INFORMATION SCRIPT

Planning Movement Joints in Facades

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1 INTRODUCTION

Regardless of whether a residential or office building, the design of a facade plays an important role in the architecture of a building. Aesthetics is just one part of this. Function in regard to sustainable use is also an issue that is becoming very important and both of these factors are reflected in the design of a facade and the different building materials used.

From a historical standpoint, natural materials such as stone, wood and loam have been predominately used for constructing buildings for a long time. Loam or putty (chalk and boiled linseed oil) were used to close the transitions between the different constructions.

Compared to today's standards, buildings erected during the middle of the last century were poorly sealed. Their lack of insulation along with drafts prevented them from being overly comfortable, especially in winter. Today, on the other hand, because of increasing energy prices and legislation that has been passed, new buildings must be constructed without such undesired weak areas. This aspect is dealt with later in this Information Script in Chapter 8 "Sustainability".

The trend toward sustainable building combined with responsible use of existing resources has only become possible through modern facade constructions and the use of high performance sealants.

Their great significance for buildings is also reflected in standards that deal with these products. Different classes of joint sealants have been covered by the standard ISO 11600 "Building construction – joint sealing products – classification and requirements" since 2002. But ever since the European harmonised product standard EN 15651 "Sealants for non-structural use in joints in buildings and pedestrian walkways" was published in the Official Journal of the EU, sealants for the respective application areas have been subject to binding rules. Parts 1 and 2 of EN 15651 ("part 1: Sealants for facade elements; part 2: Sealants for glazing") are particularly important in regard the use of sealants in facades.

But high quality products that meet standards are not the only decisive factor for the quality of a facade. Thorough planning and proper execution of joints are equally important.

The purpose of this Information Script is to explain how joints are planned, especially movement joints in facades, and to help make the selection of a suitable sealant easier.

2 TYPES OF FACADES

A wide variety of facade constructions are used today. Technological developments have been achieved over the years that allow the most different architectural visions and building styles to be realised. The construction of a facade is mainly determined by the materials selected and they also play a decisive role. Regardless of the construction and working material, all facades are exposed to weather which makes it necessary to divide the facade into sections separated by movement joints.

2.1 Concrete Facades

As a structural building material, concrete plays a great role in today's building activities. Concrete is often the construction material of choice for architects and building owners, especially for facades, because the surface of concrete can be finished in a variety of ways and it is a practically indestructible building material. Concrete facades are usually made of precast concrete units or precast concrete panels.

Three different construction principles are generally used:

- Sandwich panels
- Large, precast concrete curtain wall units
- Small-format, precast concrete curtain wall panels

Sandwich panels have built-in thermal insulation as well as a structurally relevant, load-bearing leaf. They are "load-bearing elements" of the building and directly built in place as construction progresses.

Precast concrete curtain wall units are subsequently anchored to the shell construction by mechanical means. The anchor systems for these units are either cast in the precast concrete units when they are produced or they are designed to be placed in the shell wall.

The small-format, precast concrete curtain wall panels are mechanically anchored at a certain distance from the shell wall analogous to natural stone facades.

2.2 Curtain Wall Facades

A curtain wall facade consists of individual element panels which are mechanically attached to the building at a certain distance from the external wall. These panels can be made of different materials, e.g. natural stone, precast concrete stone, metal or glass but can also serve as substrates that are subsequently decorated, for example, with a textured render, mosaic or tile cover. There are practically no limits to imagination here. Movement joints with a sufficient width must be planned between the element panels. A monolithic connection of several curtain wall panels can also be attached to the facade, depending on manufacturer.

