Draft for Public Comment

PRIVATE CIRCULATION
B/507_13_0037
For comment - Action Due Date: 2014/01/31
Form 36

DPC: 13 / 30284071 DC

BSI Group Headquarters

389 Chiswick High Road London W4 4AL

Tel: +44 (0)20 8996 9000
Fax: +44 (0)20 8996 7400
www.bsigroup.com

Date: 27 November 2013
Origin: National

Latest date for receipt of comments: 31 January 2014

Project No. 2013/01401

Responsible committee: B/507 Paving units and kerbs

Interested committees: B/565

Title: Draft BS 7533-102 Pavements constructed with clay, natural stone or concrete paving units

Part 102: Code of practice for the construction and maintenance of pavements using modular paving units

Please notify the secretary if you are aware of any keywords that might assist in classifying or identifying the standard or if the content of this standard
i) has any issues related to 3rd party IPR, patent or copyright
ii) affects other national standard(s)
iii) requires additional national guidance or information

WARNING: THIS IS A DRAFT AND MUST NOT BE REGARDED OR USED AS A BRITISH STANDARD.
THIS DRAFT IS NOT CURRENT BEYOND 31 January 2014

This draft is issued to allow comments from interested parties; all comments will be given consideration prior to publication. No acknowledgement will normally be sent. **See overleaf for information on the submission of comments.**

Further copies of this draft may be purchased from BSI Shop **http://shop.bsigroup.com**
or from BSI Customer Services, Tel: +44(0) 20 8996 9001 or email cservices@bsigroup.com.
British, International and foreign standards are also available from BSI Customer Services.

Information on the co-operating organizations represented on the committees referenced above may be obtained from **http://standardsdevelopment.bsigroup.com**

Responsible Content Developer: **Sophie Watson**
Direct tel: **01473 407767**
E-mail: **sophie.watson@bsigroup.com**

Introduction

Your comments on this draft are invited and will assist in the preparation of the resulting British Standard. If no comments are received to the contrary, this draft may be implemented unchanged as a British Standard.

Please note that this is a draft and not a typeset document. Editorial comments are welcome, but you are advised not to comment on detailed matters of typography and layout.

Submission of Comments

- The guidance given below is intended to ensure that all comments receive efficient and appropriate attention by the responsible BSI committee.

- This draft British Standard is available for review and comment online via the BSI British Standards Draft Review system (DRS) as **http://drafts.bsigroup.com.** Registration is free and takes less than a minute.

- Once you have registered on the DRS you will be able to review all current draft British Standards of national origin and submit comments on them. You will also be able to see the comments made on current draft standards by other interested parties.

- When submitting comments on a draft you will be asked to provide both a comment (i.e. justification for a change) and a proposed change.

- All comments will be checked by a moderator before they are made public on the site - the technical content of your comment will not be judged or modified; similarly your grammar or spelling will not be corrected. You will receive acknowledgement by email of all comments you submit via the DRS.

- A link to the DRS, or to a specific draft hosted by the system, may be distributed to other interested parties so that they may register and submit comments. It is not necessary to purchase a copy of the draft in order to review or comment on it; however, copies of this draft may be purchased from BSI, Tel: +44(0)20 8996 9001 or email **cservices@bsigroup.com.** Drafts and standards are also available in PDF format for immediate download from the BSI Shop: **http://www.bsigroup.com/shop.**

DRAFT BS 7533-102

Pavements constructed with clay, natural stone or concrete paving units – Part 102: Code of practice for the construction and maintenance of pavements using modular paving units

Contents

List of figures

List of tables

Foreword

Publishing information

This part of BS 7533 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on XX Month 201X. It was prepared by Technical Committee B/507, *Paving units and kerbs*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This part of BS 7533 supersedes BS 7533-3:2005+A1:2009, BS 7533-4:2006, BS 7533-6:1999, BS 7533-7:2010, BS 7533-9:2010 and BS 7533-11:2003, which are withdrawn. Together with BS 7533-101 (in preparation[1)]), it supersedes BS 7533-13:2009, which will be withdrawn upon publication of BS 7533-101.

Relationship with other publications

BS 7533 is published in the following parts:

- Part 101: *Code of practice for the design of pavements using modular paving units*[1)];
- Part 102: *Code of practice for the construction and maintenance of pavements using modular paving units*.

Information about this document

A full revision of the BS 7533 series has been undertaken, in which the principal change is to reduce the 13 parts of the series down to two.

The principal changes in respect of the material that now appears in BS 7533-102 are:

- the combination into BS 7533-102 of all the information on the installation of rigid and flexible paving (now retitled “bound and unbound paving”), using concrete, clay and stone paving units including permeable paving, from the following parts of the old series:
  - Part 3: *Code of practice for laying precast concrete paving blocks and clay pavers for flexible pavements*;
  - Part 4: *Code of practice for the construction of pavements of precast concrete flags or natural stone slabs*;
  - Part 6: *Code of practice for laying natural stone, precast concrete and clay kerb units*;
  - Part 7: *Code of practice for the construction of pavements of natural stone paving units and cobbles, and rigid construction with concrete block paving*;
  - Part 9: *Code of practice for the construction of rigid pavements of clay pavers*;
  - Part 11: *Code of practice for the opening, maintenance and reinstatement of pavements of concrete, clay and natural stone*;
  - Part 13: *Guide for the design of permeable pavements constructed with concrete paving blocks and flags, natural stone slabs and setts and clay pavers, has been incorporated only in relation to the installation*;
- the removal of repetition between the parts of BS 7533 listed above;
- some updating of references and test methods;
- clarification and removal of ambiguities and anomalies.

[1)] In preparation at the time of public consultation of BS 7533-102.

Use of this document

As a code of practice, this part of BS 7533 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this part of BS 7533 is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Introduction

This part of BS 7533 provides a comprehensive and definitive document on the installation of all types of paving units including permeable paving.

The terminology for paving has been coordinated to be consistent; the terms “rigid” and “flexible” are not used as they cause confusion with pavement engineers with respect to asphalt.

There are four forms of pavement construction considered:

- unbound surface, unbound base;
- bound surface, unbound base;
- unbound surface, bound base;
- bound surface, bound base.

It is formatted in the order that paving is installed; foundation, base, bedding layer, laying paving, jointing, aftercare, cleansing and maintenance. The final clause covers reinstatement of openings.

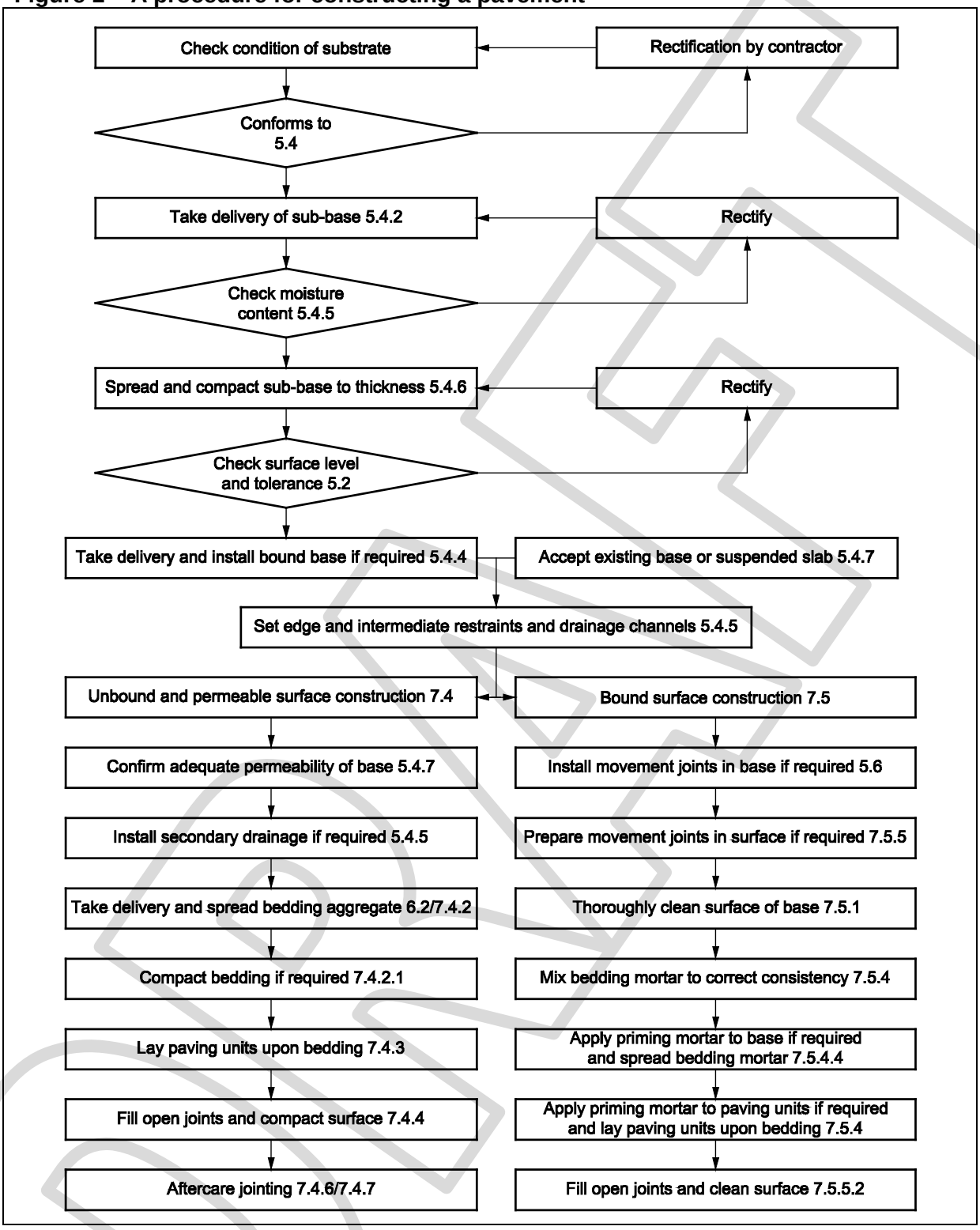
The materials for the various layers are included within the relevant activity. However the materials to be selected are the responsibility of the designer; they are included in this document for completeness and so that the installer can check and confirm that the correct materials have been supplied.

A flow chart for the process of installation is provided in Figure 1, which also can act as an index to the relevant clauses for that activity.

Because of the range of materials and forms of construction, this part of BS 7533 is inevitably lengthy and complex. It is anticipated that manufacturers and/or trade bodies will complement this document with illustrated toolbox training or site guidance publications.

This part of BS 7533 provides the basis for national occupational standards in support of National Highway Sector Scheme 30 [1].

Figure 1 – A procedure for constructing a pavement



1 Scope

This part of BS 7533 gives recommendations for conventional pavements having bound and unbound surface construction and permeable pavements using:

- concrete paving blocks manufactured in accordance with BS EN 1338;
- concrete paving flags manufactured in accordance with BS EN 1339;
- concrete kerb units manufactured in accordance with BS EN 1340;
- natural stone slabs manufactured in accordance with BS EN 1341;
- natural stone setts manufactured in accordance with BS EN 1342;
- kerbs of natural stone manufactured in accordance with BS EN 1343;
- clay paving units manufactured in accordance with BS EN 1344.

It also applies to combined drainage and kerb products, and linear drainage units.

It applies to paved areas subjected to all categories of static and vehicular loading and pedestrian traffic designed in accordance with BS 7533-1, BS 7533-2, BS 7533-8, BS 7533-10, BS 7533-12 and BS 7533-13[2)].

It provides recommendations and guidance on all layers above the formation, including capping, sub-base, base, bedding and surface layers.

It also provides recommendations and guidance on the opening, reinstatement and cleaning of surfaces paved with modular paving units.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

BS 1377-6, *Methods of test for soils for civil engineering purposes – Part 6: Consolidation and permeability tests in hydraulic cells and with pore pressure measurement*

BS 7533-1, *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*[2)]

BS 7533-2, *Pavements constructed with clay, natural stone or concrete pavers – Part 2: Guide for the structural design of lightly trafficked pavements constructed of clay pavers or precast concrete paving blocks*[2)]

BS 7533-8, *Pavements constructed with clay, natural stone or concrete pavers – Part 8: Guide for the structural design of lightly trafficked pavements of precast concrete flags and natural stone flags*[2)]

BS 7533-10, *Pavements constructed with clay, natural stone or concrete pavers – Part 10: Guide for the structural design of trafficked pavements constructed of natural stone setts and bound construction with concrete paving blocks*[2)]

[2)] These parts of BS 7533 are expected to be merged into the new BS 7533-101, which is currently in preparation.

BS 7533-12, *Pavements constructed with clay, natural stone or concrete pavers – Part 12: Guide to the structural design of trafficked pavements constructed on a bound base using concrete paving flags and natural stone slabs*[3)]

BS 7533-13, *Pavements constructed with clay, natural stone or concrete pavers – Part 13: Guide for the design of permeable pavements constructed with concrete paving blocks and flags, natural stone slabs and setts and clay pavers*[3)]

BS 594987, *Asphalt for roads and other paved areas – Specification for transport, laying, compaction and type testing protocols*

BS EN 206-1, *Concrete – Part 1: Specification, performance, production and conformity*

BS EN 932-2, *Tests for general properties of aggregates – Part 2: Methods for reducing laboratory samples*

BS EN 933-3, *Tests for geometrical properties of aggregates – Part 3: Determination of particle shape – Flakiness index*

BS EN 1097-1:1996, *Tests for mechanical and physical properties of aggregates – Part 1: Determination of the resistance to wear (micro-Deval)*

BS EN 1097-2, *Tests for mechanical and physical properties of aggregates – Part 2: Methods for the determination of resistance to fragmentation*

BS EN 1097-6:2013, *Tests for mechanical and physical properties of aggregates – Part 6: Determination of particle density and water absorption*

BS EN 1338, *Concrete paving blocks – Requirements and test methods*

BS EN 1339, *Concrete paving flags – Requirements and test methods*

BS EN 1340, *Concrete kerb unit – Requirements and test methods*

BS EN 1341, *Slabs of natural stone for external paving – Requirements and test methods*

BS EN 1342, *Setts of natural stone for external paving – Requirements and test methods*

BS EN 1343, *Kerbs of natural stone for external paving – Requirements and test methods*

BS EN 1344, *Clay pavers – Requirements and test methods*

BS EN 5212-1:1990, *Cold applied joint sealant systems for concrete pavements – Part 1: Specification for joint sealants*

BS EN 12350-2, *Testing fresh concrete – Slump-test*

BS EN 12457-3, *Characterisation of waste – Leaching – Compliance test for leaching of granular waste materials and sludges – Part 3: Two stage batch test at a liquid to solid ratio of 2 l/kg and 8 l/kg for materials with a high solid content and with a particle size below 4 mm (without or with size reduction)*

BS EN 12617-4:2002, *Products and systems for the protection and repair of concrete structures – Test methods – Part 4: Determination of shrinkage and expansion*

BS EN 12620:2013, *Aggregates for concrete*

BS EN 12390-1, *Testing hardened concrete – Part 1: Shape, dimensions and other requirements for specimens and moulds*

BS EN 13108-1:2006, *Bituminous mixtures – Material specifications – Part 1: Asphalt concrete*

[3)] These parts of BS 7533 are expected to be merged into the new BS 7533-101, which is currently in preparation.

BS EN 13242:2013, *Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction*

BS EN 13285:2010, *Unbound mixtures – Specifications*

BS EN 13412, *Products and systems for the protection and repair of concrete structures – Test methods – Determination of modulus of elasticity in compression*

BS EN 13813, *Screed material and floor screeds – Screed material – Properties and requirements*

BS EN 13877-1:2013, *Concrete pavements – Part 1: Materials*

BS EN 13892-2, *Methods of test for screed materials – Part 2: Determination of flexural and compressive strength*

BS EN 13892-3, *Methods of test for screed materials – Part 3: Determination of wear resistance-Bohme*

BS EN 13892-8, *Methods of test for screed materials – Part 8: Determination of bond strength*

BS EN 14158, *Natural stone test methods – Determination of rupture energy*

BS EN 14227-1:2013, *Hydraulically bound mixtures – Specifications – Part 1: Cement bound granular mixtures*

BS EN 15381, *Geotextiles and geotextile-related products – Characteristics required for use in pavements and asphalt overlays*

BS EN 15382, *Geosynthetic barriers – Characteristics required for use in transportation infrastructure*

BS EN ISO 9864, *Geosynthetics – Test method for the determination of mass per unit area of geotextiles and geotextile-related products*

BS EN ISO 10319, *Geosynthetics – Wide-width tensile test*

BS EN ISO 11058, *Geotextiles and geotextile-related products – Determination of water permeability characteristics normal to the plane, without load*

BS EN ISO 12236, *Geosynthetics – Static puncture test (CBR test)*

BS EN ISO 12956, *Geotextiles and geotextile-related products – Determination of the characteristic opening size*

PD 6691:2010, *Guidance on the use of BS EN 13108 Bituminous mixtures – Material specifications*

Other publications

[N1] HIGHWAYS AGENCY. *Manual of contract documents for highway works – Volume 1: Specification for highway works*. London: Highways Agency: 2009.[4)]

[N2] DEPARTMENT FOR TRANSPORT. *New Roads and Street Works Act 1991 – Specification for the reinstatement of openings in highways*. Third edition. London: The Stationery Office, 2010.[5)]

[4)] Available at www.dft.gov.uk/ha/standards/mchw/vol1/index.htm [last accessed 27 November 2013].

[5)] Available at www.gov.uk/government/publications/specification-for-the-reinstatement-of-openings-in-highways [last accessed 27 November 2013].

3 Terms and definitions

3.1 base
one or more layers of material placed above the sub-base that constitute the main structural element of a pavement on which the bedding layer is placed

3.2 bedding layer
layer of material on which paving units are bedded

3.3 bedding mortar
blend of fine aggregate and cementitious binder on which paving units are bedded

3.4 bound construction
paving units laid on and jointed with hydraulic mortar

NOTE This is irrespective of the base material, which may be bound or unbound.

3.5 bound surface construction
surface course where the paving units are laid on a laying course of bedding mortar and the joints are filled with a cementitious mortar or grout

3.6 cement bound granular material (CBGM)
granular material to which cement has been added

3.7 cobble
natural stone element rounded by erosion

3.8 commercial vehicle
vehicle over 3.5 t gross weight

3.9 complementary fitting
paving unit, of a different size to the main works, used at the end of alternate rows of paving units to break the bond

3.10 concrete paving block
precast concrete unit used as a surfacing material that satisfies the following conditions:

- at a distance of 50 mm from any edge, any cross-section does not show a horizontal dimension less than 50 mm;
- its overall length divided by its thickness is less than or equal to four

NOTE These two conditions are not applicable to complementary fittings.

3.11 conventional paving
paving designed to prevent water ingress through the surface layer

3.12 creep
horizontal movement of paving units resulting from the persistent action of deceleration, cornering forces or gravity

3.13 flag
precast concrete unit used as a surfacing material that satisfies the following conditions:

- its overall length does not exceed 1.5 m;
- its overall length divided by its thickness is greater than four

NOTE These two conditions are not applicable to complementary fittings.

3.14 flexible construction
pavement which is constructed with an unbound surface layer

3.15 foundation
structure on which the pavement is constructed

3.16 geotextile
proprietary fabric that allows water to flow through and prevents migration of particulates between construction layers

3.17 hydraulic binder
material which reacts with water and sets to bind the particles together within a rigid bound layer

3.18 hydraulic mortar
mortar using an hydraulic binder

3.19 inboard cutting
cutting a paving unit to allow the cut at the edge of the paving to be greater than one quarter of the paving unit

3.20 interlock
effect of frictional forces between paving units in unbound construction which prevents them moving in relation to each other

3.21 joint
space between two adjacent units or between paving units and edge restraint

3.22 joint width
size of the space between adjacent paving units or between paving units and edge restraint

3.23 jointing material
material applied to fill the joints between paving units

3.24 kerb race
foundation on which kerbs are laid

NOTE Also referred to as "kerb log" in some regions.

3.25 laying face
working edge of the surface course where paving units are being placed

3.26 laying pattern
arrangement of paving units to form specific patterns for either structural requirements or visual effect

3.27 modular pavement
pavement having a surface course comprising paving units with joints between

3.28 mortar joint
joint between two units filled with a cementitious mixture

3.29 movement joint
joint constructed to allow pavement to expand and contract or flex

3.30 msa
number of standard axles a pavement is designed to carry, measured in millions of standard axles

3.31 nib
small protruding profile on a side face of a block to assist with creating a consistent joint width between units after laying

3.32 pavement
any paved area subject to pedestrian and/or vehicular traffic

3.33 paving unit
pre-fabricated or selected unit used to form the surface course of a modular pavement

NOTE 1 Paving units are also known as "modules" or "pavers".

NOTE 2 Kerbs and channels can also be referred to as paving units.

NOTE 3 Units with any dimension greater than 2 m are unlikely to be covered by this standard.

3.34 permeable pavement
pavement consisting of a surface course of paving units laid with wide joints, voids or openings, that allow surface water to pass through into the pavement construction

3.35 restraint
device that serves to prevent lateral movement of paving units and to prevent loss of the laying course material where applicable

NOTE These may be edge restraint, intermediate or temporary restraint.

3.36 sett
any unit of natural stone obtained by cutting or splitting used as a paving material, in which the working width does not exceed two times the thickness, and the length does not exceed two times the width

3.37 slab
any unit of natural stone obtained by cutting or splitting used as a paving material, used for external paving and road finishes in which the working width exceeds two times the thickness

3.38 standard axle
axle carrying a load of 8 200 kg (8 t)

NOTE Detailed advice is given in HD 24/06 [2].

3.39 sub-base
one or more layers of material placed immediately above the subgrade

3.40 subgrade
part of the soil, natural or constructed, that supports the loads transmitted by the overlying pavement

3.41 capping layer
layer of granular or treated material at the top of the subgrade to improve foundation for the pavement

3.42 surface course
layer of paving units that acts as a wearing surface of the pavement

3.43 unbound construction
paving units laid on and jointed with unbound aggregate

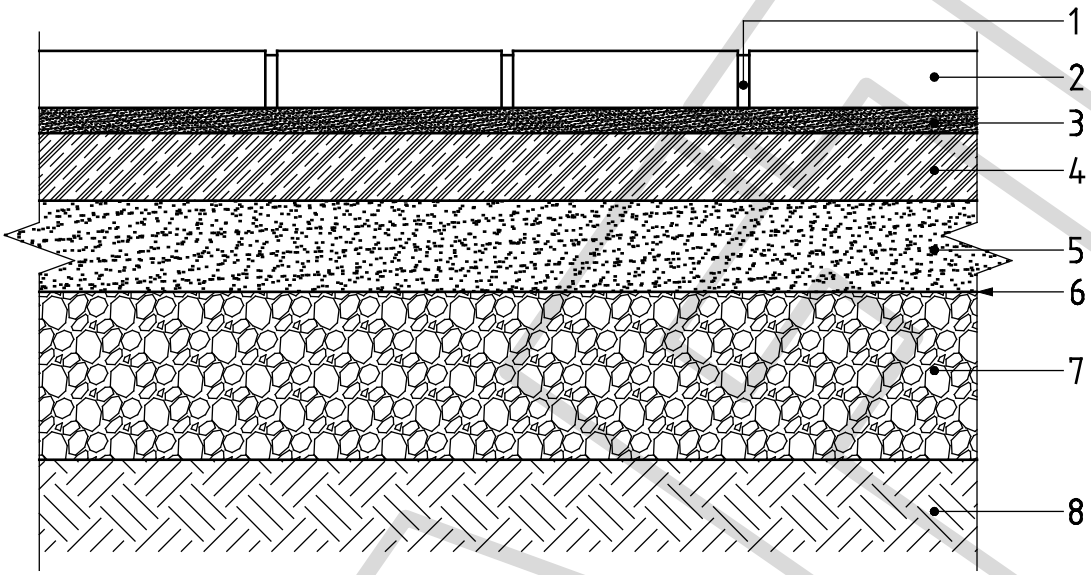
3.44 unbound surface layer
surface course where paving units are bedded on and jointed with granular material, with no binder added

3.45 void
unfilled space in the pavement construction

4 Structure of a pavement

A pavement should comprise as many of the layers shown in Figure 2 and Figure 3 as are specified by the designer.

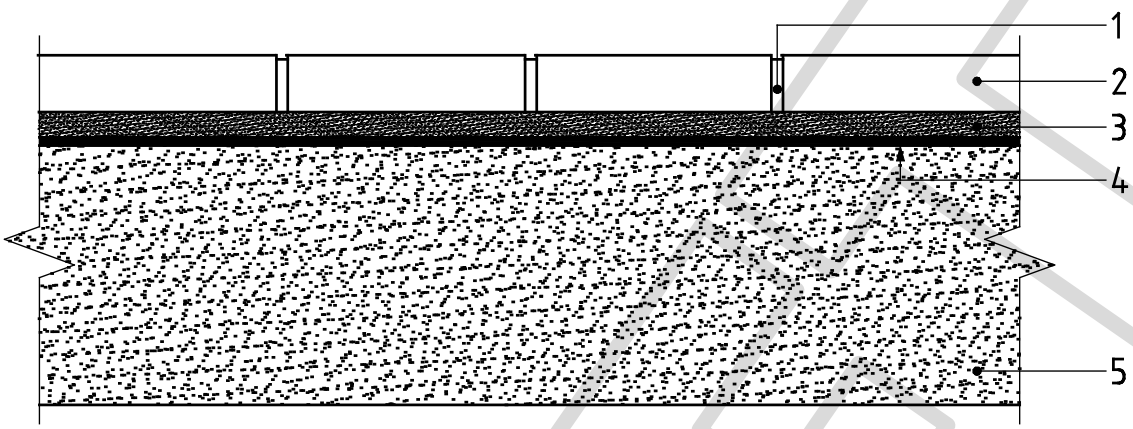
Figure 2 – Pavement layers



Key

1 Jointing material
2 Paving unit
3 Bedding layer
4 Base
5 Sub-base
6 Level of formation
7 Capping layer (not always present)
8 Subgrade

Figure 3 – Pavement layers over a structural slab



Key
1 Jointing material
2 Paving unit
3 Bedding mortar
4 Damp-proof membrane (if necessary)
5 Suspended slab

5 Construction of pavement

NOTE A procedure for constructing a pavement is represented in a flowchart in Figure 1 (see Introduction), for illustrative and reference purposes only. The flowchart shows a general sequence of operations that reflects the construction process.

5.1 Site categories

For the purpose of selection of construction type, base, bedding material and jointing material, the pavement should be categorized as shown in Table 1.

