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Norwegian Building Research Institute

Tore Gjelsvik,
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Building Sealants

Oslo/Trondheim 1987

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by

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NBI, Trondheim Division

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Preface

Building sealants constitute an important part of the modern building technology. Metal curtain walls and large panel systems could for instance hardly have done without them.

The Trondheim Division of the Norwegian Building Research Institute started their activities on building sealants in 1959. For many years, sealants and jointing problems belonged to their main working areas. Problems dealt with have covered classification of sealants and other types of jointing materials, test methods and test programmes, systems for selection of sealants as well as design of joints.

A number of publications has been presented over the years. In the present report, the accumulated knowledge has for the first time been put together in one single publication. This is at the same time an up-graded version of the material, including new knowledge and recent experiences.

Tore Gjelsvik at the Trondheim Division has been responsible to the examination of a vast material and concentration into one single report. He has been assisted by Siri B. Berg and Tor Steinar Johansen.

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Oslo/Trondheim, September 1987

Åge Hallquist

Åge Hallquist

Summary

Sealants are important in present-day building technology. A wide variety of materials is available, with highly different properties and applications. Classification of the materials is difficult, but a general classification of sealants has been developed and used with good results.

Many properties of sealants are interesting to know. As a result, testing is usually complicated and comprehensive. In the present report a high number of properties is discussed briefly and useful test methods given together with suggested evaluation of the results.

Correct use of sealants is quite as important as good materials. Joints have to be designed the right way, preferably with two-stage seals. Type of sealant has to be selected and correlated to the joint width; movements and tolerances or deviations taken into account. Correct joint shape and proper workmanship are also important points.

Different types of sealants have different possible applications. Suitable main application areas are given for the different types of sealants according to the general classification. The interesting properties for each combination of type of sealant with main application area are judged. The results are summarized in eleven tables. These can form the basis of test programmes. A possible new short test programme is also discussed briefly.

A reference list is given. Up-to-date English versions of the NBI test methods are included as the last chapter.

1 Sealants in buildings

Sealing of joints is an important part of the modern building process. This is a result of the development in the building industri over a number of years. The amount of prefabrication has increased greatly, new materials and constructions have been introduced, and, at the same time, the individual components have increased considerably in size. This development has in many ways been a happy one, and also a necessity in a changing world. The jointing problems have, however, become far more extensive than ever before.

It is usually considered necessary to seal joints to avoid penetration of air, water, vapour, smell, noice, insects etc. The requirements can differ much, but normally the sealing against air, water and vapour is considered most important. This can be achieved by the selection of good materials as well as sensible details in the design. The second point can be just as important as the first one.

1.1 Jointing materials

A wide range of materials is available for sealing joints. Classification of all the different products is difficult, but a general classification system for jointing materials for building constructions does exist (1). This will be used as a basis here.

In the classification system, the jointing materials are divided into the following six main groups or sorts:

Main group 1 : Caulks

Main group 2 : Strips and beads

Main group 3 : Sheet materials

Main group 4 : Rigid fillers

Main group 5 : Sealants

Main group 6 : Gaskets

The main groups are further divided into a number of subgroups, and the latter again into a number of types. **Table 1** is showing the subdivision of main group 5, sealants. It should be pointed out that the numbering in Table 1 does not imply any kind of quality gradation with regard to rising or falling number. Attempts have been made to put the groups and types in a logical order, but still the numbering is more or less arbitrary and mainly for identification purposes.

1.2 Building sealants

This is one of the most important groups of jointing materials. It is a very comprehensive group, and covers products like putties, plastic glazing compounds, mastics and elastic sealants. Common to all products are that they are based on organic materials, and have a paste-like consistency at the time of application. In aged condition they retain at least a certain degree of plasticity and/or elasticity, which makes them able to accomodate smaller or greater joint movements.

The classification of sealants given in Table 1 has been used by the Norwegian Building Research Institute for a number of years (2), but has also received a certain international interest. The products are here divided into eight subgroups. It is perhaps not so easy to see the distinction judging only from the names on the subgroups. It should be pointed out, however, that the most important differences between the subgroups are found in the products' ability to accomodate movements and in their expected service life. More information will be found in **Table 2.**

In earlier days, sealants were usually made from drying oils or bitumen. Such products also exist today, and are in fact still widely used. The present products are, however, usually modified by the addition of non-drying oils, synthetic resins and polymers, adhesion-promoting additives and various types of stabilizers. The modifying additives improve the properties of the traditional materials, but do not change their basic characteristics.

In the Tables 1 and 2, the traditional materials are found in the subgroups 51, 52, 53, 56 and partly also in 57. In a way, the subgroups 51-53 can be said to constitute the old series of skin-forming sealants. More interesting to the builders are usually the subgroups 54, 55, 58 and partly also 57. The subgroups 54, 55 and 58 cover a continuous range of products from purely plastic to nearly fully elastic materials. They are almost completely based on synthetic materials, and can be termed the new series of sealants.

1.2.1 Group 51. Rapid hardening putties

The products in this group are based on drying oils, and mostly intended for face glazing. They have so far usually been applied by knife, but the development is moving towards gun application.

Rapid hardening putties stiffen gradually, and finally become hard. The movements which can be accomodated at a later stage are approximately zero. The use of rapid hardening putties should therefore be restricted to small lights in comparatively "dead" framing materials, as steel, concrete and wood.

It is essential to use a good quality putty, with a sufficiently high oil content (about 15%). Porous substrates like wood must be pretreated with oil or

Table 1 Subdivision of main group 5, sealants

51	Rapid hardening putties	511	Wood sash putties
		512	Metal sash putties
52	Plastic glazing compounds	521	Plastic glazing compounds, knife grade, one-part
		522	Plastic glazing compounds, knife grade, two-part
		523	Plastic glazing compounds, gun grade, one-part
		524	Plastic glazing compounds, gun grade, two-part
53	Skin-forming plastic sealants	531	Standard quality gun grade skin-forming plastic sealants
		532	Standard quality knife grade skin-forming plastic sealants
		533	Glazing quality gun grade skin-forming plastic sealants
		534	Glazing quality knife grade skin-forming plastic sealants
54	Non-skinning plastic sealants	541	Non-skinning plastic sealants, gun grade
		542	Non-skinning plastic sealants, knife grade
55	Tough plastic sealants	551	Standard quality gun grade tough plastic sealants
		552	Glazing quality gun grade tough plastic sealants
		553	Standard quality gun grade tough plastic narrow joint sealants
		554	Gun grade tough plastic sealants for indoor applications
56	Thermoplastic sealants	561	Hot poured thermoplastic sealants for horizontal joints in horizontal constructions
		562	Thermoplastic sealants, hand applied at slightly elevated temperatures
57	Strip sealants	571	Standard quality non-drying plastic strip sealants
		572	Standard quality partly cured plastic/elastic strip sealants
		573	Glazing quality partly cured plastic/elastic strip sealants
		574	Standard quality thermoplastic strip sealants
58	Elastic sealants	581	Standard quality two-part gun grade elastic sealants
		582	Glazing quality two-part gun grade elastic sealants
		583	Standard quality one-part gun grade elastic sealants
		584	Glazing quality one-part gun grade elastic sealants
		585	Traffic bearing two-part gun grade elastic sealants
		586	Traffic bearing one-part gun grade elastic sealants
		587	Traffic bearing two-part cold poured elastic sealants
		588	Traffic bearing one-part cold poured elastic sealants

special primer to avoid undue absorption of oil into the substrate and subsequent drying and cracking of the putty. Adequate functioning is nevertheless dependent upon protection by paint, and regular paint maintenance is essential.

1.2.2 Group 52. Plastic glazing compounds

This is a fairly comprehensive group covering one- as well as two-part products. The materials are ususally applied by knife, but the use of gun grade materials is increasing.

Plastic glazing compounds are based on drying oils, modified with non-drying oils, synthetic resins etc. For this reason, they will dry out and stiffen more slowly than the rapid hardening putties. In a way, it would be more correct to use the term "slowly hardening putties" instead of "plastic glazing compounds".

These products have generally been used for bead glazing, especially of sealed glazing units. Practical experience has proved the normal service life to be from 1 to 5 years, and only in specially favourable cases longer than that. Extremely short service lifes have been recorded when the substrate has not been properly treated to avoid absorption. It is advisable to restrict the use of plastic glazing compounds to comparatively small panes at sheltered locations. Paint protection is usually necessary.

1.2.3 Group 53. Skin-forming plastic sealants

The products in this group are usually very sticky and are applied by gun, although some knife grade materials do exist. They are intended as more general sealants for joints between concrete, bricks, wood, steel etc, **Fig. 1.**

Skin-forming plastic joint sealants are based on drying oils, non-drying oils, synthetic resins and polymers. The drying oils are incorporated in sufficient amount to make the sealants form a skin in a couple of days. The bulk of the material under the skin will remain soft for a longer period of time, and only stiffen slowly, **Fig. 2.** The required aging properties are usually only obtained with a bead of selants not less than 10 mm wide and 10 mm deep. Only some special types of glazing sealants permit a reduction of width to about 5 mm.

Table 2. Survey of the most important details concerning the different classes of sealants.

Type of material	Rapid hardening putties	Plastic glazing compounds	Skin-forming plastic sealants	Non-skinning plastic sealants	Tough plastic sealants	Thermoplastic sealants	Strip sealants	Elastic sealants
group number	51	52	53	54	55	56	57	58
Main ingredients	drying oils chalk	drying oils synthetic resins chalk fibers	drying oils non-drying oils synthetic resins and polymers fibers	non-drying oils resins and polymers fibers	polyacrylates plasticized butyl rubber and other polymers, pigment solvent	rubber bitumen, resins fibers	non-drying oils and polymers. Partially vulcanized polymers, rubber bitumen, fibers	polyacrylate polymers polysulphide » polyurethane » silicone polymers pigments
Method of application	knife or gun	knife or gun	gun or knife	gun or knife	gun	hot poured or hand	hand	gun or cold poured
Recommended applications	face glazing	bead glazing bedding	joints between concrete, bricks, wood, steel etc. bead glazing	hidden joints between concrete, bricks, wood, steel etc.	joints between concrete, bricks. wood, steel, aluminium etc. bead glazing	horizontal joints in floors, roofs etc. Hand applied materials also vertical joints	lap joints in building panels. Back-up for other sealants. Bead glazing	Joints between concrete, bricks, wood, steel, aluminium etc. Bead glazing
Dimensions of joint max. width, mm min. width, mm min. depth, mm	 — — —	 6 — 10 3 10	 15—25 10 10	 15—25 5 6	 15—25 3 3	 15—25 10 10	 25 1 3	 20 3 3
Max. permissible joint movement, aged materials. tension-compression % shear %	 approx. 0 approx. 0	 5 20	 10 40	 10 40	 15 50	 10 40	 5 40	 25 75
Adhesion	Fair	Fair	Poor to good	Fair to good	Good	Good	Good	Good to excellent
Aging properties	Skin is formed in some days. Stiffen gradually and become hard.	Skin is formed in some days. Stiffen gradually. Adhesion reduced on aging.	Skin is formed in some days. Stiffen gradually. Adhesion reduced on aging.	Non-skinning, stiffen gradually. Adhesion reduced on aging.	Non-skinning, but tackfree in a week or so. Cure throughout in 3 to 6 months. Stiffen gradually. Adhesion reduced on aging.	Tackfree after cooling. Stiffen gradually. Adhesion reduced on aging	Remain tacky. Stiffen gradually. Adhesion reduced on aging	Cure to rubbery products. Hardness increases gradually. Adhesion reduced on aging
Expected service life	Variable, see below	1 to 5 years.	5 to 15 years.	5 to 20 years	15 to 20 years	1 to 10 years	20 years or more	20 years or more
Remarks	Only for glazing small panes. Require painting and regular paint maintenance. Service life from 1 to 25 years, dependent on conditions.	Only for glazing small panes. Must usually be protected with paint. Can only accomodate small movements.	Joint movement should not exceed 10 % in tension. Painting usually not recommended.	Only for hidden joint where discoloration by dirt collection is not objectionable.	Joint movement should not exceed 15 % in tension. Painting usually not recommended.	Poured material only for horizontal joints in horizontal constructions.	Should preferably be squeezed during mounting	Should only be applied by specialists. Painting only with special paints.

Fig.1. Old-fashioned joint between concrete panels with skin-forming plastic sealant in perfect condition

The ability to accomodate movements can differ much from one material to another. Some manufacturers claim figures as high as 25 % elongation in butt joints. A figure of 10 % seems more realistic, although there is an increased demand for a 15 to 20 % material.

Painting of these products is usually not necessary. On the contrary, most conventional paints will destroy the flexibility of the skin. Painting should thus only be carried out with flexible special paints.

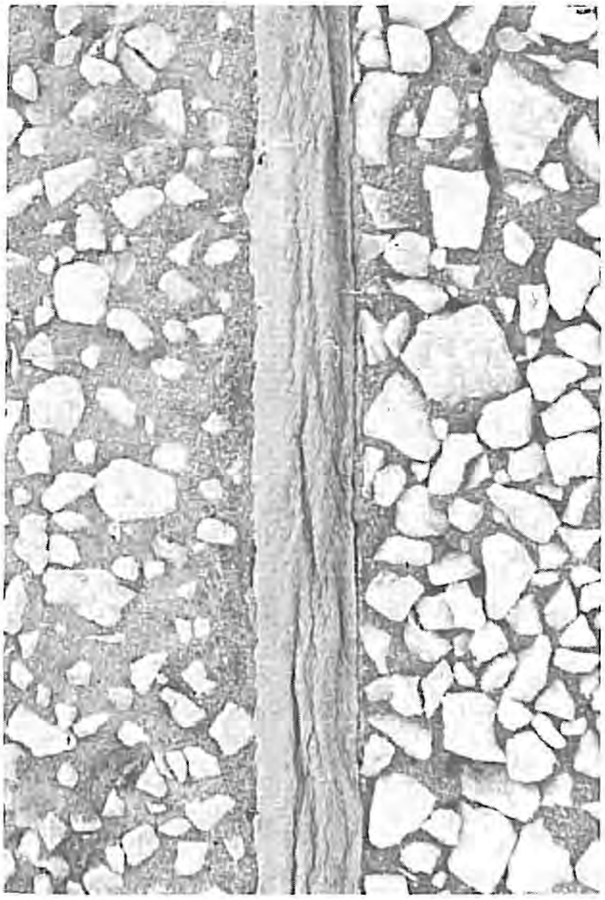


Fig.2. Vertical joint between conrete panels with typically wrinkled skin-forming plastic sealant

Expected service life is usually from 5 to 15 years.

1.2.4 Group 54. Non-skinning plastic sealants

The products in this group are based on non-drying materials like polybutenes and polyisobutylenes. They do not contain drying oil, and do not form a skin but remain tacky. They are usually applied by gun, but knife grade materials do exist.

Non-skinning plastic sealants can be used to seal joints between concrete, bricks, wood, steel etc. Since they remain tacky, they can only be used where discoloration by dust and dirt collection is not objectionable. These materials have so far not been much used, and are more of academical interest than practical importance. There is, however, an increasing interest in such materials. Their ability to accomodate movements is not known in detail, but is assumed to correspond roughly to that of skin-forming plastic sealants, or about 10 % in the tension or compression.

Expected service life varies from 5 to 20 years.

1.2.5 Group 55. Tough plastic sealants

These products are based on plasticized butyl rubber, polyacrylates and other polymers. They are especially tough and sticky, and are applied by gun. The extrudability is usually improved by addition of a certain amount of solvent, in some cases also by heating to a slightly elevated temperature. The materials are intended as general building and glazing sealants.

Tough plastic sealants do not form a surface skin, but cure or set thoughout the bulk of material by solvent release and/or chemical reactions. The release of solvent makes them shrink, and this has to be taken into consideration. Products with undue shrinkage do also exist.

Properly formulated tough plastic sealants can be used in joints as small as 3 mm wide and 3 mm deep. Their ability to accomodate movements is about 15 % in butt joints, and the expected service life about 15 years. Painting of the materials is usually not necessary, and should in most cases be avoided.

1.2.6 Group 56. Thermoplastic sealants

The materials in this group of sealants are all rather stiff at normal temperatures, but soften considerably by heating to the application temperatures. Included are all hot poured materials, first of all rubber bitumen based, and a few materials applied by hand at moderately elevated temperature. The poured materials can of course only be used in horizontal joints in floors, roofs etc., while materials applied by hand can also be placed in vertical joints and overhanging horizontal joints.

Thermoplastic joint sealants should not be used with a bead of sealant smaller than 10 x 10 mm width by depth, otherwise their aging properties can be reduced. Expected service life is from 1 to 10 years. Recent experiences indicate that the ability to accomodate movements is much smaller for materials in this group than earlier expected. It is now assumed to be about 10 % of joint width in tension and compression and 40 % in shear.

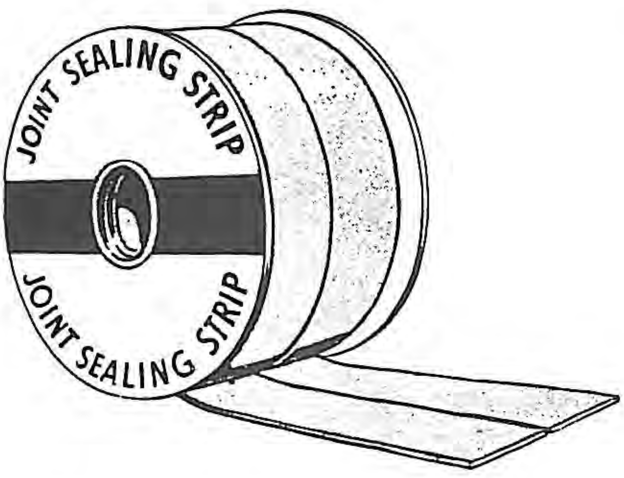


Fig.3. Typical strip sealant roll

1.2.7 Group 57. Strip sealants

The materials in this group are in fact stiffer types of plastic sealants, groups 54, 55 and 56, supplied as extruded strips, ribbons or tapes, **Fig. 3.** They have a sticky surface, and are available in rolls with an interleaving of plastic sheet or paper treated with stick-release agent. Application is by hand, sometimes in combination with special tools. Typical base materials are polybutenes, polyisobutylenes, butyl rubber and polysulphides.

Strip sealants have to be mounted with pressure and squeezed to a certain degree to obtain adequate adhesion. Typical applications are as sealants in any kind of lap joint in building panels, as back-up for other sealants, and as glazing seal.

Joint dimensions can be varied within wide limits. Due to the exellent aging properties of most of the products in this group, even a joint as narrow as 1 mm can function properly when the movements are not too great. Ability to accomodate movements is rarely more than 5 % in tension and 40 % in shear. Expected service life is 20 years or more.

1.2.8 Group 58. Elastic sealants

Some years ago, elastic sealants were exclusively based on polysulphide polymers. At present, however, this is a very comprehensive group, covering a number of products, and one-part as well as two-part materials. Most of them are applied by gun, although, application by knife is possible. A limited number of cold poured materials is also available.

The present selection of elastic sealants comprises products based on polysulphides, polyurethanes, silicones and other polymers. Several polymers can be used in different combinations, and also modified with various additives. The two-part materials usually have a pot life from 1 to 8 hours after the mixing has been completed.

All products cure to a rubbery substance, two-part products in 2 to 7 days, while one-part products need from one day up to several months. Although the cured materials are rubbery and elastic, they always show a certain degree of plasticity and cold flow when stressed.

Polysulphide materials are the elastic sealants with the longest period of practical experience. In the beginning, such materials were set to a fairly high Shore A hardness and a high degree of elasticity. This resulted in a lot of adhesion trouble and adhesive failures. Over the years they have undergone an important development, and are now made much softer than before with more balanced elasticity and plasticity. The adhesion properties have been greatly improved, and new and better primers developed. Many good products are found in this group.

Polyurethane sealants have existed in the laboratories for many years, but have been very slow to come on the market. The now available types have properties comparable with the polysulphides. Some brands are even better in some respects, for instance with regard to puncture resistance. This makes them specially suitable for horizontal joints in traffic areas. Another advantage is that primer treatment of the substrate can often be omitted.

Silicone sealants are the most elastic of the elastic sealants. Their degree of plasticity varies from very little to practically nothing. The silicone rubber itself is very durable and practically not influenced by weather and other aging factors. There has, however, been a lot of adhesion trouble, and primers have been needed on most substrates except glass and ceramics. Modern silicone sealant usually have greatly improved adhesion. Many good products are found in this group too.

Elastic sealants can also be made on various other bases than those mentioned, but more details shall not be given here.

Elastic sealants are the most advanced general building and glazing sealants. They can be used on nearly any substrate, although primers are necessary or recommended in several cases. Adhesion is good to exellent when the sealant is properly applied. Joints can be made as narrow as 3 mm and shallow as 3 mm. Ability to accomodate movements is at present estimated at 25 % in tension and 75 % in shear. Expected service life is 20 years or more. Painting is usually undesirable, and should when necessary only be carried out with special elastic paints.

1.2.9 Concluding remarks to sealants

The most important properties of building sealants are their ability to accomodate movements and expected service life. Ability to accomodate movements is usually given as a percentage of the joint width. Figures for the material dealt with here have been given in the previous sections. These figures are, however, not based on systematical laboratory testing, but on practical experiance and a lot of assumptions. It is known that the ability to accomodate movements of building sealants is not constant, but dependent on factors like the type of movement, the temperature and the aging conditions. The expected service life is in the same way dependent on movements and degree of exposure. Service life and accomodation of movements are in other words interconnected. This is a field where much work is still left to be done.

There is also no general agreement about whether a sealant shall be plastic or elastic. Some manufacturers claim that sealants shall be fully elastic, while others prefer to have at least a certain degree of plasticity and cold flow to relieve stresses in the material. The balance of plasticity to elasticity is a very interesting problem, which must also be viewed in relation to accomodation of movement and service life.

Although much is still unknown, there is at least sufficient knowledge to give advices on sensible use of sealants (3), (4), (5). One of the main rules is: Reduce the load on the sealant. Do not use sealants as a combined water and air barrier at the same point. The possibilities of early seal failures are many, and in any case the sealant will always fail ultimately. Such a one-stage seal can easily lead to serious water damage. The recommended use of sealants is as air and/or vapour barrier, although they have been used as rain screen with good results.

2 Testing of properties and evaluation of results

The primary function of a building sealant is to seal. It must seal well, and it must do so for a sufficiently long time. To be able to fulfill the primary functional requirements, it is also necessary that the sealant fulfills a number of secondary requirements derived from the primary. Due to the many different types of sealants available, the test methods and requirements will not always be the same. In the following, the individual properties are described and discussed as extensive as possible. The succession is following the CIB master list (6). The information given has partly been taken from available literature (7), (8), (9), (10), (11), but is partly also a result of new developments and more recent experiences.

Many properties can be tested in several different ways. The best way is often a matter of opinion. The available test equipment and knowledge about how to evaluate the results may be the decisive factors. Sometimes there may also be different opinions on what are the most interesting properties. For these reasons, the following examination of a number of properties and test methods should not be considered as final. It should, however, present a well balanced survey of the present situation.

2.01 Volatile content (CIB 3.1)

The mass and volume of a sealant is influenced by the volatile content. Loss of volatile constituents may result in essential changes in other properties, for instance by shrinkage.

Testing of volatile content is carried out according to test method NBI-42, NT BUILD 001. A thin layer of the sealant is heated under strictly controlled conditions, and the weight loss recorded.

The volatile content determined as weight loss on heating varies with the type of sealant. Usually figures from 1% to 15 % are found. It is difficult to put exact limits to acceptable volatile content, but the following figures can be taken as recommondations:

Group	52	maximum	3 %	by	weight
"	53	"	10 %	"	"
"	54	"	12 %	"	"
"	55	"	15 %	"	"
"	56	"	3 %	"	"
"	57	"	1 %	"	"
"	58	"	10 %	"	"

The volatile content of a sealant is given as a percentage weight loss.

2.02 Density (CIB 3.3)

The density can not be used as a measure of the quality of a sealant. It is, however, convenient to know the density when extrudability test are carried out. The density can also give some indications on various other material properties.

The density is found according to test method NBI-43, NT BUILD 002. A cylinder with known volume is filled and weighed, and the density calculated.

No requirements can normally be set to the density, but the sealants can be graded as follows:

Low density materials	< 1250 kg/m^3
Medium density materials	1250 - 1750 kg/m^3
High density materials	> 1750 kg/m^3

The density is given as a whole number in kg/m^3.

2.03 Homogeneity (CIB 3.4)

Sealants are rarely fully homogeneous. They often contain air bubbles, lumps etc. Inhomogeneities like this may influence the extrudability. Poor homogeneity may also result in early cracking of a seal, as the inhomogeneities may create stress concentrations above the acceptable limit.

The homogeneity is checked according to test method NBI-44, NT BUILD 003. A sample of the material to be tested is worked out in a groove in a metal jig, **Fig. 4**, and possible lumps, visible particles or larger air bubbles observed and noted.

The inhomogeneities recorded should not be larger than 1 mm for any sealant. As a result, the existance and size of particles, lumps, air bubbles etc is given.

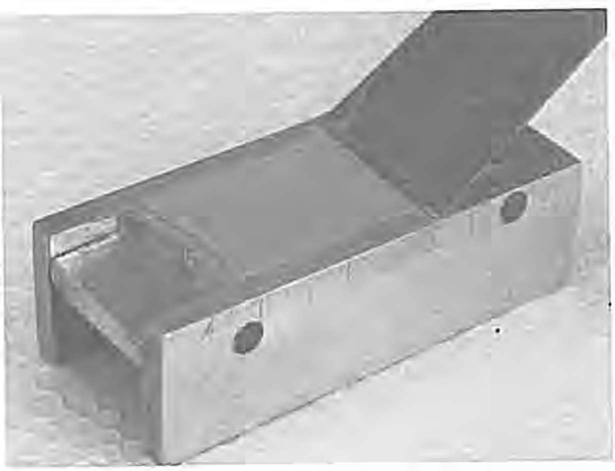


Fig.4. Testing the homogeneity in the test jig

2.04 Colour (CIB 3.4)

Sealants are often made in different colours, e.g. black, white and grey. The colour may influence the quality of the product. Appropriate information on available colours and possible quality differences should be given by the manufacturer.

