BRITISH STANDARD

Design of joints and jointing in building construction –

Guide

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Contents

List of tables

Summary of pages

This document comprises a front cover, an inside front cover, pages i and iv, pages 1 to 60, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution and came into effect on 28 July 2006. It was prepared by Technical Committee B/547, *Sealants for building and construction*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

BS 6093:2006+A1:2013 supersedes BS 6093:2006, which is withdrawn.

Information about this document

Text introduced or altered by Amendment No. 1 is indicated in the text by tags [A1⟩ ⟨A1]. Minor editorial changes are not tagged.

As a code of practice, this British Standard 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 British Standard is expected to be able to justify any course of action that deviates from its recommendations.

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.

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.

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1 Scope

This British Standard gives recommendations for the design of joints and the use of jointing products in building construction. Following an analysis of joint functions and of the performance of the parts to be joined, joints are classified in this standard on the basis of the movements and inaccuracies they have to accommodate. Mechanisms by which joints operate are identified and recommendations are made on the use of sealants and gaskets. Some emphasis is placed on weather resistance of joints in the external envelope of buildings.

The code does not present guidance in the form of a catalogue of proven joint designs, because the extent to which a design is appropriate to a particular use depends on circumstances specific to the building, e.g. its exposure, desired performance, durability and costs. The code therefore draws attention to matters that need consideration, in order that solutions may be developed that are appropriate.

The code does not cover:

a) rigidly connected joints (except type 1 joints, see **4.6.4.1**);

b) joints within components normally made in a factory, such as those around opening lights in windows;

c) the load-bearing functions of structural joints;

d) glazing (see BS 6262);

e) joints in service pipes and ducts and their connections to appliances;

f) methods of test for joints or for jointing products.

All figures in this standard showing detailed joint designs illustrate principles in a recognizable context and are not production drawings of proven and universally applicable joints.

2 Normative references

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

BS 5606, *Guide to accuracy in building*

[A1) *Text deleted* (A1]

[A1) BS 6100-6, *Building and civil engineering – Vocabulary Part 6 – Construction parts*

BS 6100-11, *Building and civil engineering – Vocabulary: Part 11 – Performance, characteristics measurement and joints* (A1]

BS 6213, *Selection of construction sealants – Guide*

BS 6750, *Specification for modular coordination in building*

BS 6954-3 (ISO 3443-3), *Tolerances for building – Part 3: Recommendations for selecting target size and predicting fit*

BS 8000-16, *Workmanship on building sites – Part 16: Code of practice for sealing joints in buildings using sealants*

[A1) *Text deleted* (A1]

BS 8210, *Guide to* [A1) *facilities* (A1] *maintenance management*

BS 8297, *Code of practice for design and installation of non-loadbearing precast concrete cladding*

BS 8449, *Building and construction sealants with movement accommodation factors greater than 25 % – Method of test for determination of adhesion/cohesion properties at variable temperatures*

[A1] BS EN 1996-1-2, *Eurocode 6: Design of masonry structures – Part 1-2: General rules –Structural fire design*

BS EN 1996-2, *Eurocode 6: Design of masonry structures – Part 2: Design considerations, selection of materials and execution of masonry* [/A1]

BS EN 13830, *Curtain walling – Product standard*

[A1] BS EN 15651-1, *Sealants for non structural use in joints in buildings and pedestrian walkways – Part 1 Sealants for facade elements*

BS EN 15651-2, *Sealants for non structural use in joints in buildings and pedestrian walkways – Part 2 Sealants for glazing*

BS EN 15651-3, *Sealants for non structural use in joints in buildings and pedestrian walkways – Part 3 Sealants for sanitary joints*

BS EN 15651-4, *Sealants for non structural use in joints in buildings and pedestrian walkways – Part 4 Sealants for pedestrian walkways* [/A1]

BS EN ISO 6284, *Construction drawings – Indication of limit deviations*

BS EN ISO 11600, *Building construction – Jointing products – Classification and requirements for sealants*

BS EN ISO 9047, *Building construction – Jointing products – Determination of adhesion/cohesion properties of sealants at variable temperatures*

ISO 2445, *Joints in building – Fundamental principles for design*

[A1] PD 6697, *Recommendations for the design of masonry structures to BS EN 1996-1-2 and BS EN 1996-2* [/A1]

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in [A1] BS 6100-6 and BS 6100-11 and the following apply. [/A1]

3.1 Joint design

3.1.1 induced deviation

dimensional deviation that occurs as a consequence of operations performed such as setting out, manufacture, assembly, erection, etc.

3.1.2 inherent deviation

dimensional deviation that occurs as a consequence of an inherent material property such as changes component dimension caused by changes in temperature, humidity, stress, bond breaker, etc.

3.1.3 interchangeability

ability of a component to be used and jointed satisfactorily with a variety of other components

3.1.4 joint (1)

construction formed by the adjacent parts of two or more products, components or assemblies when these are put together, fixed or united with or without the use of a jointing product

3.1.5 joint (2)

position in the construction works where the joint (**3.1.4**) is situated

3.1.6 joint clearance

distance between the joint faces of adjacent building components, i.e. the joint gap widths considered in order to achieve fit

3.1.7 joint gap

space between adjacent components, with or without a jointing product

3.1.8 joint geometry

disposition of all the parts that contribute to the functions of a joint

3.1.9 joint profile

form of that part of the cross-section of a joint derived from each of its components

3.1.10 joint reference plane

theoretical reference plane from which the relative position of the joint profiles of adjacent building components and/or associated jointing products may be determined

3.2 Materials for jointing

3.2.1 seal

physical barrier that is notionally impenetrable and is in contact with the components forming the joint

NOTE The term does not presuppose the use of any particular material or mechanism, but implies effectiveness in sealing against whatever agent is relevant, such as water, air, fire or sound.

3.2.2 sealant

material which, applied in an unformed state to a joint, seals it by adhering to appropriate surfaces within the joint

3.2.3 movement accommodation factor (MAF)

<of a sealant> maximum movement, the difference between the maximum and minimum joint widths, which a sealant is capable of tolerating throughout its working life, expressed as a percentage of the minimum joint width

3.2.4 elastic sealant

sealant that has been classified as type E according to BS EN ISO 11600

NOTE Elastic sealants are more suitable for joints where the movement that occurs is reversible.

3.2.5 plastic sealant

sealant that has been classified as type P according to BS EN ISO 11600

NOTE Plastic sealants are more suitable for joints where the movement that occurs is irreversible.

3.2.6 back-up material/backer rod

material inserted in a joint that limits the depth of sealant applied and defines the back profile of the sealant

3.2.7 bond breaker

film or thin strip material applied to the back of a joint to prevent sealant adhesion to the back of the joint

3.2.8 sealing strip

preformed material that constitutes a seal when compressed between appropriate joint surfaces, and that can have adhesive properties

3.2.9 gasket

flexible, generally elastic, preformed material that constitutes a seal when compressed

3.2.10 baffle

strip of flexible material inserted into a multi-stage joint to prevent the passage of rain

3.2.11 joint filler

compressible non-adhesive material used to fill and define movement joints during their construction that may also act as a back up material

4 Design of joints

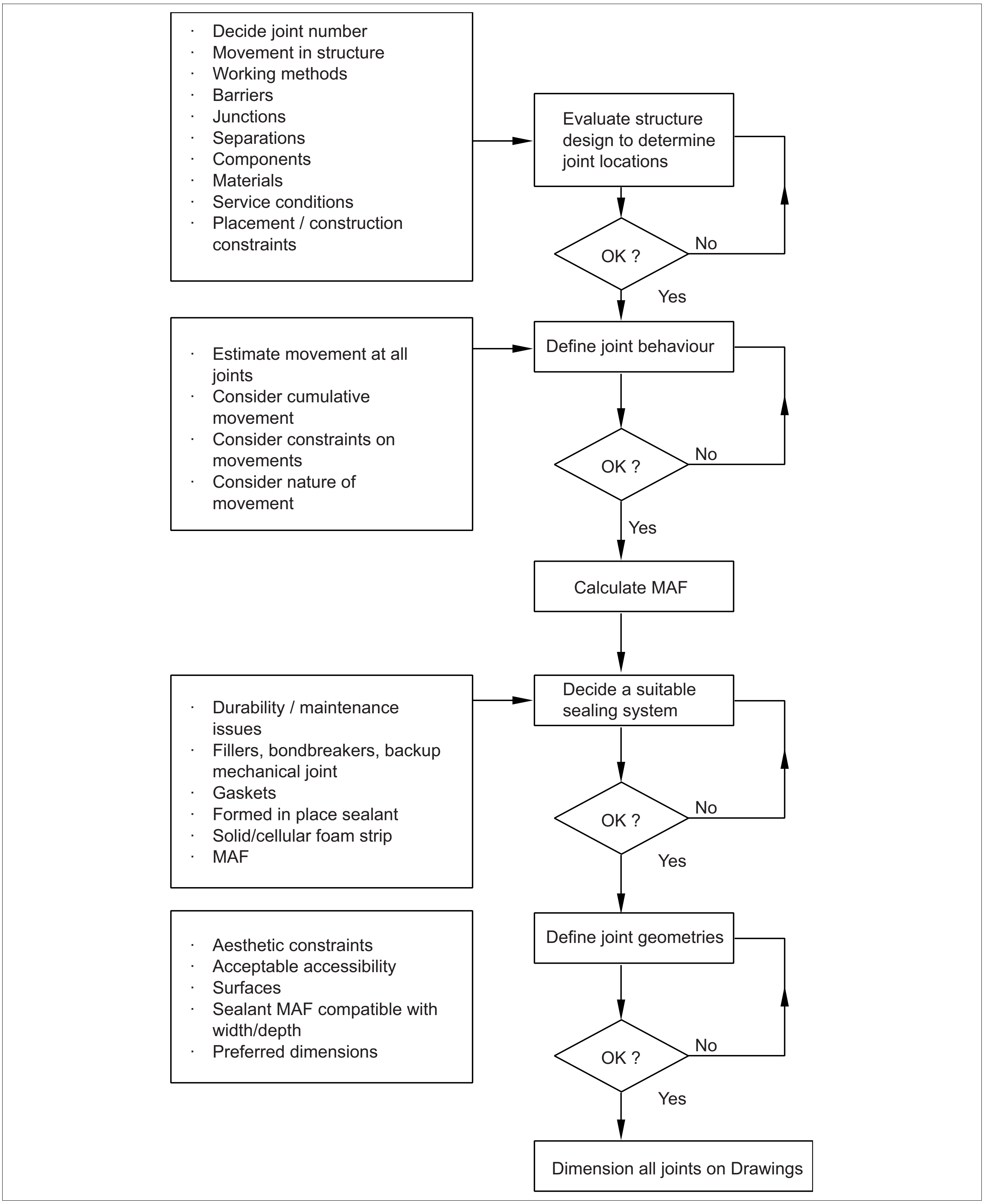
4.1 General

Since joints are breaks in the physical continuity of construction, they are potential breaks in the continuity of performance. It is therefore important that an entire assembly, including the joints, should achieve the desired performance.

4.2 The need for joints

Decisions should first be made with regard to the need for and the types of joints to be used as shown in Figure 1.

Figure 1 Joint design flow chart



From physical attributes inherent in materials and methods of work, the need for site joints arises at or on account of:

a) junctions of different elements or components and junctions comprising different materials;
b) change of conditions necessitating separation by a barrier;
c) limitations imposed by methods of working, e.g. the formation of day-work joints in *in situ* concrete construction;
d) limitations of size and/or weight of components imposed by their manufacture, handling, storage, transport and assembly;
e) limitations imposed in service by inherent properties of materials.

4.3 Location and frequency of joints

Once the need for joints is established, their location and frequency are determined from design decisions and are influenced by:

a) general planning decisions about storey height, relationships between solids and voids (e.g. walls and windows), room sizes, floor spans, etc.;
b) values chosen from the range of coordinating sizes;
c) the location of joints to take account of areas of high stress of components and elements in service;
d) the avoidance of complex joint intersections;
e) the facilitating of fit, e.g.:
    1) by increasing the number of joints;
    2) by avoiding components having to be fitted within preformed openings;
    3) by preforming internal and external corners;
f) the minimizing of the extent of jointing for reasons of e.g. hygiene, cost or performance;
g) the obtaining of a particular appearance of scale, proportion, pattern, symmetry or other attributes such as false joints.

4.4 Procedure for the design of a joint

NOTE See also Annex B.

The procedure for designing a joint should be as follows and is further illustrated in Figure 1.

a) Examine the types and positions of all the joints in the building.
b) Examine each joint at a large scale: full size or half full size.
c) Establish the joint reference plane for each joint and relate it to a building reference plane.
d) Check the joint functions (see **4.5**), and whether provision should be made for dimensional deviations (see **4.6**).
e) Modify the design of the joint to meet all the requirements at the positions where it occurs.

4.5 Sealed joint functions

NOTE The recommendations in this subclause are similar to those given in ISO 3447.

4.5.1 Environmental factors

When the general needs for joints have been considered, environmental factors should be quantified.

The data for joints are the same as those needed for the components. Some values emerge from user requirements. Other values derive from the natural environment.

Designers should also consider the immediate environment that could exist during construction. This can be more severe than the service conditions referred to previously.

Joints might need to be constructed so as to obstruct the passage of any or all of the following:

a) insects and vermin;

b) plants, leaves, roots, seeds and pollen;

c) dust and inorganic particles;

d) heat, light, sound, radiation;

e) air, gases and odours;

f) water, snow, ice and water vapour;

g) joints might need to avoid the generation of sound and odours.

4.5.2 Capacity to withstand movement induced stresses

4.5.2.1 Types of movement

The performance of any sealed joint will be affected not only by the magnitude of the movement but also by the mode, frequency and rate of movement.

Sealed joints might need to withstand stress (either during or after assembly) in one or more directions due to compression, tension, bending, shear, torsion, vibrations or any other type of stress that can induce fatigue, impact, abrasion, shrinkage, creep, and expansion or contraction due to temperature variations.

4.5.2.2 Mode

The principal modes of movement are:

a) *tension/compression*, typified by the common plain butt joint, where movement is at right angles to the line of the joint;

b) *shear*, typified by the lap joint, where the movement is parallel to the adhesion faces of the joint. Shear also occurs in butt joints where the joint, for example, is designed to accommodate settlement or other types of differential movement;

c) *combined movement*: sometimes a joint might move in tension/compression and in shear.