Table 1 – Site categories

Site category	Standard axles per day	msa	NRSWA road type	Typical applications	Construction type	Installed unbound base stiffness	Unbound bedding material category		Unbound jointing material category	Bound bedding material category	Bound jointing material category
10		>30	0	Adopted highways and commercial/industrial developments used by a high number of commercial vehicles Ports and airport landside Bus stops and bus lanes	Fully bound or fully unbound construction	100 MPa	Concrete, clay and sawn sided stone paving units **6.2.2.1; 6.2.2.2** Cropped/ cleft stone paving units **6.2.2.3**	Table 9, cat. I	Concrete, clay and sawn sided stone paving units **6.3.2.1** Cropped/ cleft stone paving units **6.3.2.2** Permeable paving **6.3.3**	**6.4.2** Type A or Type B as specified	**6.5.1** Type A or Type B as specified
9	2 000	<30	1								
8	≤700	<10	2								
7	≤275	<2.5	3								
6	≤60	<0.5	4	Adopted highways and other roads used by a moderate number of commercial vehicles Pedestrian projects subjected to regular overrun of commercial vehicles. Industrial premises Petrol station forecourts		80 MPa	Concrete, clay and sawn sided stone paving units **6.2.2.1 6.2.2.2** Cropped/ cleft stone paving units **6.2.2.3** Permeable paving **6.2.3**	Table 9, cat. II			
5	≤5	0.05		Pedestrian projects subjected to occasional overrun of commercial vehicles Car parks receiving occasional commercial vehicular traffic Railway platforms		Conventional paving Table 7 Permeable paving refer to **5.4.6**		Table 9, cat. III			
4	1	N/A		Walking areas used by emergency vehicles	Fully bound or fully unbound or bound surface over unbound base construction			Table 9, cat. IV		Site-batched to **6.4.3**	Site-batched to **6.5.2**
3	0			Occasional car, light vehicle and motorcycle access							
2	0			Pedestrian and cycles areas							
1	0			Slabs bedded in mortar pedestrian area only							
0	0			No requirement (decoration)							

5.2 Pavement construction falls and tolerances

Pavements, other than permeable pavements, should conform to the recommendations given in Table 2 for falls and tolerances.

Table 2 – Falls for surface drainage

Type of drainage	Recommended	Extreme limits
Crossfalls:		
Course-textured paving units[A)]	3.0%	1.25% to 7%
Fine-textured paving units[B)]	1.25%	
Longitudinal:		
Course-textured paving units[A)]	2.5%	1.0% to 8.0%
Fine-textured paving units[B)]	1.0%	0.0% to 8.0%
Drainage channel	1.25%	1.0% to 8.0%

NOTE 1 Some materials can be laid on slopes steeper than these gradients, but as most paved areas are shared with pedestrians they would be considered to be unwalkable. 8% is considered to be a comfortable maximum.

NOTE 2 In large paving areas, it is important to take into account the resultant fall from the combination of crossfalls and longitudinal fall.

NOTE 3 Large areas can be divided into panels which can be drained, particularly where levels are constrained by edges of buildings, etc.

NOTE 4 Surface falls are built into permeable pavements that are laid on sloping sites, but there is no need for surface falls on flat sites.

[A)] Course-textured paving units are cleft or riven stone, or profiled concrete paving units.

[B)] Fine-textured paving units have a plane surface.

5.3 Tolerance of the surface levels of the different layers of a pavement and the surface regularity of the surface course

The tolerance of the surface levels of the different layers of a pavement should be not greater than the maximum permissible deviations given in Table 3.

The application of these tolerances should not result in the minimum thickness at any point of a layer being reduced by more than 5 mm from the design thickness (sub-base and base) or specified thickness (bedding layer) (see **7.2.2** and **7.5.1**).

NOTE 1 Certain applications, e.g. aircraft pavements, might require stricter tolerances particularly for the surface course.

Table 3 – Tolerance of the surface levels of the different layers of a pavement

Layers of pavement	Maximum permissible deviation from the design level	
	Conventional paving	**Permeable paving**
	mm	mm
Sub grade/ formation	$^{+20}_{-30}$	$^{+20}_{-30}$
Sub-base	$^{+5}_{-10}$	$^{+20}_{-20}$
Base	$^{+5}_{-10}$	$^{+20}_{-20}$
Bedding layer	$30\,^{+10}_{-5}$	$50\,^{+20}_{-20}$
Surface course	$^{+6}_{-6}$	

The surface course should be between 5 mm and 10 mm above adjacent draining fittings/gullies and between 3 mm and 6 mm above surface drainage channels and outlets for pedestrian areas.

NOTE 2 This is important to avoid ponding around drainage inlets or channels.

Wherever possible, surface regularity of the surface course should conform to the values given in Table 4.

In some situations, e.g. when laying riven face units, the tolerances for surface course regularity given in Table 4 might not be possible. In such situations, the minimum practicable tolerances should be adopted.

Table 4 – Surface regularity of the surface course

Measure of surface regularity	Maximum deviation	
	Conventional paving	**Permeable paving**
Flatness of pavement	≤10 mm under 3 m straight edge	Not applicable
Difference in level at the joint of adjacent paving units	≤2 mm	≤2 mm

The finish level of the jointing material should be not greater than 3 mm below the surface of the pavement.

The difference in level at the surface between two adjacent units should not exceed 3 mm.

NOTE 3 This measurement is taken on the paving unit surface, not at the base of the chamfer.

5.4 Subgrade, sub-base and base

5.4.1 General

5.4.1.1 Conventional paving

The thickness of sub-base and base (if present) should be as specified by the designer.

Preparation of the subgrade and the construction of the sub-base and base layers (if present) should generally be in accordance with relevant current practice as described in appropriate series of the Highways Agency's *Specification for highway works* [N1] for the layer, except for reinstatements, which should be in accordance with Clause **10** in the present part of BS 7533.

NOTE The sub-base layer may be used as the base in an unbound pavement construction.

The subgrade, sub-base and base (if present) should be presented such that:

a) they provide a construction platform;

b) they provide adequate frost protection to the subgrade;

c) the surface levels of the sub-base and base (if present) are within the tolerances given in Table 3;

d) the longitudinal falls and the cross-falls of the completed pavement are introduced into the pavement at the subgrade level and allow the water to run off, thus avoiding ponding, aII in accordance with Table 2;

e) the extent of the site preparation includes provision for adequate foundations and backing for any edge restraint;

f) any trenches across the works are permanently reinstated to prevent local settlement;

g) the surface of the sub-base and base (if present) is tight and dense enough to prevent bedding layer material being lost into it during construction and use;

h) any necessary measures are taken to prevent migration of the bedding layer material into the sub-base, e.g. by using a geotextile or by using compatible gradings of bedding layer and sub-base material;

i) the extent of the site preparation includes enough room to provide adequate foundations and backing for any edge restraint.

Work should not take place when the subgrade is waterlogged or frozen.

Where an existing road or footway surface is to be overlaid, it should be checked for structural adequacy in accordance with the appropriate part of BS 7533 for the paving type being used[6)].

Where the sub-base or base contains hydraulic binder and is not to be covered by another pavement course within 2 h of compaction, it should be protected from moisture loss, e.g. by covering with plastic sheeting. If a curing membrane or compound is used, the manufacturer's instructions should be followed. If the process cannot be completed within 2 h, a minimum of 72 h should elapse before mechanical vibratory compaction of the bedding or surface takes place, to prevent damage.

A permeable sub-base should not be used as a temporary access road for general site traffic or as a storage area.

5.4.1.2 Additional recommendations for permeable paving

5.4.1.2.1 General

In addition to the recommendations given in **5.4.1.1**, the sub-base and base (if present) of permeable paving should be presented such that the surface is open and porous.

NOTE There are three systems of permeable paving: System A (total infiltration into the subgrade), System B (partial infiltration into the subgrade) and System C (no infiltration into the subgrade).

If it is necessary to build up subgrade levels for a System A permeable pavement, the material should have similar or superior properties to the existing subgrade, e.g. permeability, density and strength.

For System B and System C pavements, the subgrade should be trimmed with a nominal fall to allow water collected in the bottom of the pavement to drain towards the outlet points.

5.4.1.2.2 System C permeable pavements

The capping layer, if specified by the designer, should be installed in accordance with the Highways Agency's *Specification for highway works* [N1] and the capping materials should meet the requirements of *Specification for highway works*, Series 600, Table 6.1, 6F1 or 6F4, 6F5.

An impermeable membrane should be provided to contain water within the pavement construction.

The surface texture of the capping should be smooth and dense, preventing sharp elements puncturing membrane.

NOTE The capping can be blinded with fine aggregate and/or a geotextile installed on top of the capping to achieve this.

A geotextile fleece may be specified to protect membranes where leakage could have particularly severe consequences.

The membrane should be a non-reinforced polymeric geosynthetic barrier [GBR-P] conforming to BS EN 15382. It should be resistant to puncture caused by loading or sharp points of contact with the aggregate throughout the design life of the pavement, and should be able to withstand the additional loads applied during construction. The membrane should be unaffected by potential pollutants such as alkaline or acidic groundwater.

---

6) The design-related parts of the BS 7533 series (BS 7533-1, BS 7533-2, BS 7533-8, BS 7533-10, BS 7533-12 and BS 7533-13) are expected to be merged into the new BS 7533-101, which is currently in preparation.

All joints between adjacent layers and discharge outlets should be watertight to ensure the integrity of the system.

5.4.2 Sub-base material for conventional paving

5.4.2.1 Unbound sub-base material for conventional paving

Materials should be crushed rock, crushed artificial or recycled aggregates designation $C_{90/3}$ conforming to BS EN 13285:2010, designation 0/31.5 UF_9 OC_{75} GP.

NOTE Materials conforming to the Highways Agency's Specification for highway works *[N1], Clause 803 (Type 1 sub-base) and Clause 807 (type 4 sub-base asphalt arisings) satisfy these recommendations.*

Where a more permeable sub-base has been designed, the material should be crushed rock, crushed artificial or recycled aggregates designation $C_{90/3}$ conforming to BS EN 13285:2010, designation 0/40 UF_5 OC_{80} GO.

The sub-base material should be as specified by the designer.

5.4.2.2 Bound sub-base material for conventional paving

NOTE 1 For more heavily trafficked pavements (site categories 5 to 10 in Table 1), to strengthen and stiffen the pavement, the sub-base might require the inclusion of a hydraulically bound aggregate layer (e.g. CBGM) as specified by the designer.

CBGM should conform to BS EN 14227-1:2013, minimum strength class C 8/10 (as defined in BS EN 14227-1:2013, Table 2).

NOTE 2 Higher strengths might be specified by the designer.

5.4.3 Sub-base material for permeable paving

5.4.3.1 Geotextile laid between sub-base and subgrade

NOTE For System A pavements, a geotextile may be installed between the sub-base and subgrade, to prevent migration of fines from the sub-base into the subgrade.

The geotextile should conform to BS EN 15381 and Annex A.

Geotextile materials should be protected from ultraviolet light whilst stored on site.

Geotextile should be laid with a minimum overlap of 200 mm.

5.4.3.2 Unbound sub-base material for permeable paving

Materials should be crushed rock, crushed artificial or recycled aggregates conforming to BS EN 12620:2013 or BS EN 13242:2013, G_C80/20 4/40 or G_C80/20 4/20 GT_C20/17.5 coarse aggregate as shown in Table 5, and as specified by the designer. The physical properties of sub-base material for permeable paving should be in accordance with Table 6.

Blast-furnace slag and other recycled materials should be tested for leaching of contaminants in accordance with BS EN 12457-3.

NOTE 1 Attention is drawn to the requirements of the Environment Agency in their Guidance for waste destined for disposal in landfills *[3], in respect of leaching of contaminants if blast-furnace slag and other recycled materials are used.*

The selection of sub-base material should be made in accordance with the guidance in BS 7533-13[7)].

NOTE 2 For permeable paving, where it is proposed to use recycled concrete as sub-base, the designer is expected to have taken into account that the alkalinity of water infiltrated through the layer might be elevated beyond allowable limits.

[7)] The design-related content of BS 7533-13 is expected to form part of the new BS 7533-101, which is currently in preparation.

Table 5 – Grading for sub-base material for permeable paving

Sieve size	**Percentage by mass passing**	
	BS EN 12620:2013, G_C80/20 4/40	**BS EN 12620:2013, G_C80/20 4/20**
mm	%	
80	100	—
63	98 to 100	—
40	90 to 99	100
31.5	—	98 to 100
20	25 to 70	90 to 99
10	—	25 to 70
4	0 to 15	0 to 15
2.8	0 to 5	0 to 5

Table 6 – Physical properties for sub-base material for permeable paving

Properties	**Category to BS EN 13242:2013 or BS EN 12620:2013**
Grading	4/20 (preferred) or 4/40, G_c 85–15, GT_c 20/17.5
Fines content	f_4
Shape	FI_{20}
Resistance to fragmentation	LA_{30}
Durability: • water absorption to BS EN 1097-6:2013, Clause **7**, for *WA* > 2% • magnesium sulfate soundness	 $WA_{24}2$ MS_{18}
Resistance to wear	$M_{DE}20$
Acid-soluble sulfate content: • aggregates other than air-cooled blast furnace slag • air-cooled blast furnace slag	 $AS_{0.2}$ $AS_{1.0}$
Total sulfur: • aggregates other than air-cooled blast furnace slag • air-cooled blast furnace slag	 G1% by mass G2% by mass
Volume stability of blast-furnace and steel slags: air-cooled blast-furnace slag • steel slag	Free from dicalcium silicate and iron disintegration in accordance with BS EN 13242:2013, **6.4.2.2**, V_5

NOTE 3 For heavier trafficked permeable pavements (site categories 3, 4, 5 or 6 as shown in Table 1), to strengthen and stiffen the pavement, the sub-base might require the inclusion of a hydraulically bound coarse graded aggregate layer (HBCGA).

5.4.3.3 Bound sub-base material for permeable paving

NOTE 1 For more heavily trafficked pavements (site categories 5 to 10 as shown in Table 1), to strengthen and stiffen the pavement, the sub-base might require the inclusion of a hydraulically bound coarse graded aggregate layer (HBCGA) as specified by the designer.

The HBCGA for permeable paving should be coarse graded granular aggregate HBCGA with the addition of a cement binder.

*NOTE 2 This HBCGA layer can be partially or totally substituted with a permeable asphalt concrete (see **5.4.3.4**).*

HBCGA should conform to BS EN 14227-1:2013:

- minimum cement content by mass: 3%;
- strength class: C 5/6 (as defined in BS EN 14227-1:2013, Table 2);
- minimum permeability: 20 000 mm/h.

5.4.3.4 Asphalt concrete as a permeable base or sub-base layer

NOTE 1 Asphalt concrete is the material formerly referred to as bitumen macadam in the UK.

NOTE 2 If a temporary access is required, an asphalt concrete layer may be installed that will remain in situ throughout the service life of the pavement.

NOTE 3 For load categories 1 and 2, an asphalt concrete layer is in addition to the CGA.

For load categories 3, 4, 5 and 6, an asphalt concrete layer may be substituted for some, or all, of the HBCGA layer, but the minimum thickness of the remaining HBCGA layer should be not less than 125 mm.

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

The asphalt concrete layer should be installed in accordance with BS 594987. When laying asphalt concrete over CGA sub-base, a tracked asphalt paving machine should be used.

NOTE 4 There is a danger of rutting and damaging the surface profile of the CGA if a wheeled asphalt paving unit is used, as it can become embedded in the CGA.

Before installing the permeable block layer, the impermeable asphalt concrete should be converted into a permeable layer by coring or punching the asphalt concrete with 75 mm diameter holes on a 750 mm orthogonal grid. All debris should be removed and the holes in the asphalt concrete should be filled with CGA or laying course aggregate.

5.4.4 Bound base materials for conventional paving

Base materials should be as specified by the designer.

NOTE 1 For unbound paving, the sub-base may be used as a base.

NOTE 2 The following materials are commonly used for conventional paving:

a) asphalt concrete mixtures as specified in BS EN 13108-1:2006:

   1) AC20 open binder course 40/60 pen;

   2) AC 20 dense 40/60 designed binder course;

   3) AC 20 dense 100/150 recipe binder course;

   4) AC 32 dense 40/60 designed base

b) hydraulically bound mixtures:

   1) concrete conforming to BS EN 13877-1:2013, strength class 32/40;

   2) CBGM B conforming to BS EN 14227-1:2013, strength class 16/20.

*NOTE 3 The materials commonly used for permeable paving are as given in **5.4.3.3**.*

5.4.5 Drainage

5.4.5.1 General

The sub-base and unbound base should be adequately free-draining to the depth of frost penetration and be frost-resistant.

NOTE 1 Permeability is normally deemed to be adequate if it exceeds a value of 1×10^{-4} m/s or greater. The permeameter test described in Annex B may be used to assess and verify permeability.

Suitable drainage should be provided to ensure the bedding layer does not become saturated.

NOTE 2 This is particularly important, for example, when overlaying an existing carriageway or a structural deck.

Where an impermeable layer exists beneath the pavement construction such that the passage of water downwards is impeded, lateral drainage should be provided where necessary.

Drainage should be carried out as specified by the designer.

5.4.5.2 Provision of secondary drainage to bedding layer over an impermeable base

Where a base or sub-base is impermeable, secondary drainage to the bedding layer should be provided in order to prevent the layer becoming saturated with water in service.

NOTE 1 Where the base is formed from an existing pavement, other bound base, or structural slab (see Figure 3), and where adequate crossfall exists to direct water laterally through the bedding aggregate to the carriageway edge, weep holes in gulleys might suffice, depending on their frequency. Where no gulleys exist or they are infrequent, it might be necessary to provide a fin drain detail or a proprietary edge drain. See Annex C, Figure C.8 for a typical detail.

Where there are no gulleys and on relatively flat gradients, especially pedestrian precincts with large areas from which water cannot escape the bedding layer laterally, secondary drainage should be provided at regular intervals across the paved area.

*NOTE 2 This may be effected by coring the base with 75 mm diameter holes on a 750 mm orthogonal grid and filling with CGA or laying course aggregate (see **5.4.3.3**).*

*NOTE 3 The use of joint sealers or stabilized joint filling aggregates can reduce the ingress of water (see **7.4.9.2**).*

5.4.6 Sub-base and base compaction

Before compaction, sub-base materials should be moist but not saturated. Frozen material should not be used.

NOTE 1 With the specified sub-base, it is difficult for sub-base to be too wet as it will drain. Material that is too dry is difficult to compact adequately.

If there is evidence of the fine and coarse aggregate separating during transportation or delivery (segregation), it should be remixed with a loading shovel; additional water may be added if necessary).

Unbound sub-base/base and bound base should be compacted to the layer thickness designed for the long-term soil or sub-base strength (CBR% or stiffness modulus MPa). In summer, if the found sub-base strength is higher than the design sub-base strength, no change should be made. If the found sub-base strength is less than the design sub-base strength, the sub-base thickness should be increased to suit.

The sub-base and/or unbound base material for conventional paving should conform to **5.4.2.1** and in site categories 6 to 10 should be compacted in the design thickness to the stiffness taken from Table 1; in site categories 0 to 4 it should be compacted using the compaction equipment and the number of passes for the relevant plant, taken from Table 7, as appropriate. The sub-base and/or unbound base material for permeable paving should conform to Table 5 and care taken when compacting to avoid crushing or segregation of the particles.

Table 7 – Recommended compaction equipment for sub-base and unbound base compaction

Type of compaction plant	Mass	Minimum number of passes		
		Compacted layer thickness ≤110 mm	Compacted layer thickness ≤150 mm	Compacted layer thickness ≤225 mm
Vibrating plate	1 400 kg/m^2 to 1 800 kg/m^2 [A)]	8	Unsuitable	Unsuitable
	1 800 kg/m^2 to 2 100 kg/m^2 [A)]	5	8	Unsuitable
	Over 2 100 kg/m^2 [A)]	3	6	10
Vibrating roller	700 kg/m to 1 300 kg/m [B)]	16	Unsuitable	Unsuitable
	1 300 kg/m to 1 800 kg/m [B)]	6	16	Unsuitable
	1 800 kg/m to 2 300 kg/m [B)]	4	6	10
Engine driven vibro-tamper	50 kg to 65 kg	4	8	Unsuitable
	65 kg to 75 kg	3	6	10
	Over 75 kg	2	4	8

NOTE For intermediate thickness the number of passes may be interpolated.

[A)] Unit area beneath the base plate.

[B)] Unit width of roller.

For permeable paving, the sub-base is compacted to ensure that the maximum density is achieved for the particular aggregate type and grading, without crushing the individual particles, or reducing the voids ratio below the design value. Care should be taken to avoid segregation of the aggregate particles. If segregation occurs, corrective action should be taken to ensure that the completed sub-base has evenly distributed aggregate particle sizes.

Cement bound base should be compacted with 2 h of manufacture and without drying out

A dense asphalt concrete base should be compacted whilst still hot, i.e. compaction completed before the temperature falls below 90° C.

On completion of compaction and immediately before overlaying, the surface of any layer of material should be well closed, free from movement under construction plant and from ridges, cracks, loose material, pot holes, ruts or other defects. All loose, segregated or otherwise defective areas should be removed to the full thickness of the layer, and new material laid and compacted.

For site categories 6 to 10 (Table 1), the surface modulus should be checked by measuring with a light weight falling weight deflectometer (LWD), also known as a portable dynamic plate (PDP). For site categories 6 and 7, a minimum value of 80 MPa should be achieved. For site categories 8 to 10, a minimum value of 100 MPa should be achieved

NOTE 2 If this value is not achieved it could be as result of segregation of the sub-base, poor compaction (normally the result of compacting too dry), or insufficient thickness.

On completion of compaction, the surface of the layer should be checked to determine whether it is within the tolerances in Table 3. If remedial works are necessary, the top 50 mm of the layer should be scarified and additional material added or removed.

5.4.7 Damp-proof membranes for structural slabs

If a damp-proof membrane (DPM) is required on a structural slab, as shown in Figure 3, it should be a liquid and applied by a brush or spray. The materials should be compatible with the bound or unbound bedding material.

*NOTE Normally, for unbound bedding a bituminous DPM is adequate. For bound bedding, a non-bituminous DPM conforming to BS 8102:2009, **8.2.3** (liquid applied membranes) may be used to which the bedding mortar adheres in accordance with **6.4.2**, Table 12.*

The DPM should be applied to the structural base. It should be applied to a clean, dust-free surface in accordance with the manufacturer's instructions. If the top surface of the structural base is not tamped when laid, some coarse sand particles sprinkled over the wet membrane should be used to help adhesion between the membrane and bedding mortar. Any loose sand should be brushed from the surface before the bedding mortar is laid.

Where an insulation board and/or levelling screed is installed, the minimum and maximum thickness for the bedding layer should be observed.

5.5 Restraint

5.5.1 Edge restraint

A substantial edge restraint should be included within the construction of the pavement, as it is crucial to the pavement's performance.

NOTE 1 Edge restraints give a guide to levels and falls. Typical examples of edge restraints are kerbs, channels, established structures, and rigid abutments such as securely fixed paving units, as shown in Annex C.

Edge restraints should be used at junctions between different materials, e.g. paving unit and bitumen bound material

NOTE 2 In certain applications, e.g. at junctions between different materials on steep slopes or at a movement joint, intermediate restraints might be required. Examples of intermediate restraints are shown in Annex D.

Edge restraints should be sufficiently robust to withstand override by the anticipated amount of pedestrian and vehicular traffic, creep and construction activity, and to prevent loss of the bedding layer material from beneath the surface course.

Where there is a need for water to escape from the bedding layer though edge restraints, they should contain weep holes or gaps to ensure that water entering the bedding layer can escape.

The edge restraint should present a vertical face down to the level of the underside of the bedding layer.

In unbound construction, where the laid paving units are to be vibrated, the paving units laid adjacent to an edge restraint should not be compacted into the bedding layer with a plate vibrator (see **7.4.2.1**, Table 15) until the edge restraints and/or the method with which it is being fixed into place has gained sufficient strength.

5.5.2 Temporary restraints in unbound surface construction

During full compaction of the pavement, temporary restraints should be installed to resist lateral movement of the pavement.

It is essential that any temporary edge restraints are secured so that they do not move under load.

NOTE 1 Temporary restraints are particularly important if a partially completed pavement is to be trafficked or when it is necessary to preserve the integrity of the laying face at the end of the working period.

NOTE 2 For areas of pavement that cannot be completed for some time and that might be subjected to trafficking near the edge of the pavement, it might be necessary to construct temporary restraints to prevent the movement of the laid paving units.

5.6 Movement joints in bound surface construction

*COMMENTARY ON **5.6***

Two types of movement are taken into account at the design stage: expansion and contraction.

Movement joints are provided at perimeters, around fixed points of restraint e.g. manholes, columns, upstands, building façades), at significant changes in slope, and within large areas of paving.

Where differential vertical movement is anticipated, an expansion joint is provided.

Examples of movement joints are given in Annex E.

5.6.1 General

Where there is a movement joint in the base, it should be carried through accurately to the surface.

5.6.2 Materials

Various materials can be employed as compressible joint fillers, although cellular polymers (e.g. polyethylene and polyurethane foam materials) should normally be used as these materials can be compressed to at least 50% of their original thickness.

Polyethylene film or masking tape should be used as a barrier to prevent the sealant sticking to the joint filler, as this can adversely affect the extensibility of the sealant.

The joint sealant should conform to BS EN 5212-1:1990, Type N. The advice of the manufacturer of the joint filler or sealant should be followed.

5.6.3 Expansion joints

Expansion joints should typically be provided at perimeters if the paved area exceeds 6 m in any one dimension. In some situations, such as on suspended slabs or in areas where temperature or moisture fluctuations are more severe, the joint spacing should be reduced to 4.5 m.

NOTE 1 Manufacturers might be able to offer advice on movement joint spacing in relation to their own products.

NOTE 2 The joint itself is normally 10 mm in width and comprises the following materials:

a) a compressible joint filler (backup material);

b) a barrier (joint breaker); and

c) an extensible tack-free sealant.

Intermediate expansion joints should be provided if the paved area exceeds 20 m in any one dimension.

Complementary edge restraints should be provided where necessary to support setts adjacent to intermediate joints subject to vehicular trafficking.

NOTE 3 Examples are given in Annex D.

Proprietary jointing products containing compressible materials within plastic, stainless steel, or brass edging are available and should be laid in accordance with the manufacturer's instructions.

5.6.4 Contraction joints

Contraction joints should be provided at intervals typically no greater than 6 m.

NOTE Joints created during construction, e.g. day joints, act as contraction joints. Examples are given in Annex D.

6 Materials

6.1 General

Before use, the installer should confirm that each material conforms to the appropriate standard, as follows:

- concrete paving blocks: BS EN 1338;
- concrete paving flags: BS EN 1339;
- concrete kerb units: BS EN 1340;
- natural stone slabs: BS EN 1341;
- natural stone setts: BS EN 1342;
- kerbs of natural stone: BS EN 1343;
- clay paving units: BS EN 1344.

Details of laying patterns should be planned before laying begins.

NOTE 1 For establishing the visual acceptability of materials and workmanship maintained during paving construction work, compare the texture, colour and finish with the manufacturer's sample or trial panel, using an observer standing in turn at a distance of 2 m from each edge of the square in natural daylight conditions.

NOTE 2 Paving units might have variations in colour and surface texture even when from the same source; this might be a natural feature of the product and not a defect. Where variation occurs, materials can be mixed to randomize the effect.

NOTE 3 Natural stone paving units might have variations in dimensions, even when from the same source; this might be a natural feature of the product and not a defect, provided that the units conform to the requirements of the product standard, the declarations made by the supplier or approval samples provided. Where variation occurs, materials can be sorted into batches of similar size if necessary to maintain joint widths within tolerance.

NOTE 4 It might be necessary to batch paving units by depth to ensure that the depth of the bedding layer remains constant and within the permitted tolerance.

When reclaimed paving units are used, they should be cleaned thoroughly of all loose material before use.

NOTE 5 The use of reclaimed paving units in bound construction is not recommended, unless special cleaning measures are employed to ensure the complete removal of all residues or contaminants which might adversely affect the ability of bedding and jointing mortars to adhere.