2.05 Smell, toxicity (CIB 3.4)

Many sealants have a typical smell in uncured condition. For this reason, great care should be exercised when they are used indoors. Good ventilation is in most cases needed to avoid high consentrations of volatile and possibly toxic constituents.

In cured condition, most sealants only have a light smell. Some exceptions do, however, exist. Such sealants should not be used indoors.

Any possible harmful smell or toxicity should be clearly declared by the manufacturer.

2.06 Elongation properties (CIB 4.02)

Sealants in joints in buildings are in practical use subjected to deformations due to changes in joint dimensions at changing temperatures, moisture content of materials etc. To be able to fulfill their sealing functions, the sealants have to be able to follow the joint movements and to take up the deformations. At the same time, they have to maintain the required adhesion to the substrate, otherwise they will fail, **Fig. 5.**

The elongation properties of sealants are found according to test method NBI-45, NT BUILD 004. As the different types of sealants do not have the same elongation properties, and as they are used in different ways in practice, a total of 5 varieties of the same test method have to be used.

The basic principle implies that test joints are made between different types of substrate, and sealed with the material to be tested. The test pieces are subjected to aging cycles before elongation to break. The elongation properties are found from the diagrams showing force versus elongation. The most important point is usually the elongation at the maximum force.

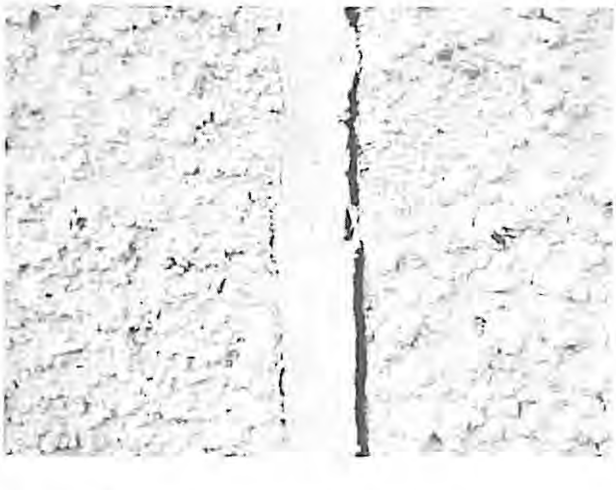


Fig.5. Overextended joint has failed

It is difficult to evaluate the results of elongation tests in all details. The following figures for elongation at maximum force are considered to be the minimum elongation acceptable for the various groups of sealants:

Group	52	10 %
"	53	15 %
"	54	15 %
"	55	20 %
"	56	15 %
"	57	15 %
"	58	100 %

It should be pointed out that these figures are for the evaluation of straight-forward elongation tests only, and should not be mixed up with ability to accomodate movements.

The elongation properties of a sealant are given as the maximum force in Newton in the force versus elongation diagram and the per cent elongation corresponding to this force.

2.07 Hardness (CIB 4.02)

For elastic materials, group 58, there is a connection between the hardness and the modulus of elasticity. Measuring the hardness can then be a simple and convenient way of obtaining some knowledge about the elastic properties. In the same way, changes in the hardness can give information about the aging properties.

The hardness of a sealant should always lie between acceptable limits. If the hardness is too high, great stress will be put on the adhesion, with possible adhesive failure as a result. If the hardness is too low, indentation problems may arise.

The hardness is measured according to test method NBI-46, NT BUILD 005. The apparatus used is a Shore A durometer. Measurements are carried out on a test block after initial curing as well as after heat aging. Both instantaneous hardness and 15 seconds hardness readings are taken.

For most types of building sealants, the results should be within the following limits:

Fully cured material:

10 to 30 ° Shore A instantaneous value
5 to 30 ° Shore A 15 seconds value

Heat aged material:

10 to 40 ° Shore A instantaneous value
5 to 40 ° Shore A 15 seconds value

Sealants in floor joints have to be harder. Recommended hardness figures are in the range 40 to 80 ° Shore A.

The hardness is given in ° Shore A, as a whole number, both instantaneous and 15 seconds values, together with the corresponding curing or aging state. When a single hardness value is needed, the 15 seconds value after long time heat aging should be preferred.

Hardness measurements with the Shore A durometer can only be made on sealants which are fully elastic or with at least a dominating elastic behaviour. For sealants with a dominating plastic behaviour, this method has to be substituted by a penetration test. Various types of penetration bodies are possible, dependent on the type of sealant, as for instance the "grease cone", or a ball-ended needle. Many different possibilities do exist, and the preferred variety is often a result of experience and opinion.

2.08 Deformability characteristics (CIB 4.02)

Elastic sealants are never 100 % elastic, but also have a certain degree of plasticity. The relationship between elasticity and plasticity is sometimes interesting to know. Measurement of deformability characteristics is one way of obtaining information about this relationship.

Deformability characteristics are found from measurements according to test method NBI-47, NT BUILD 006. A hardness meter with a spring-loaded needle is put against a block of the sealant, and the penetration depth recorded as a function of time. An elasticity figure p is calculated from the readings. The lower the p, the more elastic the sealant.

The results can be evaluated as follows:

Elasticity figure p from 0,1 to 1,0 as good

Elasticity figure p below 0,1 as exellent

2.09 Resistance to indentation (CIB 4.02)

This is an interesting property for sealants in horizontal joints in floor and other types of traffic areas.

A suitable test method is, however, missing. Judgement of a materials resistance to indentation has so far to be based on the information obtained from hardness testing, see point 2.07.

2.10 Peel strength (CIB 4.02)

Adhesion to the substrate is one of the most important properties of a sealant. Ideally, the adhesion should be better than the cohesion. This means that cohesive breaks should be aimed at in all adhesion tests. The adhesion to a substrate is depending upon the properties of the sealant as well as the substrate, **Fig. 6.** Substrate failure may occasionally occur. The adhesion is usually reduced over time. Testing should be carried out on fully cured as well as aged material.

Information about adhesive properties is to some degree obtained from the elongation tests as described in point 2.06. For materials curing to a mainly elastic state, more specific information about the adhesion is usually needed. The adhesion of such a sealant to a substrate is most conveniently tested as adhesion in peel, using a 180 ° peel test according to test method NBI-48, NT BUILD 007.

The peel force in Newton is recorded, and the type of break observed. The normal requirement is a purely cohesive break and a peel force not less than 10 N. Normal values are in the range 30 to 60 N. All figures refer to 25 mm wide strips.

Fig.6. Adhesion loss from a brick wall

Adhesion in peel is given as peel force in Newton to a specified substrate. The type of failure is also given.

2.11 Resistance to sagging (CIB 4.02)

Sealants must be able to stay in the joints after application, otherwise the joint sealing operation may be adversely affected and the function of the seal adventured. The sagging properties are dependent on the width and depth of the joint as well as the rheological properties of the sealant mix.

The sagging properties are found from closely controlled sagging tests in aluminium channels. The testing is carried out according to test method NBI-49, NT BUILD 008. The channels are available in eight different sizes, and the appropriate dimensions are selected for each test. The normal test temperatures are 323 K (50 °C) and 275 K (2°C).

The test method simulates the behaviour of a sealant in a joint with smooth surfaces under unfavourable conditions. In joint with rough surfaces, the materials are usually kept more easily in place. The test will tell whether a sealant will keep in place in a joint with certain dimensions or have a tendency to slump, sag or bulge. Repeated tests with different joint sizes will give information on the maximum joint dimensions without risk of sagging.

The results of the sagging tests are normally evaluated as given in **Table 3.**

Table 3 Evaluation of results of sagging tests

Slump or sag, mm		Bulging mm	Quality level
Channel 1	Channel 6	Channel 8	
0	0 - 1	0,5	Good
0 - 1	>1 - 5	2	Acceptable

The results are given in mm, separately for the two temperatures 323 K (50 °C) and 275 K (2 °C), either as slump and sag for channel 1 and channel 6 or as bulging for channel 8.

2.12 Flow characteristics (CIB 4.02)

All pouring grade materials must be able to flow sufficiently easily, to fill the joints well and to self-level to a smooth surface. This is valid for hot poured as well as cold poured materials, and single- as well as multi-component. Such materials are used in horizontal or low slope joints in floors, terraces etc.

The flow characteristics of pouring grade sealants are studied according to test method NBI-50, NT BUILD 009. The material is filled into an open joint with closed ends under controlled conditiones, and the ability to flow and self-level observed. Any irregularities are noted and possible deviations measured to the nearest 0,5 mm.

Table 4 is showing the evaluation of the result.

Table 4 Evaluation of results of self-levelling tests

Measurable deviations mm	Visible defects	Quality level
< 0,5	Small	Good
0,5 - 1,0	Moderate	Acceptable

The flow characteristics of a sealant are given as possible visible defects as well as measureable deviations in mm.

Flow characteristics is one of the properties that may be studied in a number of other ways than the one described in test method NBI-50, NT BUILD 009.

2.13 Combustibility (CIB 4.03)

All known types of building sealants are combustible. The degree of combustibility will depend upon the material composition. This property is interesting at least for fire doors and similar, but information is also of general interest. Testing has to be carried out to find out whether a cured sealant may be classified as non-combustible, self-extinguishing or combustible. In most cases also burnt part, burning time or burning speed has to be measured and recorded.

Test methods are also available for checking other fire properties as smoke release and development of toxic or corrosive gases, but these properties are usually of minor interest in this connection.

Fire testing of building sealants is carried out according to test method NBI-51, NT BUILD 010. Strips of sealants are exposed to open flame, and the burning characteristics observed. The results are evaluated as given in **Table 5.** This table is valid for all types of building sealants.

Table 5 Evaluation of results of combustibility tests

General result	Burnt part mm	Burning time s	Burning speed mm/s	Quality level
Self-extinguishing	< 25	< 10		Good
Self-extinguishing	≥ 25	≥ 10		Acceptable
Combustible			≤ 1,0	Acceptable

The results are first of all given by the general terms "self-extinguishing" and "combustible". For self-extinguishing sealants, the burnt part and burning time is also given, for combustible sealants the burning speed.

2.14 Air penetration (CIB 4.04)

To make a joint sealed with a building sealant sufficiently tight against penetration of air and other gases, including water vapour, the following three conditions have to be fulfilled:

- The sealant itself must be sufficiently homogeneous and tight
- The sealant must have proper adhesion to the substrates in the joint surfaces
- The sealant must have been perfectly applied in the joint.

In general, the sealant themselves seem to be sufficiently tight against air, gas and water vapour penetration. The problems arising from requirements to air and gas tight joints are then covered by studies of adhesion properties, point 2.10, and the chapters on joint design and joint sealing.

2.15 Water absorption (CIB 4.04)

Building sealants are partly used in positions where they are subjected to driving rain. Contact with liquid water may also arise from condensation. In both cases, the sealants must not absorb so much water that they get unacceptable changes in dimensions, mechanical properties a.s.o.

This is also the case with most sealants. Exceptions are a limited number of materials intended for indoor use under dry conditions. Such materials are always clearly marked. Testing of water absorption has so far not been considered as interesting.

2.16 Rain penetration (CIB 4.04)

Sealants used as rain barriers in joints have to stop water from entering the joint in unacceptable amounts. The performance of the sealant as a rain barrier is, however, not only dependent on the sealant itself, but more on a number of details in the design of the joint where the sealant is used. Testing is then only possible when a fully detailed joint design is available. The scope of tests like that is first of all to check the joint design and the quality of the sealing work. The sealants themselves are sufficiently water tight.

2.17 Resistance to alkalies (CIB 4.04)

Concrete and other cement based building materials contain highly alkaline constituents. Moisture movements can bring these alkalies to the surface. In joints made with building sealants, the materials have to be able to withstand the alkalies without loss of ability to fulfill the intended functions. The adhesion as well as the elongation properties may be influenced.

The resistance to alkalies is tested according to test method NBI-52, NT BUILD 011, as tensile tests with the sealant in combination with an alkaline substrate. Specimen details, test procedures and requirements are otherwise much the same as for the elongation tests, test method NBI-45, NT BUILD 004.

The resistance to alkalies of a sealant is given as the maximum force i Newton in the force versus elongation diagram, and the per cent elongation corresponding to this force.

2.18 Resistance to solvents, salt spray, cleaning agents and other chemicals (CIB 4.04)

Joints with building sealants are frequently subjected to contact with various types of chemical agents. Alkalies have been mentioned already. Other possibilities are for instance wind driven salt water spray, solvents and window cleaning agents etc. Sealants must be sufficiently resistant to these types of chemicals.

Resistance to solvents etc is tested according to test method NBI-53, NT BUILD 012. The sealants are subjected to the influence of solvents and chemical agents under controlled conditions. Any visible changes are recorded. The specimens may also be weighed and the dimensions measured, as agreed.

The results are expressed as any visible changes, as well as possible changes in weight and dimensions. The normal requirement is no significant changes.

The sealants used in floor joints are in many cases subjected to long time exposure of special chemicals as for instance organic acids. A suitable test method to simulate this type of exposure is still missing. Resistance to petroleum products can, however, be studied by testing elongation specimens as described in point 2.06 before and after immersion.

2.19 Seepage, loss of liquids to porous substrates (CIB 4.04)

Liquid constituents may be absorbed from the sealants into porous substrates. This is referred to at seepage. Usually seepage is considered as unwanted, as undue seepage may result in increased hardness in the sealant and even loss of adhesion or cracking. Staining of the porous substrate may also occur.

Seepage is tested according to test method NBI-54, NT-BUILD 013. The sealant is brought into contact with a specified porous material and the seepage measured under controlled conditions, **Fig. 7**. The result is expressed as a seepage figure, u.

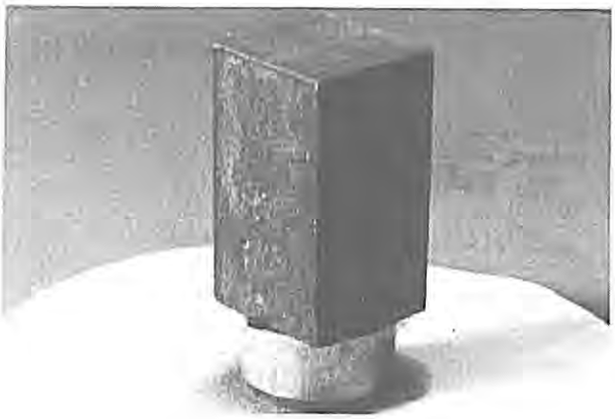


Fig.7. Unacceptably high seepage

Materials with a high seepage figure have a high tendency to give off liquid constituents to porous substrates. A normal requirement is to ask for a seepage figure lower than 5. For materials with high seepage, special pretreatment of the substrate is usually necessary to avoid loss of binder.

The seepage figure is given as a whole number without denomination.

2.20 Staining of porous substrates (CIB 4.04)

Discolouration of building materials adjacent to joints may occour for unfavourable combinations of sealant and substrate. Oilbased sealants have for instance a tendency to loose liquid binder. Even primers may result in chemical reactions and discolourations around the joints. Sealants with a high seepage figure are particularly riskful on porous substrates.

Valuable information about the possible staining of porous substrates is usually derived from the seepage test as described in point 2.19. The possible staining as a result of secondary chemical reactions in an alkaline environment is tested according to test method NBI-55, NT BUILD 014. This test is combined with the alcali resistance test, NBI-52, NT BUILD 011.

A staining less than 1 mm wide is usually considered as acceptable. The ideal situation is no staining of the material adjacent to the joints.

The possible staining is given as a staining figure in mm with one decimal, as well as description in appropriate wording.

2.21 Free shrinkage (CIB 4.04)

Weight loss on aging or curing indicate that a sealant will tend to shrink. For materials with a high content of volatile matter, this shrinkage may even result in internal stresses and subsequent cracking of the seal. A convenient way of obtaining a figure for the risks involved, is to measure the free shrinkage. In practice, a sealant bead in a joint is always more or less restrained, but comparable figures for the free shrinkage are in any case of great interest.

Free shrinkage is measured according to test method NBI-56, NT BUILD 015. A specified volume of the sealant is allowed to shrink approximately freely by curing and subsequent heat aging. The resulting shrinkage is measured and given as per cent by volume.

Recommended maximum figures for free shrinkage of different types og sealant are the following:

Group 52	maximum	6 %	by volume
" 53	"	20 %	"
" 54	"	20 %	"
" 55	"	20 %	"
" 56	"	5 %	"
" 57	"	5 %	"
" 58	"	20 %	"

The shrinkage is given as a per cent figure with one decimal for values above 1 % and two decimals below 1 %.

2.22 Restained shrinkage (CIB 4.04)

Cracking of the sealant bead may occur if the material is allowed to shrink in restained condition, **Fig. 8.** A special test is necessary to check this property.

Restrained shrinkage is studied according to test method NBI-57, NT BUILD 016. The sealant is filled in a special test channel and allowed to cure and shrink under closely controlled conditions. This model joint is checked at the end of a specified aging period and any visual changes noted.

The normal requirement to a sealant is no visible cracking or similar on restrained shrinkage.

Restrained shrinkage is given by proper wording, indicating the observations made.

The restrained shrinkage of hot applied sealants on cooling can be studied by a combination of the two test methods NBI-56 and -57.

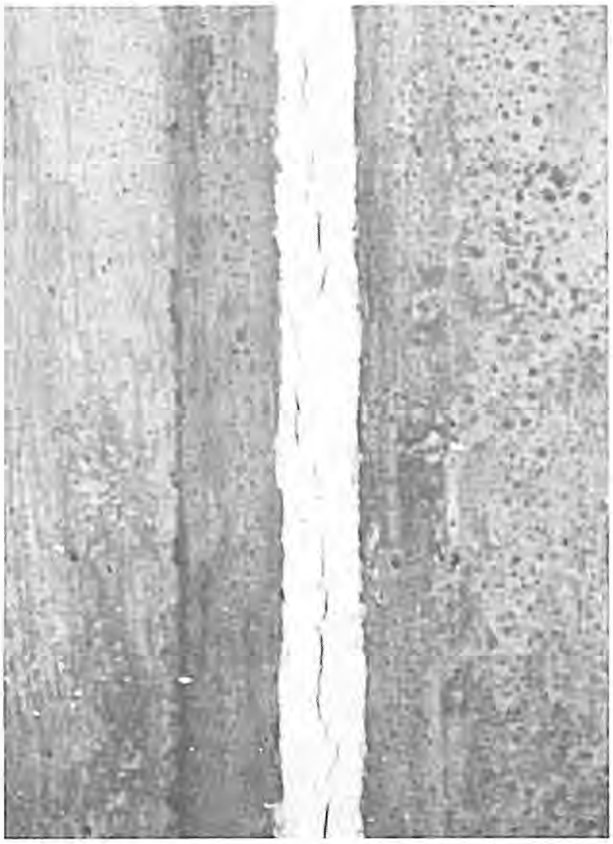


Fig.8. Shrinkage cracking of a tough plastic sealant in a joint

2.23 Weight loss on heat aging (CIB 4.04)

All sealants loose weight on heat aging. It is interesting to compare this with the shrinkage.

The weight loss on heat aging is found according to test method NBI-58, NT BUILD 017. The measurements made on the sample used for determining the free shrinkage, are also used to calculate the weight loss.

The following figures for weight loss on heat aging can be taken as upper recommended limits:

Group 52	maximum	3 %	by weight
" 53	"	10 %	"
" 54	"	12 %	"
" 55	"	15 %	"
" 56	"	3 %	"
" 57	"	1 %	"
" 58	"	10 %	"

Weight loss on heat aging is given as a per cent figure with one decimal for values above 1 % and two decimals below 1 %.

2.24 Tack-free time (CIB 4.04)

All sealants with an exposed surface should become tack-free within an acceptable period of time.

The tack-free time is found by using test method NBI-59, NT BUILD 018. A tack-free surface is defined as a surface where glass beads of a specific type will not stick when applied and tested under specified conditions.

The normal requirement to tack-free time is a maximum of 14 days at 296 K (+ 23 °C) and 50 % RH, and 56 days at 278 K (+ 5 °C) and 70 % RH.

Tack-free time is given in whole days, except for rapid curing and setting materials. For the latter materials, the tack-free time is given in hours.

2.25 Skin formation (CIB 4.04)

Oil-based sealants containing drying oils will gradually form a surface skin. This skin will protect the rest of the material and delay the drying of the deeper part of a joint. The skin thickness has to be tested after aging, to check that only a surface skin is formed.

Testing of skin formation is carried out according to test method NBI-60, NT BUILD 019. The skin formation during heat aging at 343 K (+ 70 °C) is observed and measured.

The normal requirement is a skin thickness not more than 1,0 mm after 7 days at 343 K (+ 70 °C) and not more than 1,5 mm after 56 days.

The skin thickness is given in mm with one decimal after 7 and 56 days respectively at 343 K (+ 70 °C).

2.26 Resistance to solar radiation (CIB 4.04)

Sealants may be influenced by solar radiation in several different ways. The most easily observed change is in the colour. Other possibilities are sweating, cracking or similar.

Testing of resistance to solar radiation is carried out according to test method NBI-61, NT BUILD 20. A sample of the sealant is exposed to artificial solar radiation and the possible changes observed.

The normal requirement is no significant changes.

As a result, the possible visible changes are given.

2.27 Adhesion to glass, influence of solar radiation (CIB 4.04)

Glazing sealants must have a sufficiently good adhesion to glass, not only initially, but also over time.

Testing is carried out according to test method NBI-62, NT BUILD 021. The usual type of elongation test samples are used, see point 2.06, but the substrates are glass and non-anodized aluminium. The samples are exposed to artificial solar radiation through the glass, at simultaneous influence of water. Force versus elongation diagrams are recorded.

The following figures for elongation at maximum force are considered to be the minimum elongations acceptable for the various groups of sealants:

Group 52	10 %
" 53	15 %
" 55	20 %
" 57	15 %
" 58	100 %

Influence of solar radiation on the adhesion to glass of a sealant is given as the maximum force in Newton in the force versus elongation diagram, and the per cent elongation corresponding to this force.

2.28 Resistance to peeling, influence of solar radiation (CIB 4.04)

The adhesion to glass measured as peel strength after the combined influence of solar radiation and water, is often the property most conveniently used to evaluate the quality and suitability of a glazing sealant. This property should consequently be checked in addition to the traditional elongation tests as referred to in point 2.27.

Testing is carried out according to test method NBI-63, NT BUILD 022. The usual type of peel test samples is used, but the samples are subjected to artificial solar radiation through the glass and simultaneously influenced by water. The peel force in Newton is recorded, and the type of break observed.

The normal requirement is a purely cohesive break and a peel force not less than 10 N.

The influence of solar radiation on the resistance to peeling is given as peel force in Newton and observed type of failure.

2.29 Extrudability (CIB 4.04)

All gun grade materials must have a sufficiently high extrudability to be easily applied by craftsmen doing the sealing work. This is true for normal temperatures as well somewhat lower temperatures, as sealing work is often carried out under changing temperature conditions.

Extrudability is tested according to test method NBI-64, NT BUILD 023.

The sealant to be tested is filled into a standardized caulking gun, and extruded completely under closely controlled conditions. A conical nozzle is used for glazing sealants, and a straight nozzle for standard quality building sealants. Measurements are always taken at 278 K (+ 5 °C) and 296 K (+ 23 °C), but other temperatures may be used.

The normal requirements to minimum extrudability for various types of sealants are summarized in **Table 6.**

Extrudability is given in m^3/h with three decimals at 278 K (+ 5°C) as well as 296 K (+23 °C), possibly also at other temperatures.

2.30 Pot life (CIB 4.04)

Two- and multicomponent materials start to cure immediately after they have been mixed. The pot life is defined as the time they can be used, without becoming too stiff.

The pot life is checked according to test method NBI-65, NT BUILD 024. The extrudability of a gun grade material is measured at the end of the time

Table 6 Extrudability in m³/h, minimum requirements for various types of sealants

Type of nozzle	Temperature	Type of sealant 52	53	54	55	58
Conical 10/5 mm	278 K(+ 5°C)		0,002		0,002	0,002
	296 K(+23°C)	0,006	0,012		0,012	0,012
Straight 10 mm	278 K(+ 5°C)		0,003	0,003	0,003	0,003
	296 K(+23°C)		0,024	0,024	0,024	0,024
	Elevated				0,024	0,024

given by the manufacturer as the pot life. The result is compared with the normal extrudability requirements as given under point 2.29. The test method NBI-65, NT BUILD 024, is consequently not a direct measure of pot life, but only a check of extrudability at the stated pot life. If more detailed information is needed, measurements can be taken at different points of time.

The pot life of lower viscosity materials can be studied in a similar way with a Brookfield viscosimeter.

2.31 Resistance to attack by birds (CIB 4.05)

Sealants may contain constituents wich make them attractive for birds. The tightness of a sealed joint may be destroyed if the sealant is eaten up by birds. The effect is similar to the observed attacks on sealants by human beings, **Fig. 9.** Certain oilbased sealants seem to be especially attractive to birds. Overpainting the sealant is a measure that usually helps.

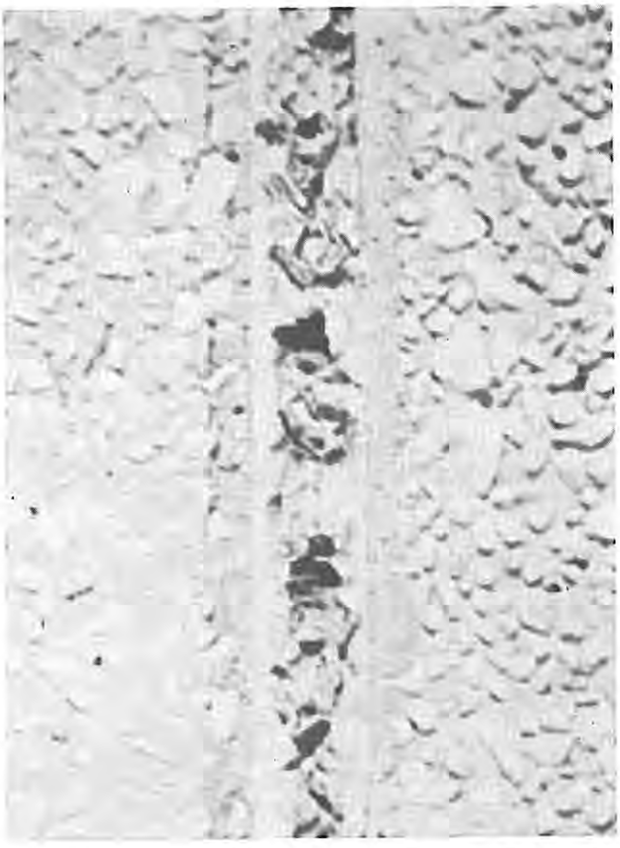


Fig.9. Sealant subjected to attack by human beings

A suitable test method is missing. Information about possible risks have to be given by the sealant manufacturer.