4.5.2.3 Movement in curved components

Usually movement at a joint is considered to be uniformly distributed along two straight components positioned parallel to each other to form the joint.

Where shaped or curved components form one or both joint boundaries, a careful study of the distribution and magnitude of movement should be made. Thermal expansion and contraction will cause changes in the length of curved surfaces which, if restrained at the edges, will result in bowing or deformation. Movement at the position of restraint will be small and will be at a maximum at the mid-point between the restraints.

Where dissimilar materials of differing coefficients of thermal expansion form the joint interface, the amount of movement occurring at the mid point can be magnified, necessitating wide joints or a reconsideration of the design to reduce the movement.

4.5.2.4 Movement frequency

This can range from a steady movement in one direction that occurs only once in the life of the structure, to more or less regular cyclical movement corresponding to diurnal and seasonal temperature and moisture changes. An example of the former is the irreversible shrinkage of concrete and an example of the latter is the daily thermal movement of lightweight cladding.

It should be noted, however, that because of friction and other constructional factors, cyclic movement can operate on a slip/stick basis. The effect of this might be more severe than a steady extension and compression, depending on the rate of joint movement and the characteristics of the sealant with respect to physical movement accommodation.

4.5.2.5 The rate of movement

Large movements occurring at high rates in joints can place severe strains on the seal. High rates of movement tend to be associated with lightweight forms of construction with efficient insulation immediately behind the external skin of the component. Such components often have a relatively high coefficient of expansion and low thermal inertia. Thus temperature changes are immediately reflected in dimensional changes in the components and, consequently, movement is rapid and under certain weather conditions continually alternating. The use of dark surfaces on such components exacerbates the situation because of the higher temperatures attained and the rapid heat gain or loss that occurs.

4.5.3 *Safety*

NOTE See also ***8.5***.

The functions of sealed joints in the context of safety are:

a) to obstruct the passage of fire, smoke, gases, radiation and radioactive materials;

b) to resist sudden positive or negative pressures due to explosion or atmospheric factors;

c) to avoid the generation of toxic gases and fumes in case of fire;

d) to avoid harbouring or proliferation of dangerous micro-organisms.

4.5.4 Appearance

Sealed joints should have an acceptable appearance. The effects of weathering of the appearance (colour) of the jointing material itself should be borne in mind during its selection.

Sealed joints should also avoid:

a) promotion of mould and plant growth;
b) discoloration due to UV radiation and biological, physical or chemical action;
c) all or part of the internal structure showing;
d) dust collection.

4.5.5 Durability

NOTE See also **8.6**.

If a sealed joint is likely to be less durable than the components joined, then the maintenance and ease of repair should be considered. In considering durability and the minimum life of such a joint, designers should aim to reduce its exposure, minimize damage to the fabric and, should the joint fail, provide access for repair or replacement, and establish the expected frequency of replacement.

Sealed joints might be required to resist abrasive action and damage or unauthorized dismantling. They might also be required to resist the action of animals and insects, plants and micro-organisms, water and water vapour and aqueous solutions or suspensions, polluted air, light and radiation, freezing of water, extremes of temperatures, airborne or structure borne vibrations, shock waves and high intensity sound, and acids, alkalis, oils, fats and solvents.

4.5.6 *Maintenance*

NOTE See also **8.6**.

The design of joints should allow for inspection, partial or complete dismantling and reassembly, and the replacement of decayed jointing products, during maintenance.

4.5.7 Ambient conditions

Joints and jointing products should be able to perform the required functions over a specified range of temperature, atmospheric humidity, air or liquid pressure differential, joint clearance variation and driving rain volume.

4.6 Variation in the sizes of joints

4.6.1 The consequences of variation in joint width

The accommodation of movement after assembly (inherent deviations) and the variability in size and placement of jointed parts (induced deviations) should be taken into account as these are crucial factors in the performance of seals. Variations in joint width should allow for performance limitations of jointing products and can be limited by tolerances of assembly.

Variations in joint width become even more critical at junctions; stresses can become more concentrated in sealant joints and gaskets might lose their effectiveness. Manufacturing tolerances impacting the geometry and deformation of components affect joint profile which, in turn, affects joint gap sizes.

Data concerning inherent and induced deviations in components and openings should be used where needed to determine the effects of these deviations on joint dimensions and to aid selection of appropriate joint mechanism and materials.

The data needed are as follows:

a) the predicted variability in the size and position of components and openings normally achievable in construction given in BS 5606 (or, when not given therein, the normally achievable deviations estimated by the building designer);

b) the predicted changes in sizes of components and openings in services due to thermal, moisture, creep and load deformation;

c) the number of joints in the assembly involved/required to accommodate the deviations predicted in a) and b).

NOTE Guidance on calculations to predict target size, clearances and fit are given in BS 5606 and BS 6954-3.

When building components are located in relation to a continuous reference system such as a modular grid so that the structure is subjected to overall dimensional control, deviations of size, shape and position have to be absorbed within the jointing system.

The consideration of tolerances for the manufacture of components and for the construction of buildings is therefore inseparable from the design of joints to provide the required dimensional flexibility (see ISO 2445). This does not mean that all joints should necessarily have this capability, but it is necessary for deviations to be accommodated at some point; this may be achieved at the joints between individual components, or by the provision of special joints at intervals.

4.6.2 Inherent deviations

4.6.2.1 *Reversible inherent deviations.* Reversible inherent deviations are due to cyclic environmental factors such as thermal and moisture variations and vibration.

The greatest range of temperature is usually experienced on the external face of buildings and especially on south facing elevations, but resulting dimensional changes might tend to be balanced by opposite movements due to changes in moisture content. Internally, both thermal and moisture movements can be less significant depending on the environment within the building.

Whereas the annual air temperature range in the United Kingdom is about 35 K (–5 °C to 30 °C), the actual temperature range to which materials are subjected due to radiant heat is greater and depends on the orientation of, and the incidence of radiation on, the surface, as well as on the colour and degree of protection (insulation or shading). Surface temperatures can, in extreme circumstances, be as high as 80 °C and as low as –20 °C.

Movement per unit length can be influenced by:

a) temperature range;

b) degree of exposure;

c) response of materials to thermal change;

d) colour of surfaces;

e) restraint of movement.

NOTE Information concerning the calculation of thermal movement per unit length is given in BRE Digests 227, 228 and 229 [1].

The capability of joints to accommodate movement determines the maximum interval between them, taking account of the way in which fixings may permit or distribute movement.

While it may be sufficient for a designer to make allowance for movement for in-service conditions on the basis of thermal movement only (see Annex A for list of coefficients), the validity of this assumption should always be confirmed. Examples of exceptions are sandstone and timber (across grain), where movement due to moisture might exceed that due to thermal change (see Annex A). Movement due to moisture along the grain of timber is not significant.

Some materials respond to changes in moisture content following changes in weather conditions, and appropriate allowance has to be made taking into account the environment at the time of construction. Examples of such materials are concrete blockwork and timber.

Care should be taken about the moisture content of absorbent materials in storage and during the course of construction, in order to minimize subsequent movement.

In such environments as are found in swimming pools and certain industrial processes where high humidity occurs, the behaviour of moisture-sensitive materials should be given special consideration.

4.6.2.2 Irreversible inherent deviations

Irreversible inherent deviations are due to non-cyclic factors. They occur over predictable short or long-term periods depending on the nature of the material.

In addition to reversible movement, concrete is subject to irreversible drying shrinkage and thermal contraction.

Plastic shrinkage can occur during the first few hours after placing through the loss of water from the plastic concrete by evaporation or, sometimes, by absorption into adjacent materials. Plastic shrinkage is common in hot weather and in drying winds and can result in cracking. It can largely be avoided by slowing down the drying of the concrete. Early thermal contraction can be significant in concrete over about 0.5 m thickness. It is due to the natural cooling that takes place when the heat of hydration passes its peak. The temperature rise can typically be about 20 K, two days after placing. The designer should be aware of the effect of early thermal contraction and, where appropriate, should provide joints or planes of weakness to confine cracking to predetermined positions.

Drying shrinkage is a long-term process and can continue over many months. Any movement is influenced by the size of section, the concrete mix, the amount of reinforcement and the environment. Allowance should be made for the effects of drying shrinkage when detailing concrete blockwork. Calcium silicate bricks need to be protected against excessive moisture up to and during construction. Provision should be made for the free circulation of air within the stack so that the bricks may dry out before they are built in.

Fired clay units exhibit reversible movements due to changes in moisture content. These are usually small but there is a permanent moisture expansion, the rate of which decreases with time and is dependent upon the type of clay and firing process.

For various masonry materials, information on moisture movement and thermal properties is given in [A1⟩ BS EN 1996-1-2. Guidance on the determination of spacing and design width of movement joints is given in PD 6997 and BS EN 1996-2. ⟨A1]

The effect of creep might need to be taken into account in joint sizes. Continuous loading of concrete structural frames will cause beams and slabs to continue to deflect beyond their initial elastic deflection and columns and concrete walls to shorten over a long period of time. After the first year, movements due to creep are very small but recognition should be given and allowance made in the joints between the frame and components fitted to it.

4.6.3 Induced deviations

An individual component normally deviates both from its intended size and from its intended position in the building. Both kinds of deviation occur three-dimensionally. When two components are placed with a joint clearance between them, these deviations affect the size and shape of the joint three-dimensionally. Designers have to design for the generality of such deviations, but a particular assembly when constructed contains deviations with particular values. If systematic account is taken of deviations, the majority of joints can be expected to lie within the desired joint clearance limits.

If the size of a joint is likely to exceed the specified limits, consideration should first be given to the possibility of adjusting the position of the components in the assembly so as to distribute excess deviation among the joints in the assembly and optimize the joint clearances. Particular types of deviation in joint size might still need special action, e.g. the tapering of joint clearances, bow and twist of components and inaccuracy in component alignment.

When it is not practical to rectify joints that have sizes outside the specified limits, an alternative joint design should be adopted.

4.6.4 Provision for dimensional deviations

4.6.4.1 General

The initial generation of solutions may be based upon four assumptions that can be made about the distribution of induced and inherent deviations (see Clause **3**). These are as follows.

a) *Type 1 joint.* No allowance made for any deviations.

b) *Type 2 joint.* Allowance made for inherent and induced deviations.

c) *Type 3 joint.* Allowance made for inherent deviations only.

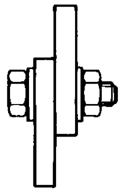
d) *Type 4 joint.* Allowance made for induced deviations only.

Examples of joints for which each assumption is usually made are given in Figure 2 to Figure 5. Having made a provisional assumption about the design of the joint, the designer should then consider:

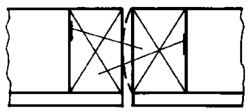
1) the significance and values of dimensional deviations to be accommodated;

2) the consequences of this assumption for joints elsewhere in that assembly.

Figure 2 **Examples of type 1 joints**



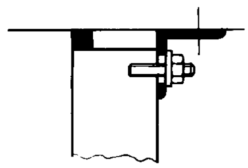
a) Section. Plain bolted joint. Holes sized for bolt clearance only.



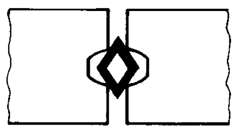
b) Plan. Junction of timer panels skew nailed together, These will abut at "high spots"

(no allowance made for any deviations)

Figure 3 **Examples of type 2 joints**



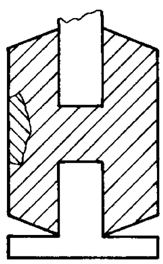
a) Section. Joint at head of partition panel with restraining cleat designed to allow movement. Prefixing of cleat to soffit is a type 1 point.



b) Plan. Joint between panels with gasket.

(allowance made for inherent and induced deviations)

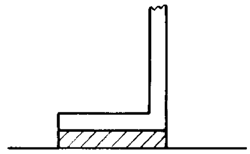
Figure 4 **Examples of type 3 joints**



a) "Zipper" structural gasket in rubber/plastic

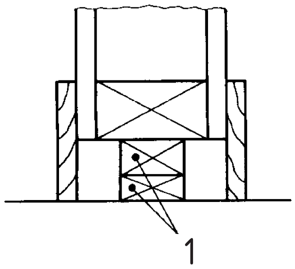
(continued)

Figure 4 **Examples of type 3 joints** *(continued)*

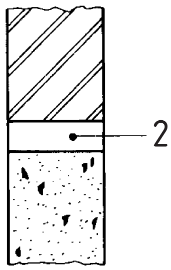


b) Component on resilient packing (anti-vibration)
(allowance made for inherent deviations only)

Figure 5 **Examples of type 4 joints**



a) Base of partitioning component with folding wedge



b) Horizontal mortar joint packings

Key

1 Folding wedges
2 Mortar

(allowance made for induced deviations only)

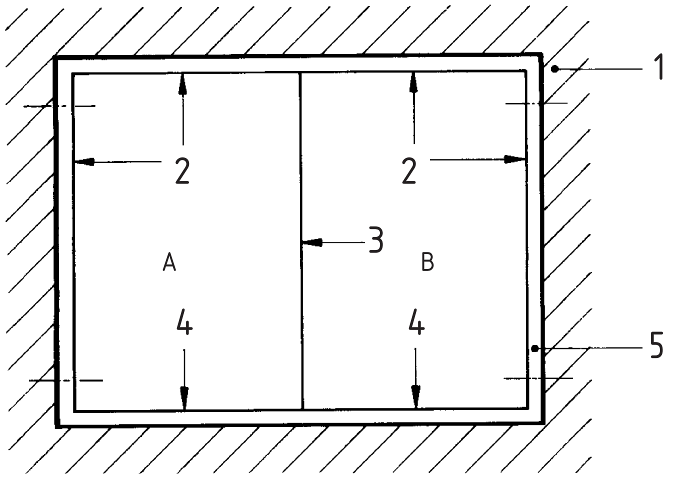
4.6.4.2 Interaction of the four joint types

An assembly usually contains more than one of the four joint types. The designer should assess the distribution of induced and inherent deviations throughout the assembly in order to choose the appropriate combination of joint types.

Figure 6 illustrates the interrelationship and effects of an assembly of two panels of walling erected in an existing opening.

Fixings can modify the distribution of inherent deviations in the assembly and this needs separate consideration. For example, central fixings cause inherent deviations to be shared between the end joints: fixings at one end concentrate all inherent deviations at the other end.