6.2 Bedding materials for unbound surface construction

6.2.1 General

Unbound bedding layers in pavements should contain no material which acts as a binder and could detract from the flexible nature of the pavement, e.g. cement or lime. The bedding material should be clean, hard and durable, containing no deleterious materials such as wood, plastic or soil.

The bedding layer material should be free-draining in service.

NOTE 1 Recycled aggregate may be used as bedding layer material for site categories 0 to 4 as given in Table 1.

NOTE 2 Angular shaped particles perform better than rounded particles in unbound pavements.

NOTE 3 Where angular shaped particles and recycled glass are used, thickness variation in paving units might be difficult to accommodate due to the stability of the layer.

6.2.2 Conventional paving

6.2.2.1 Conventional paving with concrete, clay and sawn sided stone paving units in all site categories

The bedding layer for conventional paving with concrete, clay and sawn sided stone paving units in all site categories should be suitable coarse aggregate as follows:

a) with a flakiness index of less than FI_{35} when measured in accordance with BS EN 933-3; and

b) which conforms to BS EN 13242:2013, $G_C85/20$ 2/6 aggregate, as shown in Table 8 and in addition for bedding layer material in site categories 6 to 10 (Table 1); and

c) with resistance to impact conforming to BS EN 13242:2013, category SZ_{18}, determined in accordance with BS EN 1097-2. Where, for a given material, this information is unavailable, impact resistance may alternatively be measured in accordance with Annex F and the change in grading from the untreated sample should be not greater than the values in Table 8. These unbound bedding materials are denoted Category I, II, III or IV as shown in Table 9.

NOTE 1 The wear regime described in Annex F is intended to simulate the grinding effect caused by the movement of paving units as heavy vehicle tyres pass and turn. The test involves placing the specimen in a rolling bottle containing stainless steel balls and measuring the increase in fine material generated.

After testing in accordance with Annex F, Category I bedding layer material should have D10 not less than 0.10 mm (100 µm), where D10 is the particle size for which 10% of the material is finer.

NOTE 2 D10 is a surrogate measure of permeability. The ongoing water permeability of the laying material is important to ensure that the layer drains and does not become waterlogged.

Table 8 – Grading of bedding layer for unbound laying material in all site categories

Sieve size	**Percentage by mass passing**	**Maximum change from untreated sample**[A)]
mm	%	
14	100	—
8	98 to 100	—
6	85 to 99	—
2	0 to 20	—
1	0 to 5	—
0.25	—	+20
0.125	—	+10
0.063 (fines content)	See Table 9	—

[A)] See Annex F.

The fines content of the material, i.e. the percentage of material passing a 0.063 mm sieve, is determined by the bedding layer material category. The fines content for specific bedding layer material categories should be not greater than the values given in Table 9.

Table 9 – Fines content of bedding layer material for conventional paving

Site category (Table 1)	**Bedding layer material category**	**Maximum percentage by mass passing 0.063 mm**	**BS EN 12620:2013 or BS EN 13242:2013 fines content category**
7, 8, 9, 10	I	1.5[A)]	$f_{1.5}$
6	II	2.0	$f_{12.0}$
5	III	3.0	$f_{3.0}$
0, 1, 2, 3, 4	IV	4.0	$f_{4.0}$

[A)] See Annex F.

6.2.2.2 Conventional paving with concrete, clay and sawn sided stone paving units in site categories 0 to 4 only

Bedding layer materials for conventional paving in site categories 0 to 4 (see Table 1) should be graded in accordance with Table 10 and should conform to either BS EN 12620:2013 or BS EN 13242:2013, G_F85 0/4 or $G_C85/20$ 2/6 aggregate in accordance with **6.2.2.1**.

Table 10 – Grading for alternative bedding layer material for conventional paving with concrete, clay and sawn sided stone paving in site categories 0 to 4

Sieve size	Percentage by mass passing
mm	%
8	100
6	95 to 100
4	85 to 99
0.5	30 to 70
0.25	—
0.125	0 to 5
0.063 (fines content)	See Table 9

6.2.2.3 Conventional paving with cropped/cleft stone paving units

The bedding layer for conventional paving with cropped/cleft stone paving units should be crushed igneous rock:

a) with a flakiness index of less than FI_{35} when measured in accordance with BS EN 933-3; and

b) which conforms to a BS EN 12620:2013 or BS EN 13242:2013, $G_C85/20$ 2/6 aggregate, as shown in Table 8; and

c) with fines content for specific bedding layer material categories not greater than the values given in Table 9; and

d) with resistance to impact conforming to either BS EN 13242:2013, category SZ_{18}, determined in accordance with BS EN 1097-2 or Annex F.

6.2.3 Permeable paving

The bedding layer for permeable paving should be crushed igneous rock:

a) with a flakiness index of less than FI_{35} when measured in accordance with BS EN 933-3; and

b) which conforms to a BS EN 12620:2013 or BS EN 13242:2013, $G_C85/20$ 2/6 aggregate, as shown in Table 8.

6.2.4 Moisture content

For conventional paving, when the bedding layer is being prepared, the material should be moist without being saturated. It should show no free water.

NOTE 1 If the prepared bedding layer becomes saturated prior to laying the paving units, it may be removed and replaced, or allowed to dry to an acceptable moisture content.

NOTE 2 To control the moisture content of a stockpile, covers may be used.

NOTE 3 It is not necessary to assess the moisture content of material used in the preparation of the bedding layer of a permeable pavement.

6.3 Joint filling materials for unbound surface construction

6.3.1 General

The joint filling material in unbound pavements should contain no material which acts as a binder and could detract from the flexible nature of the pavement, e.g. cement or lime. The material should be clean, hard and durable, containing no undesirable leachates.

NOTE Angular shaped particles perform better than rounded particles in unbound pavements.

6.3.2 Conventional paving

6.3.2.1 Conventional paving with concrete, clay and sawn sided stone paving units

The jointing material for conventional paving with concrete, clay and sawn sided stone paving units should be dried free-flowing silica aggregate, the grading of which is given in Table 11 and conforms to a BS EN 12620 G_F85 0/1 (FP) *F*4 fine aggregate.

Table 11 – Grading for jointing material for conventional paving

Sieve size	**Percentage by mass passing**
mm	%
2	100
1	85 to 99
0.5	55 to 100
0.063	0 to 2

6.3.2.2 Conventional paving with cropped/cleft stone paving units

6.3.2.2.1 General

NOTE Wide joints are usually filled using the bedding material.

Nominal joint width should generally be two and a half times the maximum particle size of the aggregate used to fill the joint.

Aggregate used to fill joints should be free draining.

Where, because of narrower widths than permitted with use of the bedding aggregate as joint filling, it is necessary to use a finer jointing material, crushed igneous rock should be used. The grading should be determined using formulae 1 and 2 as appropriate for the bedding layer material:

$$\frac{D_{15}}{d_{85}} < 4 \qquad (1)$$

and

$$\frac{D_{50}}{d_{50}} < 10 \qquad (2)$$

where:

D = sieve size of bedding layer material;

d = sieve size of joint filling material;

$_n$ = sieve size for that percentage passing.

6.3.2.2.2 Fine topping material

Crushed igneous rock or carboniferous limestone, specified as 1 mm to dust, with not less than 50% passing the 0.09 mm sieve, should be used.

6.3.3 Permeable paving

Where the joint void is to be filled with aggregate, the material used should be free draining and conform to **6.3.2.2.1**.

NOTE When using proprietary paving units, advice about exactly what material is suitable as jointing and void filling material for a particular paving unit may be sought from the paving unit manufacturer.

6.4 Bedding materials for bound surface construction

6.4.1 Bonding slurry primer

Bonding slurry primer is a blend of cementitious binder and fine aggregates, applied as a liquid slurry with a thick creamy consistency. If used, it should be maintained in a homogenous consistency by regular agitation.

*NOTE Recommendations for the use of bonding slurry primer are given in **7.5.4.4**.*

6.4.2 Bedding mortar

For site categories 5 to 10 (as shown in Table 1), proprietary bedding mortars should be used which conform to Table 12 for the appropriate bedding mortar type.

Table 12 – Bedding mortar characteristics

Characteristic	Performance	
	Type A bedding mortar	**Type B bedding mortar**
Compressive strength [A)]	≥25 MPa	≥35 MPa
Flexural strength [A)]	≥3.5 MPa	≥4.5 MPa
Modulus of elasticity [B)]	(15 000 ± 3 500) MPa	(18 000 ± 3 500) MPa
Shrinkage [C)]	≤0.09%	≤0.09%
Adhesive strength [D)]	—	≥2.0 MPa
Impact resistance [E)]	≥2.5 J	≥3.5 J
Permeability [F)]	≥5 × 10^{-5} m/s	≥5 × 10^{-5} m/s

[A)] Measured in accordance with BS EN 13892-2 after 28 days.
[B)] Measured in accordance with BS EN 13412 after 28 days.
[C)] Measured in accordance with BS EN 12617-4:2002, Clause **6** after 91 days.
[D)] Measured in accordance with BS EN 13892-8 (includes the use of priming mortar) after 28 days.
[E)] Measured in accordance with BS EN 14158 after 28 days.
[F)] Measured in accordance with BS 1377-6.

NOTE In all situations, Type A mortar may be substituted with Type B mortar.

Proprietary bedding mortars may be prepared as either a moist mix or a plastic mix, as follows.

a) Moist mix should be contain enough water to fully hydrate the cement, but not so much as to prevent the paving units being hammered in by hand; this is assessed by squeezing the mix in the hand. When the pressure is released the mix should show no water on the surface and should remain bound together.

b) A plastic mix should have a slump of (150 ±15) mm in accordance with BS EN 12350-2.

6.4.3 Site-batched non-proprietary bedding mortar

NOTE 1 For site categories 0 to 4, site-batched non-proprietary mortars may be used. A mortar comprising 1:4 Portland cement-aggregate (proportions by volume) has been found to be satisfactory.

The aggregate used in the bedding mortar should be in accordance with Table 13.

Table 13 – Recommendation for aggregate used for site-batched non-proprietary bedding mortar

Properties	Category to BS 12620:2013
Grading	2/6 (preferred) or 1/4 or 2/8, G_c85/20
Minimum % crushed surfaces	$C_{70/10}$
Maximum fines content	$f_{1.5}$
Shape – flakiness index	FI_{20}
Shape – shape index	SI_{40}
Resistance to fragmentation	SZ_{26}
Acid-soluble sulfate content:	$AS_{0.2}$
Total sulfur:	S_1
Durability against freeze-thaw	F_1
Constituents which alter the rate of setting and hardening of hydraulically bound mixtures	Recycled materials should not be used

The components should be accurately measured by volume using suitable equipment, e.g. clean gauge boxes or buckets.

*NOTE 2 Site-batched non-proprietary bedding mortar is normally moist mix as described in **6.4.2**.*

NOTE 3 The use of dry or semi-dry mortar for bedding is not recommended. It leads to inadequate support and uncertain performance in-service.

NOTE 4 The substitution of the recommended aggregate with natural sand or fine aggregate can result in efflorescence and surface staining due to moisture migration resulting from capillary action within the mortar.

6.5 Joint filling materials for bound surface construction

6.5.1 Slurry grout jointing mortar

The maximum aggregate particle size should be not greater than 40% of the joint width

The material used for jointing should be a cementitious slurry grout conforming to Table 14 for the appropriate jointing mortar type.

It should have a compressive strength depending on the site category as described in Table 1.

Table 14 – Jointing mortar characteristics

Characteristic	Performance	
	Type A jointing mortar	**Type B jointing mortar**
Compressive strength [A)]	≥25 MPa	≥40 MPa
Flexural strength [A)]	≥3.5 MPa	≥6 MPa
Density [A)]	≥2 000 kg/m^3	≥2 000 kg/m^3
Modulus of elasticity [B)]	(18 000 ±4 000) MPa	(20 000 ±4 000) MPa
Shrinkage [C)]	≤0.15%	≤0.15%
Adhesive strength [D)]	≥1.0 MPa	≥1.5 MPa
Wear resistance Böhme class [E)]	A15	A15
Frost/salt resistance class [F)]	3	3

[A)] Measured in accordance with BS EN 13892-2 after 28 days.
[B)] Measured in accordance with BS EN 13412 after 28 days.
[C)] Measured in accordance with BS EN 12617-4:2002, Clause **6** after 91 days.
[D)] Measured in accordance with BS EN 13892-8 after 28 days.
[E)] Measured in accordance with BS EN 13813, using BS EN 13892-3, after 28 days.
[F)] Measured in accordance with BS EN 1339.

6.5.2 Site-batched non-proprietary jointing mortar

NOTE 1 For site categories 0 to 4, site-batched non-proprietary jointing mortar may be used. A mortar comprising 1:3 Portland cement-aggregate mortar (proportions by volume,) using fine aggregate conforming to BS EN 12620:2013, GF85 0/1 (MP), has been found to be suitable.

The components should be accurately measured by volume using suitable equipment, e.g. clean gauge boxes or buckets.

This mortar should be applied as a plastic mix. Dry fine aggregate and cement mixtures should not be used as they are susceptible to shrinkage, have poor adhesion properties and are not frost-resistant.

When installed, the cured mortar should form an impermeable joint.

NOTE 2 The addition of excess water is not recommended. It can cause excessive shrinkage and results in a mortar which is permeable to water.

7 Laying paving units

7.1 General

Laying of unbound pavements should proceed only when the sub-base or base has been accepted as being suitable by virtue of its surface characteristics and tolerances. Sub-base and base should be constructed in accordance with **5.4**.

7.2 Preparation of bedding layer

7.2.1 General

The bedding layer should be laid on the base or, if there is no base, the sub-base. The bedding layer material should not be used as a regulating course or to achieve falls.

The properties and grading of the bedding material should conform to the recommendations given in Table 1 for the relevant site category.

NOTE 1 The nominal aggregate size for bedding materials is typically between 20% and 40% of the bedding layer thickness.

Where the bedding layer is found to be too thin, the level of the base should be adjusted, by removal of material.

NOTE 2 Where previous experience of a particular bedding layer material is lacking, a small trial area may be constructed in order to determine the amount of material surcharge that will be needed to compensate for the decrease in thickness that happens as a result of all the compactions that occur during the construction of a pavement.

7.2.2 Tolerances and levels

When laying concrete, clay or sawn sides stone paving units on a sub-base or a base, the target bedding layer thickness after paving unit compaction should be 30^{+15}_{-5} mm.

When laying cropped or riven stone paving units on a sub-base or a base, the target bedding layer thickness after paving unit compaction should be 40^{+10}_{-5} mm

Where the bedding layer is found to be too thick, the level of the base should be adjusted by the addition of material having the same mechanical properties as the base.

NOTE 1 Around ironwork, additional bound material (asphalt or concrete) might be required in order to ensure similar thickness of bedding whilst maintaining adequate drainage.

NOTE 2 If any disturbance of the bedding layer material by pedestrian or wheeled traffic occurs prior to placing paving units, re-screeding or re-compacting areas of bedding layer material, it is essential to achieve uniformity of compaction after laying.

NOTE 3 Details regarding the thickness design of sub-base and base layers are given in the appropriate part of BS 7533 for the paving type being used[8)]*.*

7.3 Laying pattern

*COMMENTARY ON **7.3***

The laying pattern is chosen, not only for appearance, but also as a means of resisting the effects of vehicular traffic, whether travelling in straight lines or turning.

In unbound constructions, laying patterns are crucial to the ability of the surface to achieve interlock and resist lateral forces.

For bound constructions, the laying pattern is of less importance; however, resistance to heavy trafficking is enhanced by choice of pattern in the same way as for unbound construction.

For pedestrian-only areas, the laying pattern is not as important to serviceability.

Examples of laying patterns for precast concrete and clay paving units are given in Annex G.

Examples of laying patterns for natural stone setts are given in Annex H.

7.3.1 Rectangular paving units

Rectangular units may be laid in areas subjected to vehicular traffic not exceeding site category 6 (see Table 1) in a stretcher course pattern, but the stretcher course pattern should generally not be in line with the flow of traffic.

NOTE 1 For heavy traffic, an angle of 45° to direction of traffic flow has been found to be more effective than at 90°. For higher traffic levels, site category 7 to 10 (see Table 1), herringbone pattern is strongly recommended

NOTE 2 For precisely dimensioned small paving units such as precast concrete paving units, the most effective laying pattern is the herringbone pattern. The orientation of herringbone pattern 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 of the pavement.

For cropped setts, where straight line bond patterns have been requested, e.g. stretcher bond, running bond or herringbone, the paving units should be graded into appropriate sizes and the joint should display a straight line along its centre rather than trying to achieve a line along the edge of the paving unit.

When segmental arch or decorative arch patterns have been requested, suitably sized paving units should be selected to ensure that the desired pattern is achieved. A proportion

[8)] The design-related parts of the BS 7533 series (BS 7533-1, BS 7533-2, BS 7533-8, BS 7533-10, BS 7533-12 and BS 7533-13) are expected to be merged into the new BS 7533-101, which is currently in preparation.

of the material delivered should contain sufficient trapezoidal and undersized units to enable the setting out of the arch.

NOTE 3 Small paving elements nominally square in plan are used to form arch patterns, commonly referred to as cubes.

7.3.2 Non-rectangular and irregularly shaped paving units

Where irregularly shaped interlocking paving units have been supplied, advice about which laying pattern to use should be obtained from the manufacturer.

7.4 Installation of paving with unbound surface construction

7.4.1 General

Suitably protected weepholes should be present or other drainage installed prior to installation of the bedding layer where the base is impermeable (see **5.4.5.2**).

7.4.2 Installation of bedding for unbound surface construction

*NOTE Excessive thickness of bedding layer outwith the tolerances in **7.2.2** can lead to deformation of the surface under traffic. Inadequate bedding layer thickness can lead to cracked and broken units under traffic.*

7.4.2.1 Pre-cast concrete, clay and sawn sided stone paving units

One of the following methods of screeding the bedding layer should be used for concrete block paving, sawn sandstone setts, clay paving units, concrete flags and sawn natural stone slabs.

NOTE 1 The most appropriate method of bedding course installation depends on type of product, the product's permissible manufacturing tolerance and the surface laying pattern.

a) Pre-compacted bedding layer. Spread the material loose in a uniform layer and pre-compact with a suitable plate compactor or vibrating roller. Screed to a thickness that, after the paving blocks have been laid and compacted into place, will give the final target bedding layer thickness. Level the surface by screeding.

   NOTE 2 The bedding layer may be placed, screeded and compacted using a mechanical device such as an asphalt laying machine.

   NOTE 3 Vibrating plate compactors as described in Table 15 have been found suitable for compacting the bedding layer.

b) Uncompacted bedding layer. Spread the material loose in a uniform layer. Screed to a thickness that, after the paving blocks have been laid and compacted into place using equipment conforming to Table 15, will give the final target bedding layer thickness.

NOTE 4 Screeding rails may be used to control levels of uncompacted bedding.

Table 15 – Plate vibrator details for unbound surface construction

Site category	Min. plate area	Min. effective force per area of plate	Frequency	Min. mass
	m^2	kN/m^2	Hz	kg
6 to 10	0.25	75	65 to 100	200
5 and 6	0.2	60	75 to 100	80
1 to 4	0.2	35	75 to 100	60

For clay paving units and mechanically laid units, method a) should be used.

Any disturbance of the bedding layer material that could adversely affect the laying of paving units should be corrected.

After the careful removal of the screeding rails, the disturbed area should be filled and re-screeded with bedding layer material.

The area of bedding layer prepared should generally be such that at the end of a working day, its boundary is not less than 1 m ahead of the laying face.

All areas of prepared bedding layer material should be protected and not left exposed overnight.

7.4.2.2 Cropped/cleft or textured side paving units

The bedding layer for cropped/cleft or textured side paving units should be installed at the same time as the units (see **6.2.2.3**).

7.4.2.3 Permeable paving

The thickness of the bedding layer after final compaction of the surface course (see **7.2.2**) should be a function of the aggregate nominal size with a surface level tolerance conforming to Table 3.

NOTE The nominal aggregate size is typically be between 20% and 40% of the bedding depth.

The screeding of the bedding layer should be performed in accordance with the uncompacted bedding layer method given in **7.4.2.1**b).

7.4.3 Installation of paving units for unbound surface construction

7.4.3.1 General

It is essential that any soil, fine material and other materials that arise during construction are prevented from contaminating the surface of the base.

Paving units should be placed on the prepared bedding layer in the nominated pattern. An order of laying which maintains an open laying face should be followed. The first row of a rectangular pattern should be aligned against a straight section of the edge restraint, intermediate or temporary restraint or by using a straight edge or string line. The alignment of paving units should be checked periodically for all laying patterns, e.g. by using string lines, and adjustments made where necessary.

The paving units should be laid in such a way that, after final compaction, the surface course will conform to the surface level tolerances and surface regularity given in **5.3**.

Both curved and straight lines should be carefully set out and maintained using lines and squares, as appropriate, to achieve consistency, as haphazard deviation mars the appearance of the paving.

Quarter-, half- and third-overlapping bonds may be adopted to accentuate the linear character of the pattern; however, with quarter-overlapping bonds, care should be taken if curves are part of the design as the bond is easily lost when easing the paving units around the curve.

On slopes, paving units should be laid commencing from the bottom working upwards whenever possible.

NOTE 1 Full support to the paving units is necessary, i.e. a full bed with no voids.

NOTE 2 A flow chart of the general process of construction is given in Figure 1.

NOTE 3 Success in laying rectangular paving units to curved patterns depends on the tolerances of the joint to ease the units around the radii. By using cut paving units, more joints are introduced and, therefore, more adjustment is possible. By splaying the cut units, tighter radii can be built.

NOTE 4 Suitable curved units might be available as well as circular patterns and feature work details from some manufacturers.

NOTE 5 It can be difficult to achieve straight lines when laying paving units, because the straightness is dependent on workmanship and the differences in sizes of the paving units that result from the manufacturer's accepted tolerance levels. It is advisable to use a number of packs of the same product concurrently to mix the products.

NOTE 6 When laying paving units of inconsistent colour, size and shape , sorting of units into batches might be necessary in order to ensure consistent pattern, alignment and bond.

7.4.3.2 Joint widths for unbound surface construction

7.4.3.2.1 Conventional paving

Paving units should be laid with a joint width as shown in Table 16.

The paving unit shape and the laying pattern influence the joint width. The width of the joint should not include the chamfer dimension (if any).

NOTE 1 Where the paving units do not have nibs, purpose-made spacer units may be used.

Table 16 – Recommended joint widths for unbound surface construction

Paving unit	Joint width mm
Concrete block and clay paving units	2 to 5
Sawn stone slabs and concrete flags	2 to 5
Stone slabs with fettled edges	6 to 12
Cropped stone setts Size 1	6 to 10
Cropped stone setts Size 2[A)]	8 to 12
Cropped stone setts Size 3[A)]	8 to 12
Cropped stone setts Size 4[A)]	10 to 15

[A)] For cropped setts laid in site categories 7 to 10 (see Table 1), it is good practice to carefully grade and lay setts closely together such that adjacent setts touch where possible. The irregular nature of cropped setts ensures that even when touching at a single point, space remains available to receive joint filling material.

NOTE 2 Paving units laid in small widths on footways with a permeable bedding layer and sub-base may be laid hand tight with the joint width determined by the paving unit plan tolerance. This is not suitable for an impermeable base.

*NOTE 3 The selection of suitable joint filling material for unbound pavements is described in **6.3**.*

NOTE 4 The selection of sett size is described in BS 7533-10[9)].

7.4.3.2.2 Permeable paving

Paving units should be laid to maintain a joint or void width sufficient to ensure adequate flow of water through the surface course.

Joint widths for proprietary paving units manufactured for permeable paving should be in accordance with the manufacturer's instructions.

7.4.3.3 Cropped/cleft or textured side paving units (e.g. granite)

The bedding layer material should be spread loosely and adjusted for each paving unit individually to ensure that, after the hammering into position of each paving unit by hand, the correct line and level including surcharge is achieved.

When laying the bedding layer material, the layer should achieve uniform density as far as possible.

Joint widths should be in accordance with Table 16.

After the paving units have been hammered into position, additional bedding material should be added to loosely fill the joint. In the case of narrower joints, joint filling aggregate as described in **6.3.2.2** should be used.

[9)] The content of BS 7533-10 is expected to form part of the new BS 7533-101, which is currently in preparation.

Joints should not be allowed to remain unfilled at the end of a working shift.

7.4.4 Jointing and void filling material for unbound surface construction

7.4.4.1 Conventional paving

7.4.4.1.1 General

Where it is necessary to provide reduced permeability or prevent material loss during mechanical cleansing, a proprietary stabilized jointing material may be used. Cement bound materials should not be used for this purpose. These materials should not be assumed to provide additional structural strength.

7.4.4.1.2 Pre-cast concrete, clay and sawn sided stone paving units

The jointing material for conventional paving should conform to **6.3.2**. Material that might stain the pavement surfaces should not be used.

NOTE The filling of joints with dry jointing material is not possible in damp conditions and can lead to an insufficiently filled joint.

7.4.4.1.3 Cropped/cleft sided paving units

NOTE 1 Where joint widths are not less than 10 mm, it is normal practice to fill the joints using the same aggregate as for the bedding layer.

For narrow joints, <10 mm wide, a joint filling aggregate as described in **6.3.2.2.1** should be used to fill the joint.

NOTE 2 The nominal aggregate size is typically between 20% and 40% of the joint width.

The joint filling material should be swept into the joints, filling them completely, and the paving units compacted to refusal using a plate vibrator as described in Table 15.

The fine topping aggregate, described in **6.3.2.2.2** should be spread over the surface to a thickness of between 5 mm and 10 mm and, to ensure the joints are completely filled, the surface should be sprayed with a fine water spray to wash the material into the joints.

7.4.4.2 Permeable paving

The jointing and void filling material for permeable paving should conform to **6.3.3**. Material that might stain the pavement surfaces should not be used.

7.4.5 Compaction of paving units into the bedding layer for unbound surface construction

Prior to joint filling, the paving surface should be checked for the following:

a) the surface is free of debris;

b) the surface level tolerance conforms to **5.3**;

c) the flatness of the pavement conforms to **5.3**;

d) the difference in level at the joint of adjacent paving units conforms to **5.3**;

e) joint width is consistent;

f) joints are correctly aligned;

g) there are no damaged or broken units.

Any necessary corrective action should be taken.

Prior to compaction, the joints should be filled to excess with jointing material as described in **6.3.2**, as appropriate.

NOTE 1 The filling of joints with dried sand is not possible in damp conditions.

NOTE 2 As an alternative to the filling of joints with dried sand, washing in of jointing sand is permissible if the free draining properties of the bedding and base and drainage provisions are sufficient to prevent the bedding layer becoming saturated.

NOTE 3 Washing in of jointing sand is not recommended if the bedding layer material is not free-draining and base and drainage provisions are inadequate to prevent the bedding layer becoming saturated.

A vibrating plate compactor should be used to fully bed the paving units into the bedding layer material.

NOTE 4 Vibrating plate compactors as described in Table 15 have been found suitable for compacting the paving units into the bedding layer.

NOTE 5 The use of a compactor with a neoprene sole plate might be necessary to protect special surfaces.

Additional jointing material as described in **6.3.2** should be applied to assist in maintaining blocks in their correct position, except for clay paving units, stone elements with sawn arrisses and concrete paving blocks with a small or no chamfer. In these cases, all surplus jointing material should be removed from the surface prior to compaction.

The surface course should be compacted using a plate compactor, making two or more passes.

The compaction should be carried out as soon as possible after the laying of the paving units. Compaction should not occur within 1 m of any laying face.

