Sealing with mastics

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PREFACE

During recent years there has been a tremendous increase in the use of joint sealing materials in building construction as well as many changes in the sealants and their application to meet the exacting demands of the newer structural elements. This report, published by the Norwegian Building Research Institute is of particular interest to Canadian practice because of the similarity in the climatic conditions of Norway and Canada and because of similar problems that have been associated with the performance of sealants.

This report describes the different sealants available in Norway and their limitations for particular conditions of use. The importance is emphasized of proper joint design and good workmanship in the installation of the sealants. The two-stage sealing system is outlined and its advantages over a one-stage system that acts as a combined wind and rain screen are given.

The Division of Building Research is grateful to Mr. A. Tveit, a guest worker with the Division from the Norwegian Building Research Institute, for his work in preparing this translation.

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SEALING WITH MASTICS

by

Tore Gjelsvik

1. Introduction

For several reasons there have been few problems with joint sealing until recently. Formerly most of the structural elements used were comparatively small and rigidly connected to each other. In addition, the structures were massive and had high water-storing capacities; therefore a long time might pass before leakages were observed on the inside.

Modern construction techniques use prefabrication to an increasing degree and the structural elements are steadily increasing in size. These larger units move in closer relation to each other because of changing temperatures and moisture content in the materials. Traditional sealants, such as putty and mortar, have had to yield to newer materials that have been made in a way that allows for joint movements that might occur. The joint sealing problem has now become more acute because many of the new structures do not absorb water and therefore an incipient leakage is noticeable almost instantaneously.

Movable joints occur in connecting concrete elements, in facades of natural stone, around windows and in non load-bearing external or curtain walls. In curtain walls, there might well be many joints between different materials that move in close relation to each other; here the sealing between glass and aluminum becomes a critical problem.

At present a variety of different materials is available for the sealing of movable joints. Sealing with mastics has increased extensively and it is expected that its use will continue to increase. Sealing with mastics is the subject of this paper.

Of the existing mastic joint sealings, many have proven quite successful, others not very successful. The majority of unsatisfactory performance can be attributed to three main causes: choice of unsuitable materials, bad joint design and poor workmanship.

2. Types of Mastics

Caulking compounds are available in bulk or as ribbons. At present a great number of products exist with highly varying properties. Classification of these products is very difficult but may be divided into 4 main groups:

(a) quick-hardening mastics (b) plastic mastics

(c) plastic mastic ribbons (d) rubber elastic mastics

2.1. Quick-hardening caulking compounds

This group primarily comprises normal linseed oil putty that gradually hardens until it is rigid. Putty may be applied to seal small panes in framing materials with small movements. It is, however, not suitable for sealing of movable joints, since it then will crack or lose adhesion to the joint edges.

It is frequently claimed that putty used today is not of equal quality to that used formerly. The manufacturers may explain this by stating that competition will not permit them to produce better material. There are other reasons, however, why putty of linseed oil does not last so long now as it did formerly. Window panes are larger and the strain on the sealants has therefore increased. In addition, the pretreatment of the rabbets of wooden window frames is not carried out properly. This causes the putty to dry more rapidly and subsequently to crack. Finally, most people do not have time now to maintain windows properly. For putty to perform well, it must be painted a couple of weeks after application and regularly thereafter, preferably every two years.

2.2. Plastic Compounds

This group spans a large number of types with widely varying properties. A feature common to all of them is that they are markedly plastic and have little or no elasticity.

Many of the plastic compounds form a skin after a couple of days that prevents dust collection and delays the drying of the material. This skin in time will become a little uneven and wrinkled. Some more recent types will harden all the way through without forming a skin. The types with a permanently sticky surface will readily collect dust and dirt and should not be used in visible places.

All plastic compounds harden in time. The durability of the different products is variable and, in extreme cases, they may last just a couple of years. Normally, they will last 10 to 15 years; some of the more recent products will last even longer.

Among the plastic compounds one may recognize at least four characteristic subgroups: plastic glazing compounds, viscous plastic compounds, plastic oil-based compounds and thermoplastic compounds.

Plastic glazing compounds exist as both one- and two-component materials. Most have been sold as 'thermo-compounds' and used for factory-sealed glazing units. Most frequently the compounds have been applied using a knife but in some cases by a caulking gun.

Experiences with these products have been mixed. On the whole they tend to age quickly and thus lose most of their ability to accommodate movements. A more critical consideration of the conditions (1) has shown that these types of plastic compounds should not, strictly speaking, be used. In any case, they should only be used for sealing of joints with very small movements.

