Technical Note No. 19

SELECTION AND USE OF SEALANTS

Introduction

The principal role of a sealant installed within a cladding system or around the perimeter of a window frame is to seal the joint against water ingress and/or air leakage. It must be able to maintain the seal while accommodating variations in joint size due to manufacturing and erection deviations, and repeated building movements induced by externally applied loads and changes in environmental conditions. This Technical Note describes the range of sealants currently available, summarises the selection process and identifies issues important to the successful functioning of sealants. Further guidance on the design of sealant joints is given in Technical Note 20 *Design of sealant joints*.

Performance

The properties required of sealants are as follows:

- Adhesion to the substrate material(s) without damage (e.g. staining);
- Ability to deform to accommodate movement of the joint;
- Weather resistance and durability.

For the sealant to perform these functions:

- An appropriate generic type and formulation of sealant (and if necessary primer) must be selected. Materials should preferably be supplied by a reputable manufacturer;
- The sealant joint must be properly designed, constructed and prepared;
- The sealant must be correctly mixed (two-part systems), installed and tooled.

A sealant should normally be applied as part of a system. Primers help to provide adhesion to the sides of the joint however adhesion to material at the back of the joint may restrict movement and may be prevented by using bond breakers. The use of a backing strip helps to ensure the correct depth of sealant and a joint filler may be used to help form the joint prior to sealant installation. Some types of backing strip also act as a bond breaker. Figure 1 shows the components of a typical joint.

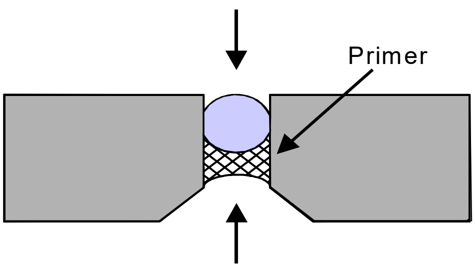

Figure 1 Components of a typical sealant joint.

Accommodation of joint movement

Joints may be static (i.e. fixed) or dynamic (i.e. moving). Most joints in windows, cladding and curtain walling systems are dynamic and will have to accommodate:

- Single uni-directional movements (e.g. concrete drying shrinkage and creep, ground settlement);
- Repeated reversible movements (e.g. thermal and moisture movement).

There are two basic types of behaviour exhibited by sealants, namely elastic and plastic deformation, however, some elastic sealants exhibit some plastic properties and some plastic sealants exhibit some elastic properties. Further details are given below.

Elastic sealants (e.g. polyurethane, silicone)

These respond immediately to joint movement, the induced stress being closely proportional to the imposed strain, with rapid recovery when the stress is removed. Elastic sealants are suitable for joints subject to large, frequent, cyclic movements, and hence for sealing external components of low thermal mass, for example thin walled metal panels. When used for joints which give slow or permanent movements the sealant will be subject to stress for long periods increasing the risk of adhesion failure.

Plastic sealants

Plastic sealants exhibit minimal and slow recovery from deformation when stress is removed and are only suited to joints of negligible and relatively slow movement; large frequent cycles of movement lead to creasing, folding and eventual splitting. They have been successfully used to seal joints in traditional construction and in heavyweight cladding systems but they are not recommended for most cladding applications. Non-curing sealants become stiffer with age, and less able to accommodate movement or deform plastically.

Elasto-plastic sealants (e.g. polysulfides and some acrylics, and silicones)

These have predominantly elastic properties, but exhibit some plastic properties when stressed for other than short periods (the relaxation of stress reduces the risk of adhesion failure). The more elastic types can accommodate cyclic movements.

Elasto-plastic sealants are best suited to slow moving and permanently deformed joints such as in masonry and concrete/stone cladding systems.

Plasto-elastic sealants

Plasto-elastic sealants have predominantly plastic properties with some elastic recovery when stressed for short periods. Like elasto-plastic sealants they are suited to slow moving joints, for example between components of high thermal mass such as concrete and stone cladding panels.

Sealant modulus

Where sealants exhibit elastic properties, deformation of the sealant will induce stress in the sealant. The relationship between stress and deformation is governed by the elastic modulus. For a high modulus material a small deformation will give rise to a large stress whereas a low modulus material will generate a low stress under a much larger deformation.

The effect of the induced stress on the performance of the sealant will be taken into account in deriving the Movement Accommodation Factor, which is described below. However the stress in the sealant will cause stresses to be set up in the material adjacent to the joint and this should be considered in the selection of the sealant and the design of the joint. These stresses will be most significant when the sealant has to accommodate large movements and the adjacent material is weak.

The low stress resulting from low modulus material is generally an advantage where the material is used as a pure sealant but is a disadvantage where the sealant is used as an adhesive or subject to loads as in structural sealant glazing for example.

Movement Accommodation Factor

In order to design joints it is necessary to know how much movement a proposed sealant can tolerate. To achieve this, BS 6093 and 6213 use a value called the Movement Accommodation Factor (MAF), which is defined as the total movement which a sealant is capable of tolerating throughout its working life expressed as a percentage of the minimum joint width.

