BS 5385-5:2009

BSI British Standards

Wall and floor tiling –

Part 5: Design and installation of terrazzo, natural stone and agglomerated stone tile and slab flooring – Code of practice

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Contents

Summary of pages
This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 66, an inside back cover and a back cover.

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Foreword

Publishing information

This part of BS 5385 is published by BSI and came into effect on 1 January 2009. It was prepared by Technical Committee B/539, *Ceramic tiles and other rigid tiling*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This part of BS 5385 supersedes BS 5385-5:1994, which is withdrawn.

Relationship with other publications

This part of BS 5385 is one of a series dealing with the installation of floor and wall tiling, the other parts being:

- Part 1: *Design and installation of internal ceramic, natural stone and mosaic wall tiling in normal conditions – Code of practice*;
- Part 2: *Design and installation of external ceramic and mosaic wall tiling in normal conditions – Code of practice*;
- Part 3: *Design and installation of internal and external ceramic and mosaic floor tiling in normal conditions – Code of practice*;
- Part 4: *Design and installation of ceramic and mosaic tiling in special conditions – Code of practice*.

Information about this document

This is a full revision of the standard, and introduces the following principal changes:

a) guidance on composition block flooring has been deleted and guidance on agglomerated stone has been included;

b) updated references to take account of the new harmonized European product standards (BS EN 12004 (Adhesives), BS EN 12057 and BS EN 12058 (Natural stone products), BS EN 13748 (Terrazzo tiles) and their supporting suites of test methods);

c) updated specifications for cements, including European Standard specifications for cements which incorporate a number of cement types and standard strength classes;

d) updated specifications for sands (aggregates), which are now provided by European Standards for the specification of aggregates (throughout this standard, "sand", the term commonly used in the UK building and tiling industry, is interchangeable with the term "aggregate" that is used in the European specifications).

Use of this document

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Hazard warnings

WARNING. This British Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

As a code of practice, this part of BS 5385 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this part of BS 5385 is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

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

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

Contractual and legal considerations

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

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

1 Scope

This part of BS 5385 gives recommendations for the design and installation of terrazzo tile and slab and natural stone internal and external floorings, and contains recommendations covering the laying of agglomerated stone, a cast manufactured item containing natural stone that is subsequently sawn to size.

The types of bedding methods that can be used and their suitability are given; as well as recommendations for the protection, cleaning and maintenance of the finished floor surface.

2 Normative references

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

BS 1521, *Specification for waterproof building papers*

BS 4027, *Specification for sulfate-resisting Portland cement*

BS 4483:2005, *Steel fabric for the reinforcement of concrete – Specification*

BS 5268-2, *Structural use of timber – Part 2: Code of practice for permissible stress design, materials and workmanship*

BS 5385-3, *Wall and floor tiling – Part 3: Design and installation of internal and external ceramic and mosaic floor tiling in normal conditions – Code of practice*

BS 5385-4, *Wall and floor tiling – Part 4: Design and installation of ceramic and mosaic tiling in special conditions – Code of practice*

BS 5974, *Code of practice for temporarily installed suspended scaffolds and access equipment*

BS 6100-1, *Building and civil engineering – Vocabulary – Part 1: General terms*

BS 6100-9, *Building and civil engineering – Vocabulary – Part 9: Work with concrete and plaster*

BS 6213, *Selection of construction sealants – Guide*

BS 6399-1, *Loading for buildings – Part 1: Code of practice for dead and imposed loads*

BS 8000-11.2, *Workmanship on building sites – Part 11: Code of practice for wall and floor tiling – Section 11.2: Natural stone tiles*

BS 8102:1990, *Code of practice for protection of structures against water from the ground*

BS 8203, *Code of practice for installation of resilient floor coverings*

BS 8204-1, *Screeds, bases and in situ floorings – Part 1: Concrete bases and cement sand levelling screeds to receive floorings – Code of practice*

BS 8204-3:2004, *Screeds, bases and in situ floorings – Part 3: Polymer modified cementitious levelling screeds and wearing screeds – Code of practice*

BS 8204-5:2004, *Screeds, bases and in situ floorings – Part 5: Mastic asphalt underlays and wearing surfaces – Code of practice*

BS 8204-7:2003, *Screeds, bases and in situ floorings – Part 7: Pumpable self-smoothing screeds – Code of practice*

BS EN 197-1:2000, *Cement – Part 1: Composition, specifications and conformity criteria for common cements*

BS EN 450-1, *Fly ash for concrete – Part 1: Definition, specifications and conformity criteria*

BS EN 459, *Building lime – Part 1: Definitions, specifications and conformity criteria*

BS EN 934-2, *Admixtures for concrete, mortar and grout – Part 2: Concrete admixtures – Definitions, requirements, conformity, marking and labelling*

BS EN 12002:2002, *Adhesives for tiles – Determination of transverse deformation for cementitious adhesives and grouts*

BS EN 12004:2007, *Adhesives for tiles – Definitions and specifications*

BS EN 12057, *Natural stone products – Modular tiles – Requirements*

BS EN 12058, *Natural stone products – Slabs for floors and stairs – Requirements*

BS EN 12326-1, *Slate and stone products for discontinuous roofing and cladding – Part 1: Product specification*

BS EN 12878, *Pigments for the colouring of building materials based on cement and/or lime – Specifications and methods of test*

BS EN 13139:2002, *Aggregates for mortar*

BS EN 13707, *Flexible sheets for waterproofing – Reinforced bitumen sheets for roof waterproofing – Definitions and characteristics*

BS EN 13748-1:2004, *Terrazzo tiles – Part 1: Terrazzo tiles for internal use*

BS EN 13748-2, *Terrazzo tiles – Part 2: Terrazzo tiles for external use*

BS EN 14647:2005, *Calcium aluminate cement – Composition, specifications and conformity criteria*

BRE IP 10/00 (2000), *Flooring, Paving and Setts – Requirements for safety in use*

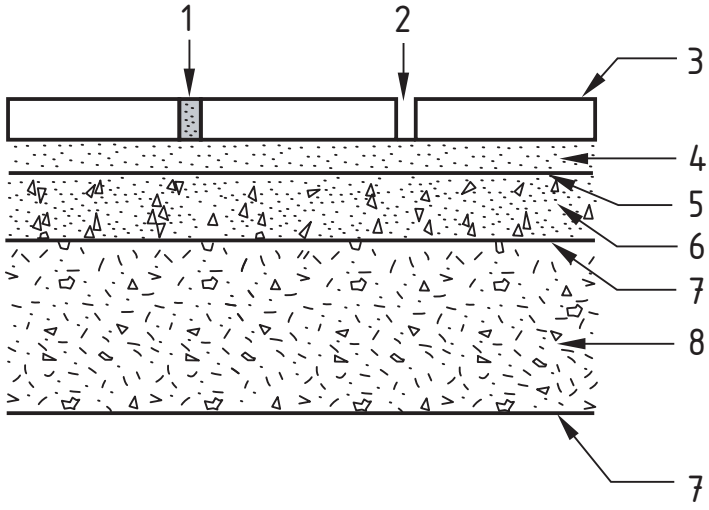
3 Terms and definitions

For the purposes of this Part of BS 5385 the terms and definitions given in BS 6100-1, BS 6100-6 and the following apply. An illustration of some selected definitions is shown in Figure 1.

3.1 light loading
low density pedestrian traffic with possibly lightweight soft-wheeled trolleys (e.g. domestic and office locations)

3.2 heavy loading
high density pedestrian traffic and/or a static, moving, dropped or dragged heavy load (e.g. in shopping malls, industrial and engineering premises and garages for heavy vehicles)

Figure 1 **Illustration of definitions**



Key

1	Grout	5	Separating layer (optional)
2	Joint	6	Screed (optional)
3	Flooring unit	7	Damp-proof membrane[A)]
4	Bed	8	Structural base

[A)] Alternative positions of damp-proof membrane.

4 Exchange of information and time schedules

*NOTE Clause **4** deals with the exchange of information for the whole floor, including the flooring, bed, base and screed (if any).*

4.1 Exchange of information

The working drawings and specifications should be prepared in sufficient detail to afford proper guidance in the preparation of estimates and the execution of the work. At the tendering stage the following information should be provided by the contract administrator and should be documented.

a) *Site*. Location and means of access.

b) *Building*. Nature of building, assessment of type and density of traffic, particulars of corrosive or other potentially damaging conditions to which the installation might be subjected in service.

c) *Floor*. Structure of floor, type of damp-proof membrane and its location within the floor construction, details of screed (including its surface regularity and the category of soundness required), curing and drying times, particulars of any floor warming installation, separating layer, movement joints, finished floor levels and falls with permissible deviations.

d) *Associated work*. Services embedded in or passing through the floor, skirtings and abutments, junctions with other adjacent flooring.

e) *Finishes*. Type of finishing product, bedding and jointing requirements and required surface plane.

f) *Contract*. Details, if the work is to be completed in any specific order or in sections.

g) *Health and safety*. Information on articles and substances for use during the work that are liable to be a health hazard.

h) *Time schedule*. A time schedule for the progress of the work.

i) *Testing*. Details of any compliance testing required.

4.2 Provision of utilities, facilities and materials

4.2.1 General

To prevent misunderstanding, particularly at the tendering stage, and to avoid possible situations detrimental to installation, it should be made clear whether or not the following will be provided and by whom:

a) adequate clean, dry, lockable storage space protected from frost (if necessary);

b) clean water supply adjacent to working areas;

c) adequate artificial lighting (if required) (see **4.2.2**);

d) safe means of access and places of work;

NOTE 1 Safety considerations might include suitable scaffolding and staging, conforming to BS 5974.

e) unloading and hoisting facilities;

NOTE 2 Attention is drawn to:

- *Lifting Operations and Lifting Equipment Regulations 1998 [1]*
- *Manual Handling Operations Regulations 1992 [2].*

f) electric power supply adjacent to working areas;

g) protection of work during and after fixing;

h) supplies of cement and sand in accordance with **5.4** and **5.5**;

i) tiles, adhesives, grouts and movement joint materials.

4.2.2 Lighting on site

At the design stage, the lighting type, direction and intensity to be used during installation should be specified to ensure that work is completed in similar conditions to those in which the finished installation is intended to be viewed.

NOTE If lighting conditions during installation are different from those envisaged for the completed installation, the appearance of the finished floor might be different from that originally intended.

4.3 Time schedule

The time schedule for the whole building work should be planned in the initial stages before operations commence and, where possible, in consultation with those responsible for carrying out the work of each of the trades concerned.

Where a screed is being laid, a minimum of three weeks should be allowed for it to dry. The screed should be covered with impervious sheeting for at least the first seven days of this three week period to prevent rapid surface drying in order to reduce the possibility of cracks appearing. These time periods are for good drying conditions (20 °C and 65% relative humidity). In the UK a longer drying period is normally required.

The drying time required should reflect the type and thickness of the screed and the on-site drying conditions. Where the flooring unit is to be directly bonded to the screed with adhesive, guidance in BS 8204-1 and BS 8203 should be followed.

NOTE Typically, one day of drying can be allowed for each millimetre of (screed) thickness for the first 50 mm, followed by an increasing time for each millimetre above this thickness. It is therefore reasonable to expect a levelling screed 50 mm thick drying under good conditions, to dry sufficiently in about 2 months.

Where underfloor heating is present in the sub-floor then the guidance in Clause **7** should be followed.

Where insufficient drying time and/or unsuitable drying conditions exist, the stone (and any adhesive) should be isolated from the screed below e.g. by using an uncoupling membrane. If at the design stage (see Clause **6**) it becomes apparent that only shorter drying periods are available the stone should be set on an unbonded, reinforced semi-dry cement sand bed.

The schedule should also allow time for all cutting of holes and chases in the floor that is to receive the tile bed.

Provision should be made for adjustment to the schedule to allow for suspension of operations due to frost or other unfavourable weather or other conditions that jeopardize the safety of workers and/or the success of the installation.

Alternatively, consideration should be given to the possibility of providing a protective enclosure, e.g. cocooning, to enable work to continue during unfavourable conditions.

5 Materials

5.1 Transport and storage

The delivery of materials should be arranged to minimize handling. Adequate precautions should be taken to guard against the possibility of damage.

Materials should be stored in clean, dry, frost-free (if necessary), lockable storage and stacked in such a way to avoid excessive handling, theft and damage.

5.2 Terrazzo tiles and slabs for internal and external floorings

5.2.1 Terrazzo tiles

The designer should specify that only terrazzo tiles conforming to BS EN 13748-1 for internal floorings and BS EN 13748-2 for external floorings and having a wear layer after grinding of at least 6 mm are to be used.

5.2.2 Terrazzo pre-cast slabs

5.2.2.1 General

The following designation of pre-cast units should be considered by the designer for ordering purposes.

a) The units should be described as having either a Type A surface for use as stair treads, landings and pavings in positions subject to concentrated traffic or a Type B surface for all other units.

b) The size of the aggregate in the facing layers, the dimensions and shape of the unit and the surface finish required should be stated. The colour and type of the surface and the size of aggregate should be designated by reference to the manufacturer's sample.

c) The sizes of the terrazzo aggregate for the purpose of ordering units should be described as follows:

   1) up to 5 mm;

   2) up to 12 mm;

   3) up to 25 mm;

   4) random;

   5) pebble marble.

Selection of aggregate sizes should take into consideration the finished thickness of the unit.

5.2.2.2 Manufacture

The following characteristics of the manufacture of materials to be used should be considered at the design stage.

a) *Terrazzo facing*. The terrazzo mix consists of cement and a suitably graded aggregate mixed in a dry state to which the minimum amount of water is added to provide optimum compaction having regard to the method of consolidation being used. The finished terrazzo facing should have a minimum thickness of 10 mm for wearing surfaces and 6 mm for non-wearing surfaces. Where the terrazzo forms an integral part of the structural design the provisions of BS 8204-1 should apply.

b) *Concrete backing*. The backing concrete should conform to the recommendations for precast structural concrete given in BS 8204-1.

c) *Fabrication*. Units are cast in suitable moulds using concrete faced with terrazzo on one or more faces or, in special cases, terrazzo alone. The mixes as laid in the moulds should be adequately compacted. The terrazzo facing and the backing or core concrete, where applicable, should be cast monolithically. Where units

are designed for bedding, keyed concrete is used. When the edges of units are required to be terrazzo faced, care should be exercised in casting to ensure that the minimum thickness specified is obtained and that an adequate bond is achieved with the backing concrete. Where structural design considerations require, reinforcement should be accurately positioned within the unit and adequately covered, all in accordance with BS 8204-1. Care should be taken to avoid displacement of the reinforcement during vibration and, if necessary, terrazzo bobbins might be used. The surface is treated by grinding, ensuring sufficient time is allowed between casting and grinding to allow the unit to attain adequate hardness to enable the face to be ground without dislodging the surface aggregate. Any slight surface imperfections are filled by grouting with a neat cement paste coloured to match the original mix and well worked into the surface. The excess of grouting coat is removed by grinding using a stone not coarser than No. 80 grit, no sooner than 72 h after the surface has been grouted. When the operation has been completed the surface is thoroughly washed.

Because the thickness of flooring units increases in proportion to their length, thicknesses should be as follows:

1) internal sills, precast treads, fully bedded, up to 1.5 m long 40 mm thick;
2) from over 1.5 m to 2 m long 45 mm thick;
3) from over 2 m to 2.5 m long 50 mm thick;
4) shower trays made to dimensions 750 mm × 750 mm a minimum of 40 mm thick at the outlet.

d) *Inserts*. Non-slip inserts for pavings and treads should, by agreement between the purchaser and supplier, be set into the wearing surface of the unit. They might be cast in or applied after manufacture, subject to being of a suitable cross section, being securely fixed in position and dimensionally stable. Where cramps, dowels or other fixing devices are required, these should be of non-ferrous metal or non-corrosive stainless steel securely cast into the core of the unit; handling devices might be of alternative material suitable for their purpose.

e) *Finish*. Units should be supplied either:

1) ground and grouted for site finishing;
2) ground, grouted and re-ground to a fine grit finish; or
3) ground, grouted and polished as agreed between the purchaser and the supplier.

f) *Uniformity of colour*. The overall colour of units is practically uniform for any complete section of a contract, except where special random effects are ordered.

NOTE 1 Owing to variations in the colour of aggregates and cement, and in the processes of manufacture, slight variations in the colour of pre-cast units are unavoidable.

g) *Tolerances*. Units should not exceed the basic sizes agreed between the purchaser and the supplier and tolerances should be related to work size as follows:

1) thickness: ± 1.5 mm on free standing units and ± 3 mm on bedded units;

2) length and width: ± 1.5 mm up to 1.5 m and ± 3 mm above 1.5 m and up to 3 m.

h) *Flatness, twist, winding and bow*. Units should have a deviation of less than 3 mm from a 1.5 m straight edge placed in any position on a nominally plane surface. For facing slabs the permitted bowing should be all one way on all units supplied for any separate area of cladding as agreed between the supplier and the purchaser.

i) *Regularity of plan shape*. Units should have a deviation of less than 1.5 mm from the intended true line of the unit in any direction.

The manufacturer's advice should be obtained when close tolerances are required, as those which can be achieved depend on the shape of the unit, the position of any projections, stiffness of the mould, method of assembly and the number of castings from each mould. For irregular, curved or specially shaped units, dimensions and tolerances should be clearly defined at the design stage.