2.3 Tile and Stone Veneer Panel Facades

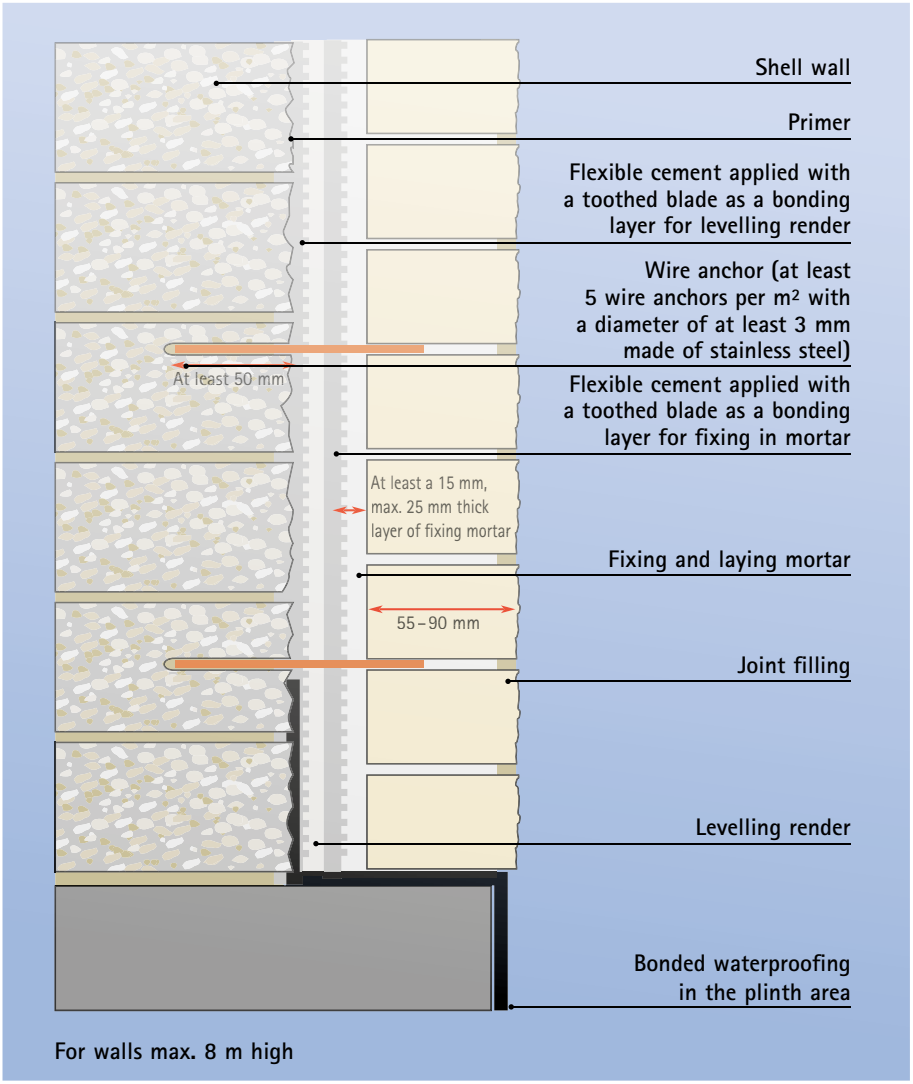
This type of facade is directly clad with a ceramic or stone cover. The mortar used for fixing the cover creates a monolithic bond between the load-bearing wall construction and the tile/stone cover. If tiles or stone covers are to be fixed in mortar, DIN 18515, parts 1 and 2 "Cladding for external walls" must be observed which defines how the cladding is to be divided into fields or sections of a certain size and movement joints. Decisive points are the special features of the tiles/covers: their format and weight. The tiles/covers are fixed in a mortar pursuant to DIN EN 12004 by the combined buttering and floating method. As a rule, the joints between the individual tiles/covers are filled with a hydraulic setting joint mortar.

2.4 Brickwork and Stonework Facades

The brickwork or stonework facade described here consists of masonry stone as a facing leaf made of natural stone or clinker. The stones, which must have a minimum thickness so that they can be securely laid, are normally set in a half-stone laying pattern. As a rule, two versions of brickwork and stonework facades are used for buildings.

Version 1 is described in DIN 18515, part 2 "Cladding for external walls – facing bricks fixed in mortar on supports".

Illustration 1:
System "Facing bricks fixed in mortar on supports"



With this version, the stones are laid with mortar on a supporting surface (extended floor/ceiling slab) directly in contact with the shell wall. The stones must have a minimum depth of 55 mm to 90 mm. In addition to fixing in mortar, the mortared masonry diaphragm is usually also anchored to the shell wall using masonry anchors.

The second version is a brickwork or stonework facade which is constructed as a facing leaf at a distance from the shell wall. As a rule , an insulation material is placed behind the facing leaf. Clinker is often used for brickwork facades – a material typically found in many villages and cities in northern Germany. The curtain wall brickwork facade must be anchored to the shell wall by mechanical means.

2.5 Glass Facades

To combine aesthetic principles with concepts that place high requirements on saving energy, architects are increasingly turning to glass for the construction of facades – whether as transparent structural glazing facades using single glazing or with insulated glass elements and even as a double skin facade.

Combinations of glass with materials such as natural stone, metals or polymer coated metals also offer planners the most varied possibilities for design. But a perfect appearance is not the only deciding factor. Facades and windows in particular are subjected to extreme loads and must maintain their quality if they are to achieve a long service life. Reliable connections of the building elements and highly elastic, weather tight seals play a decisive role here. High-tech silicone sealants are required for this area which are specially formulated to meet the specific requirements and guarantee the highest performance. A wide range of highly sophisticated and innovative products for sealing facades is available today to meet all such requirements.