All areas of paving, other than an area within 1 m of a laying face, should not be left uncompacted at the completion of the day's work.

7.4.6 Joint filling after compaction of paving units into the bedding layer

It is essential that the joints between paving units are filled.

In areas of cropped/cleft natural stone setts, a fine joint topping material conforming to **6.3.2.2.2** should be applied, in order to further stabilize the joint filling and to reduce or prevent water ingress.

NOTE Generally, it is beneficial to allow excess jointing material to remain on the surface of the pavement during the early life of the pavement. Pavements constructed with wide joints, filled with bedding material, might require regular maintenance of the joints during the first year.

7.4.7 Secondary compaction of the surface course

This process of joint or void topping up should be repeated, when necessary, by brushing in further jointing material until the integrity of the pavement is established.

NOTE 1 This is particularly relevant during the initial period of the pavement life.

NOTE 2 The surface course might require topping up of joints and further compaction using a plate compactor to ensure complete filling of joints by the jointing material.

After secondary compaction, the pavement should once again be checked to ensure that the joints are filled fully and the surface conforms to the relevant surface tolerances and falls.

NOTE 3 Subsequent compaction might need to be applied after a period of time.

In the case of permeable paving, it is essential that any soil, fine material and other materials that arise during construction are prevented from contaminating the pavement surface, to ensure that the pavement remains permeable.

7.4.8 Construction in adverse weather conditions for unbound surface construction

Paving should not be carried out in freezing conditions.

For conventional paving, in wet weather conditions, units should not be laid on saturated bedding layer material.

The filling of narrow joints in conventional pavements is not possible in damp conditions. In such conditions, the joints should be topped up at the earliest opportunity.

NOTE For permeable paving, by the nature of this type of paving, all laying operations can be undertaken in wet weather conditions.

7.4.9 Additional work after early trafficking for unbound surface construction

7.4.9.1 General

The surface course should be inspected soon after completion and at regular intervals thereafter. Additional jointing material should be brushed in where necessary.

Mechanical sweepers, in particular sweepers with high suction forces, should not be used, or should be used only with care, in order to avoid the risk of losing the jointing material from between the paving units, thus adversely affecting the performance of the pavement.

7.4.9.2 Conventional paving

In time, detritus will accumulate in the joints, tending to seal them. Until this has occurred and unless a proprietary stabilized joint filling material has been used, the paving should only be brushed by hand.

If jointing material has been removed it should be replaced without delay.

If joint sealers or stabilized joint filling aggregates are used, they should be applied in accordance with the manufacturer's instructions.

NOTE 1 This type of treatment can prevent the erosion of unbound jointing materials by the use of vacuum sweepers and high pressure water cleaning.

NOTE 2 Chemical joint sealers can have an effect on the colour of the paving and its slip/skid resistance. They might require ongoing maintenance during the life of the pavement.

7.4.9.3 Permeable paving

Due to the build-up of detritus in the jointing material, the infiltration rates of permeable pavements might decrease. If necessary, maintenance should be carried out in accordance with Clause **10**.

7.5 Bound surface construction – Laying paving units on mortar

*COMMENTARY ON **7.5***

There are three types of bound surface construction.

a) Bound surface course laid upon a concrete or other hydraulically bound base. This is suitable for all site categories and types of paving unit.

b) Bound surface course laid upon an asphalt concrete base. This is suitable for all site categories for paving units having depth not less than width.

c) Bound surface course laid over an unbound sub-base or base. This is generally suitable in site categories 0 to 3 in Table 1.

Where an unbound granular sub-base or base exceeds a stiffness modulus of 100 MPa this methodology may also be used in site categories 0 to 5 in Table 1.

7.5.1 General

Before laying commences, levels and tolerances of the sub-base or base should be checked for conformity to Table 3. Remedial works should be carried out if necessary.

The surface of the base upon which the bedding mortar is to be laid should be cleaned to remove dust and foreign material by brushing and washing with water.

Paving units should be cleaned to remove dust, loose material and packaging or production aids such as paper by brushing and washing with water.

The mortars should be mixed using a forced action mixer until free from lumps and of a consistency suitable for the work, i.e. so that they will support the paving unit.

Paving units should be bedded directly into the mortar, by hand, before the initial setting of the cement begins. Only sufficient bedding mortar should be prepared and laid to enable the laying operation to be completed within reasonable time.

The bedding layer thickness after compaction should be 40 mm for moist bedding and 30 mm for plastic bedding.

Cobbles should generally be laid on a moist bedding mortar. However, if the area is subjected to vehicular trafficking, a plastic bedding mortar in conjunction with a bonding mortar should be used. The bedding depth should take into account the difference between the maximum and minimum height of cobbles, adding 25 mm to that difference.

Spot bedding should never be used.

Surplus bedding material should be quickly removed. The surface of the paving unit should be wiped clean, with care being taken not to allow excess material to stain by entering the surface texture. Care should be taken to ensure the slurry does not choke or pollute drainage systems, e.g. excess material should be washed away after laying.

7.5.2 Construction in adverse weather conditions

In adverse weather conditions, paving should not be laid or jointed if the temperature is below 3 °C on a falling thermometer or below 1 °C on a rising thermometer. The surface should not be frozen.

The paving should be adequately protected from moisture, or from frost damage in the case of cement bound granular material, until adequate strength has been achieved for damage not to occur in such conditions.

If weather conditions are such that the performances of the pavement might be jeopardized, all operations should be discontinued. Care should be taken to maintain the bedding layer material at a consistent moisture content.

7.5.3 Surface preparation of sub-base or base

7.5.3.1 Bound surface course laid upon a concrete or other hydraulically bound base

The surface of the base should be swept and washed with water to ensure that it is free from dust, loose material and debris.

The top surface of the base should be primed using a suitable fine mortar slurry or proprietary bonding coat material to a thickness of 1 mm to 2 mm immediately prior to the placement of the bedding mortar upon it.

The priming slurry should be fresh and wet when the bedding mortar is spread out upon it.

7.5.3.2 Bound surface course laid upon an asphalt concrete base

The surface of the base should be swept and washed with water to ensure that it is free from dust, loose material and debris.

7.5.3.3 Bound surface course laid over an unbound sub-base or base

The sub-base of base should be prepared in accordance with **5.4**.

7.5.4 Bedding for bound construction

7.5.4.1 Moist bed with vibratory compaction

Mortar for moist mix should conform to Table 12, Type A or B as specified by the designer.

The moist mortar should be spread out, including surcharge to form the bedding layer, and paving units rammed into place to partially compact the layer. The mortar should rise up in the joint to approximately 50% of the depth of the paving unit.

Additional moist mortar should be spread over the surface and brushed to completely fill the joint, and final compaction should be completed by vibratory compaction using equipment conforming to Table 15. The area should then be soaked. The joint should finish at least 30 mm below the top surface before re-grouting is carried out to fill the joint completely.

Joints should be covered if left open before final grouting takes place.

7.5.4.2 Moist bed with full depth slurry joint

Mortar should conform to Table 12, Type A or B as specified by the designer.

This method should be carried out only by an experienced installer. The moist mortar should be spread out, including surcharge, and paving units rammed into place to compact the bedding layer to a consistent degree. The mortar should rise up in the joint to no more than 10 mm. The mortar bed should be allowed to cure to reach initial set, which typically takes approximately 1 day, before the filling of the joint is attempted.

7.5.4.3 Plastic mix laying

Mortar should conform to Table 12, Type A or B as specified by the designer.

Plastic mortar should be spread out over the base to the required depth, including surcharge, and the paving units immediately placed on the bed and tapped to final level.

7.5.4.4 Plastic mix laying in conjunction with the application of bonding mortar

Mortar should conform to Table 12, Type B.

The surface of the bound base should be primed using a suitable fine bonding mortar slurry to a thickness of 1 mm to 2 mm immediately prior to the placement of the bedding mortar. The priming slurry should be fresh and wet when bedding mortar is placed.

Plastic mortar should be spread out over the freshly primed base to the required depth, including surcharge.

The backs of the units should be primed using a suitable fine bonding mortar slurry to a thickness of 1 mm to 2 mm immediately prior to their placement upon the bedding mortar. The priming slurry should be fresh and wet when the units are placed upon the bedding mortar

Paving units should be immediately placed on the bed and tapped to final level.

7.5.5 Joint construction using mortar

7.5.5.1 Filling of joints using a pourable mortar slurry grout

Mortar should conform to the strength category given in Table 13 as specified by the designer.

After the initial set of the bedding layer mortar (approximately 12 h depending upon ambient temperature), the whole surface of the laid paving should be thoroughly wetted with clean water and maintained in a wet condition until jointing is completed and the area finally cleaned.

Jointing mortar should be mixed in a forced action mixer until free from lumps and of a consistency suitable for the work, i.e. a pourable slurry grout suitable for application using either of the following methods of application:

a) spread over the entire surface and moved towards open joints. A quantity of mortar slurry should be allowed to remain on the surface and should be moved across the surface at least twice in order to top up joints in which the mortar has slumped excessively. During this time the mortar should be maintained in a wet condition by the application of a spray of water; or

b) poured in from a can. The grout in the can should be constantly stirred during application.

The finish level of the joints should not be greater than 3 mm below the surface of the pavement.

NOTE 1 Where coloured grout is used, particular care is required to prevent staining of the paving units.

The surface should be cleaned by spraying or wetting with more water and a squeegee used to remove any excess mortar from the surface of the paving units. This process should be repeated until all the jointing material is cleaned off the surface of the paving units.

Mortar joints should be allowed to harden before allowing access to the surface. The area should not be opened to traffic until the jointing material has achieved sufficient strength to withstand the traffic over-riding the pavement without causing failure.

NOTE 2 Typically this might be a period of 7 to 10 days in warm weather, longer in lower ambient temperatures.

Cobbles should only be jointed using a pourable slurry grout. After the jointing mortar slurry has settled, excess mortar should be removed from the heads of the cobbles using a fine spray of water.

7.5.5.2 Filling of joints using a plastic non-proprietary jointing mortar (site categories 0 to 4)

Mortar should conform to **6.5.2**.

The mortar should be spread on the side of the laid paving unit. The next paving unit should be offered to this, and any surplus mortar should be removed.

The joint should be well compacted, using an ironing tool to create a bucket handle profile, to give a dense top surface. The profile should be formed level with the top surface of paving units to provide support to arrisses of units.

NOTE If the joint profile is recessed below the top surface of paving units, chipping of the arrisses of paving units can occur.

Any mortar on the surface should be cleaned off immediately to avoid staining.

7.5.6 Protection and curing

In winter and adverse weather conditions, the finished paving should be covered by polyethylene sheeting for at least 24 h after completion to allow adequate curing.

NOTE In winter months additional precautions such as frost mats might be required to avoid frost damage to immature joints.

In summer, joints should be protected against rapid drying out by covering the finished area with polyethylene sheeting or hessian sheeting.

7.5.7 Site testing

7.5.7.1 Bedding mortar

The compressive strength of the bedding material should be measured by producing samples taken from actual site batches, placed in a 100 mm cube mould, compacted by hand in accordance with BS EN 12390-1.

These should be stored under wet hessian in the open, close to the site.

The cubes should be tested to determine the strength gain of the in-situ material at appropriate age, depending on when the area is opened for use. The strength should be not less than the manufacturer's stated strength for the age and ambient temperature. It should achieve a minimum of half the design strength before being opened to vehicles.

7.5.7.2 Jointing mortar

To ensure that joints are fully filled, small diameter cores should be taken to ensure that no voids are present and that bedding mortar has not risen excessively into the joint.

The strength of the jointing mortar should not be measured using samples prepared on site. Evidence of strength and strength gain should be obtained from the manufacturer.

7.5.8 Early trafficking for bound surface construction

NOTE 1 The rate at which strength develops within the bedding and jointing material depends upon prevailing weather conditions and the adequacy of the protective measures adopted. Correctly protected areas develop sufficient performance for pedestrian-only applications after 3 days.

In vehicular trafficked areas, the strength should be at least 50% of the specified design strength (typically 10 to 14 days).

NOTE 2 The full design strength of the recommended bedding and jointing material develops after 28 days at an ambient temperature of 20 °C.

NOTE 3 In low ambient temperatures, the strength gain of mortar is slower. In an ambient temperature of 10 °C, strength gain is half that achieved at 20 °C; in an ambient temperature of 5 °C, strength gain is quarter that achieved at 20 °C.

Where early trafficking is required, the use of a proprietary mortar with high early strength may be used; the manufacturer's recommendations should be followed.

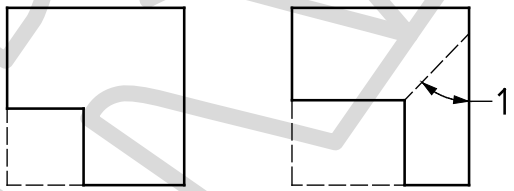
7.6 Cutting and trimming

7.6.1 General

The paved area should be covered as far as possible with full sized paving units. Where paving units need to be trimmed, sizes smaller than a third of the original plan size of the large paving unit should be avoided. No plan dimension should be less than 75 mm unless this is unavoidable and is outwith a trafficked area. When using small paving units (40 mm to 60 mm), cutting should be avoided if possible.

Wherever possible, cutting paving units should be avoided, e.g. by using other sizes of the same thickness. If more than 25% of the paving unit has to be notched, the remaining shape (from the internal corner of the cut-out to the external corner of the paving units) should be cut as shown in Figure 4.

Figure 4 – Typical ways of cutting flags and slabs



Key
1 45° desirable

If necessary, complimentary fittings and inboard cutting should be used to complete the surface course.

NOTE 1 An example of complementary fittings is given in Annex G, Figure G.3 and an example of inboard cutting is given in Annex G, Figure G.4.

Whole large paving units should be laid first, followed by paving units cut around obstructions (see **7.6.2**) and adjacent to edge restraints.

NOTE 2 This can be achieved by inboard cutting where necessary or by using complementary fittings.

Cutting and laying cut paving units should be completed as soon as is practicable, preferably in the same working day and before any fine concrete bedding layer has set.

The joint between the cut paving units and the full paving units or the edge restraint should be the same as those of full-size paving units laid within the body of the pavement.

NOTE 3 These are dependent upon the system of bedding used.

Wherever possible, cut paving units or complementary fittings should be incorporated into the curved lengths of running bond patterns to prevent cross-joints coinciding and to re-establish the correct pattern.

Where this is not possible, the void should be filled in accordance with **7.6.2**.

Raw materials should be selected for matching colour. Proper curing of the concrete is essential; bitumen sprays, curing agents, wet material or plastic sheeting held in place are effective. Care should be taken to avoid staining the finished face of the paving units with cementitious material.

Concrete should be mixed and laid as dry as possible to obtain the surface finish. Compaction in place should be carried out to remove air bubbles and voids.

NOTE 4 Rapid setting cementitious mortar can be used, in accordance with manufacturers' instructions.

To achieve a straight cut face, concrete paving blocks should be cut using a hydraulic or mechanical splitter or a bench-mounted water-cooled power saw.

Cropped stone setts and slabs having fettled edges should be cut or trimmed manually using a hammer and chisel.

Sawn-sided paving units should be sawn by disc cutter or masonry saw.

The accuracy of cutting the paving unit should be such that the joint width conforms to Table 16 for the appropriate paving unit type.

7.6.2 Trimming and laying around obstructions

The paving units should be trimmed to fit after laying full paving units around any obstruction. The joints between the obstruction and the paving units should be such that the joint width conforms to Table 16 for the appropriate paving unit type. Mortar should not be used to infill small gaps.

NOTE 1 Examples of details around structures within pavements are given in Annex I.

NOTE 2 Ideally, wherever new ironwork or other features that penetrate the pavement are to be installed within the pavement, they will have been carefully chosen to ensure that the paving units will need only a minimum of cutting.

Where it is necessary to use infill around an obstruction, one of the following materials should be used for the infill:

a) a C32/40 pavement quality concrete (PQC) conforming to BS EN 206-1 (maximum aggregate size of 10 mm); or

b) a 3:1 mix of BS EN 12620:2013, G_C85/20 6/14 coarse aggregate (or any BS EN 12620:2013 aggregate that is a maximum of a quarter of the size of the gap being filled) and cement;

c) a clean, washed single size aggregate and slurry grouted with a jointing mortar conforming with Table 13, Type B, loosely filling the void.

The area should be kept to a minimum, with a minimum width of 100 mm, and should be the full depth of the paving unit or ironwork, plus bedding layer, whichever is the greater.

Wherever possible, when new ironwork is being used in conjunction with paving units, the shape, size and orientation of the ironwork should be taken into account when choosing it so as to ensure minimum cutting.

8 Laying natural stone, precast concrete and clay kerb units

8.1 Forms of construction

8.1.1 General

Kerbs, channels, edgings and quadrants, combined drainage and kerb products, and linear drainage units should be laid using one of the following methods, depending upon the extent to which they are subject to vehicular over-run:

a) set on a race of fresh concrete (not applicable to clay units);

b) bedded on a Type A mortar (Table 12) race 25 mm thick on top of an edge beam of compacted hardened concrete or onto a Type A mortar bedding on a carriageway base;

c) suitably affixed to the surface layer.

Unless otherwise specified, units should then be haunched/backed with concrete of the same compressive strength as the concrete base.

NOTE Examples of edge details are given in Annex C.

Units conforming to BS EN 1340 and BS EN 1343 should not be cut to a length of less than 300 mm.

8.1.2 Laying units on a kerb race

NOTE 1 Laying units on a kerb race is suitable for carriageway edges on all site categories 0 to 6 and locations subject to vehicular over-run in site categories 0 to 3 (Table 1).

When laying units on a kerb race, a foundation of fresh ST1 or similar concrete should be deposited along the line of units, onto which the units are laid directly and set to line and level. The race should sit on a layer of sub-base.

NOTE 2 The race is typically a minimum of 150 mm thick below the kerb after laying, and of width 150 mm behind and in front of the kerb. Dimensions are specified by the designer.

In areas subjected to heavy loading [site categories 5 and 6 (Table 1)], either the backing concrete should be laid monolithic with a race of fresh concrete, or 25 mm diameter dowel bars should be firmly fixed in the base and extended into the backing haunching.

8.1.3 Laying units on an edge beam or existing carriageway base

NOTE Laying units on an edge beam or existing carriageway base is suitable for carriageway edges and locations subject to vehicular over-run on all site categories 0 to 10 (Table 1).

When laying units on an edge beam or existing carriageway base, a concrete edge beam should be formed of vibrated concrete having compressive strength class C25/30. It should be not less than150 mm thick, and wide enough to accommodate both kerb units and backing concrete.

On pavements with a concrete base, the base layer should be extended if possible to provide a suitable base for the kerb or channel and backing concrete. A chase might need to be formed but the remaining thickness should be not less than 150 mm.

In areas subjected to heavy loading, either the backing concrete should be laid monolithic with the base or, if installed subsequently, dowel bars should be firmly fixed in the base and extended into the backing concrete.

Kerb units should be bedded down on a layer of plastic mortar, 20 mm to 40 mm thick.

Mortar should be chosen as follows.

- For all site categories 0 to 10 (Table 1), the mortar may be a Type B mortar conforming to Table 12.
- For site categories 0 to 5 (Table 1), the mortar may be a Type A mortar conforming to Table 12.

- For site categories 0 to 3 (Table 1), the mortar may be site-batched mortar as described in **6.4.3**.

Mortar that has begun to harden before a unit is laid should not be used.

When units are laid on a jointed concrete base, there should be a suitable aligned joint between the units. The joints should continue through the race and the kerb should be not more than 150 mm from the jointed concrete pavement.

8.1.4 Laying units on the surface layer

Units that are laid on the surface layer should be bonded to the wearing surface with a suitable synthetic resin compound or with a modified strengthened mortar, which should be used strictly in accordance with the manufacturer's recommendations for this specific application.

8.2 Construction details

NOTE 1 When laying small straight units to radii, the joints may be laid to a taper to accommodate the radius of a curve subject to aesthetic considerations, or a proprietary tapered unit may be employed.

A string line should be accurately set out along the carriageway channel to the required level of the top of the units.

Units should then be laid on fresh concrete or mortar bed and adjusted to line and level.

Allowances should be made on curves for the string line being in a series of straight lines. The final unit alignment should be checked to ensure that it follows a smooth curve both horizontally and vertically.

When concrete units conforming to BS EN 1340 are used, radius kerbs and channels should be used on curves of 12 m radius or less.

Large units should be aligned so that they are within 10 mm of their design alignment and the differences in level at the top between two adjacent units does not exceed 3 mm.

NOTE 2 Some minor visual adjustment might be necessary when the units are laid, especially on curves and when linking with other edge details.

Kerbs should be laid accurately to line and level. Crossing kerbs at vehicular crossings should be laid 25 mm above the final road surface unless otherwise specified.

At pedestrian crossing points, dropped kerbs should be laid level with the channel at the high side of the road and between 0 mm and 6 mm above the channel level at the low side.

Where necessary, provision should be made for the removal of surface water at the crossing point by the judicious placing of a drainage outlet.

8.3 Jointing

Mortar jointing between units of natural stone and concrete is generally unnecessary; however, the units should not be butt jointed. The gap between them should be not less than 2 mm, to avoid potential chipping and spalling either during installation or in use.

When mortar joints are used, the mortar should completely fill the joint; however, clay units should be laid with a 10 mm joint between adjoining units and the mortar joints finished with a tooled profile to ensure a durable surface.

Where kerbs are jointed using mortar, expansion joints should be installed at intervals of not more than 15 m for natural stone or concrete and 6 m for clay units.

8.4 Reinstatement

Reinstatement should follow the methods described in **8.1** and **8.2** for the appropriate construction.

When resurfacing takes place, the units and backing might need to be lifted and re-laid. If the surface is raised by 40 mm or less, the units should be re-bedded with a suitable mortar or adhered to an existing surface. If the surface is raised by more than 40 mm, the units should be re-laid on a mortar bed placed on a regulating layer of hardened modified or unmodified mortar or concrete, as appropriate for the thickness.

8.5 Pavement layouts for vehicle crossings

NOTE 1 Examples of typical pavement layouts for vehicle crossings are given in Annex J.

A ramped car crossing is formed where the footpath and driveway are at similar levels. The kerbs should be placed into the required position and the adjacent paving units ramped to the footpath level. The two corner paving units should be cut diagonally to form a mitred ramp (see Annex J, Figure J.1).

Ramps should not be steeper than 1:12.

Dropped pedestrian crossings are formed when the footway crosses the carriageway. The kerbs should be placed into the required position and the two lines of paving units adjacent to the dropped kerbs should be ramped from the footway to the top of the dropped kerb (see Annex J, Figure J.2).

NOTE 2 Small element paving units can be used for vehicle crossings and in areas where footways might be subjected to over-run by vehicles.

NOTE 3 Radial paving at the intersection of footways and footpaths may be carried out in a number of ways. Two examples are described as follows.

a) Run-out corner. The laying pattern of the major footways continues through the corner, with the paving units abutting the radial kerb marked and cut to fit. The paving units on the minor footway may abut the inner edge of the major footpath (see Annex J, Figure J.3).

b) New town corner. This can be used with either equal or unequal width footways but the inner edges of the footways may be connected with a straight line from the start points of the curves. The paving units are laid from this line. The outer paving units are cut to meet the curved kerbs and marked using a template (see Annex J, Figure J.4).

9 Construction of steps

9.1 Forms of construction

NOTE 1 Steps may be formed using monolithic precast concrete or natural stone units, or they may be formed with a suitable concrete base in the profile of the step which is clad using paving units.

NOTE 2 Examples of step details are given in Annex K.

9.1.1 Monolithic precast concrete or natural stone steps

9.1.1.1 General

One of the following two methods of installation should be used when laying more than one level of steps, i.e. a flight of steps.

a) The higher step is laid resting upon the lower step or on the pavement surface. In this case the height of the unit should be not more than the design height of the step less any mortar used to bed the unit where it rests on the unit below.

b) The higher step is laid behind the rear arriss of the lower step. This method is typically employed when successive rows of steps do not follow a common level, i.e. it is necessary to achieve a tapering of the height.

Construction should start at the base of a flight of steps. Either the work should be carried out from the sides of the steps, or each level should be sufficiently protected or cured before it is walked on to prevent any movement in the freshly laid units.

Where there is a danger of water ingress at a higher level resulting in moisture egress behind the concrete foundation, measures should be taken to prevent moisture entering the

concrete foundation or bedding mortar and subsequently migrating through the surface of the steps.

*NOTE 1 The use of a DPM (see **5.4.7**), brushed or spray applied, has been found to be effective in preventing the passage of moisture.*

NOTE 2 If a membrane is not included, there is a risk of efflorescence appearing on the face of the steps.

9.1.1.2 Monolithic steps laid onto fresh concrete

A foundation of fresh ST1 or similar concrete should be deposited along the line of units, onto which the units should be laid directly and set to line and level.

9.1.1.3 Monolithic steps laid onto a profiled concrete foundation

A foundation of ST1 or similar concrete should be constructed in the profile of the step, allowing sufficient clearance for a 30 mm mortar bed upon which the steps are to be laid and sufficient clearance behind to permit accurate placing of the step.

Step units should be bedded down on a layer of moist mix mortar conforming to **6.4.2**, 30 mm thick.

Mortar that has begun to harden before a unit is laid should not be used.

NOTE The void behind the step may be filled using a plastic mix mortar or grout.

9.1.2 Steps clad using modular paving units

The step foundation should be formed with a suitable concrete in the profile of the step.

When the concrete has cured or is otherwise ready for the units, it should be brushed or sprayed with a suitable DPM (see **5.4.7**).

NOTE 1 If a membrane is not included, there is a risk of efflorescence appearing on the face of the steps.

A DPM membrane should be selected which will not creep and forms a lasting adhesion bond with the bedding mortar.

NOTE 2 Bituminous DPM materials are generally unsuitable.

The modular paving units should be primed with slurry (see **7.5.4.4**) and laid on plastic mix mortar conforming to **6.4.2**, 30 mm thick, or **6.4.3**, 10 mm thick.

9.2 Jointing

9.2.1 General

Where steps are jointed using mortar, expansion joints should be installed at intervals of not more than 6 m.

NOTE 1 Manufacturers might be able to offer advice on movement joint spacing in relation to their own products.

NOTE 2 The joint itself is normally 10 mm in width and comprises the following materials:

a) a compressible joint filler (backup material);

b) a barrier (joint breaker); and

c) an extensible tack-free sealant.

9.2.2 Monolithic precast concrete or natural stone steps

Mortar jointing between units of natural stone and concrete is generally unnecessary for structural purposes, and units should not be butt jointed. The gap between them should be not less than 2 mm.

When mortar joints are used, one of the following methods should be used.

a) Mortar conforming to **6.5.1** or **6.5.2**, having plastic consistency, should be carefully applied, taking care to fill the joint to the maximum depth possible.

b) The vertical face should be filled using mortar of a plastic consistency, which should be allowed to harden, following which a liquid slurry grout conforming to **6.5.1** should be applied to the open horizontal joint.

Where it is desirable for the ingress of water to be prevented through open joints, a flexible mastic sealant should be carefully applied to the open joints.

9.2.3 Steps clad using modular paving units

When small modular paving elements, such as clay paving units, are used it is usual to fill the joints with mortar. One of the following methods should be used.

a) Mortar conforming to **6.5.1** or **6.5.2**, having plastic consistency, should be carefully applied, taking care to fill the joint to the maximum depth possible.

b) The vertical face should be filled using mortar of a plastic consistency, which should be allowed to harden, following which a liquid slurry grout conforming to **6.5.1** should be applied to the open horizontal joint.

