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Part 102: Installation of pavements using modular paving units - Code of practice

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Introduction
Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international and European standards, comments will be reviewed by the relevant UK national committee before submitting the consensus UK vote and comments. If the draft standard is approved, it is usual for the resulting published standard to be adopted as a British Standard.

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BS 7533-102, Pavements constructed with clay, concrete or natural stone paving units – Part 102: Installation of pavements using modular paving units – Code of practice

Contents

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 xxxxxx 202X. 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BS 7533-3:2005+A1:2009, BS 7533-4:2006, BS 7533-6:1999, BS 7533-7:2010, BS 7533-9:2010 and BS 7533-11:2003, which are withdrawn.

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*;
- Part 13: *Guide for the structural design of permeable pavements constructed with concrete paving blocks and flags, natural stone slabs and setts and clay pavers*; and
- Part 102: *Code of practice for the construction and maintenance of pavements using modular paving units*.

Information about this document

A revision of the BS 7533 series has been undertaken, in which the principal change is to reduce the number of relevant standards to three codes of practice (see "Relationship with other publications").

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 bound and unbound pavements, using concrete, clay and natural stone paving units from the following parts of the old series:
  - Part 3: *Code of practice for laying precast concrete paving blocks and clay pavers for flexible (unbound) 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 (bound) construction with concrete block paving*;
  - Part 9: *Code of practice for the construction of rigid (bound) pavements of clay pavers*;
  - Part 11: *Code of practice for the opening, maintenance and reinstatement of pavements of concrete, clay and natural stone*;
- the removal of repetition between the parts of BS 7533 listed above;
- some updating of references and test methods; and
- clarification and removal of ambiguities and anomalies.

Product certification/inspection/testing. Users of this part of BS 7533 are advised to consider the desirability of third-party certification/inspection/testing of product conformity to this part of BS 7533. Appropriate conformity attestation arrangements are described in

BS EN 17025. Users seeking assistance in identifying appropriate conformity assessment bodies or schemes may ask BSI to forward their enquiries to the relevant association.

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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.

Users may substitute any of the recommendations in this British Standard with practices of equivalent or better outcome. Any user claiming compliance with this British Standard 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.

Where words have alternative spellings, the preferred spelling of the Shorter Oxford English Dictionary is used (e.g. “organization” rather than “organisation”).

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1 Scope

This part of BS 7533 gives recommendations and guidance for the installation of pavements having bound and unbound surface construction using:

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

It 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, including domestic applications.

It gives recommendations and guidance on:

- all layers above the formation, including capping, sub-base, base, bedding and surface layers; and
- on the opening, reinstatement and cleaning of surfaces paved with modular paving units.

It provides guidance in traffic categories 3 and below for the construction of a pavement using standard paving units, where a design produced in accordance with BS 7533-101 has not been provided.

It is not applicable to other applications such as aircraft pavements and those in ports and specialized industrial areas.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes provisions of this document.[1] 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 7533-101, *Pavements constructed with clay, natural stone or concrete pavers – Part 101: Code of practice for the design of pavements using modular paving units*

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*

BS 8300-1, *Design of an accessible and inclusive built environment – Part 1: External environment – Code of practice*

BS 8300-2, *Design of an accessible and inclusive built environment – Part 2: Buildings – Code of practice*

BS 8102:2022, *Protection of below ground structures against water ingress – Code of practice*

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[1] Documents that are referred to solely in an informative manner are listed in the Bibliography.

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 1338:2003, *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 12350-2, *Testing fresh concrete – Slump-test*

BS EN 12620:2013, *Aggregates for concrete*

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

BS EN 13242:2002+A1, *Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction*

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 13755, *Natural stone test methods – Determination of water absorption at atmospheric pressure*

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 14157:2017, *Natural stone test methods – Determination of the abrasion resistance*

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

BS EN 14231, *Natural stone test methods – Determination of the slip resistance by means of the pendulum tester*

BS EN 16165, *Determination of slip resistance of pedestrian surfaces – Methods of valuation*

PD CEN/TS 15209, *Tactile paving surface indicators produced from concrete, clay and stone*

Other publications

[N1] DEPARTMENT FOR TRANSPORT. *Specification for the Reinstatement of Openings in Highways*. Fourth edition. London: The Stationery Office, 2020.[2)]

[2)] Available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/977196/specification-for-the-reinstatement-of-openings-in-highways-fourth-edition.pdf.

[N2] NATIONAL HIGHWAYS. *Manual of contract documents for highway works – Volume 1: Specification for highway works*. London: Highways Agency.[3)]

3 Terms, definitions and abbreviated terms

3.1 Terms and definitions

For the purposes of this part of BS 7533, the following terms and definitions apply.

3.1.1 aspect ratio
ratio between length and width

NOTE For example, a ratio of 2:1 means the length is twice the width.

3.1.2 base
one or more layers of material placed above the sub-base that constitute the main structural element of a pavement on which the laying course is placed

NOTE This has sometimes previously been referred to as roadbase. See Figure 1.

3.1.3 bedding mortar
blend of fine aggregate and binder upon which paving units are laid

3.1.4 binder
rectangular setts having length greater than width used at the end of a row to effect the offset of joints in adjacent rows of setts square in plan

3.1.5 bishop's mitre
complimentary paving unit having five sides, placed at the end of a row of paving units where that row forms an angle of typically 45º to the pavement edge

NOTE See Annex L, Figure L.3.b).

3.1.6 bound construction
paving units laid on and jointed with mortar

NOTE 1 This is irrespective of the base material, which may be bound or unbound.

NOTE 2 This has often previously been referred to as rigid construction.

3.1.7 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 mortar or grout

3.1.8 capping layer
layer of granular or treated material at the top of the subgrade to improve foundation

NOTE See Figure 1.

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

3.1.10 coarse graded aggregate (CGA)
aggregate having a particle size grading typically between 4 mm and 20 mm

3.1.11 clay paving unit
fired clay unit used as a surfacing material

NOTE Requirements for clay paving units are specified in BS EN 1344.

3.1.12 cobble
natural stone element rounded by erosion

3.1.13 commercial vehicle
bus or goods vehicles over 3.5 t and less than 7.5 t gross weight

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[4)] Available at https://www.gov.uk/government/publications/v3551-notes-about-tax-classes.

3.1.14 complementary fitting
paving unit or part of a paving unit, of a different size to the main works, used to infil and enable an area to be fully surfaced or to enable the offset of a pattern at the end of a row

3.1.15 concrete paving block
precast concrete unit used as a surfacing material

NOTE Requirements for concrete paving blocks are specified in BS EN 1338.

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

3.1.17 design and build
project delivery system in which design and construction services are contracted by a single entity, typically a design and build contractor, from whom the client may seek legal remedies for any fault

3.1.18 drainage fitting
ironwork, plastic, clay or concrete gulley, linear drain or similar collection point where surface water flows into a drainage system and is removed from the pavement surface by gravity

3.1.19 flag
precast concrete unit used as a surfacing material

NOTE Requirements for flags are specified in BS EN 1339.

3.1.20 level of formation
level above which the structural layers of the pavement are constructed

NOTE See Figure 1. A subgrade improvement or capping layer might be included below the formation layer.

3.1.21 foundation
structure upon which the pavement is constructed

3.1.22 geogrid
proprietary fabric mesh having high tensile strength intended to reinforce soils and layers of unbound granular material

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

3.1.24 heavy goods vehicle
HGV
goods vehicle exceeding 7.5 t gross weight

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

3.1.26 hydraulic mortar
mortar using a hydraulic binder

3.1.27 inboard cutting
paving unit within a row, cut in order to allow the cut unit at the edge of the pavement to be greater than one quarter of the length of a standard paving unit

3.1.28 inspection and test plan
plan for managing quality control by providing information on the requirements, an overview of installation methods, the test methods and evidence to be provided to verify compliance and the responsibilities of relevant parties

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

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

3.1.31 joint offset
distance between joints in adjacent rows of paving units

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

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

NOTE See Figure 1 and Figure 2.

3.1.34 kerb race
fresh concrete onto which kerbs/channels are laid directly

NOTE Also referred to as “windrow” in some regions.

3.1.35 kerb edge beam
hardened concrete onto which kerbs/channels are laid using a mortar bed

NOTE This might be an extension of a pavement base course.

3.1.36 laying course
layer of material on which paving units are bedded

NOTE See Figure 1 and Figure 2.

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

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

3.1.39 light goods vehicle (LGV)
goods vehicle having a gross weight not exceeding 3 500 kg

NOTE See DVLA (Drivers and vehicles licensing agency) guidance leaflet V355/1 [1].

3.1.40 light commercial vehicle
goods vehicle not exceeding 3 500 kg gross weight

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

3.1.42 mortar joint
joint between two units filled with a mixture of fine aggregate and cementitious or other suitable binder

3.1.43 movement joint
joint constructed to allow pavements to expand and contract or flex

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

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

3.1.46 pavement
paved area subject to pedestrian and/or vehicular traffic

3.1.47 paving unit
prefabricated or selected unit used to form the surface course of a modular pavement

NOTE 1 See Figure 1 and Figure 2. 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.

3.1.48 porcelain slab
paving unit manufactured predominantly from naturally occurring clay and minerals, by shaping and firing to form a vitrifed, flat paving slab having very low water absorption, high strength and durability

3.1.49 public realm
typically but not exclusively urban, external paved areas to which the public has free access

3.1.50 race
strip of hardened, levelled concrete onto which kerbs and similar paving units are laid with a layer of bedding mortar

3.1.51 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.

3.1.52 screeder board
straight and stiff board of timber, metal or plastic which is drawn across fresh laying coarse material in order to create an accurate level

3.1.53 screeding rail
slender piece of timber, metal or plastic, typically 3 m to 5 m in length, embedded temporarily within a fresh laying course, across which a screeder board is drawn

3.1.54 sett
unit of natural stone obtained by cutting or splitting, used as a paving module, in which the working width does not exceed two times the thickness

NOTE Requirements for setts are specified in BS EN 1342.

3.1.55 sharp sand
coarse grained, gritty sand used in concrete and for the laying course in unbound construction

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

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

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

3.1.58 statutory undertaker
companies or agency given general licence to carry out certain works on public highways

NOTE Examples are utilities, telecom and nationalised companies.

3.1.59 stiffness modulus (*E*)
ratio of applied stress to induced strain

NOTE California bearing ratio (CBR) has historically been used as an indirect measure of stiffness. The approximate relationship between the two, acknowledging a degree of uncertainty, is $E = 17.6\ (CBR)^{0.64}$ *MPa.*

3.1.60 stop point
completion of a stage of the works or process whereby inspection and approval of the works is to be made before work is allowed to continue

3.1.61 sub-base layer
layer of material placed above the subgrade or capping (if used) which distributes the loading from the upper pavement layers down to the subgrade

NOTE See Figure 1. In some circumstances, the sub-base layer may be omitted.

3.1.62 sub-base material
unbound granular material or bound material used to construct a sub-base layer.

NOTE With an unbound base, the sub-base and base might be the same material.

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

NOTE See Figure 1.

3.1.64 surface course
layer of paving units together with bedding or laying course, that comprises the wearing surface of the pavement

3.1.65 traffic categories
classification of traffic rates for the purposes of pavement construction

NOTE The relevant traffic categories are set out in Table 1.

Table 1 – Traffic categories for pavement construction

Traffic category	Road category A)	Typical applications
9	1	Adopted highways and commercial/industrial developments used by a high number of commercial vehicles
8	2	
7	3	
6	4	Adopted highways and other roads used by a moderate number of commercial vehicles Pedestrian areas subjected to regular overrun of commercial vehicles Industrial premises Petrol station forecourts
5	N/A	Pedestrian areas subjected to occasional overrun of commercial vehicles Car parks receiving occasional commercial vehicular traffic
4	N/A	Urban footways with unplanned commercial vehicular overrun Pedestrian areas used by light goods vehicles, emergency vehicles and maintenance vehicles
3	N/A	Footways, pedestrian and cycle areas, domestic driveways or access routes subject to manoeuvring of cars and light goods vehicles No access for other commercial vehicles
2	N/A	Footways, pedestrian and cycle areas, parking spaces subject to car and light goods vehicles No access for other commercial vehicles
1	N/A	Footpaths, pedestrian and cycle areas, excluding all vehicles

A) For road categories, see *Specification for the reinstatement of openings in highways* [N1], Table S1.1. This document is available from local authorities.

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

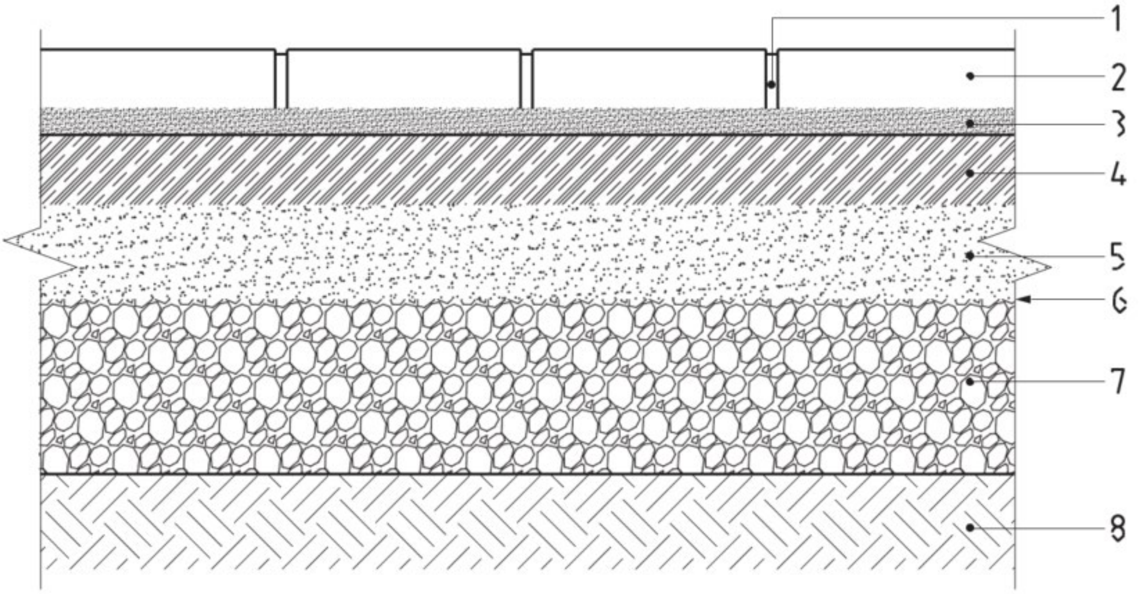
NOTE This has often previously been referred to as flexible construction.

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

3.1.68 void
unfilled space in the pavement construction

3.1.69 windrow
strip of fresh concrete onto which kerbs and similar units are laid directly

Figure 1 – Pavement layers

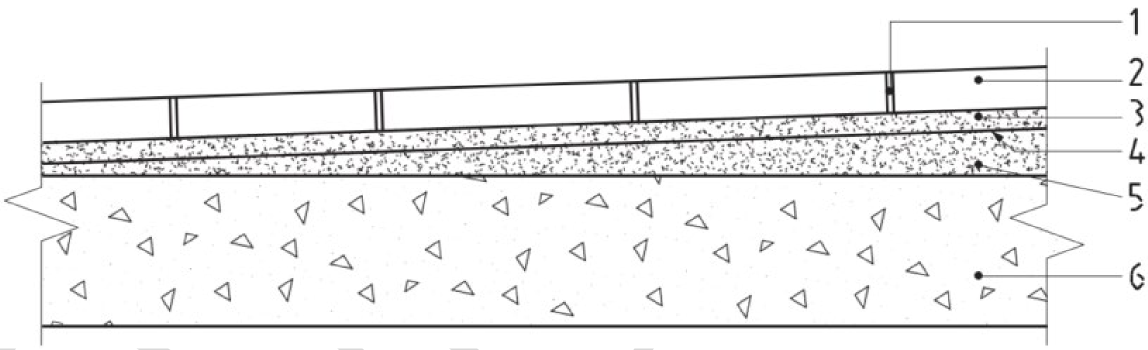


NOTE The sub-base and capping layers (5 and 7) comprise the pavement foundation.

Key

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

Figure 2 – Pavement layers over a structural slab



Key

1	Jointing material	4	Waterproofing layer
2	Paving unit	5	Regulating layer laid to fall (not always required)
3	Laying course	6	Structural slab

3.2 Abbreviated terms

For the purposes of this part of BS 7533, the following terms and definitions apply.

CBGM cement bound granular material

CBR	California bearing ratio
DPM	damp-proof membrane
HBM	hydraulically bound material
HGV	heavy goods vehicle
ITP	Inspection and Test Plan
msa	million standard axles
N/A	not applicable
PPV	polished paver value
PQC	pavement quality concrete
PSRV	polished slip resistance value
USRV	unpolished slip resistance value

4 Traffic categories 3 and below where no design has been provided in accordance with BS 7533-101

4.1 General

*COMMENTARY ON **4.1***

An unbound surface course generally requires more maintenance than bound but might be more easily repaired and can be lifted and re-laid thus extending the life of the pavement indefinitely.

Bound surface course construction laid over a bound base layer provides the stiffest combination and generally allows the use of thinner paving units in the same loading and traffic conditions. However, there is a risk that cracks form if the surface is overloaded or poorly constructed.

Thin paving slabs of natural stone or porcelain and concrete flags are at the lowest risk of failure when bonded onto a concrete base using high performance proprietary bedding and bonding mortar.

Laying flags and slabs onto a bedding mortar, over an unbound base, avoids the uncertainty of adequately compacting an unbound laying course. The mass of bedding mortar adhering to the underside of the flag or slab adds to the overall mass of the paving unit, enhancing stability and reducing the risk of trip hazards forming.

The practice of laying down a strong geosynthetic or lightweight stainless-steel mesh as laying of the bedding mortar proceeds over an unbound base provides additional tensile strength and reduces the risk of cracks forming in the surface course.

*For sites where a design has been provided in accordance with BS 7533-101, the recommendations of **4.2** to **4.9** are not applicable.*

For sites in traffic categories 3 and below, where no design has been provided in accordance with BS 7533-101, the recommendations of **4.2** to **4.9** should be followed.

4.2 Surface drainage

*COMMENTARY ON **4.2***

Surface water can penetrate the pavement structure through joints in unbound pavements and cracks in bound pavements. Water which cannot freely drain from within the pavement structure could saturate the structural layers, resulting in weakness and frost damage.

Persistent dampness of the pavement surface might lead to discoloration and growth of flora such as algae and moss, sometimes referred to as "greening", which might cause the pavement to become slippery and dangerous for both pedestrians and vehicles.

Sufficient fall should be provided in accordance with Annex D to allow surface water to flow freely to a drainage fitting without ponding.

At least one drainage fitting should be provided per 75 square metres or part thereof of paving and surface water should not be required to travel a distance greater than 10 linear metres to reach a drainage fitting.

4.3 Paving units and their installation

4.3.1 Performance criteria for paving units

The unpolished slip resistance (USRV) of paving units should be not less than 40.*NOTE 1 Information on slip and skid resistance is given in Annex F.*

In areas with intensive pedestrian traffic, some types of natural stone (most commonly, limestone) and some clay pavers can become polished with time. To avoid this, paving units with a polished paver value (PPV) of 45 or greater should be selected.

NOTE 2 Unless they have been ground or polished, it may be assumed that precast concrete paving units and clay pavers achieve the recommended values.

NOTE 3 Coarse textured and hewn natural stone paving units are assumed to give satisfactory slip resistance.

NOTE 4 Intensive pedestrian traffic refers to areas expected to receive over 500 million pedestrians in the life of the pavement. Examples are busy commuter stations, airports and large shopping malls.

If a different characteristic bending strength or class to that recommended in Table 2a) is declared by the supplier for concrete flags, a unit thickness design should be provided in accordance with BS 7533-101.

Composite flags and slabs comprising a thin natural stone or porcelain surface bonded to a precast concrete flag should be considered as having similar mechanical properties and be treated in the same way as concrete flag in Table 2a).

The recommendations for natural stone slabs in Table 2b) are divided into two strength classes; Class 1 is based on a flexural strength of 12 MPa, Class 0 should be assumed when no values for flexural strength have been declared.

NOTE 5 Class 0 is based on a flexural strength of 8.0 MPa.

When it is known that the flexural strength is less than 8 MPa, a unit thickness design should be provided in accordance with BS 7533-101.

NOTE 6 Where a declared value for the flexural strength of natural stone is available the user or supplier may determine length, aspect ratio and thickness based on the formulae in BS 7533-101.

NOTE 7 When it has not proved possible to obtain a flexural strength value for the stone Class 0 may be assumed.

NOTE 8 An increased risk of failure exists no values for flexural strength have been declared. A similar risk exists where the other recommendations for the properties of the stone given in Annex E are not followed.

Where a declared value for flexural strength has been used to determine unit thickness in accordance with BS 7533-101, the recommendations of **E.11.3** for wear resistance, **E.11.4** for water absorption and **E.11.5** for weathering resistance should be followed.

4.3.2 Standard dimensions of paving units

The length of concrete blocks and natural stone setts should not exceed 4 times the thickness and the thickness of natural stone setts should additionally be not less than half the width.

The length of clay pavers selected should not exceed 6 times the thickness.

The length of precast concrete flags, natural stone slabs should not exceed 1 000 mm.

The length of porcelain slabs and composite concrete/porcelain slabs should not exceed 1 200 mm.

The maximum aspect ratio and minimum thickness for concrete and clay paving units should be as recommended in Table 2a).

The maximum aspect ratio and minimum thickness for natural stone and porcelain paving units should be as recommended in Table 2b).

Table 2a) – Limiting dimensions and thickness: Concrete and clay paving units

Construction type	Traffic category	Paving unit type	Minimum thickness (mm) at aspect ratio			
			3:1	**2:1**	**1.5:1**	**1:1**
Unbound surface over unbound or bound base	3, 2, 1	Concrete block pavers	50			
	3	Clay pavers Class T4	60			
		Concrete flags Class 1	140	112	100	80
		Concrete flags Class 3	115	95	80	70
	2	Clay pavers Class ≥T3	50			
		Concrete flags Class 1	105	85	75	60
		Concrete flags Class 3	90	70	65	50
	1	Clay pavers Class ≥T1	40			
		Concrete flags Class 1	50	40	35	30
		Concrete flags Class 3	40	35	30	25
Bound surface over unbound or bound base	3, 2, 1	Concrete block pavers	50			
	3	Clay pavers Class T4	50			
		Concrete flags Class 1	120	100	84	70
		Concrete flags Class 3	100	80	70	60
	2	Clay pavers Class ≥T3	40			
		Concrete flags Class 1	90	75	64	52
		Concrete Flags Class 3	80	65	55	45
	1	Clay pavers Class ≥T1	30			
		Concrete flags Class 1	42	35	30	25
		Concrete flags Class 3	35	30	25	25
Bonded to concrete base	3, 2, 1	Concrete Block Pavers	50			
	3	Clay pavers Class T4	30			
		Concrete flags Class 1	63	50	45	36
		Concrete flags Class 3	55	45	40	30
	2	Clay pavers Class ≥T3	30			
		Concrete flags Class 1	48	40	34	28
		Concrete flags Class 3	40	35	30	25
	1	Clay pavers Class ≥T1	30			
		Concrete flags Class 1	22			
		Concrete flags Class 3	20			

A) The recommendations for clay pavers are based on the minimum transverse breaking loads set out in BS EN 1344:2013, Table 3.

B) There is no maximum aspect ratio for clay pavers.

c) The recommendations for concrete flags in Table 3a) are based on bending strength classes 1 and 3 in accordance with BS EN 1339:2003, Table 5 (Class 1 has a characteristic bending strength of 3.5 MPa, Class 3 has a characteristic bending strength of 5 MPa).

Table 2b) – Limiting dimensions and thickness: Natural stone and porcelain paving units

Construction type	Traffic category	Paving unit type	Minimum thickness (mm) at aspect ratio			
			3:1	2:1	1.5:1	1:1
Unbound surface over unbound or bound base	3, 2, 1	Natural stone setts [A)]	70			
		Porcelain slabs	N/A			
	3	Natural stone slabs Class 0	90	75	65	55
		Natural stone slabs Class 1	75	55	45	40
	2	Natural stone slabs Class 0	70	60	50	40
		Natural stone slabs Class 1	65	50	40	35
	1	Natural stone slabs Class 0	35	30	25	20
		Natural stone slabs Class 1	30	25	20	20
Bound surface over unbound or bound base	3, 2, 1	Natural stone setts [A)]	50			
	3	Natural stone slabs Class 0	80	65	60	45
		Natural stone slabs Class 1	65	55	45	40
		Porcelain slabs	40	30	30	30
	2	Natural stone slabs Class 0	60	50	45	35
		Natural stone slabs Class 1	50	40	35	30
		Porcelain slabs	40	30	30	30
	1	Natural stone slabs Class 0	30	25	20	20
		Natural stone slabs Class 1	25	20	20	20
		Porcelain slabs	20			
Bonded to concrete base	3, 2, 1	Natural stone setts	50			
	3	Natural stone slabs Class 0	45	35	30	2
		Natural stone slabs Class 1	35	30	25	20
		Porcelain slabs	20			
	2	Natural stone slabs Class 0	35	30	25	20
		Natural stone slabs Class 1	30	25	20	20
		Porcelain slabs	20			
	1	Natural stone slabs Class 0	20			
		Natural stone slabs Class 1	20			
		Porcelain slabs	16			

A) Natural stone setts laid in stack bond pattern using unbound surface or base require an engineering design.

4.3.3 Non-standard paving units

Where paving units which do not achieve the performance or dimensions recommended in **4.3.1** and **4.3.2** are to be used in traffic categories 3 and below, a unit thickness design should be provided in accordance with BS 7533-101.

4.3.4 Joint width

4.3.4.1 Joint width for unbound construction

The nominal joint width for unbound construction should be as recommended in **14.3**, Table 7.

The apparent joint width between natural stone setts having cropped sides is governed by the roughness of the sides; when laid, each sett should be in contact with adjacent setts at one or more points.

For sawn sandstone setts, precast concrete blocks and clay pavers, natural stone slabs and concrete flags having chamfers, the joint width should be as recommended in **14.3**, Table 7.

NOTE Joint width might be governed by the presence of nibs cast onto the sides of the paving units and joint spacers may be used in order to generate a greater joint width and to provide stability.