3 BASIC PRINCIPLES FOR PLANNING

When planning a construction project, not only legal provisions and valid standards must be taken into consideration but also climatic conditions. It should also be born in mind that construction activities are becoming more and more international and construction projects are increasingly being planned by local planning offices and developers and executed abroad, also beyond Europe's borders. In these cases, the regulations and climate conditions at the site of use – such as DIN 18540 "Sealing of exterior wall joints in buildings using joint sealants" which applies in Germany – must also be an integral part of planning.

The low modulus value at -20 °C required in Germany pursuant to DIN 18540, for example, will be of no significance for a building project in southern Italy and absolutely none in Dubai but when planning a building project in the Alps or in Finland, the behaviour of a joint sealant at -30 °C will be required for calculation. Consequently, the temperature to be expected on site as well as the respective differences in temperature must be taken into account when calculating joint width as well as when selecting a sealant. Along with the building material (coefficient of expansion), the colour of the facade also plays a role. A light-coloured facade, for example, is not likely to heat up in sunlight nearly as much as a dark-coloured or black facade.

Examples of linear expansion of different building materials

Material / building material	Coefficient of expansion α in 10^{-6}/K (at 20 °C)	Change in length (in mm/m) at a change in temperature of 100 K
PVC	80	8.0
Concrete	10 - 12	1.0 - 1.2
Glass	4.3	0.5
Aluminium	23.5	2.4
Natural stone, e.g. marble	5 - 16	0.5 - 1.6
Tiles / ceramic	6	0.6
Polycarbonate	70	7.0
Steel	12 - 16	1.2 - 1.6
Wood (along the grain)	7	0.7

Permissible total deformation of sealants:

As a rule, facade sealants with 20 % to 25 % total deformation are used in Europe. In DIN EN ISO 11600 "Building construction – joint sealing products – classification and requirements" the requirements are described according to which sealants are classified. In Germany, DIN 18540 "Sealing of exterior wall joints in buildings using joint sealants" must also be observed when sealing facades. The tests in regard to total deformation are identical to those set out in DIN EN ISO 11600, the only difference being that DIN 18540 only allows class 25 LM.

In the standards mentioned above, mechanical properties at +23 °C and at -20 °C are dealt with. In the new European standard EN 15651-1 (Facade sealants), requirements for mainly Scandinavian countries have now been included and a "cold climate class" was introduced. For sealants that are to be used in cold climate zones, tests on mechanical properties must also be carried out at -30 °C.

3.1 Division of the Facade into Fields/Sections

Along with the necessary movement joints in the facade determined by calculation, there are also other factors to consider which may make movement joints necessary. When curtain wall facade elements are built in, for example, a joint must always be placed at the end of the element. Further joints may be necessary due to the geometry of the facade or because of possible openings and interpenetrations. The following illustration with individual details should serve as orientation.