Figure 6 **Elevation showing assembly of panels and joint types in an opening**



Key

1 Surround to opening

2 Type 2

3 Type 1

4 Type 4

5 Joint gap

4.7 Dimensioning joints on drawings

It is not unusual for joint clearances to be shown on drawings as finite dimensions. This is a matter of convenience that enables component sizes and joint clearances to be added up to give a correct overall size. However, joint clearances shown in this way can lead to the expectation that they are of fixed size when, in reality, they are of variable size and have to be so in order to fulfill their function of accommodating dimensional deviations. Limit deviations should be presented in accordance with BS EN ISO 6284.

This is illustrated in Figure B.1 as “8 ± 2 mm”. If this is felt to be unduly laborious, the permitted deviations may be shown in the drawing notes. Indicating joint clearances in this way makes readily available the criteria for checking compliance on site and confirming that the joint can be expected to be able to accommodate future dimensional deviations in the way intended by the designer.

5 Jointing materials

5.1 Joint sealing materials

Sealing to prevent air and water penetration is achieved using sealants, sealing strips, gaskets and baffles.

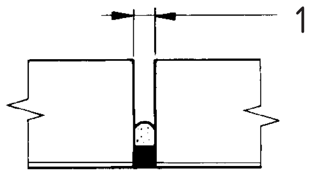
Guidance on the selection, applications and use of sealants is given in BS 6213. More information is available on sealants than on gaskets which are normally purpose-made (for which only general guidance can be given). In all cases, the details of the properties and performance of seals should be obtained from the manufacturers.

There are at least two critical features of seal performance that have to be considered, firstly the interfaces between the seal and the components to be joined and secondly the nature of the sealing material itself.

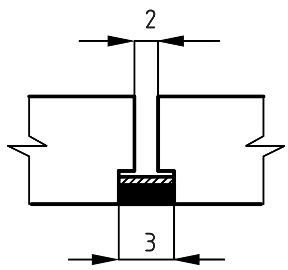
Obtaining good adhesion is essential to sealant performance. Adhesion can be compromised by contamination of the substrate surfaces, such as mould release agents on concrete and waxes and polishes on metal. See BS 6213 for more detail.

In service, jointing products have to maintain contact with the joint. Satisfactory performance depends upon the design of the joint, selection of appropriate jointing products and upon workmanship during installation. Joints will often require a degree of maintenance during the life of a building. As part of the maintenance procedure, jointing products might need to be replaced. Satisfactory durability will depend on the joint design, jointing materials, quality of installation and the specific service environment. Profiling to optimize appearance, application and durability is illustrated in Figure 7.

Figure 7 **Profiling to optimize appearance, application and durability**



a) Gun-applied sealant



b) Gun-applied sealant

Key

1 5 mm is the minimum practical size for gun application. Accessibility for inspection and preparation is restricted.

2 Minimum width taking into account of inherent and induced deviations

3 Accessibility is better than a)

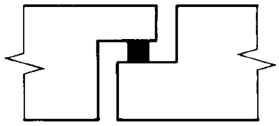
Sealant

Back-up/bond breaker material

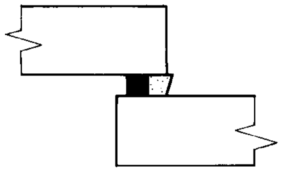
Bond breaker tape – thickness exaggerated for visibility

(continued)

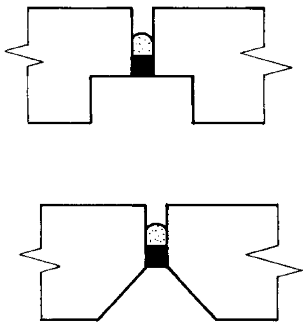
Figure 7 **Profiling to optimize appearance, application and durability** *(continued)*



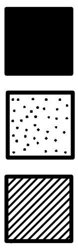
c) Sealant (or gasket) difficult to inspect and inaccessible for maintenance



d) Sealant accessible for maintenance



e) and f) When sealants are recessed from the face, access needs to be adequate. It is recommended that the width of the recess be not less than twice its depth.



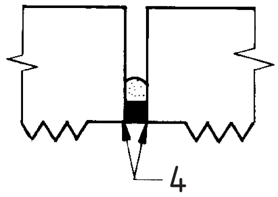
Sealant

Back-up/bond breaker material

Bond breaker tape – thickness exaggerated for visibility

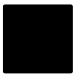
(continued)

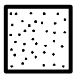
Figure 7 **Profiling to optimize appearance, application and durability** *(continued)*

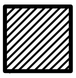


g) Arrangement for tooling

4 Edges of component against which sealant is tooled need to be plane and smooth.

 Sealant

 Back-up/bond breaker material

 Bond breaker tape – thickness exaggerated for visibility

The effectiveness of the seal is dependent on adhesion in the case of sealants, and on compression in the case of gaskets. Some gaskets may possess adhesive properties on one or more faces to overcome surface imperfections or as an aid in assembly.

Some general comparative data are given in Annex A.

The performance of the seal in a lap joint is improved because of the lower stresses to which it is subjected for a given amount of joint movement and because it is less exposed to weather than in a butt joint. However, in many lap joints, seals are inaccessible for maintenance and replacement.

Gasket seals might need a profile to locate their position in the joint, as in Figure 9. The need for location might be to aid correct positioning in assembly or to secure the seal in position on one component (as for seals to opening components).

Gaskets depend for effectiveness on the pressure they exert on the substrate and this will depend in turn on the variability of the joint gap width. Size, shape and cross section need to be considered carefully. Gaskets impose greater demands on dimensional accuracy in the manufacture and assembly of building components than do sealants. (See **5.3**.)

Baffles depend on the existence of an effective air barrier at the back of the joint in order to perform effectively. The air pressure in baffled joint is equalized with that of the atmosphere. The lack of an air pressure differential across the joint inhibits the movement of moisture across the joint. Water that enters the joint due its kinetic energy is intercepted by the baffle. Intercepted water runs down the baffle and is drained to the outside.

5.2 Sealant jointing systems

5.2.1 General

BS EN ISO 11600 provides a systematic performance classification scheme for sealants that are used in building and construction applications.

This standard classifies sealants as elastic or plastic, type E and type P respectively and uses elastic recovery from maintained extension as the basis for this classification.

BS 6213 covers sealant selection.

BS 8000-16 gives recommendations for basic workmanship on building sites.

[A1) BS EN 15651-1 provides a systematic performance classification scheme for facade sealants.

BS EN 15651-2 provides a systematic performance classification scheme for glazing sealants.

BS EN 15651-3 provides a systematic performance classification scheme for sanitary sealants.

BS EN 15651-4 provides a systematic performance classification scheme for pedestrian walkway sealants. (A1]

5.2.2 Movement accommodation factor (MAF)

The MAF indicates the full range of movement between the minimum and maximum joint width that the sealant can accommodate. It is expressed as a percentage of the minimum joint width in this code.

NOTE 1 MAF is sometimes expressed as a percentage about the mean joint gap width ± N %. This mode of expression is deprecated.

The movement accommodation factors corresponding to BS EN ISO 11600 movement classes are 7.5 %, 12.5 % and 20 % or 25 %.

NOTE 2 MAF values of greater than 25 % are outside the scope of BS EN ISO 11600. See BS 6213 and BS 8449 for further information.

The method of calculation of minimum design joint gap width for a particular sealant using its MAF is given in **5.2.5**. Irrespective of movement accommodation, a joint gap width of 6 mm is the minimum that is practical for the application of sealants.

5.2.3 Back-up material, bond breaker and joint fillers

5.2.3.1 Backup materials and bond breakers

Back up materials and bond breakers are very important components in the design and application of sealant joints.

The correct installation of the back-up material, or bond breaker and joint filler enables the specified sealant joint design to be achieved (see **5.2.8**).

These components:

— control the sealant joint design, giving the correct joint width to depth ratio;

— provide a firm surface for the sealant to be tooled against, forcing the sealant against the bonding substrates and assisting adhesion development;

— prevent wastage of sealant;

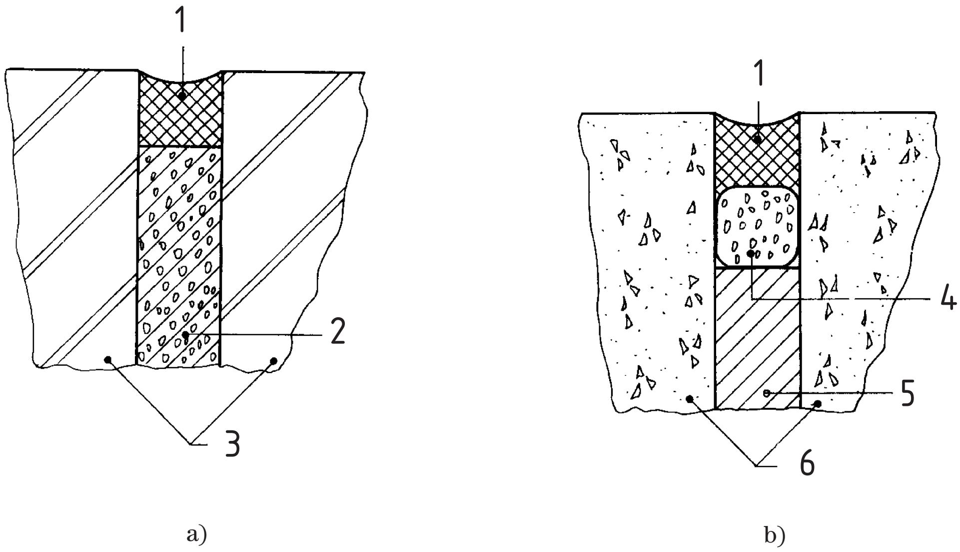
— prevent three sided adhesion of the sealant.

Sealant should be applied against a backup material that will provide sufficient resistance so that it is forced against the sides of the joint substrates during application and tooling. This will ensure good wetting contact of the sealant with the substrates, which will optimize sealant adhesion.

Sealants used in movement joints shall not adhere to the backup material and thus three sided adhesion can be avoided. If three sided adhesion does occur stresses within the sealant will be increased and premature failure will occur.

The sealant backup can be manufactured from a range of materials and supplied in a variety of shapes and sizes. No matter what back-up, bond breaker or filler is used it shall have tested for sealant compatibility. Combinations of these components may be used to give the required sealant depth and support as shown in Figure 8.

Figure 8 **Use of backup materials and bond breakers to movement joints**

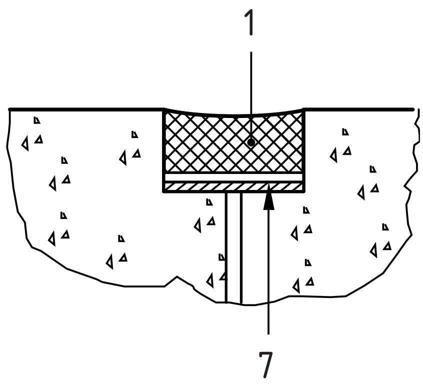


Key

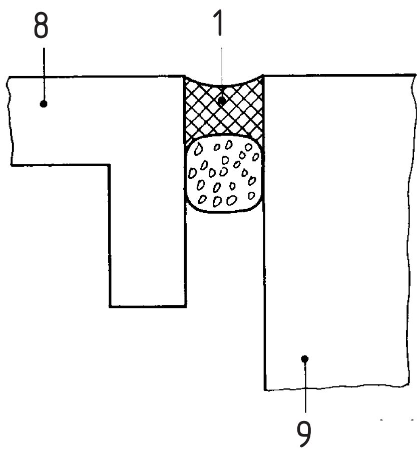
1 Sealant
2 Closed cell foam back-up material serving as a bond breaker (also serves as a joint filler)
3 Brickwork
4 Closed cell foam back-up material (also serves as a bond breaker)
5 Joint filler
6 *In situ* concrete
7 Bond breaker tape
8 Cladding infill panel, etc.
9 Column or steel frame or mullion, etc.

(continued)

Figure 8 **Use of backup materials and bond breakers to movement joints** *(continued)*



c)



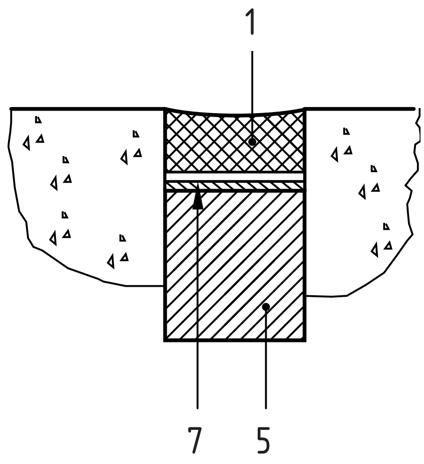
d)

Key

1 Sealant
2 Closed cell foam back-up material serving as a bond breaker (also serves as a joint filler)
3 Brickwork
4 Closed cell foam back-up material (also serves as a bond breaker)
5 Joint filler
6 *In situ* concrete
7 Bond breaker tape
8 Cladding infill panel, etc.
9 Column or steel frame or mullion, etc.

(continued)

Figure 8 **Use of backup materials and bond breakers to movement joints** *(continued)*



e)

Key

1 Sealant
2 Closed cell foam back-up material serving as a bond breaker (also serves as a joint filler)
3 Brickwork
4 Closed cell foam back-up material (also serves as a bond breaker)
5 Joint filler
6 *In situ* concrete
7 Bond breaker tape
8 Cladding infill panel, etc.
9 Column or steel frame or mullion, etc.

In open joints, the use of oversized (25 %) circular or rectangular closed cell foam should be installed to give the required sealant joint detail. Closed cell foam products need to be installed without the occurrence of physical damage. If a closed cell backer rod is damaged, the joint should be left for at least 20 min before the sealant is applied. If this procedure is not followed bubbles of gas from the damaged rod will be trapped in the sealant. This can lead to blistering of the sealant bead and thus to reduced performance. Where there is a possibility that the sealant will adhere to the joint filler a bond breaker tape shall be used, Figure 8e).

Where the sealant requires maximum support from external forces, e.g. in floors or retaining walls subject to subsoil water pressure a thin, low tack bond breaker tape might be required to prevent adhesion of the sealant to the joint filler. If bitumen or fluid impregnated joint filler is used, low tack tape or foam backer rod might not prevent the migration of low molecular weight materials to the sealant. This can cause discoloration and/or reduction in physical properties. In extreme cases, adhesion of the sealant to the substrate will be lost or the sealant may not cure. Soft, compressible back-up materials should not be used where maximum sealant support is required.