Where larger modular paving elements, such as slabs or flags, are used, either the joints should be filled with mortar, or a flexible mastic sealant should be carefully applied to the open joints.

10 Structural maintenance and repair

10.1 General

Where an opening is to be reinstated, it is essential that prior to installation of the bedding layer and paving units, any excavation made is adequately filled in accordance with **5.4**, based on the site category as described in Table 1.

Before repairs are undertaken, it is essential to determine and quantify what the problem is, so the appropriate corrective action can be undertaken if necessary.

With modular pavements, reinstatement should be carried out in such a manner that the repair does not leave a scar, as would be the case with homogenous surfacing materials.

NOTE This is particularly true for units laid in unbound construction as the units can be removed undamaged and re-used.

For units laid in bound construction, i.e. with mortar joints, damage can occur when removing units, and care should be taken that replacement units match the original in colour and texture.

10.2 Opening of surface layer

10.2.1 Opening of modular paving surfaces in unbound construction

To open the surface area of unbound pavement, as much aggregate as possible should be removed from the joints surrounding the first unit. This should be carried out using suitable hand tool or power equipment such as high pressure water jet.

Using suitable levers, or a proprietary extractor, the first unit should be levered out. Once the first unit is removed, subsequent units can be more easily lifted clear. This method should be continued until the required area of paving units has been removed.

NOTE 1 In the case of small elements, such as setts, the passing of a vibrating plate over the surface of the units adjacent to the opening can assist in breaking the interlock.

NOTE 2 Units which have been laid and trafficked for a period of time, or where the joints have been sealed, can be tightly locked together so that it is difficult to remove the first few units. Where this is the case, one or more units might have to be broken to gain access before carefully removing the remaining units over the required area. However, this requires replacement units for those that have been broken.

Lifted units should be carefully cleaned with a stiff brush or scraper, and then stacked to one side of the trench in a position that does not restrict access but is convenient for subsequent

reinstatement. For paving flags and natural stone slabs, timber spacing pieces should be placed between units to minimize surface damage.

NOTE 3 The use of steel wire brushes can result in rust staining to the pavement surface following reinstatement.

The bedding layer and jointing material should then be removed and disposed of.

10.2.2 Opening of modular paving surfaces in bound construction

For flags and slabs, great care should be taken in removing the units to avoid surface and/or edge damage. Joints around one unit should be removed using a power saw and the unit removed by vertical lift methods, e.g. vacuum. If this fails to release the unit, a hammer and chisel should be used to break open the surface.

For paving units and setts, the mortar joint and pointing should be broken out from around the units using a hammer and chisel or specialist power tools. The units should be lifted using lifting bars or proprietary tools.

All traces of mortar from the bed face and sides of the unit should be completely removed (see **7.5.5**).

NOTE Effective cleaning might require the removal of paving units from site to a specialist cleaning facility.

The units should be stored in a location that does not restrict access but is convenient for subsequent reinstatement. Timber spacing pieces should be placed between flags and slabs to prevent surface damage.

The bedding layer and jointing material should then be removed and disposed of.

10.3 Reinstatement of foundation layer in trench and openings

10.3.1 General

Materials used to reinstate should be selected in accordance with **5.4**, based on the site category as described in Table 1.

10.3.2 Unbound construction

Granular sub-base material or base material should be used to reinstate the foundation layer as detailed in **5.4**.

NOTE 1 It is necessary to use new material for sub-base or base because of the variable nature of excavated material, and the difficulties associated with its replacement.

NOTE 2 Low strength bound materials, e.g. C3/4 concrete or foamed concrete, may be used in lieu of unbound materials provided that they are water permeable when cured.

Reinstatement should be carried out by infilling layers that are less than 100 mm thick. Each layer should be thoroughly compacted using a plate or trench vibrator.

After compaction, the top of the reinstatement should be not more than 6 mm higher than the existing surrounding sub-base or base construction.

10.3.3 Bound construction

Sub-base and base materials should be used to reinstate the foundation layer as detailed in **5.4**.

10.3.4 Foamed concrete

Where reinstatement of sub-base is to be carried out using foamed concrete, all excavated backfill material should be removed from site.

Foamed concrete is relatively weak, and should not be used as a replacement for base layer materials in heavily trafficked locations where it is necessary for the base to be stronger than the foamed concrete.

The foamed concrete should conform to the requirements of the Highways Agency's *Specification for highway works* [N1], Clause 1043, and the *New Roads and Street Works Act 1991 – Specification for the reinstatement of openings in highways* [N2].

NOTE 1 The foamed concrete may be prepared off-site and delivered in a truck-mounted mixer.

Foamed concrete should be placed up to the top of the sub-base and levelled.

NOTE 2 The material is generally self-levelling and flows to fill the void, covering the newly exposed or installed utilities.

Standard foamed concrete should be allowed to cure for between 12 h to 18 h before replacement base and bedding materials are overlaid.

NOTE 3 Where rapid curing foamed concrete is used, reinstatement of the base, bedding and surface layers may be effected sooner.

10.4 Reinstatement of surface layer

10.4.1 Unbound and permeable construction

10.4.1.1 Preparation before laying

Where units at the open edge of the reinstatement and the underlying bedding layer material have been disturbed during the trench opening and reinstatement work, the affected units (generally those within 150 mm of the edge of the excavation) should be removed and stored in accordance with **10.2.1**.

All exposed bedding layer material should be cut back, removed and discarded.

10.4.1.2 Laying of paving units

Replacement bedding and jointing material should be chosen in accordance with **6.2** and **6.3**, based on the site category as described in Table 1.

The original, cleaned units should be re-laid in the pattern to match the original and adjacent pavement surface.

Where replacement units have been used to substitute the original, special care should be taken to achieve a close match with the original.

Joint filling and compaction of the surface course should be carried out in accordance with **7.4**.

Where areas were originally treated with surface impregnators and joint stabilizers or sealant, similar material should be applied to the reinstated area after the jointing procedure has been completed.

10.4.2 Bound construction

10.4.2.1 Preparation before laying

The perimeter of the exposed area should be closely examined and any loose paving units removed.

All exposed bedding material should be removed and disposed of.

All traces of mortar from sides of paving units exposed at the perimeter of the excavation should be completely removed.

10.4.2.2 Laying of paving units

Replacement bedding materials should be chosen in accordance with **6.4.2** or **6.4.3**, based on the site category as described in Table 1.

Replacement jointing materials should be chosen in accordance with **6.5.1** or **6.5.2**, based on the site category as described in Table 1.

Any paving units to be re-used should be thoroughly cleaned, to ensure the complete removal of all residues or contaminants which might adversely affect the ability of bedding and jointing mortars to adhere.

Installation of bedding and surface layers should be carried out in accordance with **7.5**.

10.4.3 Reinstatement of damaged or lost jointing mortar between adjacent units in bound pavements

All jointing material in the affected area should be removed, by hand or using mechanical methods, to a depth of between 15 mm to 30 mm or at least twice the joint width, whichever is the greater.

The exposed joint void should be thoroughly cleaned, to ensure the complete removal of all residues or contaminants which might adversely affect the ability of jointing mortar to adhere.

NOTE High pressure water jetting has been found to be the most effective method for both removal of existing jointing mortar and cleaning of the exposed sides of paving units.

The joints should be filled with a jointing mortar type in accordance with **6.5.1** or **6.5.2**, appropriate to the site category as described in Table 1 and using the appropriate method described in **7.5.5**.

The paving should be cleaned on completion to remove any surface residue.

11 Cleaning and protection from staining of modular paving

11.1 Cleaning

*COMMENTARY ON **11.1***

Surface contamination can affect not only the visual appearance of a pavement, but also important properties such as slip resistance.

There are three active components of any cleaning process, each of which may be reduced proportionately with a corresponding increase in either or both of the other two:

*a) cleaning chemicals (see **11.1.1.2**);*

*b) temperature (see **11.1.1.3**);*

*c) agitation (see **11.1.1.4**.*

In some areas, e.g. fast food outlets, the frequency of cleaning may be increased with caution. However, the use of excessively aggressive cleaning methods can result in irreversible damage to the pavement.

Owing to the nature of modular paving and the environment, there can be some vegetation growing in the joints or on the paving in shaded areas or areas subjected to long periods of dampness. This can become a health and safety issue if slip resistance is affected. Paving units having relatively high water absorption are most susceptible. More frequent cleaning might be necessary and advice may be sought from specialist pavement treatment manufacturers.

In all situations, the application of a specialist chemical impregnator to the pavement surface might reduce the necessary frequency of cleaning.

11.1.1 General

11.1.1.1 Maintaining slip resistance of pavement surfaces

To maintain the slip resistance of surfacing material, the surface build-up of contaminants should be removed by regular washing, using a suitable detergent if necessary, or other method that does not damage the surface.

NOTE Some paving materials, especially hard natural stone surfaces and hard fired clay pavers, might polish over time and become slippery. Where this has happened, it might be possible to retexture the surface, but experience has shown that the beneficial results are typically short-lived.

11.1.1.2 Cleaning chemicals

The use of strong chemicals and aggressive processes such as high pressure jetting can result in the pavement surface becoming more open in microtexture and therefore more susceptible to subsequent staining. An acceptable compromise should be sought whereby an acceptable level of cleanliness is achieved for the least wasteful and damaging cleaning regime.

Care should be taken when selecting a suitable cleaning product, as some cleaning chemicals might react with and cause damage to paving units and joint filling materials.

Chemicals which react with specific contaminants should be used with caution for isolated incidents and not for general cleaning; for example, an acidic cleaner might be effective in removing a mortar stain but its repeated and/or excessive use might damage the pavement.

Detergents are chemicals which do not react with substances but instead pull contaminants into solution with cleaning water. These are the chemicals that should generally be used for regular maintenance cleaning. The surface should be thoroughly rinsed to remove any detergent residue that might be sticky or slippery.

It has been found that chemicals having a neutral pH value (pH not less than 6 and not more than 8) are generally safe for use on modular paving. Chemicals having a higher or lower pH should generally be avoided.

Care should be taken to avoid run-off from cleaning chemicals into drains and aquifers. Care should also be taken not to damage, contaminate or stain any adjoining material or landscape areas.

When disposing of run-off water and chemicals, especially chemicals entering drains and watercourses, the manufacturer’s instructions should be followed.

Since there is a wide range of cleaning products available, the advice of the paving manufacturer and/or cleaning chemical suppliers should always be sought before cleaning any area. It is essential that a small, preferably inconspicuous, area is tested before treating the full area, whatever treatment is to be used.

11.1.1.3 Temperature

The following factors should be taken into account when determining the temperature of the cleaning products to be used.

a) Chemicals generally act more quickly in increased ambient temperatures. Warm water is more effective than cold water in all cleaning processes.

b) The use of very high temperatures, such as with high pressure steam jetting, can cause thermal shock if used by an inexperienced operative, resulting in damage to paving units and joint filling materials.

11.1.1.4 Agitation

The following factors should be taken into account when determining the amount of agitation to use.

a) Agitation serves to lift contaminants from the pavement surface and help to carry them into solution with cleaning water.

b) Excessive scrubbing or brushing can polish a pavement surface and so reduce slip resistance.

11.1.2 Specific contaminants

11.1.2.1 General dirt and soiling

General dirt and detritus should be removed by washing using warm water and a pH neutral detergent, using gentle brushing to agitate the water.

All the detergent should be thoroughly washed from the surface on completion of the cleaning, and the resulting run-off should be carefully channelled to drainage points or containers from where it can be safely disposed.

If a power hose is used, care should be taken to avoid the removal of the jointing material.

NOTE High-pressure jetting machines have been known to damage the surface of the pavement.

11.1.2.2 Moss, lichens and algae

Where undesirable growth of moss, lichens or algae has occurred, the area should be treated with a proprietary chemical in accordance with the manufacturer's instructions.

NOTE 1 Such products take some days to be effective, and might be most effective when applied during a spell of dry weather.

Any thick growths should first be removed by scraping and the chemical should be vigorously brushed in.

NOTE 2 Moss, lichens and algae are more likely to flourish when the area is heavily shaded, under trees or not laid to an adequate fall.

NOTE 3 Some treatments leave a residue to discourage the re-growth of the moss and algae, but this is only of limited value if the conditions leave the paving damp and in shade.

11.1.2.3 Rust stains

The source of rust staining should be identified and a means of eliminating the source should be put in place.

To remove rust stains, water should be applied to make the surface wet and then the affected area should be treated with a 5% to 10% phosphoric acid or other similar solution. Since acid attacks concrete and can leave a slightly roughened surface, care should be taken when using the cleaner and all manufacturers' instructions should be strictly followed. After cleaning, the area should be rinsed with clean water, taking care to dispose of the run-off safely.

Buff clay paving units should not be treated with acid without discussing the stain with the paving unit supplier.

Hydrochloric acid should never be used on paving, especially natural stone, as it can encourage rust staining in some situations.

11.1.2.4 Oil stains

Oil penetrates readily into concrete and certain natural stones, so any spillages should be removed promptly with an absorbent material, e.g. paper towels, cloth or granules, to prevent staining. For large areas of spillage, sand or sawdust should be immediately applied to absorb the oil.

NOTE This does not directly remove the spill material but keeps it on the surface and aids in its subsequent removal.

The oil should not be wiped, since this drives it into the surface and spreads the contamination over a larger area.

If the stain persists, one of the two following methods should be used.

a) Ideally, an emulsifying degreaser should be brushed onto the affected area, and left for a period of time, in accordance with the manufacturer's instructions. The emulsified oil should be washed away with plenty of water.

b) Alternatively, the surface may be scrubbed with a concentrated pH neutral detergent, which should then be washed away with warm water. However, care should be taken since this method can result in the leaching out of some pigment from concrete products.

Oil does not penetrate readily into clay paving units, but if oil is spilt on the paving units, the spillage should be removed promptly with an absorbent material, such as paper towels, a cloth or granules. The oil should not be wiped, since this spreads the contamination over the surface of the paving unit.

Steam cleaning should be used on clay paving units to remove oil staining, but if this is unsuccessful, an emulsifying degreaser may be applied as for concrete and natural stones.

Deep oil stains can be most effectively removed by the use of a poultice comprising a fine inert power, such as kaolin, and a solvent which is effective and dissolving the type of oil present. The poultice is spread onto the affected area and allowed to slowly dry. When the poultice has completely dried and reduced to powder, it should be removed with a brush and the area washed using warm water and a pH neutral detergent.

11.1.2.5 Bitumen stains

Bitumen should not be removed until it has cooled. Once cooled, it should be removed using a paint scraper or a similar mechanical device. If this is unsuccessful, ice should be applied to make the bitumen more brittle, prior to scraping it from the paving. Any residue should be removed with an abrasive powder and the whole area should be rinsed with clean water. Certain proprietary cleaning agents are available to remove bitumen, but these should be tested on an inconspicuous area of paving before wider application.

11.1.2.6 Graffiti and paint stains

Fresh wet paint should be soaked up with an absorbent material, such as paper towels, cloth or granules. It should not be wiped, as this can spread the stain. The area should be treated with a suitable solvent such as white spirit. The area should then be washed with a degreasing agent, taking care to dispose of the run-off safely.

With dried paint, the paint should be scraped off as far as possible and then an appropriate paint remover should be applied. This should be used in accordance with the manufacturer's instructions.

NOTE Paint manufacturers are generally able to give advice about the removal of graffiti and it might be necessary to consult them if there are large areas of vandalism.

11.1.2.7 Epoxy and polyester stains

Areas of solidified epoxy or polyester resin should be removed by carefully burning off the area with a blow torch. Care should be taken not to inhale any fumes given off.

If after burning a black stain remains, this should be removed by scrubbing with a pH neutral detergent and water. For larger areas, grit blasting may be used. Where grit blasting is to be carried out, a small area should be tested before any large-scale operation is undertaken.

NOTE Grit blasting does not affect the durability of the material, but it can affect the micro-texture of the surface.

11.1.2.8 Smoke, fire and tobacco stains

Smoke, fire and tobacco stains should be removed by scrubbing with soap and water. Where the stains persist, a mixture of scouring powder and household bleach should be applied. When using bleach, the bleach should be washed from the area using clean water once cleaning is completed, taking care to dispose of the run-off safely.

11.1.2.9 Beverage stains

Beverage stains should be removed by scrubbing the area with hot soapy water. If the stain is persistent, household bleach should be applied and the area should be rinsed with clean water, taking care to dispose of the run-off safely.

11.1.2.10 Chewing gum

Newly discarded gum should be scraped off using a scraper. Hardened gum should be removed in either of the following ways:

a) by softening using an appropriate solvent; or

b) by freezing using a proprietary system and then chiselling from the surface of the pavement; or

c) by using a hot water, steam cleaner or high-pressure jet-blasting equipment

NOTE The use of aggressive high temperature and high pressure equipment can damage the pavement surface and render it more vulnerable to subsequent staining.

11.1.2.11 Scuff marks from vehicle tyres

Scuff marks from vehicle tyres should be removed by scrubbing the area with warm water and a strong pH neutral detergent.

11.1.2.12 Efflorescence

*COMMENTARY ON **11.1.2.12***

Efflorescence is commonly referred to as lime staining. A build-up of efflorescence can occur on all paving materials as a result of contamination from an external or hidden source, such as concrete street furniture or concrete structures beneath the pavement. A frequent manifestation of this type of efflorescence occurs at the face of steps.

Efflorescence is a temporary phenomenon that does not affect the structural integrity of concrete products and which, with time, disappears as a result of normal weathering and trafficking.

Further information on the causes of efflorescence is given in Annex L.

11.1.2.12.1 General

Where it is considered desirable to remove efflorescence, the area should first be thoroughly soaked with clean water and a commercial acid washing material, e.g. dilute phosphoric acid, then applied in accordance with the manufacturer's instructions.

As the efflorescence dissolves, there is some frothing (effervescence), and once this has finished, the whole surface should be rinsed thoroughly with clean water, taking care to dispose of the run-off safely in accordance with the manufacturer's instructions. The treatment should be repeated if necessary.

Hydrochloric acid should never be used on paving, especially natural stone, as it can encourage rust staining in some situations.

11.1.2.12.2 Efflorescence associated with clay products

For most clay paving units, white salts that occur on the surface immediately after laying should be allowed to weather naturally, the length of time required depending on many factors such as rainfall, atmospheric pollution and trafficking.

Chemical treatments should generally not be used.

NOTE 1 Although most clay paving units have a low soluble salt content, white salts on the surface can result either from salts emanating from bedding and jointing materials or following saturation of the paving units. These salts are not damaging to the paving units.

Where light coloured paving units have been manufactured from fireclay and metallic salts staining has occurred, these stains should be allowed to weather away naturally. Where such stains persist they should be treated with bleach or oxalic acid in strict accordance with the manufacturer's instructions. The clay paving unit manufacturer's advice should be sought.

NOTE 2 Vanadium efflorescence takes the form of a yellow/green stain. Iron or manganese compounds form orange/brown stains.

11.1.2.13 Cement staining

Where cement staining has occurred, the pavement should be thoroughly wetted with water and a phosphoric acid solution of up to 10% concentration poured over the surface. Some time should be allowed for the reaction to occur and the surface should be repeatedly agitated in order to make fresh cement available to acid which has not already reacted. When the effervescence has finished, the surface should be washed with clean water. The treatment should be repeated if necessary.

NOTE It is preferable to apply several treatments rather than applying concentrated acid, since this can damage the surface of some types of paving unit.

Hydrochloric acid should never be used on paving, especially natural stone, as it can encourage rust staining in some situations.

11.1.3 Cleaning and sweeping using mechanical sweepers on pavements

The recommendations in a) to k) should be followed where suction sweepers and associated equipment are used to sweep channels, paved footpaths and pedestrian precincts with flexible construction.

a) Equipment should be purpose-designed to sweep the particular area. If there is any doubt, the vehicle manufacturer should be consulted.

b) Where appropriate, low ground pressure tyres should be fitted to reduce the risk of breaking or cracking of units.

c) Tyres should be inflated in accordance with the manufacturer's recommendations to ensure optimum weight distribution and minimize contact pressure.

d) Tyre pressures should be regularly checked in accordance with the manufacturer's recommendations.

e) Polypropylene, not wire, brushes should be used to reduce surface damage.

f) Sweeping machine suction pressures should be set to the minimum required to suit the particular task. For surfaces swept regularly, the suction pressure should be at a lesser setting than for those swept infrequently or those covered with heavy deposits.

   NOTE 1 Brushes fitted to dry vacuum cleaning machines are intended to guide litter to the vacuum inlet; they are not intended to strike the pavement surface with any pressure. Dry brushing of a pavement surface quickly polishes the pavement and reduces slip resistance.

g) The ground-bearing pressure of brushes fitted to wet cleaning machines should be regularly checked in accordance with the manufacturer's recommendations.

h) Operators should be trained in the manufacturer's recommendations.

i) Operators should be advised that when equipment is stationary or left unattended, suction, brush rotation and water jetting equipment should be switched off to avoid the risk of damage to the area below the stationary equipment.

j) In new or re-laid areas, agreement should be reached with the local Highway Authority on a period of manual cleaning to allow pavements to become established and for unbound joints to stabilize before mechanical cleaning is introduced.

   NOTE 2 This period is normally 56 days.

k) When water jetting equipment is used, the jets or hand-held lance should be directed at the surface at an angle not greater than 30° to the horizontal across the diagonal, i.e. not parallel to joints, and at a minimum height of 300 mm above the paving, using a concentrated pH neutral detergent solution. The area should be inspected after cleaning to determine whether joints are still filled or whether remedial joint filling sand is required.

11.2 Protection

NOTE Chemical impregnators are intended to prevent contaminants adhering strongly to the pavement surface and make cleaning easier. However, chemical treatments which seal the surface against the passage of moisture can result in damage to the paving materials.

Since there is a wide range of impregnation products available, the advice of the paving manufacturer and/or chemical suppliers should always be sought before treating any area. It is essential that a small area is tested before treating the full area, whatever treatment is to be used.

11.3 Health and safety

WARNING. Some cleaning and impregnation chemical could be hazardous if not specified and used correctly. It is essential that any safety warnings issued by the chemical suppliers are carefully read and strictly adhered to.

The recommendations given in a) to f) should be followed when using chemicals for cleaning or sealing.

a) Protective clothing such as gloves, face protection, boots and overalls should be worn.

b) Adequate ventilation should be provided in confined spaces.

c) Cigarettes, naked flames and other sources of ignition should be removed from an area where flammable materials are being used.

d) When diluting acids, acid should always be added to water and not water to acid.

e) Any clothing that is contaminated with chemicals should be disposed of safely.

f) Care should be taken when operating in an area of cleaning/sealing to protect personnel from any hazard created by the cleaning/sealing.

Annex A (normative)
Subgrade geotextile characteristics

***Assessed capability**. Users of this British Standard are advised to consider the desirability of sourcing geotextile from suppliers who operate quality systems that have been assessed and registered against the appropriate standard in the BS EN ISO 9000 series by an accredited third-party certification body.*

Geotextile should conform to BS EN 15381. The tensile properties should be verified in accordance with BS EN ISO 10319.

The physical properties should conform to Table A.1.

Table A.1 – Subgrade geotextile characteristics

Characteristic	Standard	Value	
		Woven filter	Non-woven filter
Weight	BS EN ISO 9864	≥200 g/m^2	≥300 g/m^2
Ultimate tensile strength			
Longitudinal	BS EN ISO 10319	≥30 kN/m	≥15 kN/m
Transverse		≥30 kN/m	≥15 kN/m
Strain at nominal tensile strength			
Longitudinal	BS EN ISO 10319	≤25%	≤70%
Transverse		≤25%	≤70%
CBR puncture	BS EN ISO 12236	≥3 kN	≥3 kN
Opening size	BS EN ISO 12956	≥0.2 mm	≥0.1 mm
Water permeability	BS EN ISO 11058	≥200 × 10^{-3} m/s	≥6 × 10m/s

Annex B (informative)
A simple permeameter test

B.1 General

The test method given in this annex may be used to assess and verify permeability.

B.2 Test equipment

B.2.1 *Metal or plastic ring*, having inside diameter approximately 290 mm and height minimum 30 mm.

B.2.2 *Mastic sealant*, rapid mortar or another method of making a watertight seal between the ring to the surface of the base to be tested.

B.2.3 *Circular template or stencil*, having outside diameter approximately 290 mm.

B.2.4 *Test liquid*, consisting of clean water.

B.2.5 *Stopwatch*.

B.3 Test procedure

B.3.1 Place the circular template or stencil on the surface of the base to be tested.

B.3.2 Apply the sealant or mortar to the surface of the base, around the perimeter of the stencil, to a width of at least 10 mm.

B.3.3 Remove the stencil.

B.3.4 Press the metal or plastic ring into the sealant so that a watertight seal is achieved.

B.3.5 If the materials used to form seal requires a period of time to cure, allow this time to elapse before proceeding further with the test.

B.3.6 Make a mark on the inner wall of the ring, 30 mm above the surface of the base.

B.3.7 Pour 2 L of clean water into the ring.

B.3.8 After waiting for about 60 s, add clean water, up to the level of the 30 mm mark.

B.3.9 Using the stopwatch, measure the time taken until all water has drained through the surface of the base.

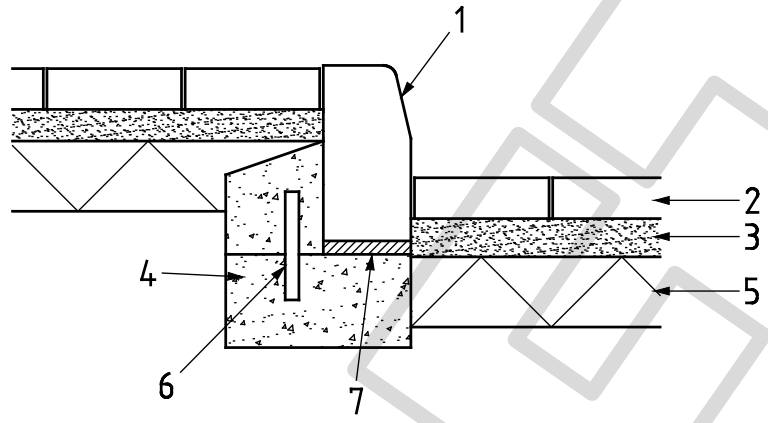
B.4 Evaluation of test results

If the time taken to drain the water into the base is faster than 5 min, the material is deemed to be adequately permeable. (5 min approximates to 1×10^{-4} m/s.)

Annex C (informative)
Examples of edge restraint and kerb edge details

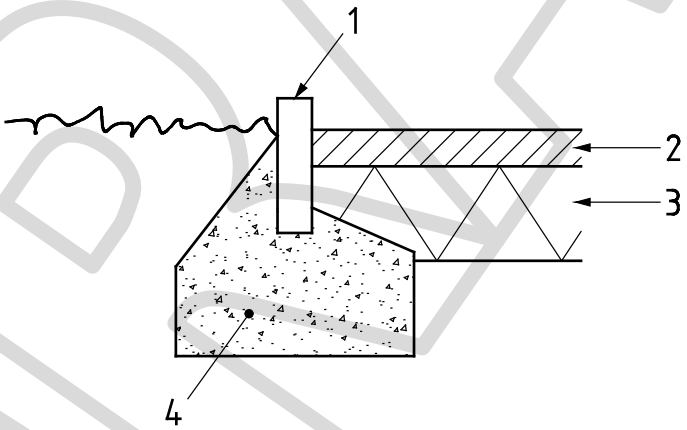
Examples of edge restraint and kerb edge details are shown in Figure C.1 to Figure C.8.