4.3.4.2 Joint width for bound construction

A joint filled with mortar should be not less than 5 mm in width and not greater than 25 mm at any point, unless a wider joint is permitted by the design and the jointing mortar is suitable.

4.3.5 Construction depth

4.3.5.1 General

The construction depth should comprise the thickness of the paving unit given in Table 2, plus the depth of the laying course or bedding layer, base layer and sub-base given in Table 3.

4.3.5.2 Thickness of bedding or laying course

The bedding or laying course thickness should be as given in Table 3.

Table 3 – Laying course, base and sub-base thickness

Construction type	Traffic category	Paving unit type	Laying course or bedding layer thickness and material	Base thickness and material	Sub-base thickness	
					Subgrade CBR >2.5% to ≤5%	Subgrade CBR >5%
Unbound surface over unbound or bound base	3	Clay pavers	30 mm sand	≥ 150 mm unbound material ≥ 100 mm CBGM or concrete	≥ 200 mm unbound material	≥ 100 mm unbound material
		Concrete block pavers				
		Sawn sided setts				
		Concrete flags				
		Stone slabs	40 mm crushed rock			
		Cropped sided setts				
	2	Clay pavers	30 mm sand	≥ 100 mm unbound material or ≥ 100 mm CBGM or concrete	≥ 100 mm unbound material	No sub-base required
		Concrete block pavers				
		Sawn sided setts				
		Concrete flags				
		Stone slabs	40 mm crushed rock			
		Cropped sided setts				
	1	Clay pavers	30 mm sand		No sub-base required	
		Concrete block pavers				
		Sawn sided setts				
		Concrete flags				
		Stone slabs	40 mm crushed rock			
		Cropped sided setts				

Table 3 – Laying course, base and sub-base thickness (*continued*)

Construction type	Traffic category	Paving unit type	Laying course or bedding layer thickness and material	Base thickness and material	Sub-base thickness	
					Subgrade CBR >2.5% to ≤5%	Subgrade CBR >5%
Bound surface over unbound base	3	Clay and concrete pavers, all natural stone setts	40 mm bedding mortar	≥ 150 mm unbound material	≥ 200 mm unbound material	≥ 100 mm unbound material
		Concrete flags, natural stone and porcelain slabs	40 mm bedding mortar with bonding mortar			
	2	Clay and concrete pavers, all natural stone setts	40 mm bedding mortar	≥ 100 mm unbound material	≥ 100 mm unbound material	No sub-base required
		Concrete flags, natural stone and porcelain slabs	40 mm bedding mortar with bonding mortar			
	1	Clay and concrete pavers, all natural stone setts	40 mm bedding mortar			
		Concrete flags, natural stone and porcelain slabs	40 mm bedding mortar with bonding mortar			
Bonded to concrete	3	All paving unit types	40 mm bedding mortar with bonding mortar applied to both underside of paving unit and surface of concrete base	≥ 100 mm concrete	≥ 200 mm unbound material	≥ 100 mm unbound material
	2				≥ 100 mm unbound material	No sub-base required
	1				No sub-base required	

4.3.6 Base layer for all surface construction types

4.3.6.1 Minimum thickness

The base course layer for all surface construction types should be constructed with the following minimum thickness or greater if required by Table 3:

a) unbound base – 100 mm; or

b) CBGM base – 100 mm; or

c) concrete base – 100 mm.

Where a bound base layer 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 The provision of 50 mm diameter holes on a 2 m orthogonal grid and at low points has traditionally been used to provide secondary drainage through bound base layers, filling with coarse graded aggregates (CGA) or water permeable laying course aggregate (see Table E.3).

NOTE 2 Weepholes within edge restraints and linear drainage systems may be used to allow water to escape from the laying course.

4.3.6.2 Sub-base and base layer materials

Only materials and mixtures recommended in Annex E, **E.1**, should be used in the unbound base and sub-base layers for pavements.

Layers should be compacted to the applicable maximum thickness given in Table 4, using proprietary equipment such as a vibrating roller, vibratory plate compactor or vibro-tamper. The information provided by the manufacturer should first be checked for a clear statement about the suitability of equipment for the application and adequate guidance for its correct use.

NOTE 1 Table 4 provides recommendations for the maximum thickness of an unbound sub-base of base layer, using generally available equipment for a minimum of 4 passes (2 longitudinal and 2 transverse). Information is also given for engine driven vibro-tampers where these are employed for small areas such as trench filling. The vibratory compaction equipment described in Annex H, Table H.1, is representative of equipment typically provided and can assist in understanding manufacturers' designation of equipment sizes.

Table 4 – Maximum thickness of unbound material to be compacted

Head	**Effective force** kN	**Width of plate or roller** mm	**Typical machine designation**	**Typical machine weight** kg	**Maximum uncompacted thickness** mm	**Maximum installed thickness** mm
Vibratory plate compactor	25 [A)]	500	25/50	155	100	80
	35	600	35/60	230	120	100
	40	600	40/60	260	180	150
	45	450	45/45	460	180	150
	50	600	50/60	460	180	150
Vibrating roller	25 [A)]	650	65	800	100	80
	40	750	75	1100	120	100
	72	850	85	1500	180	150
Engine driven vibro-tamper	15	230	60	58	120	100
	17	280	65	68	120	100

[A)] Minimum 8 passes (4 longitudinal and 4 transverse).

Cement bound granular material (CBGM) should be compacted within 2 h of manufacture and not be allowed to dry before being installed.

Concrete base should conform to BS EN 13877-1 with a minimum compressive strength class C20/25.

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

NOTE 2 This may be effected by coring the base with 50 mm diameter holes on a 2 m orthogonal grid and filling with coarse graded aggregates (CGA) or water permeable laying course aggregate (see Table E.3).

4.4 Site assessment and investigation

4.4.1 Presence of plants and tree roots

Where roots or creeping invasive plants are present, an assessment should be made as to how these could affect the structural integrity of the paving over time and appropriate measures implemented to mitigate any effects.

NOTE 1 For example, if a tree preservation order is in place affecting nearby ground, a “no dig” or “shallow dig” solution might be required.

NOTE 2 If the construction site is in a conservation area, the approval of the local planning authority is required for the intended work/activity. The protection of a conservation area extends to trees in public and private land.

4.4.2 Visual site investigation

Site investigation should involve:

a) identification of the existing surface type; and

b) collecting evidence of surface water drainage.

4.4.3 Simple intrusive investigation

An intrusive investigation should be carried out where necessary to establish the nature of the existing soil and subgrade.

To assess the condition of the ground on which the pavement is to be constructed, trial holes should be excavated, and the subgrade assessed in accordance with **5.8.2**.

If unsuitable material persists beyond 500 mm an engineering design should be carried out in accordance with BS 7533-101.

4.4.4 Previously built ground

4.4.4.1 General

When constructing a modular pavement over previously built ground, for example when replacing or overlaying an existing driveway, arrangements should be made for recycling existing materials that are to be removed, as appropriate.

Where it is intended to overlay existing layers of material as a substitute for a new sub-base or base layer, the thickness, stiffness and strength, as appropriate, of those material layers should be not less than the minimum values given in Table 3.

Prior to being accepted, materials to be overlaid should be inspected and assessed in accordance with **5.8.4**.

Where an existing 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 This may be effected by coring the base with 50 mm diameter holes on a 2 m orthogonal grid and filling with coarse graded aggregates (CGA) or water permeable laying course aggregate (see Table E.3).

Where an existing base is not laid to a fall, an assessment should be made as to whether to create a gradient using a regulating layer or screed. Where possible, the fall of the base should replicate the fall of the pavement surface.

Where the surface of the base falls to low points, provision should be made for water to drain freely to a subsurface drainage fitting or suitable egress.

NOTE 2 Water which accumulates within the laying course of a pavement can generate water vapour in hot weather which can result in staining of the pavement surface.

4.4.4.2 Adjacent areas combining existing base and new base construction

Where a new base course is to be laid adjacent to an existing base, unequal movement should be expected and a determination made of the need to compensate for unequal lateral and vertical movement of the adjacent paved surfaces.

Where a new base course is laid adjacent to an existing base and the surface course is laid in unbound construction, unequal settlement during the life of the pavement should be compensated for by setting the level of the surface course over the new base between 1 mm and 3 mm higher.

4.5 Kerbs and restraints

4.5.1 Kerbs and perimeter edge restraints

*COMMENTARY ON **4.5.1***

Kerbs, edgings or edge restraints are necessary for all free edges of unbound pavements. Free edges are those not bounded by a stable fixed structure such as a wall or adjacent area of bound paving.

Kerbs and edgings may also be used with bound pavements.

The maximum distance between intermediate restraints is usually not greater than 10 m.

Kerbs and edgings should be not less than 300 mm in length unless manufactured as intentionally shorter units, such as small unit kerbs.

Kerbs, edgings, edge restraints and intermediate restraints should be laid on a fresh concrete windrow or a hardened race with mortar and haunched with concrete as soon as possible after installation.

The depth of the concrete windrow or race should be not less than 100 mm.

Haunching should extend up to at least half the depth of the kerb units but not higher than within 60 mm of the adjacent pavement surface or the depth of the surface course below the top of the kerb unit. The width of haunching should be not less than 100 mm.

Laying tolerances, line and level, should be in accordance with Clause **12**.

Kerbs and edgings laid to a radius less than 10 m should be ordered as preformed, radiused units or formed using straight units not greater than 300 mm in length.

Where possible, the ends of kerbs and edging units should be cut in order to maintain close joints (2 mm to 5 mm). At no point should kerbs and edging units be butt jointed.

Where wider joints are unavoidable, mortar should be used to fill joints.

Any joint to be filled with mortar should be not less than 6 mm and not greater than 15 mm in thickness.

4.5.2 Intermediate restraints

*COMMENTARY ON **4.5.2***

Intermediate restraints are positioned within an area of unbound paving to restrain lateral movement and limit creep of the surface course. They may comprise flush kerbs and channels or feature matching or complementary paving units.

Where more than one intermediate restraint is required, they are generally spaced evenly across the pavement. The maximum distance between intermediate restraints is dependent upon slope and laying pattern.

Intermediate restraints should be provided within areas of unbound paving where a steep slope or trafficking might otherwise result in lateral creep of the paving units.

The distance between an intermediate restraint and another intermediate or edge restraint is typically 6 m to 10 m and the maximum distance should not exceed 15 m.

Where paving is laid to a slope of 1 in 20 or steeper, intermediate restraints should be positioned more closely together.

NOTE Intermediate restraints may comprise one or more rows of bound paving units or a fixed kerb or channel that is laid with the surface flush with the surrounding paving.

4.6 Installation of kerbs and restraints

Where kerbs and restraints are to be installed, the recommendations of Clause ***9*** should be followed.

4.7 Construction of sub-base and base

For the construction of sub-base and base, the recommendations of Clause **7** should be followed.

4.8 Construction of an unbound pavement

Where an unbound surface course is to be constructed, the recommendations of Clause **14** should be followed.

4.9 Construction of a bound pavement

Where a bound surface course is to be constructed, the recommendations of Clause **15** should be followed.

5 Pre-construction phase for work in all traffic categories

5.1 Review of design and specification

The design and specification should be appropriately reviewed for suitability of intended use and compliance with BS 7533-101 or Clause **4**.

Where a design deviates from the recommendations of BS 7533-101 or Clause **4**, it should be verified that any alternative is demonstrated to achieve an equivalent or better outcome and the details are recorded.

5.2 Construction drawings

It should be confirmed that construction drawings agree with the written design and specification. Any discrepancies should be brought to the attention of the project manager.

5.3 Risk assessments

*COMMENTARY ON **5.3***

A risk assessment of the workplace is required to:

a) *identify what could cause injury or illness (hazards);*

b) *determine how likely it is that someone could be harmed and how seriously (the risk); and*

c) *take action to eliminate the hazard, or if this is not possible, control the risk.*

Risk assessments should be constantly reviewed and updated as required and made available to the project manager.

5.4 Storage and disposal of waste

All contaminated materials should be stored separately and liquid waste and rain water draining from stored waste should be prevented from running into adjacent ground and water courses.

NOTE Waste can only be removed from site by a carrier registered for the licenced disposal of waste.

5.5 Construction programme management

A construction programme, e.g. a Gantt Chart, should set out the sequences, milestones, hold points and key dates of the construction process in a logical format.

The construction programme should be regularly reviewed, updated to show progress against the timeline and reported to the project manager.

Lead times for the provision of critical services such as statutory undertakers, traffic management and site access should be taken into account.

5.6 Method statement

5.6.1 General

Prior to the start of works the contractor should produce a method statement which lists the tasks to be carried out and the checks they intend to carry out in order to satisfy themselves that the works have been carried in accordance with the design.

The method statement should be kept up to date.

The method statement should be made available to the project manager and address some or all of the topics in **5.6.2** to **5.6.7**.

5.6.2 Hold points

A list of hold points should be prepared comprising a process or series of processes which clearly defines the completion of a stage in the works and beyond which work cannot proceed without approval.

When work completed at a hold point is found to be contaminated or otherwise substandard, all faults should be rectified before work proceeds to the next stage.

5.6.3 Personnel and welfare

The method statement should clearly identify the project manager.

Where multiple teams are working on a project, each team should include a person who is responsible for the immediate organization of that team and who reports to their immediate superior or directly to the project manager.

NOTE Users of this part of BS 7533 are advised to consider the desirability of treating a skills card issued by the Construction Skills Certification Scheme (CSCS) or other suitable scheme, such as NHSS 30 (National Highways Sector Scheme 30), as recognized qualifications for relevant skills.

Welfare facilities should be provided.

5.6.4 Equipment

The equipment selected for use should be appropriate, well maintained and appropriately certified.

The selection and location of equipment for the mixing of mortar should be carefully reviewed. The relative risks and inconvenience of siting a mixer remotely and transporting fresh mortar to the position of installation should be balanced against a mixer and raw materials being located at the position of installation.

NOTE 1 Specialist hand tools and mechanised equipment are described in the Technical Training Manuals for unbound and bound Modular Paving prepared for National Highways Sector Scheme 30 [3], [4] and [5].

NOTE 2 Guidance on compaction equipment is given in Annex H.

5.6.5 Materials

Where applicable, materials should conform to the requirements of the project specification. If the specification is either incomplete or unclear, the matter should be brought to the attention of the client.

If required, reference samples of paving units and visible components should be provided, such as cured jointing mortar, comprising an adequate number of a sufficient size to indicate the general appearance of the finished work. The recommendations of Annex G should be followed for visual inspection and acceptance of reference samples.

NOTE The client or designer may request a sample panel for the purpose of comparing and evaluating the appearance of the completed pavement as designed and specified.

5.6.6 Lead times

Allowance should be made for lead times when ordering materials, especially for natural stone, manufactured materials which are not standard, and stock products that are being manufactured exclusively for the project.

5.6.7 Acceptance and storage of materials

The supervisor should verify that materials are stored safely and maintained in suitable conditions to prevent damage and deterioration.

5.6.7 Recording and correcting defects identified during the installation

Records should identify and describe any defects identified during installation and confirm that the remedial works carried out are acceptable.

5.7 Inspection and test plan

Where the design and execution of a project includes an inspection and test plan, this should include the following:

a) checking set-out for preparatory groundworks;

b) checking for utilities prior to excavation;

c) checking suitability of subgrade/formation level;

d) checking any geosynthetic layers;

e) checking subgrade drainage;

f) checking capping/improvement layers;

g) checking the sub-base and base, in particular for contamination;

h) checking kerbs and edge or intermediate restraints;

i) checking sub-surface drainage;

j) checking surface course levels and falls;

k) checking laying pattern and joint widths; and

l) checking cleanliness of completed surface course.

The design specification should be checked to ascertain the requirements to be met and the standards to be followed.

The person or laboratory sampling and testing materials should be identified and the frequency of testing should be recorded.

5.8 Site investigation

5.8.1 General

The contractor should carry out a sufficient site investigation to validate the design information provided.

5.8.2 Trial holes and ground conditions

In order to assess the condition of the exposed subgrade, trial holes should initially be excavated to the proposed construction depth:

a) a minimum of two trial holes should be excavated for a site of 100 m² or less; or

b) a minimum of one trial hole per 50 m² should be excavated for a site greater than 100 m².

The location of trial holes should include low points within the area to be paved.

If at the base of a trial hole, standing water, topsoil, loose backfill or any unexpected material is detected, the depth of the trial hole should be increased until a suitable subgrade is identified, up to a maximum of 500 mm.

A simple method of assessing CBR when following the recommendations of Clause **4** in traffic categories 3 and below is given in **5.8.3**. When this test is applied:

1) if an imprint of 2 mm or less is formed, a CBR of approximately 5% may be assumed and a sub-base layer should be added only if required;
2) if an imprint of 2 mm − 4 mm is formed, a CBR of approximately 2.5% may be assumed, and the required depth of sub-base should be added; and
3) if an imprint greater than 4 mm is formed, the design process given in BS 7533-101 should be followed.

NOTE 1 In all situations, the subgrade CBR may be estimated from the soil properties as given in Annex B.

NOTE 2 For large areas of paving it may be economical to employ a laboratory technician to carry out a CBR test in accordance with BS 1924-2 [light weight deflectometer (LWD)].

If the CBR or stiffness is found to be greater than the design requirement, the thickness of the layers above should not be reduced.

Only where the site investigation confirms and validates the design provided, should work proceed.

If the site investigation fails to confirm the design requirements for CBR or stiffness, the contractor should inform the client and seek further instructions.

5.8.3 Footprint test for subgrade (CBR)

Tread firmly upon dry ground, wearing a conventional construction industry safety shoe or boot and determine the depth of the imprint.

NOTE Further information on assessment of the subgrade is given in Annex B, Table B.1.

5.8.4 Evaluation of existing materials for overlay construction

Any existing granular, bituminous, cement bound or concrete pavement structural materials should only be retained in situ if they are in a suitable condition, as determined by the following assessments.

a) Unbound granular material should be assessed for layer thickness and firmness. Thickness should be determined by excavating trial holes. Layers of granular material should be rolled to check firmness and any material found to be soft should be removed and replaced.
b) Concrete, cement bound and bituminous materials should be assessed for layer thickness, cracks and loose material. The following are unsuitable for overlaying and should be removed:
    1) concrete, cement bound and bituminous layers less than 80 mm thick;
    2) instances of cracks sufficiently wide and deep to allow water ingress; and
    3) loose and friable material considered unsuitable for recompaction.
c) Backfilled trenches should be identified and examined as follows.
    1) Trenches that have been excavated through a bound base layer and backfilled with unbound material should be excavated and filled with a bound material similar to and compatible with the existing base.
    2) Trenches that have been excavated through a bound base layer and backfilled with bound material that has visibly subsided or has been backfilled with a material different in nature to the existing base should be carefully examined and if doubt exists, should be excavated and filled with a bound material similar to and compatible with the existing base.

NOTE If the number of trenches is extensive it might be more economical to increase the depth of excavation to incorporate replacement of an existing base layer.

If the thickness of existing construction materials found to be suitable is equal to or exceeds the required thickness of sub-base required, it may be retained.

If the thickness of an unbound material layer is less than required, it should be topped up with fresh material and compacted only after the existing surface has been loosened, to create a binding connection between existing and fresh material.

If the thickness of a bound material is less than required, it should only be topped up if the thickness of the fresh material being applied is greater than 2.5 times the largest particle size. If this is not possible the substandard bound material layer should be removed.

Where the addition of fresh material requires that the pavement surface level is raised and this is not possible, all existing substandard material should be removed.

5.8.5 Acceptance of overall construction design

Only where the site investigation confirms and validates the design provided, should work proceed.

6 Site set out

6.1 General

*COMMENTARY ON **6.1***

Methods used to set out the edge restraints and laying patterns depend on the size and complexity of the scheme.

When setting out a bound surface course over a concrete base, care should be taken to align movement joints in the concrete base with similar types of movement joint in the surface course above.

NOTE A contraction joint in a concrete base may be overlain with either a contraction joint or a low modulus joint in the surface course.

Where a low modulus expansion joint in the surface course does not align with the laying pattern of paving units and a design detail setting out edge restraint to small paving units has not been provided, the designer should be consulted.

6.2 Setting out datum point, lines and levels

Design datum points should be set out and checked against immovable permanent features such as benchmarks, existing monuments and existing building corners.

Design levels should be checked against existing permanent features such as adjacent building damp proof course levels and fixed adjacent surface levels such as footways, roads, door thresholds and drainage points.

When all datum points and design levels have been confirmed, string lines should be connected and sighted through to prevent unforeseen errors in design or initial setting out resulting in intermediate levels and surface gradients which do not conform to the design.

NOTE 1 Edge and intermediate restraints form important datum levels for the pavement surface.

Lines and levels should be checked regularly during construction, as construction proceeds.

NOTE 2 Drainage fittings and edge and intermediate restraints provide a guide to levels and falls. Typical examples of restraints are kerbs, channels and established structures.

7 Construction of sub-base and base for all traffic categories

7.1 Sub-surface utilities

A check should be carried out to determine whether or not sub-surface utilities are present within the expected depth of the pavement excavation.

When relying on drawings and written information for the location of sub-surface utilities, the location should be confirmed where possibly by electronic scanning.

NOTE Guidance is given in the Health and Safety Executive publication HSG47 [6].

Prior to machine excavation, all services should first be exposed by hand digging.

7.2 Prior to installation

Prior to installation the surface of the subgrade should be closed and compacted, and checks carried out to confirm that it does not move under construction plant trafficking and is free from ridges, cracks, loose material, potholes, ruts or other defects. Defective areas should be removed and replaced.

The CBR should be checked to confirm conformity to the design requirement.

7.3 Installation procedure

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

Preparation and installation should be in accordance with the design provided.

Reinstatements should be made in accordance with **17.4**.

NOTE 1 The base layer might comprise only the sub-base material in some low traffic category designs.

Where a geogrid is specified to enhance foundation stability, it should be installed in accordance with the manufacturer's instructions.

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

a) the surface levels of subgrade (formation), sub-base and base are as designed and within the tolerances given in **12.3**, Table 5;

b) the longitudinal falls and the cross-falls of the completed pavement have been introduced into the pavement at these levels and not within the laying course;

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

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

e) the surface of the sub-base and base (if present) is sufficiently and uniformly tight and closely graded to prevent laying course material migrating into the surface during construction and use.

   NOTE 2 This may be achieved by blinding the surface of the base with crushed rock fines not greater than 4 mm.

Work should not take place when any of the pavement materials are waterlogged and/or frozen.

Where the sub-base or base contains cement, and is not to be covered by another pavement course within 2 h of compaction, it should be protected from moisture loss or heavy rain, e.g. by covering with waterproof 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 be allowed to elapse before mechanical vibratory compaction of the bedding or surface takes place, to prevent damage.

7.4 Sub-base and base compaction

Before compaction, sub-base materials should be moist but not saturated. Materials should not be compacted while frozen or dry.

NOTE 1 With the correct sub-base material, the sub-base layer is unlikely to become too wet as it is free draining. Material that is too dry is difficult to compact thoroughly.

If there is evidence of fine and coarse aggregate fractions separating during transportation and laying (segregation), the material should be remixed on site using a loading shovel and adding water where necessary.

Unbound sub-base, base and bound base materials should be installed and compacted to the layer thickness designed for the subgrade or sub-base CBR or stiffness modulus. If the CBR or stiffness is found to be equal to or higher than the design requirement, no change should be made; if it is found to be less, the designer should be consulted.

Only materials and mixtures recommended in Annex E, **E.1**, should be used in the unbound base and sub-base layers for pavements.

NOTE 2 Guidance on the compaction equipment and the number of passes for the relevant plant is given in Annex H.

NOTE 3 The designer might have specified a requirement for CBR/stiffness or density measurements of the installed layers.

Where the specified compacted layer thickness exceeds 225 mm, the material should be laid in more than one layer. The thickness of any layer being compacted should be not less than 2.5 times the maximum aggregate particle size.

NOTE 4 The specified compacted layer thickness may be made up of more than one layer.

Cement bound base material should be compacted within 2 h of manufacture and not be allowed to dry before being installed.

A dense asphalt concrete base should be compacted while still hot, i.e. compaction should be completed before the temperature of the material falls below 90 °C. If the temperature of the material falls below 90 °C, the material should be removed and replaced.

On completion of compaction and immediately before overlaying, the surface of any layer of material should be closed and compact, not move under construction plant trafficking and be free from ridges, cracks, loose material, potholes, 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.

If the sub-base or base has been used by site traffic, the surface should be examined and any remedial works carried out to verify correct levels and absence of surface contamination.

On completion of compaction, the surface level of the layer should be checked to determine whether it conforms to the design levels and is within the tolerances in **12.3**, Table 5. If remedial works require the removal of material, the top 50 mm of the layer should be scarified, and material added or removed as required. Laying course material should not be used to adjust the level of base or sub-base.

7.5 Checks on thickness of sub-base and base

Checks on levels should be carried out as work proceeds. The resulting measurements should be used to demonstrate compliance with the design.

8 Installation of waterproofing layer for structural slabs

*COMMENTARY ON CLAUSE **8***

Waterproofing layer is sometimes referred to as a damp proof membrane (DPM).

Any regulating layer required on a structural slab should be installed before application of a waterproofing layer, as shown in Figure 2.

Where a regulating layer is installed, material having strength not less than that of the concrete should be used, such as a proprietary bedding mortar or screed material. The minimum and maximum permitted thickness for the laying course and screed materials should be observed.

For bound construction, a non-bituminous waterproofing layer conforming to BS 8102:2022, **8.2.3** (liquid applied membranes), should be used. The materials should be compatible with the bound or unbound bedding material.

The waterproofing layer should be applied to a clean, dust-free surface.

NOTE For unbound construction, where a bituminous waterproofing layer has been specified, a protective layer might be necessary to prevent penetration of the bituminous material by laying course particles.

9 Installation of restraints, kerbs, drainage, and channel units

9.1 General

Kerbs, channels, restraints, and linear drainage units should be laid using one of the following methods, as specified in the design:

a) bedded using mortar onto hardened concrete;

b) set directly onto a windrow of fresh concrete; and

c) adhered to the existing surface layer.

NOTE Examples of kerb, channel and restraint details are given in Annex I.

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

9.2 Jointing kerbs

While mortar jointing between kerb units of natural stone and concrete is generally unnecessary, the units when installed should not be touching. The unfilled gap between units should be not less than 2 mm, to avoid potential chipping and spalling during installation or in service.