NOTE 2 Particular attention is drawn to the possible difficulties created by an accumulation of tolerances.

j) *Freedom from defects*. Units should have an even distribution of aggregates over the face with the profiles true and the face free from flaking and/or crazing.

k) *Age at delivery*. Units should not be delivered until a period of 28 days from the date of manufacture has elapsed.

l) *Recommendations for handling and storage on site*. The manufacturer's advice for handling and storage should be followed, and as a minimum:

1) units should be stacked under cover on clean, level, dry stacking areas;

2) to avoid bowing and/or deflection under self-weight, units should be stacked vertically on edge and non-staining laths or battens should be placed between the units;

3) to avoid discoloration, units should not be prematurely delivered to site nor come into contact with rope, straw, hardwood or other material likely to cause staining, nor should they be exposed to direct sunlight;

4) units should be protected from physical damage both before and after fixing.

5.3 Natural stone for internal and external floorings

5.3.1 General

NOTE 1 BS EN 12440 provides the classification and the correct identification of stone types and origin; however, for the purposes of this standard, the simplified descriptions in Annex A can be considered.

At the planning stage all stone types should be considered individually for their merits in use as flooring.

NOTE 2 There are many different classification schemes for stone, which have prompted the industry to simplify descriptions. This has led to many problems when, for instance, a stone laid as a granite is actually found to be a different stone type altogether and does not perform as expected.

When using natural stone for flooring, consideration should be given to the level of traffic and the desired finished effect.

5.3.2 Stone unit sizes

The suitability of stone unit sizes for various usages should be considered at the design stage as follows:

a) *Domestic*. Tiles and slabs with calibrated thickness for bedding on adhesive not exceeding 600 mm × 600 mm on face in granite, limestone, marble and slate should be used. Where units 600 mm × 600 mm on face and less than 20 mm thick are offered their ability to accept the imposed loads should be checked. Units exceeding 300 mm × 300 mm on face in granite, hard limestone, marble and slate 10 mm thick are suitable for use on existing timber floors.

b) *Domestic and light commercial*. Calibrated tiles and slabs are suitable for bedding on adhesive. Uncalibrated slabs should be bedded in sand:cement or thick bed adhesive.

c) *Commercial*. On floors with occasional over run of light maintenance vehicles, slabs not exceeding 600 mm × 600 mm with a minimum thickness of 20 mm and uncalibrated tiles and slabs for setting on semi-dry cement sand beds should be used.

Due to the suitability of units with a length to width ratio exceeding 3:1 being dependent on the material, and as they require special manufacture, handling and bedding, manufacturers' advice should be obtained for these units.

5.3.3 Selection of natural stone

5.3.3.1 General

When selecting natural stone flooring at the design stage, apart from appearance the following should also be considered:

a) proven track record in a similar environment;

b) that the stone samples are representative of that to be used, having obtained information from the supplier about any significant variation in appearance that such stone can exhibit;

c) abrasion and slip resistance;

d) flexural strength;

e) shape of stone unit selected;

f) likely loading conditions.

When the application is unusually demanding or if the designer or installer is not familiar with the type of stone, greater testing (including a petrographic examination) should be carried out.

Granite, marble, limestone, sandstones and slate are available as calibrated tiles, but consideration should be given at the design stage to the required thickness of the flooring unit based on its end use and the bedding technique employed.

NOTE 1 Slab sizes in various thicknesses greater than 12 mm are available, but selection might be limited by the characteristics of the stone, handling and transportation requirements. Due to manufacturing tolerances, smaller slabs and tiles can be laid with greater accuracy and economy, whilst thin tiles and slabs with large facial size might bow during installation.

NOTE 2 The slip resistance of natural stones varies, depending on the mechanically applied surface finish, and whether the stones polish or roughen in use.

Known absorbent stone should be tested for the effects of spilt liquids and an appropriate impregnator applied.

NOTE 3 Some natural stones are absorbent and might be susceptible to staining, e.g. from spilled liquids and absorbed dirt.

NOTE 4 All natural stone will benefit from the application of an impregnator to assist in the cleaning.

Surface treatment of stone might affect the slip resistance, either negatively or positively, and should be considered at the design stage.

Surface treatments should not be used to enhance a low-quality stone.

Consideration should be given at the design stage to the susceptibility of light coloured absorbent stone bedded in conventional mortars and adhesives to water staining due to moisture, minerals and soluble salts.

*NOTE 5 The use of rapid drying mortars and adhesives can reduce the risk of water staining (see **9.6.5**).*

Special attention should be given at the design stage to laying stone floors over any form of underfloor heating (see Clause **7**) or onto an existing timber floor (see **6.3.4**).

Natural stone tiles are available in a range of sizes and thicknesses, and consideration should be given at the design stage to the thickness of units of any given size as this can be dictated by the type of stone used. Calibrated units up to 0.36 m^2 can normally be fixed by the adhesive methods described in **9.6.5**, and larger units might require different bedding procedures (e.g. see **9.6.1** and **9.6.2**), however, advice should be obtained from the supplier or manufacturer.

Slate used should conform to the test requirements in BS EN 12326–1.

5.3.3.2 Sample unit size

A reference sample should be an adequate number of pieces of natural stone of sufficient size to indicate the general appearance of the finished work. The dimensions of individual pieces should be at least 100 mm × 100 mm and should indicate the range of appearance regarding the colouring, the vein pattern, the physical structure and the surface finish. In particular the reference sample should show specific characteristics of the stone, such as holes for travertine, worm holes for marble, glass seams, spots, crystalline veins.

NOTE The reference sample does not imply strict uniformity between the sample itself and the actual supply; natural variations can always occur.

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 shown by the reference sample should be considered typical of the stone and not as flaws, therefore they should not become a reason for rejection, unless their concentration becomes excessive and the typical character of the stone is lost.

The name and address of the producer or the supplier, as well as the denomination of the stone in accordance with the recommendations in BS EN 12057 and BS EN 12058 should be indicated on the reference sample.

Any comparison between production sample and reference sample should be carried out by placing the reference sample against the production sample and viewing them at a distance of about two metres under normal daylight conditions and recording any visible differences in the characteristics of the stones (as BS EN 12057, Figure 2).

5.4 Cement and lime

5.4.1 General

Cement and lime used should be stored under dry conditions and used in order of delivery. Cement that contains air set lumps should not be used.

WARNING. Cement of all types should be used with care, because of the possible risk of adverse skin effects. Suppliers' material safety data sheets obtained at the exchange of information stage described in **4.1** g) should be used as a basis for assessing and managing the risk associated with its use in a particular application.

5.4.2 Cement for cementitious levelling screeds

The cement used for cementitious levelling screeds should be one of the following.

a) Portland cement (CEM I) conforming to BS EN 197-1.

b) Sulfate-resisting Portland cement conforming to BS 4027.

c) Portland slag cement (CEM II/A-S & CEM II/B-S) conforming to BS EN 197-1.

d) CEM I cement manufactured in the cement mixer from Portland cement and ground granulated blast furnace slag (ggbs) conforming to BS 6699 with a mass fraction of 6% to 34% of combination of ggbs.

e) Combinations produced in the concrete mixer from Portland cement (CEM I) conforming to BS EN 197-1 and pulverized-fuel ash conforming to BS EN 450-1, where the proportions and properties conform to CEM II/A-V or CEM II/B-V of BS EN 197-1:2000, except Clause **9** of that Standard.

f) Calcium aluminate cement (high alumina cement) conforming to BS EN 14647.

g) Proprietary cements, designed to provide rapid drying and hardening properties, for which no British Standard exists. Reference should be made to the manufacturers for guidance on their use.

NOTE 1 Cements and combinations in a) to d) of strength class 42.5 have a compressive strength equivalent to that of ordinary Portland cement conforming to BS EN 197-1.

NOTE 2 Limited experience is available with the use of other types and grades of cement for cement:sand levelling screeds. For example, a cement of strength class 32.5 would probably require an increase in cement content of approximately 10%.

NOTE 3 There are no British Standards for other additions and their suitability might be ascertained from experience of their use in similar mixes.

5.4.3 Cement for cement:sand mortar beds

The cement used for cement:sand mortar beds should be one of the following.

a) Portland cement (CEM I) conforming to BS EN 197-1.

b) Sulfate-resisting cement conforming to BS 4027.

c) Calcium aluminate cement (high alumina cement) conforming to BS EN 14647.

5.4.4 Lime for mortar beds

Lime used should conform to BS EN 459.

Lime used in mortars for gauging with ordinary Portland cement (OPC) should be measured either as a putty prepared from quicklime, hydrated lime or by product lime. Hydrated lime should be used by weight; lime putty should be used by volume.

5.5 Sand

5.5.1 General

Sand used should be protected from rain, frost and any form of contamination.

5.5.2 Sand for cement:sand screeds and mortar beds

Sand used for cement:sand screeds should be as described in BS EN 13139:2002, Annex B.

5.5.3 Sand for grouting

5.5.3.1 For joints of nominal widths 6 mm and above

Sand used for grouting joints 6 mm or more in width should conform to the grading limits of BS EN 13139:2002, recommended European designation 0/2 (FP or MP), Category 2 fines.

5.5.3.2 For joints of nominal widths 3 mm to 6 mm

Sand used for grouting joints of nominal widths 3 mm to 6 mm should conform to the grading limits given in Table 1.

Sands conforming to BS EN 13139:2002 recommended European designation 0/2 (FP or MP), Category 3 fines might be suitable, but the fraction greater than 2.36 mm should be screened off.

Table 1 **Sands for grout for joints 3 mm to 6 mm wide**

BS 410-1 sieve	Percentage by mass passing BS 410-1 sieves (%)
mm	
2.36	100
1.18	95 to 100
*μ*m	
600	80 to 100
300	30 to 100
150	0 to 60
75	Not greater than 7

5.6 Water

Water used should be clean and free of materials deleterious to mortar beds in fresh and hardened states (see BS EN 1008). Drinking water is suitable. All containers used for storing or carrying water should be clean.

5.7 Adhesives

Adhesives are proprietary materials and those selected should conform to BS EN 12004.

Cementitious adhesives (BS EN 12004:2007, Type C) should be used as beds for stone tiles and slabs.

Adhesives should be used in accordance with the manufacturer's instructions.

NOTE 1 Cementitious adhesives are usually proprietary compositions in dry powder form containing cement as the basic ingredient and generally require mixing on site with water or aqueous polymer dispersion.

NOTE 2 Reaction resin adhesives are generally supplied as pre-gauged two component proprietary products, the two components (resin and hardener) being mixed together immediately prior to use on site.

5.8 Admixtures

5.8.1 Admixtures for cement:sand mortar beds and screeds

Admixtures for cement:sand mortar beds and screeds should conform to BS EN 934-2.

5.8.2 Admixtures for adhesives

A polymer additive or other liquid or powdered product should be incorporated into cementitious adhesives to provide greater adhesion, improved resilience or some degree of water resistance. Admixtures should be used strictly in accordance with the manufacturer's instructions and they should not be added to a cementitious adhesive unless approved by the manufacturer of the adhesive.

5.9 Reinforcement

Where light reinforcement is required in a screed or bed it should consist of steel fabric conforming to BS 4483:2005, reference D49 or D98.

Where reinforcement does not have to provide a structural function, adequate tensile stresses can be absorbed by reinforcement of 2.5 mm or 5 mm diameter wire in mesh sizes of 50 mm × 50 mm, 100 mm × 100 mm, 200 mm × 100 mm or 200 mm × 200 mm depending on screed or bed thickness.

Where heavier reinforcement is necessary, i.e. in screeds constructed for structural purposes, it should conform to BS 4483.

5.10 Bonding agents

Bonding agents should be considered where a high level of adhesion of screeds and/or beds to bases is required.

Bonding agents based on polyvinyl acetate or any other polymer affected by moisture should not be used in wet or external locations.

NOTE Manufacturers recommend particular grades and methods of application depending on the materials involved and service conditions, e.g. flooring in heavy duty areas, external applications.

5.11 Separating layers

5.11.1 Polyethylene film

Polythene film should be used in preference to building paper or bituminous felt and should conform to BS 3012. In most conditions a 500 gauge (0.125 mm) polythene film should be used.

5.11.2 Building paper

Building paper should be selected from those specified in BS 1521.

5.11.3 Bituminous felt

Bituminous felt should be selected from those specified in BS EN 13707.

NOTE Bituminous felt might not be suitable for use with natural stone as the oils present might leach through the sand cement screed and bed and bleed in to the stone.

5.12 Sealants and back-up materials for movement joints

5.12.1 Sealants

Joint sealants should be selected and applied in accordance with BS 6213.

NOTE Flexibility of sealant materials are included in Table C.1. Suitable materials for movement joints in flooring are included in Table C.2.

The selection of the most suitable materials depends upon design considerations (see Clause **6**) and the manufacturer's advice should be taken into account.

5.12.2 Back-up materials

Back-up materials should be compressible materials that do not force out the sealant when the joint closes. Materials used should support the sealant and not release bituminous or oily products.

*NOTE Suitable materials include cellular rubber and plastics, such as cellular polyethylene, and cork boards, which are available in strip form (see **5.13** and **8.1.6**).*

5.13 Pre-formed strips

Pre-formed strips are suitable for use in stress-relieving or compression joints where a watertight seal is not critical; cork and cork/rubber compounds strips should be used in light traffic areas; synthetic rubber strips with metal edged supports and PVC should be used in areas more heavily trafficked.

5.14 Grouts

5.14.1 General

Grouts should have good working characteristics, low shrinkage and good adhesion to the sides of the tiles.

NOTE 1 Additional properties might assume special importance, for example, impermeability; resistance to water, heat, cleaning agents and chemical attack; resistance to mould growth and bacteria; resilience and compressibility.

NOTE 2 Flexibility of joint materials is given in Table C.2.

*NOTE 3 Sands suitable for grouts are given in **6.3.3**.*

Proprietary grout materials should be stored and used in accordance with the particular manufacturer's instructions.

5.14.2 Pigments

Pigments should be inorganic and compatible with the grouting materials.

Pigments for cement:sand or cement-based grouts should conform to BS EN 12878.

NOTE Coloured grouts cannot be expected to retain pristine colour and appearance after wear.

5.14.3 Admixtures for grouts

*COMMENTARY ON **5.14.3***

Admixtures, normally in the form of aqueous dispersions, can be incorporated in grout mortars based on cement and sand to enhance adhesion in the tile joints, while improving the resilience and reducing the water permeability of the hardened grout mortar. Proprietary aqueous admixtures are available for incorporation in proprietary grouts to provide improved characteristics.

Admixtures should be used strictly in accordance with the manufacturer's instructions and they should not be added to a proprietary grout unless approved by the grout manufacturer.

6 Design

6.1 General

Solid and suspended floor constructions could be affected by the following factors, and relative importance of these factors should therefore be assessed at the design stage so that due allowance is made for their possible effect on the finished floor:

a) the load it has to support;

b) the type of tile used;

c) the resistance it offers to the passage of liquid water or water vapour either from above or from below (see **6.5**);

d) size changes produced by variations in moisture content and temperature within the floor and the attack of various corrosive agents, e.g. in chemical plants and industrial premises.

Where possible, selection of the type of flooring including its bed should be made at the design stage so that the appropriate depth can be allowed between the base and the finished floor surface.

*NOTE The variety of thicknesses in and between flooring units and beds is considerable (see **8.3**).*

The flooring proposed should be suitable for the conditions contemplated. The anticipated loading likely to occur and the size of the units should be considered.

Where there are specific functional or environmental considerations, reference should be made to BS 5385-4.

6.2 Load considerations

At the design stage, the maximum load the floor might support should be considered, including the flooring installation, and reference should be made to BS 6399-1. Where an existing floor is to be covered by the materials described in Clause **5** a check should be made to ensure that the floor is sufficiently strong and rigid to accept the added load, particularly if the floor is of timber construction (see **6.3.4**).

6.3 Bases

6.3.1 General

Concrete and cement:sand screeds are the most common bases over which terrazzo tiles and slab and natural stone floorings are laid but other bases might be encountered, namely timber (see **6.3.4**) and asphalt (see **6.3.9**). In refurbishing work, it might sometimes be necessary to apply new finishes over existing floors such as ceramic tiles, terrazzo, granolithic, stone, etc. Before the flooring is laid, the following should be checked:

a) that the correct falls have been incorporated in the base, where required;

b) that the base is free from contamination, loose areas and significant cracks;

c) that the base is true to the specified plane (see **9.4**).

NOTE Bases suitable to receive flooring and the beds recommended in each case are summarized in Table 2.

Table 2 **Suitability of flooring beds for different bases**

Base	Cement:sand mortar and cement:lime:sand mortar bonded to the base	Cement:sand semi-dry mix		Adhesives
		Bonded	Unbonded[A)]	
New concrete (less than 6 weeks old) (see **6.3.2**)	U	U	S	U
New screed (less than 3 weeks old) (see **6.3.3**)	U	U	S	U
Mature concrete (see **6.3.2**)	S	S	S	S
Mature screed (see **6.3.3**)	S	S	S	S
Screed over suspended floor or underfloor heating	U	U	S	C
Suspended in situ concrete				
Rigid and new (less than 6 weeks old)	U	U	S	U
Rigid and mature	S	S	S	S
With significant deflection	U	U	S	C
Timber (see **6.3.4**)	U	U	U	C
Asphalt (see **6.3.9**)	U	U	S	C
Existing hard floor finishes after preparation (see **6.3.10**)				
Terrazzo	C	C	S	C
Unglazed ceramic tile	C	S	S	S
Glazed ceramic tile	C	U	S	C
Granolithic topping	C	C	S	S
Natural stone	C	C	S	S

Key

S Suitable

U Unsuitable

C Confirm suitability with tile or slab manufacturer or supplier

A) Unbonded beds are unsuitable for heavy traffic conditions but see **6.4.2**.