Figure C.1 – Example of reinforced haunching



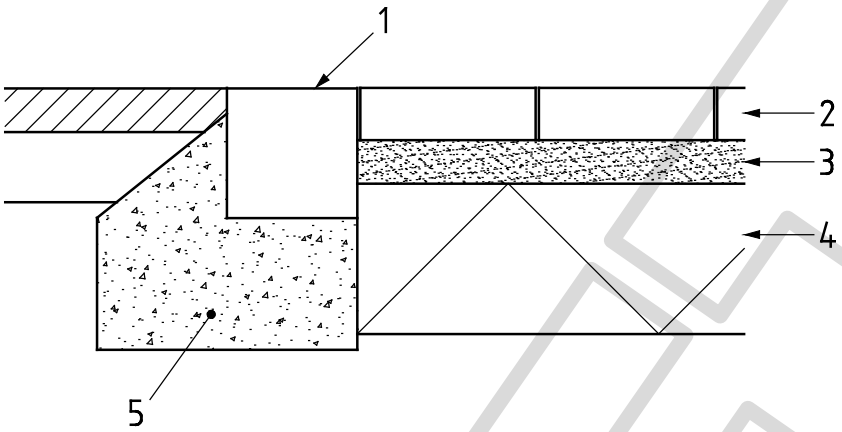
Key
1 Kerb
2 Paving units
3 Laying course
4 Concrete
5 Foundation
6 Dowel bar
7 Mortar bed

Figure C.2 – Example of edging



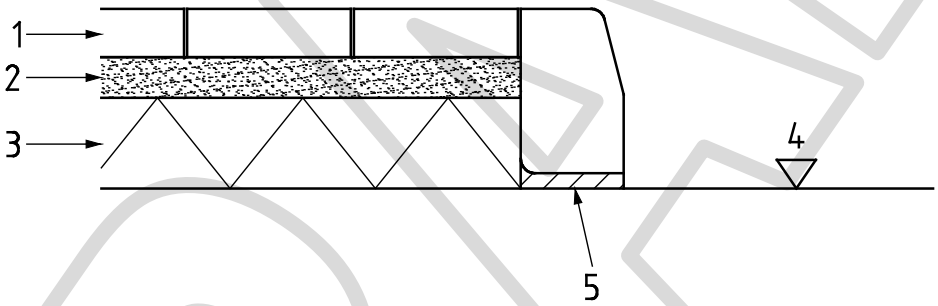
Key
1 Edging
2 Surfacing
3 Foundation
4 Concrete

Figure C.3 – Example of channel or flush kerb



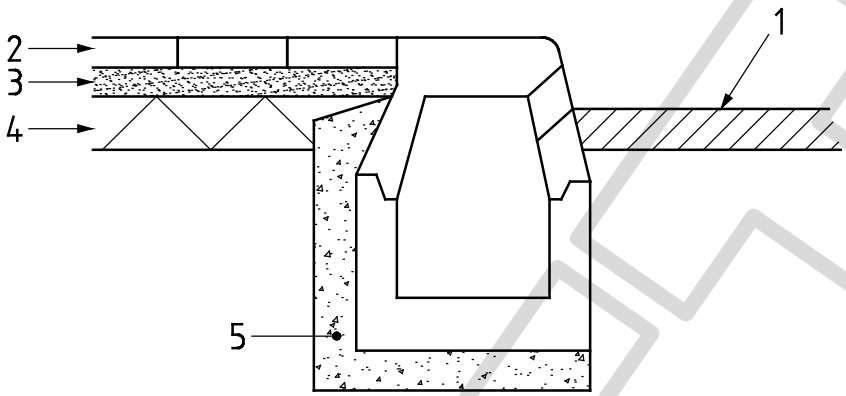
Key
1 Channel or kerb
2 Paving units
3 Laying course
4 Foundation
5 Concrete

Figure C.4 – Example of bonded kerbs (large units)



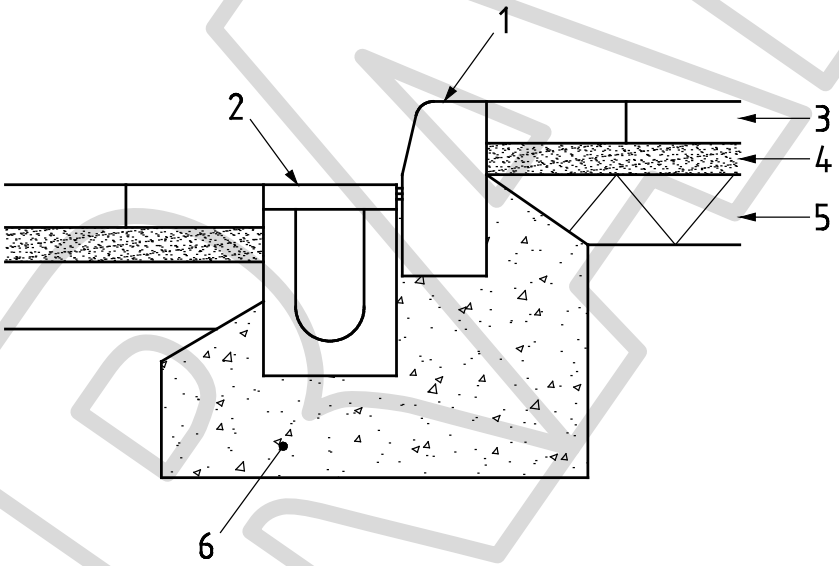
Key
1 Paving units
2 Laying course
3 Foundation
4 Existing road level
5 Modified mortar bed

Figure C.5 – Example of combined drainage and kerb



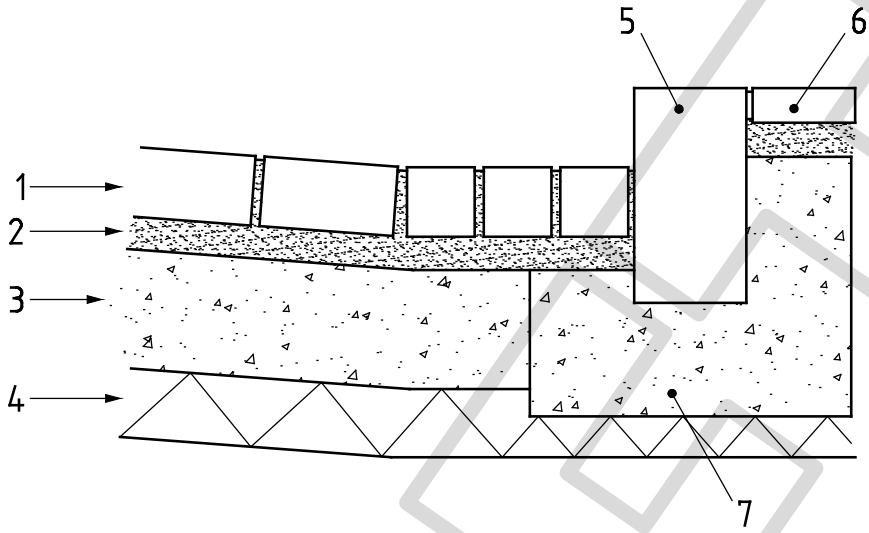
Key
1 Road surface
2 Paving units
3 Laying course
4 Foundation
5 Concrete

Figure C.6 – Example of kerb and linear drainage



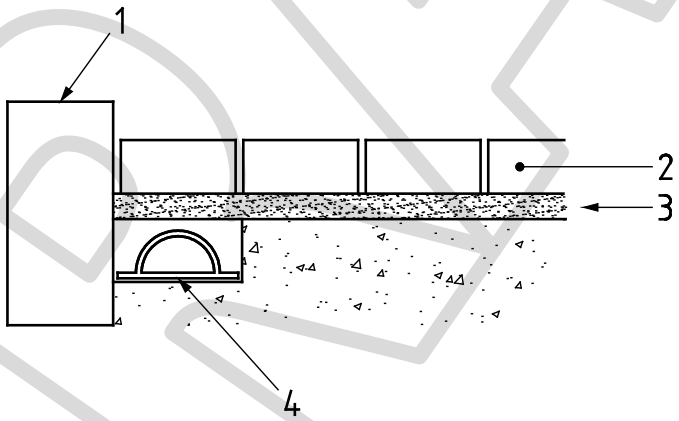
Key
1 Kerb
2 Drainage unit
3 Paving units
4 Laying course
5 Foundation
6 Concrete

Figure C.7 – Example of kerb edge details for unbound construction



Key
1 Paving unit
2 Laying course
3 Water-permeable base
4 Sub-base
5 Kerb
6 Footway
7 Concrete foundation and haunch

Figure C.8 – Example of a proprietary device for draining water from bedding layer

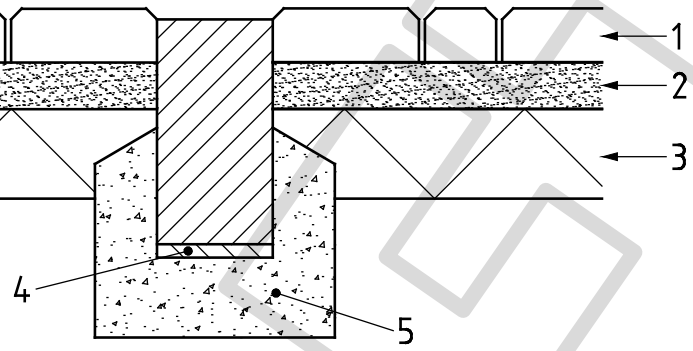


Key
1 Kerb
2 Paving units
3 Bed
4 Proprietary steel drain
5 Coarse aggregate or lightly compacted open textured asphalt

Annex D (informative)
Examples of intermediate and transition restraints and drainage channels

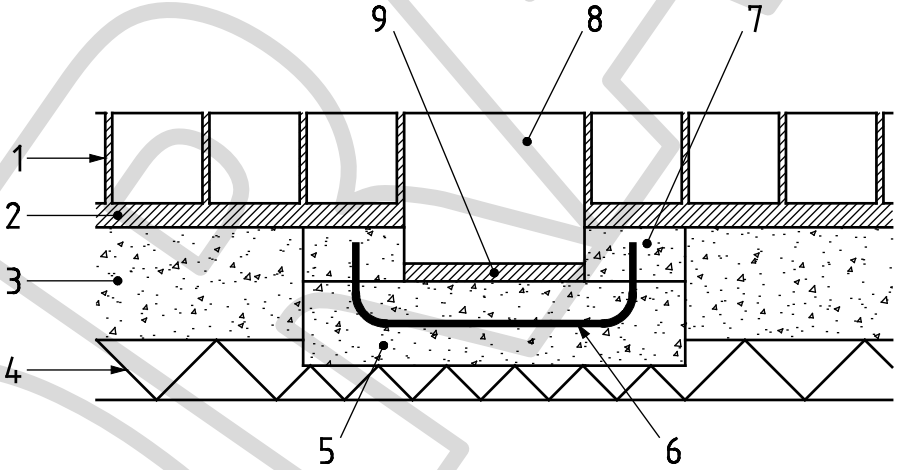
Examples of intermediate and transition restraints and drainage channels are shown in Figure D.1 to Figure D.9.

Figure D.1 – Example of intermediate restraint between areas of unbound construction (light traffic)



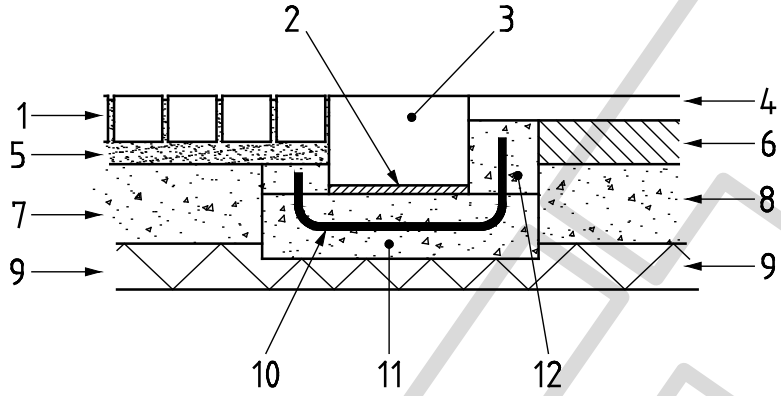
Key
1 Mortar bed (optional)
2 Concrete
3 Paving units
4 Laying course
5 Sub-base and/or roadbase

Figure D.2 – Example of intermediate restraint between areas of unbound construction (heavy traffic)



Key
1 Paving elements
2 Laying course
3 Water-permeable base
4 Sub-base
5 Concrete
6 Steel reinforcement
7 Concrete haunch
8 Concrete kerb
9 Bedding

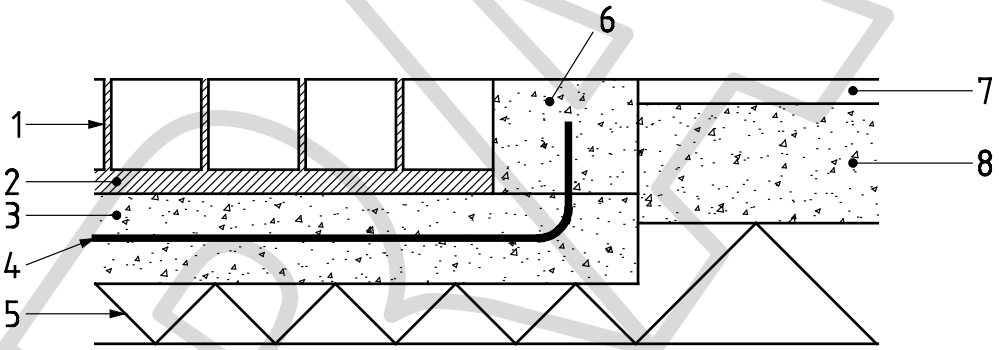
Figure D.3 – Example of transition restraint between unbound construction and different construction



Key

1 Paving unit
2 Bedding
3 Channel kerb
4 Carriageway surface course
5 Laying course
6 Carriageway roadbase
7 Water-permeable base
8 Carriageway sub-base
9 Sub-base
10 Steel reinforcement
11 Concrete
12 Concrete haunch

Figure D.4 – Example of visible concrete transition restraint between bound construction and different construction



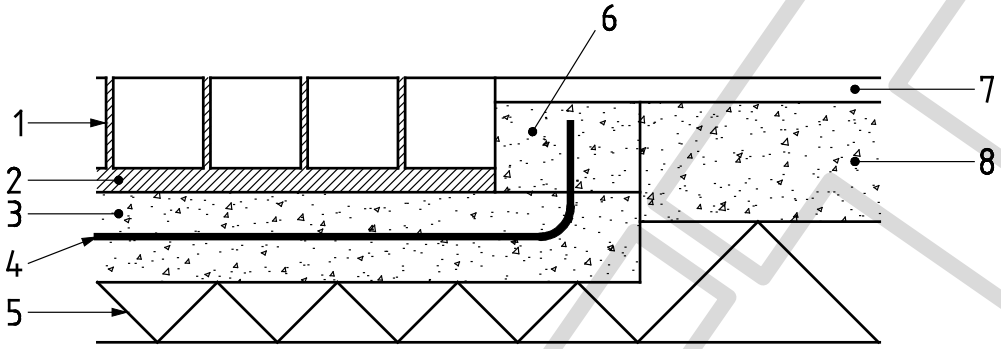
Key

1 Paving elements
2 Laying course
3 Concrete base
4 Steel reinforcement
5 Sub-base
6 Visible concrete haunch
7 Carriageway surface course
8 Carriageway roadbase

NOTE 1 The length of reinforced concrete base is at least 1 m.

NOTE 2 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.

Figure D.5 – Example of hidden concrete transition restraint between bound construction and different construction

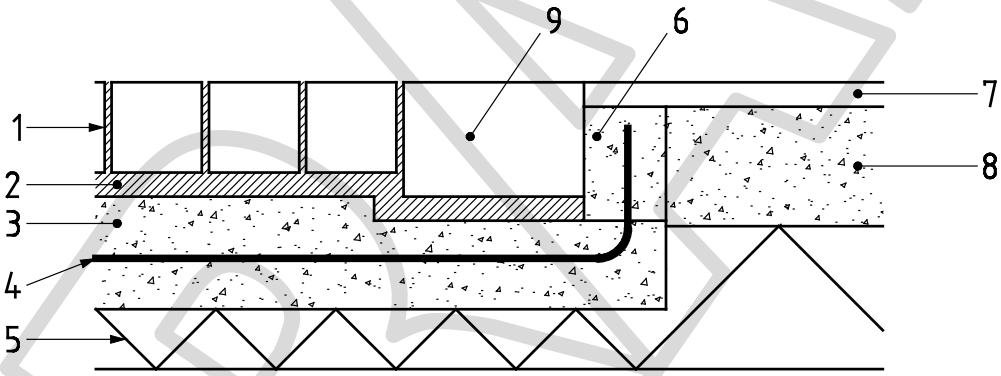


Key

1 Paving elements
2 Laying course
3 Concrete base
4 Steel reinforcement
5 Sub-base
6 Concrete haunch
7 Carriageway surface course
8 Carriageway roadbase

NOTE 1 The length of reinforced concrete base is at least 1 m.
NOTE 2 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.

Figure D.6 – Example of deep channel kerb transition restraint between bound construction and different construction

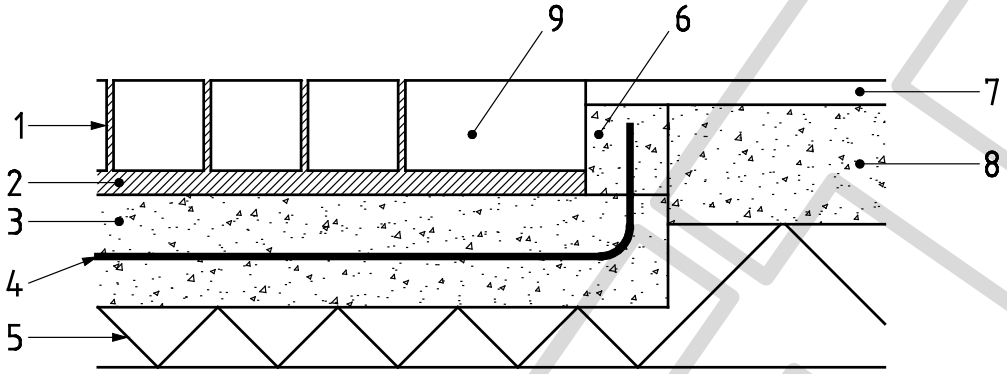


Key

1 Paving elements
2 Laying course
3 Concrete base
4 Steel reinforcement
5 Sub-base
6 Concrete haunch
7 Carriageway surface course
8 Carriageway roadbase
9 Channel kerb

NOTE 1 The length of reinforced concrete base is at least 1 m.
NOTE 2 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.

Figure D.7 – Example of shallow channel kerb transition restraint between bound construction and different construction



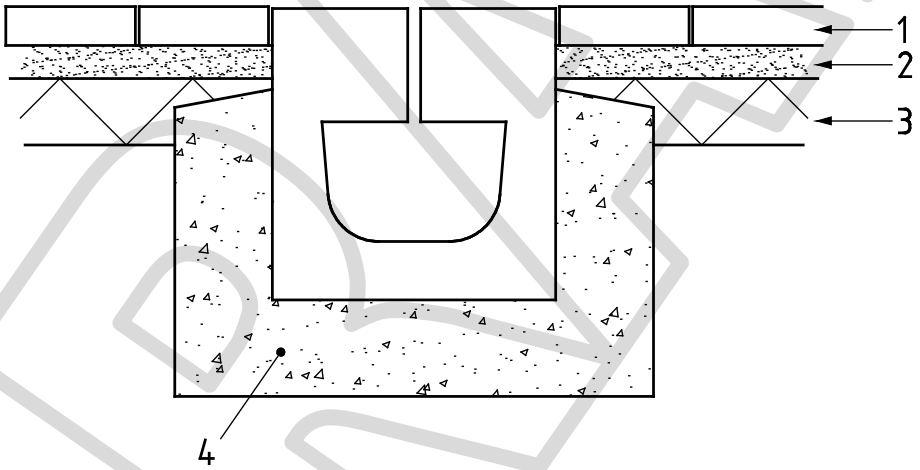
Key

1 Paving elements
2 Laying course
3 Concrete base
4 Steel reinforcement
5 Sub-base
6 Concrete haunch
7 Carriageway surface course
8 Carriageway roadbase
9 Channel kerb

NOTE 1 The length of reinforced concrete base is at least 1 m.

NOTE 2 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.

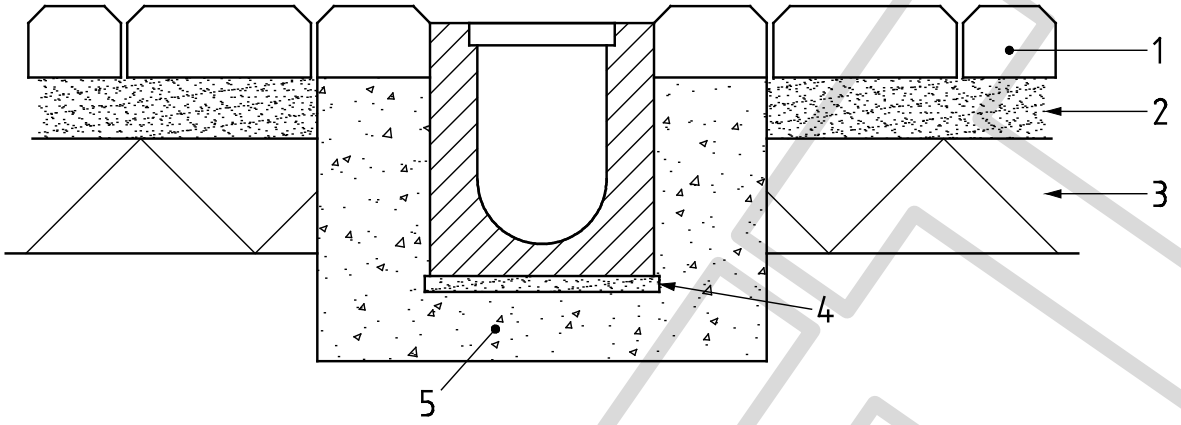
Figure D.8 – Example of linear drainage



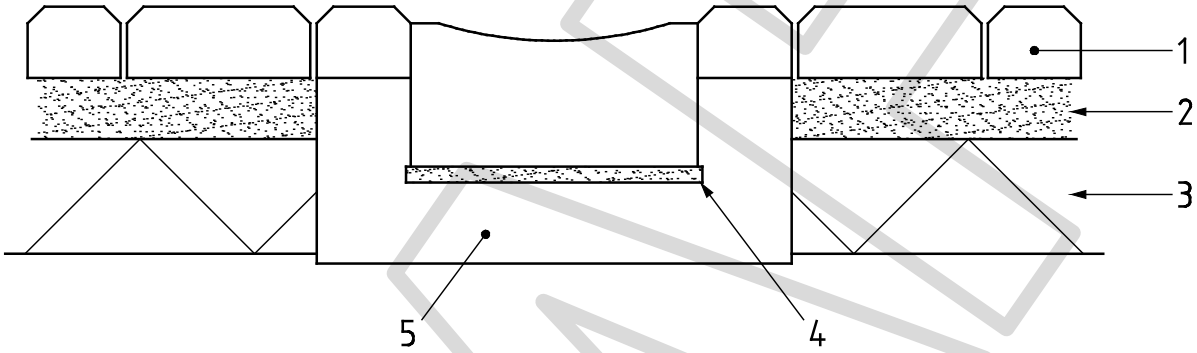
Key

1 Paving units
2 Laying course
3 Foundation
4 Concrete

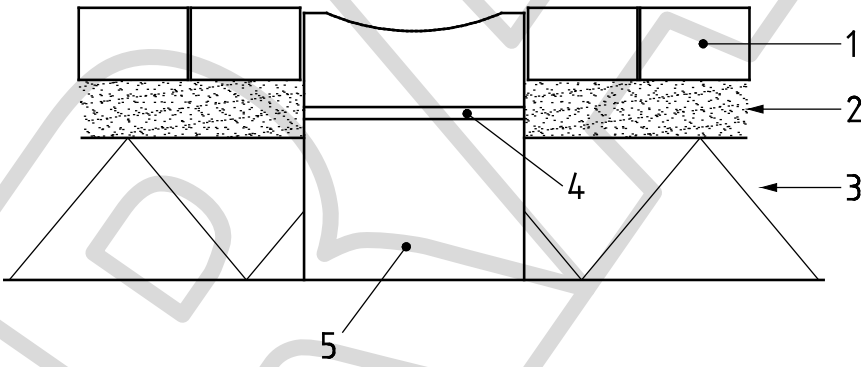
Figure D.9 – Typical details around drainage channels



a) Drainage channel for a high volume of water



b) Drainage channel for a medium volume of water



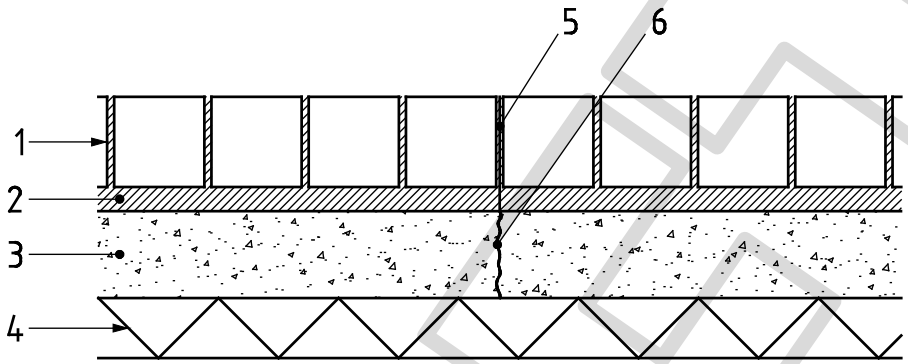
c) Drainage channel for a low volume of water

Key
1 Paving units
2 Laying course
3 Sub-base and/or roadbase
4 Mortar bed (optional)
5 In-situ concrete foundation

Annex E (informative)
Examples of movement joints

Examples of movement joints are shown in Figure E.1, Figure E.2, Figure E.3 and Figure E.4.

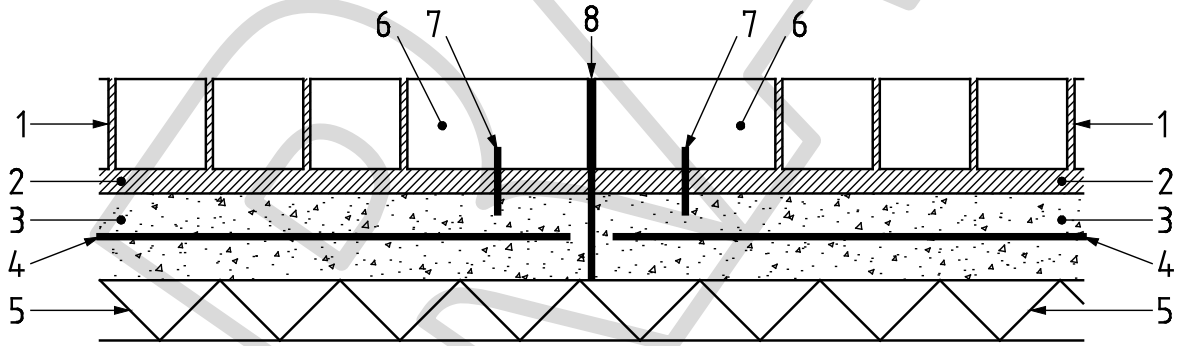
Figure E.1 – Example of induced break detail in bound surface construction



Key
1 Paving elements
2 Laying course
3 Concrete base
4 Sub-base
5 Thin paper break formed with jointing and bedding mortars
6 Induced break formed in concrete base

NOTE The length of reinforced concrete base is at least 1 m.