Mortar jointing should be provided between channel units of natural stone and concrete in order to prevent water ingress where the structure beneath is not permeable.

Clay units should be laid with a 10 mm joint between adjoining units.

9.3 Bedding on a concrete edge beam or base using mortar

*COMMENTARY ON **9.3***

Where concrete is used to form the base, it might be preferable to extend the base concrete to act as an edge beam.

Kerb units should be bedded onto a layer of mortar having plastic consistency.

Mortar that has begun to harden before a unit is laid should be replaced with fresh mortar.

When units are laid over a jointed concrete edge beam or base, joints should continue vertically through the bedding and the joint between kerbs should be not more than 50 mm from the joint in the concrete edge beam or base beneath.

9.4 Laying units directly onto a windrow of fresh concrete

The width of a concrete windrow should be adequate to provide a base for the concrete haunching.

When laying units directly onto a windrow of fresh concrete, the fresh concrete should be adequately constrained where necessary to restrict slumping of the fresh concrete.

Units should be tamped firmly into final position in order to provide adequate contact with and compaction of the concrete.

A concrete haunch should be added only after the windrow has hardened sufficiently to prevent the unit becoming displaced.

9.5 Concrete for installing kerbs and restraints

*COMMENTARY ON **9.5***

Concrete may be delivered to site ready-mixed or be mixed on site. Ready-mixed concrete may be obtained from a volumetric mixer, in which case smaller batches or multiple batches in a single delivery may be arranged.

Concrete and mortar should not be installed in ambient temperatures below 3 °C or above 30 °C.

The quantity of ready-mixed concrete delivered to site should not be greater than can be used within 4 h, depending on the specified strength of the concrete and ambient temperature.

Concrete should be sufficiently stiff to support kerbs and restraints during installation.

Fresh concrete intended for laying kerbs and restraints on a windrow should exhibit a slump of approximately 10%, commonly referred to as a Class S1 concrete slump.

NOTE An explanation of concrete slump and classes is given in Annex C.

9.6 Fixing units to an existing surface

Units that are fixed to an existing surface layer should be bonded to the surface with a suitable synthetic resin compound or proprietary mortar, as specified by the designer.

9.7 Construction details

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

At pedestrian crossing points, dropped kerbs should be laid 6 mm above the channel level at the low side to aid surface water drainage and level with the channel at the high side of the road.

When necessary, the ends of the units should be trimmed in order to maintain the maximum and minimum vertical and horizontal joint width.

9.8 Cutting kerbs and channels to short lengths

Kerbs and channels should be cut to a length not less than half that of the longest unit specified or 300 mm, whichever is the greater length.

Unless it is unavoidable, short units should be placed inboard of the end of a row of kerbs.

9.9 Laying kerbs and channels to a radius

For a design radius of 12 m or less it is unusual to lay straight kerbs and if radiused kerbs have not been delivered, the client should be informed and their advice obtained before work is continued.

Where kerbs or channels have been delivered, having been produced to a specified radius, and it is found that the radius of the units delivered does not agree with the design, the client should be informed, and their advice obtained before work is continued.

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 verify that it follows a smooth curve both horizontally and vertically.

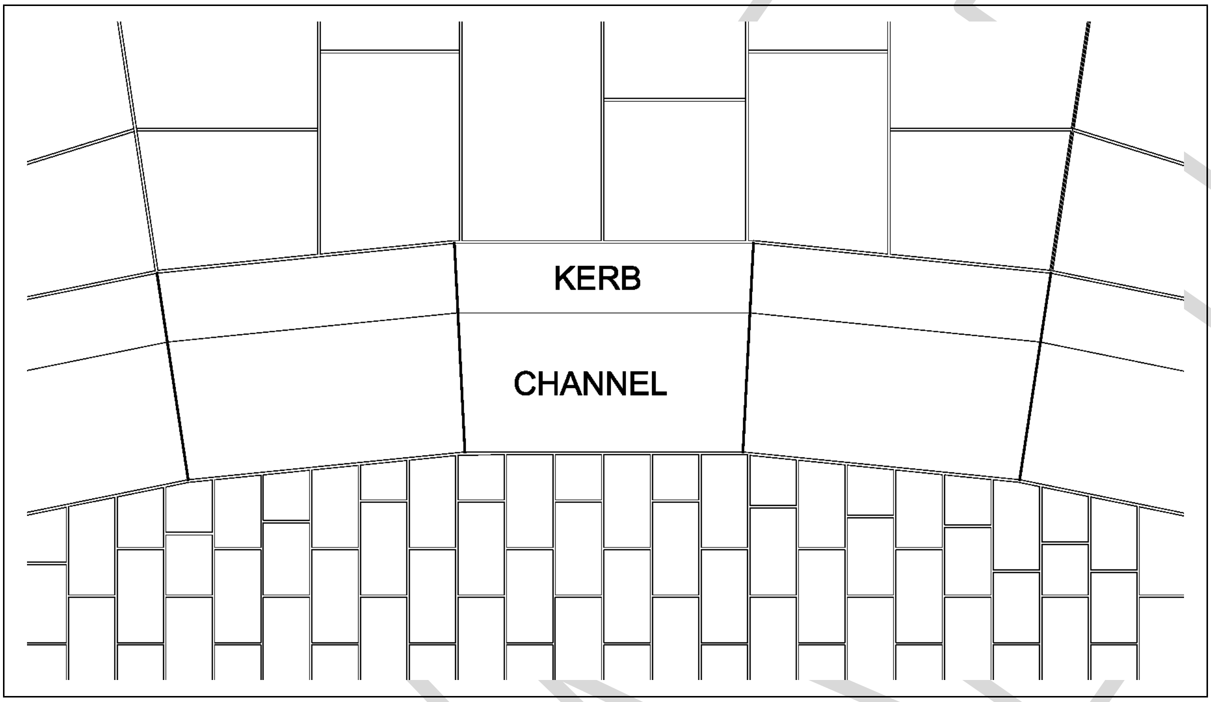
NOTE Kerbs and channels manufactured to a specified radius typically require no adjustment to the end faces in order to maintain joint width within acceptable tolerance.

9.10 Laying straight kerbs and channels to a radius

When aligning straight kerbs and channels to a radius, they should be additionally sighted in, from a number of angles, using temporary support, so that necessary cutting and trimming is made before they are laid.

When laying straight kerbs and channels in adjacent rows to a radius, the joints in each row should be aligned in order to keep the arris of the channel parallel with the face of the kerb (see Figure 3).

Figure 3 – Joints aligned in adjacent rows of straight kerb and channel units laid to a radius



9.11 Trimming the end of straight kerbs and channels to form a radius

The ends of all units should be trimmed in order to maintain the maximum and minimum vertical and horizontal joint width.

When trimming the ends of two adjacent units within a row of kerbs or channels, the degree of taper should be similarly applied to both units.

The ends should be marked prior to trimming once the units have been sighted in by scribing two parallel lines, one each side of the joint, when the final position of the units has been confirmed.

10 Construction of steps

10.1 General

Where there is a risk of water ingress at a higher level, measures should be implemented to prevent moisture entering the bedding mortar and subsequently migrating through the surface of the steps.

*NOTE 1 The use of a DPM (see Clause **8**), brushed or spray applied to the foundation or supporting structure, has been found to be effective in preventing the passage of moisture.*

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

10.2 Surface water drainage

The tread surface of a step should have a fall of not less than 1 in 80 in order to prevent ponding of surface water.

NOTE 1 Whilst the tread surface of a step typically falls towards the nose, where a storm drain channel is present, the tread surface of a step may instead fall laterally towards the storm drain channel.

Drainage fittings and pipework fitted beneath and behind steps should be fully sealed at all joints to prevent water escaping between the drainage point at the point of egress.

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

10.3 Monolithic precast concrete or natural stone steps

10.3.1 General

Construction should start at the base of a flight of steps. The work should either 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.

10.3.2 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.

10.3.3 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 30 mm thick layer of moist mix mortar conforming to **15.8.2.2**.

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.

10.4 Steps clad using modular paving units

The step foundation should be formed in the profile of the step with a concrete having strength class C20/25 or higher.

When the concrete has sufficiently hardened or is otherwise ready for the units, it should be brushed or sprayed with a DPM (see Clause **8**) which will not creep and forms a lasting adhesion bond with the bedding mortar.

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

NOTE 2 Bituminous DPM materials are generally unsuitable.

Bonding mortar should be applied as a slurry to the surface of the concrete or DPM with a thickness of 1 mm to 2 mm immediately prior to the placement of the bedding mortar. The bonding mortar slurry should be fresh and wet when the bedding mortar is placed.

Bedding mortar should be spread out over the fresh bonding mortar. The backs of the units should be primed using bonding mortar slurry to a thickness of 1 mm to 2 mm immediately prior to their placement upon the bedding mortar.

The modular paving units should be primed with slurry (see **15.4.4**) and laid on plastic mix mortar conforming to materials Annex E at a minimum thickness of 30 mm, or as specified in the designer’s details.

10.5 Jointing steps

10.5.1 General

Where steps are jointed using mortar, low modulus expansion joints should be installed at intervals of not more than 6 m if the width of the flight exceeds 6 m.

10.5.2 Jointing steps with mortar

Mortar jointing between monolithic units of natural stone and concrete is generally unnecessary for structural purposes, but where used 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 materials Annex E, 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, after which a liquid slurry grout conforming to materials Annex E should be applied to the open horizontal joint.

c) 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.

11 Sub-surface drainage

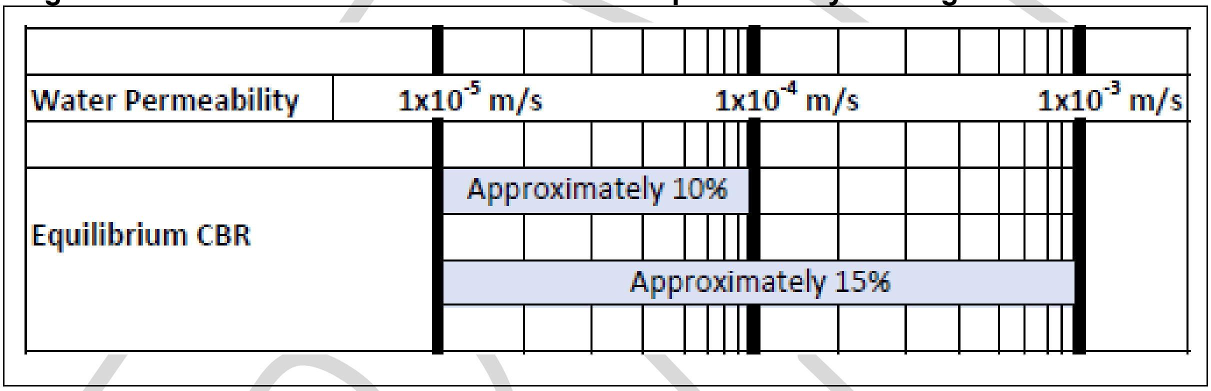
11.1 Formation level

If the permeability of the formation level surface is less than 5×10^{-5} m/s, in order to prevent the sub-surface layers becoming saturated provision should be made for sub-surface water to drain laterally to an appropriate drainage system.

NOTE 1 The permeameter test described in Annex A may be used to assess and verify permeability; alternatively, the approximate permeability of an exposed subgrade or formation may be assumed to be adequately permeable if an equilibrium CBR of 10% or more is found (see Figure 4).

NOTE 2 Examples of sub-surface drainage may be found in Annex J.

Figure 4 – Correlation between CBR and water permeability of subgrade/formation



11.2 Surface course

11.2.1 For a surface course laid using unbound construction, the base layer should be sufficiently water permeable to prevent the bedding layer becoming saturated.

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

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

11.2.3 Prior to installation of the surface course, the contractor should verify that the recommendations of **11.2.1** and **11.2.2** have been followed.

11.3 Bound surface course

Small amounts of water permeate the bedding layer, so the pavement design should provide for moisture egress at perimeter or secondary subsurface drainage points. The contractor should take care not to obstruct such features.

12 Pavement construction falls and tolerances

12.1 Surface gradients

Where the design surface gradients deviate significantly from the recommended minimum falls in Table D.1, the installer should seek confirmation from the design falls with the designer and project manager.

12.2 Gradients of subsurface layers

Where an impermeable base sits beneath a permeable laying course, the gradient of the base should replicate the gradient of the surface course or, where this is not the case and especially if the base layer has no gradient, a gradient should be provided where necessary using a regulating layer or screed.

12.3 Level tolerance of pavement layers and pavement surface regularity

The tolerance of the surface levels of the different layers of a pavement should be not greater than the deviations given in Table 5.

If the application of the maximum surface level deviations results in the thickness at any point of a layer being reduced to less than the minimum permitted design thickness, the installer should inform and obtain advice from the designer and project manager.

NOTE 1 If compliance with surface level deviations results in the thickness of the bedding or laying course being reduced to less than the minimum permitted design thickness, the level of the pavement surface may be raised, but only with the designer's approval and having checked that immovable levels such as thresholds are not compromised.

Table 5 – Tolerance of the surface levels of the different layers of a pavement

Layers of pavement	Maximum permissible deviation from the design level mm
Subgrade/formation	+20 –30
Sub-base	+5 –10
Base	+5 –10
Laying course	+10 –5
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 6.

Where possible, the tolerances for surface course regularity should be as given in Table 6. Where this is not possible, e.g. when laying riven face units, the minimum practicable tolerances should be adopted.

Table 6 – Surface regularity of the surface course

Measure of surface regularity	Maximum deviation
Flatness of pavements	≤10 mm under 3 m straight edge

Difference in level at the joint of adjacent paving units	≤2 mm

NOTE The presence of minor localized ponding on a riven face unit might still occur due to the nature of the product.

The finished 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 when measured on the paving unit surface, not at the base of the chamfer.

13 Construction of a modular pavement surface course

13.1 General

Where paving materials contain variations in appearance, the units should be distributed evenly across an installation by intermingling units from several batches, so the unique characteristics are dispersed. The ongoing installation should be inspected periodically to confirm even dispersal across the entire installation, resulting in a consistent appearance.

The delivery of consecutive single pallet deliveries to a multi-pallet project should be avoided. The contents of a single pallet of product should be mixed before laying.

Where necessary, units should be sorted into batches in order to enable the consistent alignment, pattern and bond of the completed surface course.

13.2 Setting out

13.2.1 General

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

NOTE 1 In unbound construction, laying patterns are crucially important to the ability of the surface to achieve interlock and resist lateral forces.

NOTE 2 Examples of laying patterns for precast concrete and clay paving units are given in Annex L. Examples of laying patterns for natural stone setts are given in Annex L.

Details of laying patterns should be provided by the designer in accordance with BS 7533-101 and should be planned and agreed before laying begins.

13.2.2 Rectangular paving units laid in stretcher bond pattern

For cropped setts, for which straight line bond patterns have been requested, the paving units should be graded into appropriate sizes and the nominal width of rows varied in order to accommodate the full range of paving unit widths while not exceeding:

a) the maximum joint width for unbound construction given in Table 6; or

b) the maximum joint width for bound construction given in the design of, if following the guidance in Clause **4**, the maximum width stated in Table 5.

When laying paving units in straight rows, the joint should display a straight line along its centre rather than trying to achieve a line along the edges of the paving units.

When rows start and run at right angles to the pavement edge, alternate rows should begin with units of different lengths in order to gain the necessary stagger in the joints without using small or unsightly pieces. If the units are generally square in plan, alternate rows should start with pieces of length approximately 1.5 times the width. If the units are rectangular in plan having length approximately equal to twice the width, alternate rows may be started with a unit which is square. In both situations allowance should be made for the joint width if accurate alignment is required.

For paving units having an aspect ratio not greater than 3:1, the distance between joints in adjacent rows should be not less than one third of the width of the narrower of the two adjacent rows of paving units.

For paving units having an aspect ratio greater than 3:1, the distance between joints in adjacent rows should be not less than one quarter of the length of the longer unit in two adjacent rows of paving.

When laying natural stone paving units having randomly varying lengths, no joints should align across any 3 rows of paving units.

13.2.3 Rectangular paving units having varying or random lengths

When rows are laid with units of varying lengths:

a) the paving units at the end of a row should be cut such that the resulting area of the cut unit is not less than that of the smallest unit permitted by the design;

b) if a) cannot be achieved, an inboard cut should be used where appropriate; or

c) no two joints should align within any three rows unless the design specifically requires it.

NOTE Natural stone paving is commonly supplied in variable lengths and both precast concrete and clay paving units may be supplied in a range of different lengths.

13.2.4 Rectangular units not aligning with an edge at 90°

When cutting a paving unit in order to fit with an edge which is not aligned at 90° to the rows of paving units, the paving unit should retain a minimum of four sides and the angle formed by any two sides of the paving unit should be not less than 45°; the resulting plan area of the unit should be not less than that of the smallest unit generally permitted by the design.

NOTE 1 This might require the provision of a number of larger units, to be laid as supplied and from which irregular pieces can be cut.

NOTE 2 Additional material may be ordered in order to allow for wastage when cutting.

NOTE 3 Complimentary paving units, such as the five-sided “Bishop’s Mitre”, may be used to resolve problems of alignment.

NOTE 4 The shape of the area to be laid may be changed in order to achieve an acceptable result if this is not specified by the designer.

13.2.5 Units laid in arched patterns

When laying segmental arch or decorative arch patterns, a range of suitably sized paving units should be selected to achieve that the desired pattern is achieved. A proportion of the material ordered should contain a sufficient proportion of trapezoidal and undersized units to enable the setting out of an arch.

NOTE 1 Small paving elements nominally square in plan and used to form arch patterns are commonly referred to as cubes, cube setts or mosaics (see Figure L.7).

NOTE 2 It is permitted to cut cube setts into triangular shapes when forming arched patterns.

13.2.6 Cutting of rectangular paving units to form curved rows

Where rectangular paving unit are cut to form curved rows, cuts made to opposite ends should be mirrored, adopting the same angles at each end of the paving unit.

If as a result of following the design or guidance on offset, the maximum joint widths exceed those recommended in **13.22**, this should be referred to the client/designer.

13.2.7 Irregularly shaped interlocking paving units

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

13.2.8 Complementary paving units

Where specially shaped proprietary units are available, these should be used. Where they are not available, units should be cut to shape and size from available, larger paving units or suitable material.

NOTE Examples of complimentary paving units are shown in Annex L.

13.3 Cutting of paving units around obstructions

13.3.1 General

Where it is necessary to cut paving units at edges and around obstructions interrupting the pavement surface, such as drainage features and street furniture:

a) paving units should be cut in accordance with **133** such that the resulting joint width is consistent with the general design requirements; and

b) complimentary paving units should be used in accordance with **13.2.8**.

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

If the use of infill concrete is unavoidable, it should be installed in accordance with **15.9**.

13.3.2 False joints

If the design requires visible joint lines to continue across a paving unit where for technical reasons it is not possible to install smaller units, any groove cut in the surface of a paving unit to form a false joint should not form a recess deeper than 3 mm. False joints should be used with caution as the paving unit is significantly weakened along the line of the recess.

14 Construction of an unbound surface course

*COMMENTARY ON CLAUSE **14***

Additional information on laying paving units in unbound construction is available in "National Highways Sector Scheme 30 for Modular Paving - Concrete or clay pavers, concrete or stone flags or sawn stone setts, laid on an aggregate laying course", Technical Training Manual - Course Framework [3]; and National Highways Sector Scheme 30 for Modular Paving - Unbound modular paving units laid on screeded/levelled bed of sand/fine aggregate or laid on individually prepared bed of crushed Igneous Rock [4].

14.1 Preparation

14.1.1 General

The laying course should be laid on the bound or unbound base provided. The laying course material should not be used as a regulating course or to achieve falls.

The laying course material used should have the properties and grading of the recommended given in Annex E, Table E.2, for the relevant site category.

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

Where the laying course is found to be too thin, the level of the base should be reduced by removal of material.

NOTE 2 Where previous experience of a particular laying course material is lacking, a small trial area may be constructed in order to determine the amount of material surcharge needed to compensate for the decrease in thickness arising from the compactions that occur during the construction of a pavement.

*NOTE 3 Excessive thickness of laying course outwith the tolerances in **14.1.2** can lead to deformation of the surface under traffic. Inadequate laying course thickness can lead to cracked and broken units under traffic.*

NOTE 4 Where the base layer comprises bound materials, such as concrete and asphalt, the process of reducing the level of the base is onerous and expensive; an alternative course of action is to raise the level of the pavement surface if permitted by the designer.

14.1.2 Tolerances and levels for unbound surface construction

When laying concrete, clay or sawn sided stone paving units on a bound or unbound base, the target laying course thickness for the unbound bedding course after paving unit compaction should be 30 mm.

When laying cropped or riven stone paving units on a bound or unbound base, the target laying course thickness for the unbound bedding course after paving unit compaction should be 40 mm.

In both cases, the minimum thickness of laying course beneath the deepest paving unit should not be less than 25 mm after paving unit compaction.

Where the level of the base is found to be too high, base material should be removed in order to achieve the necessary minimum thickness of laying course.

Where the level of the base is found to be too low, the level should be adjusted by the addition of material having the same mechanical properties as the base with the following minimum thickness, as appropriate:

a) cement bound material: 75 mm or 2.5 × maximum aggregate size, unless an approved proprietary cementitious product is used;

b) unbound material: 75 mm or 2.5 × maximum aggregate size; and

c) asphalt material: 2.5 × the maximum coarse aggregate size in the asphalt.

If necessary, some base material should be removed in order to achieve the necessary minimum thickness of additional material.

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

If any disturbance of the laying course material by pedestrian or wheeled traffic occurs prior to placing paving units, re-screeding or re-compacting areas of laying course material, uniformity of compaction should be achieved after laying.

NOTE 2 The minimum removal depth of unbound material may include in-situ material loosened and added to prior to compaction.

14.1.3 Installation over an impermeable base

Suitably protected weepholes should be present or other drainage installed prior to installation of the laying course where the base is impermeable.

14.2 Installation of laying course for unbound surface construction

14.2.1 General

Measures should be implemented to prevent any soil, fine material and other materials that arise during construction from contaminating the surface of the base. If the base becomes contaminated, appropriate corrective action should be taken.

NOTE Corrective action typically involves removal and replacement of contaminated material.

14.2.2 Moisture content

For unbound pavements, when the laying course is being prepared, the laying course material should be moist without being saturated; it should show no free water.

NOTE 1 If the prepared laying course 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 Covers may be used to control the moisture content of a stockpile.

14.2.3 Precast concrete, clay and sawn sided stone paving units

One of the following methods of screeding the laying course 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 the type of product, the product's permissible manufacturing tolerance and the surface laying pattern.

a) Pre-compacted laying course

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, gives the final target laying course thickness.

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

NOTE 3 Vibrating plate compactors as described in the lightest class in Table 4 have been found suitable for compacting the laying course.

b) Uncompacted laying course

Spread the material loose in a uniform layer. Screed to a thickness that, after the paving blocks have been laid and compacted in accordance with Table 4, gives the final target laying course thickness.

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

If there is significant variation in the thickness of the units, minor disturbance of the surface is permissible by raking to accommodate any thickness variations in the paving units, or method b) should be used.
For clay paving units and mechanically laid units, method a) should be used.

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

After careful removal of the screeding rails, the disturbed area should be filled and lightly compacted with laying course material.

The area of laying course prepared should 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 laying course material should be protected and not left exposed overnight.

If any disturbance of the laying course material by pedestrian or wheeled traffic occurs prior to placing paving units, re-screeding or re-compacting areas of laying course material, uniformity of compaction after laying should be achieved.

14.2.4 Cropped and riven paving units

The laying course for cropped and riven paving units should be installed as the laying of the paving units progresses.

14.3 Installation of paving units for unbound surface construction

14.3.1 Precast concrete, clay and sawn sided stone paving units

Precast concrete, clay and sawn-sided stone paving units should be placed on the prepared laying course in the nominated pattern. An order of laying which maintains an open laying face should be followed. The first row of paving units 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 achieves the surface level tolerances and surface regularity given in Table 4 and Table 5.

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 pavement.

On slopes, paving units should be laid commencing from the bottom, working in an upwards direction, when possible.

NOTE 1 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 2 Suitable curved units might be available as well as circular patterns and feature work details from some manufacturers.

NOTE 3 It might be necessary to develop and implement laying methodologies to compensate for unit dimensional tolerance in order to achieve the necessary joint spacing is achieved.

14.3.2 Cropped sided paving units

The laying course material should be spread loosely and adjusted for each paving unit individually such that, after each paving unit is tamped into position by hand, the correct line and level including surcharge is achieved. When hammering the setts into position the degree of compaction should be as uniform as possible.

Paving units should be laid with joint widths given in Table 7.

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 Annex E, **E.5.3**, should be used.

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

14.3.3 Joint widths for unbound surface construction

*COMMENTARY ON **14.3.3***

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).

With the exception of cropped-sided setts and paving units with nibs, modular paving should not be butt jointed (i.e. in direct contact with adjacent modular paving unit).

NOTE 1 This prevents potential chipping and spalling of paving unit arrises.

If a paving unit features nibs or spacers are used, these should not be relied on to maintain a consistent laying pattern and joint widths in accordance with Table 7.

NOTE 2 Where the paving units do not have nibs, purpose-made spacer units may be used.

Paving units should be laid with a joint width given in Table 7.

Table 7 – Joint widths for unbound surface construction

Paving unit	**Joint width** mm
Concrete block paving units	2 to 5
Clay paving units	3 to 6
Sawn stone slabs and concrete flags	2 to 5
Stone slabs with fettled edges	6 to 12
Cropped stone setts 100 mm or less in width	0 to 10
Cropped stone setts more than 100 mm in width	0 to 15

14.4 Compaction procedure

14.4.1 General

Full, continuous support should be provided to all perimeters of freshly laid paving units prior to compaction.

Paving units laid adjacent to structural features such as edge or intermediate restraints, drainage fittings, kerbs and channels only be compacted into the laying course when the concrete supporting those features has reached design strength.

14.4.2 Temporary restraints in unbound surface construction

During compaction of an unbound pavement surface course, temporary restraints should be installed when needed to restrict lateral movement of the paving units.

Temporary edge restraints should be secured so that they do not move under load.

NOTE 1 Temporary restraint is 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 could 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.