Plastic oil-based compounds are reinforced with fibre fillers and/or high molecular weight materials. The materials thus become more viscous and sticky so that they can accommodate greater joint movements. Normally, one can assume that these compounds are able to accommodate expansion-compression movements of approximately 10 per cent of joint width, in some cases a little more. Plastic oil-based compounds are almost always applied with a caulking gun, since they are too viscous and sticky to be applied by a knife. These compounds form a skin that can be painted. Examples of plastic oil-based caulking compounds are (in alphabetical order) Aalholm Termomastic, Secomastic K21, Secomastic BC48, Seelastic, Terostat 2620 N, and Uba Fogkitt.

Viscous plastic caulking compounds are usually based on plasticized butyl rubber. The mastics are viscous and sticky, and are applied with a caulking gun. Normally, small amounts of solvent are added to improve the extrudability. Consequently, the mastics will shrink a little, but need not cause any inconvenience if one knows just how to allow for it. Viscous plastic materials harden within a couple of months to a non-stickly, plasticelastic consistency. They will accommodate expansion-contraction movements of between 15 and 25 per cent of the joint width. Examples of viscous plastic caulking compounds are Aalholm-Butyl-mastic, Ribbonseal Gun Grade, Sandyl, and Secomastic HP.

Thermoplastic caulking compounds are fairly stiff at normal temperatures but soften considerably when heated to application temperature. This group comprises primarily all molding compounds of a rubber-asphalt base. Thermoplastic caulking compounds can accommodate expansion-compression movements up to 25 per cent of joint width. Examples are Ico-Rubb, Rubber-Seal Rubber Asphalt, Secoflex, and SH Rubber Asphalt.

2. 3. Plastic Ribbonseals

These are the more rigid plastic compounds delivered as ribbons or tapes. They are manufactured with different cross-sectional shapes and come in rolls with an interlayer of plastic foil or paper to prevent sticking. The ribbons' sticky surfaces adhere best after having been under pressure for a while. As they have a defined shape and are comparatively stiff there will be fairly strict requirements for the tolerances of the joints. They are best suited for application during construction. Ribbonseals are based on non-drying oils, unvulcanized and partly vulcanized butyl rubber, other synthetic materials and rubber asphalt. Ribbonseals are often used with more expensive caulking compounds to reduce the joint depth and the consumption of the more expensive materials. Examples are: Bostic Sealing Profiles (several types), Ribbonseal 79, Secostrip Butyl S and SS and Terostat (several types).

2.4. Rubberelastic caulking compounds

Most of these products made until now have been based on Thiokol Polysulfides and have been delivered as two-component materials. The two parts are mixed in a correct proportion just before use and the ready-mixed mass is applied by a caulking gun. During a certain period of time the mass cures to a rubberelastic product, a synthetic rubber. Depending on the formulation, one may obtain mixes with a pot life from 1 to 8 hours. They are not sticky after 1 to 2 days, partially cured after 2 to 7 days and completely cured after 1 to 3 weeks. High temperature and high relative humidity accelerate the curing process. The highest permissible application temperature is normally 40°C. At low temperatures, the curing process proceeds slowly or not at all. They should not be used, therefore, below +5°C.

Correctly used, these products will provide rubber-elastic sealings with good adhesion to most materials. At first, the material may show an elongation at breakup to some hundred per cent. Maximum expansion-contraction movements under practical conditions should, however, not exceed 50 per cent of the joint width.

The durability of these products is still unknown. Accelerated tests indicate, however, an endurance time of at least 30 to 35 years, possibly as much as 50 years. Examples of rubberelastic caulking compounds of Thiokol base are Bostic Vulkseal, Lasto-Meric, Naftoflex, ProSeal, Seco-Seal, and Weatherban. Most of these can be obtained in various qualities, depending upon the purpose.

Lately one-component Thiokol-base caulking compounds have been brought on the market. These have an intrinsic hardening system which is activated when the mass comes in contact with air. Such one-component materials have a somewhat longer hardening time than two-component materials. An example of such a one-component material is Weatherban 101.

There are a few one-component rubberelastic caulking compounds on the market that are not based on Thiokol polysulfides. One example is Mono-Lasto-Meric, which is based on polyacrylate. This material hardens very slowly but is particularly interesting as it is said to possess an incredible adhesion to most materials. Among one-compound rubber-elastic materials Dow Corning 780 on silicone-base should be mentioned.

3. Choice of caulking compound

As illustrated in the previous brief review, the various caulking compounds differ widely in their ability to accommodate joint movements as well as in their durability. When choosing a caulking compound one should keep in mind that no caulking compound lasts forever. As the replacement of a sealant is an involved and expensive task, it might be more expensive in the long run to use a cheap caulking compound if it has to be replaced after a couple of years.

The ability of caulking compounds to accommodate movements will differ depending upon whether there are expansion-compression or shear deformations. This is illustrated in Figure 1. When there are shear strains, the deformations of the caulking material are considerably less than when there is expansion and compression. A joint that is solely exposed to shear strains will subsequently be able to accommodate greater joint movements than when exposed to tension-compression strains.