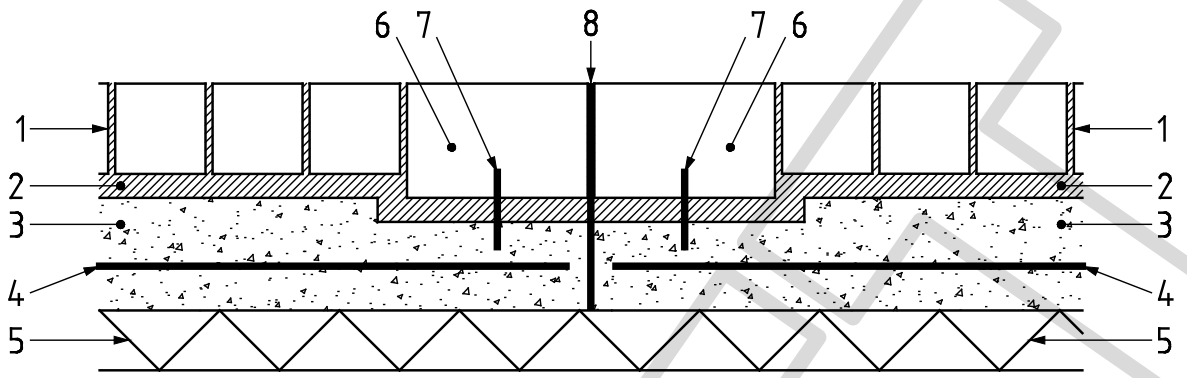
Figure E.2 – Example of low modulus movement joint using shallow channel kerbs



Key
1 Paving elements
2 Laying course
3 Concrete base
4 Steel reinforcement
5 Sub-base
6 Channel kerb
7 Steel dowel pin fixed into kerb using proprietary resin system
8 Movement joint sealed with proprietary low modulus sealant

NOTE 1 The length of reinforced concrete base is at least 1 m.
NOTE 2 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.
NOTE 3 The dowel bar is mild steel bar 20 mm diameter to BS EN 13877-3:2004, Grade B500B steel.

Figure E.3 – Example of low modulus movement joint using deep channel kerbs

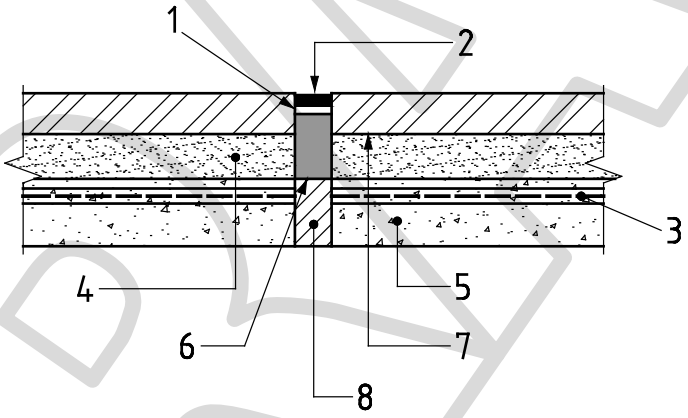


Key

1 Paving elements
2 Laying course
3 Concrete base
4 Steel reinforcement
5 Sub-base
6 Channel kerb
7 Steel dowel pin fixed into kerb using proprietary resin system
8 Movement joint sealed with proprietary low modulus sealant

NOTE 1 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.
NOTE 2 The dowel bar is mild steel bar 20 mm diameter to BS EN 13877-3:2004, Grade B500B steel.

Figure E.4 – Example of movement joints in a suspended slab



Key

1 Joint breaker
2 Tack-free flexible sealant
3 Damp-proof membrane (if necessary)
4 Bedding mortar
5 Concrete base
6 Compressible joint filler
7 Paving unit
8 Joint

Annex F (normative)
Conditions to be applied to the test procedure specified in BS EN 1097-1:1996 for determination of the resistance to wear (micro-Deval) of bedding layer material

F.1 General

The test should be carried out as specified in BS EN 1097-1:1996 for the determination of resistance to wear (micro-Deval), with the following conditions of use applied to the procedures.

F.2 Sieves

Under BS EN 1097-1:1996, **5.1.2**, the 10 mm, 11.2 mm (or 12.5 mm) and 14 mm sieve sizes should be replaced by 0.063 mm, 0.125 mm, 0.250 mm, 0.500 mm, 1.00 mm, 2.00 mm, 4.00 mm, 6.30 mm and 8.00 mm sieve sizes.

F.3 Abrasive charge

Under BS EN 1097-1:1996, **5.2.3**, the abrasive charge of steel balls (10 ±0.5) mm in diameter should be replaced by steel balls (25 ±0.5) mm in diameter.

F.4 Preparation of the sample for testing

The procedure given in BS EN 1097-1:1996, Clause **6** should be replaced as follows.

The mass of the sample sent to the laboratory should be at least 2 kg. Divide and reduce the mass of the sample, as specified in BS EN 932-2, to produce a test portion consisting of two test specimens each of (230 ±30) g. Dry the test specimens in the oven at (110 ±5) °C to constant mass. Allow the specimens to cool to ambient temperature.

Determine and record the grading of each test specimen by sieving over the 0.063 mm, 0.125 mm, 0.250 mm, 0.500 mm, 1.00 mm, 2.00 mm, 4.00 mm, 6.30 mm and 8.00 mm sieve sizes.

F.5 Test procedure

The steel ball charge specified in BS EN 1097-1:1996, Clause **7** should be replaced by two steel balls (25 ±0.5) mm in diameter. Add (2.0 ±0.05) L, instead of (2.5 ±0.05) L, of water to each drum and rotate the drums for (6 000 ±10) revolutions instead of (12 000 ±10) revolutions.

After (6 000 ±10) revolutions, wash the specimens over the 0.063 mm test sieve and dry the test specimens in the oven at (110 ±5) °C to constant mass. Allow the specimens to cool to ambient temperature.

Determine and record the grading of each test specimen by sieving over the 0.063 mm, 0.125 mm, 0.250 mm, 0.500 mm, 1.00 mm, 2.00 mm, 4.00 mm, 6.30 mm and 8.00 mm sieve sizes.

F.6 Calculation and expression of results

Calculate the initial and final gradings of the test specimens. From these results determine:

a) the difference between initial and final percentages of material passing the 0.250 mm test sieve;

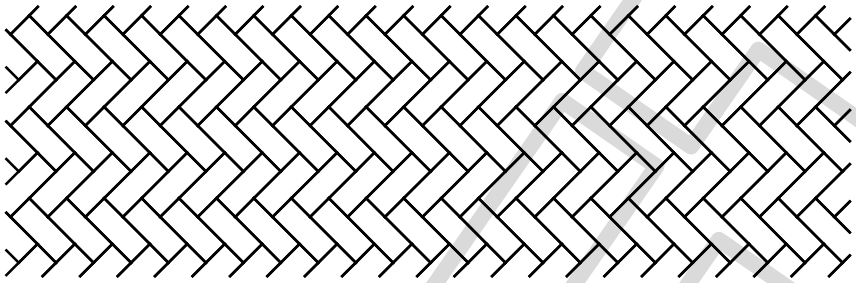
b) the difference between initial and final percentages of material passing the 0.125 mm test sieve;

c) the effective size of the material after test, D10, i.e. the theoretical sieve size at which 10% of the specimen passes. This may be determined graphically or by calculation, but using the test sieves in **F.2** only.

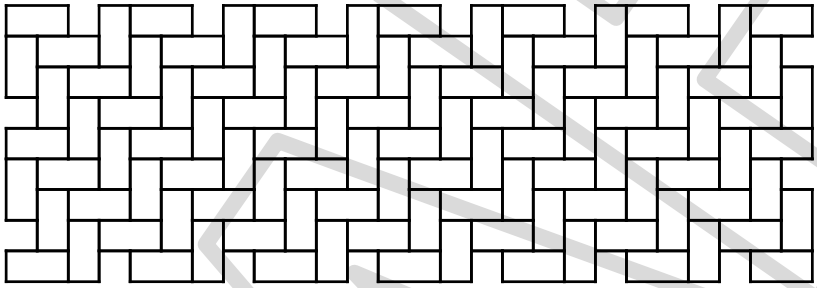
Annex G (informative)
Examples of laying patterns for precast concrete and clay paving units

Examples of laying patterns for precast concrete and clay paving units are shown in Figure G.1, Figure G.2, Figure G.3 and Figure G.4.

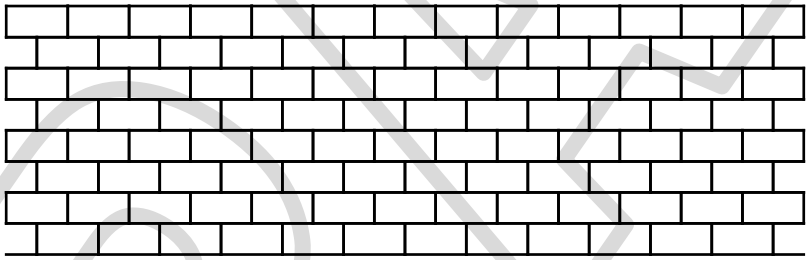
Figure G.1 – Examples of laying patterns



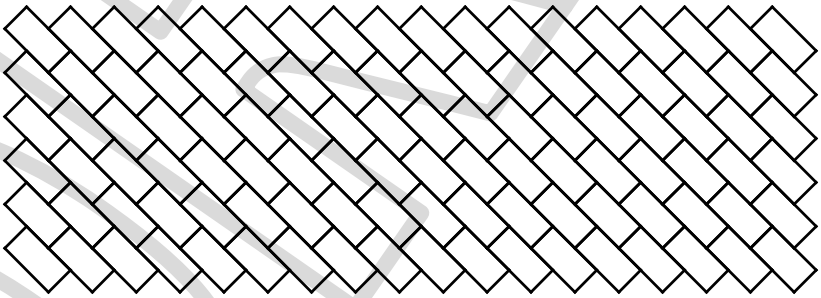
a) 45° herringbone



b) 90° herringbone

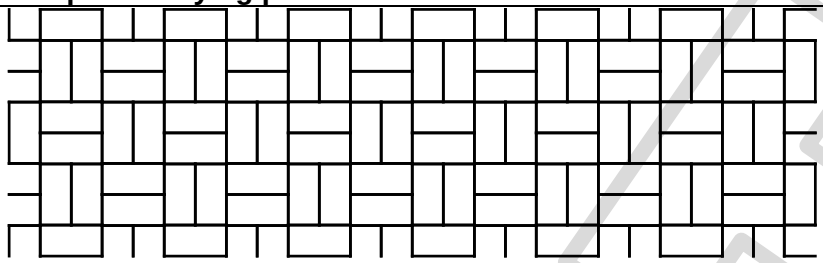


c) 90° stretcher course



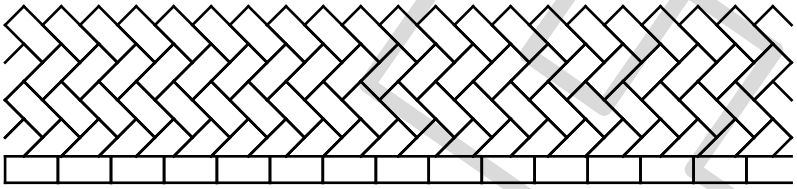
d) 45° stretcher course

Figure G.1 – Examples of laying patterns

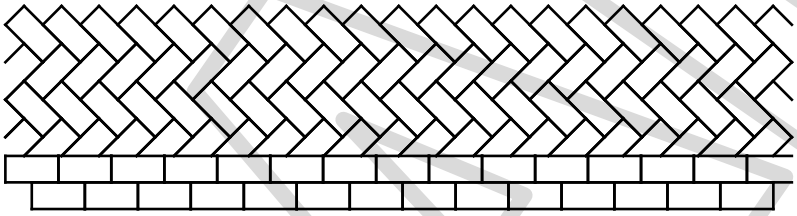


e) Basket weave

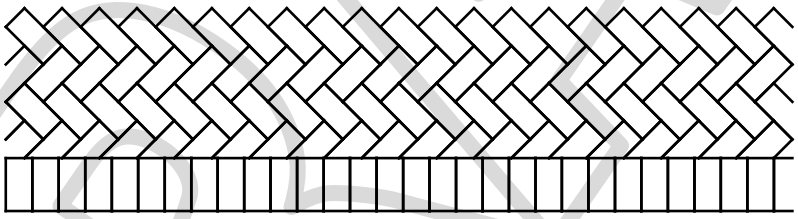
Figure G.2 – Examples of laying patterns at edges



a) Single stretcher course

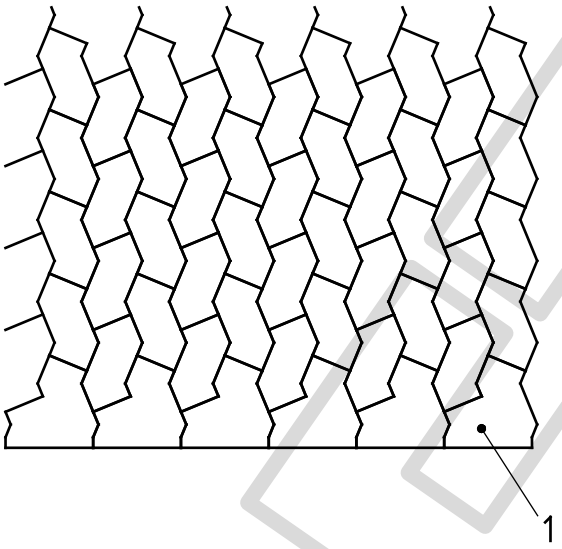


b) Double stretcher course

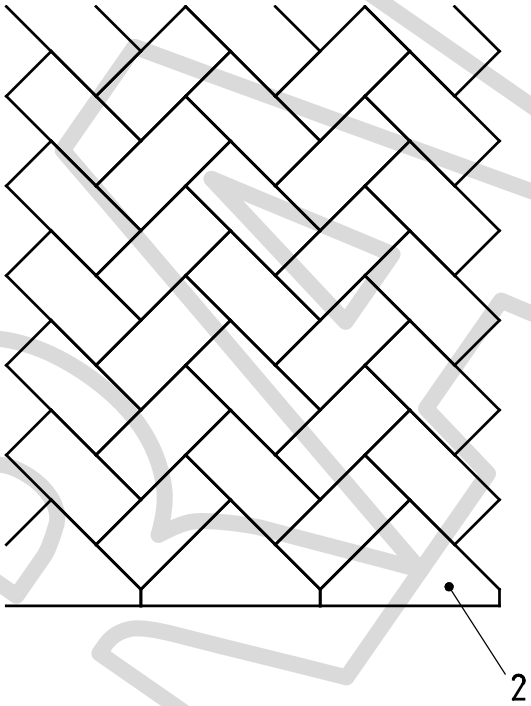


c) Soldier course

Figure G.3 – Examples of laying patterns that incorporate complimentary fittings



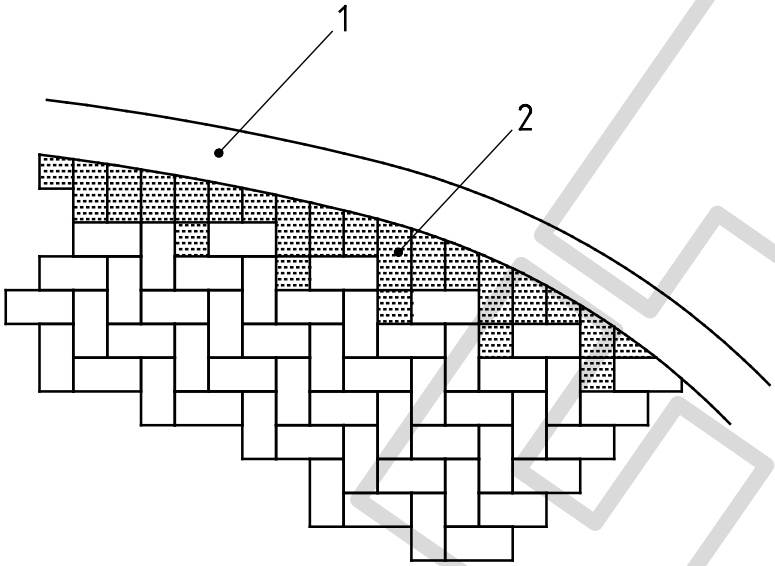
a) Irregularly shaped complimentary fitting



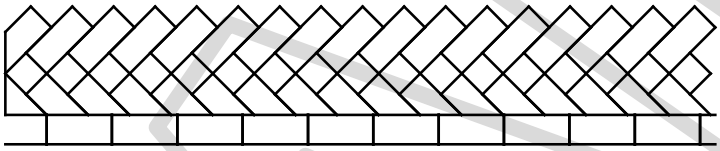
b) Bishop's mitre

Key
1 Irregularly shaped complimentary fitting
2 Bishop's mitre

Figure G.4 – Examples of laying patterns that incorporate inboard cutting at edges



a) Inboard cuts and half cuts breaking herringbone laying pattern



b) Inboard cuts and half cuts in single stretcher course

Key
1 Edge restraint
2 Cut paving units

Annex H (informative)
Examples of laying patterns for natural stone setts

Examples of laying patterns for natural stone setts are shown in Figure H.1, Figure H.2, Figure H.3 and Figure H.4.

Figure H.1 – Example of florentina pattern – Cube setts

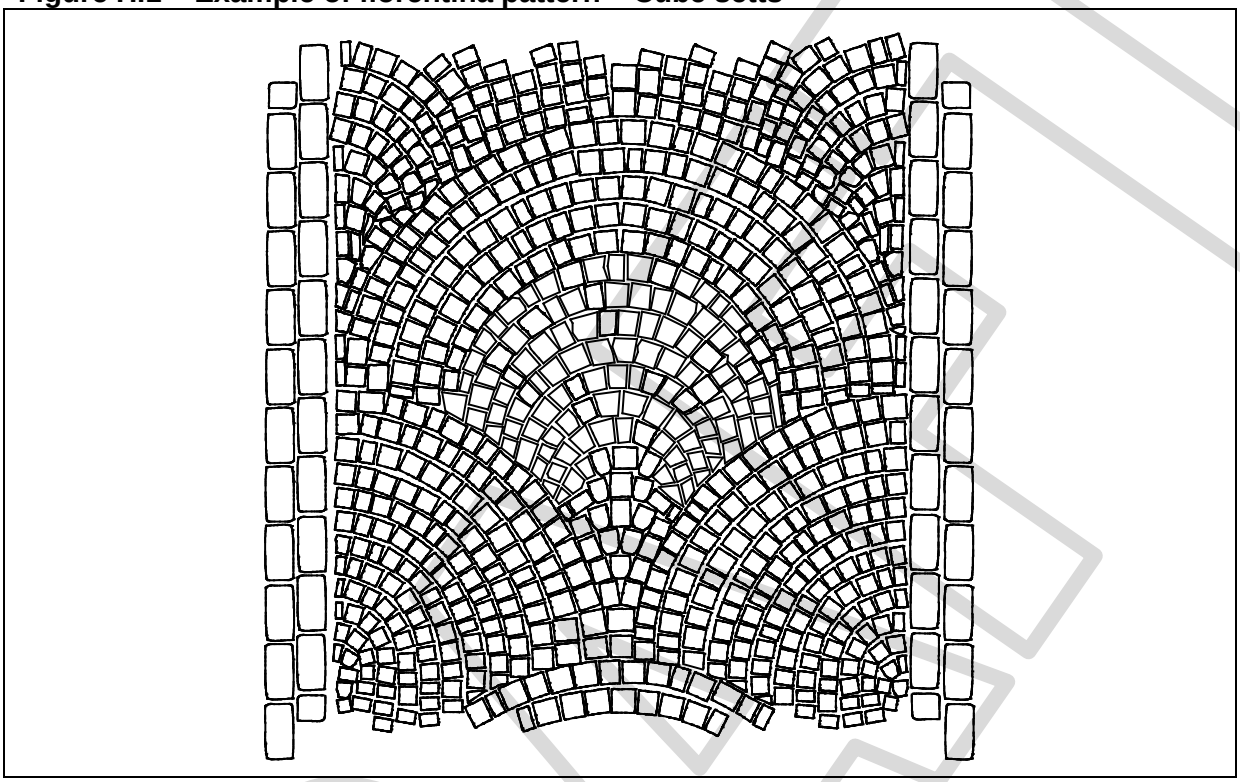


Figure H.2 – Example of segmental arch pattern 90° direction change – Cube setts

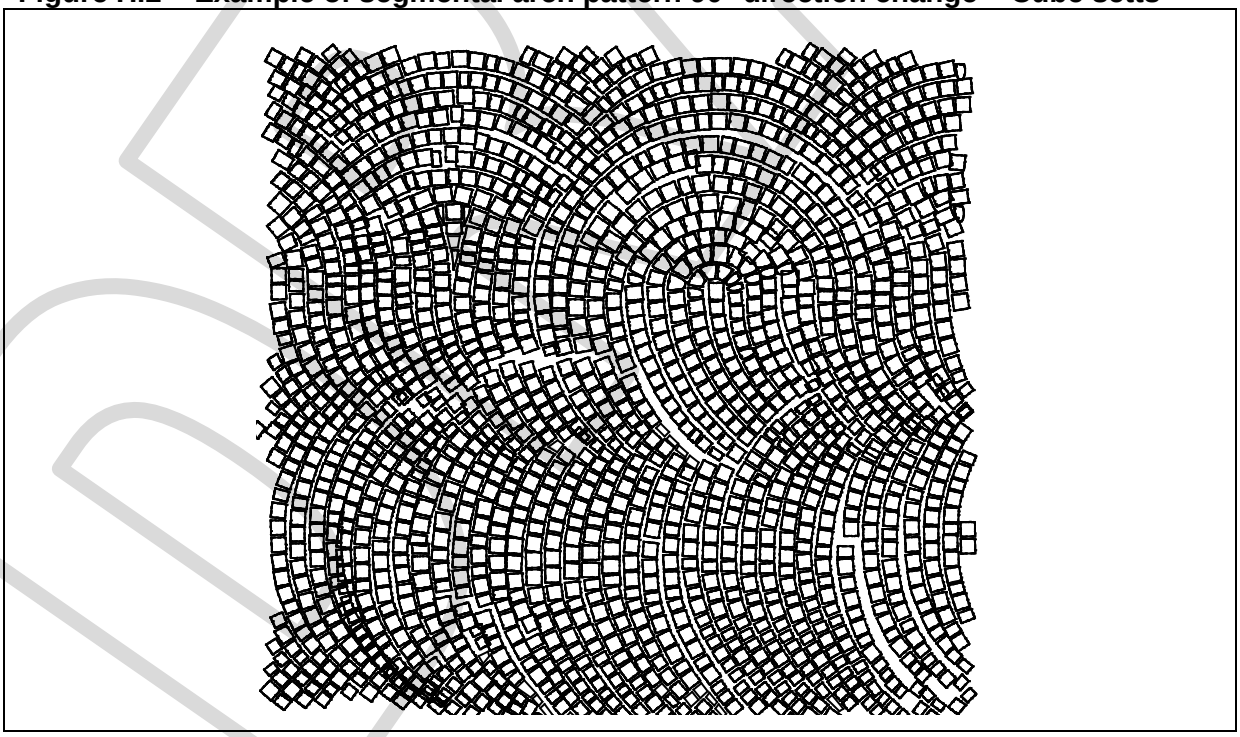


Figure H.3 – Example of chevron pattern – Setts

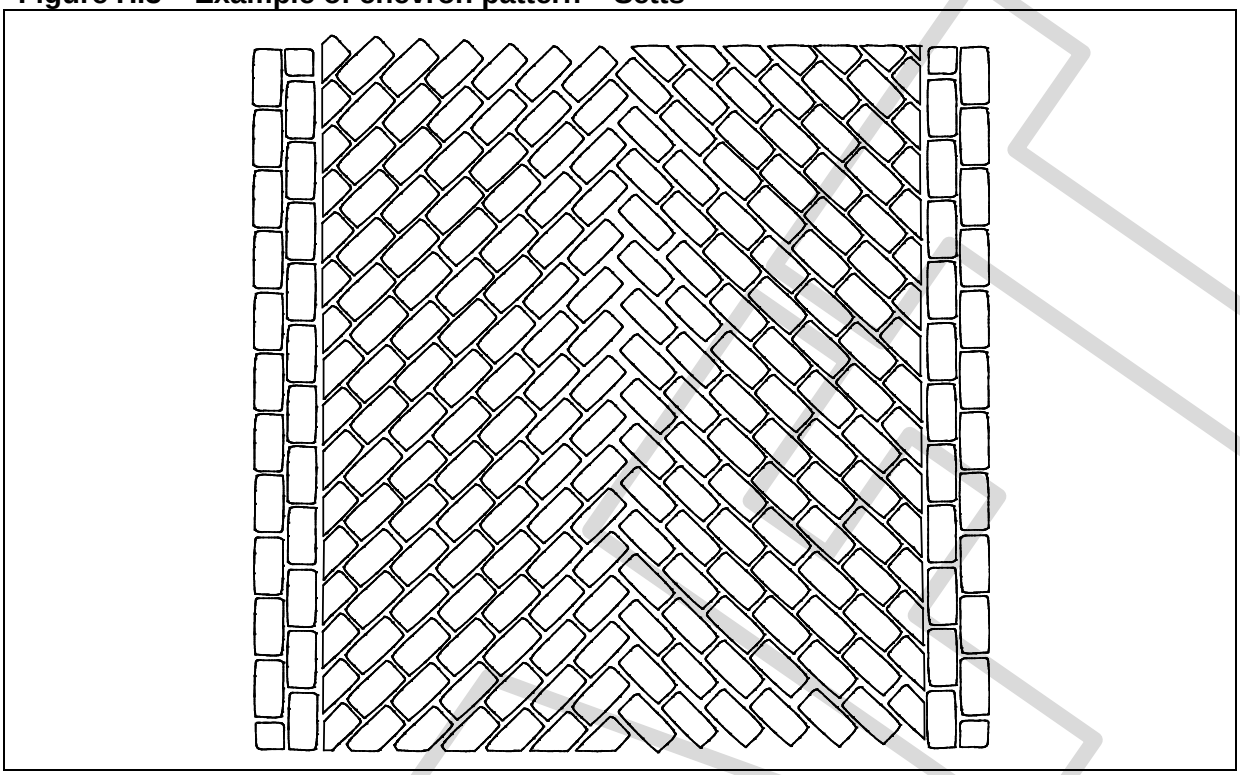
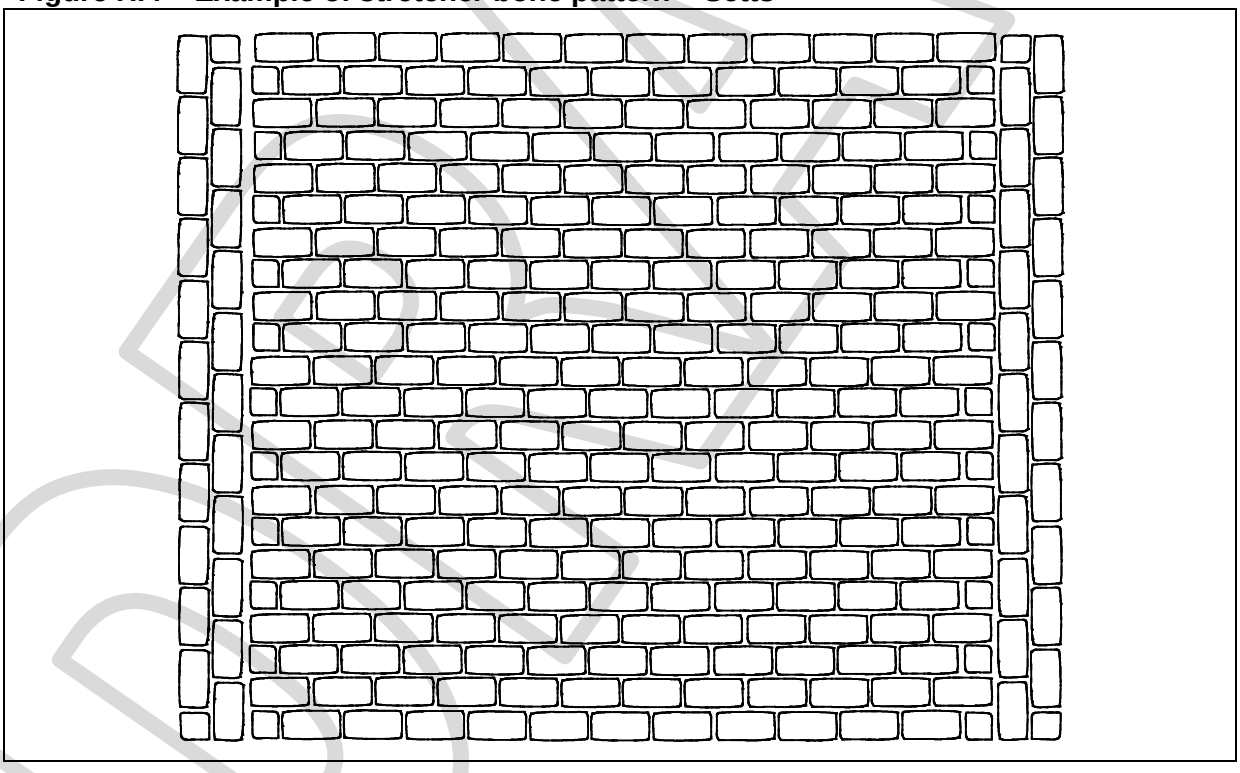


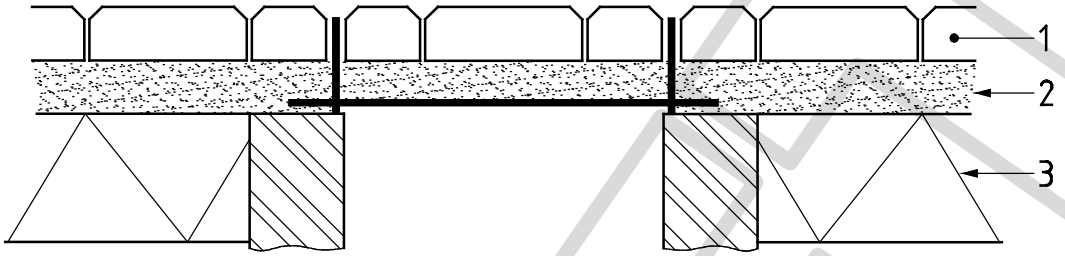
Figure H.4 – Example of stretcher bone pattern – Setts



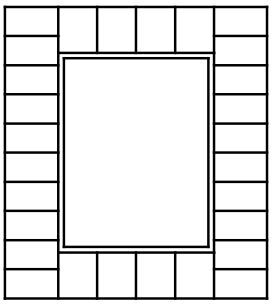
Annex I (informative)
Trimming around obstructions

The detail for trimming around obstructions at ironwork is illustrated in Figure I.1.