14.4.3 Initial compaction of paving units into the bedding layer

Initial compaction of the paving units into the laying course should occur only when the surface of the pavement is free of debris and the joints have filled.

14.4.4 Final compaction of paving units into the laying course

Prior to joint filling, the pavement surface should be checked to verify that:

a) the surface is free of debris;

b) the surface level tolerance conforms to Table 5;

c) the flatness of the pavement conforms to Table 5;

d) the difference in level at the joint of adjacent paving units conforms to Table 5;

e) joint width is consistent;

f) joints are correctly aligned; and

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 in accordance with **15.5.2**, as appropriate.

The filling of joints with dry sand should not be attempted in damp conditions.

The filling of joints by washing in sand should only be attempted if the laying course material is free-draining and sub-surface drainage provisions are adequate to prevent saturation of the laying course.

A vibrating plate compactor with the minimum and maximum sizes recommended in Table 4 should be used to fully bed the paving units into the laying course material.

Additional jointing material as described in Annex E, **E.5**, 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, for which 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 pavement, other than an area within 1 m of a laying face, should be compacted at the completion of the day’s work.

14.5 Joint filling after compaction of paving units into the laying course

The joints between paving units should be topped up prior to secondary compaction.

14.6 Secondary compaction of the surface course

In areas of cropped/cleft natural stone setts and large element paving with wide joints, a fine joint topping material conforming to **E.5.3** should be applied, in order to further stabilize the joint filling and to reduce or prevent water ingress.

The fine topping aggregate 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.

NOTE 1 It is generally 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.

The 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 2 The surface course might require topping up of joints and further compaction using a plate compactor to completely fill joints with the jointing material.

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

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

14.7 Construction in adverse weather conditions for unbound surface construction

Paving should not be carried out in freezing conditions.

In wet weather conditions, units should not be laid on saturated laying course material.

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

14.8 Additional work after early trafficking for unbound surface construction

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 loss of jointing material from between the paving units, which could adversely affect the performance of the pavement.

Fine topping material applied to help stabilize unbound joints should be crushed igneous rock or carboniferous limestone, specified as 1 mm to dust, with not less than 45% passing the 0.063 mm sieve (see Annex E, **E.5.3**).

NOTE 1 In time, detritus will accumulate in the joints, tending to seal and stabilize them.

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

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

NOTE 2 This type of treatment can prevent the erosion of unbound jointing materials by the use of vacuum sweepers and high pressure water cleaning.

NOTE 3 Chemical joint sealers can affect the colour of the pavement and its slip/skid resistance. They might require ongoing maintenance during the life of the pavement.

15 Construction of a bound surface course

*COMMENTARY ON CLAUSE **15***

Additional information on laying paving units in bound construction is given in "National Highways Sector Scheme 30 for Modular Paving, Training manual for the installation of Concrete or clay pavers, concrete or stone flags or sawn stone setts, laid on and jointed with mortar" [5].

15.1 Movement joints in bound surface construction

15.1.1 General

*COMMENTARY ON **15.1.1***

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

Movement joints are typically provided at perimeters, around fixed points of restraint (e.g. manholes, columns, building facades), at significant changes in slope, and within large areas of pavement.

Where differential vertical movement is anticipated, a low modulus movement joint should be provided.

NOTE Examples of movement joints are given in Annex J.

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

15.1.2 Contraction and day joints

*COMMENTARY ON **15.1.2***

Contraction joints are typically provided at intervals typically not greater than 8 m.

Where laid over a concrete base, the joint in the surface course should be accurately located above the base joint.

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

15.2 Tolerances and levels for bound pavements

The levels and tolerance of the sub-base or base layer should be checked to verify that they have been prepared in accordance with Clause **14**.

When laying concrete, clay or sawn sides stone paving units on a sub-base or base layer, the target laying course thickness after paving unit compaction should be 40 mm.

When laying cropped or riven stone paving units on a sub-base or base layer, the target laying course thickness should be increased if necessary, to achieve the minimum thickness of bedding mortar beneath the deepest paving unit is not less than 25 mm after paving unit compaction.

Where the thickness of the laying course is found to be greater than 80 mm, the level of the base should be adjusted by the addition of material having the same mechanical properties as the base.

A cementitious screed material may be used on concrete, an asphalt regulating layer having the same mechanical properties as the base, used on asphalt. The minimum permitted thickness for these materials should be observed. If this is not possible the existing surface should be planed to enable it.

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

15.3 Preparation

15.3.1 General

If an unbound base becomes contaminated, the contaminated parts of the base should be replaced. For a bound base, the surface should be thoroughly cleaned.

The bedding material used should have the properties and grading recommended in Annex E, Table E.2, for the relevant site category.

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

Where the level of the available laying course thickness is found to be too thick or too thin, the level of the base should be adjusted by removal of material or screeding.

NOTE 2 Where previous experience of a particular laying course material is lacking, a small trial area may be constructed in order to determine the amount of material surcharge that needed to compensate for the decrease in thickness arising from the compactions that occur during the construction of a pavement.

15.3.2 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 remove dust, loose material and debris.

15.3.3 Bound surface course laid upon an asphalt concrete base

The surface of the base should be swept and washed with water to remove dust, loose material and debris.

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

The sub-base or base should be prepared in accordance with **7.3**.

15.4 Bedding of bound construction

15.4.1 General

A moist mortar bed or a plastic mortar bed should be used, as required or as specified by the design.

15.4.2 Cleaning of paving units prior to laying

Dust and surface contaminants should be removed from paving units immediately prior to laying onto bedding mortar. The paving units should be cleaned using water and a method of physical agitation such as manual brushing or a high pressure water jet.

When laying reclaimed paving units, the recommendations of **15.5.2** should be followed.

NOTE Successful bound construction depends on a strong adhesion bond being formed with the mortar and paving units.

15.4.3 Laying of bedding mortar with bonding mortar on a concrete base

Where a design has been prepared in accordance with BS 7533-101 Bound system B, or the use of a plastic mix bedding mortar with enhanced adhesion bond is required by Tables 4 of this document, a bonding mortar should be used in conjunction with the bedding mortar.

Bedding mortar used in construction should have the properties recommended in Annex E, **E.4.1** and **E.4.2**.

Bonding mortar should be applied as a slurry to the surface of the base with a thickness of at least 2 mm immediately prior to the placement of the bedding mortar. The bonding mortar slurry should be fresh and wet when the bedding mortar is placed.

Bedding mortar should be spread out over the freshly primed base to the required depth, including surcharge. Only sufficient bedding mortar should be spread that remains fresh when the paving units are placed.

15.4.4 Laying of paving units with bonding mortar

Bonding mortar used in construction should have the properties recommended in Annex E, **E.4.3**.

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

When applying bonding mortar to the backs of porcelain paving units, the bonding mortar should fill any uneven or deep back pattern and present a thickness of not less than 2 mm.

Bonding mortar should cover at least 95% of the back of all paving units.

The paving unit should be tamped in place firmly to make a continuous contact with the base and be fully supported. The bedding mortar should not rise up into the joint by more than 10 mm.

15.4.5 Laying of bedding mortar and paving units without bonding mortar

The mortar and paving units used should have the properties recommended in Annex E.

The fresh bedding mortar should be spread out, including surcharge. The paving unit should be firmly tamped in place to make a continuous contact with the base and be fully supported. The bedding mortar should not rise up into the joint by more than 10 mm.

15.5 Filling of open joints using mortar

15.5.1 General

Unless the area of pavement to be jointed is so small that access to the surface by operatives is not required, the filling of joints should not commence until the bedding mortar has gained sufficient strength to support pedestrians.

NOTE This is typically not less than 24 hours.

15.5.2 Filling of joints using a mortar slurry grout

Any jointing mortar used should have the properties recommended in Annex E, **E.6**.

The whole surface of the laid pavement 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 the fresh slurry grout over the entire surface using a soft squeegee and move across open joints. Allow a small quantity of mortar slurry to remain on the surface and move this across the surface repeatedly at an angle oblique to the line of the joints, in order to top up joints in which the mortar has slumped excessively. During this time, maintain the mortar in a wet condition by applying a fine spray of water.

b) Pour the grout in from a cannister, constantly stirring this during application.

NOTE Where pigmented 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 any excess mortar removed from the surface of the paving units using a soft squeegee or specialist cleaning equipment, such as a motorised foam sponge belt cleaner. This process should be repeated until all the jointing material is cleaned from the surface of the paving units.

Care should be taken to prevent excess mortar slurry from choking or polluting drainage systems.

The finished level of the joints should be at the base of the chamfer, the bottom of the rounding, or 2 mm to 3 mm below the surface of the pavement.

Mortar joints should be allowed to harden before allowing pedestrian access to the surface.

In vehicular trafficked areas, the strength should be at least 50% of the specified design strength or where laboratory testing is not available, typically 7 to 10 days in ambient temperatures not less than 20 °C.

Cobbles and naturally occurring rounded stones 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 by rinsing using a fine spray of water.

15.5.3 Pointing of joints using a plastic consistency mortar

*COMMENTARY ON **15.5.3***

A plastic consistency mortar is one similar to brick laying mortar, which does not flow by gravity and requires to be forced into place using a trowel or pressurized injection device.

Jointing mortar with plastic consistency should only be used for steps, kerbs and paving not subject to vehicular trafficking.

Such mortar should conform to Annex E, **E.6**.

The mortar should be applied as a plastic mix to completely fill the full depth of the joint, compacting as necessary to produce an impermeable joint.

Mixtures of dry aggregate and cement should not be used as they are generally susceptible to shrinkage, have poor adhesion properties and are not frost-resistant.

The finished level of the joints should be at the base of the chamfer, the bottom of the rounding, or 2 mm to 3 mm below the surface of the pavement.

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

15.6 Construction in adverse weather conditions for bound surface construction

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.

Filling of joints using a mortar slurry grout should not be attempted in ambient temperatures below 3 °C and falling, above 25 °C advice should be sought.

Work should only resume when the temperature is 2 °C and rising with the expectation the temperature will exceed 5 °C.

The paving should be protected from moisture, or from frost damage until adequate strength has been achieved for damage not to occur in such conditions.

If weather conditions are such that the performance of the pavement might be jeopardized, all operations should be discontinued. The bedding layer material should be maintained at a consistent moisture content.

15.7 Protection and curing

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

In adverse weather conditions, the finished pavement should be covered for at least 24 h after completion.

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

15.8 Site sampling and testing

15.8.1 Sampling of mortar components and proprietary mortar

Where a non-proprietary mortar is used, a full package quantity or at least 20 kg of the aggregate components should be thoroughly mixed and placed onto a hard surface that is clean and dry. A quantity of this sufficient to fill the required number of molds when blended with the correct proportion of cement or cementitious binder should be taken to prepare a sample for testing.

Where a proprietary mortar is used, a full bag or similar unit container quantity should be thoroughly mixed and placed onto a hard surface that is clean and dry prior to filling the required number of molds for testing.

If silo-stored dry mortar mix is used, it should be demonstrated that no segregation has taken place during transport to site or after refilling in situ. A quantity of dry mortar should be taken from the silo by discharging from the mixer attached, sometimes referred to as a pug mill, and a grading analysis made. The resulting particle size distribution (PSD) data should be satisfactorily compared with the PSD data provided by the supplier prior to further testing being undertaken.

15.8.2 Consistency of fresh mortar

15.8.2.1 Plastic mix

Sufficient water should be added to the mix to produce a slump of between 120 mm and 150 mm in accordance with BS EN 12350-2 or alternatively by performing the ad hoc test set out in **C.2** to **C.4**.

15.8.2.2 Moist mix

Sufficient water should be added to hydrate the cement but not so much as to resist the paving units being hammered in by hand. This should be 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.

15.8.3 Bedding mortar sample preparation

Where the method statement requires the preparation of samples of bedding mortar for destructive strength testing, three 40 mm × 40 mm × 160 mm prisms or if permitted by the method statement, three 100 mm cubes, should be prepared on site from material sampled in accordance with **15.8.1** by a competent technician. The mortar should be prepared with the same water content and consistency as when installing the paving units, as determined in accordance with **15.8.2.1** or **15.8.2.2** as appropriate.

15.8.4 Jointing mortar sample preparation

Where the method statement requires the preparation of samples of jointing mortar for destructive strength testing, three 40 mm × 40 mm × 160 mm prisms should be prepared on site from material samples in accordance with **15.8.1** by a competent technician, material being taken from a single batch of fresh mortar. The mortar should be prepared as a plastic mix.

15.8.5 Storage of samples on site

Filled prisms or cubes should initially be stored under wet hessian in the open and close to the site, prior to being transferred to the designated laboratory for testing.

15.8.6 Frequency of sampling

The frequency of sampling should be as set out in the method statement.

15.8.7 Testing of samples

Samples should be initially tested for compressive or flexural strength gain in accordance with BS EN 13892-2 after one to three days stored on site, depending on ambient temperature, to verify that curing has commenced.

Samples should thereafter be stored in laboratory conditions and tested for compressive or flexural strength gain after 7 and 28 days. Test results should meet the expected values.

15.8.8 Early trafficking for bound surface construction

*COMMENTARY ON **15.8.8***

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.

When required, samples of mortar should be taken in accordance with **15.8.3** and **15.8.4** and stored on site in accordance with **15.8.5**.

For pedestrian only applications, strength gain should be at least 25% of the specified design strength or where laboratory testing is not available, typically three days for correctly protected areas in ambient temperatures not less than 10 °C.

In vehicular trafficked areas, strength gain should be at least 50% of the specified design strength or where laboratory testing is not available, typically 7 to 10 days in ambient temperatures not less than 20 °C or 14 days in ambient temperatures not less than 10 °C.

NOTE 1 The full design strength of the recommended bedding and jointing material develops after 28 days at an ambient temperature of 10 °C.

NOTE 2 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 a proprietary mortar with high early strength is used to allow early trafficking, the supplier's recommendations should be followed.

15.9 Infill concrete

Where it is necessary to infill using fresh concrete around an obstruction, the concrete used should have the properties recommended in Annex E, **E.5.2**.

The area to be filled should be kept to a minimum but with no dimension in plan less than 100 mm, in order to maintain the structural integrity of the concrete, and should be the full depth of the ironwork or paving unit plus laying course, whichever is the greater.

Concrete infill should be finished with a chamfered edge to prevent spalling.

Where the infill concrete butts against the paving unit and edge restraint or pavement penetration, such as a cast iron manhole, a bond breaker should be installed to prevent the concrete bonding to the paving unit and edge restraint.

When infilling concrete around items such as cast iron street furniture or similar, allow should be provided for differential thermal expansion and contraction.

NOTE 1 A control joint might be necessary, or the concrete infill segmented into separate sections.

NOTE 2 The design might provide suitable details.

The concrete should be fully cured; bitumen sprays, curing agents, wet material or plastic sheeting may be used. Care should be taken to avoid staining the finished face of the paving units with cementitious material. Any traces of concrete on the paving units should be removed immediately.

NOTE 3 Rapid setting cementitious mortar can be used, in accordance with manufacturers' instructions.

15.10 Pavement cleaning following completion of works

Mechanical sweeping or pressure washing of pavements constructed using mortar filled joints should only be permitted when the design strength of the jointing mortar has been reached.

All operatives should be made aware of safety data and warnings issued by the chemical suppliers.

NOTE Some of the cleaning methods and sealers already described involve the use of chemicals that could be hazardous if not used correctly.

16 Routine cleaning

Vacuum sweeping and pressure water jetting of unbound pavement surfaces should be carried out with caution; jointing material should be inspected and topped up where necessary.

Mechanical cleaning of the pavement should be carried out using sweeping machines having polypropylene, not wire, brushes. The suction pressures should be set to the minimum required to suit the task.

NOTE 1 The pavement might not have been designed for heavy cleaning machines.

Oil and grease stains should be removed as required. Since there is a wide range of cleaning products available the advice of the paving manufacturer and/or sealer suppliers should always be sought before cleaning any area. A small area should first be tested before a large area is treated, whatever treatment is to be used.

NOTE 2 Some of the cleaning methods/sealers described involve the use of chemicals that could be hazardous if not used correctly. It is essential that any safety warnings issued by the chemical suppliers are carefully observed.

NOTE 3 The removal of chewing gum requires specialist treatment.

17 Structural maintenance and repair

17.1 General

Where maintenance and repair is required, the integrity of the pavement should be maintained both structurally and aesthetically.

Before repairs are undertaken, any problem should be identified, so that appropriate corrective action can be planned and undertaken as necessary.

The existing materials and structure should be identified prior to commencing work, so that the same materials can be used.

17.2 Opening of modular pavement surfaces in unbound construction

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

Using suitable levers, or a proprietary extractor, the first unit should be prised out, after which 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, passing a vibrating plate over the surface of the units adjacent to the opening might 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, might be so tightly locked together that it is necessary to cut or destroy a small area in order to gain access.

The laying course and jointing material should then be removed and disposed of.

17.3 Opening of modular pavement surfaces in bound construction

17.3.1 General

Where it is not possible to remove paving units in bound construction without damage preventing their reinstallation, acceptable replacement materials should be sourced.

17.3.2 Removal of jointing mortar

Joints around paving units should be removed using a chisel, saw or specialist power tool.

17.3.3 Removal of large paving units, slabs and flags

Care should be taken in removing the units, to avoid surface and edge damage.

NOTE If vertical lifting methods, e.g. vacuum, fail to release a unit and other methods fail, it might be necessary to cut or destroy one or more paving units in order to gain access to the underside of remaining units.

17.3.4 Removal of small paving units, pavers and setts

Small paving units, pavers and setts should be lifted using prising bars or proprietary tools.

17.3.5 Cleaning of paving units

All traces of mortar should be completely removed from the bedding face and sides of the unit. Paving units to be reinstalled in bound construction should have all traces of mortar removed; otherwise, the adhesion bond would be compromised.

NOTE 1 The use of steel wire brushes can result in rust staining to the pavement surface following reinstatement.

NOTE 2 Effective cleaning might require the removal of paving units from site to a specialist cleaning facility, such as shot blasting.

When temporarily storing large paving units, timber or plastic spacing pieces should be placed between units to minimize surface damage.

The laying course and jointing material should then be removed and disposed of.

17.4 Reinstatement of foundation layer in trench and openings

17.4.1 General

Materials used to reinstate the foundation layer should be selected in accordance with Annex E, based on the traffic category given in Table 1 or Table 2.

17.4.2 Unbound construction

Granular sub-base material or base material as recommended in Annex E, **E.1**, should be used to reinstate the foundation layer.

NOTE 1 It is necessary to use new material for the 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 instead of unbound materials provided that they are water permeable when cured, if permitted by the highway authority.

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.

17.4.3 Bound construction

Sub-base and base materials as recommended in Annex E, **E.2**, should be used to reinstate the foundation layer.

17.4.4 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.

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

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

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

NOTE 1 Foamed concrete is generally self-levelling and flows to fill the void, covering the newly exposed or installed utilities.

NOTE 2 Where rapid curing foamed concrete is used, reinstatement of the base, bedding and surface layers may be effected sooner.

17.5 Reinstatement of unbound surface layer

17.5.1 Preparation before laying

Where units at the open edge of the reinstatement and the underlying laying course 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 also be removed and reinstated.

All exposed laying course material should be cut back, removed and discarded.

17.5.2 Laying of paving units

Replacement bedding and jointing material should be chosen in accordance with Annex E, based on the traffic category given in Table 2.

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, and new units should be mixed proportionately with original units and not concentrated in one location.

Joint filling and compaction of the surface course should be carried out in accordance with **15.4** and **15.5**.

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.

17.6 Reinstatement of bound surface layer

17.6.1 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.

Any paving units to be reused should be thoroughly cleaned, to completely remove all residues or contaminants which might otherwise adversely affect the ability of bedding and jointing mortars to adhere.

17.6.2 Laying of paving units

Replacement bedding and jointing materials should be chosen in accordance with Annex E, based on the traffic category as described in Table 1.

Bedding and surface layers should be installed in accordance with **4.3**.

17.7 Reinstatement of damaged or lost jointing mortar in bound pavements

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

The exposed joint void should be thoroughly cleaned, to completely remove all residues or contaminants which might otherwise 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 recommended in Annex E, **E.6**, appropriate to the traffic category given in Table 1 and using the appropriate method given in **15.5.2**.

The pavement should be cleaned to remove any surface residue.

Annex A (informative) Simple permeameter test

A.1 Principle

The test method given in this annex is used to assess and verify permeability.

A.2 Test equipment

A.2.1 *Metal or plastic ring*, having inside diameter minimum 290 mm and height minimum 30 mm.

A.2.2 *Mastic sealant*, rapid setting mortar or another method of making a watertight seal between the ring to the surface of the base to be tested.

A.2.3 *Circular template or stencil*, having outside diameter equal to the inside diameter of the ring.

A.2.4 *Test liquid*, consisting of clean water.

A.2.5 *Stopwatch*.

A.3 Test procedure

A.3.1 Place the circular template or stencil on the surface of the base to be tested.

A.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.

A.3.3 Remove the stencil.

A.3.4 Press the metal or plastic ring into the sealant so that a watertight seal is achieved.

A.3.5 If the materials used to form a seal require a period of time to cure, allow this time to elapse before proceeding further with the test.

A.3.6 Make a mark on the inner wall of the ring, 30 mm above the surface of the base.

A.3.7 Pour sufficient clean water into the ring to thoroughly wet the surface, typically not less than 2 l.

A.3.8 After approximately 60 s, add clean water, up to the level of the 30 mm mark.

A.3.9 Using the stopwatch, measure the time taken until all water has drained through the surface of the base.

A.4 Evaluation of test results

If the time taken to drain the water into the base is approximately 5 min, the material is deemed to be adequately permeable for a base layer (approximately 1×10^{-4} m/s).

If the time taken to drain the water into the base is approximately 10 minutes, the material is deemed to be adequately permeable for a formation or subgrade surface. (approximately 5×10^{-5} m/s).

Annex B (informative)
Identification of materials and CBR values using a simple field test

Table B.1 provides a method of identification for materials and CBR values using a simple field test.

Table B.1 Identification of materials and CBR values

Rock or soil		Simple field test	CBR %	E_{LWD} MPa
Type	**Condition**			
Rock	Hard	Requires mechanical pick for excavation	>5	>50
Sand Gravel	Compact	50 mm, square peg hard to drive in 150 mm	>5	>50
Clay Sandy clay	Stiff	Cannot be molded by fingers Need pick for excavation	5–2.5	50-15
Clay Sandy clay	Firm	Can be molded by fingers Need spade for excavation	5–2.5	50-15
Sand Silty clay Clayey sand	Loose	Dry lumps easily broken down 50 mm, square peg driven in easily	2.5	15
Silt Sandy clay Silty clay Clay	Soft	Can easily be molded by fingers	<2.5	<15
Silt Sandy clay Silty Clay Clay	Very soft	Exudes between fingers when squeezed	Refer to specialist advice	

NOTE 1 This table is based on the principles given in BS 8103-1.

NOTE 2 The CBR of the rock or soil is significantly affected by moisture content.

Annex C (informative)
Concrete and mortar slump test

C.1 General

When site mixing concrete or mortar for use, the workability of the material is critical to the performance and suitability for the given application.

To verify that the fresh concrete or mortar is suitable for use, a slump test may be performed. This test may be performed in accordance with BS EN 12350-2, if using a proprietary slump cone apparatus, or alternatively by performing the ad hoc test set out in **C.2** to **C.4**.

C.2 Test equipment

C.2.1 *Hollow cone or conical shaped container* (see Figure C.1).

C.2.2 *Compacting rod* (see Figure C.1).

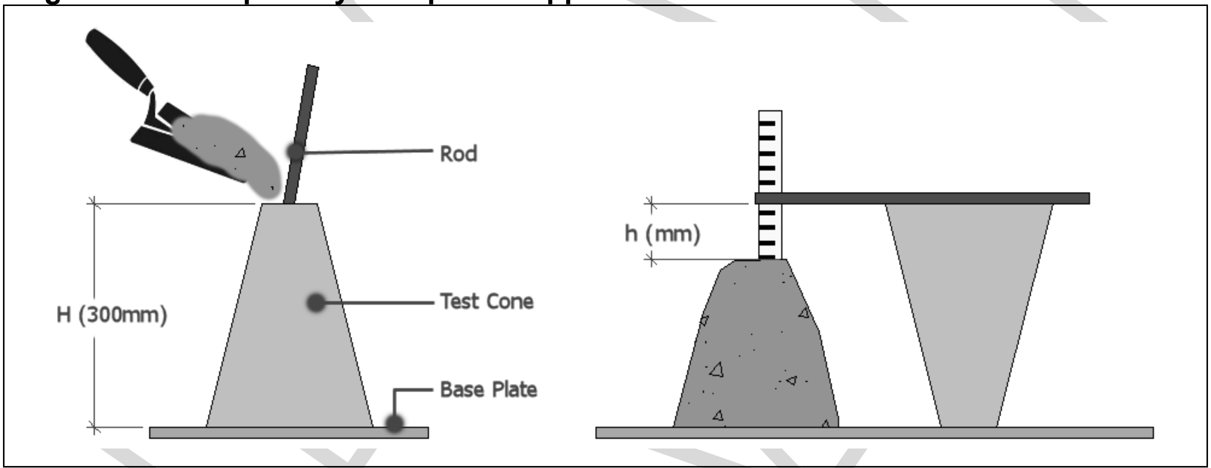
C.2.3 *Ruler or tape measure*.

C.2.4 *Non-absorbent, stiff base plate*, which is wider than and fully covers the open mouth at the base of the conical container (see Figure C.1).

C.2.5 *Shovel or trowel*.

C.2.6 *Timer*.

Figure C.1 – Proprietary slump cone apparatus



C.3 Test procedure

If using a proprietary concrete slump cone, which is filled via the open narrow end of the cone, place the cone firmly on the base plate and apply weight to the cone to prevent it from moving. This can be achieved by standing on the foot plates provided at the base of a proprietary slump cone.

When filling a proprietary concrete slump cone, insert the fresh material into the narrow top of the cone. Place the mix in three even layers. Rod each layer 25 times, evenly across the area of the layer, using a compacting rod and taking care not to touch the base plate or the sides of the container. For the second and third layers prevent the rod from extending down into the layer beneath. When introducing the final layer, add any extra material as the rodding process compacts the material.

When a proprietary concrete slump cone apparatus is not available, carry out the test using a bucket or other conical container not less than 200 mm in height.