Advice on the suitability of materials used to make the joint for harsh or sensitive applications should be from the appropriate materials supplier.

5.2.4 Conditions of temperature and moisture content of components

5.2.4.1 At time of erection of components

Between erecting components and sealing the joints, gap widths might have changed. because of altered conditions of temperature and moisture content. If components are erected with minimum specified joint gap widths, the jointing materials will not be overstressed if the principles of **5.2.5** are followed. If these principles are adhered to, the joints should perform satisfactorily through a correctly designed and specified range of movement.

5.2.4.2 At time of application of sealant

Both temperature and moisture can affect the joint gap width of the joint. The best time for application of sealants to movement joints is when the joint gap width is at the mean tending to the maximum. With elastic sealants, this reduces the tensile strain. Temperature extremes are detrimental to the satisfactory application and performance of sealants. High temperatures will reduce sealant viscosity and can result in slump or flow especially in wide joints. The working life might also be unacceptably reduced.

Low temperatures conversely can increase viscosity, giving rise to mixing (in the case of two part sealants) and application difficulties and reduction in wetting of component interfaces. Sealant cure will be reduced or even arrested at low temperature.

A high moisture content of components is detrimental to adhesion of sealants. Sealing should not be undertaken if free moisture is present on the joint faces.

5.2.5 Minimum joint gap widths for sealants

The specification of joint gap widths should be derived from all deviations to which the joint is subjected. However, minimum joint gap widths are needed for the satisfactory performance of elastic and plastic sealants in butt joints and these can be calculated if the following data are known:

a) the movement accommodation factor (MAF) of the sealant as a percentage of the minimum joint gap width taken from the material specification or manufacturer's literature;

b) the total relevant movement (TRM) of components at the joint estimated using BRE Digests 227, 228 and 229 [1].

The calculation is concerned with the ability of the sealant to accommodate the range of tensile strain that will be imposed upon it. For the purpose of calculation, the total relevant movement (TRM) excludes those irreversible (inherent) movements (see **4.6.2.2**) which "close-up" the joint. Allowances for these are made separately as are the effects of induced deviations.

Joint gap widths between the time of erection of components and the time of sealing these joints might have changed because of the changes in conditions giving rise to movement. It is important to ensure that a joint gap no smaller than the calculated minimum will be achieved irrespective of conditions at the time when the joint gap width was formed. The following formula should be used to calculate the joint gap width (*W*) for a joint with a known TRM and a sealant of known MAF.

$$W = \frac{100 \times \text{TRM}}{\text{MAF}} + \text{TRM}$$

For example, if a sealant has to accommodate a total relevant movement (TRM) of three millimetres and it has an MAF of 25, then

$$W = (100 \times 3/25) + 3 = 15$$

If, after assessment of all other deviations, *W* determines the minimum joint gap width to be specified, this width erected, at the specified minimum of 15 mm (following the example) in cold conditions, can subsequently close to 12 mm and still lie within the sealant MAF limit of 25 %.

5.2.6 Relationship of sealant choice to rate and frequency of movement

The relationship between the choice of sealant and the different types of movement is not one that permits simple recommendations, because there are usually many factors to consider. In general, however, joints subject to frequent and rapid movement need an elastic sealant while joints in massive components with high thermal inertia resulting in much slower movement, may be satisfactorily sealed with a plastic sealant. For guidance on types of sealants, see BS 6213.

5.2.7 Relationship of stress in sealants to seal shape

The stresses induced in a sealant in a joint subject to movement are more critical (for the same amount of movement) in a plain butt joint than in a lap joint. The latter can accept up to twice as much movement as a butt joint using the same compound and joint dimensions.

The joint seal shape is of less importance with plastic sealants at low rates of movement, but it is particularly important for elastic, and to a lesser extent elastoplastic, sealants where these are used in joints subject to significant movement. Elastic and elastoplastic sealants have a degree of tensile strength when fully cured, so extension of the sealant induces stress in the material that is approximately proportional to the amount of movement.

If the seal is considered as a piece of elastic material bonded at its ends to rigid components capable of moving away from and towards each other, it is apparent that the force necessary to extend or compress the elastic material is directly related to its thickness. It has been established that for elastic sealants optimum performance is obtained at ratios of about 2:1 width to depth and that the ratio should generally not be less than 1:1, subject to a minimum depth of 5 mm.

The other major factor in seal shape is the relationship of width to total movement already discussed in **5.2.5**. The aim of good sealed joint design is to produce a joint seal cross section with as low internal stresses as is consistent with a satisfactory area of adhesion and with sufficient depth to fulfill other joint functions such as resistance to pressure or abrasion.

5.2.8 Types and causes of failure of sealants

The different ways in which sealants can fail and the causes of these failures are described in BS 6213.

5.3 Gasket joints

5.3.1 General

The primary purpose of a gasket is to act as a barrier to wind and rain and, to function properly, it is essential that it remains under compression at all times.

5.3.2 Materials

Natural rubber compounds have to be protected from the weather by a synthetic rubber skin. If special properties, such as resistance to oils, are desired, synthetic rubber and plastics materials should be specifically formulated for the intended use. A range of types is given in Table A.1. Gaskets can be solid or hollow sections of various profiles formed from cellular or non-cellular material or combinations of these materials or sections.

Variations in mechanical properties of non-cellular sections can be obtained by compounding. The mechanical properties of cellular gaskets are dependent on density, material hardness, cell size and whether or not cells are interconnecting. In general, cellular gaskets have a shorter service life than non-cellular materials due to UV degradation unless they are protected by an outer skin of non-cellular material (other than the thin skin usually resulting from the process of moulding or extrusion).

Sheets of cellular material with or without adhesive and backing paper are available and can be cut to provide simple relatively inexpensive gaskets.

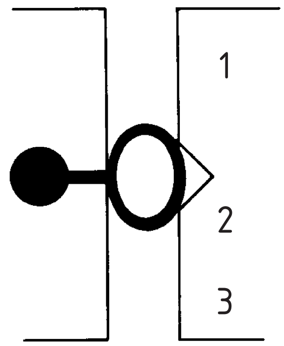
Some open cell materials are available impregnated with waxes or bituminous compounds, and may also be coated with adhesive (see **5.4**).

5.3.3 Design with gaskets

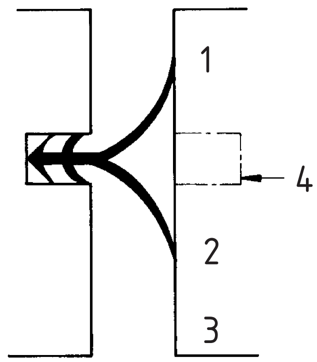
5.3.3.1 Except perhaps for the simplest gaskets, it is advisable to consult manufacturers at an early stage in joint design as the choice of components and their edge profiles, the method and sequence of erection and the gasket design interact. In designing joints to be sealed with gaskets, the recommendations of **5.3.3.2** to **5.3.3.9** should be considered.

5.3.3.2 Gasket joints should, if possible, be designed with primary and secondary seals having an air space between them (see Figure 9).

Figure 9 **Typical examples of gaskets in joints**



a) Gasket fixed into component during manufacture



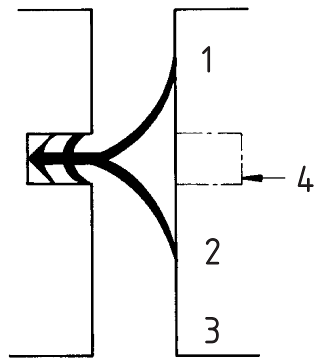
b) Gasket fitted during erection of panels

Key

1 Secondary
2 Primary
3 Outside
4 Groove if required to keep same edge profile
5 Recess not only locates the gasket but allows a larger gasket thereby increasing movement range
6 Depth of groove always greater than gasket under maximum expected compression

(continued)

Figure 9 **Typical examples of gaskets in joints** *(continued)*



c) Gasket fitted after erection of panels

Key

1 Secondary

2 Primary

3 Outside

4 Groove if required to keep same edge profile

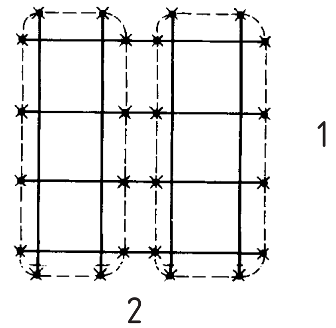
5 Recess not only locates the gasket but allows a larger gasket thereby increasing movement range

6 Depth of groove always greater than gasket under maximum expected compression

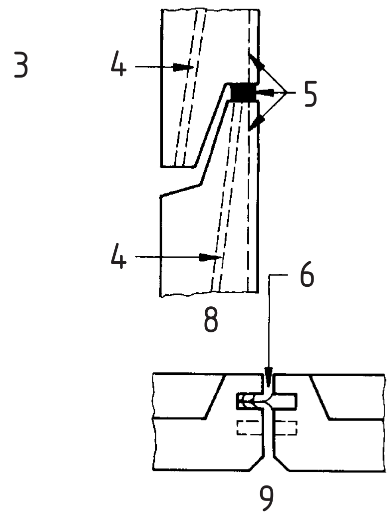
5.3.3.3 For gaskets to provide satisfactory joints, it is essential that components be manufactured and assembled within acceptable dimensional limits. Gasket joints should not be used as the only barrier against wind and rain, especially where the accuracy desired of materials, construction and workmanship is unlikely to be achieved.

5.3.3.4 For gaskets to be effective, continuity should be provided over horizontal and vertical junctions. Complex junctions are best produced as frames with factory-made joints, so that site jointing is limited to simple junctions (see Figure 10).

Figure 10 **Gasket junctions**



a) Continuous grid or ladder gasket



b) Non-Continuous grid or ladder gasket

Key

1 Sections within dotted lines fabricated in the factory. Joints marked X can be vulcanized on site
2 Elevation
3 Outside
4 Gasket
5 Air seal
6 Gaskets overlapped but contained in joint profile for whole length
7 Gasket could be as shown in Figure 9b) but could be a) and c) with a suitable joint profile
8 Section
9 Plan

5.3.3.5 Butt contact joints between gaskets are a source of weakness and simple lengths of gasket section are best used only where good protection or effective overlaps can be provided at junctions. Where continuity cannot be achieved, especially at junctions in vertical joints, it is essential that joint detailing allow for effective drainage, weather protection and gasket overlaps.

5.3.3.6 On assembly, the force needed to compress a length of gasket in a joint can be considerable and might not be achievable in practice when installed in the sequence component/gasket/component. Gaskets in position exert force and designers should consider this, particularly with lightweight construction.

5.3.3.7 For movement joints, gaskets should be stressed sufficiently to maintain compression over the movement range, yet not be so highly stressed as to incur significant compression set. For example, a cellular neoprene gasket should not be compressed in service by more than 50 % of its uncompressed thickness.

5.3.3.8 The durability of gasket materials should be considered at the design stage. In movement joints, gasket life might possibly not attain building life. Lives of over 50 years for neoprene are quoted but the circumstances of use, qualities of materials, etc. determine the actual life obtained and it is realistic to assume that these seals might need major attention or replacement at least once in the life of the building.

5.3.3.9 In movement joints, gaskets seals can be fully effective from the moment of completion of installation.

5.3.4 Installation of gaskets

To avoid deformation or damage, care is needed in handling gaskets. Preparation of surfaces is less critical than for sealants, but general cleanliness and firm surfaces free from gross imperfections are essential. Where gaskets are inserted into a joint, lubricants recommended by the manufacturer may be used on the gasket to ease fitting. Gaskets should not be stretched during installation but, if this is unavoidable, they should be given sufficient time to recover before trimming.

5.4 Sealing strips

5.4.1 General

Sealing strips are preformed to a range of sizes and sections and are of two basic types as follows:

a) mastic strips;

b) impregnated or coated cellular strips.

5.4.2 Mastic strips

Mastic strips are normally installed during the assembly of components and require an initial compressive force to ensure proper adhesion to the components forming the joint. A degree of compression should be maintained in service and mastic strips are therefore unsuitable for joints that open beyond their assembled size.

5.4.3 Impregnated or coated cellular strips

Impregnated or coated cellular strips may be supplied in a precompressed form to facilitate installation, with or without one face adhesive coated. They can be installed within the joint gaps and should be of a suitable size to be maintained under a degree of compression specified by the manufacturer, throughout the range of joint movements. The degree of compression may be varied according to the level of sealing performance required.

It is important that the joint faces are parallel to ensure uniformity of compression and seal stability. Seal stability is also dependent upon the depth to width ratio of the installed seal. An initial ratio of 2:1 should be achieved at installation and should not exceed 1:1 in service. To accommodate these depth to width ratios, care should be taken to ensure that sufficient joint depth is provided to accept the seal.

Sealing strips for external applications should have adequate exposure resistance, and should be appropriate for the proposed service exposure conditions.

5.5 Joint fillers

5.5.1 General

Fillers for movement joints should have certain properties in order to fulfil their intended functions. The sealant manufacturer should be consulted to ensure that the sealant and filler are compatible.

A list of commonly used joint fillers and their properties are shown in Table 1.

5.5.2 Functions

The functions of joint fillers should:

a) assist in the formation of a joint;

b) provide a barrier to dirt or debris during construction, which could subsequently prevent joint closure;

c) also assist in the control of the joint dimension;

d) provide support to the sealant.

5.5.3 Properties

The properties of joint fillers should be as follows:

a) they should be compressible;

b) they should not be extruded from the joint;

c) they should have resilience;

d) they should be non-staining;

e) they should have resistance to damage in handling.

Many materials used as joint fillers can be considered to present a fire hazard. In practice, however, the filler is usually enclosed in a confined space within the joint, so access to fire and oxygen is limited. Improved fire resistance, if needed, can be obtained by the use of mineral or some synthetic fibre materials.

Synthetic polymer foams may be used as joint fillers in special situations where their low compressive loading does not cause undesirable load transfer across a movement joint.

One such application is in the provision of movement joints in fired clay brickwork, where moisture induced expansion occurs reducing the width of the joint in service. Such a width reduction could, with the incorrect choice of filler, lead to unacceptable compressive loads being developed across the joint in the brickwork. See **7.1**.