Illustration 2:
Dividing the facade into fields through movement joints

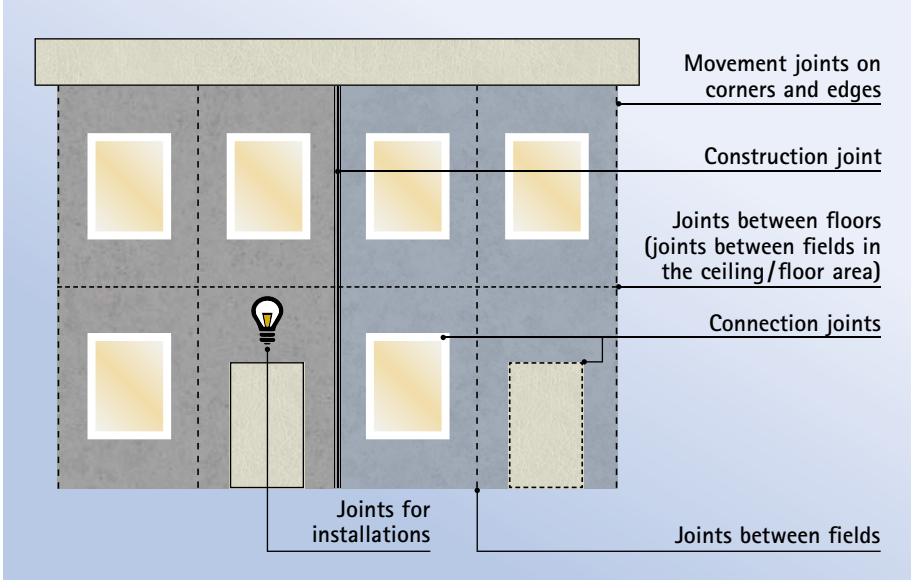


Illustration 3:
Execution of joints in detail

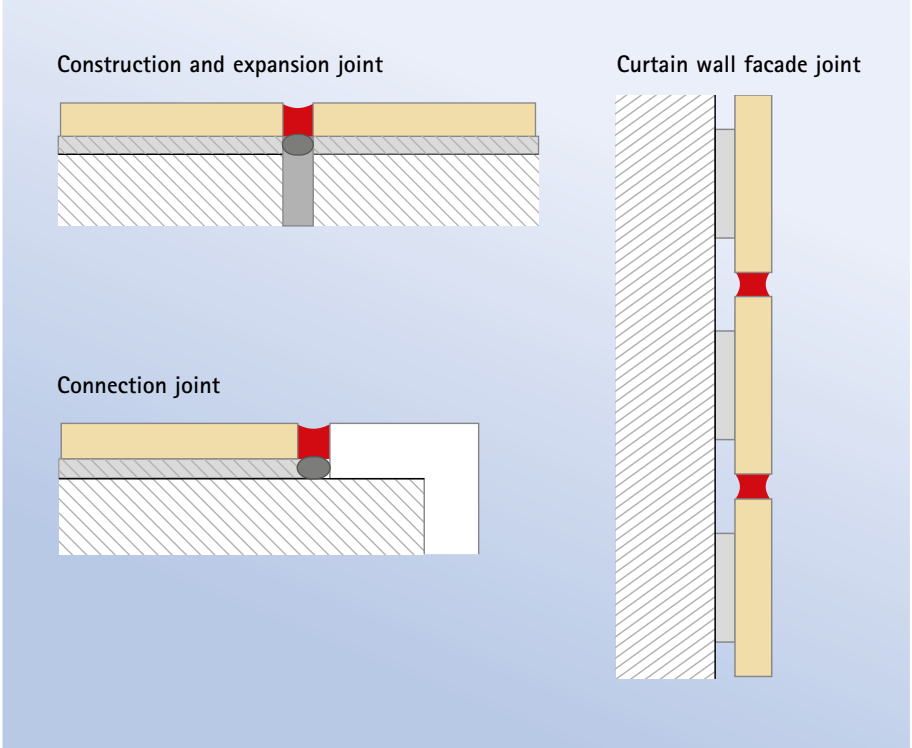
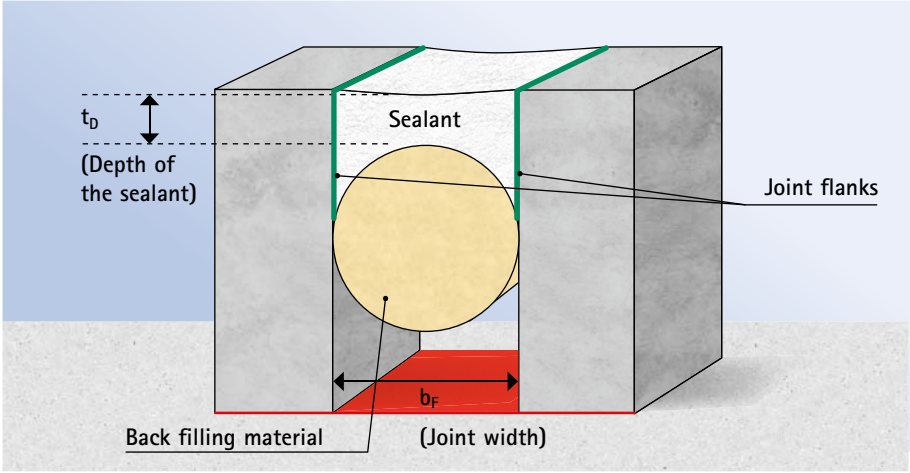


Illustration 4:
Proper execution of,
e.g. a joint between fields



4 SEALANT SELECTION

Today, single component products on a polyurethane, silane-terminated polymer (STP, hybrid systems) or silicone base are almost always used for sealing facades. Polyurethanes and silane-terminated polymers are mainly used for concrete facades. Practically all products can be used for curtain wall facades and only silicones are used for glass facades.