2.32 Influence of high and low temperatures (CIB 4.06)

Plastic sealants and non-cured elastic materials may soften and flow at temperatures around 353 K (+80 °C), in some cases even at somewhat lower temperatures. Cured elastic sealants get softer, but do not flow.

Cured sealants are not damaged by frost. Even non-cured sealants can usually resist temperatures below the freezing point, but the curing and setting is usually delayed. For some materials, the curing is not initiated before the temperature is well above zero again. The only types of sealants that can be destroyed by frost, are those containing water, e.g. acrylic dispersions.

Sealing joints at low temperatures require special precautions. The work site should be covered and protected, and if possible also heated. A possible simple solution is in some cases to watch the weather development carefully before the sealing job is started.

2.33 Accomodation of movements (CIB 4.10)

Building sealants have to maintain their properties, i.e. to seal, for a sufficiently long period of time. In practice, the sealant materials are subjected to certain deformations due to changes in temperature, moisture content of materials etc. To be able to fulfil their functions, the sealants must be able to keep a sufficiently good adhesion to the substrate, even in aged condition.

One single extention, as in test method NBI-45, NT BUILD 004, elongation properties, will give some indications. This has, however, to be supplemented with a durability test where the sealant is subjected to a high number of cyclic deformations at simultaneous aging.

Testing of ability to accomodate movements is carried out according to test method NBI-112, NT BUILD 147. This method can be used for all

Table 7 General view of amplitude of the movements (in %),total number of cyclic movements and number of days on heat aging

Type of sealant		Amplitude %	Total number of cycles	Days of heat aging
Type 53:	Skin-forming plastic sealants	10	3240	48
Type 54:	Non-skinning plastic sealants	10	3240	48
Type 55:	Tough plastic sealants	15	4680	72
Type 56:	Thermoplastic sealants	10	3240	48
Type 57:	Strip sealants	5	6120	96
Type 58:	Elastic sealants	25	6120	96

sealants in the groups 53 through 58 in the general classification. The test joints are subjected to approximately sine-shaped movements, interrupted by periods of heat aging. This procedure is repeated until failure, or until a certain number of cyclic movements is reached, as indicated in **Table 7**. Observations are visually, **Fig.10**.

The normal requirement is to ask for a sealant that can take the number of cyclic movements and days on heat aging as given in Table 7.

As a result is given the number of cyclic movements the test specimens have passed without cohesive or adhesive failure.

Fig.10. Joint seal cracked due to cyclic movements

This test method can easily be modified by combining heat aging with accelerated weathering.

2.34 Paintability (CIB 4.10)

Overpainting of sealants is a general problem to which there is no general answer. Some sealants can be overpainted, and some even should be, while others should better be left unpainted. Two problems are involved. One is whether the sealant will take paint or not. The other is whether or not the paint film is flexible enough to follow sealant deformations due to joint movements without cracking.

Generally speaking, sealants should only be covered with paints flexible enough to take the joint movements together with the sealant. Information about suitable paints has to be given by the manufacturer.

3 Joint design

Many sealants, traditional as well as more recent, perform well when tested in the laboratory. In practice the situation is often quite different. In some cases the results are good, in other cases the sealants have failed in surprisingly short time. One study (12) indicates that all available sealants will fail in a much shorter time than expected from the aging properties of the materials.

The study referred to (12) does not give the reasons for the failures. The Norwegian Building Research Institute has, on the other hand, carried out a more detailed investigation of a number of cases of sealant failures. Some of the cases can of course be attributed to inferior materials, but most of them have proved to be due to errors in joint design and accomplishment. Errors in joint design can be further divided into cases connected with unfavourable sealing systems and cases connected with wrong joint shape and back-up material. The NBI experiences are also supported by several serious manufacturers.

3.1 One-stage and two-stage seals

It is wise to remember that all sealants will ultimately fail. Some of them will fail after a few years, even when properly applied, others will serve for a longer period of time. In any case, the expected sealant life is usually much shorter than the assumed life of the building. The possible occurance of the earlier mentioned errors is joint design and accomplishment will further stress this point.

The only safe solution to the problems mentioned above is to adapt the principle of two-stage seals to any case where building sealants are used. This principle involves the use of separate water and air barriers, and has in fact been succesfully applied for centuries. The modern concept of the principle has developed in later years (13), (14).

One-stage seals have a combined water and air barrier. Such seals are usually placed in the outer parts of the joints. In two-stage seals, the water and air barriers are, as mentioned, separated. The water barrier is placed on the outside as a rain screen, behind this there is a drained and ventilated air space, and behind this again the air barrier. In this way, the air barrier is kept dry.

Joints with one-stage as well as two-stage seals will usually also need a vapour barrier. This can be a separate barrier, but in some cases also combined with the air barrier. The following classification of the different parts of the sealing system in the joints can then be established (1), dependent on the functions they have to perform:

System	A	Combined water, air and vapour barrier at the same point
"	B	Combined water and air barrier at the same point
"	C	Rain screen, with ventilated and drained air space behind
"	D	Combined air and vapour barrier
"	E	Air barrier
"	F	Vapour barrier

Some examples on one- and two-stage seals as well as the different sealing systems A - F, are shown on the **Figs. 11 to 16.** It should be pointed out, however, that the one-stage solutions of Figs. 11, 13 and 15 are not recommended by the Norwegian Building Research Institute.

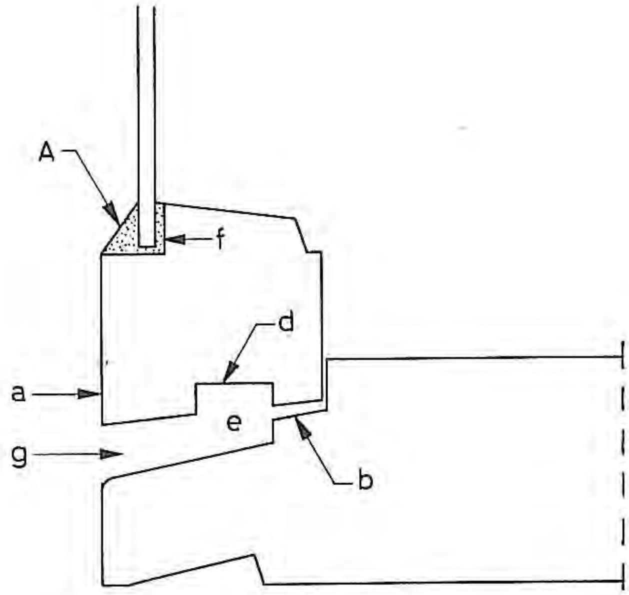


Fig. 11. Cross-section of the bottom part of the obsolete Norwegian Standard single glazed window NS 766. One-stage glazing system A

In the obsolete single glazed window in Fig. 11, the glazing with putty is a typical one-stage seal. The putty serves as a combined water, air and vapour barrier at the same point, system A. In Fig. 12, the sealed glazing unit is installed with a two-stage seal. The rebate is ventilated and drained under the bottom bead. The outher seal serves as a rain screen, system C, while the inner seal is a combined air and vapour barrier, system D.

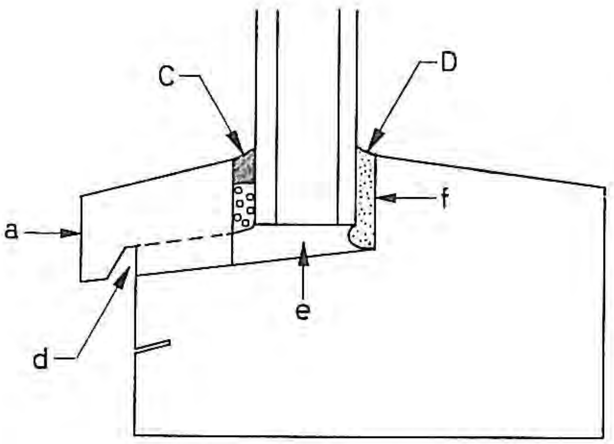


Fig. 12. Cross-section of the bottom part of a fixed window with sealed double-glazing unit. Two-stage seal with ventilated and drained rebate

Fig. 13 shows a one-stage seal between concrete panels. The external sealant bead has to serve as combined water and air barrier, system B, and the inner seal as a vapour barrier, system F. In practice, the inner seal is often omitted, and this has sometimes lead to serious condensation damage. Fig. 14 shows the alternative two-stage solution. The gasket in the vertical joint serves as a rain screen, system C. In the horizontal joint, the same function is performed by the open joint with the nib a, the threshold b and the lid c. The outer bead of sealant is now only an air barrier, system E, while the inner seal is still a vapour barrier, system F.

Fig. 15 shows a one-stage seal in a light metal wall. Here the outer gasket has to serve as a combined water and air barrier, system B, and the inner gasket as vapour barrier, system F. In the alternative two-stage solution of Fig. 16, the function as rain screen is taken over by the glass cladding, system C. The outer gasket now only serves as air barrier, system E, while the inner gasket is still a vapour barrier, system F.

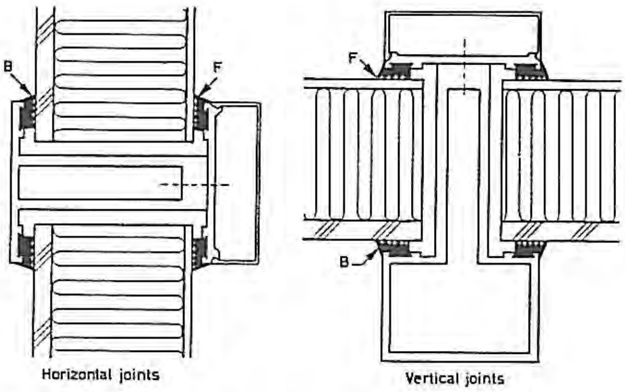


Fig. 15. One-stage seal in a light metal wall

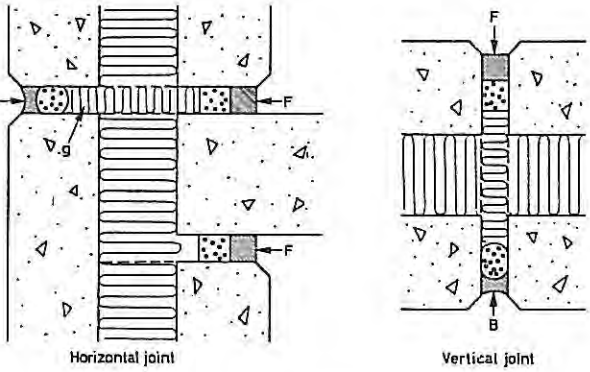


Fig. 13. One-stage seal between concrete panels

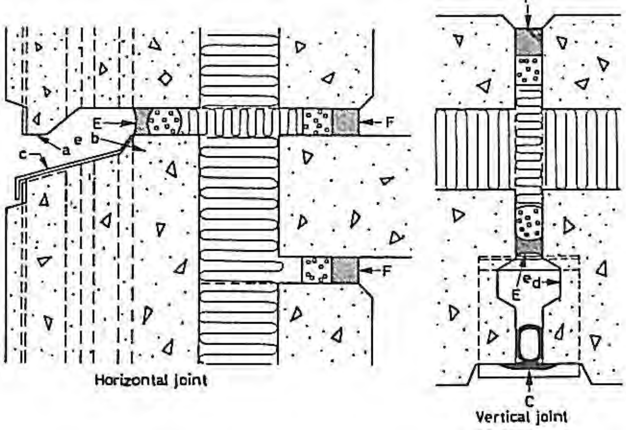


Fig. 14. Two-stage seal between concrete panels

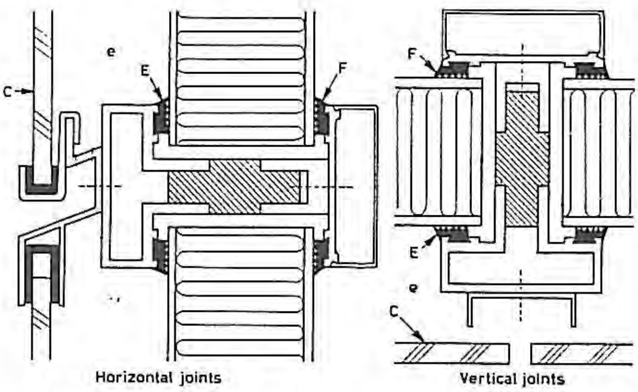


Fig. 16. Two-stage seal in a light metal wall

The Figs. 11 to 16 also help to clear some of the terms used in joint technology. The small letters in the figures indentify the following terms:

a Nib
b Threshold
c Lid
d Groove
e Pressure equalization chamber
f Rebate
g Gap

The examples shown in the Figs. 11 to 16 stress the most important differences between one- and two-stage seals:

In a **one-stage seal,** the jointing material will be heavily exposed to climatic strains, as sun and rain and high and low temperatures. For this reason the material will age more rapidly than when protected against weatering. The seal will have to take the full load of air and water as sealing system A and B and be an extremely critical part of the construction. A possible failure may easily result in severe damage due to rain penetration. In this connection it should be remembered, that there are many possibilities for seal failures, in a near or more distant future.

In a **two-stage seal,** the load is divided on at least two barriers. The water is stopped at the first barrier and the air at the second. The more important parts of the sealing system will be protected against weathering. The jointing materials will age more slowly, and in several cases the movements will be smaller. For these reasons, it may be possible to use a somewhat cheaper material. The seals will no longer be so critical, and possible failure will usually only result in air penetration and not rain penetration. In two-stage seals, the sealant and other jointing materials are not always so easily applied and maintained. Problems like that are, however, usually easily solved if they can be attacked at the planning stage.

Sensible joint design means that two-stage seals should be used whenever possible.

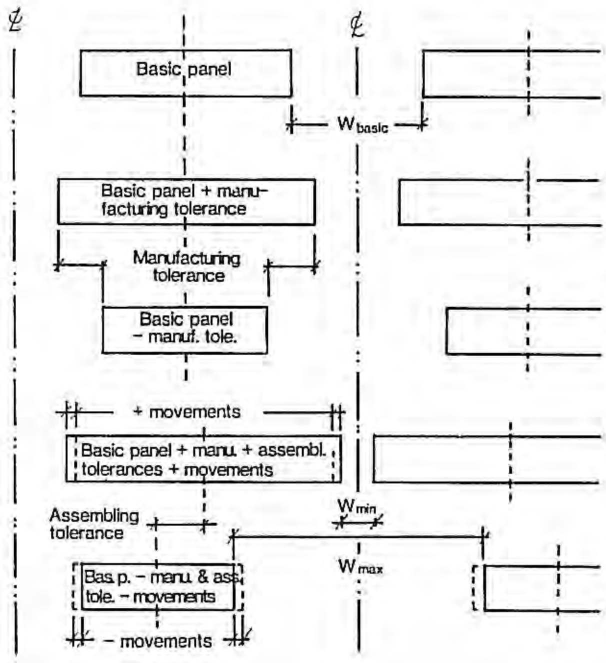


Fig 17. Manufacturing and assembling tolerances and movements. Principle figure

3.2 Selection of building sealant

One of the most important aspects of joint sealing is to size the joints correctly and to select a suitable jointing material. The joint width must not be less than a certain minimum width and not more than a certain maximum width. Otherwise the material will not function properly. It is important to know in detail all factors that influence the joint width, especially the joint movements as well as deviations and tolerances. The latter is something which is frequently overlooked. Many designers seem to forget that things in practice will not look exactly as they have shown on their drawings. It is not possible to produce the individual parts without certain deviations in dimensions, angles, edges, planes etc. The assembly of the individual parts is also subject to certain deviations.

Matters like these are usually very important when building with panels and other types of large prefabricated components. The deviations can here be of vital importance, especially for the joints. In practice, the conditions can vary somewhat, dependent on the production technique used. A typical example is shown in **Fig. 17.** It is here assumed that the panels are ordered to a spesific size termed "basic panel". The panels are planned to be mounted between set out lines to form a basic joint with a certain joint width. In practice the size of the panel will vary somewhat, the extent will depend upon the manufacturer and the one ordering. The most important point is that the deviations must be kept under control, that the acceptable deviations are specified, i.e. that manufacturing tolerances are given. The influence on the joint width will appear from Fig. 17.

When mounting the panels, it is correspondingly necessary to take into account certain deviations in the assembly and to specify assembling tolerances. These will be superimposed the manufacturing tolerances. Finally the movements in the joints due to change of temperature and moisture content, wind, settlements etc. have to be added. The combined influence of manufacturing tolerances, assembly tolerances and movements will result in a joint width varying from a minimum widt W_{min} to a maximum width W_{max} as shown in Fig. 17. It is first of all the minimum joint which is of vital importance for the selection of jointing material, e.g. joint sealant. It is the minimum joint which is subjected to the largest relative joint movement, and this joint width must then be calculated first.

The first thing to do when selecting jointing material is to calculate the joint movement. The movements will depend on the details of the construction, and have to be calculated separately in every single case. Factors that have to be taken into account are the size of the panels etc., their colour and method of fixing, the kind of material, the location of the sealant, the orientation etc. Usually the most important movements derive from changes in temperature and moisture content. In light constructions, wind loads can also result in significant movements. In more special cases initial shrinkage and settlements have to be taken into account.

The maximum and minimum temperatures occuring in the outher shell of a building can of course differ much from one country to another. In Norway the temperature fluctuations are approximately 75 °C in a light coloured and 100 °C in a dark coloured building. These figures can also be used in various other countries. When the sealant is placed internally, the temperature changes are usually smaller.

The moisture movements must be calculated and added to the thermal movements. Thermal and moisture movements may counteract, but if this is not definitely certain, they should be added, at least statistically.

When the absolute joint movements are known, the relative movements in per cent of the joint width can be calculated for different joint widths. The type of sealant and minimum joint can then be chosen and adapted to each other, taking into account that the maximum permissible relative joint movements are not exceeded.

Type of sealant and minimum joint width can consequently not be chosen independently, but have to be fixed at the same time and adapted to each other.

For joint sealants, the figures in **Table 8** can be used.

Table 8 Maximum permissible deformation of different types of sealant in aged condition

Type of material	Group No.	Maximum movement % of joint width: Tension compression	Shear
Rapid hardening putties	51	Approx.0	Approx.0
Plastic glazing compounds	52	5	20
Skin-forming plastic sealants	53	10	40
Non-skinning plastic sealants	54	10	40
Tough plastic sealants	55	15	50
Thermoplastic sealants	56	10	40
Strip sealants	57	5	40
Elastic sealants	58	25	75

It should be noted that the ability of such materials to accomodate movements is dependent on the type of joint and the kind of movement. The reason for this will appear from **Fig. 18.** The deformation of a sealant bead will be much smaller in a lap joint than in a butt joint. For this reason, sealants can take far greater movements in shear than in tension and compression.

The figures quoted for shearing strains apply to transversal shear. Longitudinal shear is not yet fully investigated. The available data indicate, however, that transversal or longitudinal shear does not make much difference for the more elastic materials, while the skin-forming materials take somewhat smaller movements in longitudinal than in transversal shear.

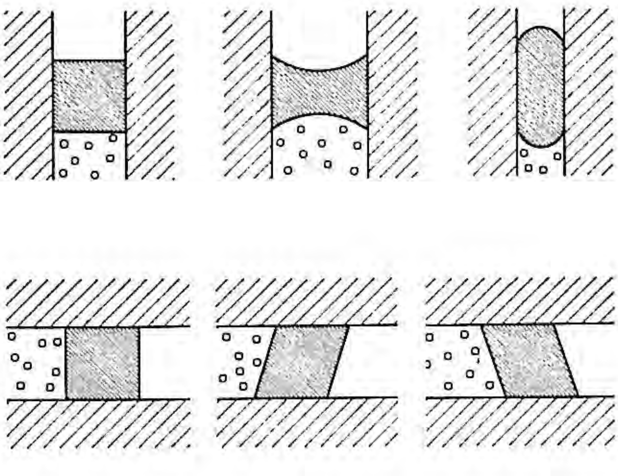


Fig 18. Deformation of sealant beads in butt and lap joints

From a theoretical point of view, all joints should be made in such a way that the sealant would only be subjected to shearing strains. In practice, however, this is not always possible.

The joint width which is calculated according to the previous sections, is, as mentioned before, not the basic joint width shown on the drawings, but the minimum joint width W_{min}. The basic joint width will follow from Fig. 17.

$$W_{basic} = W_{min} + T_m + T_a + M$$

In this case it is assumed that the tolerances are symmetrical, manufacturing tolerances $\pm T_m$, assembling tolerances $\pm T_a$, and symmetrical movements $\pm$ M from an intermediate stage. The maximum joint width will follow accordingly as:

$$W_{max} = W_{min} + 2\,T_m + 2\,T_a + 2\,M$$

More detailed examples on calculation of joint sizes and selection of jointing materials is given in an architectural data sheet (15). Questions relating to tolerances and sizing of components and joints are morever properly treated in English literature (16).

When sealants are chosen and joint widths fixed in the way described in the previous section, it will be found that a plastic joint sealant requires a wide joint to accomodate the movements, while an elastic joint sealant will do with a narrower joint. In this way, some of the differences in cost may be levelled out. In this connection it should also be remembered that the products differ greatly in expected service life. It can be quite expensive to use a cheap sealant if this has to be replaced after a few years.

There is otherwise no complete freedom in selection of sealants according to the previous. There are certain additional requirements to minimum joint width which much be kept. For oilbased skin-forming plastic sealants the width should not be less than 10 mm, to retain their aging properties. For tough plastic sealants, the minimum joint can be made somewhat smaller, down to about 5 mm, and for elastic sealants down to 3 mm, if the movements will permit.

The maximum joint width must on the other hand not be to wide, otherwise the sealant will slump or sag. This has also to be checked. For plastic sealants, the maximum joint width is usually between 15 and 25 mm. With elastic sealants, the beads can be built up in several steps, and this increases the possibilities. When joint movements and tolerances are great, it may easily turn out that plastic sealants can not be used at all, because the width of the maximum joint will have to made so wide that the material will slump from the joints. For this reason, the use of products like that will have to be restricted to joints between moderately sized components, somewhat depending upon the materials used.

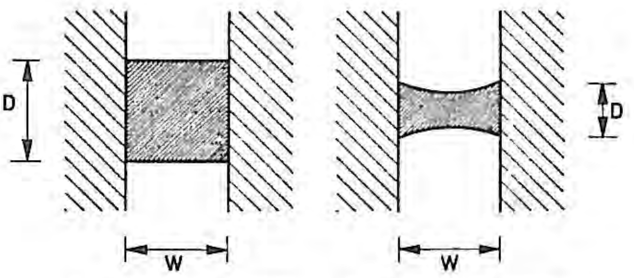
In Fig. 17, the variations in joint width are shown very great. This is not only an overdoing to better illustrate the proportions. Practical experiences have shown that the variations in joint width are very often surprisingly great. This will appear very clearly from an English report (17). Here the author draws rather discouraging conclusions with regard to the possibilities of obtaining accuracy when building with large size concrete panels. The actual studies do, however, only cover buildings which were completed when the survey was made. In cases where tolerances have been fixed and a certain control has been agreed in advance, the results are much better. It is quite clear that the right thing to do is to form a sound estimate of the deviations which can be expected, and lay down sensible requirements to tolerances in production as well as in assembly. In any case it should be remembered that tolerance problems are not solved by simply neglecting them.

A few more factors are worth taking into account when selecting building sealants. One is to be sure to get a product with good adhesion to the materials forming the joints. The various types of joint sealants do not necessarily have the same adhesion to all substrate materials. Some products need to have a specific primer to obtain good adhesion, and partly different primers on different substrates. On porous substrates like wood, brick and concrete it is also necessary to check that the substrate will not absorb to much of the binder in the sealant. Otherwise the result can be drying out, shrinkage and loss of adhesion, as well as discolouration of the joint surface. Treatment with primer can to a large extent protect against a thing like that. For certain porous substrates like fibrecement sheets, the primer may also have to fill the purpose to avoid loss of adhesion due to water migrating through the substrate. Finally, the primer may have to strengthen the substrate, e.g. porous and weak mortars and concrete.

When two or more materials are used in the same joint, the materials have to be compatible and not react with each other. Some material combinations are not very favourable.

3.3 Joint shapes and related details

It is very important to have a correct cross-section on the sealant bead, otherwise the bead may crack rapidly. If the depth is too great compared with the width, the deformation of the sealant will be rather unfavourable, and the risk for adhesive failure considerable. If the bead is too shallow,



a Plastic sealants W : D = 1 : 1 b Elastic sealants W : D = 2 : 1

Fig. 19. Cross-section of sealant beads

there is on the other hand impending risk of consentration of movements with resulting cohesive break.

For plastic sealants, the present principal rule is a bead of sealant with a square section, **Fig. 19a.** This does not necessarily imply that the depth always has to be made equal to the width. Depth equal to width is only the main rule, and minor modifications have to be introduced when necessary. In the widest joints, the depth has to be made smaller than the width, otherwise there may be an increased risk of slump. In the narrower joints, the depth has on the other hand to be made greater than the width, partly to obtain sufficient adhesion to the joint surfaces, and partly to let the sealant get the volume necessary from an aging aspect. The latter specially applies to sealants based on drying oils or bitumen. The most suitable depth is usually from 10 to 20 mm.

For elastic sealants, the ratio of width to depth should be as close to 2:1 as possible. It is further recommended to make a slightly biconcave shape, as shown in **Fig. 19b.** In this way an increased adhesion to the joint surface is obtained, and at the same time the major part of the deformation will take place in the central part of the joint. The biconcave shape is easily obtained in practice with a suitable back-up and smoothening of the bead of sealant with a suitable tool.