However, expanded polystyrene is not a suitable material as a joint filler. It has a very limited compatibility with sealants and primers, poor solvent resistance, inadequate service temperature range and very little resilience.

5.6 Baffles

Baffles are fitted loosely in multi-stage joints of cladding panels (see **6.4.2.1**) to divide the drainage zone into parts. To remain effective, they should be adequately secured in position. Metal baffles can rattle in a wind. Copper is not recommended in situations where staining would be detrimental.

5.7 Fire resistant materials

Little information is available on the fire performance *in situ* of jointing materials. The overall performance of a joint will be governed by the design of the joint and fire performance of the jointing materials and the components being joined. When jointing materials are enclosed within the confined space of a joint, access for fire and oxygen is limited. In a fire, jointing materials can generate toxic gases but, in practice, the volume of such materials is small and comparatively insignificant when considered in relation to the whole building.

If jointing materials are organic based and susceptible to degradation in fire,the integrity of the joint should be provided by other means. Improved fire resistance may be obtained by using joint fillers (see Table 1) made from ceramic-fibre, mineral-fibre, made from crushed rock or blast furnace slag, packed tightly into joints either on their own or as back-up to a suitable sealant.

Table 1 **Fillers for movement joints**

Filler type	**Property**					
	Typical uses	**Form**	**Density range** kg m^{-3}	**Pressure for 50 % compression** N mm^{-2}	**Resilience % recovery after compression**	**Tolerance to water immersion**
Cellular plastics and rubbers	Expansion joints	Sheet, strip	40 to 60	0.07 to 0.34	85 to 95	Suitable if immersion is infrequent
Mineral or ceramic fibres, or intumescent strips	Fire resistant joints: low movement	Loose fibre or braided and strip	Dependent on degree of compaction	Dependent on degree of compaction	Slight36	Not suitable
Wood fibre/ bitumren	General purpose expansion joints	Sheet, strip	200 to 400	0.7 to 5.2	70 to 85	Suitable if immersion is infrequent
Bitumen/cork	General purpose expansion joints	Sheet	500 to 600	0.7 to 5.2	70 to 80	Suitable
Cork/resin	Expansion joints in water retaining structures where bitumen is not acceptable	Sheet, strip	200 to 300	0.5 to 3.4	85 to 95	Suitable

6 Generation of solutions for joints of external walls and roofs

6.1 Basic mechanisms

The basic mechanisms for fulfilling certain functions of joints and the notional applications of some of these basic mechanisms are illustrated in Tables 2 to 4. For simplicity, the functions dealt with are limited to water and air penetration for external walls and roofs. The basic mechanisms that fulfill these functions either separately or in combination are described by the terms geometry, profile and seal.

Only those joint profiles specifically designed to serve a function, e.g. to stop the flow of water, are considered.

Key to Tables 2 to 4

The diagrams do not represent specific materials

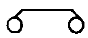
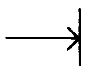
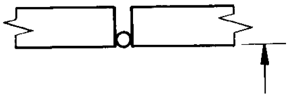
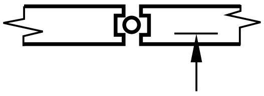
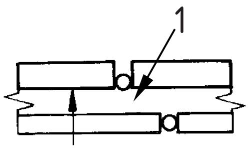
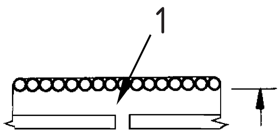
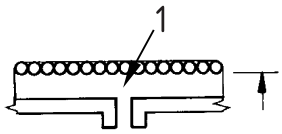
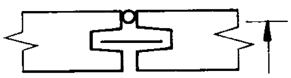
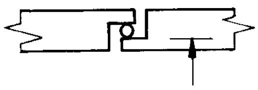
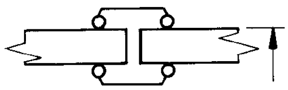
Abbreviations	Terms	Notes
EV EH	External walls: vertical joint External walls: horizontal joint	Column 1 gives a code for each joint and column 5 gives a code for those joints at right angles that can be used with it.
R	Roofs	Column 1 reference code
G P S	Geometry Profile Seal	The notations in column 2 are in the sequence in which penetration is resisted.
Symbols	**Terms**	**Notes**
	Single seal	Column 3 illustrates the jointing mechanism.
	Linked seal	
	Continuous seal	
	Bonding	
	Designed final depth of penetration of the agencies being resisted	
	Flashing	

Table 2 **Illustration of basic mechanisms**

Applied to vertical joints in external walls (functions considered: control of water and air penetration) diagrammatic plans				
Reference code	**Abbreviations**	**Mechanisms**	**Comments**	**Use with**
EV1	S		Sealant to provide single line of defence with greatest exposure. If movement is also to be accommodated, the demands on product performance are particularly great.	EH1
EV2	PS		As EV1 but with gasket joint	EH2
EV3	SG		Sealed rain-screen, e.g. masonry cavity wall construction external leaf	–
EV4	GS		Open rain-screen with sealed inner leaf	EH3
EV5	PGS		Open rain-screen. As EV4 but with additional protection to reduce side flow of water from face to cavity.	EH3
EV6	PGS		Two-stage open drained joint in cladding. Seals primarily against air penetration with a baffle against water penetration.	EH2
EV7	PGS		Rebated joint. Seal well protected and advantageously stressed in shear when subject to movement.	EH2
EV8	P		Labyrinthine joint adequate for some situations. Can also be sealed.	–
EV9	SGS		Double-sealed as in H-clip joints, patent glazing or structural gaskets. Potentially highly effective joint. Needs cladding over-laps at horizontal joints or total continuity of seals.	EH4 EH5

KEY
1 Cavity

Table 3 **Illustrations of basic mechanisms**

Applied to horizontal joints in external walls (functions considered: control of water and air penetration) diagrammatic sections

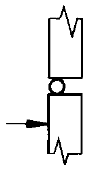
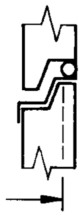
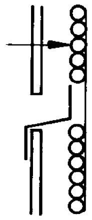
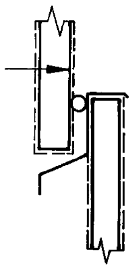
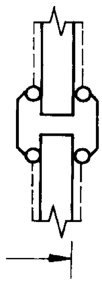
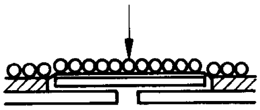
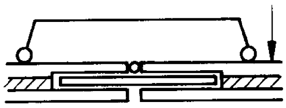
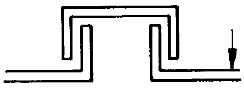
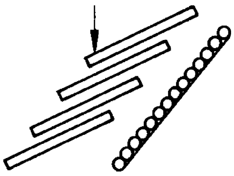
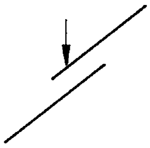
Reference code	Abbreviations	Mechanisms	Comments	Use with
EH1	S		Sealant to provide single line of defence with greatest exposure. If movement is also to be accommodated, demands on product performance are particularly great	EV1
EH2	PS		Combined flashing and gasket seal	EV2 EV6 EV7
EH3	PGS		Open rain-screen with drainage of cavity at horizontal joints to limit the volume retained in it	EV4 EV5
EH4	PS		Glazing joints water and air sealed. May be compared with EH2	EV9
EH5	SPS		Double sealed joints. Seals continuous at junctions. Void between sales may be used as a second line of defence against water penetration but drainage is necessary	EV9

Table 4 **Illustrations of basic mechanisms**

Applied to roofs (function considered: control of water penetration) diagrammatic sections

Reference code	Abbreviations	Mechanisms	Comments
R1	S		Minor movement joints, e.g, at screed bay joints in a felted roof, that interrupt bonding by a slip strip, avoid concentration of strain in the membrane
R2	S		Accommodates larger movements than if R1 specialized components are used. This principle is used where R3 cannot be adopted. Unlike R1 it relies on a separate seal at the joint. The amount of movement permissible is determined by the design of the seal
R3	PGS		Accommodates large movement, as R2 where it is possible to raise the joint above the general roof level. Can also be sealed
R4	GS		Pitched roofs with a seal provided by boarding or felt
R5	G		Pitched roofs, e.g. rigid sheeting. As angle of pitch diminishes, then sealing may be necessary

6.2 Basic examples of external walls

Examples of joints and sub-assemblies of external walls are used to illustrate the basic mechanisms and limited functions described in **6.1**.

For the purpose of discussion and illustration in this context, two basic forms are considered in **6.3** and **6.4**:

a) single stage sealing of joints in external walls;

b) multiple stage sealing of joints or assemblies in external walls.

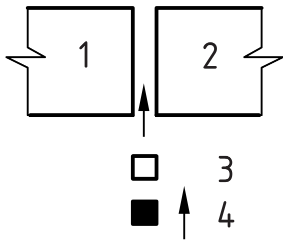
Single stage sealing implies the sole or primary use of one mechanism only as the barrier to air and water penetration (see Figure 11). Multiple stage sealing implies that this barrier is built up from more than one mechanism.

6.3 Single stage sealing of joints in external walls

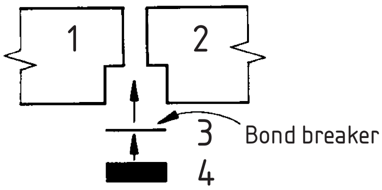
6.3.1 General principles

These jointing products form the sole barrier. The joint profile and the joint geometry, however, may be designed to provide some secondary support to the function of the seal, as given in Figure 11.

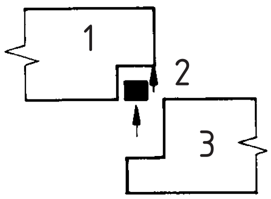
Figure 11 **Diagrams showing component profiles on plan, for one-stage joints indicating seals and sequence of assembly (1 – 4)**



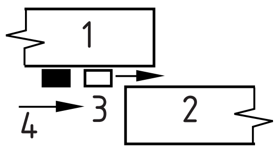
a) Sealant: no specific profile



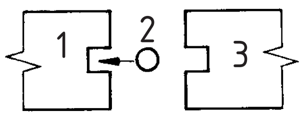
b) Sealant: rebated profile



c) Gasket or sealant: lapped with faces in line



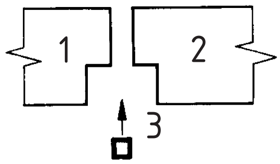
d) Sealant: lapped with faces offset



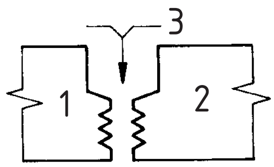
e) Gasket: to suit shape and location of seal

(continued)

Figure 11 **Diagrams showing component profiles on plan, for one-stage joints indicating seals and sequence of assembly (1 – 4)** *(continued)*



f) Gasket: to suit shape and location of seal



g) Adhesive and membrane: to locate seal and to attenuate passage of water

Consideration should be given to the protection of the joint, to access for periodic inspections, to the expected frequency of repair and to the consequences of periodic failure.

6.3.2 Assembly and repair

The assembly sequence for sealants is usually component/component/seal, and for gaskets component/seal/component or component/component/seal. Where gaskets are inserted into formed joints (component/component/seal), particular regard should be given to the sizes of gasket section in relation to the actual variation in joint widths.

Depending on how the gasket is incorporated in the assembly, the effect of creep from over-stressing necessary for insertion might need to be taken into account in determining the length of gasket section. When sealants are applied in the sequence component/seal/component, the size of the installed seal depends upon the skill of the installer in placing the sealant and in the correct positioning of the second component. After components have been brought together and the sealant subjected to compression, the opportunity for adjustment is very limited.

6.3.3 Interchangeability of components

The use of one-stage joint sealant places little demand on profiling and provides scope for interchangeability of components. However, restrictions on dimensional adjustment can arise from considerations of joint width or sealant movement accommodation. Oversized joints require special application techniques to avoid slump or sag of the sealant. Sealants are often the only materials that can be used for sealing complex junctions.

6.4 Multiple stage sealing of joints or assemblies in external walls

6.4.1 General principles

Sealing for both air and water penetration is effected separately by a combination of profile, geometry and seal design. This can be achieved within a single skin component of an external wall assembly (a two-stage jointing system), or with a void or voids between skins.

Two-stage sealing of joints in single skins has been commonly used for cast concrete panels.

Two-stage sealing of joints occurs in walls that consist of outer and inner component skins with a cavity in-between.

6.4.2 Multiple-stage sealing: single skins

6.4.2.1 General principles

Two-stage jointing of single skin components was developed initially for use with precast concrete panel components as a non-proprietary method. The jointing method can be matched to the panel material, which should have sufficient thickness to accommodate the depth of joint and the ability to accommodate dimensional deviations.

Curtain wall systems tend to be proprietary, with jointing components being an integral part of the system.

Materials and components lend themselves to a high degree of manufacturing accuracy.

By comparison with a one stage joint, the main advantage of a two-stage joint is that it has the potential of being more trouble free and durable, owing to the protection provided to the jointing products.

To exploit this advantage, water should be excluded by designing a joint profile that prevents it from reaching the air seal at the inner edge of the joint.

The effectiveness of the air seal is the most important factor in preventing rain penetration through the joint.

6.4.2.2 Curtain walls: materials and forms

Curtain walls are essentially non-loadbearing external enclosures. There are many varieties of skins that are comparatively thin and materials tend to be non-absorbent. Natural stone façades should be impervious to rain.

Many systems comprise wall and window panels that are supported by an extruded aluminium framework of mullions and transoms and to which they are gasket sealed with pressure plates. Fixed panels are commonly glass units or sandwich insulated metal panels. Some systems may incorporate panels of a variety of composite sheets or thin slabs with sealed or open joints, serving a rain-screen function, and with separate back up walls (see **6.4.3**).

The support system is sometimes erected as a framework of site jointed mullions and transoms that are then infilled or, alternatively, wall sections may be assembled into panels in the factory.

6.4.2.3 Curtain walls: joint profiles

Joint profiles of curtain walls are generally complex, exploiting the capability of metal and plastics to be formed into intricate shapes by moulding, extruding or pressing. Greater accuracy in manufacture is possible than with assemblies of traditional materials.

A considerable variety of profiles is used to create different effects, e.g. projecting, flush, recessed joints and variety of colour. Common features are the provision for drainage within the joint gap and the use of structural plastics inserts incorporated in metal sections to provide thermal breaks.