For relatively finer grained materials, such as a bedding mortar, an ad hoc test may be made using a smaller, cone shaped container such as a paper coffee/water cup

If a smaller container is being used for fine materials, typically not higher than 100 mm, this may be filled in one application but rod lightly using an appropriately sized rod, to ensure there are no voids.

If using an ad hoc conical shaped container, fill this and cover with a stiff plate before being inverted.

Carefully remove the cone in a process lasting between 2 s and 5 s, pulling the container directly and smoothly upwards without disturbing the contents.

When the cone is removed, verify that the fundamental shape of the container is retained by the slumped material.

C.4 Measurement

After the container has been lifted clear of the sample and the contents have slumped, record the height of the slumped material and compare this with the internal height of the container "H", the original height, by positioning a straight rod horizontally and level with the top of the slumped contents and subtracting the height of this from the level of the base plate from the original height. This figure "h" forms the basis of the slump measurement.

NOTE See Table C.1 for standard concrete slump classes and Table C.2 for typical concrete and mortar slump values.

EXAMPLE

If using a 300 mm high cone and the slump is recorded at 270 mm high, the slump "h" is recorded as 30 mm.

Convert the slump measurement "h" to and record as a percentage of the original height "H".

EXAMPLE 1

If using a 300 mm cone, and the slump "h" is recorded at 60 mm, record the slump as 60/300 × 100 = 20%

EXAMPLE 2

If using a 100 mm cone, and the slump "h" is recorded at 35mm, record the slump as 35/100 × 100 = 35%

If shear failure occurs or the material collapses to less than half its original height, repeat the test and/or review the mixture.

Shear failure occurs when one side of the sample slides down an inclined plane, indicating poor cohesion (see Figure C.2).

Figure C.2 – Shear failure

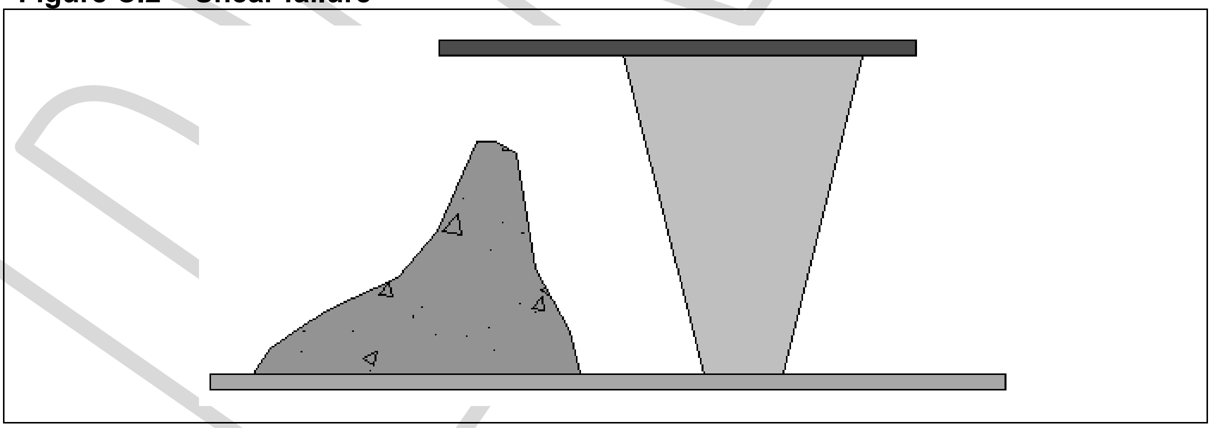


Table C.1 – Standard concrete slump classes

Class	Slump range over 300 mm	Target slump over 300 mm	Percentage slump
S1	10 – 40	20	3% – 15%
S2	50 – 90	70	15% – 30%
S3	100 – 150	130	30% – 50%
S4	160 – 210	180	50% – 70%
S5	210 +	220	70% +

Annex D (normative)
Falls for surface drainage to pavements

The falls and tolerances for surface drainage to pavements should be in accordance with Table D.1.

Table D.1 – Falls for surface drainage to pavements

Type of drainage	Recommended	Minimum
Porcelain slabs	1 in 50 (2%)	1 in 60 (1.7%)
Sawn natural stone and precast concrete flags	1 in 60 (1.7%)	1 in 80 (1.25%)
Riven natural stone slabs and heavily textured slabs and flags	1 in 50 (2%)	1 in 60 (1.7%)
Sawn and textured natural stone setts, precast concrete blocks and clay pavers	1 in 60 (1.7%)	1 in 80 (1.25%)
Natural stone setts having a cropped surface	1 in 33 (3%)	1 in 40 (2.5%)
Steps and step treads	1 in 40 (2.5%)	1 in 50 (2%)
Drainage channel	1 in 80 (1.25%)	1 in 100 (1%)

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 pavement 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.

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

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

Annex E (normative) Materials

E.1 Foundation and unbound base materials

Capping material used for the foundation and unbound base should be Class 6F1, 6F2, 6F3, 6F4 or 6F5 material in accordance with series 0600 of the *Specification for highway works* [N2].

One of the following materials should be used for the sub-base:

a) Type 1 unbound granular material to clause 803 of the Specification for Highway Works [N2];

b) Type 3 unbound granular material to clause 805 of the Specification for Highway Works [N2]; or

c) Type 4 asphalt arisings unbound mixture to clause 807 of the Specification for Highway Works [N2].

NOTE Recycled and other alternative materials may be used if they achieve an equivalent or better outcome.

E.2 Bound base materials

One of the following base materials should be used for a bound base.

Bituminous base should be constructed from one or more of the following materials:

a) AC 20 dense bin 40/60 des conforming to BS EN 13108-1;

b) AC 32 HDM base 40/60 des conforming to BS EN 13108-1;

c) AC 20 dense bin 100/150 rec conforming to BS EN 13108-1 traffic category 5 and below;

d) AC 32 dense base 100/150 rec conforming to BS EN 13108-1 traffic category 5 and below; and

e) AC 20 open bin 100/150 rec conforming to BS EN 13108-1 traffic category 5 and below

NOTE 1 AC 20 open bin 100/150 rec might be useful where improved base permeability is sought.

NOTE 2 Proprietary asphalt materials might also be suitable for use as base materials. Porous asphalts might be particularly useful where improved base permeability is sought whilst maintaining structural integrity.

NOTE 3 The terms 40/60 and 100/150 are "pen" values which indicate the hardness of the bitumen used to bind the aggregate together. "pen" refers to the depth to which a standard needle penetrates under specific test conditions. Higher values indicate a softer grade of bitumen.

NOTE 4 Table E.1 provides an explanation of the asphalt terms used in a) to e).

Table E.1 – Explanation of asphalt terms

Term	Explanation
AC	Asphalt concrete
20	20 mm upper aggregate size
32	32 mm upper aggregate size
bin	Binder course
Base	Base course
Dense	Dense mixture (non-porous)
HDM	Heavy duty Macadam
Open	Open mixture (porous)
des	Designed mixture
rec	Recipe mixture

Cementitious base should be constructed from one or more of the following materials:

1) cement bound granular material (CBGM) base should be CBGM conforming to BS EN 14227-1:2013, strength class 8/10; and
2) concrete base should be pavement quality concrete conforming to BS EN 13877-1 with a minimum compressive strength class C32/40 for traffic categories 5 and above, and a minimum compressive strength class of C20/25 for traffic categories 4 and below.

NOTE 5 The aggregate component of a site batched concrete typically comprises 4 parts by volume coarse aggregate with 2 parts fine aggregate or sharp sand.

NOTE 6 Coarse aggregate is typically 6 mm to 20 mm.

NOTE 7 Fine aggregate and sharp sand is typically less than 4 mm.

NOTE 8 Sharp sand is sometimes referred to as concrete sand.

Material described as “all-in ballast” should only be used only if it conforms to BS EN 12620 0/10 f/4 or 0/20 f4.

E.3 Laying course materials for unbound surface construction

*NOTE Recycled aggregate may be used as laying course material providing it meets all the recommendations of **E.3**.*

E.3.1 General

Laying course material used for unbound surface construction should contain nothing which acts as a binder and/or could detract from the flexible nature of the pavement, e.g. cement, lime, bitumen or resin. The laying course material should be clean, hard and durable, containing no deleterious materials such as wood, plastic or soil.

The laying course materials in **E.3.2** to **E.3.4** should be free-draining.

E.3.2 Concrete blocks and flags, clay pavers and sawn sided sandstone setts in all traffic categories for unbound surface construction

Naturally occurring sand should be selected and graded according to BS EN 12620 or BS EN 13242, GF85 0/4 (MP) fine aggregate and conform to BS 7533-101, **5.3.2**.

E.3.3 Natural stone slabs in all traffic categories and cropped natural stone setts in traffic categories 1 to 4 for unbound surface construction

The laying course material for paving with natural stone slabs in all traffic categories and natural stone setts in traffic categories 1 to 4 should be:

a) crushed igneous rock graded in accordance with Table E.2; and
b) produced in accordance with either BS EN 12620 or BS EN 13242, G_C85 0/4:
    1) with a flakiness index of less than FI_{35} when measured in accordance with BS EN 933-3; and
    2) with resistance to impact conforming to BS EN 12620 or BS EN 13242, category SZ_{18}, determined in accordance with BS EN 1097-2.

Table E.2 – Grading for unbound laying course material for natural stone slabs in all traffic categories and cropped natural stone setts in traffic categories 1 to 4

Sieve size mm	**Percentage of mass passing** %
8	100
2	35 to 60
1	17 to 42
0.5	8 to 35
0.125	5 to 10
0.063 (fines content)	2 to 9

E.3.4 Cropped natural stone setts in traffic categories 5 to 9 for unbound surface construction

The laying course material for cropped stone setts should be:

a) crushed igneous rock graded in accordance with Table E.3; and

b) produced in accordance with either BS EN 12620 or BS EN 13242, G_C85 2/6:

   1) with a flakiness index of less than FI_{20} when measured in accordance with BS EN 933-3; and

   2) with resistance to impact category not greater than SZ_{18} or LA_{20} determined in accordance with BS EN 1097-2.

Table E.3 – Grading for unbound laying course material for cropped natural stone setts in traffic categories 5 to 9

Sieve size mm	**Percentage of mass passing** %
8	100
6.3	85 to 99
2	0 to 20
1	0 to 5
0.063 (fines content)	0 to 2

If heavy vibratory compaction equipment cannot be used during installation, the laying course material should be locally substituted with the materials given in **E.3.3**.

E.4 Laying course materials for bound surface construction

E.4.1 Proprietary bedding mortar

Proprietary bedding mortar used for bound surfaces should be produced in accordance with the characteristics and performance criteria given in BS 7533-101.

E.4.2 Site-batched non-proprietary bedding mortar for bound surface construction

A site-batched non-proprietary mortar should comprise 1:4 cement-aggregate (proportions by volume).

The aggregate used in site-batched non-proprietary bedding mortar should have the properties given in Table E.4.

Table E.4 – Recommended aggregate properties for site-batched non-proprietary bedding mortar

Properties	Category to BS 12620
Grading	2/6 (preferred) or 1/4 or 2/8, $G_C85/20$
Minimum % crushed fines	$C_{70/10}$
Maximum fines content	f_4
Shape – flakiness index	FI_{20}
Resistance to fragmentation	SZ_{26} or LA_{30}
Acid-soluble sulfate content	$AS_{0.2}$
Total sulfur	S_1
Durability against freeze-thaw	F_1

Recycled materials with constituents which alter the rate of setting and hardening of hydraulically bound mixtures should not be used.

E.4.3 Bonding mortar for bound surface construction

Bonding mortar is a proprietary material comprising a blend of cementitious binder and fine aggregate, which should be applied as a liquid slurry having a thick creamy consistency.

When measured in combination with the bedding mortar, bonding mortar should achieve the performance criteria given in BS 7533-101 for adhesion bond strength.

E.5 Jointing materials for unbound surface construction

E.5.1 General

The joint filling material used 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.

E.5.2 Concrete, clay and sawn sided paving units for unbound surface construction

The jointing material for concrete, clay and sawn sided stone paving units for unbound surface construction should be:

a) dried free-flowing silica aggregate;

b) grade in accordance with Table E.5; and

c) conform to BS EN 12620, GF 85 0/1 (FP) F4 fine aggregate.

Table E.5 – Grading for jointing material for concrete, clay and sawn sided stone paving units

Sieve size mm	Percentage of mass passing %
2	100
1	85 to 99
0.5	55 to 100
0.063 (fines content)	0 to 2

E.5.3 Cropped/cleft stone paving units for unbound surface construction

NOTE Joints may be filled using the bedding material if it flows freely into the open joint.

Aggregate used to fill joints between cropped/cleft stone paving units for unbound surface construction should be crushed igneous rock graded in accordance with Table E.2. Where it is necessary to have a finer material in order to fill the joints, the grading should be determined using formulae 1 and 2:

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

where:

D_{15} is sieve size of laying course material at which 15% passes; and

D_{85} is sieve size of joint filling material at which 85% passes.

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

where:

D_{50} is sieve size of laying course material at which 50% passes; and

D_{50} is sieve size of joint filling material at which 50% passes.

Fine topping material should be crushed igneous rock or carboniferous limestone, specified as 1 mm to dust, with not less than 45% passing the 0.063 mm sieve.

E.6 Jointing materials for bound surface construction

E.6.1 Slurry grout jointing mortar

The maximum aggregate particle size for slurry grout jointing mortar used for bound surface construction should be not greater than 40% of the joint width. The material used for jointing should be a cementitious slurry grout conforming to **E.9**.

E.6.2 Proprietary jointing mortar

Proprietary bedding jointing mortar used for bound surface construction should be produced in accordance with the characteristics and performance criteria given in BS 7533-101.

E.6.3 Site-batched non-proprietary jointing mortar for bound surface construction

A site-batched non-proprietary jointing mortar should comprise 1:3 cement-aggregate (proportions by volume), using fine aggregate conforming to BS EN 12620:2013, GF85 0/1 (MP).

E.7 Light reflection value

*COMMENTARY ON **E.7***

The light reflection value (LRV) of paving units and contrast between adjacent paving units can be important when designing access for blind and partially sighted people, particularly around steps, ramps and road crossings.

Recommendations and guidance on LRV given in BS 8300-1, BS 8300-2 and PD CEN/TS 15209 should be followed.

E.8 Concrete blocks

E.8.1 General

Only concrete blocks conforming to BS EN 1338 should be used.

Unlike stone setts, dimensions should be stated as Length (L) × Width (W) × Thickness (D), e.g. 200 mm (L) × 100 mm (W) × 65 mm (D).

NOTE In this context, "D" refers to the thickness of the block.

E.8.2 Weathering resistance

In areas subject to regular treatment with de-icing salts the weathering resistance of concrete blocks should be Class 3 in accordance with BS EN 1338:2003, Table 4.2.

In areas subject to freeze/thaw without regular treatment with de-icing salts, the minimum weathering resistance should be Class 2 in accordance with BS EN 1338:2003, Table 4.1.

In areas not subject to freeze/thaw, the minimum weathering resistance should be Class 1 in accordance with BS EN 1338:2003, Table 4.1.

E.8.3 Abrasion resistance

In areas subject to intensive pedestrian and vehicular traffic, the abrasion resistance of concrete blocks should be Class 4 in accordance with BS EN 1338:2003, Table 5.

In areas subject to normal pedestrian and vehicle use (e.g. public footpaths and roads) the minimum abrasion resistance should be Class 3 in accordance with BS EN 1338:2003, Table 5.

In areas subject to light pedestrian and vehicular use (e.g. gardens and drives) the minimum abrasion resistance should be Class 1 in accordance with BS EN 1338:2003, Table 5.

NOTE Intensive pedestrian traffic refers to areas expected to receive over 500 million pedestrians in the life of the pavement. Examples would be busy commuter stations, airports and large shopping malls. Intensive vehicular traffic refers to traffic categories 7–9 in Table 1.

E.9 Concrete flags

E.9.1 General

Only concrete flags conforming to BS EN 1339 should be used.

Unlike stone slabs, dimensions should be stated as Length (L) × Width (W) × Thickness (D), e.g. 450 mm (L) × 300 mm (W) × 65 mm (D).

NOTE In this context, “D” refers to the thickness of the flag.

E.9.2 Weathering resistance

In areas subject to regular treatment with de-icing salts the weathering resistance of concrete flags should be Class 3 in accordance with BS EN 1339:2003, Table 4.2.

In areas subject to freeze/thaw without regular treatment with de-icing salts, the minimum weathering resistance should be Class 2 in accordance with BS EN 1339:2003, Table 4.1.

In areas not subject to freeze/thaw, the minimum weathering resistance should be Class 1 in accordance with BS EN 1339:2003, Table 4.1.

E.9.3 Abrasion resistance

In areas subject to intensive pedestrian and vehicular traffic, the abrasion resistance should be Class 4 in accordance with BS EN 1339:2003, Table 6.

In areas subject to normal pedestrian and vehicle use (e.g. public footpaths and roads) the minimum abrasion resistance should be Class 3 in accordance with BS EN 1339:2003, Table 6.

In areas subject to light pedestrian and vehicular use (e.g. gardens and drives) the minimum abrasion resistance should be Class 1 in accordance with BS EN 1339:2003, Table 6.

NOTE Intensive pedestrian traffic refers to areas expected to receive over 500 million pedestrians in the life of the pavement. Examples would be busy commuter stations, airports and large shopping malls. Intensive vehicular traffic refers to traffic categories 7–9 in Table 1.

E.10 Clay pavers

E.10.1 General

Only clay pavers conforming to BS EN 1344 should be used.

NOTE Although BS EN 1344 does not place limitations on dimensions, clay pavers are typically produced in small sizes for use in traditional laying patterns.

E.10.2 Weathering resistance

In areas subject to freeze/thaw, the minimum weathering resistance of clay pavers should be Class FP100 in accordance with BS EN 1344:2013, Table 2.

In areas not subject to freeze/thaw, the minimum weathering resistance should be Class FP0 in accordance with BS EN 1344:2013, Table 2.

E.10.3 Abrasion resistance

In areas subject to intensive pedestrian and vehicular traffic, the abrasion resistance of clay pavers should be Class A3 in accordance with BS EN 1344:2013, Table 4.

In areas subject to normal pedestrian and vehicle use (e.g. public footpaths and roads) the minimum abrasion resistance should be Class A2 in accordance with BS EN 1344:2013, Table 4.

In areas subject to light pedestrian and vehicular use (e.g. gardens and drives) the minimum abrasion resistance should be Class A1 in accordance with BS EN 1344:2013, Table 4.

NOTE Intensive pedestrian traffic refers to areas expected to receive over 500 million pedestrians in the life of the pavement. Examples would be busy commuter stations, airports and large shopping malls. Intensive vehicular traffic refers to traffic categories 7–9 in Table 1.

E.11 Natural stone setts and slabs

E.11.1 General

E.11.1.1 Any natural stone setts used:

a) should conform to BS EN 1342; and

b) may be sawn or cropped on any number of sides.

For natural stone setts, unlike concrete blocks, dimensions should be stated as Width (W) × Thickness (D) × Length (L), e.g. 100 mm (W) × 65 mm (D) × 200 mm (L).

NOTE In this context, "D" refers to the thickness of the sett.

The permissible tolerances on dimensions for setts should be specified by the designer as required, usually by reference to one of the options provided in BS EN 1342.

E.11.1.2 Only natural stone slabs conforming to BS EN 1341 should be used.

For natural stone slabs, unlike concrete flags, dimensions should be stated as Width (W) × Thickness (D) × Length (L), e.g. 600 mm (W) × 80 mm (D) × 900 mm (L), or 300 mm (W) × 60 mm (D) × "Random lengths" in the range 300 mm to 600 mm.

NOTE In this context, "D" refers to the thickness of the slab.

The permissible tolerances on dimensions for slabs should be specified by the designer as required, usually by reference to one of the options provided in BS EN 1341.

E.11.2 Flexural strength of natural stone slabs

*COMMENTARY ON **E.11.2***

For natural stone slabs, flexural strength governs the design thickness recommended in BS 7533-101.

In traffic categories 3 and below where no design has been provided in accordance with BS 7533-101, the recommendations of Clause **4** should be followed.

E.11.3 Abrasion resistance

*COMMENTARY ON **E.11.3***

For all projects designed using BS 7533-101, the maximum value for abrasion resistance is stated in BS 7533-101, Table 13.

In traffic categories 3 and below where a declared value for flexural strength has been used to determine unit thickness in accordance with BS 7533-101, the maximum declared value for abrasion resistance should be 22 mm for igneous and metamorphic stone, and 25 mm for sedimentary stone, when tested accordance with BS EN 14157:2017, Method A, unless evidence exists of traditional use or more than 5 years of successful use in a similar situation.

E.11.4 Water absorption

*COMMENTARY ON **E.11.4***

For all projects designed using BS 7533-101 the maximum value for water absorption is stated in BS 7533-101, Table 14.

In traffic categories 3 and below where a declared value for flexural strength has been used to determine unit thickness in accordance with BS 7533-101, the maximum declared value for absorption should be 0.5 % for igneous and metamorphic stone and 3.5 % for sedimentary stone, when tested to BS EN 13755, unless evidence exists of traditional use or more than 5 years of successful use in a similar situation.

NOTE In all traffic categories the value for water absorption can be determined in relation to resistance to staining and resistance to organic growth which might reduce slip/skid resistance.

E.11.5 Weathering resistance

*COMMENTARY ON **E.11.5***

For natural stone slabs used in traffic categories 4 and above, the recommendation for weathering resistance is given in BS 7533-101.

In categories 3 and below where a declared value for flexural strength has been used to determine unit thickness in accordance with BS 7533-101, in areas assessed as presenting a high risk of frost damage, evidence should be sought of the traditional use of a stone for more than 5 years of successful use in a similar situation.

E.12 Concrete kerbs

E.12.1 General

Only concrete kerbs conforming to BS EN 1340 should be used.

E.12.2 Bending strength

The minimum bending strength class of concrete kerbs should be Class 1 in accordance with BS EN 1340:2003, Table 3.

E.12.3 Weathering resistance

In areas subject to regular treatment with de-icing salts the weathering resistance of concrete kerbs should be Class 3 in accordance with BS EN 1340:2003, Table 2.2.

In areas subject to freeze/thaw without regular treatment with de-icing salts, the minimum weathering resistance should be Class 2 in accordance with BS EN 1340:2003, Table 2.1.

In areas not subject to freeze/thaw, the minimum weathering resistance should be Class 1 in accordance with BS EN 1340:2003, Table 2.1.

E.12.4 Abrasion resistance

*COMMENTARY ON **E.12.4***

Abrasion resistance is only relevant for kerbs and channels over which vehicles will run and/or people walk.

In areas subject to light pedestrian and vehicular use (e.g. Class 3 and below) the minimum abrasion resistance should be Class 1 in accordance with BS EN 1340:2003, Table 4.

NOTE Intensive pedestrian traffic refers to areas expected to receive over 500 million pedestrians in the life of the pavement. Examples would be busy commuter stations, airports and large shopping malls. Intensive vehicular traffic refers to traffic categories 7–9 in Table 1.

E.13 Natural stone kerbs

Only natural stone kerbs conforming to BS EN 1343 should be used.

NOTE BS EN 1343 limits the minimum length of natural stone kerbs to 300 mm for straight units and 500 mm for curved units. However, kerb lengths are typically 1 000 mm with variation unless specified otherwise.

E.14 Declaration of Performance (DoP)

*COMMENTARY ON **E.14***

The Declaration of Performance is a key part of the Construction Products Regulation [7]. It provides information on the performance of a product. Each construction product covered by a European harmonsed standard or for which a European Technical Assessment has been issued needs this Declaration and has to be CE marked. The DoP is part of the UK Construction Products Regulation [7] and is available for all construction products placed on the market in the UK.

To make an accurate assessment of the suitability of a product, the installer should check the DoP for a product to establish whether stone's performance has been confirmed in accordance with BS EN 1341, BS EN 1342 or BS EN 1343.

NOTE This guidance does not cover goods supplied to the Northern Ireland market or goods supplied to the GB market from Northern Ireland. See guidance on Construction Products Regulation in Northern Ireland [8].

Annex F (informative)
Slip/skid resistance

F.1 Introduction

Slip resistance is the property that reduces the risk of pedestrians slipping in wet conditions.

Skid resistance is the property that reduces the risk of vehicles skidding in wet conditions.

In both cases, the higher the slip resistance value, the lower the risk.

Wear, anticipated usage, potential contamination, cleaning and maintenance regimes can have an impact on the performance of a trafficked surface over its lifetime.

Useful information may be obtained from the following publications:

- Assessing the slip resistance of flooring – HSE technical information sheet [9];
- Safer surfaces to walk on – reducing the risk of slipping, C652 [10]; and
- Specifiers' handbook – Internal floor finishes [11].

F.2 Trafficked surfaces

BS EN 7533-101 gives recommendations for the slip/skid-resistance of concrete, clay and stone paving units.

It is the designer's responsibility to specify all surfaces with sufficient slip/ skid resistance in both new and polished condition.

F.3 Construction of slip/skid resistant surfaces

It is the installer's responsibility to follow the designer's specifications with respect to slip/skid resistance. Changes to the specified surface, such as the application of an impregnator or sealer, a different texture or use of materials from an alternative supplier might affect the slip/skid resistance. It is the installer's responsibility to confirm with the supplier that product data are available to confirm conformity to the design. If product data are not available, testing may be undertaken in order to demonstrate that the installed system satisfies the design requirements.

F.4 Maintenance and risk management

With time, a surface can become slippery due to a build-up of dirt or wear of the surface itself. Regular cleaning can prevent the former. Regular inspection of the paved surface can identify whether any areas are becoming worn, and potentially more slippery as a result. If wear is apparent and the surface looks and feels smoother than a less trafficked area, pendulum testing may be undertaken to determine whether the risk of slipping is acceptable or whether replacement is necessary.

When a slip leads to a fall, that fall can result in a serious injury without warning. However, a series of less serious incidents or history of concerns having been expressed by people using the surface might be a warning. If comments or concerns about the slipperiness of surfaces are made, or if there are slips that do not result in a fall, or falls that result in no or only minor injury, there is a duty to respond promptly, to review existing controls, verify that the current cleaning regime is effective and decide whether to test the surface.

An effective near miss reporting system, supported by records, can provide the intelligence that helps to identify issues before they lead to a serious incident.