Sealant types

Traditional sealing materials such as oil based mastics and caulks exhibit plastic movement characteristics and usually have a short service life. They are not generally suitable for most cladding situations which are subject to repeated movements and are not included in this Technical Note.

There are four generic types of high performance grade sealants, which are available in different forms (e.g. one/two parts and high/low modulus) to suit particular situations. Some require a primer material to adhere to particular substrates. The typical characteristics of each type of sealant are summarised in Table 1.

Acrylic resin sealants

Acrylic resin sealants are available in solvent- and water-based forms. Solvent-based acrylics have excellent weathering properties and adhere well to a wide range of substrates, including lightly contaminated surfaces. Therefore, they are primarily used for refurbishment work. Generally acrylic sealants do not require primers, except when used on friable materials.

Water or emulsion-based types are primarily used for sealing internal joints, for example for the perimeter of doors and windows. If used externally they are vulnerable to wash-off with rain before they have formed an effective skin, and so can only be applied externally under satisfactory conditions. Most of these sealants exhibit a large amount of shrinkage on drying and produce a substantially plastic seal capable of accommodating only limited movement

Polysulfide sealants

Polysulfide sealants are available as one- and two-part systems. They are elastoplastic in nature and will accommodate both cyclic and permanent deformation movements.

One-part materials cure (starting from the surface) on exposure to atmospheric moisture and are termed neutral cure because the by-product liberated during cure is neither acid nor base. Although easy to use, they cure relatively slowly - two or three weeks depending on the joint configuration, location and atmospheric conditions during cure.

Once mixed, the two-part sealant cures to a rubber-like material usually within one to two days. This can be useful when sealing larger joints because two-part polysulfides require on-site mixing, but curing takes place more rapidly and uniformly throughout the body of the material. The seal can be built up in stages to prevent slumping.

Polyurethane sealants

Polyurethane sealants are available as one- and two-part materials. One-part materials cure (normally rapidly) on exposure to atmospheric moisture. Two-part polyurethane sealants require on-site mixing, with curing taking place uniformly throughout the body of the material.

Most polyurethane sealants have very good elasticity and are generally relatively tough, but primers are required to achieve good adhesion on many surfaces.

Polyurethane sealants are now produced in both low and high modulus forms, giving them a wide range of uses. Durability depends on the nature of the polymers used but a life of between ten and twenty years is generally expected.

Sealant type: BS no.	Acrylic	Polysulfide one-part BS 5215	Polysulfide two-part low modulus BS 4254	Polyurethane one-part	Polyurethane two-part	Silicone one-part low modulus BS 5889
Rate of cure	Slow	Slow-intermediate	Intermediate-rapid	Intermediate	Rapid	Intermediate-rapid
MAF	5 to 15%	15 to 25%	15 to 25%	15 to 25%	15 to 25%	25% +
Rate of movement	Slow	Intermediate	Intermediate-rapid	Intermediate-rapid	Rapid	Rapid
Physical character	Plasto-elastic, Plastic	Elasto-plastic	Elasto-plastic	Elastic	Elastic	Elastic
Expected life yrs	15	20	20	20	20	25

Table 1 Typical characteristics of wet-applied sealants

Silicone sealants

Silicone sealants are commonly available as single-component materials and are probably the most durable. Skin formation is generally rapid, and the acid-curing versions (where the liberated by-product during cure is acid) cure quickly in depth. Low, medium and high modulus silicone sealants are available for sealing high to low movement joints respectively. Two-part silicone sealants are used in the manufacture of factory sealed insulated glazing units.

Silicone sealants generally have a very strong affinity for glass and glazing surfaces. They will adhere to many other materials but on some a primer may be required.

Adhesion to substrate(s)

Some sealants are incompatible with particular substrates or other types of sealant, or instead require a primer material to be applied to the joint faces. Guidance on the selection of sealants is given in BS 6213.

Compatibility with substrate (staining)

Migration of the oils and uncured plasticizers from the sealant into the substrate will produce a perimeter band of stain that cannot be washed or ground off. Ordinary silicone, for example, can bleed into stone (particularly slate and marble) and staining may also occur with some polyurethanes, acrylics and polysulfides.

Migration depends on the level of free fluids in the sealant, the porosity of the substrate and the thermal movement of the joint.

The risk of staining can be minimised by the use of appropriate primers, particularly those which form a film which prevents direct contact between the sealant and substrate. Recessing the seal behind the front face of the panel will also help to limit the spread of staining.

The safest option is to select a non-staining sealant that has been specifically formulated for the substrate. The performance of the proposed sealant/substrate combination should then be checked either by inspecting previous successful installations or testing of samples.

Sealant discolouration

Airborne dirt will accumulate on the surface of the sealant during and after the curing process because of exposure to the outside environment and the physical properties of sealants.

During the curing cycle dirt may adhere to the tacky surface of the sealant and become embedded. Sealants with a slow surface cure (e.g. one-part polysulfides and polyurethanes) and a low surface hardness, which are exposed to cold, dry and dusty environmental conditions are particularly prone to dirt pick-up. Abrading away the surface of the sealant is the only means of removal.