In new work the plane of the base in relation to that of the finished floor surface should be specified; usually this is possible only if the flooring units and the appropriate beds are selected at the design stage. The level of the base surface in relation to the finished floor surface should be such that the bed can be of the recommended thickness uniformly throughout the installation.

*NOTE An exception can be made when using a semi-dry mix bed (see **9.6.2.4**) as this can be applied in varying thicknesses, subject to the minimum of 25 mm, to overcome irregularities and to form falls. The recommended maximum and minimum final thicknesses of beds and their suitability under different floorings are given in Table 3.*

In refurbishing work, the new floor surface might be higher than the original and the effect on existing features such as channels, outlets, skirtings, doorways etc. should be determined.

Where a separating layer (see **9.6.2.2**) is to be interposed between the base and the bed. the base should be accurately formed and should have a true and smooth surface to enable the bed to slide freely over the base in the event of differential movement.

Table 3 **Flooring beds: final thicknesses and suitability**

Type of bed	Thickness (mm)		Terrazzo tiles and slabs	Limestones and sandstones	Marbles, granites, slates and other stones
	Minimum	Maximum			
Cement:sand mortar (**9.6.1**)					
Generally	15	25	S	C	S
Flooring units less than 10 mm thick	10	15	NA	U	C
Flooring units of variable thickness	20	30	NA	C	S
Cement:sand semi-dry mix (**9.6.2**)	25	70	S	S	S
Cement:sand semi-dry mix over a separating layer (**9.6.2.2**)	40	70	S	S	S
Cement:lime:sand mortar (**9.6.3**)	15	25[A)]	U	S	U
Adhesive (**9.6.5**)	1	6[B)]	C	C	C

Key

S Suitable

U Unsuitable

C Confirm suitability with tile or slab manufacturer or supplier

NA Not applicable

A) Might be applied up to 50 mm thick for large flooring units.

B) Some might be applied up to 12 mm thick for filling small isolated depressions.

6.3.2 Concrete

6.3.2.1 Surface finish

When floor units are bedded directly to a concrete base without a screed, the concrete should be drawn off level with a straightedge and the surface texture closed. When a bonded bed is required, any excessive laitance should be removed by mechanical means. To receive a cement:sand bonded bed, the prepared concrete surface should be wetted down and left overnight prior to the application of the bed. When a separating layer (see **9.6.2.2**) is to be interposed between the bed and a concrete base, the surface of the base should be free of ridges or steps that would impair the sliding action between the two elements.

NOTE All rigid finishing materials reflect movements arising from supporting substrates. In the early period of a structure's life cycle these arise primarily from drying shrinkage of the slab and this is normally evidenced by longitudinal or transverse construction joints in the slab opening up. The Concrete Society indicates, as a rule of thumb, that a typical slab of span 10 m can experience a drying shrinkage of 3.0 mm irrespective of design, depth, or amount of reinforcement used. This movement can manifest itself through finishes as minor spalling of grouted joints or in more extreme circumstances as fracture and major dislocation of the units.

6.3.2.2 Tolerances on levels and surface regularity

Ensure that the sub-floor meets the surface regularity requirements for the specified tile bedding method.

NOTE The sub-floor might not have been installed to the required surface regularity and may require further preparation before the installation of the floor tiling is carried out.

Where tiles are to be fixed with adhesives the recommended surface regularity of the sub-floor is SR1 and this recommendation applies regardless of the adhesive bed thickness. Where tiles are bedded in cement:sand mortar beds a greater variation in the surface regularity can be accommodated (see **2.2.12.2** of BS 8000-11.2:1990). If the surface regularity of the sub-floor is inadequate it should be corrected before the tiling trade commences work on site, e.g. by the use of a smoothing compound.

6.3.2.3 Preparation

Where a bonded tile bed is specified, the sub-floor should be correctly prepared and the recommended bonding treatment carried out to ensure good adhesion of the tile bed. Concrete surfaces should be suitably prepared to ensure that adhesion is not impaired by any surface contamination. In most cases, the concrete surface has laitance and lime bloom present that can be removed by light mechanical means.

If the concrete has been treated with a curing agent, or has had a film of laitance and fines worked up to its surface during finishing, the preparation to remove these barriers to adhesion by equipment such as contained shot blasting is usually necessary.

Where cement-based or reactive resin adhesives are used to bed the floor tiles, the sub-floor should be inspected prior to tiling to ensure that it is free of any contamination, loosely adhered materials or other surface defects.

Where a bonded cement:sand bedding system is used, the preparation work requires the sub-floor to be roughened using appropriate mechanized equipment designed specifically for this purpose and the use of a suitable bonding treatment. If the concrete sub-floor is of suspended construction, e.g. a precast concrete plank, care should be taken to ensure that any roughening by mechanized equipment, e.g. by scabbling, does not cause damage to the concrete. In such cases contained shot blasting with coarse shot should be considered.

Where there is a risk of subsequent contamination, the surface preparation should be delayed until shortly before the tile bed is laid.

6.3.2.4 Elimination of construction moisture

*COMMENTARY ON **6.3.2.4***

Cracks that occur in screeds can result in reflected cracks appearing in the terrazzo and natural stone. Common causes of cracks to screeds are those induced by rapid drying.

To prevent rapid surface drying after laying, the screed should be covered for at least seven days and then allowed to dry for at least three weeks (inclusive of the seven days being covered).

6.3.3 Screeds

A screed should be installed over a concrete base to provide a true and level surface on which to apply a finish.

The drying time required should reflect the type and thickness of the screed and the on-site drying conditions. Where the stone is to be directly bonded to the screed with adhesive, guidance in BS 8204-1 and BS 8203 should be followed, which suggests "one day of drying should be allowed for each millimetre of (screed) thickness for the first 50 mm, followed by an increasing time for each millimetre above this thickness. It is therefore reasonable to expect a levelling screed 50 mm thick drying under good conditions, to sufficiently dry in about 2 months".

Where underfloor heating is present in the sub-floor then the guidance in Clause **7** should be followed.

Where insufficient drying time and/or unsuitable drying conditions exist, the stone (and any adhesive) should be isolated from the screed below, e.g. by using an uncoupling membrane. If at the design stage it becomes apparent that only shorter drying periods are available the stone should be set on an unbonded, reinforced semi-dry cement sand bed.

At the design stage, when considering various bedding methods, the degree of surface regularity should be specified where necessary. as given in Table 4.

Table 4 **Accuracy of screed surfaces**

Surface irregularity	Maximum gap under 2 m straightedge, mm	Appropriate bed method
SR 1	3	Adhesive
SR 2	5	Sand/cement
SR 2	10	Sand/cement, semi-dry

6.3.3.1 Proprietary screeds

*COMMENTARY ON **6.3.3.1***

Proprietary screeds might be used where the requirement is for a screed that is either more rapid drying than a normal cement and sand screed, or less than 25 mm in thickness.

When a proprietary screed is required, the designer should pay close attention to the manufacturer's instructions as this will have a bearing on the required drying times and trafficking (which will often be earlier than for conventional sand and cement screeds).

Screed should be designed and laid in accordance with BS 5385-3 and BS 8204-1.

6.3.4 Timber bases

NOTE Additional guidance can be found in The Tile Association guidance note Tiling to timber substrates and alternative products [3].

6.3.4.1 General

*NOTE 1 See **6.2** for load considerations.*

Timber sub-floors should be used with caution where they are the base for large areas of floor tiling, or where heavy static/dynamic loading is likely in service, e.g. free standing baths, kitchen islands. If a timber sub-floor is to be used as a base for floor tiling, it should be rigid and stable with respect to humidity and moisture changes. Timber should not be used as a base for floor tiling in wet, frequently damp, or high humidity areas, unless appropriate precautions are taken (see BS 5385-4). Where timber is used, ventilation should be adequate and effective damp-proof courses should be correctly located.

The design should take into account the initial drying shrinkage of the timber and subsequent movement due to seasonal moisture changes, bearing in mind the type of heating.

NOTE 2 Failure to observe this can lead to subsequent warping and distortion of the boards with consequential cracking and delamination of the tiling.

Where the rigidity is satisfactory but the moisture stability of the floor cannot be assured, consideration should be given to the use of an appropriate intermediate water resistant substrate system designed for use with tiling on timber floors.

The length and strength of screw fixings should be appropriate to ensure adequate penetration into timber sub-floor or joist/nogging supports, bearing in mind that there might be underfloor services that might be damaged by oversized screws.

6.3.4.2 New timber bases

New timber bases should be constructed with noggings between the joists. Water and boil proof (WBP) exterior grade plywood of 15 mm minimum thickness should be screwed to both joists and noggings at 300 mm maximum intervals. The lower face and edges of plywood should be sealed against the ingress of moisture using preferably non-aqueous sealers, e.g. polyurethane varnish, or styrene butadiene rubber, to prevent distortion by changes in atmospheric humidity before being screwed down. All junctions between boards should be supported by noggings or joists.

If it is considered necessary to further reduce or eliminate the risk of movement, an additional layer of sheets of minimum thickness 10 mm, resistant to moisture and thermal movement, should be screwed over the plywood at 300 mm centres ensuring that the joints in both layers of sheets do not coincide.

In general, the top sheet to receive the tile finish should be laid broken-bond in both directions. Where the sheet or board has a rough and smooth side, the latter should be used for tiling. The surface to receive the tiles should be clean and free from dust and contamination.

6.3.4.3 Existing timber bases

Existing timber bases should be carefully examined to ensure that they can carry the additional dead load of the new flooring without excessive deflection that might be permitted under BS 5268-2.

Consideration should be given to removing existing boards, stiffening the floor with noggings and proceeding as for new timber bases (see **6.3.4.2**). Alternatively the required rigidity might be achieved by fixing exterior grade plywood over existing boards.

Where the existing boards are removed, any additional noggings required should be fixed to the joists at 300 mm centres, ensuring that there are no free unsecured ends to the new sub-floor. Noggings should always be positioned to ensure that the free ends of all plywood can be secured at the appropriate centres. Where two layer construction of WBP plywood is employed, the bottom layer should be not less than 15 mm thick and the top layer should be not less than 10 mm thick, screwed at right angles to each other and to the joists at 300 mm intervals using stainless steel screws ensuring that there are no vertical joints through this ply covering. If the WBP plywood floor covering is not level a self-levelling compound can be applied.

NOTE 1 Existing boards can be used providing that they are in good condition and free from contamination.

Where an alternative two layer construction of plywood and a backer board is used for the upper layer, the tile backer board should be predrilled and fixed to the plywood using stainless steel screws and specifically designed washers. The sheeting material should be cross laid to ensure there are no vertical joints through the two layer system.

NOTE 2 Timber floors of faulty construction have often behaved satisfactorily for a period of years as a result of surface evaporation of moisture. If this is hindered by the laying of a nearly impervious covering, the moisture content might rise to a dangerously high level sufficient to promote fungal attack, e.g. dry rot.

Alternatively, for floors of small area (e.g. a single sheet/board, or where board joints are unlikely to cause problems) the required rigidity might be achieved by fixing WBP plywood of 15 mm minimum thickness over existing boards. The plywood should be sealed, using preferably non-aqueous sealers, e.g. polyurethane varnish, or styrene butadiene rubber, on the lower faces and edges to prevent distortion by changes in atmospheric humidity and screwed to joists and existing boards at 300 mm intervals.

Where a proprietary intermediate system is used, it should be screwed or glued to the plywood substrate in accordance with the manufacturer's recommendations.

In all cases, professional engineering advice should be obtained to ensure that the existing timber joists are able to carry the increased dead load, without excessive deflection.

For guidance the weight of natural stone tiles/units should be taken as follows:

- 10 mm thick = 30 kg/m^2
- 20 mm thick = 60 kg/m^2
- 30 mm thick = 90 kg/m^2

6.3.5 Laying tiles or slabs on a raised metal pan floor

Before installing tiles or slabs, consideration should be given to any raised metal pan floor construction to ensure that it will accommodate the increased weight and is rigid. One layer of 25 mm thick WBP

plywood or two layer of 12 mm thick WBP plywood, cross laid, should be secured to the raised metal pan floor using stainless steel screws. Where a single layer of plywood is used a debonding membrane should be adhered to the plywood.

NOTE Where a two layer construction is used the top layer can be an intermediate board (or a debonding membrane adhered to the top layer of plywood).

6.3.6 Laying tiles on pedestals

Before laying tiles on to a pedestal system, the applied loadings (uniformally distributed loads and point loads) should be established.

A pedestal system will generally not suit slabs exceeding 600 mm × 600 mm.

The stone selected should have the thickness at the corners calibrated to ± 0.5 mm if lips between slabs are to be avoided. Shims should not be placed at tile corner / pedestal head interfaces. Before making the final choice of stone, the design should be checked in accordance with the method of calculation set out in BS EN 12372.

NOTE These calculations require the supplier of the stone to have carried out flexural strength testing in accordance with BS EN 12372 and declare the lowest expected value. If such results are not available, specific testing will be required.

6.3.7 Laying tiles on acoustic matting

If it is necessary to lay tiles directly onto acoustic matting the adhesive used should be compatible with the mat and offer some flexibility.

6.3.8 Stairs

Treads should be laid on a rigid base. If the treads are to be set on metal trays these should have a similar stiffness to the flooring unit. The steel supporting tread should be designed to limit deflection to span/720.

Treads should be fully bedded on either semi dry-sand:cement mortar or an adhesive. If semi-dry sand:cement bed is used it should be a minimum of 25 mm thick and should be fully bonded. When designing stone stairs, the risers should be seated on top of the treads and secured in place with stainless steel fixings. Risers should be set against mortar giving sufficient restraint to guard against breakage from impact damage.

Treads should have a surface that is sufficiently slip resistant and should incorporate a nosing so that the stairs are easily recognised by visually impaired people.

NOTE As to stair design, attention is drawn to the Building Regulations approved document M [4].

6.3.9 Asphalt

The asphalt base should be laid in accordance with BS 8204-5. Before floor laying commences, the asphalt base should be examined to ensure that it is in a suitable condition to receive the flooring. In

particular, it should have satisfactory cohesive strength and should be laid on a rigid base, e.g. concrete.

One of the following two preferred methods for laying floorings on an asphalt base should be adopted.

a) *Bedding in cement-based adhesives*. The use of cement-based adhesives is described in **9.6.5**, particularly **9.6.5.2**. Where cement-based adhesives are to be used for bedding direct to asphalt in both interior and exterior situations consideration should be given to the following.

   1) The asphalt base is sufficiently true to the specified plane to permit fixing with an adhesive at a bed thickness not exceeding 6 mm (see **9.4**).

   2) The adhesive used should have deformable properties S1 as defined in BS EN 12002:2002, Clause **10**.

   3) In external installations the asphalt should be laid to finished falls of not less than 1 in 60. Factors such as wind loading and climatic conditions should be taken into consideration and the bed should be of sufficient depth to be stable in these external conditions.

b) *Bedding in cement:sand semi-dry mix*. This method is described in **9.6.2**. Where this method is used a separating membrane should be interposed between the asphalt and the bed. When used in exterior situations the asphalt should be laid to ensure that it has adequate free draining falls.

6.3.10 Other bases

Existing floorings such as ceramic tiles, terrazzo, natural stone and similar hard surfaces are suitable as bases. Where existing flooring is to be used as a base, it should be clean and firmly adhered to its base. However, the choice of flooring and type of bed might be influenced by the change in level available from existing to new.

6.4 Durability and performance

6.4.1 General

*NOTE Floorings can deteriorate due to defects in the design of the structure, mechanical failure of the materials (see **6.4.3**), frost (see **6.4.4**) and the use of unsuitable cleaning agents (see **14.4**). Floorings might also be unsatisfactory because they become slippery (see **6.4.5**), are stained or the grout and/or sealants deteriorate.*

6.4.2 Traffic and load conditions

NOTE For the purpose of this standard, traffic loads are categorized as light or heavy.

Floor loading should be considered as heavy if high density pedestrian traffic, and/or heavy loads (e.g. heavy cleaning equipment, hard-wheeled trolleys, etc), static, moving, dropped or dragged, are likely to occur, e.g. in shopping malls, industrial and engineering premises and garages for heavy vehicles. For resistance to mechanical failure see **6.4.3**.

Floor loading should be considered as light if low density pedestrian traffic and/or lightweight soft-wheeled trolley traffic are likely to occur, e.g. in domestic and office locations. All types of flooring are suitable for light loading but the bed chosen should also depend on the base conditions.

Where heavy loading is likely, and particularly where the moving of heavy loads is contemplated, the flooring bed should be well compacted and free from voids to ensure good adhesion to the base. Thicker flooring units than those generally available with increased impact resistance should be used in order to achieve greater loading resistance, bearing in mind also that the joints between the tiles are usually the most vulnerable part of the flooring [see **6.4.3.3** c)].

The base conditions should be considered when selecting a flooring bed but a cement:sand mortar on a separating layer should not be used.

If the base is a suspended floor, or for some other reason a separating layer is needed, a reinforced semi-dry mix bed with intermediate movement joints should be used over the separating layer (see **9.6.2.2**). For a heavily loaded, suspended floor subject to wetting, see also **6.5**.