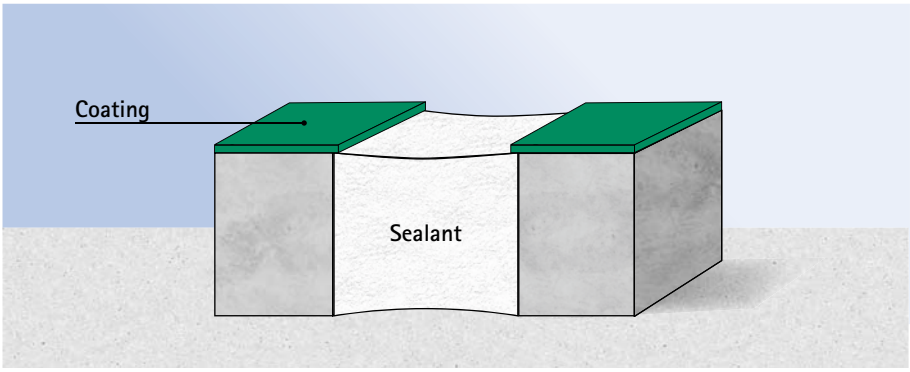
Two-component sealants on a polysulfide base only play a minor role. In general, two-component sealants are no longer of any essential significance in this area – except for individual, special markets such as India, USA or Japan.

Sealant technology	Application area	Advantages
Polyurethanes	Concrete facades, clinker construction, metal facades, render	Wide adhesion spectrum, high tear propagation resistance and high elongation at break, good weather resistance, good compatibility with coatings
STP systems (hybrid systems)	Concrete facades, clinker construction, metal facades, render	Good weather resistance, wide adhesion spectrum, good compatibility with coatings
Silicones	Glazing, metal facades, mineral building materials	High UV resistance, very good adhesion to glass, special products also for mineral building materials (natural stone, ceramics, concrete stone)

When it comes to selecting a suitable sealant, the recommendations given by the manufacturer should be followed. The durability of a joint seal depends on the quality of the sealant.

If the facade is to be painted (e.g. concrete facades), it should also be remembered that the surfaces of elastic sealants should never be entirely coated. A coating is only acceptable along the edge area (max. approx. 1-2 mm).

Illustration 5:
Executed joint seal with a subsequently applied coating



5 DIMENSIONING JOINTS

A long-lasting joint seal begins in the planning phase of a facade. The architect/planner is responsible for correctly planning and dimensioning the joint and while doing so, the following aspects should be taken into consideration:

- Correct calculation of joint movements (the calculated movements result from the properties of the building material, the length of the building elements and the expected differences in temperature)
- The required joint width is to be sufficiently dimensioned based on the anticipated dimensional change due to thermal loads and moisture and the properties of the sealant used (12.5 %, 20 % or 25 % permissible total deformation).
- Joint construction should comply with valid standards/guidelines (e.g. DIN 18540)
- Correct selection of sealant (e.g. taking permissible total deformation and compatibility with the building material (e.g. in the case of natural stone) into consideration)

Because of the high thermal loads that act on the surface of facades, it is necessary to divide the wall surface into fields or sections based on a movement joint plan. The required widths of the movement joints to be planned will depend on the materials used and their coefficients of expansion as well as the assumed possible temperature difference. The permissible total deformation of the sealant must also be a part of the calculation.

Since climate (winter/summer) and sunlight act directly on the surface of a facade, a difference in temperature of up to 100 K must be assumed when calculating possible changes in length and resulting deformation.

Calculation example:

Curtain wall facade element

Change in length Δl = original length (lo) x temperature expansion coefficient (αt) x Temperature difference (ΔT)