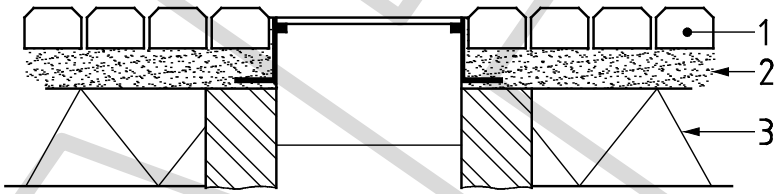
Figure I.1 – Trimming around obstructions – Detail at ironwork



a) Cross-section of a pavement at a manhole cover that is designed to be filled with paving units

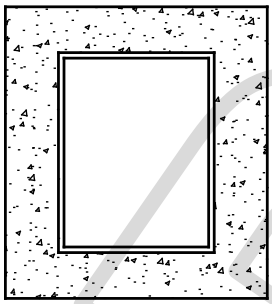


Cross-section

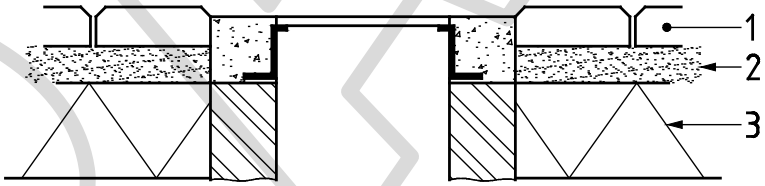


Plan

b) Cross-section of a pavement at a manhole cover surrounded by paving units



Cross-section



Plan

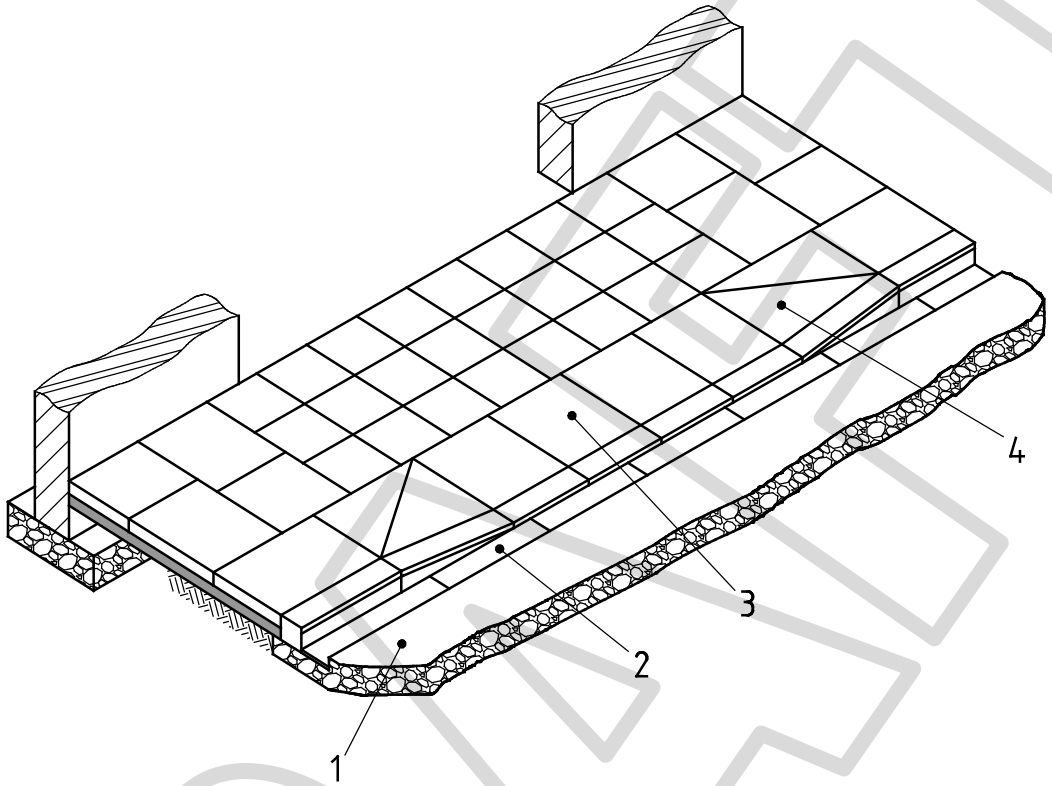
c) Cross-section of a pavement at a manhole cover surrounded by concrete

Key
1 Paving units
2 Layer course
3 Sub-base and/or roadbase

Annex J (informative)
Examples of typical pavement layouts for vehicle crossings

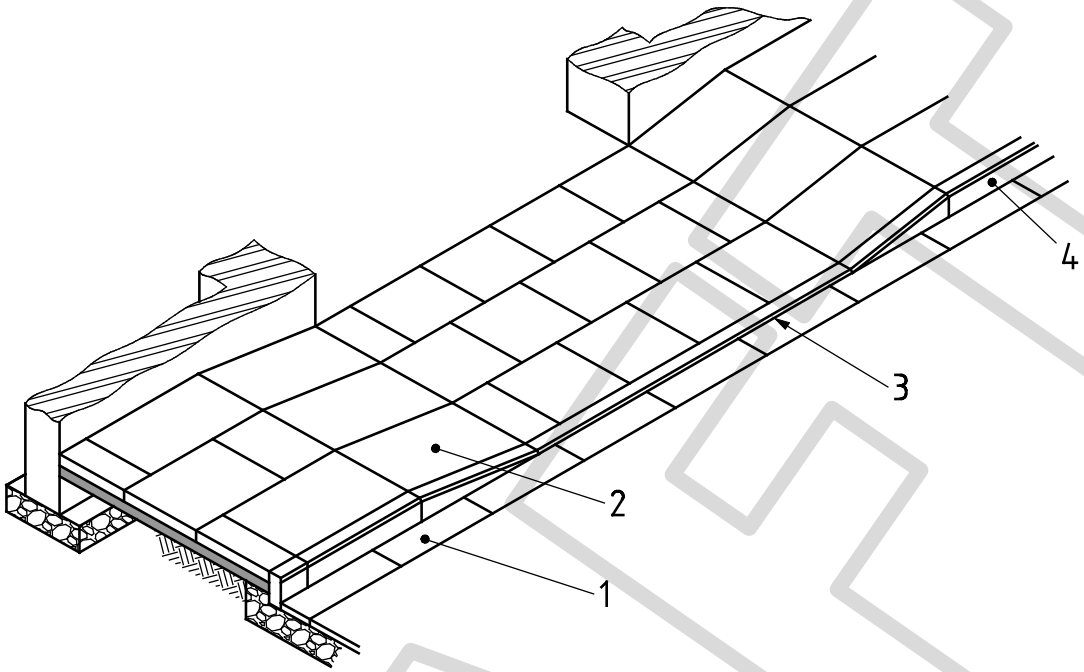
Examples of typical pavement layouts for vehicle crossings are shown in Figure J.1 to Figure J.6.

Figure J.1 – Example of a ramped crossing



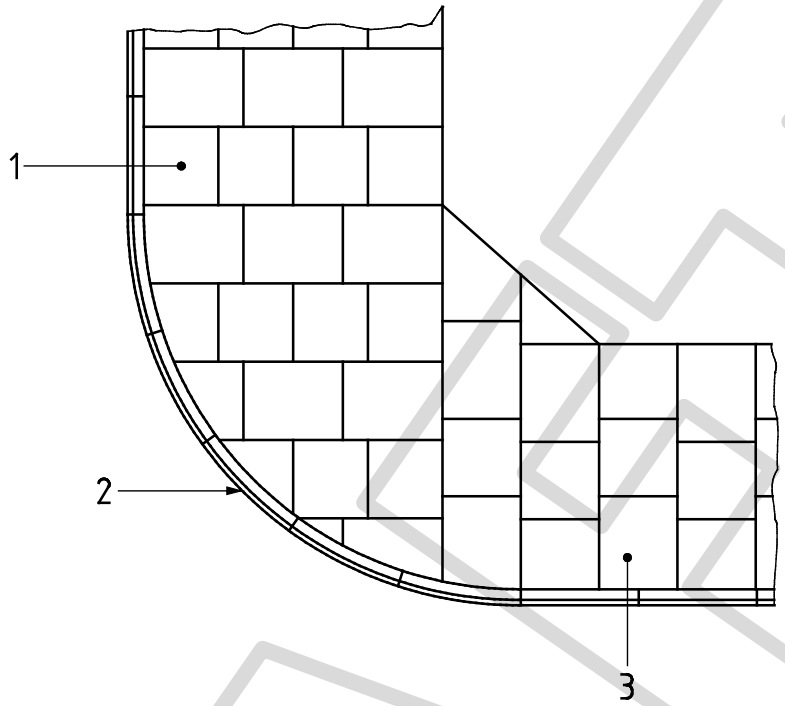
Key
1 Road surface
2 Channel
3 Flags or slabs ramped
4 Flags or slabs cut across for mitre and ramp

Figure J.2 – Example of a dropped crossing



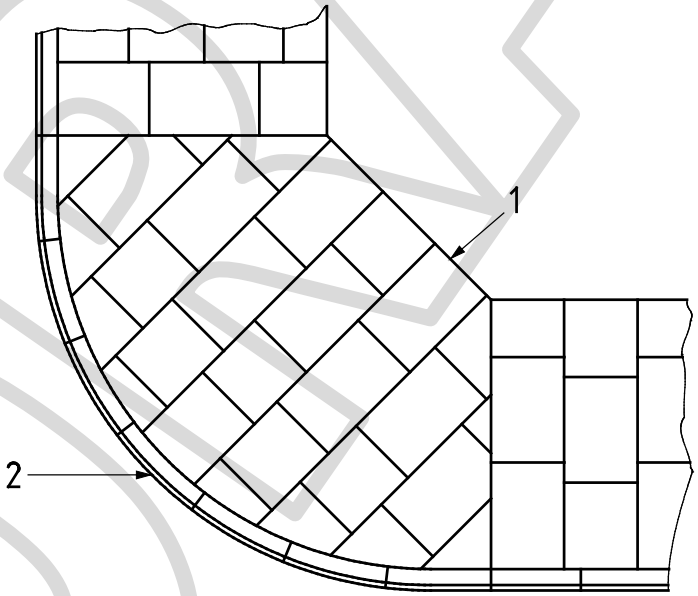
Key
1 Channel
2 Ramp flags and slabs
3 Dropped crossing
4 Kerb

Figure J.3 – Example of a run-out corner



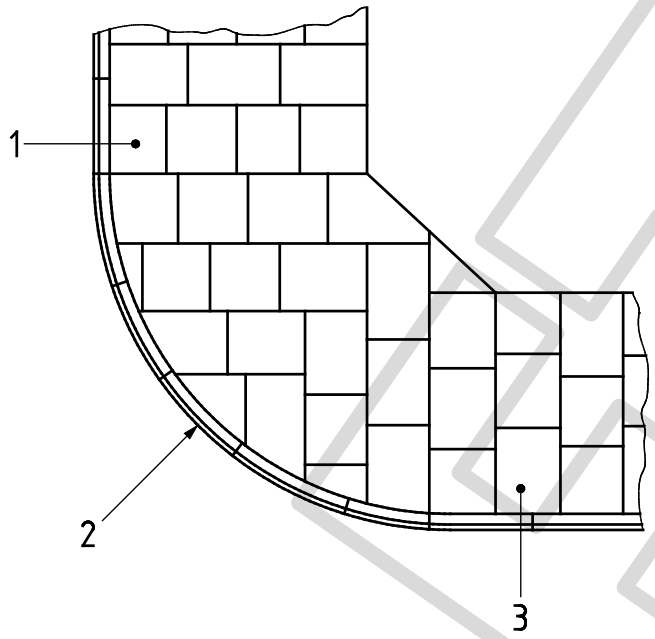
Key
1 Major footpath
2 Kerb
3 Minor footpath

Figure J.4 – Example of a new town corner



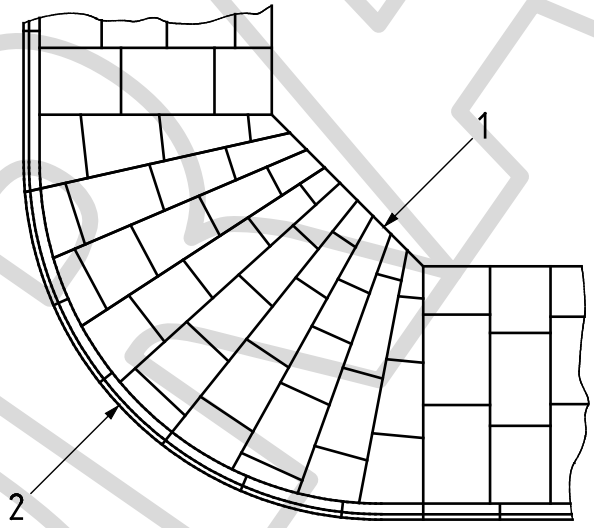
Key
1 Laying start line
2 Kerb

Figure J.5 – Example of a bonded corner



Key
1 Major footpath
2 Kerb
3 Minor footpath

Figure J.6 – Example of a splayed corner



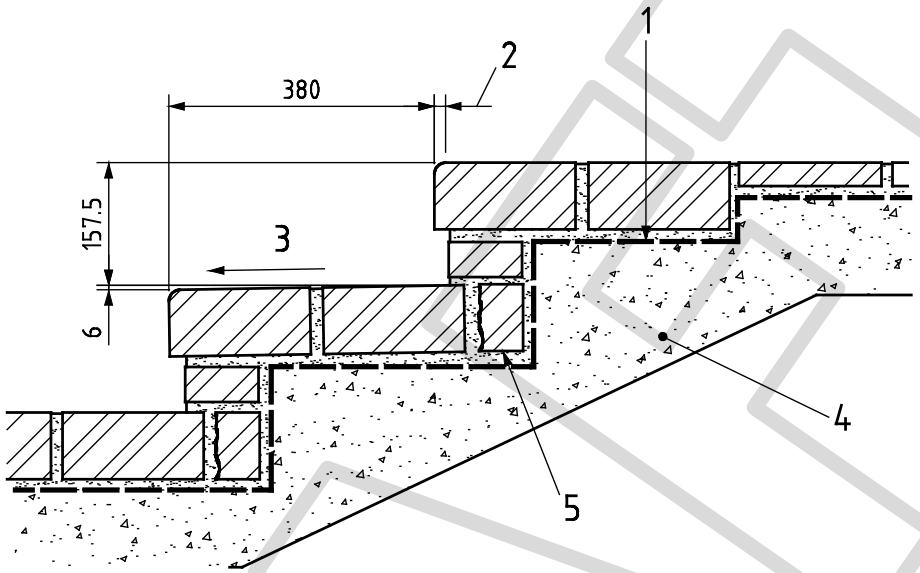
Key
1 Laying start line
2 Kerb

Annex K (informative)
Examples of steps

Examples of steps are shown in Figure K.1, Figure K.2, Figure K.3 and Figure K.4.

Figure K.1 – Example of a profile of a step constructed using clay paving units

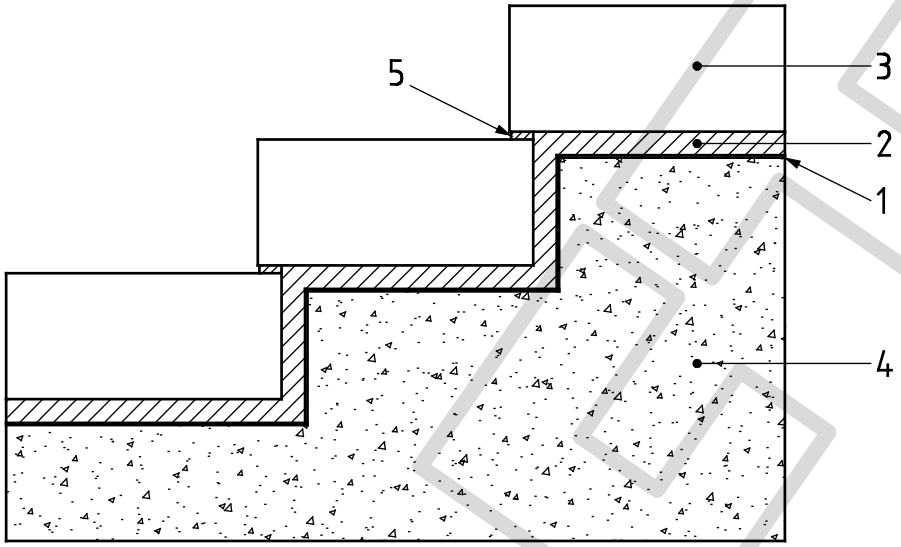
Dimensions in millimetres



Key
1 DPM conforming to BS 8102:2009, **8.2.3** (liquid applied membranes)
2 20 mm overhang
3 Fall
4 Concrete
5 Rough cutting

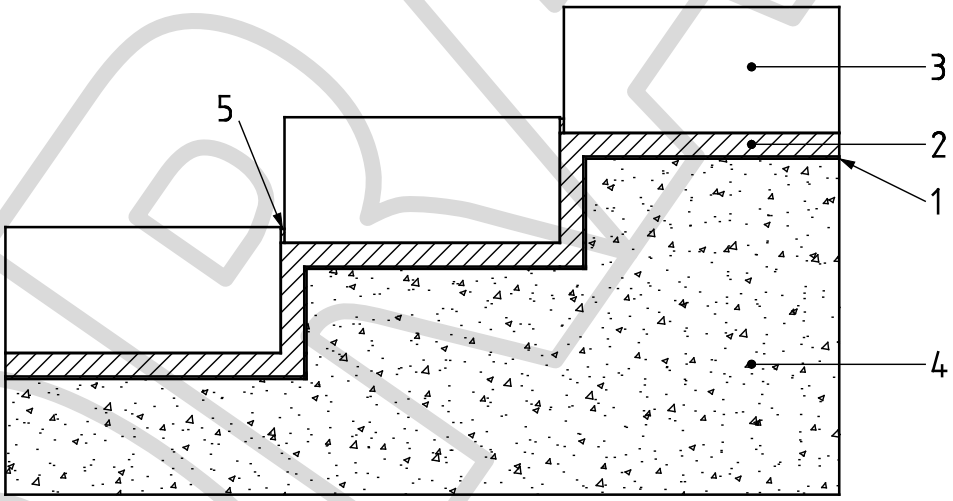
NOTE Various tread depth dimensions can be constructed as rough cutting can be masked by the riser unit.

Figure K.2 – Example of a monolithic step laid onto a profiled concrete foundation (step on step)



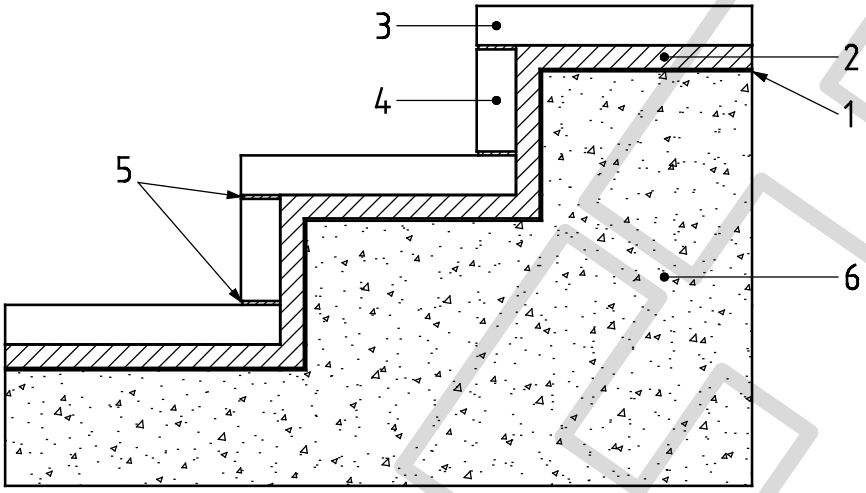
Key
1 DPM conforming to BS 8102:2009, **8.2.3** (liquid applied membranes)
2 Mortar bed
3 Step
4 Concrete
5 Mortar joint

Figure K.3 – Example of a monolithic step laid onto a profiled concrete foundation (step behind step)



Key
1 DPM conforming to BS 8102:2009, **8.2.3** (liquid applied membranes)
2 Mortar bed
3 Step
4 Concrete
5 Mortar joint

Figure K.4 – Example of a slab tread and riser step laid onto a profiled concrete foundation



Key
1 DPM conforming to BS 8102:2009, **8.2.3** (liquid applied membranes)
2 Mortar bed
3 Step tread
4 Step riser
5 Mortar joint
6 Concrete

Annex L (informative)
Efflorescence

Efflorescence, also known as lime bloom, is a temporary, naturally occurring phenomenon that occurs to a varying extent on all items containing cementitious binders. It appears as a white deposit covering all or part of the surface resulting in a lightening of the surface colour. The heavier the deposit, the lighter the surface colour. Except in very severe cases, the phenomenon disappears completely when the surface is wet and reappears as the surface dries out. This is not considered to be significant, other than aesthetically, and is not in any way detrimental to the performance of the concrete.

Efflorescence is formed by soluble salts from the cement migrating to the surface where they react with the atmosphere to produce the white film (calcium carbonate). Individual crystals are very small and are not firmly fixed to the surface. The smallness of the crystals, which is linked to their optical properties, causes them to become invisible when wet.

Concrete products are more susceptible to efflorescence under damp conditions since this aids the migration of the soluble salts to the product surface.

Mortar and concrete are particularly prone to efflorescence and this can contaminate other materials comprising the pavement structure.

The use of bedding mortar which is not free draining in accordance with **6.4.2** can result in capillary action carrying moisture through the pavement surface. This effect is more pronounced when relatively thin paving units are laid as the surface course. In this situation the manifestation of efflorescence on the pavement surface can be significant.

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 4483:2005, *Steel fabric for the reinforcement of concrete – Specification*

BS 7533-101, *Code of practice for the design of pavements using modular paving units*[10)]

BS 8102:2009, *Code of practice for protection of below-ground structures against water from the ground*

BS EN 13877-3:2004, *Concrete pavements – Part 3: Specifications for dowels to be used in concrete pavements*

BS EN ISO 9000, *Quality management systems – Fundamentals and vocabulary*

BS EN ISO 9001, *Quality management systems – Requirements*

BS EN ISO 9004, *Managing for the sustained success of an organization – A quality management approach*

Other publications

[1] SECTOR SCHEME ADVISORY COMMITTEE FOR THE INSTALLATION, MAINTENANCE AND REPAIR OF MODULAR PAVING. *National highway sector scheme for quality management in highway works – Scheme 30: National highway sector scheme for the installation, maintenance and repair of modular paving*. NHSS 30. Feltham, Middlesex: UKAS, 2013.[11)]

[2] HIGHWAYS AGENCY. *Design manual for roads and bridges – Volume 7: Pavement design and maintenance – Section 2: Pavement design and construction – Part 1: Traffic assessment*. HD 24/06. London: Highways Agency: 2006.[12)]

[3] ENVIRONMENT AGENCY. *Guidance for waste destined for disposal in landfills*. Rotherham, Environment Agency, 2006.

[10)] In preparation at the time of publication of BS 7533-102.

[11)] Latest version available at http://www.ukas.com/Technical-Information/Publications-and-Tech-Articles/Publications/PubsForCBAccred.asp [last accessed 27 November 2013].

[12)] Available at www.dft.gov.uk/ha/standards/dmrb/index.htm [last accessed 27 November 2013].