6.4.3 Resistance to mechanical failure

NOTE The basic agents, abrasion, compression and impact, operate singly but they are also found in various combinations.

6.4.3.1 Resistance to abrasion

*COMMENTARY ON **6.4.3.1***

Abrasion is wear caused by fine solid particles.

It is generally recognised that wear resulting from the movement of pedestrians is most severe in places where changes of direction occur and where people are moving in a confined area, e.g. moving slowly through a ticket barrier.

Numerous test methods exist, e.g. abrasion resistance of natural stone is carried out using the pendulum test method as described in BS EN 14157.

Tiles used should be described as "intensive", "moderate" or "individual" according to their resistance to abrasion value, as set out in BRE IP 10/00 (see Table 5).

Table 5 **Resistance value**

Abrasion	Suggested Usage
<23	**Intensive** use / heavily trafficked areas (e.g. shopping malls) (approximately equal to 500 million pedestrian traverses during floor life)
23–30	**Moderate** (e.g. offices but not shops, stations, etc.) (approximately equal to 5 million pedestrian traverses during floor life)
>30	**Individual** (e.g. houses or apartment blocks) (approximately equal to 50 000 pedestrian traverses during floor life)

6.4.3.2 Resistance to compression

Where flooring resistant to compression is required it should be in accordance with BS EN 13748-1:2004, **4.2.4**, BS EN 12057, and BS EN 12058. The bedding should have sufficient compressive strength to support the flooring under the anticipated loading and traffic conditions.

6.4.3.3 Resistance to impact

Where flooring resistant to impact is required, the mechanical properties specified in **6.4.3.1** and **6.4.3.2** should be considered, together with the following.

a) Within the normal tolerances of the flooring units used, the individual units should be laid to a true plane. Therefore, a true base is a necessary pre-requisite.

b) The flooring units should be solidly bedded so that, as far as possible, there are no voids (see **9.6**).

c) Joints should be as narrow as possible, compatible with the minimum width for the flooring units being laid.

d) The maximum width should not exceed 10 mm when conventional cement:sand grouts are used, because such joints possess lower impact and abrasion resistance than the flooring units. For joints wider than 10 mm, consideration should be given to the use of proprietary grouts specially formulated with enhanced resistance to impact and abrasion and low shrinkage.

6.4.4 Frost resistance

Where the stone or terrazzo is to be used externally, frost resistant tiles and non-slip surfaces should be used, e.g. those described in BS EN 13748-2, BS EN 12057 and BS EN 12058.

6.4.5 Slipperiness

NOTE 1 Guidance on slip resistance is given in Annex B.

Flooring units used should not be highly slippery.

In locations that suffer occasional wetting which increases surface slipperiness, i.e. shopping malls or office receptions, additional entrance matting should be installed and/or a management regime to deal with such situations should be put in place.

NOTE 2 A minimum slip resistance value SRV of 36 is required in both wet and dry conditions to meet the requirements of the HSE.

6.5 Passage of liquids through floors

6.5.1 General

NOTE 1 The floorings dealt with in this standard are not completely impervious to liquids nor do they offer substantial resistance to the passage of water vapour.

In many situations, continuous transmission of moisture is tolerable, but BS 8102:1990, Table 1 should be consulted to decide the need and effectiveness of damp-resisting construction.

NOTE 2 The use of integral admixtures containing water-repellent ingredients, such as metallic soaps in the base concrete, will make the hardened surface difficult to wet and will result in poor adhesion of conventional cement:sand mortar beds.

Where a cement:sand bed is used and firm adhesion is required between the base and the bed, a suction coat should be used. This should be a layer of cement:sand mortar without admixture, placed monolithically with the wet base. For some adhesives the suction coat can be omitted; the user should consult the manufacturer before the suction coat method is applied.

6.5.2 Passage from below

*COMMENTARY ON **6.5.2***

Ground moisture and the water used in construction is transmitted through solid floors by capillarity and by evaporation to the air above and thus leave the floor surface apparently dry.

Evaporation can be impeded by additional floor coverings less permeable than those described in this standard or by fittings or stored goods in direct contact with the floor. Local dampness might consequently be so severe as to encourage moulds and to rot or corrode materials in contact with it.

Moisture rising through a solid floor is likely to contain soluble salts from the sub-soil, the hard fill and the concrete of the floor itself. These will tend to accumulate in increasing concentration at or near the floor surface as long as they can be replenished from below.

In environments where the sub-soil or the fill is contaminated with acids or high concentrations of soluble sulfur compounds which attack cement, an adequate damp-proofing below the base in accordance with BS 8102 should be used in order to secure the safety of the whole floor.

In less aggressive situations, damp-proofing which serves only as a capillary barrier in accordance with CP 102 and BS 8102 should be used as a precaution against persistent efflorescence at the floor surface and possible attack on the concrete by small concentrations of sulfates.

6.5.3 Passage from above

*COMMENTARY ON **6.5.3***

Flooring units and beds, even when the joints are filled with impervious grout, cannot be guaranteed to eliminate entirely the passage of liquids downwards. Minor defects in workmanship and movement in the structure can cause fissures through which liquids pass readily.

In ground floor situations aggressive chemicals in solution passing through the floor can attack concrete bases leading to severe disruption.

In the case of suspended floors, water passing downwards might cause dampness on walls and ceilings below, in the worst cases leading to flooding. It might also cause attack on the structure by chemicals.

If more than occasional spillage of liquids is expected then the tiled surface should be laid to falls and drains provided to collect the run-off.

To prevent the downward movement of liquids, a membrane should be used between the base and the flooring; the membrane should be covered by a screed. The base should be constructed with falls so

that any liquid reaching the membrane flows down to a drain. The membrane material should be impervious and chemically resistant to the liquids that will come into contact with it and it should be sufficiently flexible and strong to resist movement in the structure and loads without rupturing. The membrane should be continuous around upstands and at points where services pass through the floor.

NOTE The most commonly used membrane materials are asphalt, bituminous felt, polyethylene film, composite pitch polymer sheets and synthetic rubber sheets.

6.6 Variations in moisture content and temperature

*COMMENTARY ON **6.6***

In solid and suspended floor constructions, the base and the flooring usually have different dimensional reactions to changes in moisture content and temperature.

The shrinkage of the base and/or screed persists for some time after the flooring has reached equilibrium with the result that compression forces might ultimately crack the flooring or break down the adhesion between the flooring units and the bed. Vibration, impact and thermal shock can produce early failure while the flooring is in the stressed condition, as can further contraction of the base in very cold weather.

New concrete floor or screeds should be allowed to undergo the initial drying and shrinkage in accordance with **4.3** in order to prevent extreme relative moisture movements.

6.7 Isolation of the flooring bed from the base: separating layer

Failure arising from variable stresses (see **6.6**) should be avoided by isolating the flooring bed from the base by a separating layer (see **5.11**) that prevents the two elements from adhering to each other and thus allows each to move independently, e.g. a layer might consist of building paper, bituminous felt, polyethylene film or similar material, on which the flooring units are bedded in mortar.

7 Underfloor heating

7.1 General

Particular care should be taken when using agglomerated stone with underfloor heating (see **11.4.4**).

7.2 Hot water

*COMMENTARY ON **7.2***

Piped hot water systems using plastic or copper pipes are generally not suitable for use in a timber floor construction as they preclude the installation of noggings.

There is currently insufficient information regarding the compatibility of this type of heating when used with natural stone tiles or slabs.

The system selected should be specifically suitable for use with stone or terrazzo tile floorings. It should be laid in accordance with the

heating system manufacturer's installation instructions with the pipes securely fixed.

Once the levelling screeds are cured and dried (see **4.3**) they should be heated at 5 °C per day to operating temperature. The operating temperature should then be maintained for two to three days before cooling down to room temperature. The room temperature should be maintained at or above 15 °C, while installing the flooring. This is to ensure any movement in the screed has taken place prior to the installation of the stone.

Once the floor is laid, the heating system should not be run up for at least ten days to allow the bedding to cure/dry thoroughly.

Where it is not possible to operate the heating prior to installation of the natural stone or terrazzo tile flooring, only an unbonded method of bedding should be used.

NOTE If a bonded natural stone or terrazzo tile floor is laid prior to the operation of the heating system cracking of the natural stone or terrazzo floor tiles/slabs might occur.

Where underfloor heating exists, movement joints in the screed should limit bay sizes to 40 m^2 with a maximum bay length of 8 m.

The insulation selected for use with the heating system should have a compressive strength compatible with the floor loadings. Typically for commercial applications the insulation will require a minimum compressive strength of 350 MPa.

7.3 Electric

Where electric underfloor heating is considered for use, the manufacturer should be asked to confirm in writing, that the system is suitable for use with stone or terrazzo floors. Where electric underfloor heating is used in conjunction with adhesive, an uncoupling membrane should be used. The heating cables can be positioned above or below the membrane and should follow the membrane manufacturer's instructions.

Heating cables should be located to ensure that the system is contained within the area bounded by the movement joints.

Where electric heating is used with a timber sub-floor, an uncoupling membrane should be installed. Where it is necessary, the electric matt or cables should be located below the membrane to ensure that the adhesive bed is not thicker than specified.

8 Movement joints

8.1 Stresses

8.1.1 General

*COMMENTARY ON **8.1.1***

Dimensional changes might be exhibited in the materials covered by this standard in response to environmental conditions.

When flooring units are bedded on to other materials with different movement characteristics, stress relieving movement joints should

be incorporated to prevent damage resulting from restrained dimensional change.

NOTE 1 Restrained dimensional change can manifest itself as minor spalling at grouted joints, or fracture and major dislocation of stone units.

Where flooring units are subjected to high temperatures (i.e. from heating installations or from strong sunshine) an assessment of the likely temperature range and corresponding linear changes should be made.

NOTE 2 Calculating the anticipated movement with precision is problematic but, fortunately, in the majority of cases this is unnecessary. Movement joints are provided in the floor at recommended widths and spacings.

The positions of movement joints should be established before work commences.

Movement joints should be properly formed, according to the degree of exposure, with a suitable flexible material. The joint width should be determined by the extension capability and recovery performance of the chosen joint former or sealant.

Before sealing, joints should be checked to establish that the designed minimum gap between tiles is not obstructed.

NOTE 3 Perimeter joints can usually be hidden beneath the skirting (see Figure 4).

Unusual circumstances, novel construction details or contaminated environments should be considered thoroughly and the extent of any movement should be carefully calculated.

Where day joints in the screed do not coincide with those in the floor, crack inducing joints should be post-cut.

Reinforcement should cross all day joints to ensure that no unpredicted movement can affect the performance of the flooring units, particularly where the flooring unit is set on adhesive.

Where underfloor heating is used, the pipes or cables should be located to ensure that the system is contained within the limits of the movement joints (see Clause **7**).

To counteract stresses that can cause the loss of adhesion and bulging or cracking of the flooring, movement joints extending through the flooring and its bed should be incorporated in the installation.

NOTE 4 Stresses in the finished installation can result from factors such as drying shrinkage, deflection and moisture movements in the base and thermal and moisture changes affecting the flooring.

At the design stage the magnitude of any stresses should be assessed and a decision should be made as to where movement joints, flexible joints and contraction joints are to be located, having regard to all the relevant factors including the type of flooring and bed.

The following movement joints should be used for flooring installed in accordance with this standard:

a) flexible joints aligned to structural movement joints [see Figure 2a) and Figure 2b)];

b) flexible movement joints to accommodate smaller movements than structural joints [see Figure 2c), Figure 2d) and Figure 2e)];

c) contraction joints which are non-compressible to relieve tension [see Figure 2f)].

8.1.2 Structural movement joints

Structural movement joints in the flooring and bed should be sited immediately over and be continuous with structural movement joints in the base. Where the base joints are not true (i.e. not straight and parallel), or if the layout does not coincide with that of the flooring units, the designer or engineer should be requested to advise on how to proceed.

8.1.3 Other movement joints

Flexible joints [see Figure 2c), Figure 2d) or Figure 2e)] should be inserted over supporting walls and beams and at intermediate positions to accommodate deflection of the base and movements in the flooring. Contraction joints [see Figure 2f)] should be used to accommodate shrinkage in terrazzo tile and slab flooring, and might be used instead of flexible joints over supporting walls and beams.

Flexible joints [see Figure 2c), Figure 2d) or Figure 2e)] or contraction joints [see Figure 2f)] should be used at floor perimeters and to divide the floor into bays at the intervals given in the relevant flooring sections. Where possible, they should coincide with structural features such as columns and door openings, or should be positioned to provide a decorative effect.

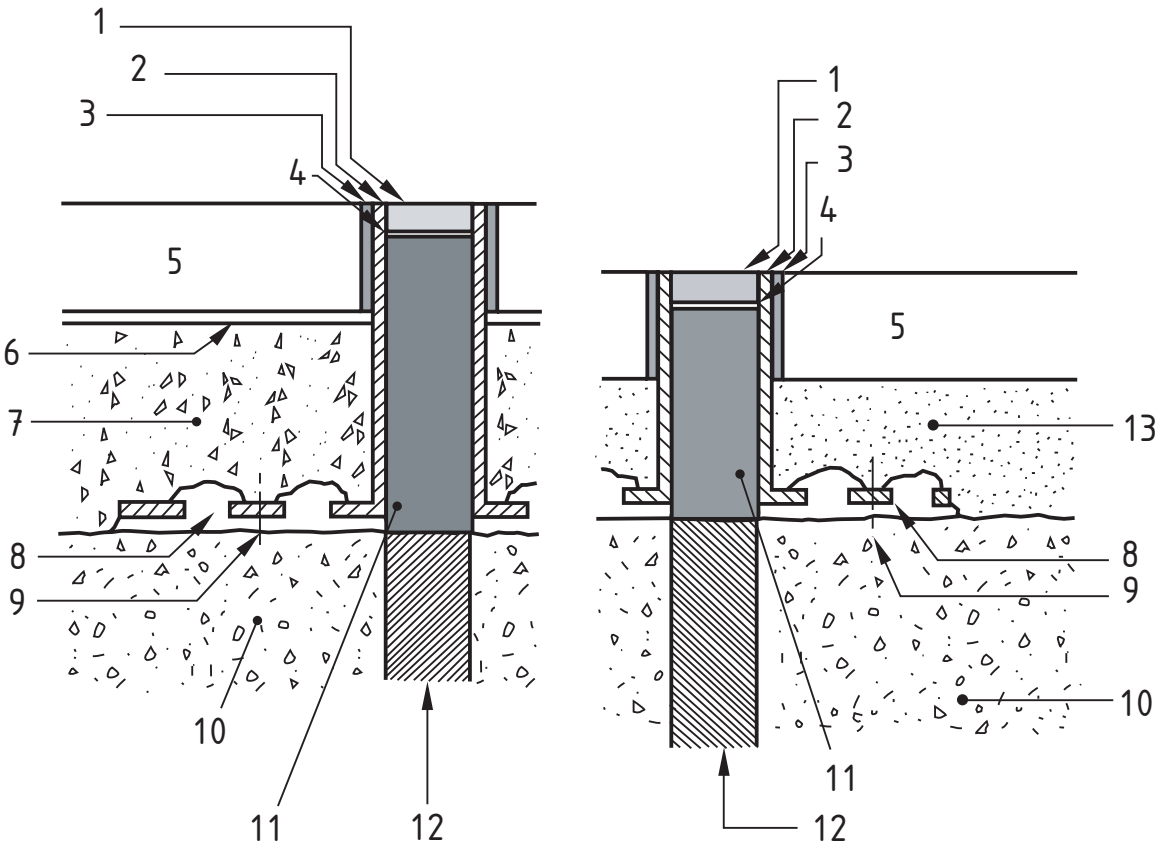
Where high temperatures are expected, for instance, around boilers, over heating installations, or from strong sunshine, an assessment of the likely temperature range and corresponding linear changes in the flooring should be made to determine whether and where any additional allowance for movement is necessary.

In floors that have to withstand hard-rimmed wheel traffic or the dragging of heavy loads, the position of movement joints should be planned so that they do not occur in the traffic area. Where this is not practicable, the joints should be of types having their edges reinforced with metal or rigid plastics sections [see Figure 2a), Figure 2b), Figure 2d) and Figure 2e)].

Joints other than those protected by metal or rigid plastic edging strips, should be not wider than 8 mm. The joint width should be selected taking into account the predicted movement of the tiles or slabs and the manufacturer's published movement accommodation factor (MAF) (see BS 6213).

NOTE The illustrations in Figures 2a) to 2f) indicate the basic principles of the types of joints referred to above. There are prefabricated types of Figure 2a), Figure 2b), Figure 2d) and Figure 2e) available that embody the principles shown but might be slightly different in detail.