The measured temperature differences (ΔT) during a day (24 hours) is 80 K

Field length (lo) = 5 m

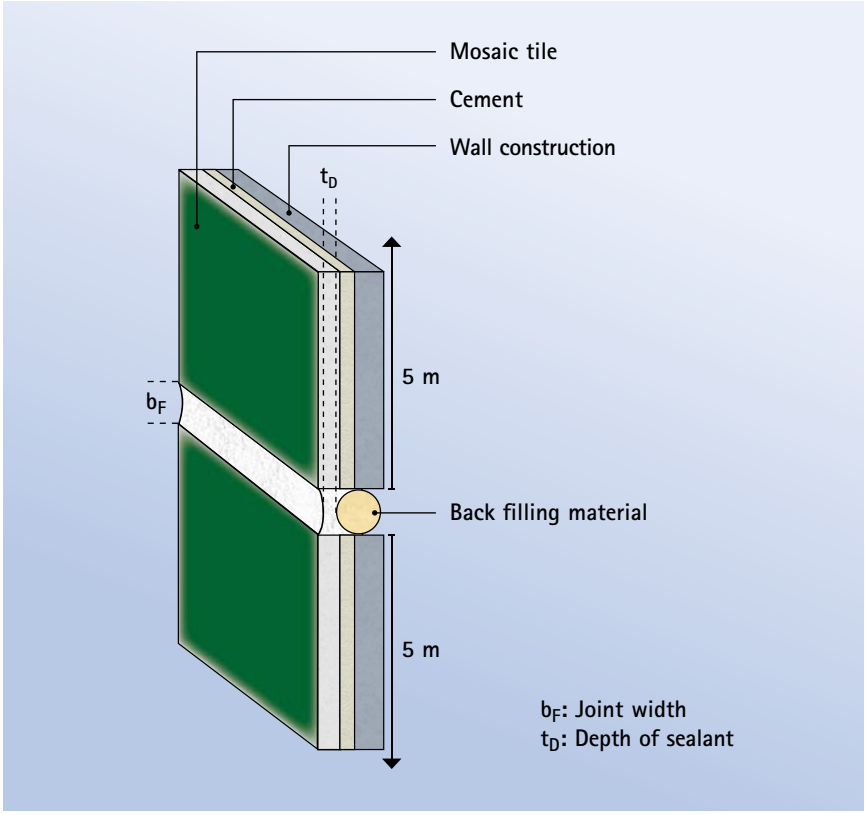
Ceramic (αt) = 0,007 mm/mK

Change in length (Δl) = lo x αt x ΔT
= 5 m x 0,007 mm/mK x 80 K
= 2.8 mm

The change in length must be compensated by the joint.
The sealant can absorb 20 % of the movement.
The dimensions of the movement joints are then determined accordingly.
20 % corresponds to the determined 2.8 mm. 100 % (total joint width) is then calculated.

Joint width (b_F) = Δl x 100 % / 20 %
= 2.8 mm x 100 % / 20 %
= 14 mm

The joint should thus be dimensioned with a width of 15 mm.



To ensure that a movement joint with an elastic sealant will function for a long period of time, it is necessary to limit the depth of the joint by using an appropriate back filling material. This is inserted into the joint before the joint is filled with the sealant. Round, closed cell foam rods with appropriate diameters as specified by DIN 18540 are most suitable. The round rod ensures that the sealant filling is shaped in the form of an hourglass at the centre, making it easier for the sealant to continuously accommodate compression and expansion.

Further notes on the formation of external wall joints in masonry or concrete facades is found in DIN 18540:

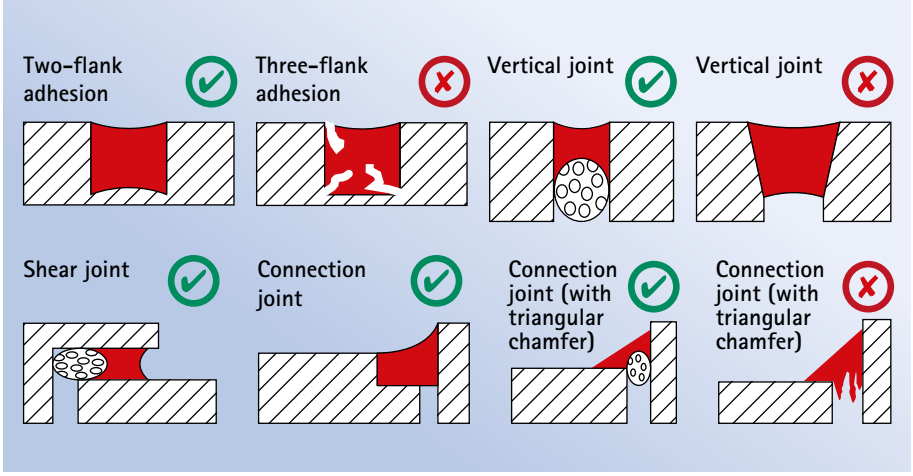
Joints and joint sealing, dimensions (excerpt from DIN 18540:2014)			
Distance between joints	Joint width b_F (mm)		Depth of joint sealant t_D (mm)
	Nominal dimension	Minimum dimension	
Up to 2 m	15	10	8
2 to 3.5 m	20	15	10
3.5 to 5 m	25	20	12
5 to 6.5 m	30	25	15
6.5 to 8 m	35	30	15

The values in the table apply to large-format concrete elements under the assumptions set out in the standard.

Correctly dimensioned joints minimise the forces that act on the bonded surfaces and prevent peak stress.

Correct dimensioning is important if the sealant is to be able to compensate movements of the building elements and maintain its sealing function at the same time. Joints that are too narrow cannot sufficiently accommodate movements. The resulting cohesion cracks and structural changes prevent the seal from functioning properly.

Illustration 6:
Deformation and expansion



6 PROPER APPLICATION

If a sealant is to seal a building element joint tightly, the material must be brought into the joint properly. Optimal adhesion between the sealant and building element cannot be achieved on dusty, greasy or wet substrates. It should also be kept in mind that a certain sealant will not adhere equally well to any substrate.

The respective primer recommendations given by the manufacturer should always be observed. Primers improve the adhesion behaviour of the sealant and substrate and should be selected based on the material and situation. The use of a primer does not eliminate the need to clean the bonding surface! After the primer has flashed off – make sure that the flash off time is neither too short nor too long – the sealant is then applied.