When any maintenance of a paved area is undertaken, surface reinstatement is necessary to achieve slip/skid performance according to the design requirements.

F.5 Slip/skid resistance requirements

F.5.1 Introduction

Products which conform to the following standards can be expected to have a slip resistance performance value stated in the Declaration of Performance for the product:

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

These product standards require slip resistance testing using the pendulum method to BS EN 16165, BS EN 14231 or manufacturer's own version of this test. If the paving units do not have a declaration of performance with a slip resistance value, testing to the most appropriate of the above standards may be carried out in order to prove conformity.

F.5.2 USRV and PPV/PSRV

Values of USRV and PPV/PSRV for concrete, clay and stone paving units are shown in Table F.1.

F.5.3 Additional testing considerations

If the surface texture exhibits any directionality, testing can be carried out in multiple directions in order to identify the lowest value for slip resistance.

Where a surface impregnator or sealer is specified, it is necessary that the combination of such product and the paving unit are tested unless test data already exist for the exact combination.

Where there is concern that a risk of slip with tactile paving, slip/skid resistance may be tested using the pendulum method, taking account of the resistance to slip for different heel strike directions and locations (e.g. both on the top of a blister/ridge and in the surrounding area/troughs).

Table F.1 – USRV and PPV/PSRV for concrete, clay and stone paving units (BS 7533-101)

Traffic category	USRV (min.)	PPV/PSRV (min.)
1-3	40	N/A D)
4 without vehicular traffic A),B)	40	N/A D)
4 and 5 A),B)	45	45
6 and above C)	50	50

A) Where there is a slope, a higher level of slip resistance is required compared to that on the level to achieve the same degree of safety. The target USRV on a slope should be increased by 1 unit for every 1% of gradient.

B) Unless the units have been ground or polished, it may be assumed that precast concrete units and clay pavers achieve the recommended values. It may be confirmed by the Declaration of Performance, or by the manufacturer that they do.

C) The Highways Authority might require a higher minimum PPV, especially on the approach to junctions, pedestrian crossings, steep slopes or on corners. Guidance is given in DMRB CD 236 [12].

D) In pedestrian areas with high footfall, some types of natural stone (most commonly, limestone) and some clay pavers can become polished with time. To avoid this, paving units with a polished paver value (PPV) of 45 or more should be selected.

Annex G (normative)
Reference sample, visual inspection and acceptance

A reference sample should comprise an representative number of paving units or pieces of paving units of such a size as to indicate the general appearance of the finished work.

NOTE 1 Natural stone setts and precast concrete and clay pavers may be presented as single, whole paving units whereas slabs and flags might typically be presented as a smaller piece, cut from the whole paving unit.

The dimensions of individual pieces should be as agreed with the project manager and supplier.

The number of samples should be such as to indicate the full range of appearance of the paving units, regarding the colouring, veins or other patterns, the physical structure and the surface finish and texture.

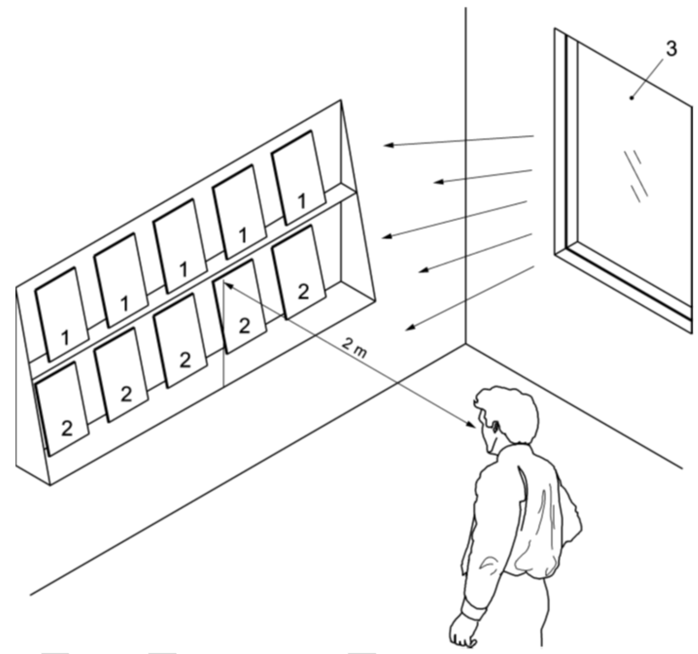
In particular a reference sample of natural stone should show specific characteristics of the stone, such as typical holes, glass seams, spots, crystalline veins and rusty spots. If the processing of the stone involves the use of patching, fillers or other similar products for natural holes, faults or cracks, then the reference sample should similarly display the impact of the same on the finished surface.

All the characteristics as shown by the reference sample should be assumed to be typical of the paving unit and not as flaws, so that they only become a reason for rejection if their concentration becomes excessive and the typical character of the paving units is lost.

NOTE 2 The reference sample does not imply strict uniformity between the sample itself and the actual supply; natural variations may always occur.

Comparison between production sample and reference sample should be carried out by placing reference samples alongside production samples and viewing them at a distance of approximately 2 m under normal daylight conditions (see Figure G.1).

Figure G.1 – Comparison between production sample and reference sample



Key

1 Reference sample

2 Production sample

3 Daylight

Annex H (informative)
Vibratory compaction equipment for surface and subsurface layers

Vibratory compaction equipment is typically identified by a numeric string comprising the effective force in kN and the width of the plate or roller in cm.

EXAMPLE

A vibratory plate compactor having an effective force of 40 kN and a plate width of 600 mm is commonly referred to as a “4060” or “40/60”.

Manufacturers of this type of equipment typically employ this identifying string within the name of the product, this is something to take into account when acquiring or hiring such a machine.

Where a different method of identifying and describing machines and their characteristics is used, the technical data provided by manufacturers generally provides these data, clearly identified in product data sheets.

A project specification or method statement might describe machine mass or weight instead of effective force. A column is included in Table 4 and Table H.1, which may be used for this purpose.

Initials commonly used within product names for identification purposes include:

- R = reversible; and
- D = diesel driven.

Table H.1 provides the minimum and maximum sizes of vibratory plate compactors typically used to install modular paving units unbound.

Table H.1 – Plate vibrator details for unbound surface construction

Paving unit thickness	**Effective force** kN	**Width of plate** mm	**Typical manufacturer’s designation**	**Typical machine weight** kg
≤ 60 mm	12	400	12/40	50
	18	450	18/45	100
	25	500	25/50	150
	35	600	35/60	230
	40 A)	600	40/60	230
60 – 80 mm	25	500	25/50	150
	35	600	35/60	230
	50 A) B)	550	50/55	460
	55 A) B)	650	55/65	460
	60 A) B)	650	60/65	460
80 - 100 mm	25	500	25/50	150
	35	600	35/60	230
	50 B)	550	50/55	460
	55 B)	650	55/65	460
	60 B)	650	60/65	460
100 - 120 mm	50	550	50/55	460
	55	650	55/65	460
	60	650	60/65	460
> 120 mm	60	650	60/65	460
	70	700	70/70	550

A) With neoprene protective mat recommended for all paving unit types.

B) Not for slabs and flags or setts and pavers with aspect ratio greater than 2:1.

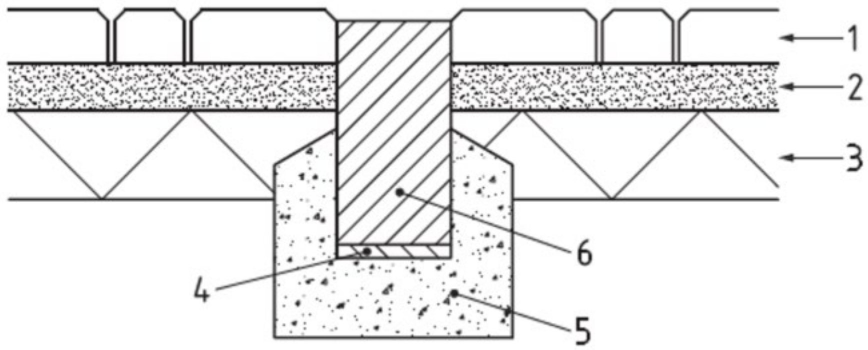
It is common practice to employ a neoprene or similar protective mat, attached to the underside of the steel plate. This is especially the case for paving units which might otherwise become scratched and marked by direct contact with a steel plate.

The use of a neoprene or similar protective can spread the energy of compaction more evenly across the surface of a large paving unit, so reducing the risk of breakage of very large or slender paving units.

The direction of travel is varied with repeated passes in order to achieve consistent compaction of the bedding while maintaining surface flatness.

Annex I (informative)
Typical edge restraint and linear drainage details

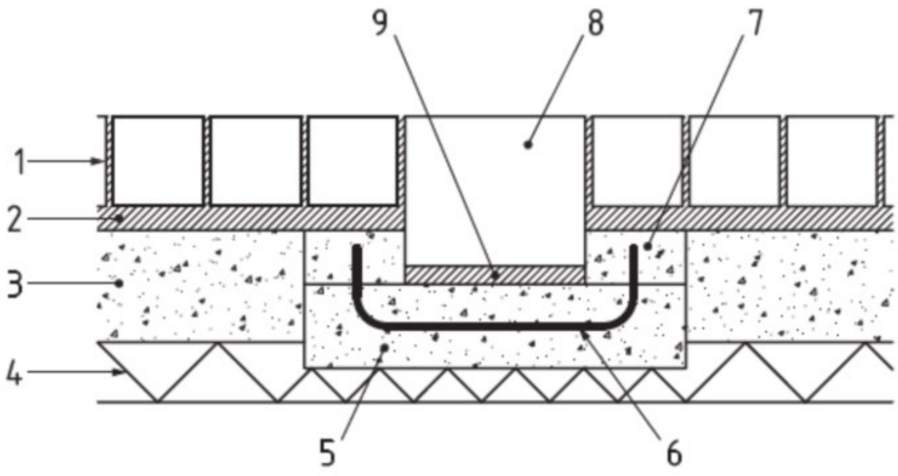
Figure I.1 – Example of intermediate restraint between areas of unbound construction (traffic categories 3 and below)



Key

1	Paving unit	4	Bedding mortar (optional)
2	Laying course	5	Concrete
3	Sub-base and/or road base	6	Channel

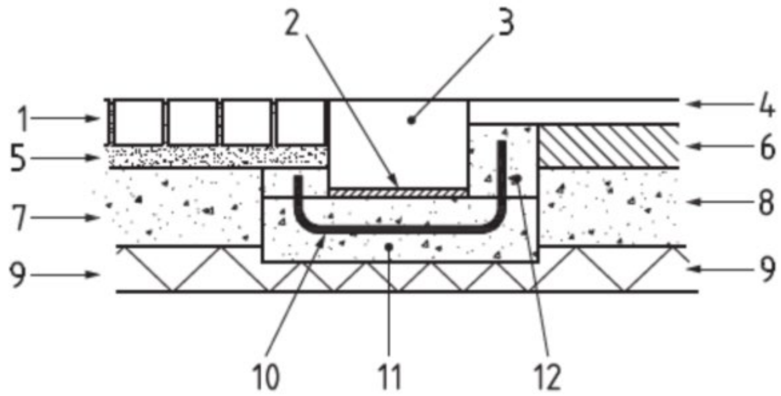
Figure I.2 – Example of intermediate restraint between areas of unbound construction



Key

1	Paving elements	6	Steel reinforcement
2	Laying course	7	Concrete haunch
3	Water-permeable base	8	Channel
4	Sub-base	9	Bedding
5	Concrete		

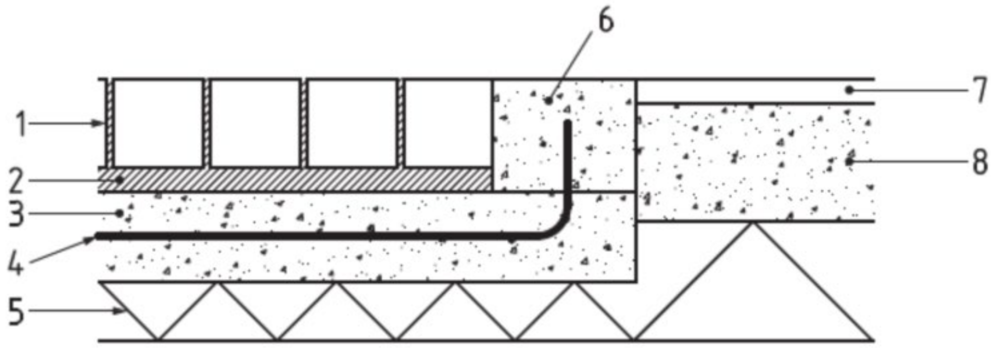
Figure I.3 – Example of transition restraint between modular construction and different construction



Key

1	Paving unit	6	Water-permeable base
2	Bedding	7	Carriageway sub-base
3	Unit	8	Sub-base
4	Carriageway surface course	9	Concrete
5	Carriageway roadbase	10	Concreate haunch

Figure I.4 – Example of visible concrete transition restraint between modular construction and different construction



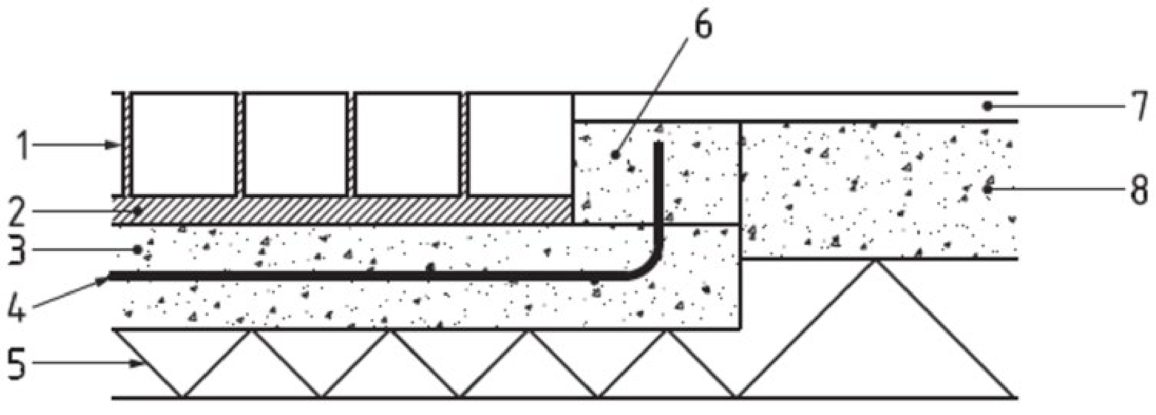
NOTE 1 The length of reinforced concrete base is at least 1 m.

NOTE 2 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.

Key

1	Paving units	5	Sub-base
2	Laying course	6	Visible concrete haunch
3	Concrete base	7	Carriageway surface course
4	Steel reinforcement	8	Carriageway roadbase

Figure I.5 – Example of a hidden concrete transition between modular construction and different construction



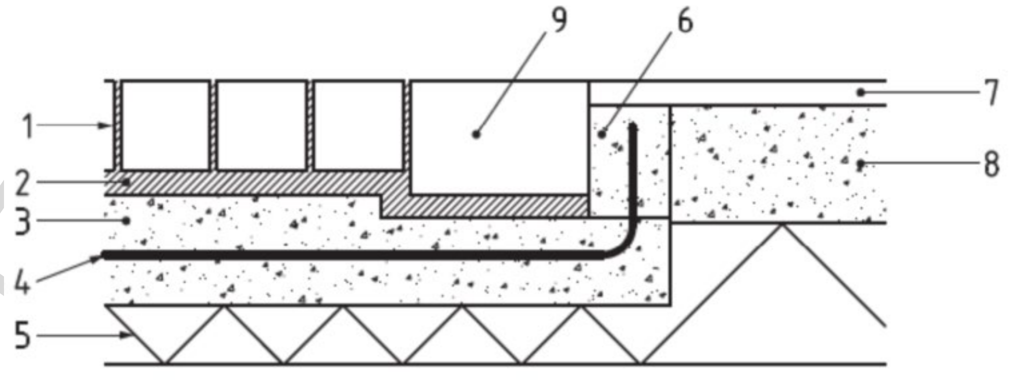
NOTE 1 The length of reinforced concrete base is at least 1 m.

NOTE 2 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.

Key

1	Paving units	5	Sub-base
2	Laying course	6	Visible concrete haunch
3	Concrete base	7	Carriageway surface course
4	Steel reinforcement	8	Carriageway roadbase

Figure I.6 – Example of a deep channel kerb transition restraint between modular construction and different construction



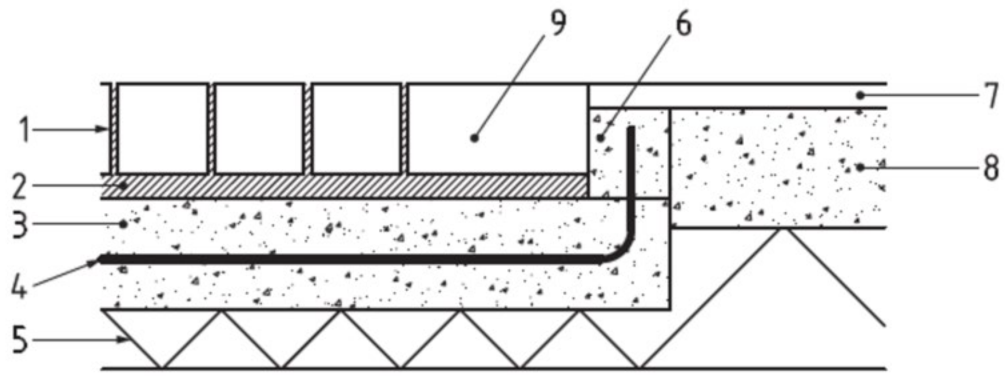
NOTE 1 The length of reinforced concrete base is at least 1 m.

NOTE 2 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.

Key

1	Paving units	6	Concrete haunch
2	Laying course	7	Carriageway surface course
3	Concrete base	8	Carriageway roadbase
4	Steel reinforcement	9	Channel
5	Sub-base		

Figure I.7 – Example of a shallow channel kerb transition restraint between modular construction and different construction



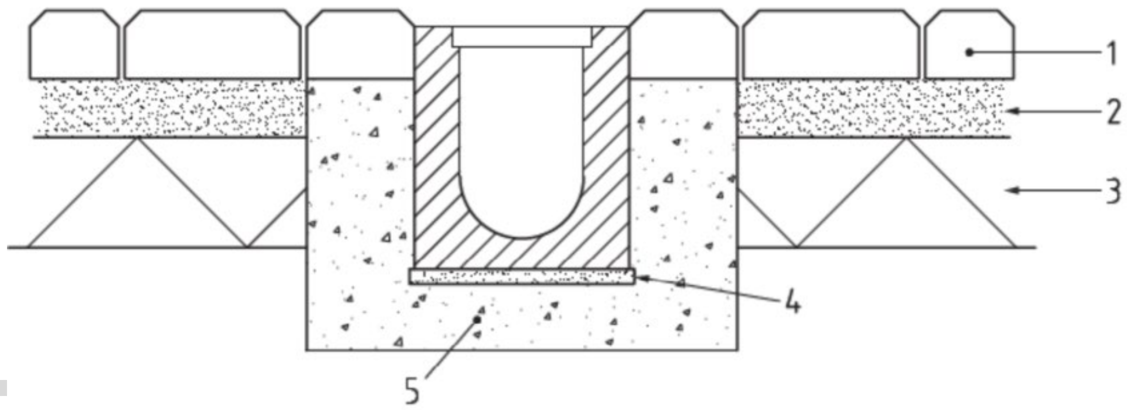
NOTE 1 The length of reinforced concrete base is at least 1 m.

NOTE 2 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.

Key

1 Paving units
2 Laying course
3 Concrete base
4 Steel reinforcement
5 Sub-base
6 Concrete haunch
7 Carriageway surface course
8 Carriageway roadbase
9 Channel

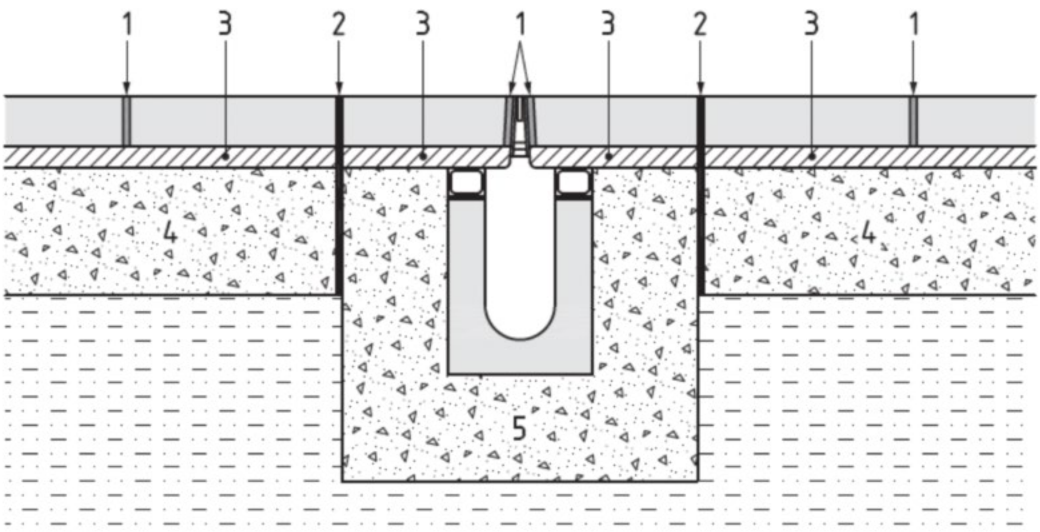
Figure I.8 – Typical details around drainage channels in unbound modular paving (traffic categories 3 and below): Linear drainage channel with grating



Key

1 Paving units
2 Laying course
3 Sub-base and/or roadbase
4 Mortar bed (optional)
5 In-situ concrete foundation

Figure I.9 – Example of a linear drainage channel in bound construction modular paving, employing low modulus movement joints to protect drainage channel from thermal movement in adjacent paving (transverse joint)