Figure 2 **Some typical movement joints**



a) Type A. Joint aligned to structural movement joint

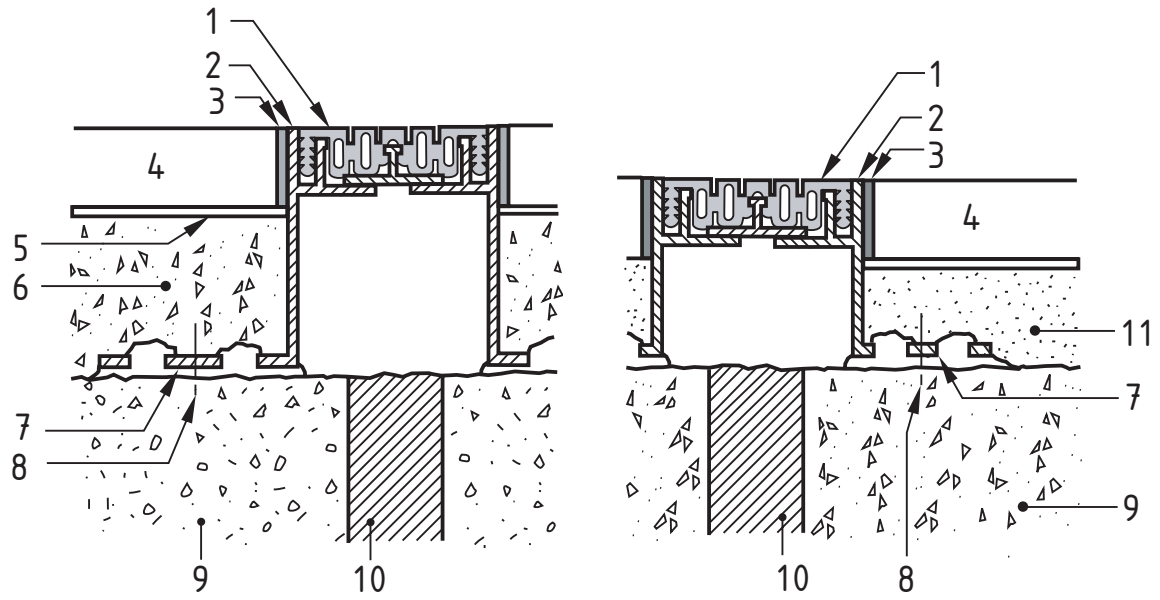
Key

1 Sealant
2 Metal angle
3 Grout
4 Bond breaker tape between sealant and back-up material
5 Flooring unit
6 Adhesive bed
7 Screed
8 Levelling bed
9 Mechanical fixing as necessary
10 Concrete base
11 Back-up material
12 Structural movement joint
13 Cement:sand mortar bed

NOTE 1 All drawings in Figure 2 illustrate principles only.

NOTE 2 Semi-dry mix beds have movement joints similar to those shown for screeds.

Figure 2 **Some typical movement joints** *(continued)*



b) Type B. Prefabricated joint with reinforced edges and capping over structural movement joint

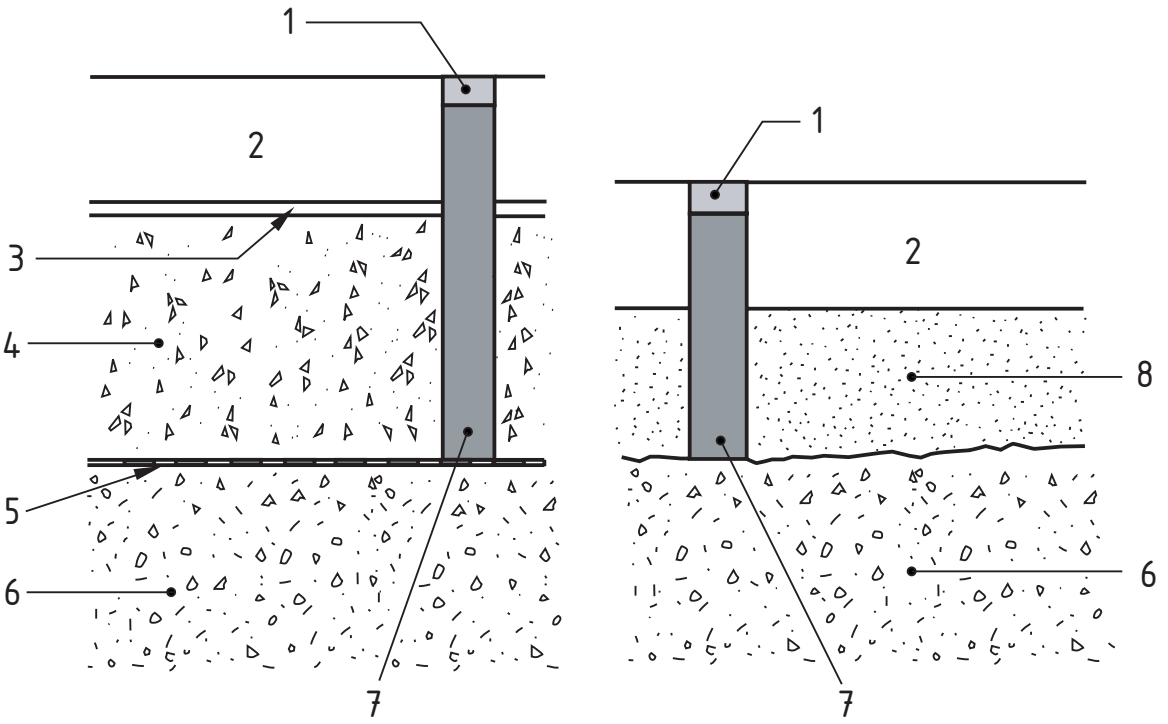
Key

1	Flexible insert	5	Adhesive bed	9	Concrete base
2	Metal profile	6	Screed	10	Structural movement joint
3	Grout	7	Levelling bed	11	Cement:sand mortar bed
4	Flooring unit	8	Mechanical fixing as necessary		

NOTE 1 All drawings in Figure 2 illustrate principles only.

NOTE 2 Semi-dry mix beds have movement joints similar to those shown for screeds.

Figure 2 **Some typical movement joints** *(continued)*



c) Type C. Flexible joint in bed, with or without separating layer

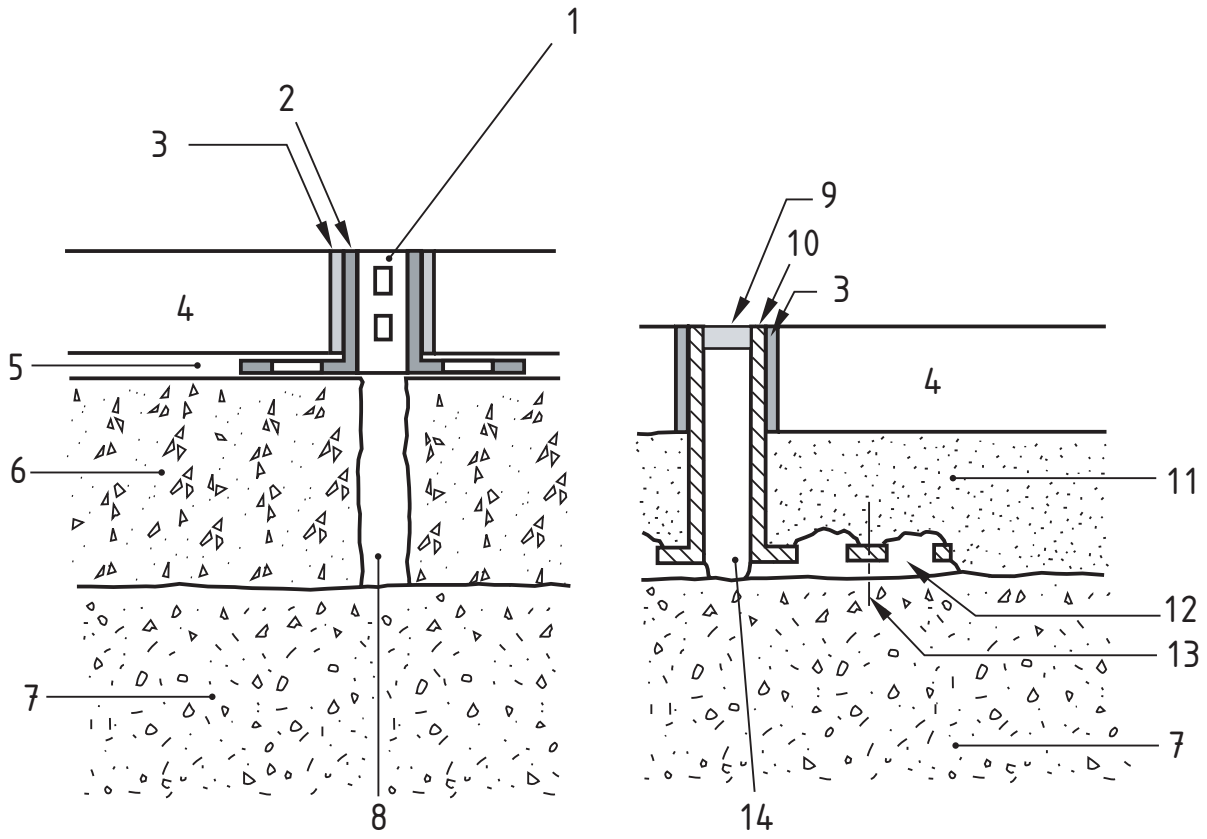
Key

1	Sealant	5	Separating layer (optional)
2	Flooring unit	6	Concrete base
3	Adhesive bed	7	Back-up material
4	Screed	8	Cement:sand mortar bed

NOTE 1 All drawings in Figure 2 illustrate principles only.

NOTE 2 Semi-dry mix beds have movement joints similar to those shown for screeds.

Figure 2 **Some typical movement joints** *(continued)*



d) Type D. Flexible joint with reinforced edges

Key

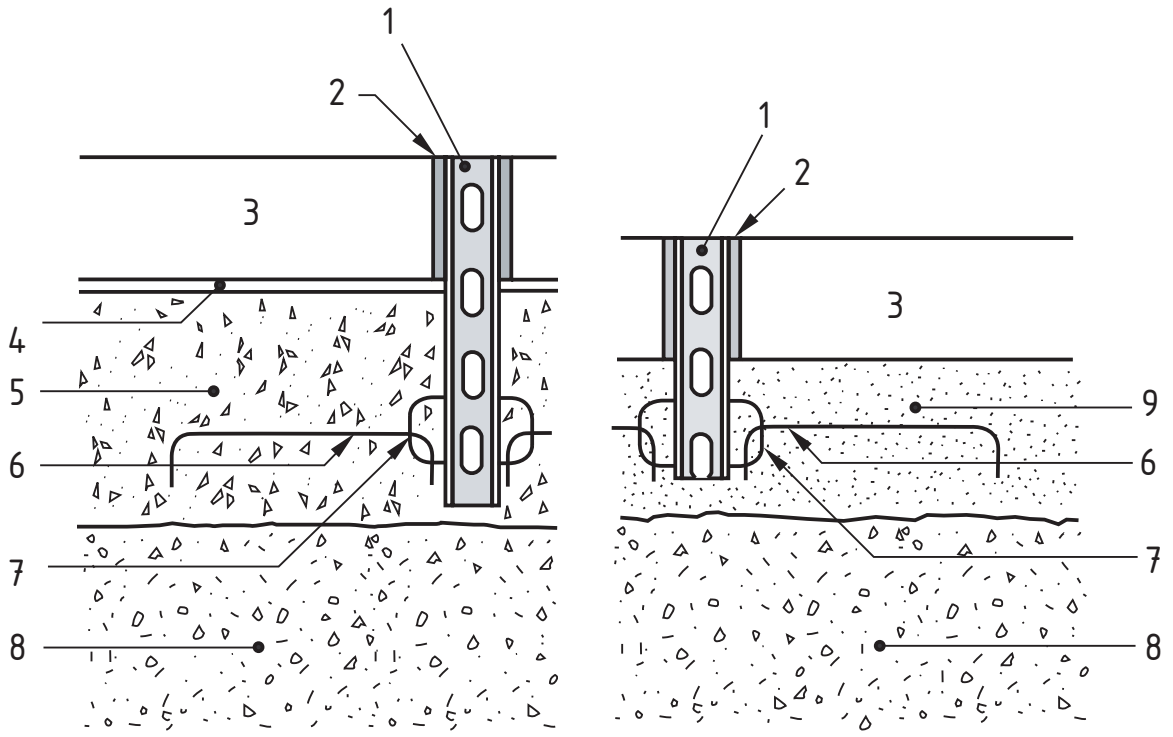
1 Neoprene bonded to metal angle
2 Non-ferrous metal angle with large, closely spaced apertures through base
3 Grout
4 Flooring unit
5 Adhesive bed
6 Screed
7 Concrete base
8 Back-up material in sawn joint
9 Sealant
10 Metal angle
11 Cement:sand mortar bed
12 Levelling bed
13 Mechanical fixing as necessary
14 Back-up material

NOTE 1 All drawings in Figure 2 illustrate principles only.

NOTE 2 Large apertures in metal angle allow adhesive through to bond edge of flooring unit to screed.

NOTE 3 Semi-dry mix beds have movement joints similar to those shown for screeds.

Figure 2 **Some typical movement joints** *(continued)*



e) Type E. Slightly flexible joint: pre-formed strip with reinforced edges

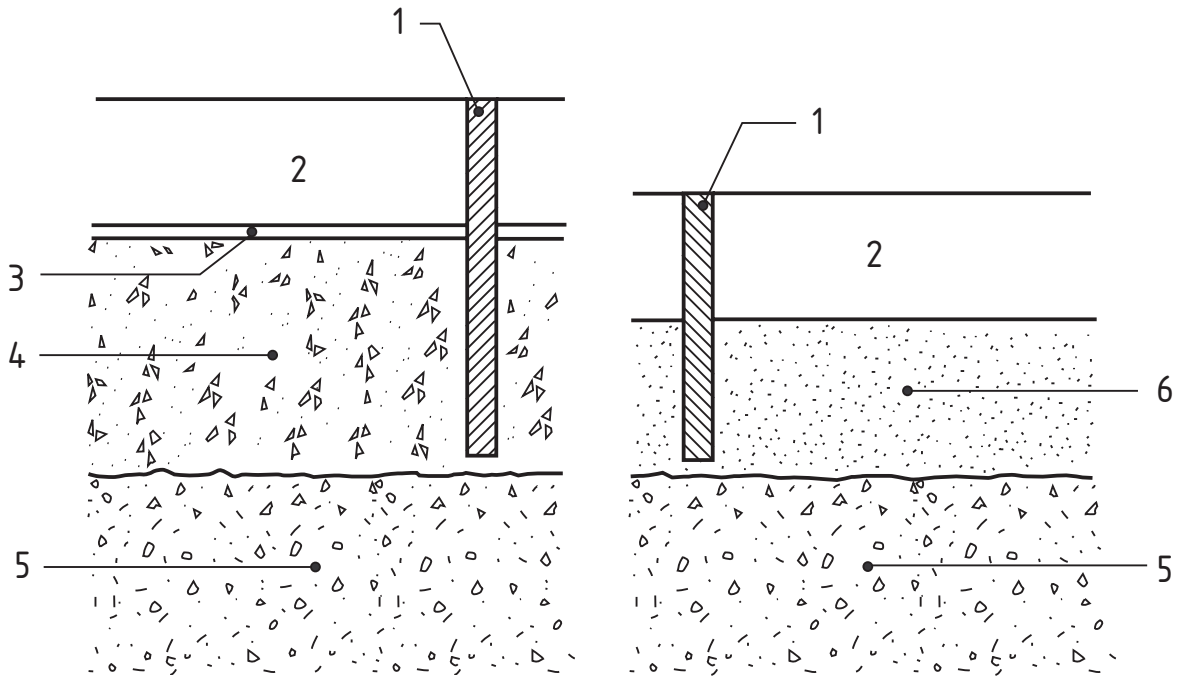
Key

1 Neoprene bonded to non-ferrous metal or rigid plastic strips
2 Grout
3 Flooring unit
4 Adhesive bed
5 Screed
6 Tie wire
7 Locating lug attached to preformed strip
8 Concrete base
9 Cement:sand mortar bed

NOTE 1 All drawings in Figure 2 illustrate principles only.

NOTE 2 Semi-dry mix beds have movement joints similar to those shown for screeds.

Figure 2 **Some typical movement joints** *(continued)*



f) Type F. Contraction joint

Key

1	Non-compressible preformed strip	4	Screed
2	Flooring unit	5	Concrete base
3	Adhesive bed	6	Cement:sand mortar bed

NOTE 1 All drawings in Figure 2 illustrate principles only.

NOTE 2 Semi-dry mix beds have movement joints similar to those shown for screeds.

8.1.4 Sealants

Where flexible joints are selected, the sealant used should be specifically suitable for use in a flooring application. The designed width of the joint should take into account the movement accommodation factor (MAF) and abrasion resistance of the sealant. In some locations resistance to chemical attack or contamination should also be considered. The regime adopted for cleaning the floor should also take into account the sealant installed.

8.1.5 Back-up materials

The back-up material in the lower part of the joint should be compatible with the sealant being used.

Sealants with a large movement capability should not stick to the back-up material, as the ability of the sealant to accommodate movement will be reduced by any restriction of its underface. Where such sealants are likely to stick to the back-up material, an additional barrier, such as polyethylene film, should be applied between the back-up material and the sealant.

8.1.6 Pre-formed strips

Strips should be inserted between flooring units as they are laid, according to the manufacturer's instructions. They should be fitted to the combined depth of the flooring and bed with the shape of the strip section forming a key with the bed.

8.2 Skirtings

NOTE Skirtings can be employed for aesthetic reasons, for protecting the base of wall surfaces, for ease of cleaning or to assist in forming a liquid-tight system at the junction of floors and walls.

Where it is important that the installation is resistant to the passage of water or other liquid and especially where tanking is necessary (see **6.5**), a coved base skirting should be used. This allows a perimeter joint to be positioned between the foot of the coved base and the adjacent floor unit to accommodate movement. When filled with an impervious sealant, it contributes to a smooth, uninterrupted resistant surface from horizontal to vertical.