When applying the sealant, make sure that it is applied bubble-free in a continuous bead without interruption. Good contact to the flanks of the joint is achieved by subsequently pressing and smoothing the sealant. Smoothing agents should be coordinated to the sealant to rule out incompatibilities and ensure that there will be no staining.

- The sealant must be correctly applied.
- Sealing work should only be executed under the conditions specified by the sealant manufacturer (e.g. temperature, moisture).
- It must be ensured that the flanks of the joints have sufficient strength as a substrate so that they can accommodate the tensile stress exerted by the sealant without damage; bonding surfaces must be clean, dry and free of grease.
- Only auxiliary materials (e.g. adhesion promotors, back filling rods, smoothing agents) specified by the manufacturer of the sealant should be used.
- A non-absorbent, closed cell, back filling material should be used to prevent adhesion to three sides and to limit the depth of the joint. The material must meet class E requirements pursuant to EN 13 501-1.
- A building site log should be kept.

7 MAINTENANCE AND REPAIR

The durability of a sealant installed in a facade is only given for a limited period of time. Along with the quality of the sealant, other factors such as the geographic location of the facade, climate conditions (direct/indirect sunlight), alternating frost-thaw cycles, cleaning agents, etc. will also affect their durability. In view of the many loads to which sealants are subjected, it is a good idea to examine the state of the joints every so often. This allows obvious damage to be discovered in time – at least in the area of the joint that is accessible and visible. Depending on the complexity of the facade construction, it may also make sense for the building operator to conclude a maintenance contract with the contractor who applied the sealants.

When does a joint need to be replaced?

Essentially, two items should be clarified:

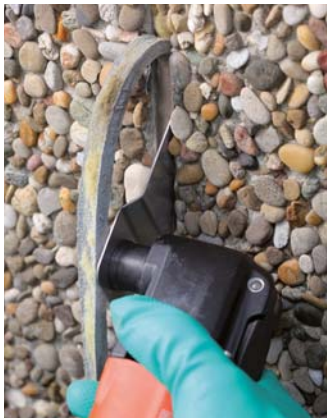
- **Does the sealant still adhere to the flanks of the joint?**
  If not, this is referred to as detachment from the flank or adhesion failure. The result is a gap between the sealant and the flank of the building element.

- **Has the appearance of the sealant changed?**
  A tacky surface, change in colour, brittleness (net-like cracks), formation of cracks (cohesion cracks) indicate that the joint seal has worn.

In both cases, the sealant is no longer or only partially able to function (sealing and movement compensating functions). Rain water can enter the joint construction, e.g. where the joint sealant has detached from the flank of the joint, and the resulting penetration of moisture can cause damage to the building. In these cases, the joint sealant should be renewed as soon as possible.

To successfully renew a joint sealant, it is important to know why the sealant failed:

- The construction of the joint may be incorrect (e.g. the joint may not be wide and/or deep enough).
- The joint flanks might not have sufficient strength.
- The wrong sealant was used (e.g. insufficient permissible total deformation, insufficient UV resistance, the quality of the sealant was not suitable for the purpose).
- The building materials and sealant are not compatible (e.g. in the case of natural stone discolouration in edge zones caused by the migration of plasticizers).
- Sealing work was not properly executed (e.g. a primer was not used, back filling was not used or an improper back filling was used, the sealant was not applied in a sufficient depth).



How is the joint sealant replaced?

Once the cause of failure is known, the joint sealant can be replaced.

Renewing joint sealants with gunnable sealants

When renewing joint sealants on facade elements, sealants defined in DIN EN 15651-1 "Sealants for facade elements" should be used.

To renew the joint sealant, the old sealant, including backfilling, must be completely removed first. The old material and the new sealant are seldom compatible and since the time and expense of testing compatibility would be disproportionately great, thorough removal of the old sealant is recommended.

Once the old sealant has been removed, the substrate should be dry, load-bearing and free of dust and grease before the new sealant is applied according to the instructions given by the manufacturer.

If it is not possible to completely remove the old sealant from the joint, a sealant on the same raw material base should be used for renewing the joint – however, the type of the old sealant to be replaced must be known or determined.

When the remains of old sealants are left behind in the joint, they become the bonding surfaces for the new sealant instead of the original building material (e.g. concrete). Therefore, the old and new sealant must not only be compatible, the fresh sealant must also adhere to the old sealant. Renewing the joint sealant with a gunnable sealant will only be successful if these conditions are met.

However, it is not always possible to renew the joint with a gunnable sealant, e.g. when damage is caused by a joint that is too narrow, the depth of the joint is insufficient or the flanks do not have sufficient strength. For these cases there are alternative sealing systems such as impregnated joint sealing tapes or elastomer water stops.