6.4.2.4 Curtain walls: junctions

Junction designs can be extremely varied and complex. Many systems make transitions between vertical and sloping surfaces, incorporating the ability to form junctions at angles between planes, i.e. providing complete geometric envelopes of walls and roofs.

BS EN 13830 refers to test methods and assessment criteria for curtain walls.

6.4.2.5 Curtain walls: accessibility for application, inspection and repair

Many systems are maintained in cleaning and repair in a similar manner to that required for windows and glazing. Long-term durability of jointing is an integral part of the durability of building fabric as a whole. Planned maintenance should be considered.

6.4.2.6 Precast concrete panels: vertical joints

NOTE See BS 8297.

Figure 12 shows two types of two-stage vertical joints. The air seal provided on the internal side of the joint prevents air flow through the joint and, by causing air pressure to rise at the back of the joint, minimizes the passage of water past the baffle. In order to provide acceptable limits for the sizes of the joint clearance, the width of the baffle has to be related to the depth of the groove and the maximum and minimum permissible joint clearances, and can be calculated from the following equation:

$$WL_m + X + Y$$

where

- L_m is the minimum baffle overlap, in millimetres;
- W is the baffle width, in millimetres;
- X is the depth of the groove for the baffle in each panel, in millimetres;
- Y is the maximum joint clearance, in millimetres.

This value of W should then be checked to ensure that it gives an appropriate baffle clearance when the joint is at its minimum clearance, from the following equation:

$$C = 2X + Z - W$$

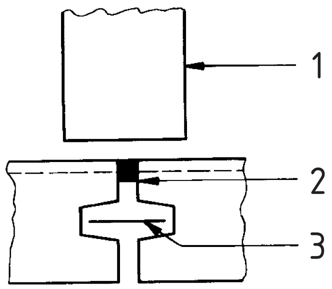
where

- C is the baffle clearance, in millimetres.
- Z is the minimum joint clearance, in millimetres.

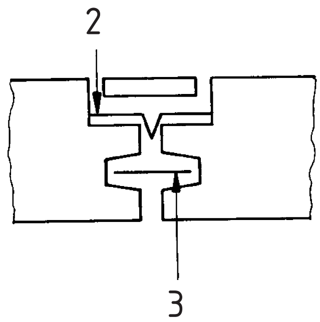
This is illustrated in Figure 13.

Figure 12 **Two-stage vertical joints**

*NOTE See also **6.4.2.9**.*



a) Plan



b) Alternative plan

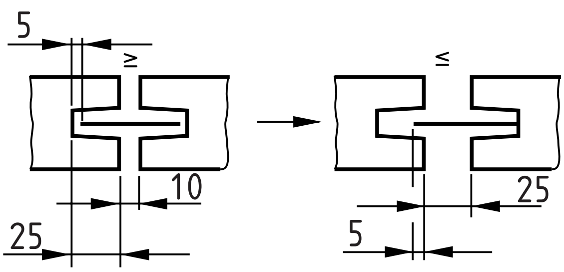
Key

1 Wall or column

2 Air seal

3 Baffle

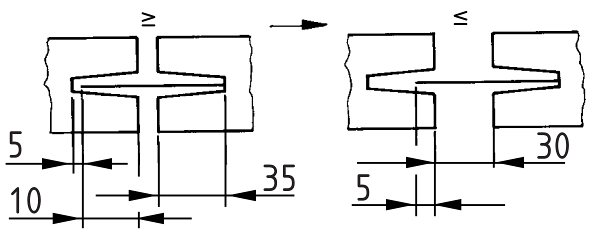
Figure 13 **Examples of relation between joint profile and permissible clearances**



a) Minimum joint clearance	Z = 10 mm
Maximum joint clearance	Y = 25 mm
Baffle width	W = 55 mm
Minimum baffle clearance	C = 5 mm
Minimum baffle overlap	L_m = 5 mm

(continued)

Figure 13 **Examples of relation between joint profile and permissible clearances** *(continued)*



a) Minimum joint clearance Z = 10 mm
Maximum joint clearance Y = 30 mm
Baffle width W = 75 mm
Minimum baffle clearance C = 5 mm
Minimum baffle overlap L_m = 10 mm

All sizes are in millimetres

The minimum depth of joint from the external face of the walling to the face of the air seal should be approximately 100 mm. The positioning of the baffle can vary depending on the materials forming the joint faces and the practicability of profiling. There should be a space between the air seal and the baffle. Recessing of the baffle from the external face helps to reduce vulnerability to vandalism and exposure.

Surfaces on the weather side of the baffle can be profiled to reduce the surface flow of water that might otherwise be driven into the joint. Such treatments as rough exterior wall surfaces and grooving the joint faces can be used, but they are not essential to the functioning of a well-constructed joint.

6.4.2.7 Precast concrete panels: horizontal joints

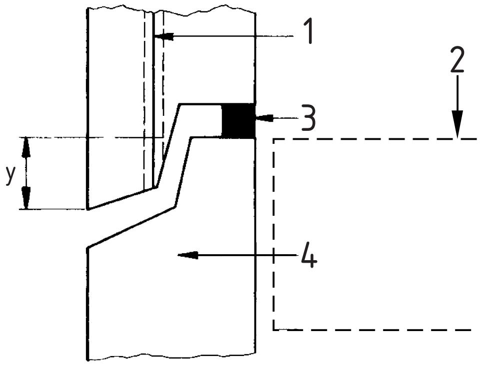
Figure 14 shows a section through a horizontal joint. The resistance to water penetration is provided by the upstand profile and the air seal at the inner edge. The choice of the upstand height Y depends on the assumed effectiveness of the air seal and the degree of its exposure.

For general construction, the recommended height of the overlap Y (Figure 14) is 50 mm or 100 mm for sheltered or exposed situations respectively. At the vertical joint intersection, the overlap is provided by the baffle. It is important that the baffle extends beyond the groove and is not left short through bad fitting or through shortening due to creep.

Depending on fixing design, horizontal joints may also incorporate devices or packings to transfer loads. Profiles of horizontal joints may also incorporate handling fixings. Such fixings or devices need to be designed so that the functional needs for sealing are not affected by them.

Figure 15 shows methods for securing the suspended loose baffle at the joint intersections. Should it prove to be necessary, the baffle shown can be removed and replaced.

Figure 14 **Diagram showing overlap in two-stage horizontal joint**



Key

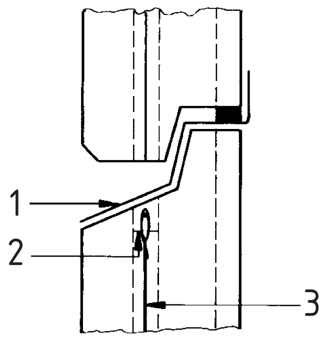
1 Baffle in groove

2 Floor or roof

3 Air seal

4 Baffles and flashing to lower panel not shown

Figure 15 **Diagram showing top of baffle in a two-stage horizontal joint: section at horizontal/vertical joint intersection**



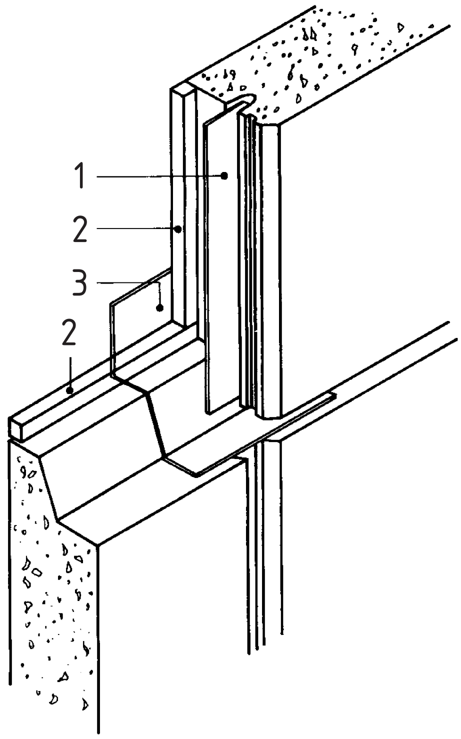
Key

1 Flashing local to vertical joint

2 Local slot to accommodate pin

3 Baffle looped over stainless steel pin

Figure 16 **Diagram showing typical intersection between horizontal and vertical two-stage joints in an external wall**



Key

1 Baffle

2 Air seal

3 Flashing

6.4.2.8 Precast concrete panels: junctions

Figure 16 shows a general arrangement at a four-way intersection of like components. Junctions, particularly with unlike components, are critical to performance, and their important aspects are:

a) the continuity of air seals;

b) the provision of a cover flashing over the lower joint.

At junctions, the geometry and profiles need to be checked in three dimensions (see also **7.1**).

6.4.2.9 Precast concrete panels: accessibility for application, inspection and repair

Insertion of jointing products in two-stage joints is simple and straightforward. Loose baffles are normally lowered from above as assembly proceeds and air seals caulked into or fixed to the internal face depending on type. An advantage of two-stage joints is that it is possible to carry out assembly without external scaffold access.

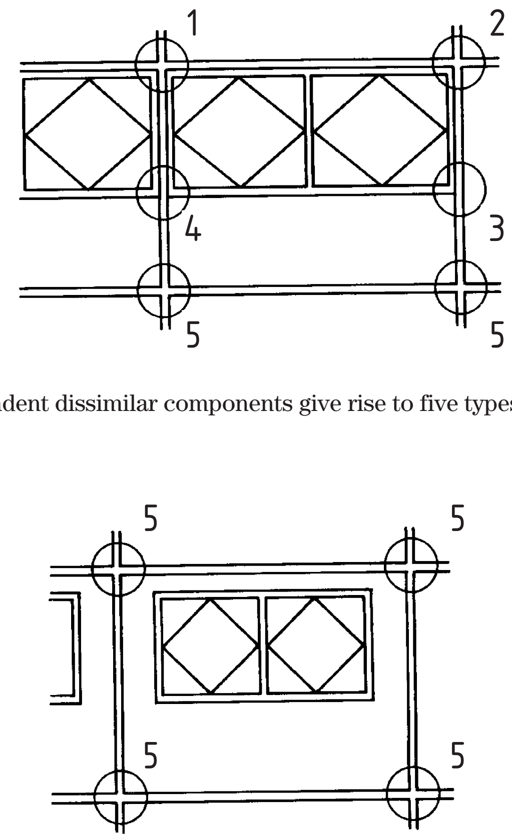
Air seals can be inserted either in the sequence component/seal/component or in the sequence component/component/seal. The choice depends on the materials and nature of construction. It is best to group individual types of operation, e.g. panel fixing, seal fixing.

Jointing products might be capable of serving their functions without maintenance, but consideration should be given to accessibility for replacement which might be needed because of natural degradation or vandalism (see Figure 15). The air seal and flashing should be designed so that maintenance or replacement will not be needed. Thought should also be given to the durability of joint faces. In part, these will be exposed, not very accessible, and might not be easy to maintain. Such faces need to be adequately durable.

6.4.2.10 Precast concrete panels: interchangeability and compatibility

The two-stage joint constitutes, with some restrictions, a basis for interchangeability. The principal restrictions arise from the need for compatible joint profiling and geometry, e.g. alignment of baffle grooves and the need for suitably durable component materials. The restrictions can be reduced by avoiding interdependences as shown in Figure 17.

Figure 17 **Diagram showing elevations of cladding, indicating how a variety of junctions can be reduced**



a) Interdependent dissimilar components give rise to five types of junction

b) Independent dissimilar components give rise to only one type of junction

6.4.3 Multiple-stage sealing: multiple skins (with emphasis on open rain-screens)

6.4.3.1 General principles

In multiple skin construction, the materials and geometry of the whole construction act together. Outer and inner skins are separated by a gap across which negligible amounts of water are expected to pass. In practice there are three basic forms (see Figure 18) as follows:

a) solid outer leaf, e.g. brick work;

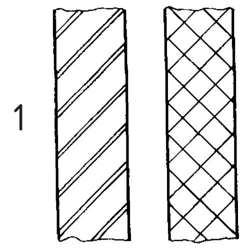
b) lapped outer courses, e.g. tiles;

c) open jointed outer layer, e.g. rain-screen construction.

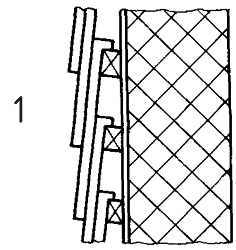
Some water might reach the rear face of the outer skin. Open rain-screens might additionally allow a limited amount of driving rain to be blown across the cavity opposite the joints.

All forms need horizontal flashings or cavity trays to drain water away from the inner skin at floors, window openings, etc.