A right type of back-up material in the joint is usually necessary for all sealants which are supplied as a bulk material (not preformed). This back-up material has to serve several purposes. First of all it has to help to give the bead of sealant the right cross-section, but it also has to do the job of holding on when the sealant is gunned into the joint. This back-up material must not in any way restrict the deformation of the sealant, but serve as a neutral bottom filler and bond breaker. If the sealant adheres to a rigid back-up or joint bottom, concentrated strains may occur at certain points in the bottom of the joint as shown in **Fig. 20.**

For plastic sealants, the problem can be solved with a back-up of soft strips of foamed rubber or plastics. This should preferably be a closed-cell material. Strips of open-celled material may be used, but then there will be a risk of damage if they are frozen in wet condition. The strips must have a cross-section which makes it possible to compress them at least as much as the expected

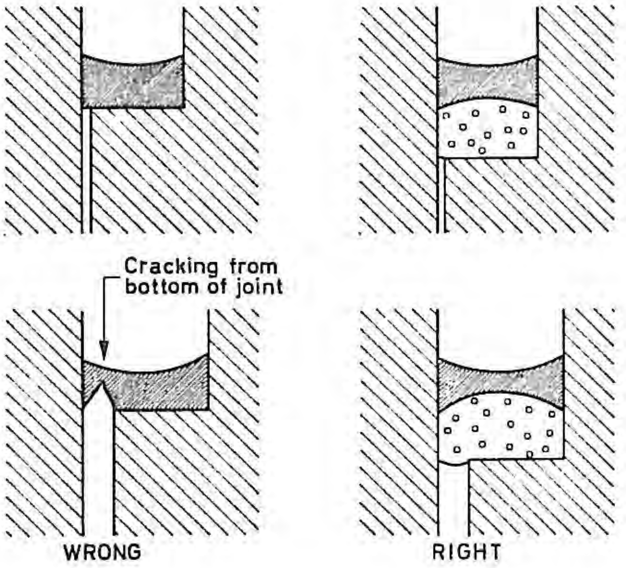


Fig. 20. The bottom of the joint must not restrict the deformation of the sealant

joint movement. Such a back-up is sufficiently soft and easily deformable, and will not transfer significant stresses to the sealant. A back-up of oakum is less favourable. It is not easy to obtain a proper shape of the bead of sealant, and traces of the oakum may as well remain on the joint surfaces and spoil the adhesion of the sealant.

A back-up of a soft foam material is also suitable for elastic sealants. Usually this is the best solution. An alternative is to use cardboard tubes coated with wax or polyethylene, polyethylene tubes, in horizontal joints even strips of polyethylene, polypropylene etc. Most of the elastic sealants do not stick to these materials when they are fully cured.

Corner joints are usually a source of trouble. In general, such joints should be avoided, but when they are unavoidable, they have to be carried out in a special way, see **Fig. 21.** One point is to avoid

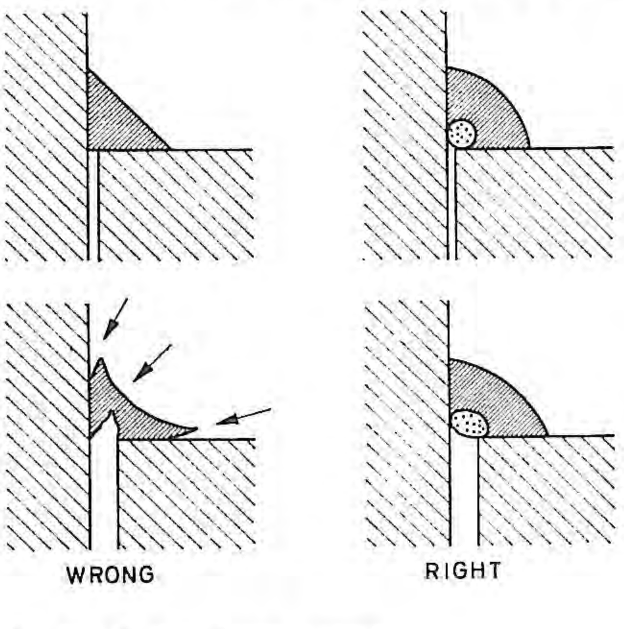


Fig. 21. Design of corner joints

a sharp or feathered edge, as this will always be a weak point. Usually the shrinkage in the surface will be sufficient to result in loss of adhesion. The right thing is here to make a convex bead. The second point to use a neutral bottom filler, to avoid cracking from the bottom of the joint. Suitable back-up materials are strips of soft foam or plastic strip sealants. Such a solution is specially useful for elastic sealants, but even many types of plastic sealants will serve all right when used in this way.

The same type of solution may as well be adapted to narrow bevelled joints. The right thing would here of course be to make the joints wide enough. But if the narrow joints already do exist, an acceptable emergency solution can be made as in **Fig. 22.** It should be pointed out that it does not help to extend the bead of sealant on the bevel, as this will usually result in cracking starting from the edges. Even when the joints are correctly sized, the sealant bead should not be extended on the bevel, but if possible set back a little in the joint.

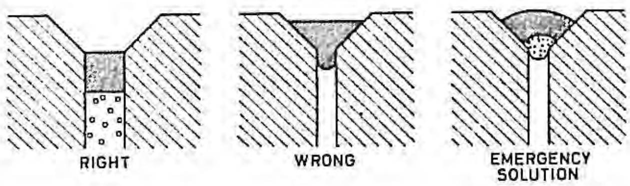


Fig. 22. Sealing bevelled joints (one-stage seals)

Joints in floors subjected to traffic need to be carried out in a special way. The best thing to do is to protect the joints with a cover-strip or similar.

Most sealants are so soft that they can not transfer any significant load. All the individual parts in a building construction must be secured by suitable fixing devices to take up all mechanical loads. Special types of glass like sealed glazing units must be properly blocked, depending upon the product used. Many problems are involved in installation of sealed glazing units, but further details shall not be given here. Reference is made to special literature (18), (19).

3.4 Concluding remarks to joint design

The available selection of building sealants is changing continuously. New materials are coming on the marked every year, and many of them are real improvements compared with earlier types. The basic consepts of proper joint design are, however, not changed. On the contrary, they remain the same.

From time to time, "wild west" conditions reappear on the sealant market with new salesmen, marketing old and new materials as the ultimate solution to all sealing problems. They are always wrong. Even the best material in the world will fail when it is used in the wrong way. Generally speaking, sealants must not be used as a kind of paint and smeared over the joints. It is always wise to remember that all joints must be properly sized and shaped, as given in the previous sections.

4 Workmanship

A successful weatherproofing with sealants depends quite as much on good workmanship as on selection of right material and correct joint design. It is very important that the craftsmen doing the job really know what they are doing, and why. The best thing would be to use only experienced specialists.

4.1 Clean and dry substrate

For all sealants it is important that the substrates are clean and free from dirt, dust, oil and fat. All kinds of contaminations must be carefully removed. Use a scraper, steelbrush, broom or vacuum cleaner, depending upon the conditions. Some times sandblasting may be suitable. Use only the specific types of solvent recommended by the sealant manufacturers. Some of them supply their own special solvents, but in most cases trichlorethylene or methylethylketone will do the job. Remember to change rags frequently; the oil and fat must be removed and not only distributed over the joint surfaces.

In most cases, the joints must also be completely dry. There do exist some types of sealants which are not quite as critical in this respect as others, but even here the only safe thing to do is to use them only on dry substrates. Cold weather is especially dangerous, due to the risk of condensation or icing. Usually + 5 °C is considered as the lowest safe outdoor temperature for sealant application without special precautions during the work. When sealant work has to be done at lower temperatures, it will be necessary with special protection by covering and heating or drying of joints with hot air.

4.2 Careful preparations

Sometimes it is appropriate to mask the joints to avoid contamination of the joint or panel surface. Use a masking tape which can be removed at a suitable point of time after application of sealant. When a primer has to be used, this must be applied properly and carefully. The back-up material must be forced in place to give right depth of joint and the necessay holding on during application of sealant. Multicomponent materials must of course be properly mixed before application. It is important to follow the manufacturers instructions.

4.3 Proper application

When the sealant is applied, care should be taken to ensure that the material is forced into all parts of the joints where it shall be, and that proper wetting of the joint surfaces is obtained. Special care must be exercised with more uneven substrates. Air bubbles in the sealant and other kinds of inhomogeneities may result in early failure. If necessary, the bead of sealant in the joint has to be made up in two or more operations, as shown in **Fig. 23.** The sealant must flow easily, i.e. not be to viscous. In many cases it is necessary to smoothen the joints, partly to force the sealant better in place in the joint, and partly to smoothen the surface. This kind of work is done with special types of tools and a smoothening agent as soap water or similar.

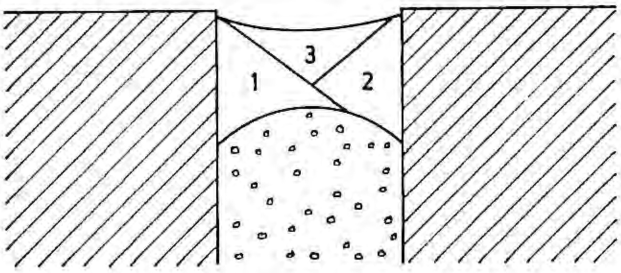


Fig. 23. Making up a sealant bead in several steps

4.4 Warranties

Successful sealing of joints is dependent on selection of right material, right joint design, correct joint details and good workmanship. Great demands are put on everybody involved in planning and performing.

The question of warranties is frequently raised, and sometimes the sealant manufacturer or the contractor is forced to give one. It should, however, be quite clear that the sealant manufacturer can only guarantee the quality of his material, and the contractor only the quality of the practical work. The only one who can guarantee that the sealant selected is the right one and that the joint design is correct, is the man doing the planning work. The only kind of warranty an owner of a house in construction should accept, is thus a common warranty from the planner, the material manufacturer and the contractor.

5 Development of suitable test programmes

5.1 Different product applications

Sealants are used for a lot of different applications. Detailed studies have shown that the actual number of possible applications is very high. This is probably the reason why nobody has so far tried to make up an exhaustive survey of the possible applications. The information given on this point by the sealant manufacturers has so far usually been comparatively short and far from satisfactory. The Expandite Ltd. company in London has, however, tried to make a more comprehensive systematical survey. A total of eleven different main applications are described in detail in their Technical Handbook (20). The main applications are further subdivided into a number of more specific application areas.

The eleven main application areas and examples on more spesific applications are as follows:

1. Joints in water retaining structures

   Irrigation canals, culverts, dams, reservoirs, sea walls, sewage works, swimming pools, water treatment and storage.

2. Joints in traffic surfaces

   Airfields, bridges, car parks, elevated roads, petrol service station forecourts, vehicle workshops and service areas, pedestrian areas.

3. Joints in building substructures and other water excluding structures

   Basements, retaining walls, site slabs, subways.

4. Joints in roofs and roof finishes

   Bitumen felt roofing, corrugated sheet roofing, mastic asphalt roofing, sheet metal roof finishes, tiled roofs, concrete roofs.

5. Joints in external walling and cladding

   Brickwork, blockwork walling, insitu concrete walling, precast concrete cladding panels, composite wall panels, light-weight cladding panels, wall tiles, mosaics, brick slips.

6. Joints in glazing, infill panels, frames and window walling

   Metal frames, timber frames, glazing without frames, curtain walling, double glazing, concrete store frames, plastic frames, roof lights.

7. Joints in internal finishes: floors

   Mastic asphalt floors, screeded floors, tiled floors, wood block floors.

8. Joints in internal finishes: walls and partitions

   Dry linings and acoustic tiles, fairfaced bricks, blockwork, plasterwork, polished stone as marble, wall tiling, internal glazing.

9. Joints in internal finishes: ceilings

   Ceiling boards and tiles, fairfaced concrete, plasterwork.

10. Joints in building services

    Air ducting, pipe work, laboratory fume extract ducting, refuse chutes, guttering, service ducts in floors, manholes, laboratory drainage ducting, services entry into building.

11. Joints in building fixtures

    Baths, handbasins, sinks, urinals, W.C.s, worktops.

For each of the main applications listed, attention is paid to different types of joints, different material surfaces to be jointed, application conditions as well as possible stresses on the jointing material.

5.2 Suitable applications of different types of sealants

The classification and grouping of sealants as given in Table 1 is first of all based on the actual use of the materials and their required functional properties, but also on the way they are applied in the joint. The grouping is relatively coarse. A number of more recent products also have a fairly wide field of use. This is specially true for some of the product subgroups in Table 1 listed as "standard quality" materials. The products available on the present market are, however, of highly different quality. A more distinct subdivision and listing of the products is obtained when functional requirements are put to every product group, combined with requirements to testing and documentation of the results obtained.

When the different groups of sealants as listed in Table 1 are related to the eleven earlier mentioned main application areas, the following brief survey can be made:

Type 511. Wood sash putties

This group of materials has a strictly limited field of use, only for glazing small panes of single glass in wooden windows. This type of material covers only a small part of application area No. 6.

Type 512. Metal sash putty

Does also cover only a small part of application area No. 6. These materials are used for glazing small panes of single glass into windows of steel and some other metals.

Types 521 - 524. Plastic glazing compounds

These materials were widely used in Scandinavia in the 1960's, but are now practically out of use here. In some other countries, they have the same field of application as before, for glazing of fairly small windows of wood, steel, aluminium etc, but still within application area No. 6.

Types 531 and 532. Standard quality skin-forming plastic sealants

Sealants of these types still have many possible applications, indoor as well as outdoor, but preferably where there is no risk of damage to the seal by human beings. Possible applications are within area No. 5, joints in external walling and cladding, area No. 8, joints in internal finishes in walls and partitions, and area No. 9, joints in internal finishes in ceilings. They have also been used withing the areas Nos. 3 and 10, but have then appeared to be less suitable.

Types 533 and 534. Glazing quality skin-forming plastic sealants

These types are now rarely found. They have been used for a number of glazing applications, but their present application is first of all limited to green house glazing. This is a part of application area No. 6.

Types 541 and 542. Non-skinning plastic sealants

Such sealants do not dry out, but remain sticky on the surface. They can then only be used where dust and dirt accumulation is no problem. Some of these sealant types are used in joints in building substructures (area No. 3) and in roofs (area No. 4). Typical are for instance a number of asphalt based sealants used against other asphalt products, concrete in the ground as well as roofing asphalt and roofing felt. Some of the non-skinning sealants are used indoors in hidden joints, in joints in external walling (area No. 5) as well as internal walls and ceilings (areas Nos. 8 and 9). A very particular field of application is for joints in air ducts and other types of building services (area No. 10).

Type 551. Standard quality gun grade tough plastic sealants

This group of material is used much for the same applications as the standard quality skin-forming materials types 531 and 532, but are better in many respects. They are found in joints in external walls and claddings (area No. 5), in joints in internal finishes in walls and partitions (area No. 8), in ceilings (area No. 9) and to some extent also in joints in building services (area No. 10).

Type 552. Glazing quality tough plastic sealants

Is used within a part of application area No. 6.

Type 553. Tough plastic narrow joint sealants

This is a very special type of material, intended only for very narrow joints, in general 3 mm wide or less. Such joints are found in external walls (area No. 5), sometimes also in indoor joints (areas Nos. 8 and 9), as well as connections in pipe work and ducting (area No.10). A clear assumption for the use of this type of material is that the joints are only subjected to minor joint movements.

Type 554. Tough plastic sealants for indoor applications

This type of sealant is more or less specially made for indoor applications (areas Nos. 8 and 9). It can also be used in joints in external walls (area No. 5), but should then only be used with proper protection against the outdoor climate.

Type 561. Hot poured thermoplastic sealants for horizontal joints

The interesting joints are found in traffic areas (area No. 2) and in joints in floors indoors (area No. 7). Other possible applications are in joints in water retaining structures (area No. 1), building substructures etc. (area No. 3) as well as roof and roof finishes (area No. 4).

Type 562. Thermoplastic sealants, hand applied at slightly elevated temperatures

This type of sealant is first of all used in vertical joints in water retaining structures (area No.1), and similar joints in building substructures (area No.3). It is also used in other areas, but has in most cases to be considered as less suitable.

Types 571 and 572. Standard quality non-drying plastic strip sealants and partly cured plastic/elastic strip sealants

Such sealants are first of all used in lap joints where the strips can be put in place during the construction work. Suitable joints are found in lapped roofs (area No. 4), in external walls (area No. 5), in walls and ceilings indoor (areas Nos. 8 and 9) as well as a number of applications in building services (area No. 10).

Type 573. Glazing quality partly cured plastic/ elastic strip sealants

Special strip sealants for glazing (area No. 6).

Type 574. Standard quality thermoplastic strip sealants

This type of material is normally used for the same applications as the type 562, i.e. in vertical joints in water retaining structures (area No. 1) or in building substructures (area No. 3), but may also be used for other applications.

Types 581 and 583. Standard quality elastic sealants

These groups have developed over the years and are both now fairly wide groups, covering materials with partly different application areas. Some of them are specially formulated for use in water retaining structures (area No. 1) or in building substructures (area No. 3), others are made for joints in roofs and walls (ares Nos. 4 and 5). The latter types may of course also be used for indoors applications (areas Nos. 8 and 9), but are rarely used here for economical reasons.

Types 582 and 584. Glazing quality elastic sealants

These are the most advanced sealants for windows, glazing and window walls (area No. 6). Some of them may also be used with success in sanitary installations (area No.11).

Types 585 - 588. Traffic bearing one- or two-part elastic sealants

These groups cover special sealants for the application areas Nos. 2 and 7 (joints in traffic areas and floors).

5.3 Test programmes for different types of sealants for different applications

Based on the earlier considerations, detailed test programmes can be worked out for different types of sealants and a number of applications. An early example is shown in **Fig. 24.** The programmes shall not be shown here in all details, as they will fill too many pages. For the purpose of this report, it has been found more convenient to show a total of eleven tables, one for each of the main application areas as listed under point 5.1.

A total of 30 different types of sealants are covering the eleven main application areas, as given in the **Tables 9 through 19.** Each table is showing the types of sealants useful for this main application area. The interesting types differ in number. For each combination of type of sealant and application area, the relevant properties are listed.

For practical reasons, it is not possible to give detailed information on the considerations laying behind the selection of relevant properties for every combination of type of sealant with main application area. In the Tables 9 - 19 the following markings have been used:

xxx relevant property to be documented with test results

xx relevant property where information shall be given, but where documentation by test results is not compulsory

x relevant property

(x) relevant property only in special cases

No marking means not relevant property in the actual case.

A test programme can easily be written out in detail in every relevant case, based on the Tables 9 - 19 and the information given in section 2.

NORWEGIAN BUILDING RESEARCH INSTITUTE 519.10

Draft Scandinavian specification for plastic glazing compounds group 52 for installation of sealed glazing units.

Scope.

This specification covers skin-forming plastic oilbased glazing compounds for application at normal temperatures. It is distinguished between:

```
Type 521 knife grade, single-component
 "   522   "     "    two-       "
 "   523 gun     "    single-    "
 "   524  "      "    two-       "
```

The materials are supposed to be used in accordance with standard glazing method No. 1.

NB: This draft does not necessarily have the form required by the standardization organizations. The test methods are described in "General view of actual properties and test methods for sealants", 17th August 1970.

Fig. 24. First part of a draft Scandinavian specification from 1970

Table 9. **Relevant properties for different types of sealants**
Main application area No. 1. Joints in water retaining structures

Properties/Useful sealants		561	562	574	581	583
2.01	Volatile content	x	x	x	x	x
2.02	Density	x	x	x	x	x
2.03	Homogeneity	x	x	x	x	x
2.04	Colour				(x)	(x)
2.05	Smell, toxicity	x	x	x	x	x
2.06	Elongation properties	xxx	xxx	xxx	xxx	xxx
2.07	Hardness				xxx	xxx
2.08	Deformability characteristics				x	x
2.09	Resistance to indentation	xxx				
2.10	Peel strength				xxx	xxx
2.11	Resistance to sagging		xxx	xxx	xxx	xxx
2.12	Flow characteristics	xxx				
2.13	Combustibility	(x)	(x)	(x)	(x)	(x)
2.14	Air penetration					
2.15	Water absorption					
2.16	Rain penetration					
2.17	Resistance to alkalies	xxx	xxx	xxx	xxx	xxx
2.18	Resistance to solvents, salt spray, cleaning agents and other chemicals	xx	xx	xx	xx	xx
2.19	Seepage	xxx	xxx	xxx	xxx	xxx
2.20	Staining of porous substrates	(x)	(x)	(x)	(x)	(x)
2.21	Free shrinkage	xxx	xxx	xxx	xxx	xxx
2.22	Restrained shrinkage	xxx	xxx	xxx	xxx	xxx
2.23	Weight loss on heat aging	x	x	x	x	x
2.24	Tack-free time				xx	xx
2.25	Skin formation					
2.26	Resistance to solar radiation	xx	xx	xx	xx	xx
2.27	Adhesion to glass, influence of solar radiation					
2.28	Resistance to peeling, influence of solar radiation					
2.29	Extrudability				xxx	xxx
2.30	Pot life				xx	
2.31	Resistance to attacks by birds					
2.32	Influence of high and low temperatures					
2.33	Accomodation of movements	xxx	xxx	xxx	xxx	xxx
2.34	Paintability					

Table 10. Relevant properties for different types of sealants
Main application area No. 2. Joints in traffic areas

Properties/Useful sealants		561	585	586	587	588
2.01	Volatile content	x	x	x	x	x
2.02	Density	x	x	x	x	x
2.03	Homogeneity	x	x	x	x	x
2.04	Colour					
2.05	Smell, toxicity	x	x	x	x	x
2.06	Elongation properties	xxx	xxx	xxx	xxx	xxx
2.07	Hardness		xxx	xxx	xxx	xxx
2.08	Deformability characteristics		x	x	x	x
2.09	Resistance to indentation	xxx	xxx	xxx	xxx	xxx
2.10	Peel strength		xxx	xxx	xxx	xxx
2.11	Resistance to sagging					
2.12	Flow characteristics	xxx			xxx	xxx
2.13	Combustibility	(x)	(x)	(x)	(x)	(x)
2.14	Air penetration					
2.15	Water absorption					
2.16	Rain penetration					
2.17	Resistance to alkalies	xxx	xxx	xxx	xxx	xxx
2.18	Resistance to solvents, salt spray, cleaning agents and other chemicals	xx	xx	xx	xx	xx
2.19	Seepage	xxx	xxx	xxx	xxx	xxx
2.20	Staining of porous substrates	(x)	(x)	(x)	(x)	(x)
2.21	Free shrinkage	xxx	xxx	xxx	xxx	xxx
2.22	Restrained shrinkage	xxx	xxx	xxx	xxx	xxx
2.23	Weight loss on heat aging	x	x	x	x	x
2.24	Tack-free time		xx	xx	xx	xx
2.25	Skin formation					
2.26	Resistance to solar radiation	xx	xx	xx	xx	xx
2.27	Adhesion to glass, influence of solar radiation					
2.28	Resistance to peeling, influence of solar radiation					
2.29	Extrudability		xxx	xxx		
2.30	Pot life		xx		xx	xx
2.31	Resistance to attacks by birds					
2.32	Influence of high and low temperatures					
2.33	Accomodation of movements	xxx	xxx	xxx	xxx	xxx
2.34	Paintability					

Table 11. Relevant properties for different types of sealants
Main application area No. 3. Joints in building substructures and other water excluding structures

Properties/Useful sealants		541	542	561	562	574	581	583
2.01	Volatile content	x	x	x	x	x	x	x
2.02	Density	x	x	x	x	x	x	x
2.03	Homogeneity	x	x	x	x	x	x	x
2.04	Colour						(x)	(x)
2.05	Smell, toxicity	x	x	x	x	x	x	x
2.06	Elongation properties	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.07	Hardness						xxx	xxx
2.08	Deformability characteristics						x	x
2.09	Resistance to indentation							
2.10	Peel strength						xxx	xxx
2.11	Resistance to sagging	xxx	xxx		xxx	xxx	xxx	xxx
2.12	Flow characteristics			xxx				
2.13	Combustibility	xx	xx	xx	xx	xx	xx	xx
2.14	Air penetration							
2.15	Water absorption							
2.16	Rain penetration							
2.17	Resistance to alkalies	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.18	Resistance to solvents, salt spray, cleaning agents and other chemicals							
2.19	Seepage	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.20	Staining of porous substrates	(x)	(x)	(x)	(x)	(x)	(x)	(x)
2.21	Free shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.22	Restrained shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.23	Weight loss on heat aging	x	x	x	x	x	x	x
2.24	Tack-free time						xx	xx
2.25	Skin formation							
2.26	Resistance to solar radiation							
2.27	Adhesion to glass, influence of solar radiation							
2.28	Resistance to peeling, influence of solar radiation							
2.29	Extrudability	xxx					xxx	xxx
2.30	Pot life						xx	
2.31	Resistance to attacks by birds							
2.32	Influence of high and low temperatures							
2.33	Accomodation of movements	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.34	Paintability							

Table 12. Relevant properties for different types of sealants
Main application area No. 4. Joints in roofs and roof finishes

Properties/Useful sealants	541	542	561	571	572	581	583
2.01 Volatile content	x	x	x	x	x	x	x
2.02 Density	x	x	x	x	x	x	x
2.03 Homogeneity	x	x	x	x	x	x	x
2.04 Colour						(x)	(x)
2.05 Smell, toxicity	(x)	(x)	(x)	(x)	(x)	(x)	(x)
2.06 Elongation properties	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.07 Hardness						xxx	xxx
2.08 Deformability characteristics						x	x
2.09 Resistance to indentation							
2.10 Peel strength						xxx	xxx
2.11 Resistance to sagging	xxx	xxx		xxx	xxx	xxx	xxx
2.12 Flow characteristics			xxx				
2.13 Combustibility	xx	xx	xx	xx	xx	xx	xx
2.14 Air penetration							
2.15 Water absorption							
2.16 Rain penetration							
2.17 Resistance to alkalies	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.18 Resistance to solvents, salt spray, cleaning agents and other chemicals							
2.19 Seepage	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.20 Staining of porous substrates	(x)	(x)	(x)	(x)	(x)	(x)	(x)
2.21 Free shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.22 Restrained shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.23 Weight loss on heat aging	x	x	x	x	x	x	x
2.24 Tack-free time						xx	xx
2.25 Skin formation							
2.26 Resistance to solar radiation	xx	xx	xx	xx	xx	xx	xx
2.27 Adhesion to glass, influence of solar radiation							
2.28 Resistance to peeling, influence of solar radiation							
2.29 Extrudability	xxx	xxx				xxx	xxx
2.30 Pot life						xx	
2.31 Resistance to attacks by birds							
2.32 Influence of high and low temperatures							
2.33 Accomodation of movements	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.34 Paintability							