8.3 Selection of types of flooring bed

When selecting types of flooring bed, **10.2** should be followed; Table 2 gives guidance on the suitable bases upon which beds should be laid and Table 3 gives guidance on their final thicknesses and the floorings for which they can be used.

8.4 Chemical attack

Where flooring is to be laid in a potentially corrosive environment, consideration should be given to the resistance to chemical attack of the flooring units, the bed and grout materials. The flooring materials included in this standard are not generally used in potentially corrosive environments. However, where this possibility arises, the manufacturer should be consulted about the suitability of the product for the given situation.

8.5 Static electricity

Where it is necessary to prevent build-up of electrostatic charges on the floor, e.g. in hospital operating theatres, or where explosion hazards can arise from the use of flammable liquids and gases and from the use of fine powders, the precautions in BS 5385-4 should be followed.

8.6 Protection of the installation during and after laying

In ideal circumstances, all work above floor level should be complete and equipment installed before floor laying commences; if this is not possible, the protection of finished and partly finished flooring from damage or contamination from following processes is an important consideration which should be taken into account at the design stage i.e. before laying commences (see Clause **13**).

9 Flooring beds

9.1 Workmanship

The application of the floorings described in this standard requires efficient supervision and the employment of skilled operatives who are familiar with the particular flooring units being laid. The requirements of BS 8000-11.2 should be considered when installing natural stone flooring.

NOTE Attention is drawn to the requirements of the Personal Protective Equipment at Work Regulations [5].

9.2 Preparation of bases to receive flooring beds

9.2.1 General

The bond between the bed and the base depends to a great extent upon the conditions of the surface of the base at the time of laying the bed; where the flooring is likely to be subject to very heavy traffic, or other rigorous service conditions, good adhesion to the base should be ensured by providing a mechanical key and/or using a suitable bonding agent depending on the base and type of bed.

Before the bed is laid, the cause of any cracking of the base should be established by a relevant expert and appropriate remedial treatment carried out in accordance with BS 8204-1. Cracked and loose or hollow portions should be cut out and made good.

Where there is a risk of further accumulation of dirt, preparation of the base should be delayed until shortly before the bed is laid.

*NOTE Where unbonded beds are to be laid, mechanical preparation of the surface is unnecessary (see **9.2.5**).*

9.2.2 In situ concrete bases

Where a bonded bed is to be laid, any excessive or unsound laitance on the base should be removed by suitable mechanized equipment. All loose debris and dirt should be removed by thorough sweeping or, preferably, by the use of vacuum equipment.

9.2.3 Precast concrete units

Where the base is a concrete layer over precast concrete units, it should be prepared as in **9.2.2**.

NOTE If the concrete layer is thin (below 100 mm) and roughening by heavy mechanical scabbling is likely to damage it or the precast unit below, the use of shot blasting or grit blasting equipment is an alternative.

Where a sand:cement bed is to be laid directly onto precast units, the surface of the units left rough during production should be thoroughly washed and cleaned, e.g. by wire brushing, to remove all adhering dirt.

9.2.4 Bonded beds

Before a cement:sand bed is laid, the base concrete should be kept wet for a minimum of 3 h, preferably overnight, any excess water being brushed off before slurrying. Within a period of 30 min before the cement:sand bed is laid (less in hot weather), a thin layer of neat cement slurry of creamy consistency should be brushed into the surface of the base concrete; it is essential that the cement:sand bed is compacted onto the base while the slurry is still wet.

Roughening of the base should be carried out (see **9.2.2** and **9.2.3**).

NOTE A proprietary bonding agent can be used or a proprietary bonding mixture can be added to the slurry in accordance with the manufacturer's instructions.

9.2.5 Unbonded beds

Where an unbonded cement:sand bed is to be laid, on either a new floor or an existing floor undergoing renovation, the base should be sufficiently clean and smooth (see **6.3.2.1**) to receive any separating layer specified.

9.3 Setting out

It is essential, when setting out, to establish the correct datum level for the floor. The level of the finished work should be controlled by a series of spot levels. A gauge rod should be set up indicating the overall measurement of a given number of units with specified joint widths; with this the flooring contractor can determine the best method of setting out to avoid unsightly cut units. Whole units should be used where possible. If cutting is necessary, then cut units should be fixed as unobtrusively as possible and should achieve symmetry with regard to cut units in the total area.

Setting out might be related to the siting of movement joints (see Clause **8**). As a general rule movement joints are detailed on working drawings but it is sometimes necessary for their positioning to be left to the discretion of the flooring contractor.

9.4 Tolerances on finished floor level

Floor surfaces should usually be level or be laid to a given fall. Where the flooring is bedded on an adhesive the tolerance of the base should be the same as that required for the finished floor. Some variations in surface level might be accommodated, including the following.

a) The central areas of a large floor (greater than 10 m wide) can be lower or higher than the edges without causing serious inconvenience; a tolerance of 15 mm can be acceptable depending on the area and use of the floor. Greater accuracy will be needed at partitions, door openings and where plant is to be installed directly onto the floor.

b) Local variations in level for a nominally flat floor should be such that, when checked with a 2 m straightedge, any gap under the straight edge, between points of contact, does not exceed 3 mm.

The maximum deviation between tile surfaces either side of a joint, including movement joints, should be as follows:

a) joints less than 6 mm wide, 1 mm;

b) joints 6 mm or more wide, 2 mm.

NOTE 1 The accuracy of the surface can be limited by the dimensional tolerances of the flooring units and it is impractical to measure tolerances of textured floor surfaces.

NOTE 2 In domestic applications, lips between stones might not be acceptable and tighter tolerances can be required.

9.5 Method of mixing cement:sand mortar

9.5.1 Mixing by mechanical means

The material should be thoroughly and efficiently mixed by means of forced action mixers.

NOTE Trough and pan paddle mixers have been found to be suitable for all types of mortar.

Free fall drum mixers have been found to produce inconsistent mixing of semi-dry mortars and their use is not recommended for mixing mortar for the semi-dry bedding method described in **9.6.2**.

9.5.2 Mixing by hand

The hand mixing of cement:sand bed mortar should be carefully checked to ensure thorough mixing.

9.6 Bedding methods

9.6.1 Bedding in cement:sand mortar bonded to the base

*NOTE Cement:sand mortar beds are suitable for terrazzo tile and slab and natural stone floorings with the exception of certain limestones and sandstones (see **9.6.3**). For the laying of the flooring units and the location of movement joints, see Clause **8**.*

9.6.1.1 Mix proportions, thickness and laying

The cement:sand mix should neither be stronger than one part cement to three parts clean sharp sand by volume nor weaker than one part cement to four parts clean sharp sand by volume. The thickness of the bed should be as shown in Table 3. The mortar should be of a stiff plastic consistency and should contain the appropriate quantity of

water so that when tamped and fully compacted into place free water does not bleed to the surface.

The mortar should be spread between wooden battens and levelled with a screed rule drawn across the containing battens. It is important that no more bedding cement:sand should be spread on the base than can be covered with the units within the 2 h open time. Care should be taken to ensure that beds adjacent to movement joints are fully compacted.

As fixing proceeds, occasionally remove a tile or slab to check that the maximum possible contact is being maintained with the bedding.

The bed should be dusted with dry cement sprinkled from a fine sieve and lightly trowelled level until the cement becomes damp. Alternatively, a slurry of neat cement and water or a cement-based adhesive should be applied to the backs of the flooring units, covering them completely.

9.6.2 Bedding in cement:sand semi-dry mix

9.6.2.1 General

Semi-dry cement:sand beds should be used for terrazzo tile and slab, and all natural stone floorings. For the laying of the flooring units and the location of movement joints see the relevant flooring clauses.

*NOTE 1 The dryness of the mix described in **9.6.2.4** results in weak adhesion between the bedding and the base and cleavage can occur at the interface in the event of differential movement.*

Separating layers should be used in special circumstances (see **9.6.2.2**).

In situations involving high dynamic or static loading, because cleavage can be detrimental to the stability of the installation, the bed should be bonded to the base (see **9.2.2** and **9.2.4**).

Where possible, a uniformly thick bed should be applied to achieve the required level of the flooring surface, with a maximum thickness of 70 mm being usually the most practical for this purpose. Where falls are formed entirely in the bed, the thickness of the bed should be not less than 25 mm.

NOTE 2 Where falls are formed entirely in the bed the thickness of the bed might be as great as 100 mm.

Free fall drum mixers produce inconsistent semi-dry mixes and should not be used for this purpose.

The laying of services (i.e. pipes or conduits within the depth of the levelling screed) should be avoided as cracking of the screed and the floor might occur. Where pipes and conduits are located within the levelling screed they should be securely fixed and have a screed cover of not less than 25 mm. Where rectangular trunking is used, local reinforcement, extending not less than 150 mm on either side of the services, should be used. If trunking or ducts are positioned in the levelling screed they should be strong enough to withstand the imposed loads.

Services should not be laid in the sand:cement bedding as their presence is liable to result in failure of the floor.

9.6.2.2 Separating layer

Where differential movement between the bed and the base is required, a separating layer should be used.

NOTE An example would be over a suspended floor subject to deflection.

The base should be smooth (see **6.3.1**) and swept clean. The separating layer (see **5.11**) should then be laid over it with joints lapped at least 100 mm.

The semi-dry mix should be spread over the separating layer between wooden battens. The bed thickness should be not less than 40 mm and reinforced with steel fabric incorporated mid-bed with joints lapped at 100 mm and wire tied (see **5.9**).

9.6.2.3 Semi-dry mix

The mix should consist of one part cement to between three to four parts sand by volume, or one part cement to four to six parts sand by weight. The sand should be in accordance with **5.5**.

A trial mix should first be batched, by weight. In order that a water:cement ratio between 0.55 and 0.60 by weight (about 27.5 L of water to 50 kg cement) can be achieved, the proportion of water in the sand should be determined beforehand, but if this is not possible the correct water content in the mix should be established by means of both of the following tests.

a) The sample should retain its shape and not crumble when squeezed in a gloved hand, which should be left slightly moist. Gloves should be thin and non-absorbent.

NOTE Disposable plastics gloves are suitable.

b) When a sample is compacted on the base, no film of water should form on the surface.

9.6.2.4 Application of semi-dry mix bed

9.6.2.4.1 Preparation

Before the bed is laid, the base should be brushed clean and, if there is likely to be excessive suction, the base should be slightly dampened. The finished floor level should be established. For bonded beds only, a slurry should be spread over the base.

The mix should be spread to a thickness of approximately 10% to 15% greater than that required for the bed, partially compacted and drawn off level. Care should be taken to ensure that beds adjacent to movement joints are fully compacted.

Compaction should be completed during the laying operation by the use of a rubber mallet.

No greater area of mix should be spread than can be compacted and topped with slurry and flooring units in one continuous operation.

9.6.2.4.2 Slurry application

A slurry consisting of one part cement to one part sand, or of neat cement, should be mixed with water and immediately spread and trowelled over the bed in an even layer of approximately 2 mm thick.

Alternatively, the backs of the flooring units can be coated with slurry to combine with the semi-dry bed. When flooring units are laid on slurries containing proprietary materials recommended for this purpose, the manufacturer's instructions should be followed.

NOTE When neat cement is used it might necessary to add a little extra water when re-working in order to achieve the desired consistency.

9.6.3 Bedding in cement:lime:sand mortar

9.6.3.1 General

This type of bed should be used only for limestone and sandstone floorings. For the application of the flooring units see **12.3.2** and for the location of movement joints see **12.1**.

The mortar mix should consist of one part cement, one part lime, to five to six parts clean sharp sand by volume. The thickness of the bed should be 15 mm to 25 mm except for units greater than 500 mm × 500 mm × 40 mm when the bed should be 30 mm to 50 mm thick. The mix should be of a stiff plastic consistency and should contain the appropriate quantity of water so that when tamped and fully compacted into place free water does not bleed to the surface.

9.6.3.2 Natural Hydraulic Lime (NHL) Mortars

The mortar mix should consist of two parts NHL 5 to five parts clean, sharp sand nominally by volume. The thickness of the bed should be 15 mm to 25 mm except for units greater than 500 mm × 500 mm × 40 mm when the bed should be 30 mm to 50 mm thick. The mix should be of a stiff plastic consistency and should contain the appropriate quantity of water so that when tamped and fully compacted into place free water does not bleed to the surface

9.6.4 Base surface

The bond between the bed and the base depends to a great extent upon the conditions of the surface of the base at the time of laying the bed; where the flooring is likely to be subject to very heavy traffic, or other rigorous service conditions, good adhesion to the base should be ensured by providing a mechanical key and/or using a suitable bonding agent depending on the base and type of bed.

Where there is a risk of further accumulation of dirt, preparation of the base should be delayed until shortly before the bed is laid.

The surface regularity of the base should comply with the SR1 requirement in Table 4 appropriate for the bedding method used.

9.6.5 Bedding in adhesives

9.6.5.1 General

NOTE 1 Some stone floor tiles and slabs are suitable for bedding in adhesives complying with BS EN 12004. Generally stone floorings of a calibrated thickness are most suited for this bedding technique. Terrazzo tiles can only be bedded in adhesives capable of accommodating the required bed thickness.

Adhesives should be as described in **5.7** and only those designed specifically for use with stone floor tiles and slabs should be used. Adhesives used should be capable of accommodating the bed thickness required to achieve solid bedding.

Where stone floor tiles and slabs are bedded in adhesives it is essential that bases achieve the surface regularity described in **6.3.2.2**, i.e. when checked with a 2 m straightedge, any gap under the straight edge, between points of contact, does not exceed 3 mm. The adhesive application technique of utilizing a notched trowel, as a spreading or distribution gauge, will follow the contours of the base and in some cases will not allow any flexibility in regulating the level of the finished surface.

It is essential that the bed should be consolidated and the flooring units thoroughly tapped down into it so that, as far as possible, voids beneath the flooring units are eliminated. Any voids will be potential points of weakness under load and, in exterior situations, water might accumulate in voids giving rise to frost damage.

The base should be clean, dry and prepared to suit the adhesive being used. The surface being adhered to should not be dampened before applying the adhesive.

The recommendations of the adhesive manufacturer should be followed concerning the mixing procedure, the method of use, the maximum thickness of bed, the working time before and after spreading and the suitability of the base. Dry powder adhesives should be mixed with clean water, or specified admixes, carefully following any specific instructions to obtain the required consistency. The components of a reaction resin adhesive should be thoroughly mixed before use.

9.6.5.2 Bedding in cementitious adhesives

The stone tiles and slabs should always be "solid bed fixed" so that no voids remain behind the tiles. The adhesive should be spread over the base and trowelled out as a ribbed bed using an appropriately sized notched trowel so that when the stone tiles or slabs are fixed, the final bed thickness will not exceed the maximum specified by the manufacturer. The backs of the tiles should be "buttered" by trowelling out a thin layer of the adhesive on the back of each tile immediately prior to bedding it into the wet and workable ribbed adhesive bed. If pourable floor tile adhesives are used it is possible to fix the tiles in a solid bed of adhesive without having to butter the backs of the tiles.

The entire back of the stone tile or slab should be in contact with the adhesive. In both methods the stone tiles or slabs should be dry and should be thoroughly tapped down to ensure complete adhesion and, as far as possible, a void-free bed.

The advice of the adhesive manufacturer on the size and type of notched trowel should be followed.

NOTE Too large an amount of adhesive under the tiles can result in excess adhesive grinning up through the joints and the tiles "swimming" on the adhesive, whilst too small an amount of adhesive will prevent solid bedding.

A freshly fixed stone tile or slab should be occasionally lifted to check that the size of notched trowel and the bedding technique used results in no voids being left beneath the tile.

9.6.5.3 Bedding in reaction resin adhesives

Reaction resin adhesives are normally supplied as pre-gauged components and the mixing and application instructions of the manufacturer should be closely followed.

The base should be dry and clean. The mixed reaction resin adhesive should be applied within the recommended working time and in most cases the mixed adhesive should be emptied out of the mixing container to prevent heating up and curtailment of the working time.

These adhesives should be applied in a similar way to the methods described in **9.6.5.2** using an appropriate notched trowel and buttering the backs of the stone tiles and slabs; the bed thickness of these reaction resin adhesives is normally limited, so they are normally only appropriate for bedding calibrated stone tiles and slabs on bases meeting surface regularity 1 (SR1) as detailed in Table 4.

10 Terrazzo tile and slab flooring

10.1 Bedding methods

10.1.1 General

Design considerations should be followed as described in Clause **6**.

Recommendations for base preparation and details of bedding methods should be followed as described in Clause **9**.

10.1.2 Workmanship

Good workmanship and efficient supervision are essential in the laying of terrazzo tiles and precast slabs; skilled operatives experienced in the installation of these materials should be employed.

10.2 Beds

*NOTE Suitable beds for terrazzo tiles and slabs are the semi-dry mix (see **9.6.2**) and cement:sand mortar (see **9.6.1**). The suitability of the bed depends on the type and size of terrazzo tile or slab, the construction and condition of the base and the anticipated loading and traffic. Concrete backed terrazzo tiles and slabs are generally not suitable for fixing with thin-bed adhesives.*

A semi-dry mix bed used with terrazzo tiles and slabs should be either isolated or fully bonded.

Where separating layers are incorporated, the semi-dry mix bed should be reinforced (see **9.6.2.3**). A cement:sand mortar bed should not be used over a separating layer for terrazzo tiles and slabs.