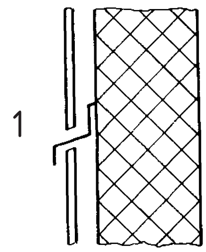
Figure 18 **Diagrams showing wall sections of basic forms of multilayer construction**



a) Solid outer leaf



b) Lapped outer leaf



c) Open rain-screened outer leaf

Key

1 Outside

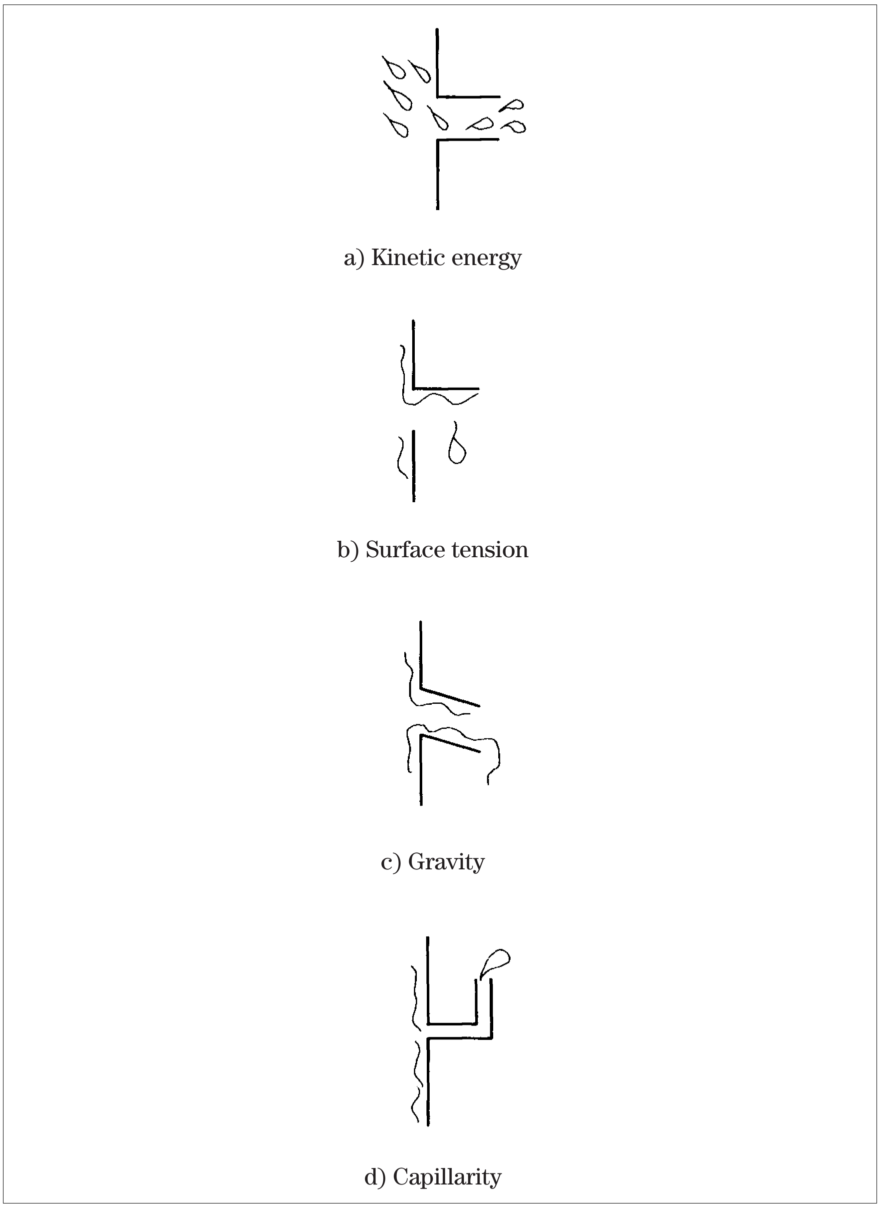
6.4.3.2 Open joints in rain-screens

Rain-screens are conveniently used for cladding of new buildings or overcladding of existing buildings. Most rainwater striking a non-absorbent rain-screen will be deflected, or drain off its face naturally. There is no separate jointing product needed specifically for sealing against water penetration. Rain-screens are sometimes described as curtain walls or are described as part of a curtain wall system.

The design intent should be to limit or minimize the penetration of water into the cavity behind the rain-screen.

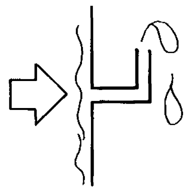
The driving forces that tend to carry rainwater through joints are varied and include wind induced pressure, the effect of kinetic energy, surface tension, gravity and capillarity. All of these should be considered in joint design by consideration of joint width, profiles and compartmentation of the cavity to enable pressure equalization to take place effectively (see Figure 19).

Figure 19 **Diagrams showing the processes by which rainwater leaks through joints**

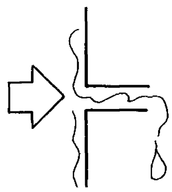


(continued)

Figure 19 **Diagrams showing the processes by which rainwater leaks through joints** *(continued)*



e) Pressure assisted capillarity



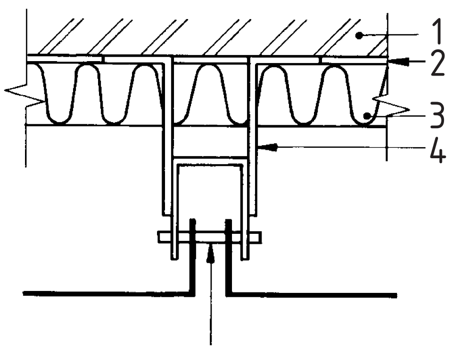
f) Air pressure differential

Rain-screen assembly design can exhibit differences in design approach for limiting or minimizing the entry of water into the cavity. The inner skin should act as a barrier to air penetration. Usually this barrier is faced or backed with the thermal insulating layer and the whole of the wall construction is sufficiently permeable to disperse moisture. The design objective is to ensure that any water that gets into the cavity does no damage to materials or affects performance.

With plain surfaced non-absorbent rain-screens, wind driven water flow will tend to concentrate at the joints. If the rain-screen cladding material lends itself to such a treatment, profiling of the outer surface to restrict the flow at the joint would be beneficial

Generally, cavities tend to be divided by the rain-screen vertical support members as shown in Figure 20, and by intermediate flashing, horizontally as shown in Figure 21. Consideration should be given to the provision of cavity fire barriers.

Figure 20 **Typical open rain screen joint**



Key

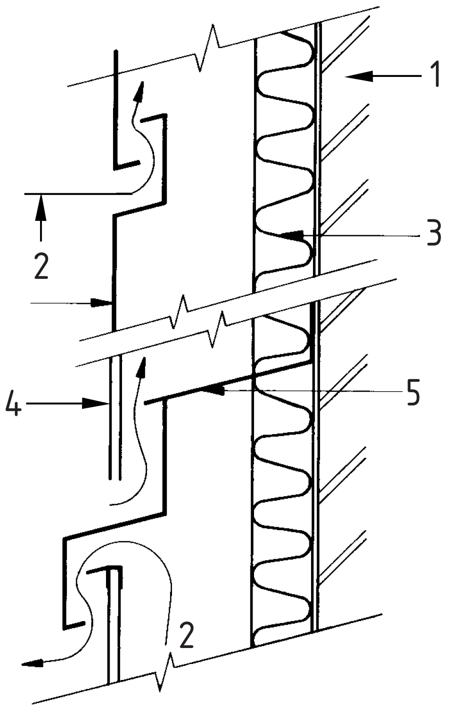
1 Structural wall

2 Air barrier

3 Thermal insulation

4 Support brackets

Figure 21 **Typical labyrinth horizontal open rain screen joint**



Key

1 Structural wall, air barrier

2 Air

3 Thermal insulation

4 Flatsheet rain-screen

5 Intermediate flashing

For plain profiled joints without a labyrinth, tests indicate the relatively small open joints of up to six millimetres in width reduce driving rain across the cavity to negligible quantities (with a minimum cavity width of 25 mm).

Only general guidance can be given about design for pressure equalization. Because of different pressures due to wind acting at the same time in different areas of a facade the cavity should be compartmented to isolate areas of different pressure. Obvious pressure differences occur at edges and corners of facades [A1⟩ *Text deleted* ⟨A1]. Even with an "engineered" system, complete exclusion of water from the cavity cannot be guaranteed. Intermediate open horizontal joints should ideally be profiled with a labyrinth which provides lippings, throatings and upstands. These joints provide the main source of inlet and outlet ventilation to the cavity providing protection against direct ingress of water and providing the openings required for pressure equalization, as shown in Figure 21. For engineered pressure equalization, wider joints are necessary (10 mm to 20 mm), and these joints often need a catchment tray to deal with high kinetic energy droplets, passing through the joint gap without touching the joint profiles.

7 Accommodation of movement

7.1 Structural and major movement joints

In addition to the accommodation of thermal and moisture changes, movement joints in the structure have also to accommodate dimensional changes due to other factors.

Other movement can include:

a) differential settlement, e.g. a structure exerting different pressures on underlying strata [see Figure 22a];

b) variation in soil properties under a building [see Figure 22b];

c) phased construction of abutting buildings;

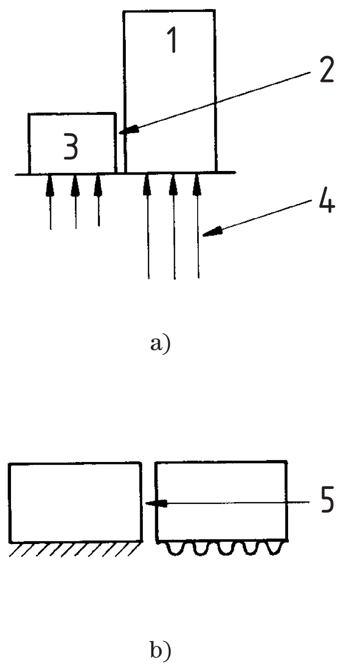
d) subsidence due to mining;

e) variations in loading, e.g. wind;

f) earthquakes.

g) buckling of long elements.

Figure 22 **Diagram showing movement joints in structures for differential loadings and ground bearing pressures**



Key

1 High block

2 Differential vertical and horizontal movement at interface of structures necessitates a movement joint

3 Low block

4 Foundation pressure difference may require a movement joint in structure and foundation

5 Uneven soil characteristics, subsidence and geological faults necessitate a movement joint

In special cases, major structural movement may be dealt with by structures stiff enough to resist wind forces but flexible enough to follow ground subsidence by allowing for movement in all main joints.

Consideration should be given to all the factors affecting movement, how they may be absorbed as additional stresses, how the structure may deform and how to subdivide it into units with major joints. Where the structure is protected by insulation or cladding, the thermal movement of the structure is less than when it is exposed. Differential movements between claddings and structure need consideration.

When it is considered that the effects of temperature and moisture are too large to be absorbed as strain, distinct provision for movement in the structure should be made by the provision of joints. Though often called expansion joints, these have in practice to accommodate both expansion and contraction. Their actual locations are determined according to particular circumstances but for the general separation of framed structures into sections the frequency of joints is usually about 30 m to 40 m.

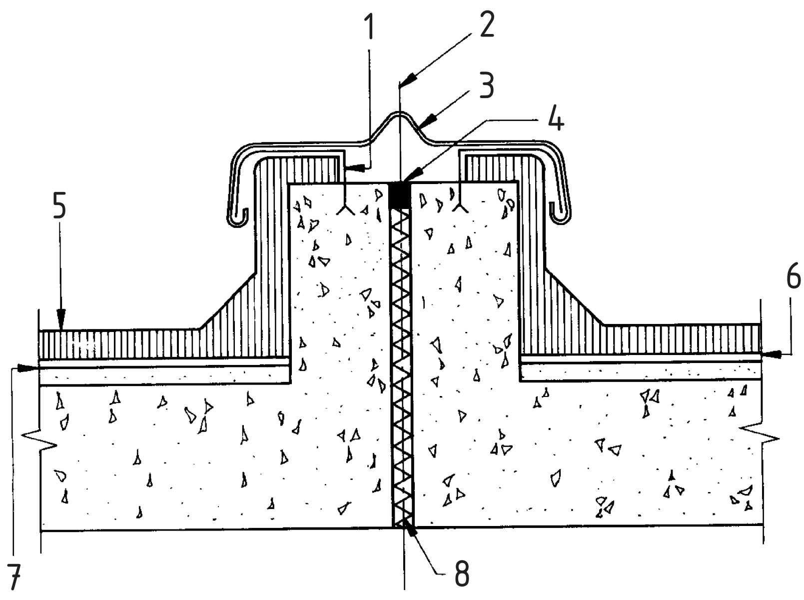
The external claddings applied to structural members may require movement joints at more frequent intervals depending on the materials because of the exposure to a more rigorous thermal and moisture regime than that of the structure they protect.

For advice on movement in masonry see [A1) PD 6697 and BS EN 1996-2. (A1] The main recommendations are to space vertical movement joints for horizontal movement at about 12 m, 7.5 m to 9 m and 6 m, for fired clay, calcium silicate and concrete masonry respectively. Because expansion is a predominant feature of fired clay compared with contraction of concrete/cement masonry, joint fillers for use with fired clay in particular need to be sufficiently compressible. Rigid board type fillers should not be used, e.g. fibreboard and cork.

Jointing products usually have to be incorporated to form the joint initially in order either to transfer load (sliding joint) or to prevent dirt collecting in the space needed for movement, and allowance for movement then has to be made in the design of all associated parts of the structure (the cladding, finishes, etc.) so that other functions, e.g. weather exclusion, can be met.

Examples of typical major movement joints for structure and finishes are shown in Figure 23, Figure 24 and Figure 25.

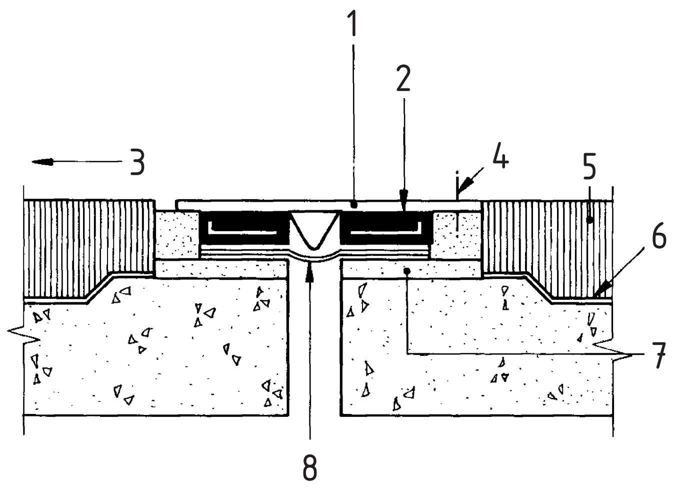
Figure 23 **Diagram showing movement joint in roof structure for differential loadings and ground bearing pressures**



Key

1 Metal cleats fixed in concrete kerb to hold capping in position
2 Joint reference plane
3 Metal capping
4 Sealant
5 Mastic asphalt
6 Isolating membrane
7 Fall away from joint minimum 1:80
8 Compressive joint filler

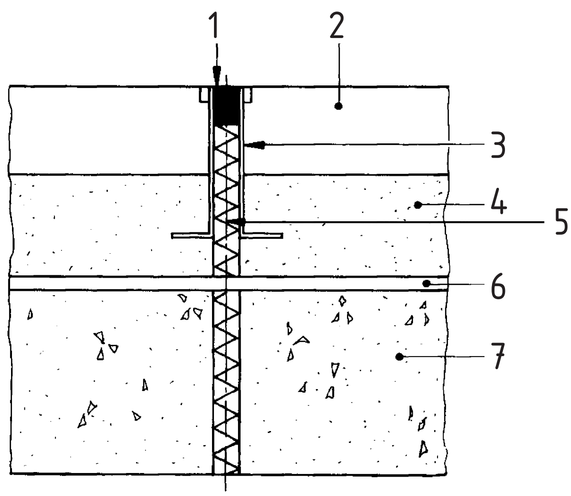
Figure 24 **Diagram showing movement joint in roofs where traffic prohibits the use of an upstand**



Key

1 Sliding steel cover plate
2 Bridge deck expansion joint
3 Fall away from joint, minimum 1:80
4 Fixing
5 Asphalt surfacing
6 Waterproof membrane
7 Polymer modified concrete bed
8 Continuous waterproof membrane

Figure 25 **Diagram showing intermediate movement joint in floor tiling**



Key

1 Sealant
2 Tile
3 Metal angle
4 Screed
5 Joint filler
6 Separating layer, if any
7 Structural concrete

7.2 Minor movement joints

7.2.1 General

Materials and products have inherent characteristic patterns of movement, e.g. shrinkage of cement based products and timber-based products and expansion of fired clay products.