8 SUSTAINABILITY

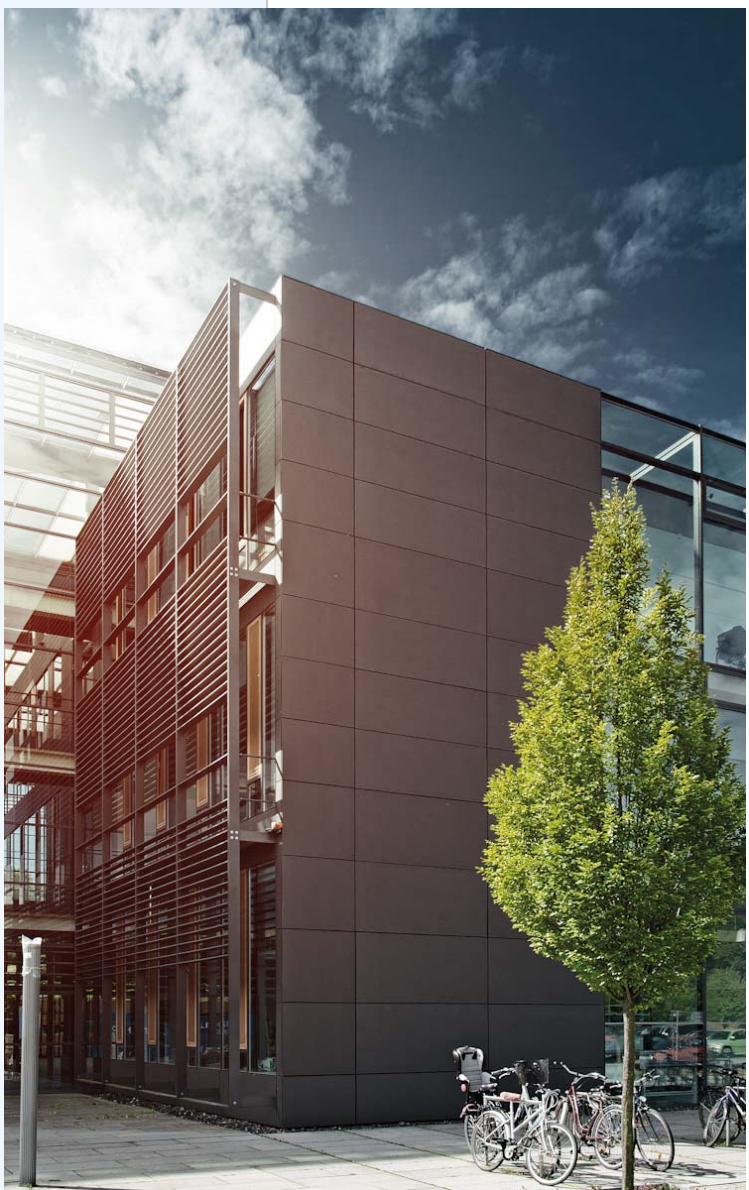
The sustainability of structures and buildings is a subject that is becoming more and more important, not only in regard to construction but also utilisation. Even products that are used in relatively small quantities can make an important contribution in the sustainability of a building.

Correctly applied, high quality sealants for buildings have a positive influence on all aspects of sustainable construction.

They prevent the ingress of moisture which not only extends the service life of the structure but also improves the actual state of the building which in turn reduces expenses for maintenance and enhances the quality of living and utilisation.

When joint sealants are used in facades they contribute to sustainability by

- Protecting against the influence of weather
- Extending the service life of building elements
- Extending the life of the building
- Making it technically possible to realise attractive facade constructions
- Improving the quality of living/eliminating drafts



The trend to high performance and environment-friendly products shows a responsible attitude towards the environment and resources. The result of this is a long life of the sealant as well as the building.

Through systems for certifying buildings (e.g. Leed or DGNB [German Sustainable Building Council]), it is possible to assess a building by the building products used. Sealants can meanwhile also be included in this certification. The Model Environmental Product Declarations (EPDs) prepared by Deutsche Bauchemie for building sealants can serve as a basis for this.

MUSTER EPD
Deutsche Bauchemie e.V.

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10 EPILOGUE

This Information Script "Planning Movement Joints in Facades" was prepared by Project Group 7.4 "Facade Sealants" and adopted by Expert Committee 7 "Building Sealants". It is intended as a source of information for member companies as well as the specialist community.

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Deutsche Bauchemie e. V. would be pleased if you would share your experience regarding the subject of this Information Script and invites you to make comments which should be directed to the main office in Frankfurt.

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