Whilst it is preferable to lay the bed over a considerable area before laying the tiles or slabs, this might not be possible where they are of unequal thickness, in which case individual bedding should be adopted.

10.3 Movement joints

*NOTE Movement joints and their uses are described in Clause **8** and typical examples are shown in Figure 2.*

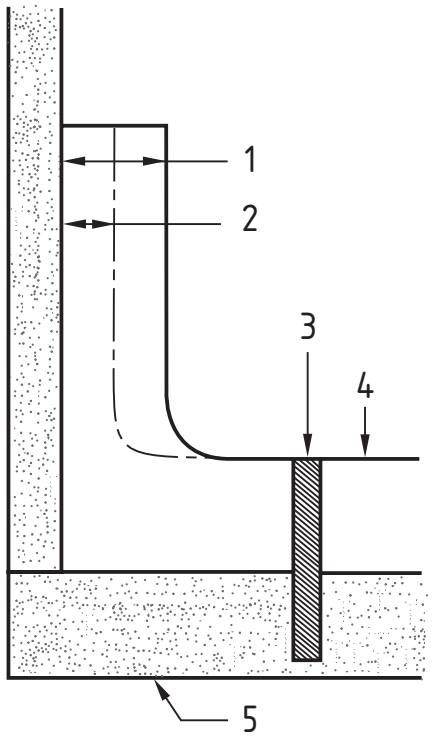
10.3.1 Structural movement joints

These joints should be as described in **8.1.2**.

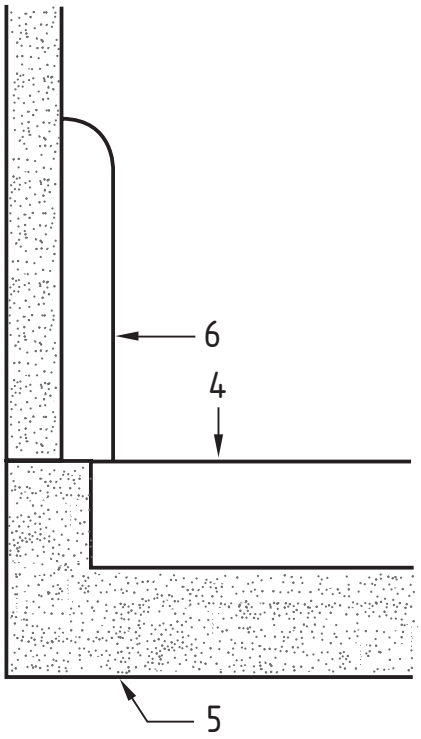
10.3.2 Perimeter joints

Where flooring abuts restraining surfaces such as perimeter walls, columns, kerbs, steps and plant fixed to the base, contraction joints type F as shown in Figure 3a) should be used. In floors with dimensions of 2 m or less between restraining surfaces, perimeter joints are not necessary [see Figure 3b)]. Where stresses are likely to be extreme, for example, large temperature changes, type E joints should be used [see Figure 2e)].

Figure 3 **Alternative perimeter joints for terrazzo tile and slab flooring**



a) Floors with dimensions over 2 m



b) Floors of 2 m or less between restraints

Key

1 Coved skirting[A)]
2 In situ terrazzo[A)]
3 Preformed strip
4 Terrazzo tile
5 Cement:sand mortar bed
6 Skirting tile

[A)] Alternative options.

10.3.3 Intermediate joints

NOTE The need for intermediate joints between perimeter joints depends on the dimensions of the floor. In floors with less than 10 m between perimeter joints, no intermediate joints are necessary.

Very large floors should be divided into bays by incorporating type E or F joints [see Figure 2e) and Figure 2f)] at not more than 30 m intervals subdivided into smaller bays by contraction joints type F, not greater than 10 m apart. Floors which are not so large should be divided into bays by the insertion of type F joints at 8 m to 10 m intervals.

On suspended floors, contraction joints type F should be inserted where flexing is likely to occur, e.g. over supporting walls or beams.

10.4 Application of terrazzo tiles and slabs

10.4.1 Curing of tiles and slabs

Before terrazzo tiles or slabs are laid they should be sufficiently cured to avoid excessive drying shrinkage which is normally achieved by air curing for at least 28 days after pressing.

10.4.2 Semi-dry bed

On semi-dry cement:sand mix (see **9.6.2**) the mix should be spread, partially compacted and slurried as described in **9.6.2.4**. The tiles should be placed in the slurried bed and, to compact the bed, firmly beaten into position with a rubber mallet down to the lowest level.

NOTE 1 This is usually established by means of a string line.

All the tiles and slabs should be fixed with joints at widths that enable subsequent grouting to penetrate deeply.

NOTE 2 Joint widths range from 2 mm to 3 mm for terrazzo tiles. Wider joints might be needed to accommodate size variations in terrazzo slabs.

On completion of each area laid, tiles should be washed with a hand brush and clean water to remove any slurry that has risen in the joints in the beating process, or has been deposited on the surface of the tiles.

10.4.3 Other beds

For application on adhesives, see **9.6.5**.

For application on cement:sand and mortar, see **9.6.1**.

10.5 Grouting

10.5.1 General

The bed should be allowed to harden sufficiently to preclude the slabs or tiles being disturbed when grouting, e.g. for two or three days. However grouting should not be unduly delayed, as open joints might collect building dust and deleterious substances.

NOTE Neat cement grouts will dry under tension, which might lead to fine transverse ladder cracking. This can be minimized by the use of proprietary additives.

10.5.2 Grout materials

10.5.2.1 Terrazzo tiles

Neat white or grey cement should be used to fill the joints, or, where required, pigments not exceeding 5% by weight can be incorporated to tone with the matrix of the terrazzo.

Where admixtures are used the manufacturer's instructions should be carefully followed.

10.5.2.2 Terrazzo slabs

Mortar consisting of one part cement to three parts fine sand should be used to fill the joints, incorporating pigments where required, as in **10.5.2.1**.

10.5.3 Grouting procedure

The grout should be mixed with clean cold water to a creamy consistency thin enough to ensure adequate penetration of tile joints. The grout should be worked over the surface with a squeegee until all settlement has ceased. Surplus grout should be removed from the surface of the tiles or slabs leaving filled flush joints. Where necessary, i.e. conditions of high temperature, the grout should be protected from excessively fast drying, e.g. by covering with plastic sheeting, to ensure adequate hydration.

10.6 Grinding and polishing

10.6.1 General

Surface grinding and polishing should not commence sooner than three days after grouting or until the grouted joints are thoroughly hardened and cured.

10.6.2 Grinding

Grinding should be carried out mechanically using rough grit stones to remove all surface grout and correct unevenness (lipping) between the tiles or slabs. A second grinding should then be carried out using finishing grade stones to remove any scratches left by the initial coarse grind.

10.6.3 Polishing

After grinding, the floor should be thoroughly cleaned and washed to remove all grinding residue and dust, then regrouted either mechanically or by hand using the same mixture as described in **10.5.3** over the whole surface of the floor, filling in any voids revealed in grinding. The final polishing should be carried out wet and mechanically using fine grit stones, e.g. No. 80 or finer. The period of time between the second grouting operation and final polishing should be not less than 24 h. On completion of the final polishing, the flooring should be thoroughly cleaned and left to dry naturally.

10.6.4 Hardeners

The hardness of the finished terrazzo surface can be improved by treatment with proprietary chemical hardeners, e.g. those based on silico-fluorides. The manufacturer's directions for their application should be strictly followed.

11 Agglomerated stone

11.1 General

*COMMENTARY ON **11.1***

The recommendations for the installation of agglomerated stone flooring are given as a separate clause as these materials have markedly different physical properties to natural stone and cement-based terrazzo products.

Agglomerated stone products are manufactured from hydraulic cement, resin or a mixture of both, combined with stones and other aggregates. They are factory manufactured in block form. These blocks are then cut into slabs and tiles.

Agglomerated stone products have different properties to natural stone and terrazzo materials and these differences should be taken into account at the design stage, e.g. the greater thermal expansion of resin-based products (see BS EN 14618).

11.2 Bedding methods

11.2.1 General

*COMMENTARY ON **11.2.1***

Agglomerated stone products are generally installed on adhesive, although cement-based units can be laid in cement:sand mortar.

To avoid moisture from the adhesive bed distorting resin-based agglomerated stone products, reaction resin adhesives or quick drying low alkalinity cement based adhesives should be used.

Agglomerated stone products should not require further finishing or polishing on site as they are usually self-finished.

11.2.2 Bedding in adhesive

Cement based adhesive to be used should comply with BS EN 12004, class C2; reactive resin adhesives to be used should comply with BS EN 12004 class R1 or R2.

11.2.2.1 Application of adhesive

Adhesives should be applied as in **9.6.5**. For consistent appearance, the backs of light coloured flooring units should have an even coat of white adhesive applied immediately before bedding in a white adhesive.

11.3 Grouting

11.3.1 Grouting timing

Grouting should be performed when the adhesive has hardened adequately according to the manufacturer's instructions. 24 h drying time should be allowed for normal-setting adhesives and 3 h drying time should be allowed for rapid-setting adhesives.

Grouting should not be unduly delayed as open joints might collect general building dust and deleterious substances.

11.3.2 Grout materials

Cement based agglomerates should be grouted with cement grouts as described in BS EN 13888.

Resin based agglomerates should be grouted with modified cement grout CG 2 or reaction resin grout RG as described in BS EN 13888.

11.4 Movement joints

11.4.1 General

The type and positions of movement joints in agglomerated stone flooring should be as described in Clause **8**, but resin based units require movement joints at a higher frequency that take into account their greatly increased coefficient of thermal expansion.

NOTE Resin based flooring units can have a coefficient of thermal expansion more than three times that of cement terrazzo and natural stone.

11.4.2 Structural movement joints

These joints should be as described in **8.1.2**.

11.4.3 Perimeter joints

Where flooring abuts restraining surfaces such as perimeter walls, columns, kerbs, steps and plant fixed to the base, perimeter joints should be installed unless the distance between restraining surfaces is less than 2 m.

11.4.4 Intermediate joints

Very large floors should be divided into bays by incorporating type C joints (see Figure 4) at not more than 10 m intervals subdivided into smaller bays by stress-relieving joints 3 m to 5 m apart.

For heated floors, closer joint spacing should be incorporated (see BS 5385-4).

12 Natural stone flooring

*NOTE Stones and their surface finishes which are suitable for flooring are given in **5.3**; for design considerations see Clause **6** and for base preparation and bedding methods see Clause **9**.*

12.1 Movement joints

*NOTE Movement joints and their uses are described in Clause **8** and typical examples are shown in Figure 2.*

12.1.1 Structural movement joints

These joints should be as described in **8.1.2**.

12.1.2 Perimeter joints

Where flooring abuts restraining surfaces such as perimeter walls, columns, kerbs, steps and plant fixed to the base, perimeter joints should be installed unless the distance between restraining surfaces is less than 2 m. Where the stone flooring abuts a previously installed wall lining, flexible joint type C should be used, but where the flooring is laid first, back-up material at the perimeter should be used (see Figure 4.)

12.1.3 Intermediate joints

The need for intermediate joints between perimeter joints depends on the dimensions of the floor; in floors with less than 10 m between perimeter joints, no intermediate joints are necessary but in larger floors they should be employed to divide the area into bays.

12.2 Granite, marble, travertine, hard limestone, slate and quartzite

12.2.1 Beds

These natural stone units should be solidly bedded, generally on a cement:sand semi-dry mix as given in **9.6.2**. Alternatively, the units can be solidly bedded on a cement:sand mortar bed as given in **9.6.1**. Stone flooring units might also be bedded in adhesive as given in **9.6.5**. For light coloured marbles and granites white cement should be used for the slurry.

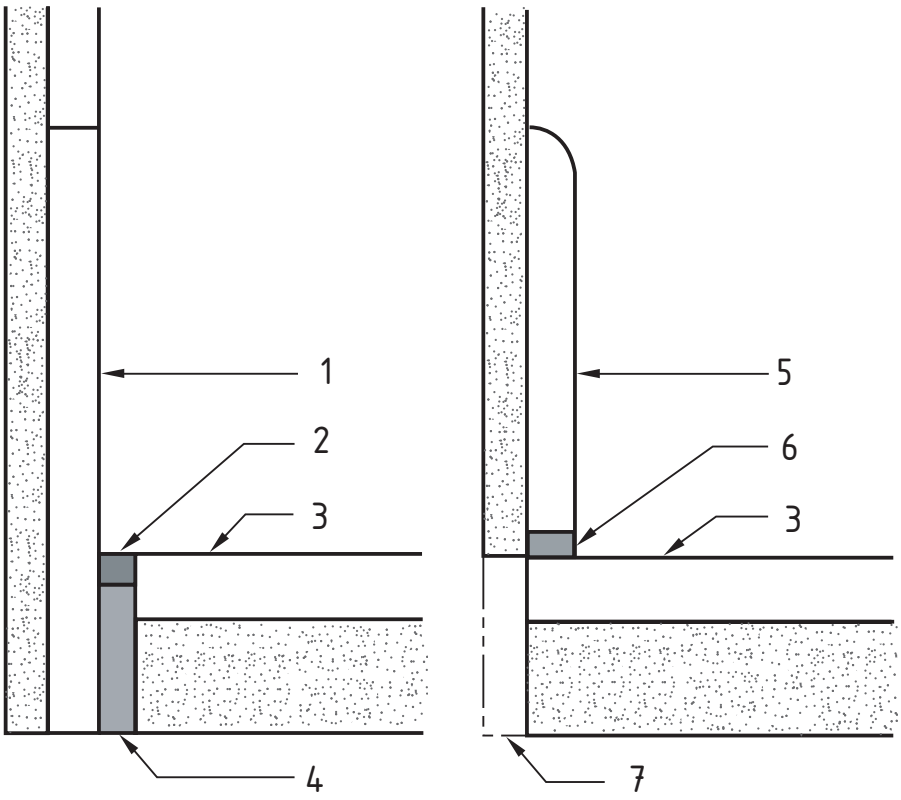
12.2.2 Application of flooring units

12.2.2.1 Cement:sand semi-dry and cement:sand mortar bed

The backs of the flooring units should be completely coated with a cement slurry (white cement for white or light coloured marbles and granites). This slurry should be of a thick creamy consistency – a water-resistant bonding agent can be incorporated in the slurry to improve bonding. When proprietary additives are used, the adhesive manufacturer's instructions should be followed. The flooring units should be tapped firmly into position using a rubber mallet and laid with joints as given in **12.2.3**. Any bedding material brought to the

surface at the joints should be wiped from the surface of smooth stone with a damp sponge or cloth as soon as possible after the stone has been placed in position.

Figure 4 **Alternative perimeter joints for natural stone flooring**



Key

1 Stone lining
2 Type C joint (for large areas)
3 Stone flooring
4 Back-up material
5 Skirting
6 Sealant (optional)
7 Void or alternatively back-up material

12.2.2.2 Adhesives

Flooring units of granite, marble, slate or quartzite should be bedded in adhesive following the recommendations given in **9.6.5**.

12.2.3 Pointing and grouting

12.2.3.1 General

Grouting can be carried out at any time to suit the convenience of the work but preferably should be left for at least 12 h after the completion of the laying of the flooring units. It is essential to allow sufficient time to elapse to ensure adequate setting of the bed to preclude disturbance of the flooring units during the joint finishing operation. However, the grouting should not be delayed beyond 48 h as open joints might collect general building dust and deleterious substances.

12.2.3.2 Natural stone with smooth finishes

The most satisfactory results are obtained when these materials are laid with narrow joints; these, however, should still be of sufficient width to permit adequate penetration of the grout. The joints should be completely filled with neat cement or modified cement grout worked into the joints.

12.2.3.3 Natural stone with textured and riven finishes

The minimum joint width should be 6 mm in order to take up any slight variations in the slab surface, thereby avoiding projecting edges.

NOTE For textured or riven surfaces, it is sometimes desirable to use a dry brush to remove surplus material before wiping with a damp sponge or cloth.

When the bed has stiffened, the joints should be pointed with mortar consisting of one part cement to three parts fine sand. Once the mortar has sufficiently set, the face should be thoroughly cleaned.

Surplus mortar should not be allowed to harden on the floor surface.

12.3 Limestone and sandstone

12.3.1 Beds

Limestone and sandstone materials should be solidly bedded on a cement:lime:sand mix as given in **9.6.3**, or on a cement:sand semi-dry mix as given in **9.6.2**. Flooring units can also be bedded in adhesive as given in **9.6.5**.

12.3.2 Application of flooring units

12.3.2.1 Cement:lime:sand bed

The flooring units should be dampened on the back with clean water and tapped into position with a mallet. They should be laid with at least 3 mm wide joints in riven sandstone paving, roughly squared and laid in a random pattern up to 20 mm. Any bed material brought to the surface at the joints should be wiped from the face of the stone with a damp sponge or cloth as soon as possible after the stone has been placed in position.

12.3.2.2 Cement:sand semi-dry mix

The units should be tapped firmly into position using a rubber mallet.

Natural stone should be laid with at least 3 mm wide joints in riven sandstone paving, roughly squared and laid in a random pattern up to 20 mm. Any bed material brought to the surface at the joints should be wiped from the face of the stone with a damp sponge or cloth as soon as possible after the stone has been placed in position.

12.3.2.3 Adhesives

Natural stone tiles and slabs (up to a maximum size of 600 mm × 600 mm × 20 mm thick, calibrated) should be bedded in adhesive following the recommendations given in **9.6.5**.