After sealant cure, dirt will naturally be deposited over time. Particular properties, characteristic of some modern sealants, can exacerbate this occurrence. For example, the surface of silicone is not wetted by water (i.e. it is hydrophobic) but the static charge that builds up on its surface attracts dust particles and prevents washing by rainwater. Dirt pick-up after the surface has developed full cure can generally be removed, by cleaning, with a mild detergent for example.

Chalking can be exhibited by polyurethane sealants, and to a lesser extent polysulfide sealants, as they age, and is caused by degradation of organic polymers due to exposure to ultra-violet radiation. As the polymer is degraded, filler is exposed on the surface affecting the uniformity of colour. The sealant surface may additionally exhibit a cracking or crazing effect, although, particularly with polysulfides, these usually remain quite shallow and do not propagate into tears.

Temperature resistance

Temperature has a major indirect impact on the performance of sealants, as, generally, it is the main cause of joint movements.

Over longer periods (10 to 25 years) high temperature is a critical factor in determining the service life of the sealant as it will accelerate chemical degradation initiated by moisture and sunlight and thus contribute to the deterioration of its physical properties, including adhesion.

Falling temperatures increase joint widths and induce tensile stresses in the joint seal. Winter temperatures in the UK are not sufficiently low for sealant materials to reach their glass transition temperature (where an abrupt change in modulus occurs) but they will behave as stiffer materials with a reduced stress relaxation. Stiffening is particularly significant for the more plastic one-part acrylic sealants, whereas silicones and other elastic sealants are relatively unaffected.

Installation

For the joint to perform as intended, its constructed width must lie within certain limits, depending on various factors as follows:

- Joints of excessive width are unsightly, and difficult (and costly) to seal as the large mass of sealant will tend to slump under its own weight. It may be possible to prevent slumping by installing the sealant in stages by sealing across the back two corners of the joint and later installing sealant to fill the joint.

- Conversely, narrow joints are difficult to clean, prime and seal and can over-strain the sealant because movement of the joint will be large in relation to the joint width. It may be possible to substitute the proposed sealant with another type having increased movement accommodation (e.g. lower modulus), or seal the joint at the mid-temperature (i.e. mid-movement) point to utilise the full movement capacity of the sealant.

A major cause of failure of sealant joints is inadequate preparation of the substrates resulting in premature loss of adhesion. Because sealants are workmanship-sensitive and perform a fundamental role, which if not satisfied will be expensive to rectify, a specialist applicator who is a member of the Association of Sealant Applicators (ASA) should be used.

Good joint preparation involves:

- An assessment of the type, nature and condition of the joint surfaces;

- Removal of surface contaminants such as dust, loose particles, corrosion products, water, release agents and grease;
- Applying masking tape to the outside edges of the substrate to prevent primer staining and ensure a neat sealant finish;
- Application of the recommended primer or surface conditioner to improve the inherent adhesive strength and/or bond durability between the sealant and the prepared substrate.

Good sealant installation entails:

- Installation of a backer-rod into the joint to form the correct joint depth. For joints sealed on both sides (e.g. structural glass assemblies) a temporary backing is used which is removed after sealant cure.
- Application of bond-breaker tape to the back of the joint face so that the sealant is bonded only to the sides of a movement joint and is free to deform. Some backer rod materials with appropriate surface release properties will perform this function (e.g. closed cell polyethylene with a surface skin) and a separate bond breaker is unnecessary.
- Mixing (two-part sealants) in the correct proportions by a suitable power-driven mixer operating at low speed to minimise air entrapment (which can cause surface bubbling) and heat generation (which shortens application life).
- Application of the sealant within the 'open time' of the primer/conditioner (i.e. after primer has dried but before the surface is deactivated) and the application life of the sealant after mixing (two-part sealant systems). Sealants should not be applied to green mortar/concrete or when air temperatures are below 5°C because frost or condensation may be present on the substrate.
- Tooling the sealant to remove any entrapped air, which could cause surface bubbling and/or attract water, to aid contact of the sealant with the joint sides, which will maximise adhesion, and to produce a satisfactory finish. Tooling also produces a slightly concave surface, which reduces internal stresses arising from joint movement.
- Removal of masking tape before the sealant has cured.

Durability

All polymer systems suffer from some form of degradation as a result of being exposed to ultraviolet radiation and weathering. This is accelerated in situations where the polymer is under stress. The performance of a sealant joint in service is determined by its exposure, size, geometry and the materials used. The design life of sealants according to manufacturers' estimates are given in Table 1.

Sealant selection should be based on the planned life span of the building or cladding system. Performance will be maximised by using materials conforming to the British Standard, which have the correct polymer content, and by the use of adhesion promoters.

Summary

Proper selection of a sealant system requires knowledge of the substrate material(s) and the expected movement of the joint. For any sealant to function properly, the joint must be properly designed, constructed within the installation and working range of the sealant and then correctly prepared and sealed. Deficiencies in any one of these operations will affect the durability of the sealed joint and the performance of the cladding system.

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