Table 13. Relevant properties for different types of sealants
Main application area No. 5. Joints in external walling and cladding

Properties/Useful sealants		531	532	541	542	551	553	554	571	572	581	583
2.01	Volatile content	x	x	x	x	x	x	x	x	x	x	x
2.02	Density	x	x	x	x	x	x	x	x	x	x	x
2.03	Homogeneity	x	x	x	x	x	x	x	x	x	x	x
2.04	Colour										(x)	(x)
2.05	Smell, toxicity	x	x	x	x	x	x	x	x	x	x	x
2.06	Elongation properties	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.07	Hardness										xxx	xxx
2.08	Deformability characteristics										x	x
2.09	Resistance to indentation											
2.10	Peel strength										xxx	xxx
2.11	Resistance to sagging	xxx	xxx	xxx	xxx	xxx		xxx	xxx	xxx	xxx	xxx
2.12	Flow characteristics											
2.13	Combustibility	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx
2.14	Air penetration											
2.15	Water absorption					(x)		(x)				
2.16	Rain penetration											
2.17	Resistance to alkalies	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.18	Resistance to solvents, salt spray, cleaning agents,and other chemicals	xx	xx			xx	xx				xx	xx
2.19	Seepage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.20	Staining of porous substrates	xxx	xxx	(x)	(x)	xxx	xxx	(x)	xxx	xxx	xxx	xxx
2.21	Free shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.22	Restrained shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.23	Weight loss on heat aging	x	x	x	x	x	x	x	x	x	x	x
2.24	Tack-free time	xx	xx			xx	xx				xx	xx
2.25	Skin formation	xxx	xxx									
2.26	Resistance to solar radiation	xx	xx			xx	xx		xx	xx	xx	xx
2.27	Adhesion to glass, influence of solar radiation											
2.28	Resistance to peeling, influence of solar radiation											
2.29	Extrudability	xxx		xxx		xxx	xx	xxx			xxx	xxx
2.30	Pot life										xx	
2.31	Resistance to attacks by birds	x	x									
2.32	Influence of high and low temperatures											
2.33	Accomodation of movements	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.34	Paintability	x	x			(x)			(x)	(x)	(x)	(x)

Table 14. Relevant properties for different types of sealants
Main application area No. 6. Joints in glazing, infill panels, frames and window walling

Properties/Useful sealants	511	512	521	522	523	524	533	534	552	573	582	584
2.01 Volatile content	x	x	x	x	x	x	x	x	x	x	x	x
2.02 Density	x	x	x	x	x	x	x	x	x	x	x	x
2.03 Homogeneity	x	x	x	x	x	x	x	x	x	x	x	x
2.04 Colour											(x)	(x)
2.05 Smell, toxicity	x	x	x	x	x	x	x	x	x	x	x	x
2.06 Elongation properties			xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.07 Hardness											xxx	xxx
2.08 Deformability characteristics											x	x
2.09 Resistance to indentation												
2.10 Peel strength											xxx	xxx
2.11 Resistance to sagging			xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.12 Flow characteristics												
2.13 Combustibility							(x)	(x)	(x)	(x)	(x)	(x)
2.14 Air penetration												
2.15 Water absorption												
2.16 Rain penetration												
2.17 Resistance to alkalies			xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.18 Resistance to solvents, salt spray, cleaning agents and other chemicals	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.19 Seepage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.20 Staining of porous substrates			xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.21 Free shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.22 Restrained shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.23 Weight loss on heat aging	x	x	x	x	x	x	x	x	x	x	x	x
2.24 Tack-free time	xx	xx	xx	xx	xx	xx	xx	xx	xx		xx	xx
2.25 Skin formation			xx	xx	xx	xx	xxx	xxx				
2.26 Resistance to solar radiation	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx
2.27 Adhesion to glass, influence of solar radiation	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.28 Resistance to peeling, influence of solar radiation											xxx	xxx
2.29 Extrudability					xxx	xxx	xxx		xxx		xxx	xxx
2.30 Pot life											xx	
2.31 Resistance to attacks by birds	x	x	x	x	x	x	x	x				
2.32 Influence of high and low temperatures												
2.33 Accomodation of movements							xxx	xxx	xxx	xxx	xxx	xxx
2.34 Paintability	x	x	x	x	x	x	x	x	(x)	(x)	(x)	(x)

Table 15. Relevant properties for different types of sealant
Main application area No. 7. Joints in internal finishes: floors

Properties/Useful sealants		561	585	586	587	588
2.01	Volatile content	x	x	x	x	x
2.02	Density	x	x	x	x	x
2.03	Homogeneity	x	x	x	x	x
2.04	Colour					
2.05	Smell, toxicity	x	x	x	x	x
2.06	Elongation properties	xxx	xxx	xxx	xxx	xxx
2.07	Hardness		xxx	xxx	xxx	xxx
2.08	Deformability characteristics		x	x	x	x
2.09	Resistance to indentation	xxx	xxx	xxx	xxx	xxx
2.10	Peel strength		xxx	xxx	xxx	xxx
2.11	Resistance to sagging					
2.12	Flow characteristics	xxx			xxx	xxx
2.13	Combustibility	xx	xx	xx	xx	xx
2.14	Air penetration					
2.15	Water absorption					
2.16	Rain penetration					
2.17	Resistance to alkalies	xxx	xxx	xxx	xxx	xxx
2.18	Resistance to solvents, salt spray, cleaning agents and other chemicals	xx	xx	xx	xx	xx
2.19	Seepage	xxx	xxx	xxx	xxx	xxx
2.20	Staining of porous substrates	xxx	xxx	xxx	xxx	xxx
2.21	Free shrinkage	xxx	xxx	xxx	xxx	xxx
2.22	Restrained shrinkage	xxx	xxx	xxx	xxx	xxx
2.23	Weight loss on heat aging	x	x	x	x	x
2.24	Tack-free time		xx	xx	xx	xx
2.25	Skin formation					
2.26	Resistance to solar radiation					
2.27	Adhesion to glass, influence of solar radiation					
2.28	Resistance to peeling, influence of solar radiation					
2.29	Extrudability		xxx	xxx		
2.30	Pot life		xx			
2.31	Resistance to attacks by birds					
2.32	Influence of high and low temperatures					
2.33	Accomodation of movements	xxx	xxx	xxx	xxx	xxx
2.34	Paintability	(x)	(x)	(x)	(x)	(x)

Table 16. Relevant properties for different types of sealants
Main application area No. 8. Joints in internal finishes: Walls and partitions

Properties/Useful sealants	531	532	541	542	551	553	554	571	572	581	583
2.01 Volatile content	x	x	x	x	x	x	x	x	x	x	x
2.02 Density	x	x	x	x	x	x	x	x	x	x	x
2.03 Homogeneity	x	x	x	x	x	x	x	x	x	x	x
2.04 Colour											
2.05 Smell, toxicity	x	x	x	x	x	x	x	x	x	x	x
2.06 Elongation properties	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.07 Hardness										xxx	xxx
2.08 Deformability characteristics										x	x
2.09 Resistance to indentation											
2.10 Peel strength										xxx	xxx
2.11 Resistance to sagging	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.12 Flow characteristics											
2.13 Combustibility	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx
2.14 Air penetration											
2.15 Water absorption											
2.16 Rain penetration											
2.17 Resistance to alkalies	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.18 Resistance to solvents, salt spray, cleaning agents and other chemicals											
2.19 Seepage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.20 Staining of porous substrates	xxx	xxx	(x)	(x)	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.21 Free shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.22 Restrained shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.23 Weight loss on heat aging	x	x	x	x	x	x	x	x	x	x	x
2.24 Tack-free time	xx	xx			xx	xx	xx			xx	xx
2.25 Skin formation	xxx	xxx									
2.26 Resistance to solar radiation											
2.27 Adhesion to glass, influence of solar radiation											
2.28 Resistance to peeling, influence of solar radiation											
2.29 Extrudability	xxx		xxx		xxx	xx	xxx			xxx	xxx
2.30 Pot lif										xxx	
2.31 Resistance to attacks by birds											
2.32 Influence of high and low temperatures											
2.33 Accomodation of movements	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.34 Paintability	x	x			x		x	(x)	(x)	(x)	(x)

Table 17. Relevant properties for different types of sealants
Main application area No. 9. Joints in internal finishes: Ceilings

Properties/Useful sealants		531	532	541	542	551	553	554	571	572	581	583
2.01	Volatile content	x	x	x	x	x	x	x	x	x	x	x
2.02	Density	x	x	x	x	x	x	x	x	x	x	x
2.03	Homogeneity	x	x	x	x	x	x	x	x	x	x	x
2.04	Colour											
2.05	Smell, toxicity	x	x	x	x	x	x	x	x	x	x	x
2.06	Elongation properties	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.07	Hardness										xxx	xxx
2.08	Deformability characteristics										x	x
2.09	Resistance to indentation											
2.10	Peel strength										xxx	xxx
2.11	Resistance to sagging	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.12	Flow characteristics											
2.13	Combustibility	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx	xx
2.14	Air penetration											
2.15	Water absorption											
2.16	Rain penetration											
2.17	Resistance to alkalies	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.18	Resistance to solvents, salt spray, cleaning agents and other chemicals											
2.19	Seepage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.20	Staining of porous substrates	xxx	xxx	(x)	(x)	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.21	Free shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.22	Restrained shrinkage	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.23	Weight loss on heat aging	x	x	x	x	x	x	x	x	x	x	x
2.24	Tack-free time	xx	xx			xx	xx	xx			xx	xx
2.25	Skin formation	xxx	xxx									
2.26	Resistance to solar radiation											
2.27	Adhesion to glass, influence of solar radiation											
2.28	Resistance to peeling, influence of solar radiation											
2.29	Extrudability	xxx		xxx		xxx	xxx	xxx			xxx	xxx
2.30	Pot life										xx	
2.31	Resistance to attacks by birds											
2.32	Influence of high and low temperatures											
2.33	Accomodation of movements	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2.34	Paintability	x	x			x		x	(x)	(x)	(x)	(x)

Table 18. Relevant properties for different types of sealants
Main application area No. 10. Joints in building services

Properties/Useful sealants		541	542	551	553	571	572	582	584
2.01	Volatile content	x	x	x	x	x	x		
2.02	Density	x	x	x	x	x	x		
2.03	Homogeneity	x	x	x	x	x	x		
2.04	Colour								
2.05	Smell, toxicity	xx	xx	xx	xx	xx	xx		
2.06	Elongation properties	xxx	xxx	xxx	xxx	xxx	xxx		
2.07	Hardness								
2.08	Deformability characteristics								
2.09	Resistance to indentation								
2.10	Peel strength								
2.11	Resistance to sagging	xxx	xxx	xxx	xxx	xxx	xxx		
2.12	Flow characteristics								
2.13	Combustibility	xx	xx	xx	xx	xx	xx		
2.14	Air penetration								
2.15	Water absorption								
2.16	Rain penetration								
2.17	Resistance to alkalies	xxx	xxx	xxx	xxx	xxx	xxx		
2.18	Resistance to solvents, salt spray, cleaning agents and other chemicals								
2.19	Seepage	xxx	xxx	xxx	xxx	xxx	xxx		
2.20	Staining of porous substrates	(x)	(x)	(x)	(x)	(x)	(x)		
2.21	Free shrinkage	xxx	xxx	xxx	xxx	xxx	xxx		
2.22	Restrained shrinkage	xxx	xxx	xxx	xxx	xxx	xxx		
2.23	Weight loss on heat aging	x	x	x	x	x	x		
2.24	Tack-free time			xx	xx				
2.25	Skin formation								
2.26	Resistance to solar radiation								
2.27	Adhesion to glass, influence of solar radiation								
2.28	Resistance to peeling, influence of solar radiation								
2.29	Extrudability	xxx		xxx	xxx				
2.30	Pot life								
2.31	Resistance to attacks by birds								
2.32	Influence of high and low temperatures								
2.33	Accomodation of movements	xxx	xxx	xxx	xxx	xxx	xxx		
2.34	Paintability								

Table 19. Relevant properties for different types of sealants
Main application area No. 11. Joints in building fixtures

Properties/Useful sealants		582	584
2.01	Volatile content	x	x
2.02	Density	x	x
2.03	Homogeneity	x	x
2.04	Colour		
2.05	Smell, toxicity	x	x
2.06	Elongation properties	xxx	xxx
2.07	Hardness	xxx	xxx
2.08	Deformability characteristics	x	x
2.09	Resistance to indentation		
2.10	Peel strength	xxx	xxx
2.11	Resistance to sagging	xxx	xxx
2.12	Flow characteristics		
2.13	Combustibility	xx	xx
2.14	Air penetration		
2.15	Water absorption		
2.16	Rain penetration		
2.17	Resistance to alkalies	xxx	xxx
2.18	Resistance to solvents, salt spray, cleaning agents and other chemicals	xxx	xxx
2.19	Seepage	xxx	xxx
2.20	Staining of porous substrates	xxx	xxx
2.21	Free shrinkage	xxx	xxx
2.22	Restrained shrinkage	xxx	xxx
2.23	Weight loss on heat aging	x	x
2.24	Tack-free time	xx	xx
2.25	Skin formation		
2.26	Resistance to solar radiation		
2.27	Adhesion to glass, influence of solar radiation		
2.28	Resistance to peeling, influence of solar radiation		
2.29	Extrudability	xxx	xxx
2.30	Pot life	xx	
2.31	Resistance to attacks by birds		
2.32	Influence of high and low temperatures		
2.33	Accomodation of movements	xx	xx
2.34	Paintability	(x)	(x)

6 Development of a short test programme

As appeared from the previous chapters, testing of sealants is usually a time-consuming and expensive task. There is a high number of interesting properties where appropriate data should be made available, and in many cases these data can only come from testing. Prototype testing according to complete test programmes based on the Tables 9 - 19 is .consequently rarely carried out for purely economical reasons.

Very often the following question has been put: Can't the testing be made in a simpler and cheaper way? The answer has so far been definitely no. Complete prototype testing is necessary to get an over-all picture of what a sealant is good for. Anyhow, the demands for a simpler and cheaper test have been met through the development of a NBI short test programme.

The basic idea behind this programme is quite simply that the following three functional properties are always the most important:

- Adhesion to the substrate
- Cohesion, i.e. ability to accomodate movements
- Weather resistance.

The testing of these three properties can be combined in the following two tests:

- An adhesion test as 180° adhesion in peel, combined with heat aging and water immersion
- An accomodation of movements test combined with an accelerated weathering cycle.

6.1 The modified adhesion test

This is based on the convenitional peel strength test as described in point 2.10. The normal substrates are the traditional flat pieces of glass, aluminium and concrete, but other substrates may be included according to agreement. After initial

Table 20. Short test programme. Results of adhesion tests, peel strength in Newton (N) and type of failure

Sealant No.	Substrate	Start		7 days		28 days	
1	Glass	< 0,5	Cohesive	2	Cohesive	1	50 % Adhesive
	Aluminium	< 0,5	Cohesive	< 0,5	30 % Adhesive	1	50 % Adhesive
	Concrete	< 0,5	Cohesive	< 0,5	50 % Adhesive	< 0,5	50 % Adhesive
2	Glass	< 0,5	Cohesive	2	Cohesive	1	50 % Adhesive
	Aluminium	< 0,5	Cohesive	1	Adhesive	1	50 % Adhesive
	Concrete	1	Adhesive	< 0,5	Adhesive	< 0,5	Adhesive
3	Glass	2	Adhesive	< 0,5	Adhesive	< 0,5	Adhesive
	Aluminium	7	Adhesive	1	Adhesive	< 0,5	Adhesive
	Concrete	3	Adhesive	1	Adhesive	1	Adhesive
4	Glass	30	50 % Adhesive	20	Cohesive	19	Cohesive
	Aluminium	35	15 % Adhesive	20	Cohesive	20	Cohesive
	Concrete	42	Cohesive	22	Cohesive	19	Cohesive
5	Glass	50	40 % Adhesive	70	Cohesive	70	Cohesive
	Aluminium	9	Adhesive	30	60 % Adhesive	5	Adhesive
	Concrete	5	Adhesive	< 0,5	Adhesive	< 0,5	Adhesive
6	Glass	45	Cohesive	40	40 % Adhesive	9	Adhesive
	Aluminium	10	90 % Adhesive	50	Cohesive	35	Adhesive
	Concrete	35	30 % Adhesive	< 0,5	Adhesive	< 0,5	Adhesive
7	Glass	65	10 % Adhesive	62	Cohesive	59	Cohesive.
	Aluminium	50	50 % Adhesive	105	Cohesive	25	Cohesive
	Concrete	95	80 % Adhesive	< 0,5	Adhesive	< 0,5	Adhesive
8	Glass	73	Cohesive	48	Cohesive	42	Cohesive
	Aluminium	67	Cohesive	45	Cohesive	28	Cohesive
	Concrete	15	80 % Adhesive	< 0,5	Adhesive	< 0,5	Adhesive

Table 21. **Short test programme. Results of accomodation of movements tests**

Sealant No.	Elongation	Comments
1	10 %	Beginning failure in surface skin after 2nd period of 360 cycles, total failure in surface skin after 4th period. Adhesion and cohesion of the sealant itself OK after 9 periods of 360 cycles
2	10 %	Beginning failure in surface skin after 1st period of 360 cycles, total failure in surface skin after 4th period. Adhesion and cohesion of the sealant itself OK after 9 periods of 360 cycles
3	10 %	Adhesive failure after 2nd period of 360 cycles
4	25 %	Beginning adhesive failure after 1st period of 360 cycles, adhesive failure after 4th period
5 I	25 %	Adhesive failure after 1st period,
5 II	25 %	OK after 9 periods of 360 cycles
6	25 %	OK after 9 periods of 360 cycles
7	25 %	OK after 9 periods of 360 cycles
8	25 %	OK after 9 periods of 360 cycles

setting and curing, the test pieces are subjected to heat aging combined with liquid water by immersion in a water bath at 323 K (+ 50 °C). The adhesion in peel testing is carried out at room temperature 296 K (+ 23 °C) after 0, 7 and 28 days of water loading.

6.2 The modified cyclic movements test

This is in fact the normal procedure for accomodation of movements testing according to point 2.33, with one minor modification: The six days of heat aging every week have been changed to three days of heat aging followed by three days of accelerated weathering.

6.3 Results from testing according to the short test programme

To study the suitability of the planned short test programme, a total of eight sealants were tested according to it. Basically, the adhesion in peel tests are made only for elastic materials. In this case, however, they were made for all eight materials without exception.

The results have been summarized in the two **tables 20 and 21.**

The eight materials tested shall not be given by brand names, but the following more general description:

Sealant 1 was a skin-forming plastic sealant, standard quality gun grade, type 531, traditional oil-based type

Sealant 2 was a similar material, type 531, but based on synthetic oils

Sealant 3 was an acrylic based gun grade tough plastic sealant, claimed to be type 551 standard quality for general use

Sealant 4 was a polyurethane material, glazing and standard quality one-part gun grade elastic sealant, type 583/584

Sealant 5 was a polysulphide material, standard quality one-part gun grade elastic sealant, type 583

Sealant 6 was a silicone material, glazing quality gun grade elastic sealant, type 584

Sealant 7 was a silicone material, standard quality gun grade elastic sealant, type 583

Sealant 8 was a silicone material, glazing and standard quality gun grade elastic sealant, type 583/584.

All sealants were from well-known manufacturers.

The results shall not be given any comments here, except the comments hidden in the following three questions:

- What are the present selection of sealants really good for?
- Have the sealant quality been drastically lowered over the last ten years period?
- Is concrete really such a difficult substrate as the test results indicate?

The results and questions are there for individual considerations.

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8 Appendix

Norwegian Building Research Institute Test Methods for Building Sealants

Building Sealants
Determination of Volatile Content

NBI-42
1987

BYGGFORSK

1 SCOPE

This test method can be used to check the volatile content of all kind of building sealants. It is of great interest to know the content of the volatile constituents as this effects the shrinkage as well as other properties.

2 FIELD OF APPLICATION

The test method described is intended to be used with all kind of building sealants.

3 REFERENCES

This test method is based on internal unpublished work at the Building Research Station, Garston, England. It has in its present form been included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used several years before that date. It was adopted as NORDTEST method NT BUILD 001 in June 1976.

4 DEFINITIONS

None.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the tests. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate and must be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

A thin layer of sealant is dried a short period of time at a high temperature. Weight loss is recorded.

6.2 Apparatus and Materials

Press-on lid or other kind of metal dish with a diameter of approximately 80 mm.

Apparatus for metering $2 \cdot 10^{-6}$ m^3 ($2 cm^3$) building sealant.

Putty knife or similar.

Balance, measuring accuracy 10^{-6} kg (1 mg).

Ventilated heating cabinet.

6.3 Preparation and Conditioning of Test Specimens

Materials and equipment are conditioned at 296 K (23°C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and are reconditioned, if necessary, at 296 K (23°C) and 50 % RH.

6.4 Procedure

The press-on lid or metal dish is dried at 323 K (50°C), cooled to 296 K (23°C) and weighed. The weight W_1 is noted.

The press-on lid is placed upside down. Using the metering apparatus, $2 \cdot 10^{-6}$ m^3 (2 cm^3) sealant is placed on the surface. The sealant is spread evenly to a thickness of about 0,5 mm. Dish with sealant is weighed, and the weight W_2 recorded.

The specimen is dried for 4 hours in a ventilated heating cabinet at 378 K (105°C), cooled to 296 K (23°C), and weighed again, W_3.

6.5 Expression of Results

Volatile constituents F are calculated from the following formula:

$$F = 100 \frac{W_2 - W_3}{W_2 - W_1} \%$$

The result is given in % with one decimal.

6.6 Accuracy

The accuracy of this test method is good.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Density

NBI-43
1987

1 SCOPE

This test method is intended for determining the density of all kind of putties and sealants which are applied at normal temperatures or at slightly elevated temperatures. The density is a property it is very conveniant to know when doing a number of other tests, among others the extrudability test for gun grade materials. The density can also give certain ideas about various other material properties.

2 FIELD OF APPLICATION

The test method can be used for all materials as described in point 1, scope.

3 REFERENCES

A similar method is described in British Standard BS 3712: Part 1: 1964. This test method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used several years before that date. It was adopted as NORDTEST method NT BUILD 002 in June 1976.

4 DEFINTIONS

None.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the tests. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate and must be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 **Principle**

A known volume is filled with sealant, weighed, and the density calculated.

6.2 **Apparatus and Materials**

Metal cylinder with a length of approx. 40 mm and an inner diameter of approx. 20 mm. The inner volume of the cylinder, V, should be approx. $15 \cdot 10^{-6}$ m^3 (15 cm^3) and determined with an accuracy of 0,1 per cent.

Two pieces of flat glass, approx. 50 mm x 50 mm.

Balance, measuring accuracy 10^{-6} kg (1 mg).

6.3 **Preparation and Conditioning of Test Specimens**

Materials and equipment are conditioned at 296 K (23°C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and are reconditioned, if necessary, at 296 K (23°C) and 50 % RH.

6.4 **Procedure**

The metal cylinder and the flat glass pieces are weighed and the total weight, W_1, is noted.

The cylinder is placed on one of the glass pieces and carefully filled from the top with sealant to avoid trapping of air. When the cylinder is filled, the sealant should be levelled with the top of the cylinder. It is then closed with the other piece of glass.

The filled cylinder, includig the glass pieces, is weighed, and the weight, W_2, is noted.

6.5 **Expression of Results**

Density D is calculated from the following formula:

$$D = \frac{W_2 - W_1}{V}$$

The density is given as a whole number, without decimals, and with a calculating accuracy of 0,5 - 1 per cent.

6.7 **Test Report**

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Homogeneity

NBI-44
1987

BYGGFORSK

1 SCOPE

This test method is a rapid and easy way of checking the homogeneity of building sealants. The homogeneity is here an important property. Materials with poor homogeneity can be difficult to apply, e.g. with poor extrudability. Poor homogeneity can also result in early cracking of a seal.

2 FIELD OF APPLICATION

The test method can be used for all types of putties and sealants which are applied at normal temperatures or at slightly elevated temperatures.

3 REFERENCES

This test method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used several years before that date. It was adopted as NORDTEST method NT BUILD 003 in June 1976.

4 DEFINITIONS

Homogeneity is defined as absence of lumps, air bubbles and other irregularities.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the tests. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate, and must be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 **Principle**

The sealant to be tested is applied in a groove in a metal jig. The homogeneity is checked as the sealant is forced to flow in the groove.

6.2 **Apparatus and Materials**

Metal block with a 30 mm wide and 100 mm long groove, the depth varying from 5 mm to 0 mm in the longitudinal direction. Along the edge of the groove there should be a scale graduated every 0,5 mm, showing the depth in the groove.

Putty knife or similar.

6.3 **Preparation and Conditioning of Test Specimens**

Material and equipment are conditioned at 296 K (23 ^{o}C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and are reconditioned, if necessary, at 296 K (23 ^{o}C) and 50 % RH.

Sealants that are too stiff to be smoothened out at 296 K (hot poured sealants and some types of strip sealants) are, if necessary, heated to a sufficiently high temperature to allow easy handling. Temperatures above 296 K (23 ^{o}C) are noted.

6.4 **Procedure**

Approx. $20 \cdot 10^{-6}$ m^3 (20 cm^3) sealant is applied in the deepest part of the groove in the metal block. The putty knife is carefully drawn along the edge of the metal block so that the sealant is leveled out in the groove from the deep to the shallow end. Observe and note the largest particle that causes a trace in the sealant, and any visible lumps, larger air bubbles etc.