12.3.3 Pointing and grouting limestone and sandstone

Grouting can be carried out at any time to suit the convenience of the work but preferably should be left for at least 12 h after the completion of the laying of the flooring units; it is essential to allow sufficient time to elapse to ensure adequate setting of the bed to preclude disturbance of the flooring units during the joint finish operation. However, the grouting should not be delayed beyond 48 h as open joints might collect general building dust and deleterious substances.

When laying limestone or sandstone floor slabs requiring a 3 mm wide joint, only calibrated slabs (generally a maximum of 600 mm × 600 mm × 20 mm) should be used. Where 3 mm wide mortar pointed joints are to be installed, the edges should be flushed up with mortar. The mortar mix will depend on the type of stone used. Where the stones are being pointed using a modified grout they should not be narrower than 2 mm.

13 Protection

The protection of finished and partly finished flooring from damage or contamination from following trades should be considered.

During the laying operation, the newly laid tiles or slabs should be accessible to no-one but the flooring operatives. It is equally important that completed flooring should not be subjected to traffic until the bedding has stiffened and sufficient bond has developed between the bedding and the floor units to preclude any likelihood of disturbance.

On floors bedded in non-rapid-setting adhesive and in cement:sand mortars, four days should be allowed after the completion of laying and grouting before it is subjected to light pedestrian traffic; heavier traffic should not be permitted to use the floor for 14 days after completion.

Where flooring units are laid in a rapid-setting adhesive the floor should be able to take traffic earlier than four days after completion.

NOTE Unless a rapid-hardening grout is used, it would be inadvisable to reduce the four day period.

The precise times when a floor can be safely put into service vary for different rapid-setting products and the manufacturer's recommendations should be followed.

At all times the flooring should be kept clean and free from cement and plaster droppings, and all materials likely to cause stains. The flooring should be covered during work carried out on or over the floor involving substances that could cause permanent staining, e.g. oils, grease, paint. Appropriate types of sheets or boards should be laid loosely over the finished floor to protect it. The sheets and boards selected should allow the stone to breath and offer appropriate protection. The sheets or boards should not retain moisture that will encourage staining of the stone flooring units. Sawdust should not be used for this purpose.

If plant likely to cause damage has to be used, any parts in contact with the floor surface should be padded; sliding of plant over the surface should not be allowed. When heavy equipment has to be moved over the floor surface, special precautions should be taken (e.g. the use of timber planking) to ensure that the equipment, moving tackle and the

protective covering itself are not allowed to damage the tiled surface by abrasion.

Stair finishings, especially nosings, are vulnerable to damage from following trades and should be protected by temporary casings.

14 Cleaning and maintenance

14.1 General

Damage can occur to a floor finish by misuse or incorrect maintenance due to inadequate initial instructions; personnel responsible for maintenance should be given full information concerning any particular risks of misuse likely to occur and this information should include recommendations for cleaning.

The floorings considered in this standard require some maintenance and are easily kept clean; they should be regularly swept, then washed with warm water to which a soapless detergent has been added and rinsed with clean water. Fine abrasive cleaners should be used occasionally on finishes other than polished marble and polished granite to remove particularly stubborn blemishes. Scrub and rinse cleaning machines fitted with abrasive pads, other than the finest grades, should not be used regularly as they can damage the surface of the stone and might result in gradual loss of thickness in the wear layer.

Cement and plaster droppings should be removed with a soft spatula, then vacuum cleaned. Residual cement staining on stones other than limestone or marble should be washed with large quantities of water, followed with a dilute hydrochloric acid, or proprietary mortar remover, and then washed off again with clean water.

Oil and grease on granite and slate should be treated with a detergent and a soft brush.

NOTE In some cases this can result in spreading the problem. Where this occurs, a commercial poultice containing a suitable solvent can be applied to "lift" the stain.

14.2 Granite and marble

Granite and marble polished surfaces and slate should be washed regularly using a soapless detergent and, at intervals, wax polished.

Abrasives should not be used, and domestic soap should be avoided as it leaves a slippery scum, particularly in hard water areas. After cleaning polished floors with water and detergent, they should be lightly machine polished to a non-slip finish.

After extensive use, polished granite and marble floors can be machine repolished by a specialist contractor, which will restore them to an almost new appearance.

14.3 Limestone and sandstone

Limestone and sandstone floors should be kept clean by regular daily brushing or vacuuming prior to washing. The floors should be washed on a weekly basis using warm water to which a neutral detergent

has been added. Any stubborn stains (e.g. rubber shoe marks) should be removed using a special multipurpose cleaner. Household or commercial cleaning agents such as cleaners containing bleach should not be used to clean stone; these cleaning products can burn or discolour stone finishes. Impregnators, sealants and cleaning products should be applied in strict accordance with the manufacturers' advice.

NOTE Guidance on products can be obtained from the Stone Federation Members and specialist companies.

14.4 Maintenance

Open joints should be repointed at the earliest opportunity.

Major stains might need professional attention. Care should be taken to assess whether changes in stone appearance or defects will result from varying cleaning regimes, as inappropriate cleaning might serve to fix or worsen a discoloration.

NOTE 1 The incorrect use of cleaning machines with hard plastics bristles might damage and erode grouted joints.

Cleaning agents should not be allowed to come into contact with adjacent fixtures and wall surfaces.

NOTE 2 Apart from normal usage or obvious misuse, surface contamination can arise from:

- *frequent use of unsuitable cleaning agents, including highly alkaline detergents and chemicals;*
- *the reaction of cleaning agents with hard water;*
- *efflorescence on terrazzo tile and slab flooring and stone flooring;*
- *surface sealing materials on terrazzo tile and slab flooring and stone flooring.*

14.5 Efflorescence

*NOTE Efflorescence is aggravated by excessively damp conditions following installation or prolonged delay in drying out and can be persistent if it is due to rising moisture where damp resisting construction (see **6.5.2**) is inadequate.*

The deposit should disappear with washing but might reappear after drying; it should diminish with progressive washing and the most effective treatment is to increase the frequency of washing until the deposit ceases to appear. Persistent deposits should be identified and specialist advice sought.

14.6 Surface protection

14.6.1 Surface sealing

Surface seals and polishes should not be applied as they might be absorbed into the surface, which can cause the surface to become slippery and difficult to clean. Linseed and other oils should not be used.

14.6.2 Oil staining of terrazzo tiles and slabs, agglomerated stone and marble

Although terrazzo tiling, agglomerated stone and marble have a high resistance to oil staining, they are not completely impervious to oil penetration; proprietary treatments available for the removal of oil stains should be used to clean them. To increase resistance to staining, proprietary chemical hardeners should be used.

NOTE Terrazzo tile flooring treated with hardeners might require occasional additional treatment.

14.7 Cleaning agents

Effective cleaning can usually be achieved by normal washing or scrubbing with warm water and a neutral sulfate-free detergent (see **14.1**); greasy deposits can be removed by detergent incorporating an organic solvent or an alkaline detergent (pH > 9), but these should only be used for occasional cleaning. The detergent used for regular cleaning should only be that recommended for the particular flooring. The occasional use of abrasive cleaners can be beneficial but should not be used on polished marble or polished granite.

Household soaps should not be used as they tend to leave a slippery scum, particularly in hard water areas.

The cleaning agent should be completely removed by a final rinsing with clean water.

Annex A (informative) Natural stone descriptions

A.1 Granite

The term granite has been applied to almost any igneous stone that can retain a polish. True granites provide many of these stones but other types of igneous stone that might fall into this classification include syenites, gabbros, dolerites, and diorites. The metamorphic stones gneiss, schist and granulite are frequently also included in this "granite" classification.

The formation of these igneous rocks by the slow cooling of molten minerals such as quartz, feldspar and hornblende has resulted in a wide variety of colours and grain patterns. The interlocking crystal structure imparts both the high strength and low porosity necessary for a wide range of applications other than just flooring; these characteristics are also important in allowing successful use of slabs that are thinner than other types of stone.

The surface finish affects the appearance of granite and those available include sawn, flame textured, dolly pointed, fine axed, rough punched, honed, bush hammered and water jet. It is in the gloss polished form, however, that these granites reveal fully their colours and grain patterns.

A.2 Sandstone

The term sandstone is used to describe almost any stone of sedimentary origin with a granular texture. Some other types of stone that might fall under this classification include gritstones, siltstones, greywackes, conglomerates and marls. Aside from particle size variations, the dominant factor affecting sandstone performance is the grain cement that might be siliceous, calcareous, clay bearing or iron-rich.

It is the granular nature of sandstone that provides the typically excellent slip resistance, even under wet conditions, and also helps to maintain this resistance with wear. The slip properties might be at the expense of resistance to abrasive effects and evidence for abnormally high abrasion losses should be assessed. Generally, the best performing stones are predominantly cemented by silica.

Sandstone has many colours ranging from white, grey and buff to various shades of pink and red.

Sandstones generally have an even texture, which might vary from coarse to fine, but the stone from some quarries also show attractive natural markings.

Many types of sandstone are suitable for paving or flooring. Some can be split ("riven") otherwise the normal finish is sawn.

A.3 Quartzites

Quartzites are typically the metamorphosed product of an original sedimentary rock, e.g. sandstone, composed almost entirely of quartz.

In general quartzites are hard wearing, have low porosity, a high compressive strength and good durability making them suitable for use as flooring. The metamorphic varieties in particular might be brittle and so some care is required in assessing a material prior to use.

While composed largely of quartz, the presence of some impurities can lead to the development of different colours and the typical range is from white to yellowish brown, through to green, brown, gold, grey and blue. In Ireland the metamorphic quartzites have a complex geological history which has tended to result in them having a relatively small natural block size.

A.4 Slate

The term slate is often used to describe any rock that can be easily split into thin sheets, principally for roofing purposes. True slate is defined by the presence of a "slaty" cleavage; this allows the slate to be split at almost any point through the stone parallel to the cleavage plane. Most true slates are metamorphosed sediments, often formerly mudstones; however, some British "slates" are derived from volcanic ash sequences and are not true slates in the strict geological sense.

Slate is easily split ("riven") into thin sections, giving a natural finish. Other finishes include sawn, sanded, fine rubbed, flame textured, bush hammered and water jet.

A.5 Limestone

Limestone is a sedimentary rock. Many of the commonly used varieties were formed by the accretion of the hard remains of former organisms such as corals and shells. These materials principally comprise calcium carbonate (calcite), as does the cement. Calcite is a relatively soft mineral and places many restrictions on the way limestone is to be used. Variations in the types and quantities of shell and other remains and the nature of the cement provide a huge range in the types of limestone available.

The colour of limestone ranges from almost white to a warm honey tone. Textures range from fine even grained stones to the smooth fossil bearing types and to the coarse open textured. Certain limestones such as Hopton Wood, Purbeck and some imported stones will take a polish. Finishes including honed, sawn flame textured and polished are also offered.

Careful selection is needed when choosing limestone for use as flooring, particularly with respect to slip and abrasion resistance.

A.6 Marble

True marbles in the geological sense are metamorphosed limestone and are principally composed of recrystallised calcite formed into an interlocking granular structure. Some hard or partially metamorphosed limestones are incorrectly referred to as marble, even though they exhibit many of the characteristics of marble.

In its "purest" state marble is typically white, however the presence of other minerals can often provide colour(s). In some cases the colour appears as irregular shaped patches (brecciation) or as substantial veining.

A.7 Travertine

Travertine is the name normally given to a type of precipitated calcite associated with the cooling of waters around hot springs or in caves.

Being formed very slowly it often incorporates dead matter such as tree debris that later rots away to leave a voided structure.

The performance of travertine greatly depends on the size and density of the voids, which, in most instances, are routinely resin surface filled before the finished stone is supplied.

A.8 Green marble or verde

Green or verde marble is considered separately to true marble because its origin is often the result of the metamorphism of rocks other than limestones. The green colour is typically derived from the presence of serpentine minerals. These minerals are relatively soft and the structure often weak, the stone commonly requiring reinforcement from matting glued to the underside.

Verdes are rarely used for whole floors and are preferred for providing coloured inserts to other flooring materials. Care should always be taken to ensure their compatibility with other stones.

A special consideration for any verde marble is the presence or otherwise of asbestiform minerals that might be naturally present, e.g. chrysotile (white asbestos) and the amphiboles tremolite and actinolite. It might be prudent to establish that, where present, fibres of these minerals in the respirable range are not generated during any cutting, grinding and polishing operations – particularly if carried out dry.

Annex B (informative) Slip resistance

B.1 General

People slip because the frictional force between footwear and floor surface is too small to resist the horizontal force applied. Guidance in relation to slip resistance of stone is presented in BRE IP 10/00 and also in the UK Slip Resistance Group Guidelines document [6]. In general terms, polished surfaces can initially be expected to provide less slip resistance but there is a widespread misconception that shine, which is a light reflection property, is directly related to slipperiness which might not always be the case.

Some limestones actually polish with use so that the potential for slip might increase during the period of service. Riven slate and sandstone are usually inherently non-slip.

B.2 Measuring slip resistance

Whilst many instruments have been designed for measuring the slipperiness of flooring, the pendulum test has been adopted as the accepted harmonised test for natural stone across Europe (see BS EN 14231).

The pendulum tester measures the frictional resistance between a slider mounted on the end of a pendulum and a floor surface. These values of slip resistance are read directly from the pendulum scale. The design, calibration and operation of the instrument are described in BS 7976.

Surface roughness is another property that can be usefully considered. Monitoring the change in surface roughness (R_z) of a surface due to wear and other factors can be helpful in gauging the likely change in slip resistance, although it is not a substitute for proper measurement of slip resistance (see BS 1134-1). The required surface roughness depends on the contaminant, e.g. dirty water is likely to require a higher surface roughness than clean water because the viscosity is higher.

There is some evidence however that stones with rough surfaces, e.g. 0.5 mm to 1.0 mm, can still be slippery if the surfaces of individual grains become polished. This suggests that the macro- and micro-textures of some stones should be established when considering slip potential.

B.3 Guidance on slip resistance results achieved

Interpretation of measurements is not always straightforward and it is important that the instruments are used in a consistent way and that adequate consideration is given to the proposed installation environment and design, as well as the numerical data obtained. For this reason it is recommended that the UK Slip Resistance Group Guidelines [6] are followed when carrying out the tests.

The pendulum tester and roughness meter can be utilised for assessment of materials both in the laboratory and on installed floors. It should be clearly noted that results obtained on factory-fresh samples might not be directly comparable to in-service performance, where contamination, wear and cleaning regimes all influence the behaviour of the flooring material.

A slider applicable to most internal flooring materials (i.e. with roughness less than 30 μm R_z) was subsequently developed (previously called standard simulated shoe sole or 4S rubber, now referred to as Slider 96) and adopted in the UK Slip Resistance Group Guidelines [6].

The 4S-rubber slider is applicable for use on normal internal flooring materials that are not enhanced to provide additional safety for hazardous conditions. The slip resistance of the floor for able-bodied pedestrians should be interpreted as set out in Table B.1.

Table B.1 **Slip resistance results (Slider 96 Pendulum)**

Pendulum Value (Slider 96)	Potential for Slip
0–24	High
25–35	Moderate
> 36	Low

To assess the slip potential in areas which might become wet, the values when the test is carried out on the wet floor should be used.

It is also important to remember that the slip resistance of a surface might change with use, either becoming more slippery as a result of natural polishing or less slippery as a result of abrasion and roughening of the surface. Therefore, no single measurement or piece of information should be used to assess a floor. All test information, environment and design influences should be taken into account before a categorisation is reached.

B.4 Measuring surface roughness

Roughness can bring about an improvement in slip resistance in wet or contaminated conditions. Surface irregularities can break up a water or contamination film, establishing contact with the shoe or heel, and in this respect peaks are more important than troughs.

The actual measurement of the various aspects of surface roughness is complex, but it has been established empirically that a measure of peak to trough roughness (R_z) is a guide to slip resistance. Surface roughness can be measured with a roughness meter.

Surfaces contaminated with pure water require a surface roughness of at least 10 μm (microns) R_z to provide a reasonable level of slip resistance. In circumstances where wetness is normal or expected, this figure should be increased by a factor of two or more. More viscous contaminants such as dirty water and oils require a higher surface roughness.

Annex C (informative) Sealant properties

Table C.1 **Flexibility of sealant materials**

Material	Flexibility
Bitumen compounds	Plastoelastic
Polysulfide	Very resilient
Silicone	Very resilient
Polyurethane	Very resilient
Epoxy/polysulfide	Slightly resilient

Table C.2 **Flexibility of joint materials**

Material	Flexibility
Portland cement mortar	Rigid
High alumina cement mortar	Rigid
Rubber latex cement	Slightly resilient
Furane resin	Rigid and tough
Epoxide resin	Rigid and tough

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Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 410-1:2000, *Test sieves – Technical requirements and testing – Part 1: Test sieves of metal wire cloth*

BS 1134-1, *Assessment of surface texture – Part 1: Methods and instrumentation*

BS 7976 (all parts), *Pendulum testers*

BS 8000-11.2:1990, *Workmanship on building sites – Part 11: Code of practice for wall and floor tiling – Section 11.2 Natural stone tiles*

BS EN 1008, *Mixing water for concrete – Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete*

BS EN 12372, *Natural stone test methods – Determination of flexural strength under concentrated load*

BS EN 12440, *Natural stone – Denomination criteria*

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