At the time of manufacture and at construction, movement of materials and products begin to normalize to the surrounding conditions. The period of time over which this occurs may be long or short and the surrounding conditions will be subject to change to a greater or lesser extent.

A variety of examples are given in **7.2.2** and **7.2.3**.

7.2.2 Construction and contraction joints

7.2.2.1 General

Construction and contraction joints should be provided with cement based materials to accommodate drying shrinkage.

7.2.2.2 Construction joints

Construction joints may be introduced at selected positions to allow temporary breaks in the construction process. These joints may be used to position controlled crack lines, or they may need to be treated or sealed to eliminate the weakness they create.

Construction joints occur commonly in *in situ* concrete work and may be needed, e.g.:

a) at joints between elements, e.g. junctions of walls and floors;

b) for day joints;

c) where the depth or extent of concrete pour needs to be limited, e.g. in mass concrete to limit heat generation.

7.2.2.3 Contraction joints

Contraction joints may be introduced to locate potential cracks in *in situ* concrete or concrete masonry in controlled positions.

The frequency of contraction joints may depend on circumstances. With *in situ* toppings and screed they need to correspond at least with any joints in the substrata. [A1) *Text deleted* (A1]

7.2.3 In service movement: primarily structural, thermal and moisture

Major vertical joints to accommodate horizontal movement are considered in **7.1**. The opportunity for the positioning of horizontal joints to accommodate vertical movement tends to occur naturally at junctions of wall and floor elements. At these junctions the wall may be loadbearing, non-loadbearing or a mixture of both.

Non-loadbearing wall/floor junctions will result in the effects of vertical movement being concentrated at that location. Allowance for movement should be made for this in the horizontal joints (soft jointing). Soft joints may be needed for external walls and internal walls.

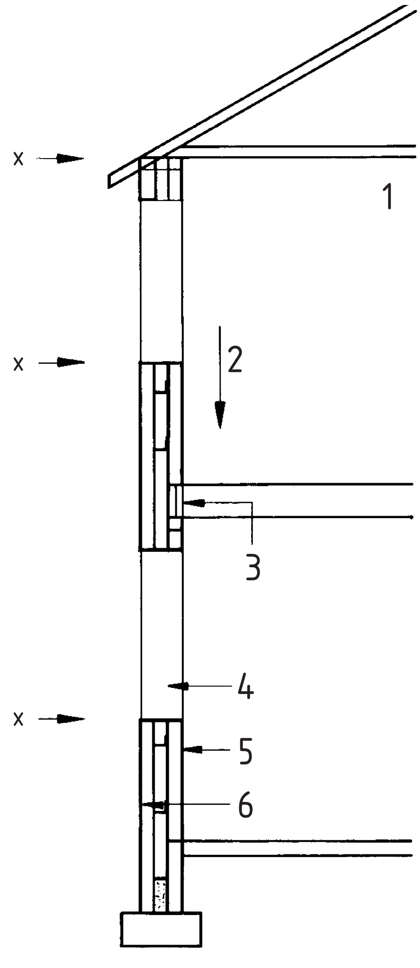
There will be different ranges of movement externally and internally because of the differing thermal and moisture environments. Creep and deflection of the structural members may be common to both circumstances.

Soft jointing introduces the need to consider anchorages to support and stabilize non-loadbearing walls against wind forces or impact forces. These will need to provide lateral restraint and allow vertical movement. See [A1] BS EN 1996-2 [A1] for guidance on external masonry walls.

NOTE Further information may be found in NHBC Standards: Chapter 6.2: External timber framed walls[2].

Loadbearing wall/floor joints should not in themselves cause problems but designers should be aware of their relation with associated construction, e.g. loadbearing wall leaves of timber will shrink more than an associated non-loadbearing external cladding of brickwork. Movement between leaves needs to be accommodated (see Figure 26).

Figure 26 **Diagram showing section through masonry/timber frame external wall**



Key

1 Allowance for differential movement required on lines at X i.e. at roof and window sills.

2 Drying shrinkage of timber

3 Biggest proportion of overall shrinkage normally occurs at floor zone (cross grain timer)

4 Window opening

5 Timber frame inner leaf

6 Masonry external leaf

8 Assembly, installation and maintenance

8.1 Communication

Experience suggests that poor communication is at the root of many failures. Clear communication is important when traditional building skills cannot be applied and when jointing details are unfamiliar. Inadequate communication of design intentions at repetitive joints may produce correspondingly repetitive failures. Simple cross-sections alone rarely provide sufficient information, especially for construction at joint intersections, and three-dimensional representations should be provided wherever necessary (indeed, they are usually essential at the design stage if the jointing solution is to be considered fully).

It is recommended that drawings of jointing details should be in accordance with the recommendations of Annex B.

8.2 Control of jointing on site

Control on site is essential and should take account of critical factors, particularly where specifically identified. Examples are that:

a) joint clearances are maintained within specified limits (see also **4.7**);
b) continuity of seals is maintained;
c) operations which are difficult (such as forming and sealing of cloaks and cavity trays) are correctly executed;
d) the correct assembly sequence is followed;
e) work to be hidden by subsequent work is inspected before being covered;
f) features difficult and costly to rectify are checked.

8.3 Preparation for jointing

Inadequate preparation of component surfaces to receive jointing materials is the major cause of the failure of a joint system (see **5.2.9**). Joint faces are most commonly contaminated by dust, loose particles, moisture, oils and greases, and corrosion products. Contaminants should be cleaned from the joint faces before application of primers and sealants. Rough surfaces may need to be ground flat before installation of gaskets. Some components may be delivered to site with a temporary protective coating that has to be removed before the application of the sealant or gasket.

8.4 Application and insertion of jointing products

It is essential that manufacturer's recommendations on the application of their products should be followed. The sequence of building operations should be such that ready access by the operator to the joints is ensured and that interaction with other trades is avoided.

8.5 Safety in application of jointing products

There are few hazards from jointing products in application, but some sealants and primers contain flammable solvents or toxic constituents, and can cause dermatitis and nausea in certain individuals. Reference should be made to manufacturer's literature for guidance on the use of their products and the precautions that need to be taken. In particular, care is needed in the safe disposal of hazardous waste and containers in accordance with statutory requirements.

The Control of Substances Hazardous to Health Regulations [3] requires employers to assess the risks which may arise from hazardous substances at work and then to determine the measures needed to prevent or adequately control exposure to them. It may be possible to eliminate the hazardous substance by changing the process or substituting with a safe or safer substance. Where this is not reasonably practicable, exposure should be controlled by e.g. enclosure, the use of ventilation equipment, general ventilation, safe systems of work and handling procedures. Personal protective equipment should only be used where other measures cannot adequately control exposure.

8.6 Maintenance

It is recommended that joints be inspected at intervals equivalent to one-fifth of their life expectation and additionally that, after their first year in service, all joints subject to movement be inspected for signs of premature failure.

Building maintenance manuals should provide:

a) an inspection schedule;

b) an expected replacement schedule for jointing products;

c) an identification of joints where lack of maintenance would lead to significant consequential damage;

d) guidance on how to maintain joints (including any special precautions needed to avoid inappropriate repairs);

e) means to identify products or types of jointing products used.

See also BS 8210 for further guidance to building maintenance management.

Annex A (informative) Data for the design of movement joints

Coefficients of linear thermal expansion of common building materials are given in Table A.1.

For details of materials not listed, consult the supplier.

Table A.1 **Coefficients of linear thermal expansion of common building materials**

Materials	**Coefficients of linear thermal expansion** $10^{-6}K^{-1}$
a) Stone	
granite	8 to 10
limestone	3 to 4
marble	4 to 6
sandstones	7 to 12
b) Concrete	
dense gravel aggregate	10 to 14
limestone aggregate	7 to 8
lightweight aggregate	8 to 12
glass-reinforced cement	7 to 12
c) Plaster	
dense plaster	18 to 21
lightweight plaster	16 to 18
d) Masonry	
bricks (clay)	5 to 8
bricks (calcium silicate)	8 to 14
concrete blocks	6 to 12
e) Metals	
aluminium and alloys	24
brass	18
bronze	20
copper	
cast iron	10 to 11
lead	29
stainless steel (austenitic)	18
stainless steel (ferritic)	10
mild steel	12
zinc (parallel to rolling)	33
zinc (perpendicular to rolling)	23
f) Wood[A)]	
across	30 to 70
with grain	4 to 6

(continued)

Table A.1 **Coefficients of linear thermal expansion of common building materials** *(continued)*

Materials	**Coefficients of linear thermal expansion** $10^{-6}K^{-1}$
g) Plastics	
acrylic-cast sheet	50 to 90
polycarbonate	60 to 70
polyester 30 % glass fibre (GRP)	18 to 25
rigid PVC	42 to 72
expanded PVC	35 to 50
phenolic	30 to 45
foamed phenolic	20 to 40
expanded polystyrene	15 to 45
foamed rigid polyurethane	20 to 70
h) Glass	
sheet or float	8 to 9

A) In practice, a temperature change is accompanied by a compensating change in moisture content which becomes the controlling factor.

The normal range of moisture content attained by timber in building is 10 % to 18 % (see PRL Technical Note 46, *The moisture content of timber in use* [4]), although a higher moisture content can be present at installation. Poor storage on site may also lead to higher moisture contents.

Tests have been made with many species for movement due to moisture between 60 % r.h. and 90 % r.h. at 25 °C. Table A.2 gives a few examples of selected from PRL Technical Note 38, *The movement of timbers* [5].

Table A.2 **Moisture movement of timber**

Species	**Equilibrium moisture content in 90 % r.h.** %	**Equilibrium moisture content in 60 % r.h.** %	**Corresponding tangential movement** A) %	**Corresponding radial movement** A) %
Hemlock, Western	21	13	0.9	1.9
Pine, Scots (Redwood)	20	12	2.0	0.9
Oak, English	20	12	2.5	1.5
Teak	15	10	1.2	0.7
"Parana Pine"	21	13	2.5	1.7
Spruce, European (Whitewood)				

A) Movement caused by the change in equilibrium moisture content accompanying a change from 90 % r.h. to 60 % r.h.

Annex B (normative) Recommendations for the presentation of joint drawings

Each joint drawing should be laid out as follows:

a) on an A4 sheet area, either a single sheet or part of a larger sheet (A1, A2, A3);

b) drawn to a scale either twice full size, full size or half full size.

The information contained in the sheet title and on the drawing itself (see Figure B.1) should be as follows:

1) reference planes;
2) material of the building components;
3) material and location of the jointing products;
4) size of clearance;
5) tolerance on the clearance;
6) sequence of assembly;
7) outside of walls, at right or at the base of sheet;

For further guidance, see also BS 5606 and BS 6750.

Figure B.1 **Typical jointing detail through transom**

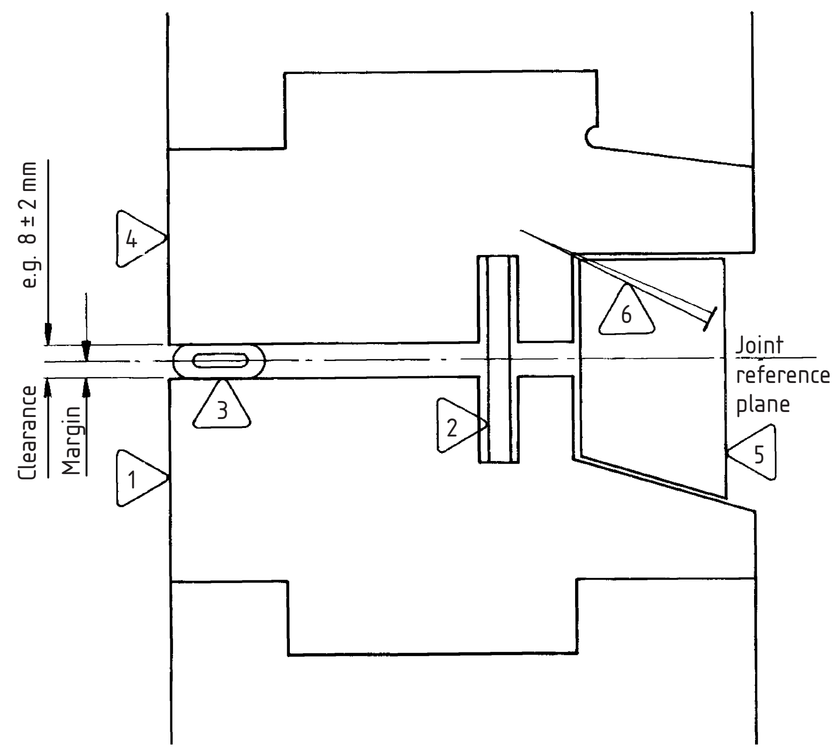


Diagram showing typical section (not to scale)
Suggested sequence of erection
1 Building component, e.g. timber window frame
2 Jointing product, section, e.g. metal weather bar
3 Jointing product, material e.g. PVC gasket
4 Building component, e.g. timber window frame
5 Jointing product, section, e.g. timber cover strip
6 Jointing product, component, e.g. lost-head aluminium nail

Bibliography

Standards publications

ISO 3447:1975, *Joints in building — General check-list of joint functions.*

Other publications

[1] BRE Digests 227, 228 and 229. Estimation of thermal and moisture movements and stresses: Part 1:1979, Part 2:1979, Part 3:1979. Garston: Building Research Establishment.

[2] NHBC Standards: Chapter 6.2: *External timber framed walls*. National House Building Council.

[3] GREAT BRITAIN. COSHH Regulations. London: TSO.

[4] PRL Technical Note 46, *The moisture content of timber in use*. Garston: Building Research Establishment, 1970.

[5] PRL Technical Note 38, *The movement of timbers*. Garston: Building Research Establishment, 1976.

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