6.5 **Expression of Results**

As a result the existance and size of particles, lumps, air bubbles etc. are given.

6.6 **Accuracy**

The homogeneity varies considerably for some products, and the result can vary, depending on which part of the sealant that happens to be selected. In practice, at least 3 different samples should be taken.

6.7 **Test Report**

Use NBI-G01, point 6.7, and include the points applicable to this test method.

BYGGFORSK

Building Sealants Elongation Properties

NBI-45
1987

1 SCOPE

This test method can be used to find the elongation properties of various types of building sealants.

For classification of sealants in groups and types, reference is made to the general classification of jointing materials of the Norwegian Building Research Institute.

2 FIELD OF APPLICATION

In practice, sealants are subjected to deformations due to changes in joint dimensions at changing temperatures, moisture content of materials etc. If the sealant is to fulfill its sealing function, it must be able to follow these deformations and to maintain the required adhesion to the substrate. This method is intended for determining the elongation properties of the sealants.

As the different types of sealants do not have the same elongation properties, and as they are used in different ways in practice, a total of 5 main varieties of the method have to be used. This will be dealt with in paragraph 6.4, Procedure.

3 REFERENCES

Interim Federal Specification TT-S-00230b.

This test method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used several years before that date. It was adopted as NORDTEST method NT BUILD 004 in June 1976.

4 DEFINITIONS

None

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the tests. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate, and must be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

Test joints are made between different types of materials, and sealed with the material to be tested. The test pieces are subjected to aging cycles before elongation to break. The elongation properties are found from the diagrams showing force versus elongation.

6.2 Apparatus and Materials

Universal tensile testing machine with a speed of 0,025 ± 0,008 mm/s (1,5 ± 0,5 mm/min).

Test pieces of the following types:

- Aluminium, grade 2 S (Al 99,0), dimensions 8 x 20 x 120 mm and 6 x 15 x 120 mm
- Concrete, quality as described in TT-S-00230b, dimensions 30 x 50 x 100 mm
- Glass, sheet or float glass, dimensions 6 x 50 x 100 mm
- Wood, selected knotless spruce, dimensions 15 x 15 x 120 mm.

Blocks with other dimensions may be used only if the given sizes and shapes of the joints in the points 6.4 A - 6.4 E are kept.

Specimens can also be made with blocks of other materials than those mentioned in the points 6.4 A - 6.4 E. The combination concrete/concrete belongs to these. Other materials can be for example brick, natural stone, coated wood and plastics. The material in the blocks should be described carefully in the test report.

Back-up materials, spacer bars and clips.

Water bath with distilled water, temperature 296 K (23 °C).

Ventilated heating cabinet.

Climate chambers for temperatures of 275 ± 1K (2 ± 1 °C), 263 K (-10 °C), and 248 K (-25 °C).

6.3 Preparation and Conditioning of Test Specimens

- Materials and equipment are conditioned at 296 K (23 °C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary, at 296 K (23 °C) and 50 % RH.

Sealants that have to be applied in a heated state are heated to the recommended temperature as instructed by the manufacturer.

6.4 Procedure

A Procedure for plastic glazing compounds types 521, 522, 523 and 524 and oil based sealants types 533 and 534.

Specimens are made for the elongation tests as shown in Fig. 1, 6 specimens between aluminium and concrete and 6 between wood and glass. The joints should be 3 x 15 x 80 mm. All blocks are pretreated as recommended by the manufacturer of the sealant in question. In order to make joints with exact dimensions and to reduce the end effects, a 4 mm high closed-cell back-up material is used at both ends of the joints. These pieces are glued to one of the blocks in the correct position and compressed to 3 mm. The correct joint width is secured with spacer bars and the blocks are kept together by clips. Finally, the sealant is filled into the joint from one of the free sides to the level of the edge of the smallest block.

The specimens are stored for 7 days at 296 K (23 °C) and 50 % RH and then heat aged at 343 K (70 °C) in a ventilated heating cabinet. Aging time is 28 days for glazing compounds (group 52) and 56 days for oil based sealants (group 53). After cooling to 296 K (23 °C), the specimens are divided into two groups, each group consisting of 3 specimens aluminium/concrete and 3 specimens glass/wood.

One group is stored for at least 24 hours at 263 K (-10 °C) and afterwards elongated until failure at this temperature and an elongation velocity of 0,025 ± 0,008 mm/s (1,5 ± 0,5 mm/min). The mounting in the tensile testing equipment is shown in Fig. 2.

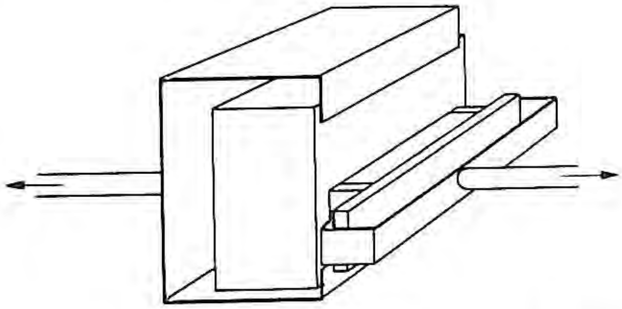


Fig. 2, Mounting of test specimen in the tensile testing equipment

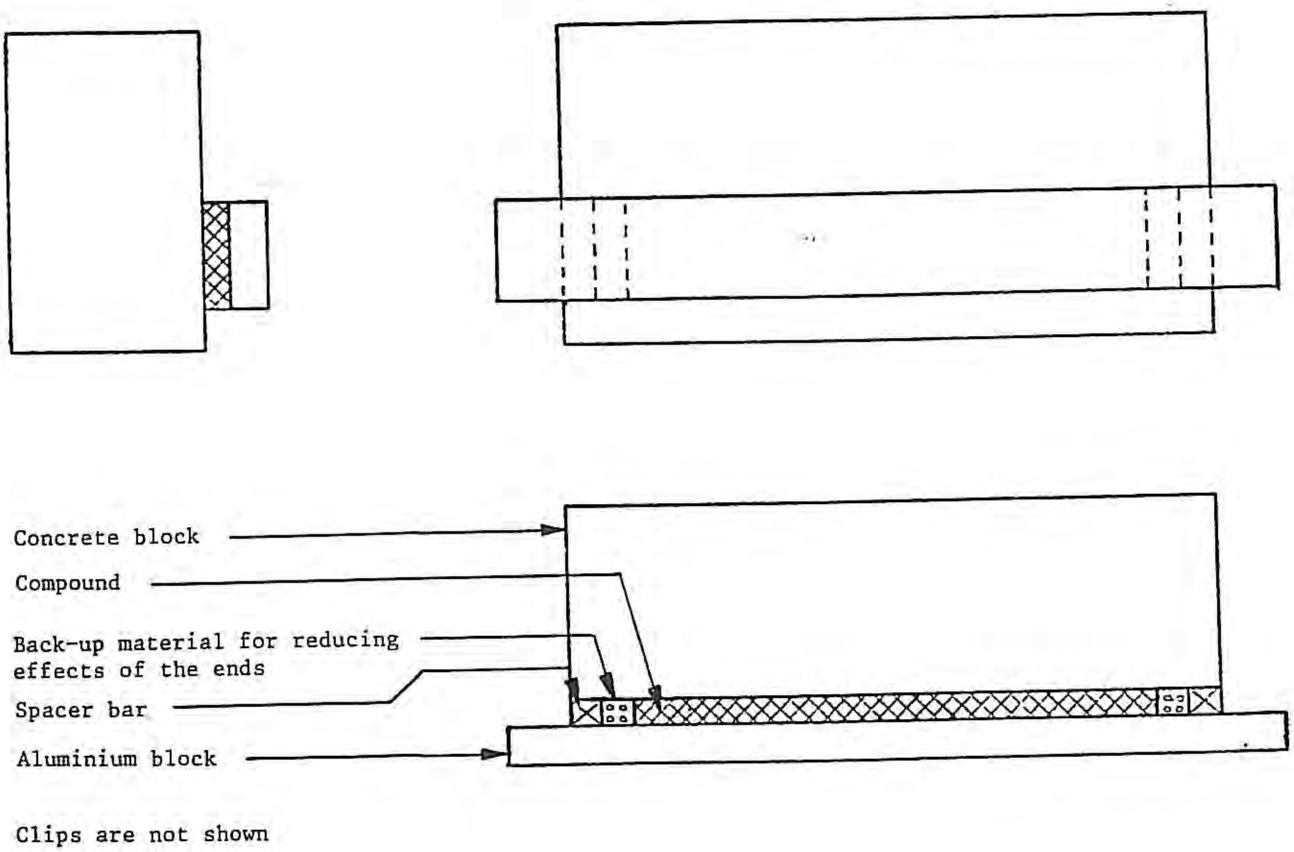


Fig.1. Specimen for elongation test on plastic glazing compound

The other group is stored for 4 days in distilled water at 296 K (23 °C), cooled in the water to 275 ± 1 K (2 ± 1 °C) and afterwards elongated until failure at this temperature and a speed of 0,025 ± 0,008 mm/s (1,5 ± 0,5 mm/min).

The force versus elongation diagram is recorded for all the tests.

6.4 B1 Procedure for standard quality plastic sealants, types 531, 532, 541, 542, 551 and 562

Specimens are made for the elongation tests with a cross section of the joint as shown in Fig. 3, type B. Otherwise, the details are as shown in Figs. 1 and 2. A total of 6 specimens between aluminium and concrete are made. All blocks are pretreated as recommended by the manufacturers. The joints should be 10 x 10 x 80 mm, and should be made with a back-up strip with closed cells. This should be 15 mm high and compressed to 10 mm. In order to make joints with exact dimensions and to reduce the end effects, a 15 mm high back-up strip with closed cells is used in each end of the joints. The strips are glued to one of the blocks in the correct position and compressed to 10 mm. The correct joint width is ensured by means of spacer bars, and the specimen blocks are kept together with clips. Finally the sealant is filled into the joint from the free side and leveled out to the edge of the smallest block.

The specimens are stored for 7 days at 296 K (23 °C) and 50 % RH, and afterwards heat aged at 343 (70 °C) for 56 days in a ventilated heating cabinet. After cooling to 296 K (23 °C) the specimens are divided into two groups of 3 specimens each.

One of the groups is stored for at least 24 hours at 248 K (-25 °C) and afterwards elongated until failure at this temperature and an elongation velocity of 0,025 ± 0,008 mm/s (1,5 ± 0,5 mm/min). The mounting in the tensile testing equipment is made as shown in Fig. 2.

The other group is stored for 4 days in distilled water at 296 K (23 °C), cooled in the water to 275 ± 1 K (2 ± 1 °C), and afterwards elongated until failure at this temperature and a speed of 0,025 ± 0,008 m/s (1,5 ± 0,5 mm/min).

The force versus elongation diagram is recorded for all the tests.

6.4 B2 Procedure for hot applied pouring grade plastic sealants, type 561

The procedure is in accordance with paragraph 6.4 B1 with the following exception :

- The closed-cell back-up material is replaced by a heat resistant backer rod.

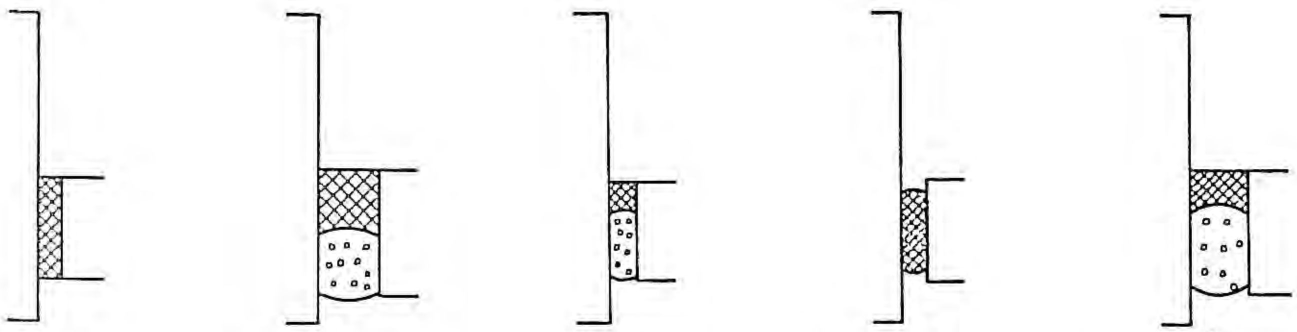
6.4 B3 Procedure for tough plastic sealants for indoor use, type 554

The procedure is in accordance with paragraph 6.4 B1 with the following exceptions:

- The heat aging at 343 K (70 °C) is for 28 days only
- The low temperature elongation tests are carried out at 263 K (-10 °C).

6.4 C Procedure for sealants in glazing quality, tough plastic sealants type 552 and elastic sealants types 582 and 584

Specimens are made for the elongation tests with a cross section of the joint as shown in Fig. 3, type C. Otherwise the details are as shown in Figs. 1 and 2. A total of 6 specimens between aluminium and concrete and 6 between wood and glass are made. All blocks are pretreated as recommended by the



TYPE A	TYPE B	TYPE C	TYPE D	TYPE E
Filled joint 3 mm x 15 mm	Joint 10 mm x 10 mm with back-up material	Joint 3 mm x 3 mm with back-up material	Strip approx. 3 mm x 10 mm squeezed to good adhesion	Joint 10 mm x 5 mm with circular back-up material

Fig. 3. Cross-sections through the various types of joint

manufacturers. The joints should be 3 x 3 x 80 mm, and must be applied against a back-up strip with closed cells. This should be 4 mm high and compresed to 3 mm. In order to make joints with the exact dimensions and to reduce the end effect, a 4 mm high back-up strip with closed cells is used in each end of the joints. The strips are glued to one of the blocks in the correct position and compressed to 3 mm. The correct joint width is ensured by spacer bars, and the specimen blocks are kept together by clips. Finally the sealant is filled into the joint from the free side and leveled out to the edge of the smallest block.

The specimens are stored for 7 days at 296 K (23 °C) and 50 % RH, and afterwards heat aged at 343 K (70 °C) for 56 days in a ventilated heating chamber. After cooling to 296 K (23 °C), the specimens are divided into two groups, each group consisting of 3 specimens aluminium/concrete and 3 specimens glass/wood.

One of the groups is stored for at least 24 hours at 263 K (-10 °C) and afterwards elongated until failure at this temperature and a speed of 0,025 ± 0,008 mm/s (1,5 ± 0,5 mm/min). The mounting in the tensile testing equipment is made in accordance with Fig. 2.

The other group is stored for 4 days in distilled water at 296 K (+23 °C), cooled to 275 ± 1 K (2 ± 1 °C), and afterwards elongated until failure at this temperature and a speed of 0,025 ± 0,008 m/s (1,5 ± 0,5 mm/min).

6.4 D1 Procedure for glazing quality strip sealants type 573

Specimens are made for the elongation tests with a cross section of the joint as shown in Fig. 3, type D. Otherwise the details are as shown in Figs. 1 and 2. A total of 6 specimens between aluminium and concrete and 6 between wood and glass are made. All blocks are pretreated as recommended by the manufacturer. The joints should be approx. 3 x 10 x 80 mm. They are made with sealant strips approx. 3 x 10 x 80 mm, placed in the correct position on one of the specimen blocks. The strip is then compressed to good adhesion. The specimens are kept together by clips.

The specimens are stored for 7 days at 296 K (23 °C) and 50 % RH, and afterwards heat aged at 343 K (70 °C) for 56 days in a ventilated heating chamber. After cooling to 296 K (23 °C) the specimens are divided into two groups, each group consisting of 3 specimens aluminium/concrete and 3 specimens glass/wood.

One of the groups is stored for at least 24 hours at 263 K (-10 °C) and afterwards elongated until failure at this temperature and at a speed of 0,025 ± 0,008 mm/s (1.5 ± 0,5 mm/min). The mounting in the tensile testing apparatus is made in accordance with Fig. 2.

The other group is stored for 4 hours in distilled water at 296 K (23 °C), cooled in the water to 275 ± 1 K (2 ± 1 °C) and afterwards elongated until failure at this temperature and a speed of 0,025 ± 0,008 mm/s (1,5 ± 0,5 mm/min).

The force versus elongation diagram is recorded for all the tests.

6.4 D2 Procedure for standard quality strip sealants, types 571, 572 and 574

The procedure is in accordance with paragraph 6.4 D1 with the following exceptions:

- Specimens are made between aluminium and concrete only
- Test temperature 248 K (-25 °C).

6.4 E Procedure for elastic sealants for use in buildings, types 581 and 583, and for horizontal joints used in traffic areas, types 585, 586, 587 and 588

Specimens are made for the elongation tests with a cross section of the joint as shown in Fig. 3, type E. Otherwise the details are as shown in Figs. 1 and 2. A total of 6 specimens between aluminium and concrete are made. All blocks are pretreated as recommended by the manufacturer. The joint should be 10 x 5 x 80 mm, and should be applied on a circular back-up strip of expanded polyethylene or other closed-cell material.

The joint depth 5 mm is measured in the middle of the joint cross section. Before compression, the back-up strip should have a diameter of approx. 15 mm and be compressed to 10 mm. In order to reduce the end effects, a 15 mm high back-up strip with closed cells is used in each end of the joints. The strips are glued to one of the blocks in the correct position, and compressed to 10 mm. The correct joint width is ensured by means of spacer bars, and the specimens are kept together with clips. Finally the sealant is filled into the joint from the free side and leveled out to the height of the edge of the smallest block.

The specimens are stored for 7 days at 296 K (23 °C) and 50 % RH. A longer curing time can be agreed on, but this have to be clearly stated in the report. After curing, the specimens are heat aged at 343 K (70 °C) for 56 days in a ventilated heating cabinet. After cooling to 296 K (23 °C) they are divided into two groups of 3 specimens each.

One of the groups is stored for at least 24 hours at 248 K (-25 °C) and afterwards elongated until failure at this temperature and a speed of 0,025 ± 0,008 mm/s (1,5 ± 0,5 mm/min). Mounting in the tensile testing equipment is made in accordance with Fig.2. The other group is stored for 4 days in distilled water at 296 K (23 °C), cooled in the water to 275 ± 1 K (2 ± 1 °C), and afterwards elongated until failure at this temperature and a speed of 0,025 ± 0,008 mm/s (1,5 ± 0,5 mm/min).

The force versus elongation diagram is recorded for all the tests.

6.5 Expression of Results

As a result the maximum force during the elongation test and the elongation at this force is given for each specimen. The force is given in Newton as a whole number (kilopond with one decimal), the elongation in mm with one decimal.

6.6 Accuracy

Normally there are some variations in the results, sometimes large variations. This is due to the fact that the method is very sensitive to arbitrary small faults and irregularities as, for example, small variations in the joint shape, air bubbles in the sealant, irregularities at the bottom or on the surface of the joint, variations in the surface of the substrate and in pretreatment etc. But variations like this will also occur in practice. Therefore, the method is considered to give a realistic picture of the elongation characteristics of a sealant.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

BYGGFORSK

Building Sealants
Hardness

NBI-46
1987

1 SCOPE

This test method may be used for measuring the hardness of sealants which, after curing and/or aging, reach a mainly elastic state.

2 FIELD OF APPLICATION

Primarily this method is valid for elastic sealants, group 58 in the general classification of joint sealing materials. The hardness itself is not a particularly interesting property. There is, however, a connection between the hardness and the modulus of elasticity, and measuring the hardness can be a simple and convenient way to obtain some knowledge about the elastic properties of a material. In the same way, changes in the hardness can give information about the aging properties of the materials.

3 REFERENCES

ASTM D 2240.

The method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used several years before that date. It was adopted as NORDTEST method NT BUILD 005 in June 1976.

4 DEFINITIONS

None.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the tests. The sealants can be delivered in buckets, cans or similar, in barrels and in cartridges. Sealants in cans or buckets often have a tendency to separate, and must, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 TEST METHOD

6.1 Principle

An apparatus with a spring-loaded needle is put against the material. The depth of penetration is converted to hardness degrees Shore A.

6.2 Apparatus and Materials

Durometer in accordance with ASTM D 2240, Shore Durometer, Type A.

Ventilated heating cabinet.

6.3 Preparation and Conditioning of Test Specimens

Material and equipment are conditioned at 296 K (23 °C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary, at 296 K (23 °C) and 50 % RH.

A block of the material is made with the dimensions 10 x 50 x 50 mm. This should be cured for 28 days at 296 K (23 °C) and 50 % RH.

6.4 Procedure

The block of the test material is placed on the testing table of the apparatus. The durometer is lowered carefully until the top of the needle is slightly above the surface of the specimen, at least 12 mm from the edge. The durometer is then lowered steadily until there is a full contact between the base disc and the specimen. The instantaneous value of the hardness i read on the maximum value needle. After 15 seconds the movable needle of the durometer is read. Both values are given in Shore A degrees. At least 5 measurements should be taken on the specimen, each time at a different place and at least 6 mm from the previous one. The test is according to ASTM D 2240.

The specimen is placed in the heating cabinet at 343 K (70 °C) for 28 days. It is then taken out and allowed to cool to 296 K (23 °C) before the hardness is measured again according to the procedure given above.

The specimen is placed in the heating cabinet for another 28 days at 343 K (70 °C). The hardness is measured the third time according to the procedure given above after a total of 56 days heat aging.

In addition to the given test conditions, which are compulsory, tests can also be carried out at the temperatures 273 K (0 °C) and 248 K (-25 °C) and a storing time of 56 days.

6.5 Expression of Results

The instantaneous and the 15 second values are calculated and given as the mean value of the five readings for each aging condition, rounded off to the nearest whole number. A total of 6 values for the hardness should be given, depending on the aging condition of the material.

6.6 Accuracy

In practice the durometer can be read for every half degree. Normally there is a scattering of a couple of degrees in the measurements, depending on how rapid the base disc of the durometer is brought into contact with the specimen. It is then sufficient to round off the calculated hardness to the nearest whole number as a mean value of 5 measurements.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

BYGGFORSK

Building Sealants
Deformability Characteristics

NBI-47
1987

1 SCOPE

This test method is only used for sealants which after curing and/or aging reach a mainly elastic state.

2 FIELD OF APPLICATION

The method is valid for sealants in group 58 of the general classification of sealants. Such sealants are never 100 % elastic, but also have some degree of plasticity. When studying deformation properties according to this method, a figure for plasticity in relation to elasticity is obtained.

3 REFERENCES

Swedish Standard SIS 16 22 01.

This method has been developed at the National Testing Institute in Sweden. It was adopted as NORDTEST method NT BUILD 006 in June 1976.

4 DEFINITIONS

None.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the tests. The sealants can be delivered in buckets, cans or similar, in barrels or in cartridges. Sealants in cans or buckets often have a tendency to separate and must, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

A hardness meter with a spring-loaded needle is put against the material. The depth of penetration is recorded as a function of time. The deformability characteristics are calculated from the recorded values.

6.2 Apparatus and Materials

Hardness measuring device according to SIS 16 22 01.

Ventilated heating cabinet.

6.3 Preparation and Conditioning of Test Specimens

Material and equipment are conditioned at 296 K (23 °C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary, at 296 K (23 °C) and 50 % RH.

6.4 Procedure

A block of the sealant is made with the dimensions approx. 10 x 100 x 100 mm. This is allowed to cure for 28 days at 296 K (23 °C) and 50 % RH.

The block is divided into six pieces, approx. 10 x 35 x 50 mm each. On three of these the penetration depth is measured according to SIS 16 22 01 after 5, 10, 20, 40 and 60 seconds.

The three other pieces are heat aged for 56 days at 343 K (70 °C). After cooling to 296 K (23 °C), the penetration depth is measured according to SIS 16 22 01 after 5, 10, 20, 40 and 60 seconds.

In addition to the given test conditions, which are compulsory, testing can also be carried out after a curing time of 56 days.

6.5 Expression of Results

The penetration depth is plotted on a diagram as a function of the time (logarithmic scale). This should produce a straight line. If not, the sealant is too plastic for this method to be used.

The straight line is extrapolated to time = 1 second (log t = 0). The cut off length L on the axis for the penetration depth is read.

The angle of deviation coefficient, k, is calculated.

The ratio $p = \frac{k}{L}$ is calculated.

As a result the ratio p is given for a sealant which has only cured for 28 days and for a sealant which has also been heat aged for 56 days at 343 K (70 °C).

The smaller the p, the more elastic the sealant. If p = 0, the sealant is fully elastic.

6.6 Accuracy

No comments.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

BYGGFORSK

Building Sealants
Peel Strength

NBI-48
1987

1 SCOPE

This method is used to study the adhesion of sealants to substrates, measured as adhesion in peel.

2 FIELD OF APPLICATION

This method can only be used for sealants with a sufficiently high degree of elasticity after curing and/or aging. It is valid for sealants in group 56 and group 58 in the general classification for joint sealing materials.

3 REFERENCES

Interim Federal Specification TT-S-00230 b.

This method is included in the Norwegian Building Research Institute's test programme for buildings sealants from August 17, 1970, but has been used several years before that date. It was adopted as NORDTEST method NT BUILD 007 in June 1976.

4 DEFINITIONS

None.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the tests. The sealants can be delivered in buckets, cans or similar, in barrels or in cartridges. Sealants in cans or buckets often have a tendency to separate and must, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

The peel strength is measured on special samples, where a strip of the material is peeled off at 180° angle. The peel strength is a measure of the adhesion of the sealant to the substrate.

6.2 Apparatus and Materials

Universal tensile testing machine with an elongation velocity of 0,85 mm/s (50 mm/min).

Test plates of the following materials:

- Aluminium, grade 2 S (Al 99,0), dimensions 6 x 80 x 150 mm
- Concrete, quality as described in TT-S-00230 b, dimensions 25 x 80 x 150 mm
- Glass, sheet or float glass, dimensions 6 x 80 x 150 mm.

Cloth, heavy type, about 0,2 kg/m^2.

Paper masking tape.

Water bath with distilled water, temperature 296 K (23 °C).

6.3 Preparation and Conditioning of Test Specimens

Materials and equipment are conditioned at 296 K (23 °C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary, at 296 K (23 °C) and 50 % RH.