Key

1 Jointing mortar
2 Low modulus movement joint, if required
3 Bedding mortar
4 Concrete base
5 Concrete foundation

Figure I.10 Example of 3 Row dished Drainage Channel

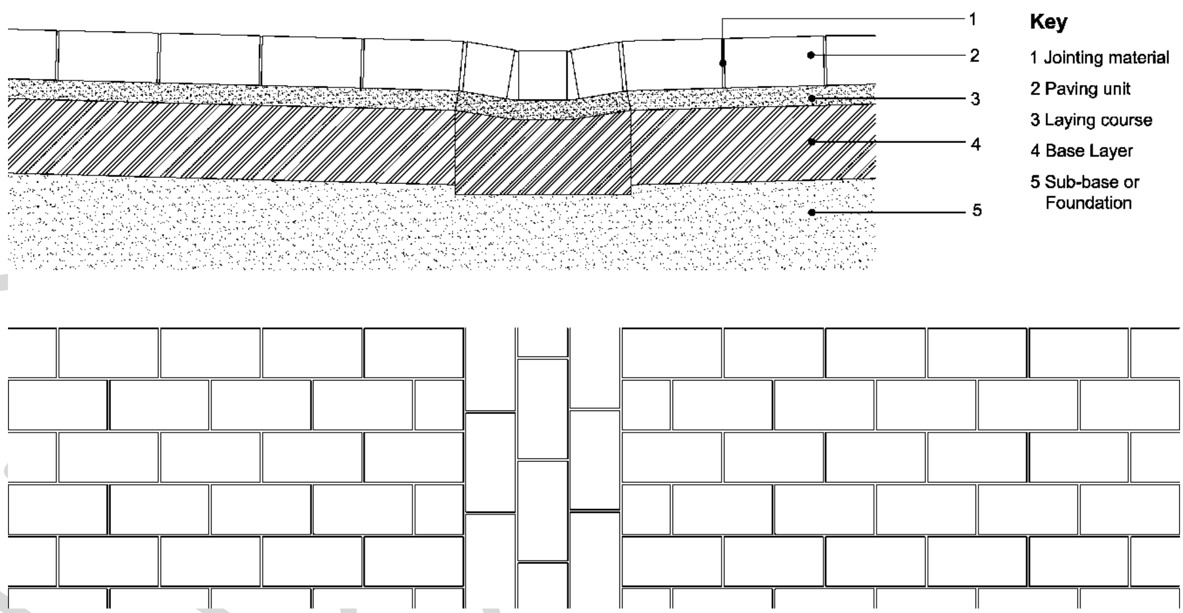


Figure I.10 – Example of combined drainage and kerb

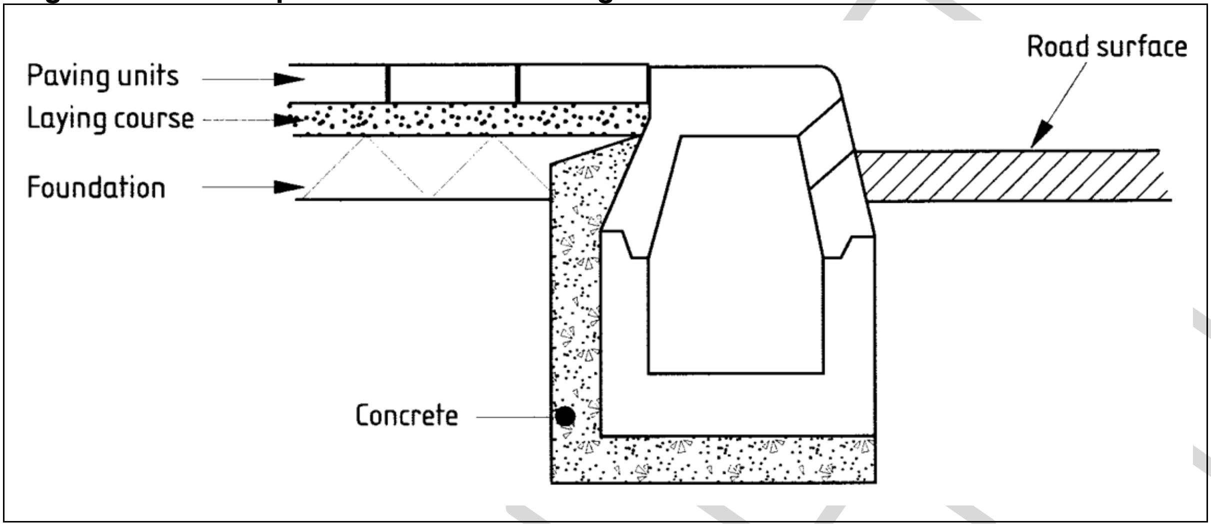
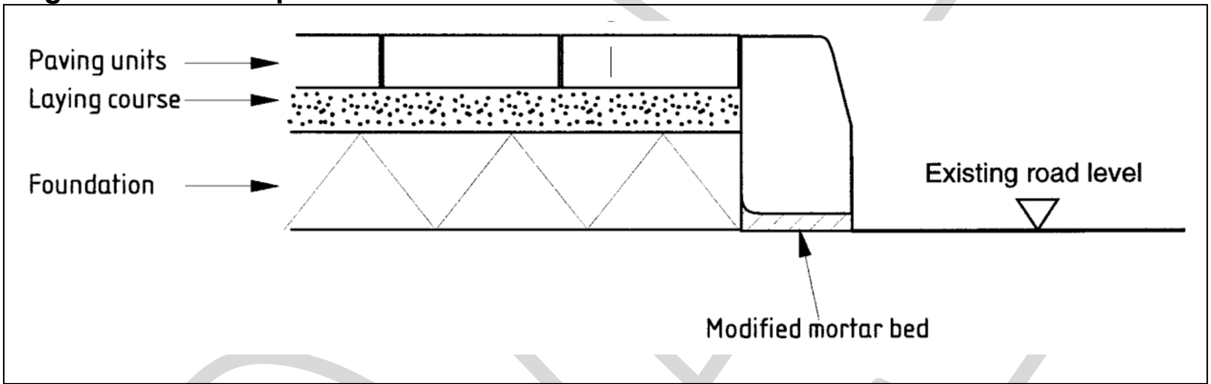
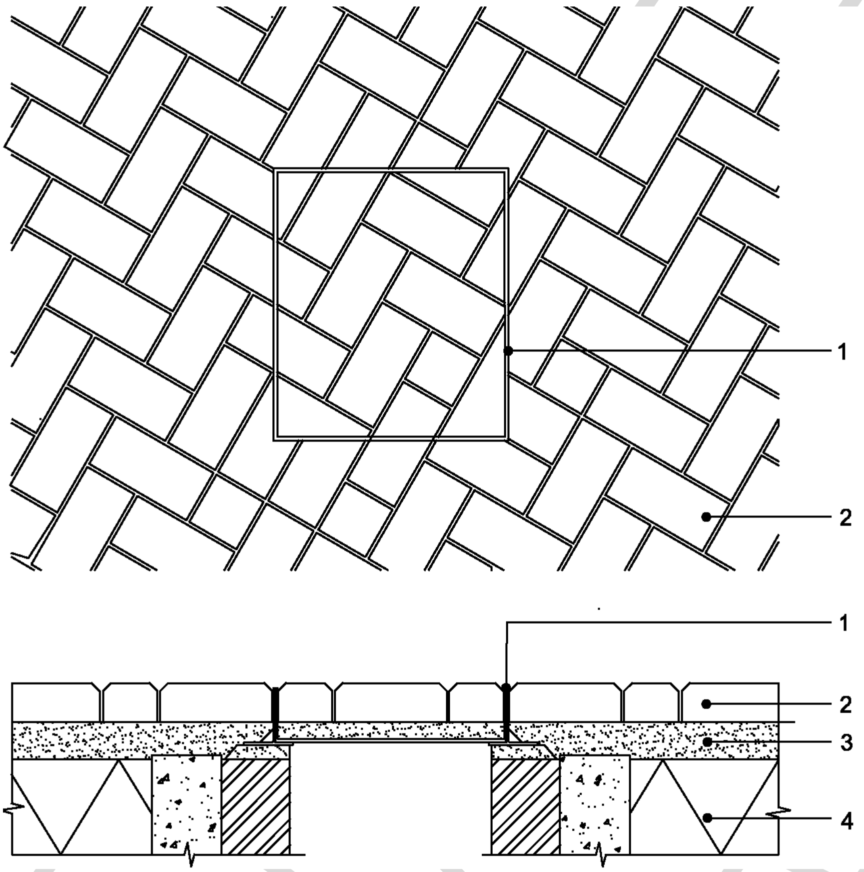


Figure I.11 – Example of bonded kerbs



Annex J (informative)
Typical construction details

Figure J.1 – Recessed Access Chamber Cover



NOTE Inboard cuts are shown in this example where made necessary in order to avoid small units at the periemeter of the frame. See ***13.2.4****.*

Key

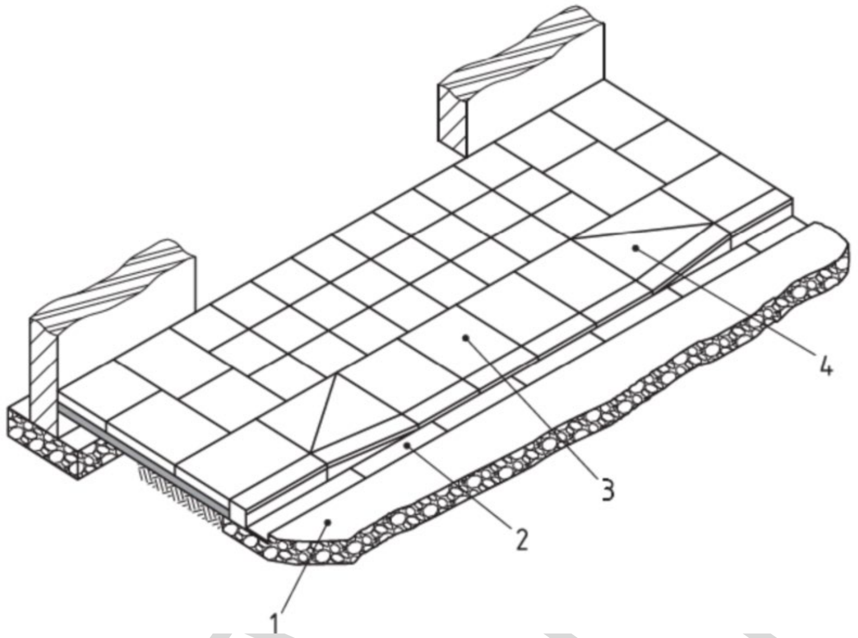
1 Recessed access chamber frame

2 Paving unit

3 Laying course

4 Base

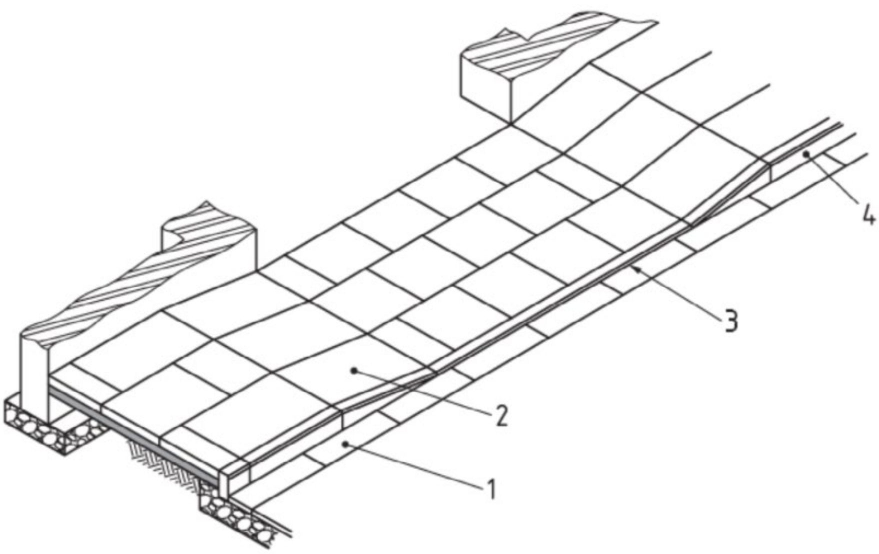
Figure J.2 – Example of a ramped crossing



Key

1 Road surface
2 Channel
3 Flags or slabs ramped
4 Flags or slabs cut across for mitre and ramp

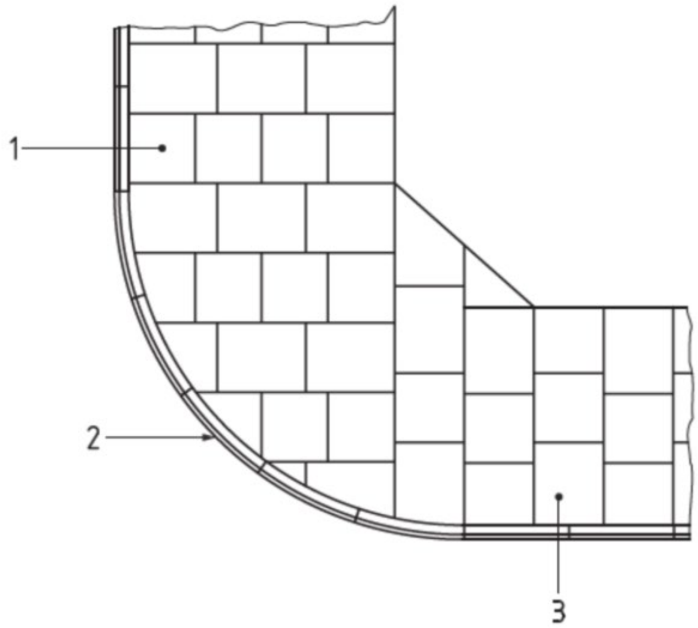
Figure J.3 – Example of a dropped crossing



Key

1 Channel
2 Flags or slabs
3 Dropped crossing
4 Kerb

Figure J.4 – Example of a run-out corner



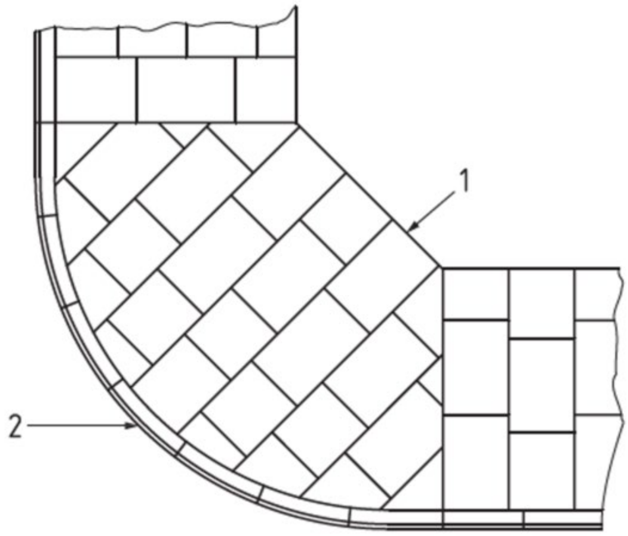
Key

1 Major footpath

2 Kerb

3 Minor footpath

Figure J.5 – Example of a new town corner

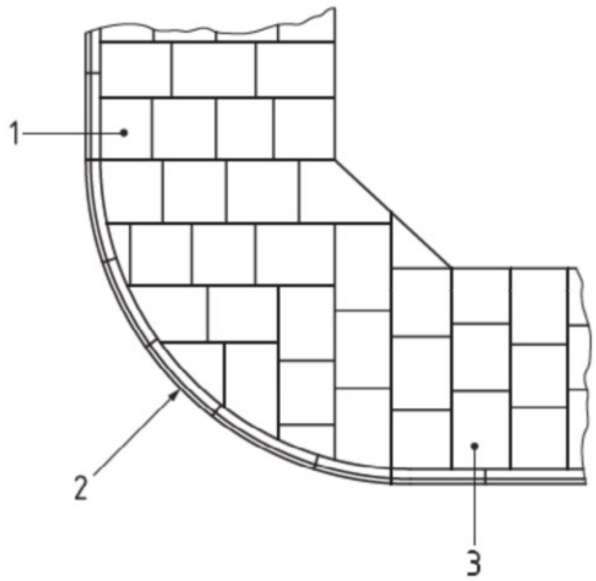


Key

1 Laying start line

2 Kerb

Figure J.6 – Example of a bonded corner



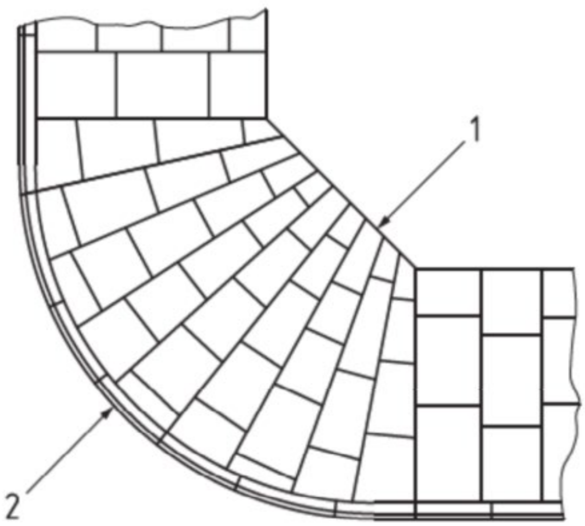
Key

1 Major footpath

2 Kerb

3 Minor footpath

Figure J.7 – Example of a splayed corner



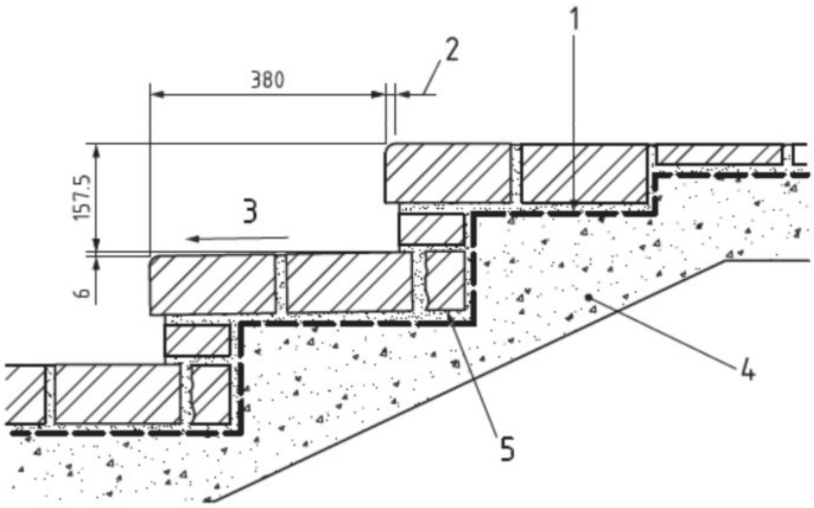
Key

1 Laying start line

2 Kerb

Figure J.8 – Example of a profile of a step constructed using small paving units

Dimensions in millimetres



NOTE Various tread depth dimensions can be constructed as rough cutting can be masked by the riser unit.

Key

1 DPM conforming to BS 8102:2009, **8.2.3** (liquid applied membranes)

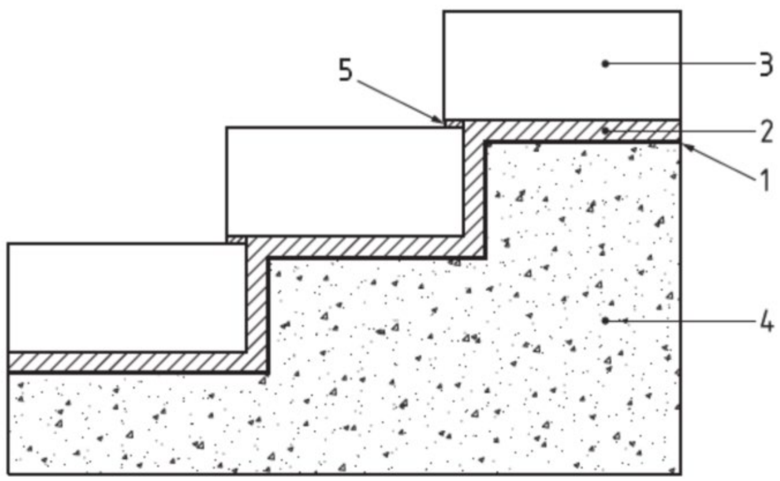
2 20 mm overhang

3 Fall

4 Concrete

5 Rough cutting

Figure J.9 – 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)

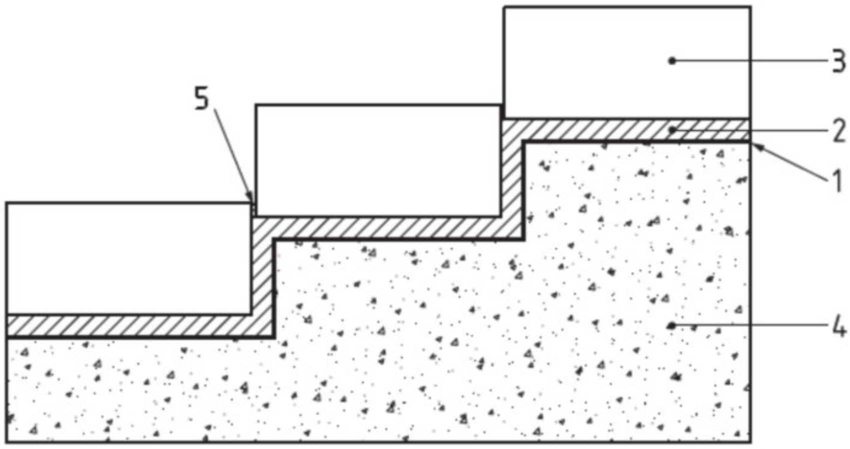
2 Mortar bed

3 Step

4 Concrete

5 Mortar joint

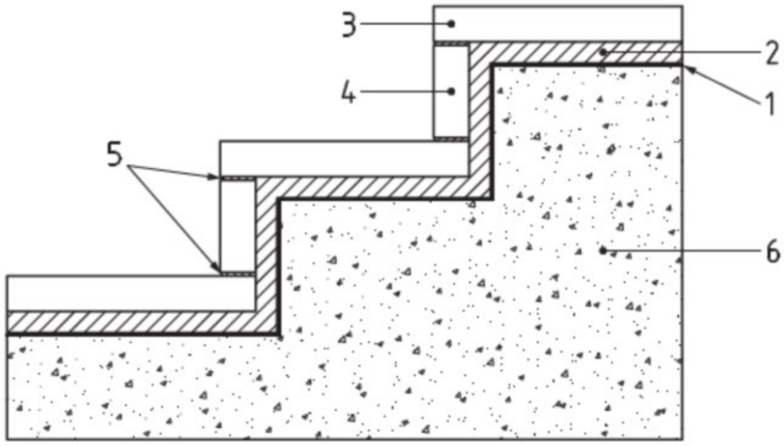
Figure J.10 – Example of a monolithic step laid onto a profiled concrete foundation (step behind step)



Key

1 DPM conforming to BS 8102:2009, **8.2.3** (liquid applied membranes)
2 Mortar bed
3 Step
4 Concrete
5 Mortar joint

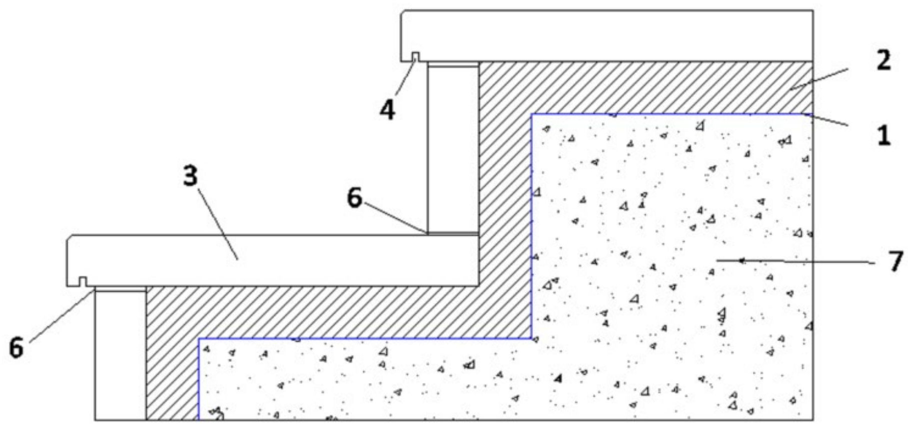
Figure J.11 – Example of a flag/slab tread and riser laid onto a profiled concrete foundation



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

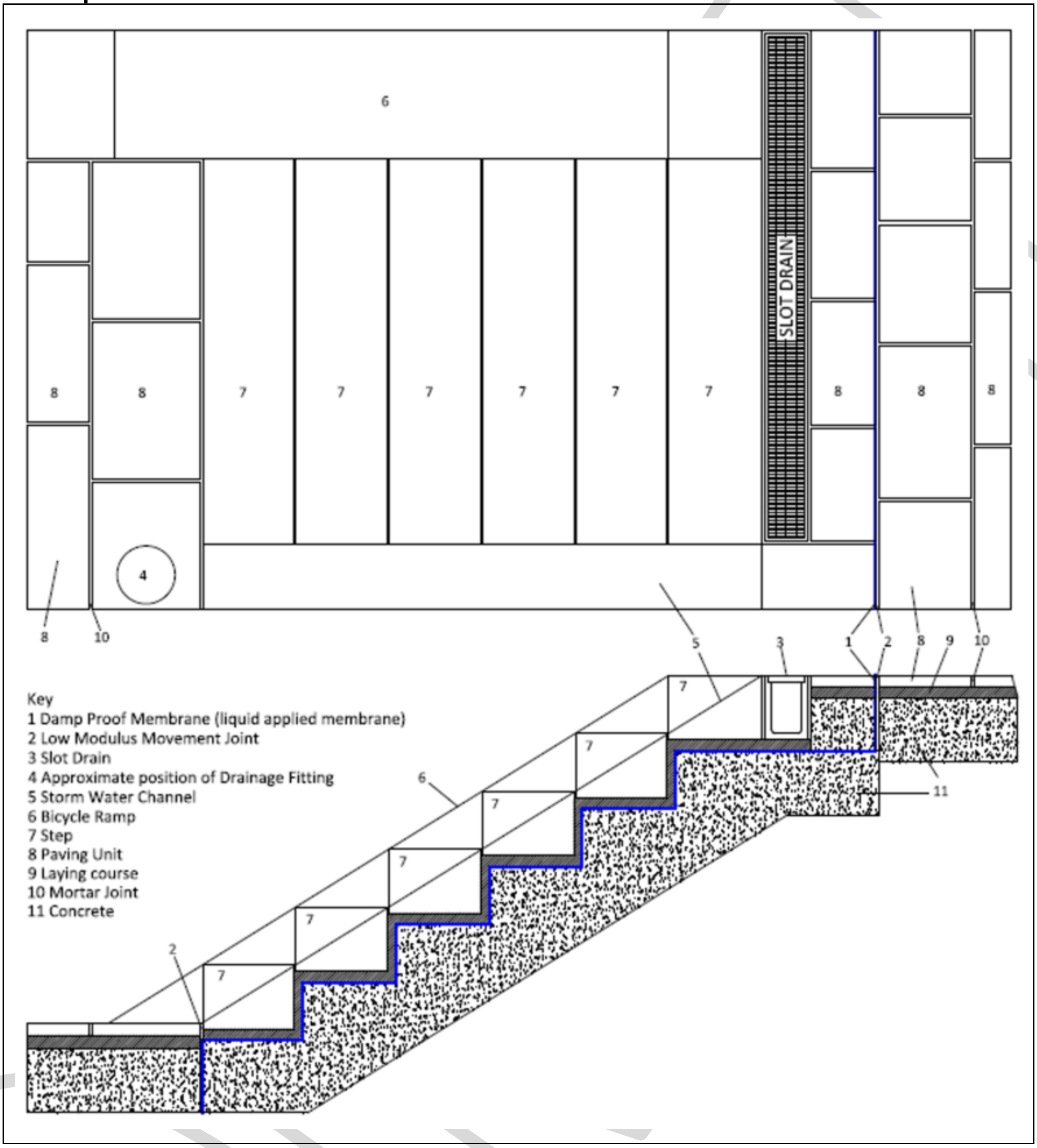
Figure J.12 – Example of a flag/slab tread with overhanging tread and drip



Key

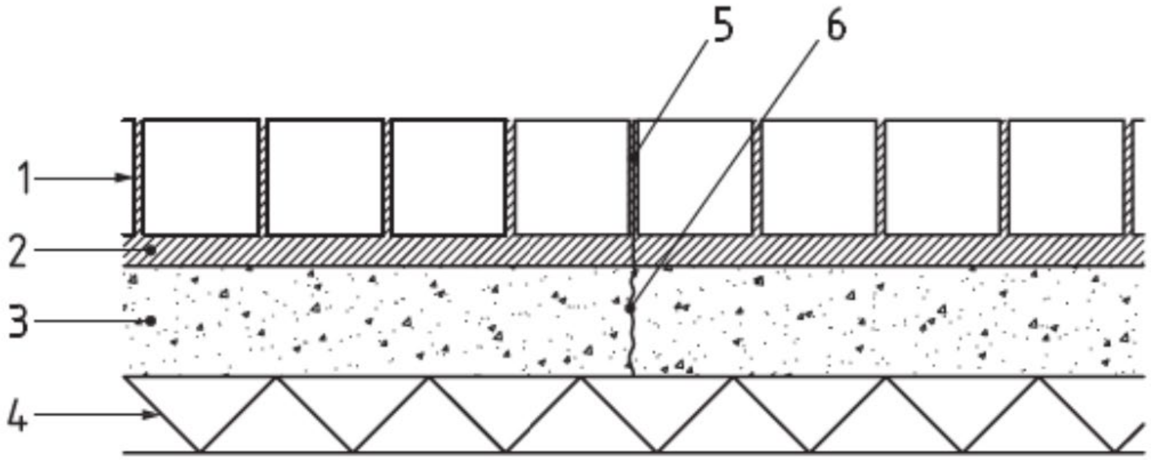
1	Damp proof membrane	5	Step riser
2	Mortar bed	6	Mortar joint
3	Step tread	7	Concrete
4	Drip		

Figure J.13 – Example of a storm drain channel and bicycle ramp attached to a flight of steps



Annex K (informative)
Typical movement joint details

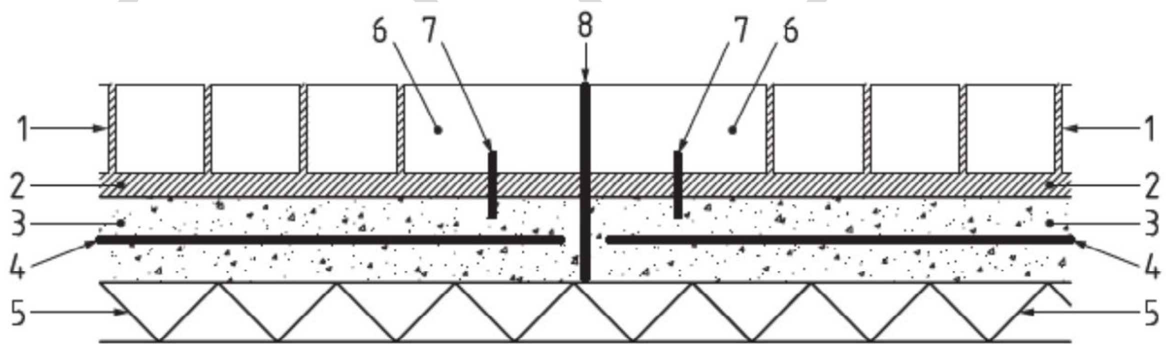
Figure K.1 – Example of induced break detail in bound surface construction



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

Figure K.2 – Example of low modulus movement joint using shallow channel kerbs



NOTE 1 The length of reinforced concrete base is at least 1 m.

