of surface sealing used on the paving must be applied in strict accordance with the manufacturer's instructions. It must be accepted that sealants, see Sealing of Block Paving, may have an effect on the colour of the paving, its slip/skid resistance and may require on-going main-tenance during the life of the paving. It is also important that the surface of the units is dry and clean before any sealer is applied.

Mechanical sweepers on paved areas:

Important considerations:

The following recommendations deal with vehicles and associated equipment and their use in sweeping and washing paved and flagged footways, footpaths, pedestrian areas and roads:

- Equipment should be purpose designed to sweep the particular area. If there is any doubt about suitability the vehicle manufacturer should be consulted.
- Where possible, low pressure tyres should be fitted to reduce the risk of breaking or cracking flags.
- Tyres should be inflated according to the manufacturers recommendations, again to ensure mini-mum weight per unit area.
- Polypropylene, rather than wire, brushes should be used.
- Sweeping brush pressures should be set to the minimum required to suit the particular task, i.e. surfaces swept regularly will require a lower setting than those swept infrequently or covered with heavy deposits.
- Tyre and brush pressures should be regularly checked.
- When sweeping, engine speed should be set at the minimum required to maintain vacuum (suc-tion) pressure.
- Operators, including reliefs, should be trained to operate machinery in accordance with manu-fac-turers recommendations.
- When equipment is stationary or left unattended, suction, brush rotation and water jetting equip-ment should be switched off to avoid the risk of damage to the paved area below the stationary equipment.
- For conventional block pavements or flag pavements in new or re-laid areas, agreement should be reached with the local highway authority on a period of manual cleaning to allow flags and block paving to become established, and the joints to seal with detritus. This period may be reduced by using either a water based bonding agent or elastomeric prepolymer sealant, and by agreement with the cleansing authority on an appropriate sweeping and sealant replacement regime.
- When water jetting equipment is used to wash areas, the jets or hand held lance should be di-rected at the surface at an angle not greater than 30° to the horizontal and diagonally across the joints (i.e. not parallel) using a high concentrate detergent solution. The area should be inspect-ed after cleaning to ensure that joints remain full with any required jointing material replacement carried out after the pavement is dry.

Sealing of block paving:

- The introduction of a sealer to a conventional or permeable concrete block pavement can be a cost effective method of improving its appearance and, under some circumstances, prolonging its life.
- The sealing of jointing material in many environments in conventional block pavements cannot be relied upon to occur naturally since (modern) cleaning tools such as pressure washers and vacuum sweepers can have adverse effects.
- Other benefits may include inhibition of weed growth in the joints and prevention of staining to paver surfaces.

Types of Sealers

Water based emulsions:

These rely on penetration of solids into the jointing sand. As the solids are filtered out only a weak, short-term bonding is achieved within the joint. However, they do have a limited use, particularly in sit-uations where solvent based products are expressly excluded.

Solvent based acrylics:

These in the short term will create a glossy finish to the surface providing an aesthetic appeal for some and an unnatural look for others. The main disadvantage is that, in general, they do not have elas-tomeric properties (essential for flexible paving) and their ability to repel staining from hydrocarbons is short lived. Furthermore they can become softened when exposed to hydrocarbons (e.g. diesel, petrol) and even destroyed by brake fluid.

Specialist Pre-Polymer Urethane:

This is an effective sealer/stabiliser, having good long term performance with the ability to stabilise jointing sand, allowing it to be utilised in harsh environments such as airfields and ports. This type of sealer is highly elastomeric and therefore appropriate for a flexible pavement system. Some sealers are manufactured with a high solids content and are able to resist staining from engine oils.

Preparation of paved surfaces:

Sealers may be used on old or new paved surfaces, coverage depending on the porosity of the paving material and the depth and width of the joints. Sealers should generally not be applied if rainfall is fore-cast within the following 8 hours.

Newly laid paving surfaces:

The surface should be clean and free from oil, algae, dust and lime bloom. Surface temperature must be above 5°C and below 30°C. Application outside of these temperatures ranges may be possible however advice should be sought from the manufacturer. Before installation, joints should only be par-tially filled with kiln dried sand. Before application of the sealer, care should be taken to ensure that the jointing sand is completely dry and where necessary refilled in the joints.