6.4 Procedure

A total of six specimens are made with two plates of aluminium, two of concrete and two of glass. All of them are pretreated according to the manufacturer's instructions for the sealant under test. The specimens are made in the following way:

Masking tape is placed straight across of the plate, from the center and at least 30 mm towards one end. On the free half of the plate, a 3 mm thick layer of sealant is spread evenly. A piece of cloth, approx. 80 x 200 mm, is covered with sealant on both sides to half of the length. The cloth with the sealant is pressed evenly and carefully against the sealant on the plate. Using spacer bars and a glass rod the sealant is rolled to a thickness of approximately 2 mm.

The specimens are cured for 28 days at 296 K (23 °C) and 50 % RH. Afterwards the cloth with the sealant is cut down to the substrate lengthwise to the specimens. In that way, two strips with a width of 25 mm and spaced about 10 mm are obtained.

The so prepared specimens are stored for four days in distilled water at 296 K (23 °C).

The specimens are then removed from the water. They are carefully surface dried and fixed in the tensile testing equipment. The plate is held in one of the grips, and one strip of the cloth at a time is bent back and fixed in the other grip. The cloth is pulled parallel to the plate at a speed of 0,85 mm/s (50 mm/min). The peel force is measured. If the sealant comes away from the cloth, the test is discarded. In such cases, it is necessary to try to cut down to the substrate with a sharp knife or similar, in order to obtain a failure at the substrate or in the sealant.

A total of four strips are tested for each substrate of aluminium, concrete and glass.

6.5 Expression of Results

As a result the peel force is given for each of four tests with three different substrates. The force is given in Newton as a whole number (kilopond with one decimal).

6.6 Accuracy

A certain amount of experience is required to do the tests in the right way, but with some experience, the results are reliable. Sometimes there may be a large scatter in the results. This is due to differences in the substrate, and may occur, even if all the rules are followed during the specimen preparation. However, these variations may also occur in practical joint sealing operations and do not reduce the value of the testing.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

BYGGFORSK

Building Sealants
Resistance to Sagging

NBI-49
1987

1 SCOPE

This test method is intended for studying whether or not a sealant will keep in place in a joint with certain dimensions after it has been applied, or if it will show a tendency to sag. After carrying out tests on joints of different dimensions, it is possible to find out how wide the joint can be before the sealant is sagging too much.

2 FIELD OF APPLICATION

The method can be used for all types of sealants for joints in vertical surfaces.

3 REFERENCES

British Standard BS 3712: Part 1: 1964.

The method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used for several years before that date. It was adopted as NORDTEST method NT BUILD 008 in June 1976.

4 DEFINITIONS

Sagging, slumping and/or bulging are defined as inabilites of the sealants to retain their original positions and configurations. Such deviations are recorded at two different test temperatures as indicated in point 6.4.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate and must, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 **Principle**

The test method permits the testing of sealants under conditions similar to those occuring in actual use. The sealants are filled in aluminium channels, and these are stored under specified conditions. Possible changes are observed and measured.

6.2 **Apparatus and Materials**

U-shaped aluminium channels with open ends, length 250 mm, with the following inner dimensions:

Channel No.	Width mm	Depth mm
1	7,5	7,5
2	10,0	10,0
3	12,5	12,5
4	15,0	12,5
5	17,5	12,5
6	20,0	12,5
7	25,0	12,5
8	30,0	20,0

Transversally across the center of the channels Nos. 1 - 7, there must be a small V-shaped notch.

Ventilated heating cabinet.

Climate chamber 275 ± 1 K (2 ± 1 °C).

6.3 **Preparation and Conditioning of Test Specimens**

Materials and equipment are conditioned at 296 K (23 °C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary, at 296 K (23 °C) and 50 % RH.

6.4 **Procedure**

The channel chosen is cleaned with trichlorethylene, dried and filled with sealant to the edge at 296 K (23 °C). With a knife or similar, a line is made across the surface of the sealant at the V-shaped notch. Two specimens are made for each channel dimension.

One channel of each dimension is placed in a heating cabinet at 323 K (50 °C) and the other in a climate chamber at 275 K ± 1 K (2 ± 1 °C). Channels of dimensions Nos. 1 - 7 are placed vertically and channel No. 8 horizontally, lying on the side. The channels are stored for 24 hours at the temperatures stated.

For channels Nos. 1 - 7 sagging by the line in the middle of the channel and slump at the bottom of the channel are recorded. For channel No. 8 bulging is noted. If the sealant, partly or completely, has dripped or run out of the channel, this will also be noted.

6.5 Expression of Results

As a result sagging, slump or bulging respectively, is noted, both at 323 K (50 °C) and at 275 K (+2 °C). Any dripping is also recorded.

6.6 Accuracy

The method is good as it simulates the behaviour of a sealant during unfavourable conditions on smooth joint surfaces. When the joint surfaces are rough, the practical conditions will be more favourable.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Flow Characteristics

NBI-50
1987

BYGGFORSK

1 SCOPE

This test method has been developed to test the flow characteristics of hot or cold applied pouring grade sealants. The flow characteristics are found from visual inspections and measurements made on the surface of test joints.

The actual sealants are hot applied sealants type 561 or cold poured sealants types 587 and 588 in the general classification of joint sealing materials. It is good to know if the sealants can flow easily and be sufficiently self-levelling and able to fill the joints well with a smooth surface.

2 FIELD OF APPLICATION

This method is only used for self-levelling, pouring grade sealants for joints in horizontal building parts such as floors, terraces etc.

3 REFERENCES

Interim Federal Specification, TT - S - 00230b.

The method is included in the Norwegian Building Research Institute's test programme for building sealants from August 7, 1970. It was adopted as NORDTEST method NT BUILD 009 in June 1976.

4 DEFINITIONS

Good flow characteristics means that the sealant has the ability to self-level when applied in horizontal joints. Sealants with good flow characteristics are completely free from indentations and irregularities and present a smooth surface.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can bli delivered in buckets, cans or similar, or in barrels. Some sealants have a tendency to separate, and should, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

A test channel is filled with the sealant. The material is allowed to flow, cool and cure. After an agreed time, the surface of the joint is inspected for any irregularities. Deviations are measured to the nearest 0,5 mm.

6.2 Apparatus and Materials

U-shaped aluminium channel with closed ends, length 200 mm, inner width 20 mm and inner depth 12,5 mm.

Ruler, length 150 mm.

Ventilated heating cabinet or any other suitable equipment for heating hot applied sealants to the right temperature.

6.3 Preparation and Conditioning of Test Specimens

Materials and equipment are conditioned at 296 K (23 °C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary, at 296 K (23 °C) and 50 % RH.

Hot applied sealants are heated to the recommended pouring temperature in a way approved by the manufacturer.

6.4 Procedure

The channel is placed in a horizontal position with the opening upwards and is filled with sealant to the edge. Fast setting materials are poured into the channel in one movement from one end to the other. Slow setting materials are filled at the center of the channel and allowed to flow freely towards both ends.

After 1 hour the specimens are inspected visually. Any defects are noted. The smoothness of the surface is checked with the ruler. Deviation from plane is measured with an accuracy of 0,5 mm.

6.5 Expression of Results

State as result whether or not the surface is smooth and if any deviations or defects can be observed.

6.6 Accuracy

The experiences with this test method are limited, but indicate an acceptable reproducibility.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants Combustibility

NBI-51
1987

BYGGFORSK

1 SCOPE

This method is intended to give a comparative evaluation of the combustibility of sealants.

2 FIELD OF APPLICATION

The test can be used for all types of sealants.

3 REFERENCES

ASTM D 635 - 81.

The method is included in the Norwegian Building Research Institute's test programme for sealants from August 17, 1970, but has been used a little longer. It was adopted as NORDTEST method NT BUILD 010 in June 1976.

4 DEFINITIONS

Observations are made to study if a material is ignited, and if so, in which way it is burning. The materials are judged in the following way:

- Non-combustible according to the method, if they do not burn after two ignition attempts of 30 seconds each
- Self-extinguishing according to the method, if the specimen is extinguished before the flame has reached a mark 75 mm from the free end. The burnt part is measured as 75 mm minus the unburnt length, measured along the lower edge of the specimen. The time from removal of the flame until the specimen is extinguished is noted as the burning time
- Combustible accordning to the method, if the specimen burns to the 75 mm mark. The burning speed is calculated from the time the flame front is using from a first to a second mark, observed at the lower edge of the specimen.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate, and must therefore, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 **Principle**

The sealants are exposed to the heat from the open flame of a propane burner. The non-combustibility, the possible self-extinguishing characteristics or a clear combustibility as defined in point 4, is noted.

6.2 **Apparatus and Materials**

Plates of aluminium, three pieces, size 50 x 100 mm.

Adjustable stand for horizontal positioning of two 1,5 mm Ø brass wires, 10 mm apart.

Propane burner, 10 mm Ø.

Ventilated test chamber.

6.3 **Preparation and Conditioning of Test Specimens**

Materials and equipment, are conditioned at 296 K (23 °C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary, at 296 K (23 °C) and 50 % RH.

Sealants which have to be applied in a heated state, are heated to the recommended temperature in a way approved by the manufacturer.

6.4 **Procedure**

On each of the three aluminium plates a strip of sealant with dimensions approx. 5 x 20 x 100 mm is applied. If necessary the sealants should be framed to prevent from flowing. The specimens are stored for 7 days at 296 K (23 °C and 50 % RH, heat aged for 7 days at 323 K (50 °C) and afterwards reconditioned to 296 K (23 °C).

The strips of sealant are carefully taken away from the plates with a knife or similar, and are mounted, one at a time, on the two brass wires fixed to the stand. The longitudinal axis should be horizontal and the flat side at an angle of 45° to the horizontal plane, as shown in Fig. 1. Two lines are marked on the specimen, one 25 mm and the other 75 mm from the outer end.

The specimen is ignited with a 25 mm blue

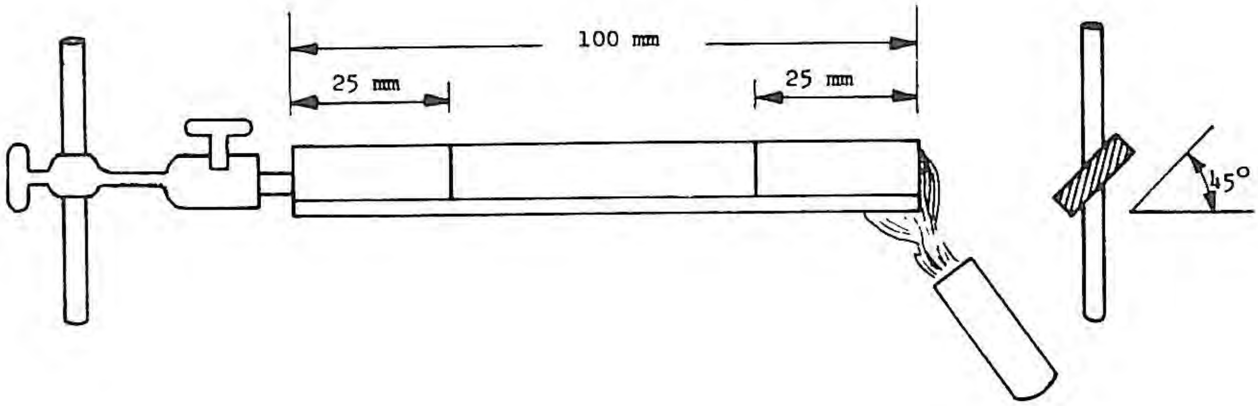


Fig.1. Equipment for testing of combustibility

flame as shown in Fig. 1, ignition time 30 seconds.

6.5 **Expression of Results**

State whether the material has been found non-combustible, self-extinguishing or combustible, and if relevant, also the observed burning time, burnt part or burning speed. Mean values are used, if the specimens do not behave so differently that they belong to different classes. In such a case the results are given separately for each specimen.

6.6 **Accuracy**

The method is sensible to drafts, which should be avoided as stated in ASTM D 635 - 81.

6.7 **Test report**

Use NBI-G01, point 6.7, and include the points applicable to this method.

Building Sealants
Resistance to Alkalis

NBI-52
1987

BYGGFORSK

1 SCOPE

This test method can be used to check if a sealant used on a concrete substrate is able to withstand the alkalis in the concrete without loss of adhesion.

2 FIELD OF APPLICATION

The method can be used for all types of sealants used in buildings.

3 REFERENCES

NBI-45, 1987, Building Sealants. Elongation Properties.

British Standard BS 3712: part 2: 1964

The method is included in the Norwegian Building Research Institute's test programme for sealants from August 17, 1970, but has been used a bit longer. It was adopted as NORDTEST method NT BUILD 011 in June 1976.

4 DEFINITIONS

Resistance to alkalis is defined as ability to withstand the alkalis present in concrete without loss of ability to fulfil the intended functions. The degree of resistance is found from tensile tests with sealants in combination with an alkaline substrate.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate and must, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1. **Principle**

Test specimens are made with alkaline substrate, and subjected to an aging cycle, followed by tensile testing.

6.2 **Apparatus**

Universal tensile testing equipment with a testing speed of 0,025± 0,008 mm/s (1,5 ± 0,5 mm/min).

Test pieces of the following types:

- Fibre cement sheets, dimensjons 6 x 50 x 100 mm. The sheets are stored for 24 hours in a 5 % solution of caustic soda, air dried for ½ hour at 296 K (23 °C)and 50 % RH and then dried for 4 hours at 423 K (150 °C) in a ventilated heating cabinet
- Wood, selected knotless spruce, dimensions 15 x 15 x 120 mm.

Back-up strips, spacer bars and clips.

Tray with an approx. 10 mm thick layer of cotton, kept wet with distilled water at 296 K (23 °C).

Ventilated heating cabinet.

Climate chamber with a temperature of 275 K ± 1 K (2 ± 1 °C).

6.3 **Preparation and Conditioning of Test Specimens**

Materials and equipment are conditioned at 296 K (23 °C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary, at 296 K (23 °C) and 50 % RH.

Sealants that have to be applied in a heated state, are heated to the recommended temperature as instructed by the manufacturer.

6.4 **Procedure**

Three specimens made between wood and fibre cement sheets are used for elongation tests. The cross-section of the joint specimen and the rest of the procedure will depend on the type of material and must be in agreement with test method NBI-45, point 6.4.

The specimens are stored for 7 days at 296 K (23 °C) and 50 % RH, then heat aged at 343 K (70 °C) in a ventilated heating cabinet. Aging time 7 days for sealants in group 52 and 14 days for sealants in groups 53-58. After cooling to 296 K (23 °C), the specimens are placed with the fibre cement sheet down on the tray with wet cotton.

After 14 days storage on wet cotton the

specimens and the tray with the wet cotton are cooled to 275 K ± 1 K (2 ± 1 °C). The specimens are afterwards elongated until failure at that temperature with a testing speed of 0,025 ± 0,008 mm/s (1,5 ± 0,5 mm/min).

The force versus elongation diagram is recorded for all the tests.

6.5 Expression of Results

The maximum force recorded for each elongation test, and the elongation at this force are given. The force is given in Newton as a whole number (kilopond with one decimal), the elongation in mm with one decimal.

6.6 Accuracy

Normally there are some variations in the results, sometimes large variations. This is due to the fact that the method is very sensitive to arbitrary small faults and irregularities at the bottom or on the surface of the joint, variations in the surface of the substrate and in pretreatment etc. But variations like this will also occur in practice. Therefore, the method is considered to give a realistic picture of the alkali resistance of a sealant.

6.7 Test report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Resistance to Solvents, Salt Spray, Cleaning Agents and Other Chemicals

NBI-53
1987

1 SCOPE

This test method is used to check if sealants are sufficiently resistant to solvents, salt spray, cleaning agents etc. Sealants may come into contact with chemicals like this, at least periodically. The method is **not** intended for studying the chemical resistance of sealants used in floor joints, for instance resistance to organic acids on long time exposure.

2 FIELD OF APPLICATION

The method can be used for all types of sealants which are subjected to the influence of solvents, salt spray, cleaning agents or other chemicals periodically during normal use.

3 REFERENCES

The method is included in the Norwegian Building Research Institute's test programme for sealants from August 17, 1970, but has been in use several years before that date. It was adopted as NORDTEST method NT BUILD 012 in June 1976.

4 DEFINITIONS

Acceptable resistance to the influence of agents as indicated in point 1 is present if no significant change in the condition of the sealant can be observed at the end of the test.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate and must, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

The sealants are subjected to the influence of solvents and chemical agents under controlled conditions. Any visual changes are recorded. The specimens may also be weighed and the dimensions measured, as agreed.

6.2 Apparatus and Materials

Aluminium sheets, size 50 x 100 mm.

Glass beaker, Ø > 60 mm.

Ventilated heating cabinet.

6.3 Preparation and Conditioning of Test Specimens

Materials and equipment are conditioned at 296 K (23 °C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and are reconditioned, if necessary, at 296 K (23 °C) and 50 % RH.

Sealants that have to be applied in a heated state, are heated to recommended temperature as instructed by the manufacturer.

6.4 Procedure

One specimen is made for each of the chemical agents to be used by taking an aluminium sheet and applying a strip of sealant approx. 5 x 20 x 100 mm. If necessary, the sealant should be prevented from flowing. The specimens are stored for 7 days at 296 K (23 °C) and 50% RH, heat aged for 7 days at 323 K (50 °C) and finally reconditioned to 296 K (23 °C).

The different solvents etc are poured into glass beakers, one for each of them, to a depth of about 50 mm. A specimen is put into each beaker so that the lower half of the sealant strip is immersed. After about 300 s (5 min) the specimens are taken up again and stored almost horizontally with the dipped end in the lower position. The immersion is carried out four times a day with intervals of 2 hours during a total of 5 days.

The specimens are inspected at regular intervals and any visible changes noted. The specimens are weighed and the dimensions measured as agreed, and possible changes given.

6.5 Expression of Results

Any visible changes are given. Changes in weight and dimensions are given as agreed.

6.6 Accuracy

The method is simple and reliable. Of course there may be some problems with the visual inspection, but experienced observers seem to have no problems. Measurements of weight and dimensions are usually more difficult to carry out, and are for this reason not compulsory.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

1 SCOPE

This test method can be used to study the absorption of liquid constituents from a sealant into porous substrates. If the absorption is too high, the sealing properties of the material can be destroyed, and at the same time there may be a risk of staining of the adjoining materials.

2 FIELD OF APPLICATION

The test method can be used for all types of building sealants containing liquids liable to absorption by porous substrates.

3 REFERENCES

British Standard BS 3712: Part 2: 1964.

The method is included in the Norwegian Building Research Institute's test programme for sealants from August 17, 1970, but has been used several years before that date. It was adopted as NORDTEST method NT BUILD 013 in June 1976.

4 DEFINITION

For definition of seepage, see point 6.5.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in buckets or cans often have a tendency to separate and must, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

The sealant under test is applied on a porous substrate under closely controlled conditions. The seepage into the porous substrate is measured.

6.2 Apparatus and Materials

Filter paper Whatman No. 1 or equivalent.

A brass ring with a bevelled lower edge, inner diameter 22 mm, height 13 mm.

Weight 0,2 kg, base surface at least 25 x 25 mm or 25 mm diameter.

6.3 Preparation and Conditioning of Test Specimens

Materials and equipment are conditioned at 296 (23°C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturers instructions and are, if necessary, reconditioned at 296 K (23°C) and 50 % RH.

6.4 Procedure

The brass ring is placed on a stack of 10 filter papers with the bevelled edge down and is filled with sealant until just below the edge. Note! The ring should not be overfilled. Sealants which are applied in a heated state are heated until they are easily filled in the ring.

A piece of polyethylen sheet is placed on the top of the sealant. The ring is loaded with the 0,2 kg weight and the specimen stored in a dark place for 7 days at 296 K (23°C) and 50 % RH. The finished specimen is shown in Fig. 1.

After 7 days, the widest distance l the liquid binder in the sealant has migrated in the top filter paper is measured in mm. The number of filter papers m through which the binder has penetrated is also noted.

6.5 Expression of Results

The seepage figure u is given as the sum of the distance l measured in the top filter paper and the number of filter papers m

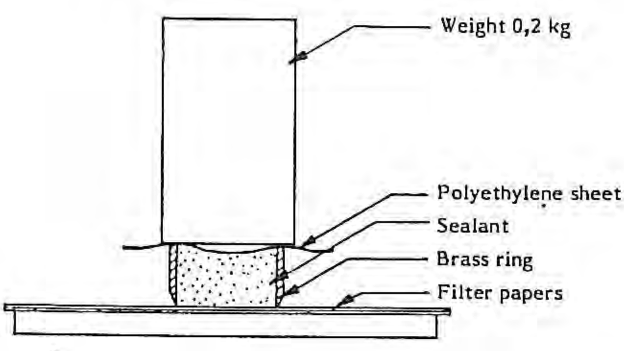


Fig. 1. Specimen for seepage measurements.

penetrated. The seepage figure u is given as a whole number.

6.6 Accuracy

The seepage figure is usually a little variable, especially for sealants with a high seepage figure. In practice three parallel tests should always be made and the mean value given.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Staining of Porous Substrates

1 SCOPE

This test method can be used to study the possible staining of the substrate by absorption of liquid constituents from the sealant. This matter is also partly covered by test method NBI - 54.

2 FIELD OF APPLICATION

This method is especially suitable for studying stainings due to secondary chemical reactions caused by liquid components absorbed into an alkaline substrate.

3 REFERENCES

NBI - 54, 1987, Building Sealants. Seepage. Loss of Liquids to Porous Substrate.

British Standard BS 3712: part 2: 1964.

The method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been in use a longer period of time. It was adopted as NORDTEST method NT BUILD 014 in June 1976.

4 DEFINITION

Staining is defined as visible marks on the porous substrate, adjacent to the sealant.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in buckets or cans often have a tendency to separate and must, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 **Principle**

The sealant to be tested is brought in contact with an alkaline, porous substrate under controlled conditions.

6.2 **Apparatus and Materials**

Fibre cement sheets, dimensions 6 mm x 50 mm x 100 mm. The sheets are treated as described in BS 3712: part 2: 1964, item 6c, i.e. stored for 24 hours in an 5 % caustic soda solution, air dried for ½ hour at 296 K (23°C) and 50 % RH and dried for 4 hours at 423 K (150°C) in a ventilated heating cabinet.

Tray with an approx. 10 mm thick layer of cotton, kept wet with distilled water at 296 K (23°C).

Ventilated heating cabinet.

6.3 **Preparation and Conditioning of Test Specimens**

Materials and equipment are conditioned at 296 K (23°C) and 50 % RH.

Two- and multicomponent materials are mixed according the maufacturers instructions and reconditioned, if necessary, at 296 K (23°C) and 50 % RH.

Sealants that have to be applied in a heated state, are heated to the recommended temperature as instructed by the manufacturer.

6.4 **Procedure**

Three pieces of fibre cement sheet are pretreated as recommended by the manufacturer of the sealant. A strip of sealant with dimensions approx. 5 mm x 20 mm x 100 mm is placed on each piece. If necessary the sealants should be prohibited from flowing.

The specimens are stored for 7 days at 296 K (23°C) and 50 % RH, then heat aged at 343 K (70°C) in a ventilated heating cabinet. Aging time 7 days for sealants in group 52 and 14 days for sealants in groups 53 - 58. After cooling to 296 K (23°C), the specimens are placed with the fibre cement sheet down on the tray with wet cotton.

After storing for 14 days on wet cotton, the specimens are observed visually for any staining of the fibre cement sheets. The extent (width etc) of any staining is measured and noted.

6.5 **Expression of Results**

Any observed staining, and the extent of such staining is stated.

6.6 **Accuracy**

This test method has proved to be exellent in reproducing the pink stainings of light coloured concrete due to absorption of phenolic resins in an alkaline environment.

6.7 **Test Report**

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Free Shrinkage

NBI-56
1987

BYGGFORSK

1 SCOPE

This test method is used for measuring how much a sealant will shrink if it is allowed to shrink freely. A sealant in practical use is always more or less restrained, but in spite of this, a figure for free shrinkage is of great interest.

2 FIELD OF APPLICATION

The method can be used for all types of sealants. Regarding restrained shrinkage, see NBI - 57, 1987.

3 REFERENCES

British Standard BS 3712: part 2: 1964.

The method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used several years before that date. It was adopted as NORDTEST method NT BUILD 015 in June 1976.

4 DEFINITION

Free shrinkage is defined as the reduction in volume of a sealant when it is allowed to shrink freely under controlled conditions.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in buckets or cans often have a tendency to separate and must, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

A sample of the sealant is permitted to shrink freely under controlled conditions. Weighing is carried out before and after heat aging. The shrinkage is calculated according to a given formula.

6.2 Apparatus and Materials

Press-on lid or other type of metal dish with a diameter of approx. 80 mm and a depth of approx. 9 mm. A small hole in the flange is used to fix a copper wire, about 0,2 mm thick.

Balance, measuring accuracy 10^{-6} kg (1 mg).

Ventilated heating cabinet.

6.3 Preparation and Conditioning of Test Specimens

Material and equipment are conditioned at 296 K (23°C) and 50 % RH.

Two- and multicomponent materials are mixed according the maufacturers instructions and are reconditioned, if necessary, at 296 K (23°C) and 50 % RH.

6.4 Procedure

The press-on lid and wire is dried at 323 K (50°C) at least one hour, cooled to 296 K (23°C) and weighed in air. Weight W_1 is noted.

After weighing, the dish is immersed completely in water and the weight W_2 noted.

The dish is dried again at 323 K (50°C), cooled to 296 K (23°C) and filled with sealant to the edge. Sealants which have to be applied in a heated state may, if necessary, be heated untill that they are easily applied. Afterwards the specimen is reconditioned at 296 K (23°C).

The specimen is weighed in air, W_3, and immersed in water, W_4.

The specimen is stored for 7 days at 296 K (23°C) and 50 % RH and then heat aged for 56 days at 343 K (70°C) in a ventilated heating cabinet.

After cooling to 296 K (23°C) the specimen is weighed again in air, W_5, and immersed in water, W_6.

6.5 Expression of Results

Free shrinkage K is calculated from the following formula:

$$K = 100 \frac{W_3 - W_4 - W_5 + W_6}{W_3 - W_4 - W_1 + W_2} \%$$

The result is given with one decimal for shrinkage above 1 % and with two decimals for shrinkage below 1 %.