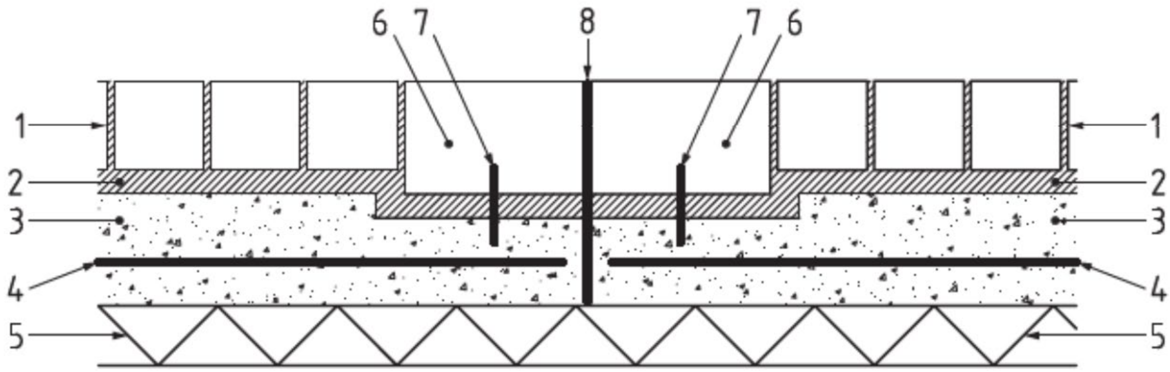
NOTE 2 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.

NOTE 3 The dowel bar is mild steel bar 20 mm in diameter to BS EN 13877-3:2004, Grade B500B steel.

Key

1 Paving elements
2 Laying course
3 Concrete base
4 Steel reinforcement
5 Sub-base
6 Channel
7 Steel dowel pin fixed into kerb using proprietary resin system
8 Movement joint sealed with proprietary low modulus sealant

Figure K.3 – Example of low modulus movement joint using deep channel kerbs



NOTE 1 The reinforcement is at least steel mesh as given in BS 4483:2005, A 393.

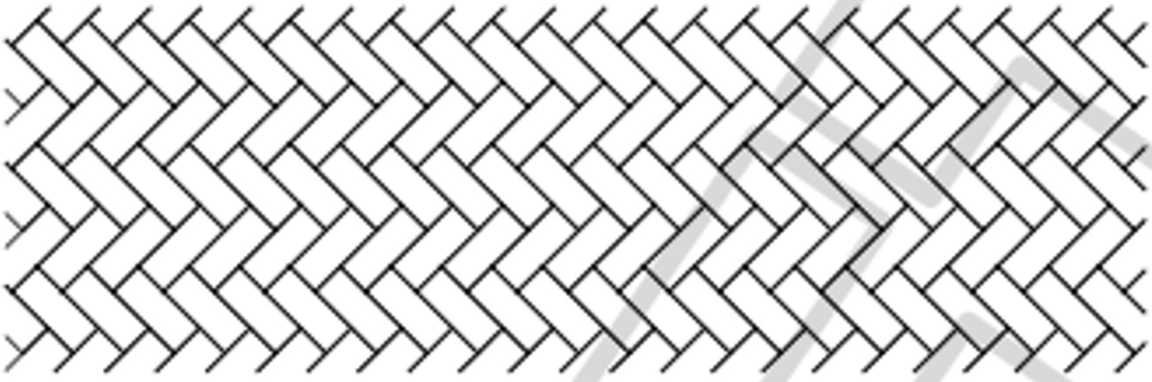
NOTE 2 The dowel bar is mild steel bar 20 mm in diameter to BS EN 13877-3:2004, Grade B500B steel.

Key

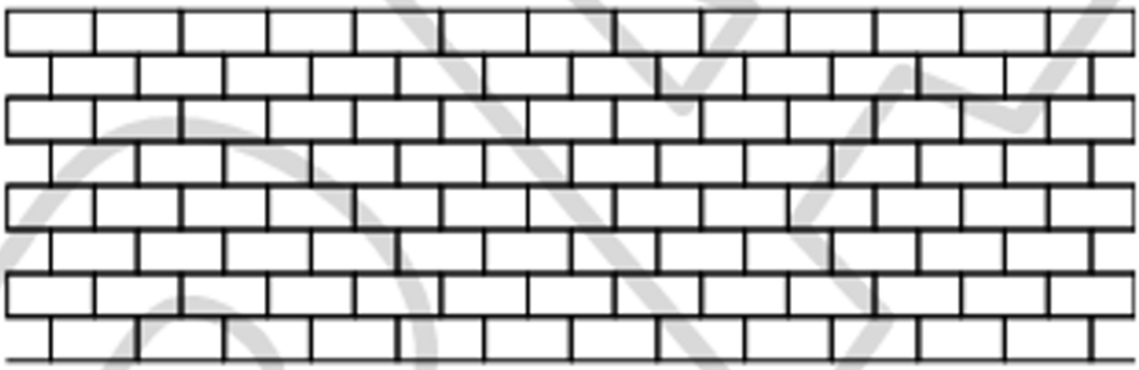
1 Paving elements
2 Laying course
3 Concrete base
4 Steel reinforcement
5 Sub-base
6 Channel
7 Steel dowel pin fixed into kerb using proprietary resin system
8 Movement joint sealed with proprietary low modulus sealant

Annex L (informative)
Modular payment laying patterns

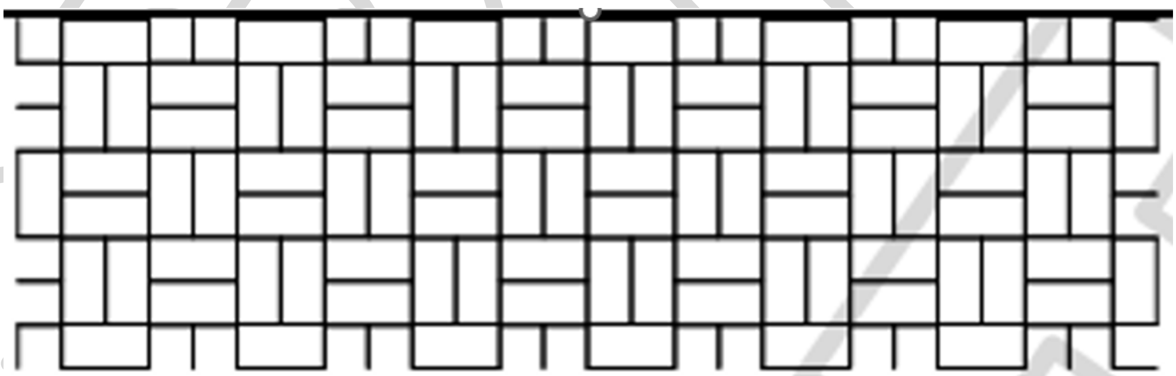
Figure L.1 – Concrete block, clay paver and sawn-sided sandstone sett laying patterns for unbound construction



a) Herringbone

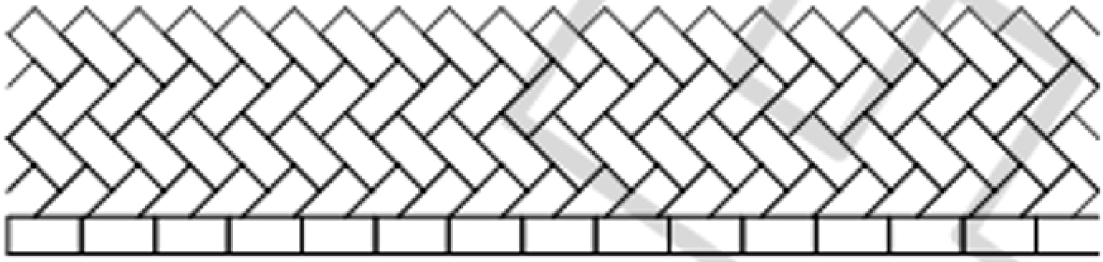


c) 90° stretcher course

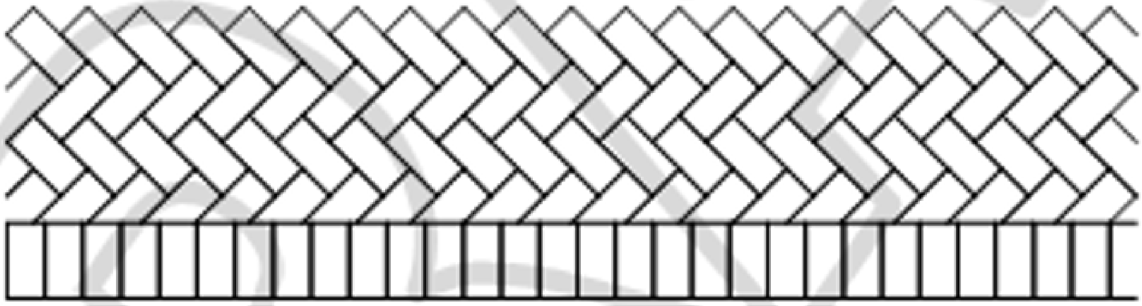


c) Basket weave

Figure L.2 – Concrete block, clay paver and sawn sett edge details



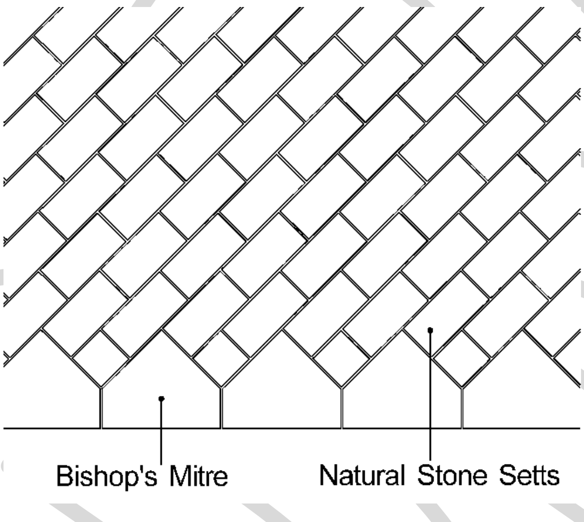
a) Single stretcher course



b) Soldier course

Figure L.3 – Example of laying pattern that incorporates complimentary fittings

a) Bishop’s Mitre with natural stone setts laid in stretcher bond pattern



b) Bishop’s Mitre with concrete block pavers laid in herringbone pattern

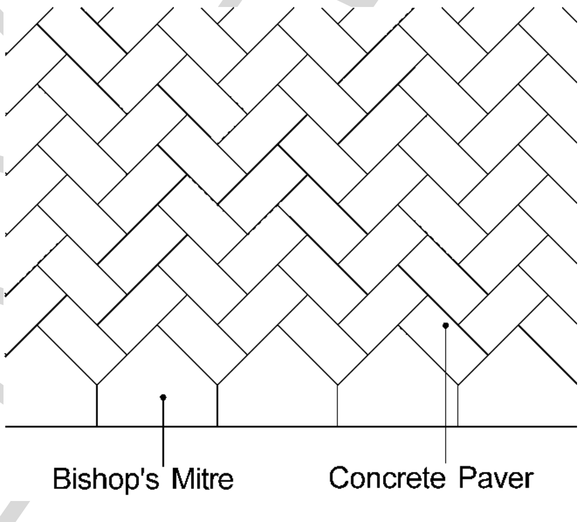
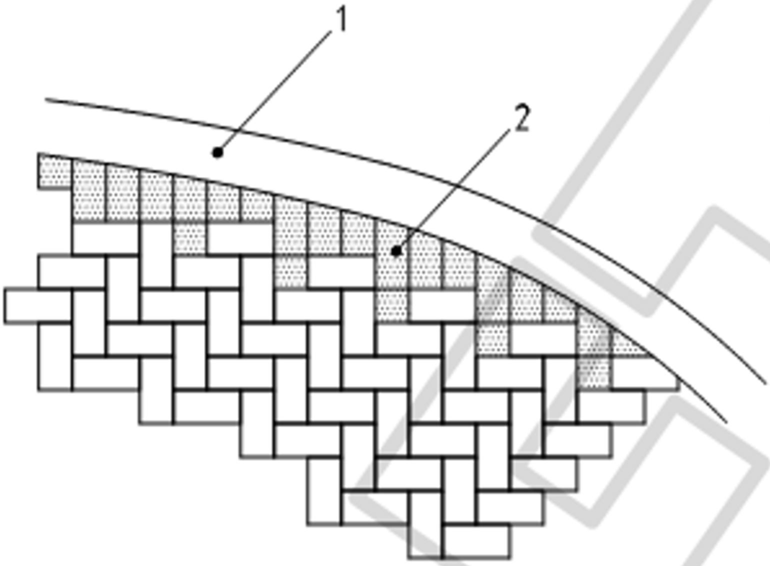


Figure L.4 – Example of laying pattern that incorporates inboard cutting at edges: Inboard cuts and half cuts breaking herringbone laying pattern



Key

1 Edge restraint

2 Cut paving units

Figure L.5 – Florentina pattern – cube setts

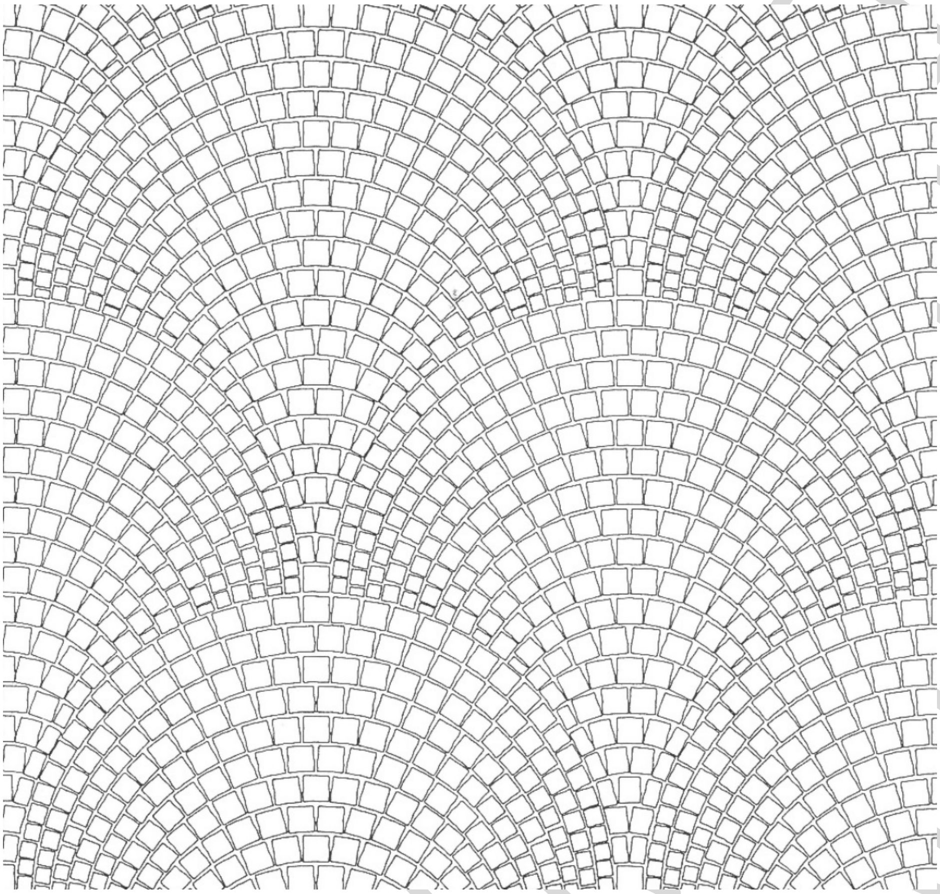
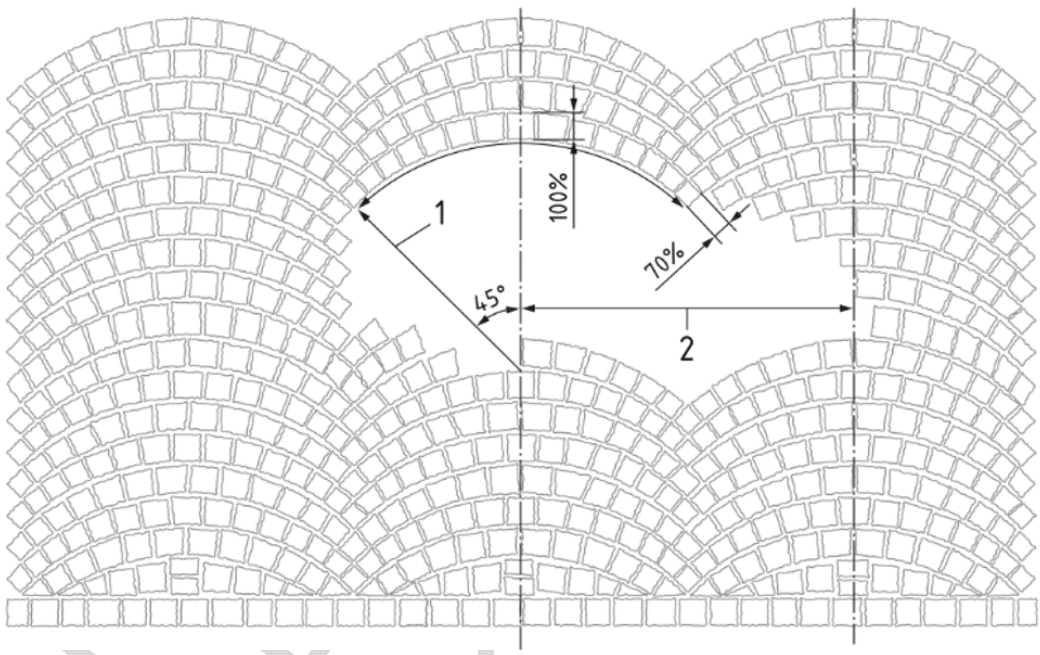


Figure L.6 – Segmental arc pattern in single direction – cube setts

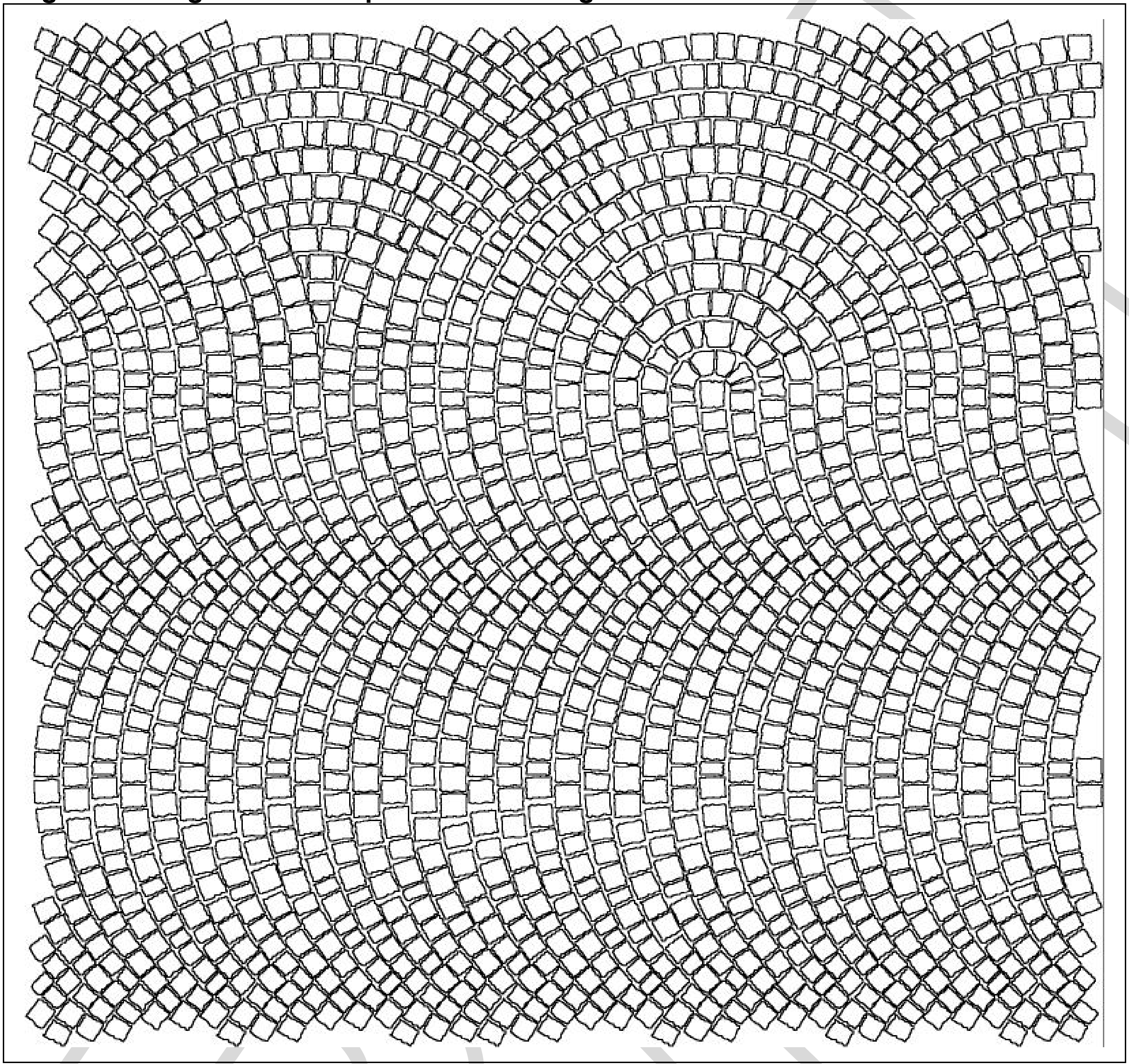


Key

1 Radius = 0.70 * chord width

2 Chord width

Figure 7 – Segmental arch pattern 90° change in direction – cube setts



Annex M (informative)
Roles and responsibilities

M.1 General

Pavement construction projects vary in size and complexity. The range and diversity of resources can also vary, but the responsibilities of the various parties involved, as set out in **M.2** to **M.7**, are fundamental to all projects.

M.2 Construction (Design and Management) Regulations 2015 [13]

The Construction (Design and Management) Regulations 2015 (CDM Regulations), provide a framework for embedding the health and safety of everyone involved in the planning, design, delivery and maintenance of a construction project.

A plan satisfying the CDM Regulations is required for every type of construction project or activity where at least one person is employed, no matter how small.

A householder is not required to produce a CDM plan if they are carrying out work themselves on their own domestic property. However, if a contractor is employed for the work, the contractor is responsible for compliance with the CDM Regulations.

M.3 Client's responsibilities

The client provides the brief for the project and is responsible for appointing the designer, the project manager and the contractor. These may be individual roles or combined.

NOTE It is suggested that the client discusses and agrees with the contractor the nature and extent of insurance cover for the property and the scope of the works.

On smaller projects, the client may assume the role of the designer and/or the project manager. However, in any combination of roles, the client may choose to introduce an inspection and test plan in order to maintain the quality of the project.

M.4 Designers' responsibilities

The designer may be an individual or a team, working to achieve a competent and cost-effective solution that fulfils the client's requirements.

The role of the designer is generally to understand and deliver the aspirations of the client via a formal design while maintaining compliance with relevant legislation are met and verifying that the materials specified are suitable.

The designer designs the construction of a pavement based on a number of factors, including but not limited to the following:

a) makeup of the existing ground;

b) traffic volumes using the pavement;

c) materials specified; and

d) drainage requirements.

The designer or design team is also responsible for defining and stating any stop points during the construction process required to check quality and compliance in accordance with an inspection and test plan.

NOTE An inspection and test plan might require supplying samples and material data sheets, as well as assessing compliance through testing throughout the construction process.

Further information is provided in BS 7533-101.

M.5 Project manager's responsibilities

The project manager controls all aspects of the project's planning and execution, including programme timelines, budget, quality control and performance.

The project manager is responsible for maintaining compliance throughout the project in accordance with the inspection and test plan specified by the designer.

M.6 Contractor's responsibilities

The contractor obtains reassurance that the design is has been prepared in accordance with BS 7533-101 or Clause **8** of this part (see **9.1**).

The contractor completes the construction of the project to the specifications in the design, in accordance with the terms of a contract, and is responsible for any subcontracted processes, such as materials procurement, appointment of specialist subcontractors and the quality of the subcontracted works.

The contractor implements inspection and test plans, so that these are programmed as necessary and test data are made available promptly.

NOTE 1 It is suggested that the contractor discusses and agrees with the client the nature and extent of insurance cover for the property and the scope of the works.

The contractor should raise any issues as they become apparent.

Any changes are approved through the procedures set out in the contract, and any verbal agreements are confirmed in writing.

The contractor is responsible for confirming that all site operatives have received adequate training and are competent to undertake the tasks they are required to perform.

NOTE 2 Relevant skills training is provided by the Construction Skills Certification Scheme (CSCS).

M.7 Design and build responsibilities

In a design and build project, the contractor assumes the role, and therefore the responsibilities, of the designer and/or project manager together with that of contractor.

The design and build contractor prepares inspection and test plans to deliver the quality of the contract at all relevant stages.

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For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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