Older paved surfaces:

The pavers must be thoroughly cleaned using a pressure cleaner to remove all algae and lichen. Pressure cleaning/washing will also remove all weeds and grass and most of the top layer of jointing sand from between the joints of the blocks. Sufficient time should be left before sealing takes place to ensure that the substrate dries out and to ensure that there is no efflorescence. Therefore at least two weeks between cleaning and sealing are recommended, and the joints refilled before applying sealer.

Methods of application:
The preparation and application including all safety requirements should be undertaken in accor-dance with the supplier's/manufacturers' recommendations

Efflorescence:

White patches appearing on the surface of concrete paving naturally cause concern. However, such concern is rarely justified in the long term, as the appearance is normally the result of '*efflorescence*'.

Forms of Efflorescence

The term 'efflorescence' is also frequently used to describe whitish deposits or stains on building materials. However there are many forms of efflorescence, which have little in common, other than the fact that they result in a white discolouration. Efflorescence, as generally found on concrete paving products, is known as 'lime bloom.' It is a surface deposit on the concrete, seen either in the form of white patches or as a more general lightening in colour. When the latter effect is seen it is often misinterpreted as a fading or 'washing out' of the colour of pigmented concrete.

Formation of Lime Bloom

Lime bloom, when it occurs, is a natural phenomenon brought about by the normal chemical reaction between cement and water. A product of this reaction is calcium hydroxide, 'lime,' which is slightly soluble in water. Under certain conditions it can migrate through damp concrete to the surface where it in turn reacts with atmospheric carbon dioxide to produce a deposit of calcium carbonate crystals.

This deposit gives rise to the white patches or the overall lightening referred to earlier. It is normally extremely thin, and when wetted, the deposit becomes transparent and seems to disappear.

Occurrence

The occurrence of lime bloom on the surface of concrete paving products is a spasmodic and unpredictable phenomenon not associated with poor quality manufacture. The weather is a signif-icant factor with lime bloom forming more readily when concrete becomes wet and dries slowly; therefore occurrences are more frequent in winter months. Generally it only occurs in the early life of concrete paving products, and materials which have been in place for a year or more, without experiencing lime bloom, are unlikely to be affected. The phenomenon is temporary and superficial and will generally disappear in time without affecting concrete strength or durability.

Block paving showing efflorescence

The same blocks after weathering

Removal of Lime Bloom

Introduction

Lime bloom can generally be expected to disappear over a period of time, depending on the envi-ronment to which the paving is subjected. Rainwater, being slightly acidic, dissolves the surface deposit. Where paving is fully exposed to the weather any efflorescence would normally be expected to disappear within the first year or two, although it might be longer for a sheltered site.

Removal would be accelerated by abrasion caused by foot or vehicular trafficking.

Treatment

Equipment:

The following minimum equipment is required:

1 Protective gloves and goggles
2 Appropriate footwear
3 Brush with soft bristles/plastic watering can for application
4 Supply of clean water

Procedure

Proprietary cleaners can be used for more immediate removal of lime bloom. Most proprietary cleaning treatments contain acids and detergents, so it is important to ensure that the manufac-turers' instructions and all relevant environmental regulations are followed. Incorrect or careless cleaning may result in injury or damage and discolouration to the surface of the concrete pav-ing. It is advisable to carry out a test on a small and inconspicuous area of paving before under-tak-ing cleaning over the complete area.

The procedure is best carried out in cool conditions. When the paving is hot, rapid evapo-ration may lead to recurrence of deposits. Care should be taken when applying acid based clean-ers to concrete. Acid attacks concrete and over application may alter the appearance of the paving.

Wash off the residue and inspect the paving. In the case of stubborn or heavy deposits repeat the application as necessary.

After final application of the cleaner wash off any residue with plenty of water to prevent stain-ing, taking care to dispose of the run-off safely. Allow the paving to dry and inspect the surface and joints and resand/replace mortar to joints as necessary.

Long term experience suggests that it is unlikely that lime bloom will recur after removal with acid based treatments. It is not possible, however, to give a guarantee against recurrence.

Preventing recurrence:

A further possibility, which may be considered after successful cleaning, is the use of a sealant to minimise recurrence, see Paving Sealants.

Advice on the use of such treatments can be obtained from specialist companies.

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