6.6 Accuracy

The method is very accurate and the reliability is good, as long as the specimens are prepared carefully.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Restrained Shrinkage

BYGGFORSK

NBI-57
1987

1 SCOPE

This test method is used to study the possible cracking of a sealant when it is kept restrained in a fixed joint.

2 FIELD OF APPLICATION

The method can be used for all types of sealants. Regarding free shrinkage, see NBI-56.

3 REFERENCES

The method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used several years before that date. It was adopted as NORDTEST method NT BUILD 016 in June 1976.

4 DEFINITION

Cracking is defined as visible separation in the test material.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in buckets or cans often have a tendency to separate and must if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

A sealant in a fixed joint is observed under controlled conditions and any cracks or shrinkage is noted.

6.2 Apparatus and Materials

Channel of untreated steel with a length of 100 mm and inner width by depth of 17 mm x 18,5 mm.

Ventilated heating cabinet.

6.3 Preparation and Conditioning of Test Specimens

Materials and equipment are conditioned at 296 K (23°C) and 50 % RH.

6.4 Procedure

A three mm thick strip of closed-cell sponge plastic or rubber is placed in the bottom of the steel channel. The rest of the channel is filled with sealant and leveled off at the top and ends of the channel. When very soft or liquid materials are tested, the ends of the channel may have to be closed with tape. Sealants which are applied in a heated state can, if necessary, be heated so that they are easily applied.

The specimens are stored for 7 days at 296 K (23°C) and 50 % RH, followed by heat aging at 343 K (70°C) for 56 days in a ventilated heating cabinet.

The specimens are inspected visually for any cracks or other visual changes.

6.5 Expression of Results

As a result of the testing, any visual changes are given.

6.6 Accuracy

This test method is very accurate and reliable, provided that the test specimens are properly prepared.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this method.

Building Sealants
Weight Loss on Heat Aging

NBI-58
1987

1 SCOPE

This test method is used to find the weight loss of a sealant on heat aging. It is very interesting to have proper information on this matter, and especially to compare it with the shrinkage.

2 FIELD OF APPLICATION

All building sealants liable to weight loss may be tested with this method.

3 REFERENCES

NBI-56, 1987, Building Sealants. Free shrinkage.

The test method is included in the Norwegian Building Research Instute's test programme for building sealants from August 17, 1970, but has been used several years before that date. It was adopted as NORDTEST method NT BUILD 017 in June 1976.

4 DEFINITIONS

Weight loss is defined as the reduction in weight of a sealant when it is allowed to be heat aged under controlled conditions.

5 SAMPLING

See NBI-56.

6 METHOD OF TEST

6.1 Principle

A sample of the sealant is heat aged under controlled conditons. The weight loss is recorded.

6.2 Apparatus and Materials

See NBI-56.

6.3 Preparation and Conditioning of Test Specimens

See NBI-56.

6.4 Procedure

See NBI-56.

6.5 Espression of Results

Weight loss on heat aging, V, is calculated from the following formula:

$$V = 100 \frac{W_3 - W_5}{W_3 - W_1} \quad \%$$

The result is given with one decimal for weight losses above 1 % and with two decimals for weight losses below 1 %.

6.6 Accuracy

The method is very accurate and the reliability very good.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Tack-free Time

1 SCOPE

This test method is used to find the time lapse from the application of a sealant until it has a tack-free surface.

2 FIELD OF APPLICATION

All building sealants formulated to get a tack-free surface.

3 REFERENCES

This method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used considerably longer. It was adopted as NORDTEST Methode NT BUILD 018 in June 1976.

4 DEFINITIONS

A tack-free sealant surface is defined as a surface where glass beads of a specific type will not stick when applied and tested under specified conditions.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate and must, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

The surface of a sealant is checked at regular intervals by putting 0,2 mm glass beads on it. Attempts are made to try to remove the beads again with a soft brush.

6.2 Apparatus and Materials

Aluminium dish, 50 mm x 100 mm.

Glass beads diameter 0,2 mm.

Soft brush.

6.3 Preparation and Conditioning of Test Specimens

Materials and equipment are conditioned at 296 K (23°C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturers instructions and reconditioned, if necessary, at 296 K (23°C) and 50 % RH.

Sealants that have to be applied in a heated state may, if necessary, be heated until they are easily applied.

6.4 Procedure

An appoximately 5 mm thick layer of sealant is laid on two aluminium dishes 50 mm x 100 mm. One specimen is stored at 296 K (23°C) and 50 % RH, the other at 278 K (5°C) and 70 % RH.

The specimens are checked at regular intervals, to find whether or not the surface of the sealant is tack-free. The specimen is held horizontally, glass beads are carefully spread from a height of 50 mm onto part of it. Then the specimen is kept at a 20° angle to the horizontal plane, and attempts are made to brush the glass beads away. The surface is considered to be tack-free when the glass beads can be brushed away completely 10 seconds after they have been put on the specimen and without any visible damage to the surface.

The test is carried out both at 278 K (5°C) and at 296 K (23°). The earliest point of time each of the specimens is found to be tack-free is noted.

6.5 Expression of Results

The time the sealant needs to set a tack-free surface is given for 278 K (5°C) and 296 K (23°C).

6.6 Accuracy

The method implies that it is necessary to test at regular intervals. With a bit of experience, the tests can usually be successfully performed without difficulties. However, sometimes it is necessary to make new specimens in order to find the tack-free time more accurately.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

BYGGFORSK

Building Sealants Skin Formation

NBI-60 1987

1 SCOPE

This method is only used for sealants containing so much drying oil that a clearly noticeable surface skin is formed. The purpose of the method is to find the thickness of this skin when the sealant is aged, and also to check that only a skin is forming on the sealant, and that the sealant itself does not dry out completely.

2 FIELD OF APPLICATION

The method can be used for sealants in the groups 52 and 53 in the general classification of jointing materials of the Norwegian Building Research Institute.

3 REFERENCES

This method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used considerably longer. It was adopted as NORDTEST method NT BUILD 019 in June 1976.

4 DEFINITIONS

The skin thickness is defined as the thickness of the solid surface skin formed on sealants containing drying oils.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate and must, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

The skin formation on the surface of a sealant is observed under controlled conditions, and the thickness of the skin measured.

6.2 Apparatus and Materials

Press-on lid with a diameter of approx. 80 mm and a depth of approx. 9 mm.

Slide rule, micrometer or other equipment for measuring thicknesses with an accuracy of 0,05 mm.

Ventilated heating cabinet.

6.3 Preparation and Conditioning of Test Specimens

Materials and equipment are conditioned at 296 K (23°C) and 50 % RH.

6.4 Procedure

The press-on lid is filled with sealant to the edge and stored for 7 days at 296 K (23°C) and 50 % RH. It is then heat aged for 56 days at 343 K (70°C).

After 7 and 56 days of heat aging, pieces of the surface with the skin are cut out. These are carefully scraped on the back and washed with mineral terpentine.

The thickness of the skin is measured with an accuracy of 0,05 mm.

Alternatively, the thickness of the skin can be measured with optical equipment on micro cuts.

6.5 Expression of Results

The skin thickness after 7 and 56 days respectively is given with an accuracy of 0,1 mm.

6.6 Accuracy

The method is accurate and the reliability is good.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

BYGGFORSK

Building Sealants
Resistance to Solar Radiation

NBI-61
1987

1 SCOPE

This test method can be used to investigate the possible changes in a sealant, first of all on the surface, when it is exposed to solar radiation.

2 FIELD OF APPLICATION

All types of building sealants used in places where the surface is exposed to solar radiation.

3 REFERENCES

Test method NBI-83, 1983, Building Materials and Components for Exterior Walls etc. Weather Resistance, Cyclic Short Time Test.

Swedish Standard SIS 245820.

This test method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used a little longer. It was adopted as NORDTEST method NT BUILD 020 in June 1976.

4 DEFINITIONS

None.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate and should therefore, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

The sealant is exposed to artificial solar radiation under controlled conditions and observed for possible visible changes.

6.2 Apparatus and Materials

Glass or aluminium plate approx. 3 mm x 40 mm x 100 mm.

Xenotest apparatus according to SIS 245820, point 5.3.

Equipment for accelerated weathering of building materials and components according to the Norwegian Building Research Institute, test method NBI-83, 1983.

6.3 Preparation and Conditioning of Test Specimens

Materials and equipment are conditioned at 296 K (23 °C) and 50% RH.

Two- and multicomponent materials are mixed according to the manufacturers instructions and reconditioned, if necessary, at 296 K (23 °C) and 50% RH.

Sealants that have to be applied in a heated state, are heated to the recommended temperature in a way approved by the manufacturer.

6.4 Procedure

A three mm thick layer of the sealant is placed on a test plate and allowed to cure for 7 days at 296 K (23 °C) and 50 % RH.

The specimen is then mounted in a Xenotest apparatus and exposed to light according to SIS 245820, item 5.3, until standard colour 6 shows a colour change corresponding to class 3 on the grey range.

Alternatively, the test specimen is mounted in the NBI apparatus for accelerated weathering and exposed for 56 days.

The test specimens are inspected visually and any colour changes, sweating, cracking or similar changes are noted.

6.5 Expression of Results

Any changes observed according to point 6.4 are given.

6.6 Accuracy

The reproducibility obtained with this test method is good.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Adhesion to Glass, Influence of Solar Radiation

NBI-62
1987

BYGGFORSK

1 SCOPE

The purpose of this test is to find out if a sealant has sufficiently good adhesion to glass after it has been exposed to solar radiation through the glass and at the same time influenced by water.

2 FIELD APPLICATION

This method is only used for glazing sealants. The actual products are plastic glazing compounds group 52, types 521, 522, 523 and 524, plastic oil based sealants types 533 and 534, tough plastic sealants type 552, strip sealants type 573 and elastic sealants types 582 and 584 in the general classification of jointing materials.

3 REFERENCES

NBI-45, 1987, Building Sealants. Elongation Properties.

This test method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used a little longer. It was adopted as NORDTEST metod NT BUILD 021 in June 1976.

4 DEFINITIONS

None.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate and should therefore, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 **Principle**

The sealants are tested for adhesion to glass after exposure to artificial solar radiation under controlled conditions. The force used for elongation is measured and the corresponding elongation recorded.

6.2 **Apparatus and Materials**

Universal tensile testing machine with a speed of 0,025 ± 0,008 mm/s (1,5 ± 0,5 mm/min).

Test pieces of the following types:

- Aluminium, grade 2 S (Al 99,0) dimensions 6 mm x 16 mm x 120 mm.
- Glass, sheet or float glass, dimensions 6 mm x 50 mm x 100 mm.

Back-up materials, spacer bars and clips.

Water bath with distilled water, temperature 275 ± 1 K (2 ± 1 °C).

Ventilated heating cabinet.

Climate chamber for temperature 275 ± 1 K (2 ± 1 °C).

Sunlight lamps, Osram Ultra Vitalux GUR 53 300 W or equivalent.

6.3 **Preparation and Conditioning of Test Specimens**

Materials and equipment are conditioned at 296 K (23 °C) and 50% RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary, at 296 K (23 °C) and 50% RH.

Sealants that have to be applied in a heated state, are heated to the recommended temperature in a way approved by the manufacturer.

6.4 **Procedure**

Three specimens for elongation tests are made between glass and aluminium. The cross-section of the joint and the procedure depend on the type of material, and should be according to test method NBI-45.

The specimens are stored for 7 days at 296 K (23 °C) and 50% RH, and heat aged at 343 K (70 °C) in a ventilated cabinet. Aging time is 7 days for sealants in group 52 and 14 days for sealants in the groups 53 to 58.

After cooling to 296 K (23 °C), the specimens are placed in the water bath at a temperature of 275 ± 1 K (2 ± 1 °C) with the glass upwards. The level of the bath is controlled to not exceed the upper glass surface or go below the lower. The specimens are at the same time exposed to the light from sunlight lamps at a distance of

500 mm. The exposure time is 14 days for sealants in the groups 52 to 57 and 21 days for sealants in group 58. After the exposure, the specimens are elongated until failure at a temperature of 275 ± 1 K (2 ± 1 °C) and a speed of 0,025 ± 0,008 mm/s (1,5 ± 0,5 mm/min).

The force versus elongation diagram is recorded for all the tests.

6.5 Expression of Results

As a result the maximum force during the elongation test and the elongation at this force is given for each specimen. The force is given in Newton as a whole number (kilopond with one decimal), the elongation in mm with one decimal.

6.6 Accuracy

Normally there are some variations in the results, sometimes large variations. This is due to the fact that the method is very sensitive to arbitrary small faults and irregularities, as for example small variations in the joint shape, air bubbles in the sealant, irregularities at the bottom or on the surface of the joint, variations in the surface of the substrate and in the pretreatment etc. But variations like this will also occur in practice. Therefore, the method is considered to give a realistic picture of the elongation characteristics of a sealant.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Peel Strength, Influence of Solar Radiation

NBI-63
1987

BYGGFORSK

1 SCOPE

The purpose of this metod is to study the adhesion of a sealant to glass, measured as peel strength, when the sealant has been exposed to solar radiation through the glass and at the same time influenced by water.

2 FIELD OF APPLICATION

This method can only be used for sealants with a sufficiently high degree of elastisity after curing and/or aging. It is valid for sealants in group 56 and group 58 in the general classification of joint sealing materials.

3 REFERENCES

NBI-48, 1987, Building Sealants. Peel Strength.

The method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used much longer. It was adopted as NORDTEST method NT BUILD 022 in 1976.

4 DEFINITIONS

None.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, or in cartridges. Sealants in cans or buckets often have a tendency to separate, and should therefore, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 **Principle**

The peel strength is measured on special samples, where a strip of the material is peeled off at 180° angle, after exposure to artificial solar radiation and water under controlled conditions.

6.2 **Apparatus and Materials**

Universal tensile testing machine with an elongation velocity of 0,85 mm/s (50 mm/min).

Test plates of sheet or float glass, dimensions 6 mm x 80 mm x 150 mm.

Cloth, heavy type, about 0,2 kg/m^2.

Paper masking tape.

Water bath with distilled water, temperature 275 ± 1 K (2 ± 1°C).

Climate chamber with temperature 275 ± 1 K (2 ± 1 °C).

Sunlight lamps, type Osram Ultra Vitalux GUR 53 300 W or equivalent.

6.3 **Preparation and Conditioning of Test Specimen**

Materials and equipment are conditioned at 296 K (23 °C) and 50% RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary, at 296 K (23 °C) and 50% RH.

6.4 **Procedure**

Two specimens with glass plates as described in test method NBI-48, point 6.4 are made.

The so prepared specimens are placed in the water bath at a temperature of 275 ± 1 K (2 ± 1 °C) with the glass upwards. The level of the water bath is controlled to not exceed the upper glass surface or go below the lower. The specimens are at the same time exposed to light from sunlight lamps at a distance of 500 mm for 28 days.

After exposure, the peel strength is measured as described in test method NBI-48, point 6.4.

A total of four strips is tested.

6.5 **Expression of Results**

As a result the peel force is given for each of the four tests. The force is given in Newton as a whole number (kilopond with one decimal).

6.6 **Accuracy**

A certain amount of experience is required to do the tests in the right way, but with some experience, the results can be reliable. Sometimes there may be a large scatter in the results. This is due to differences in the substrate, and may occur, even if all rules are followed during the specimen preparation. However, these variations may also occur in practical joint sealing operations, and do not reduce the value of the testing.

6.7 **Test Report**

Use NBI-G01, point 6.7, and include the points applicable to this test method.

BYGGFORSK

Building Sealants Extrudability

NBI-64
1987

1 SCOPE

This method is used to measure the extrudability of gun grade building sealants.

2 FIELD OF APPLICATION

The method is valid for the following types of gun grade sealants according to the general classification of jointing materials of the Norwegian Building Research Institute:

Glazing sealants types 523, 524, 533, 552, 582 and 584, building joint sealants types 531, 541, 551, 554, 581 and 583 and for horizontal joint sealants types 585 and 586.

3 REFERENCES

British Standard BS 3712: Part 1: 1964.

NBI-43, 1987, Building Sealants. Density.

This method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used considerably longer. It was adopted as NORDTEST method NT BUILD 023 in June 1976.

4 DEFINITIONS

Extrudability is a quantified measure of the amount of sealant extruded through a specified nozzle under controlled conditions.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels, or in cartridges. Sealants in cans or buckets often have a tendency to separate, and should, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 Principle

The sealant is extruded through a specified nozzle at a given pressure under controlled conditions and the extrudability measured and expressed in m^3/h.

6.2 Apparatus and materials

Caulking gun, air powered, as described in British Standard BS 3712: Part 1:1964, point 8, with two nozzles:

- straight, circular cross section, diameter 10 mm, length = 50 mm
- conical, circular cross section, diameter 10/5 mm, length = 50 mm.

Climate chamber 278 K (5 °C).

Ventilated heating cabinet.

6.3 Preparation and Conditioning of Test Specimens

Materials and equipment are conditioned at the specified testing temperature. Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary.

6.4 Procedure

Testing can be carried out at different temperature levels. Normally the tests are taken at 278 K (5 °C) and 296 K (23 °C). For sealants where the manufacturer recommends a higher application temperature, the testing should be carried out at the recommended temperature.

The nozzle to be used should be fitted to the gun, and the caulking gun filled with approx. 250×10^{-6} m^3 (about 250 cm^3) sealant. If necessary, the filled gun should be reconditioned at the specified temperature. The conical nozzle is used for glazing sealants and straight nozzle for the other sealants.

The filled gun i weighed. The sealant is extruded at a pressure of $0{,}5 \times 10^6$ N/m^2 (5 kp/cm^2). The time required to extrude the whole volume is measured. The caulking gun is weighed again. With the help of the known density, found according to test method NBI-43, the weight is recalculated to volume extruded.

6.5 Expression of Results

As a result the extrudability in m^3/h is given with 3 decimals (cm^3/min as a whole number). The nozzle used and the temperature at which the test is carried out must be specified.

6.6 Accuracy

The method is very sensitive even to small temperature fluctuations. It is important that the caulking gun and the sealant is conditioned for a sufficiently long time. However, two- and multicomponent sealants must not be reconditioned longer than absolutely necessary, when they have been mixed, as the curing reactions start immediately and make the sealant more and more difficult to extrude. It is also important that approximately the same volume is always used, 250 x 10^{-6} m^3 (about 250 cm^3), and this should be completely extruded. The instantaneous extrudability depends, to some extent, on the degree of filling of the caulking gun. The extrudability, which is measured by this test method, is the average extrudability when emptying the completely filled gun.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Pot Life

NBI-65
1987

1 SCOPE

This method can only be used with two- and multicomponent gun grade materials. Such sealants begin to cure immediately after the mixing has been completed and change gradually from a plastic to a mainly elastic state. They consequently have a limited pot life, measured from the end of the mixing until the time when they are still soft enough to be used.

2 FIELD OF APPLICTION

The purpose of the method is to check that the sealant has the required extrudability at the time stated by the manufacturer as the pot life of the material. The actual sealants are types 581, 582 and 585 in the general classification of jointing materials.

By this method the extrudability is measured at a stated pot life. The testing method is consequently only a check. If more detailed information is required about the variation of the extrudability with time, consecutive measurements can be made at different points of time.

3 REFERENCES

NBI-64, 1987, Building Sealants. Extrudability.

The method is included in the Norwegian Building Research Institute's test programme for building sealants from August 17, 1970, but has been used considerably longer. It was adopted as NORDTEST method NT BUILD 024 in June 1976.

4 DEFINITIONS

Pot life is the time from the end of the mixing of a sealant until it is still soft enough to be used. The method is to be regarded as a check method rather than a method of testing the actual pot life of the sealant.

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants can be delivered in buckets, cans or similar, in barrels or cartridges. Sealants in cans or buckets often have a tendency to separate, and should, if necessary, be remixed before use. Otherwise the sealants can be used as supplied.

6 METHOD OF TEST

6.1 **Principle**

The test principle makes use of the fact that a sealant's extrusion properties are subject to changes with time. The extrudability is remeasured at the end of the specied pot life, and this is used to evaluate this property.

6.2 **Apparatus and Materials**

Caulking gun, air powered, as described in British Standard BS 3712: Part 1: 1964, point 8, with two nozzles:

- straight, circular cross section, diameter 10 mm, length = 50 mm
- conical, circular cross section, diameter 10/5 mm, length = 50 mm.

6.3 **Preparation and Conditioning of Test Specimens**

Material and equipment are conditioned at 296 K (23 °C) and 50% RH.

The sealants are mixed according to the manufacturer's instructions.

6.4 **Procedure**

The nozzle to be used is fitted to the caulking gun and the gun filled with approx. 250×10^{-6} m^3 (250 cm^3) sealant. The nozzle should be conical for glazing sealants type 582, and straight for the general sealants types 581 and 585.

The filled caulking gun is weighed and afterwards stored at 296 K (23 °C) until the time stated by the manufacturer as the pot life. At this point of time, the sealant is extruded at a pressure of $0{,}5 \times 10^6$ N/m^2 (5 kp/cm^2). The time required to extrude the whole volume is measured. The caulking gun is weighed again. With the help of the known density, found according to the test method NBI-43, the weight is recalculated to volume extruded.

6.5 **Expression of Results**

As a result the extrudability in m^3/h is given with 3 decimals (cm^3/min as a whole number). The nozzle used and the temperature at which the test is carried out must be specified.

6.6 **Accuracy**

See comments in test method NBI-64.

6.7 **Test Report**

Use NBI-G01, point 6.7, and include the points applicable to this test method.

Building Sealants
Ability to Accomodate Movements

NBI-112
1987

BYGGFORSK

1 SCOPE

This test method describes a testing procedure for determining the ability to accomodate movements of various types of building sealants.

2 FIELD OF APPLICATION

Building sealants have to maintain their properties - i.e., to seal - for a sufficiently long period of time. In practice, the materials are subjected to certain deformation due to changes in temperature, moisture content of materials etc. To be able to fulfil their functions, the materials must be able to accomodate these movements, and also to keep a sufficiently good adhesion to the substrate, even in aged condition.

One single extension, as in test method NBI-45, elongation properties, will give some indications. This has, however, to be supplemented with a durability test where the sealant is subjected to a high number of cyclic deformations at simultaneous aging.

This test method can be used for all types of sealants in the groups 53 through 58, but not for putties or glazing compounds, groups 51 and 52 in the NBI general classification of jointing materials. It was adopted as NORDTEST method NT BUILD 147 in September 1981.

3 REFERENCES

T. Gjelsvik: Classification of jointing materials. Build International, Vol. 3, No. 4, April 1970, pp 111-116.

Test method NBI-45, 1987, Building Sealants. Elongation properties.

4 DEFINITIONS

None

5 SAMPLING

Unless otherwise agreed, the material to be tested is supplied by the sponsor of the test. The sealants may be delivered in buckets, cans or similar , in barrels, cartridges or as extruded strips. Sealants in cans or buckets often have a tendency to separate, and must therefore, if necessary, be remixed before used. Otherwise the sealants may be used as supplied.

6 METHOD OF TEST

6.1 Principle

Test joints are made between blocks of fibre cement or concrete and sealed with the material to be tested. The test pieces are stored under closely controlled conditions and then tested in a cyclic movement tester at a given low temperature and a given number of cyclic movements. The test pieces are retested after heat aging. This procedure is repeated until damage occurs or until a certain number of cyclic movements are reached.

6.2 Apparatus and Materials

Cyclic movement tester, able to render approximately sine-shaped movements, 18 cycles/h (0,3 cycles/min).

Four blocks of 20 mm fibre cement sheet dimensions 20 mm x 30 mm x 125 mm, alternatively concrete blocks.

Back-up materials, spacer bars and clips.

Ventilated heating cabinet.

Climate chamber for a temperature of 275 K ± 1 K (2 ± 1 °C).

6.3 Preparation and Conditioning of Test Specimens

Materials and equipment are conditioned at 296 K (23 °C) and 50 % RH.

Two- and multicomponent materials are mixed according to the manufacturer's instructions and reconditioned, if necessary, at 296 K (23 °C) and 50 % RH.

Sealants that have to be applied in a heated state are heated to the recommended temperature as instructed by the manufacturer.

6.4 Procedure

Two test specimens are prepared from two blocks each. The cross-section of the joint and the rest of the details will be slightly different for different types of materials, but have to be as stated in test method NBI-45, point 6.4.

The test specimens are stored at 296 K (23 °C) and 50% RH until they have cured sufficiently, minimum 7 days, maximum 28

Table 1. General view of amplitude of the movements (in %), total number of cyclic movements and number of days heat aging.

Type of sealant		Amplitude %	Total number of cycles	Days of heat aging
Type 53	Skin-forming plastic sealants	10	3240	48
Type 54	Non-skinning plastic sealants	10	3240	48
Type 55	Tough plastic sealants	15	4680	72
Type 56	Thermoplastic sealants	10	3240	48
Type 57	Strip sealants	5	6120	96
Type 58	Elastic sealants	25	6120	96

days, according to agreement with the manufacturer.

The test specimens are subjected to approximately sine-shaped cyclic movements at 275 K ± 1 K. The apparatus has to be adjusted so that the test specimens are only subjected to elongation from the initial state and compression back to this state. The speed of the movements shall be 18 cycles/h, the total number of cyclic movements 360, and the amplitude (in %) as given in Table 1.

The test specimens are locked in the initial state and heat aged for six days at 343 K (70 °C).

The procedure is repeated until a total number of cycles and days of heat aging are reached as given in Table 1.

The test specimens are inspected visually after each period of 360 cyclic movements, and any kind of damage such as cracks, flow, etc. that might have occured are noted.

6.5 Expression of Results

As a result is given the total number of cyclic movements the test specimens have passed without cohesive or adhesive failure.

As a failure is considered any visual complete or partial crack going from the front surface of the test joint to the bottom.

A sealant may be classified as "good" if it is able to accomodate the number of cyclic movements given in Table 1.

6.6 Accuracy

In practice, the amplitude and type of joint can differ greatly. There is also a clear relationship between durability and size and type of movement as well as climatic strains. A single accelerated testing of durability can consequensly only give an indication of the durability of the products in practice. The indication given by this method is, however, considered as valuable.

6.7 Test Report

Use NBI-G01, point 6.7, and include the points applicable to this test method.