Table I shows the maximum joint movements that one can expect the various caulking compounds to accommodate in an aged condition. If for one reason or another the caulking compound should crack or slip from the edge of the joint, joints that are exposed to shear strains only will simply lie as weather-stripping. Joints with expansion-compression movements, however, might have large cracks when they have expanded to the maximum joint width.

All joints should be principally designed to give shear strains only. In practice, however, this is not always possible. The first thing one must do when choosing a caulking compound is to compute the magnitude of the movements of the actual joints. These movements will depend upon the construction and must be computed in each individual case.

One must take into consideration the size, colour, and method of fastening of the elements, the kind of material, the location of the joints, orientation in relation to skyward direction, etc. Normally, movements caused by changes in moisture content and temperature are decisive. Sometimes strains from wind loads and building settlement have to be considered because of many reasons, among them primary shrinkage.

At the present time there are no Norwegian investigations showing which temperatures may occur in the external shell of buildings under practical conditions. A comparatively comprehensive English study (2) may be used as an indication of what might occur under Norwegian conditions. If the caulking is placed in the outer shell of the building, annual temperature variations with amplitudes between 75 and 100°C must be taken into consideration, depending upon whether the facade is light or dark. If the caulking is inside, only smaller temperature variations will occur. Movements from changing moisture content must be added to the calculated temperature movements. These movements may also counteract each other, but if it is not certain that this is the case it must be assumed that they are cumulative. When the absolute joint movements are known, the relative joint movements for different joint widths can be computed. Next the joint width must be adjusted and a caulking compound chosen so that the maximum permissible limits of joint movement given in Table I will not be exceeded. Joint width and caulking compound, therefore, should not be determined independent of each other; they must be decided simultaneously and adjusted in relation to each other.

The joint width determined in this way is, however, a minimum joint width, not the basic width given on the drawings. The narrowest joints will have, relatively, the greatest movements. In practice, the joint width may vary considerably. In the first place, certain movements in the joints may lead to variations in width, but more important by far are those variations that always will occur due to the varying shapes and sizes of structural elements and their relative positions.

Basic joint width will, as shown in Figure 2, be equal to minimum joint width plus the negative deviation: $B_{nom} = B_{min} + t_m$. In the same way the maximum joint width is equal to the basic width plus the positive deviation: $B_{max} = B_{nom} + t_p = B_{min} + t_m + t_p$.

When choosing a caulking compound, it is not sufficient only to know the joint movements. One must also know something of the expected variations in the joint widths. It is desirable to know the tolerances of the structural elements, the relative positioning of the elements, and the width of the joints.

When choosing the caulking compound and determining the joint widths, as described previously, plastic caulking compounds that can only accommodate small joint movements must have a large joint width, whereas by using the rubber-elastic caulking compounds that can accommodate greater joint movements, a narrower width may be used. In this way, the difference in price of these materials is diminished.

Accordingly one is not quite free in the choice of a caulking compound. Minimum joint width may not be made arbitrarily small. The minimum joint width of oil-based plastic caulking compounds must not be less than 10 mm, (because of their aging characteristics), particularly for sealing between porous materials. For viscous plastic caulking compounds the minimum width may be a little less, approximately 5 mm, and for rubberelastic materials, even 3 mm, if the joint movements permit this.

The maximum joint width should not be made arbitrarily large, as the compound might sag out of the joint. This, therefore, must be checked. For plastic caulking compounds the maximum width will normally be between 15 and 25 mm. By using rubberelastic compounds one has a little more freedom as this caulking can be built up in a number of successive operations.

If joint movements and tolerances are large, the cheapest products may not be at all applicable, as the width of the maximum joints will be so large that the compound will sag. In practice, variations of the joint width have often been surprisingly great. This is recognized in a Danish investigation (3). The application of plastic compounds will be naturally limited to joints between structural elements of moderate dimensions and will be somewhat dependent upon the applied materials.

The caulking compound chosen must ensure good adhesion to the material in the joint edges. The different types do not necessarily stick equally well to all kinds of surfaces. When a porous material, such as wood, is used, one must also check that the joint faces do not absorb any of the binder of the compound. If they do, the compound may dry, shrink and lose adhesion, and at the same time, the joint surfaces will probably discolour. Thiokol-based caulking compounds at one time frequently contained an additive of phenolic resin to improve adhesion and in certain cases this caused bad discolourings on light concrete. Now, there are also types without phenols on the market. Alternatively, the joint surfaces may be treated with a special primer to prevent absorption of liquid components from the caulking compound.

Pretreatment of the joint faces with a special primer may also be necessary for other reasons. As mentioned, the treatment may be carried out to prevent absorption and discolouring of the joint face, but the purpose might also be to bind dust and to improve the adhesion to certain substrates. The purpose of the primer for some highly absorbtive substrates, for instance cement-asbestos sheets, may also be to prevent water from the rear side reaching the joint edges and reducing the adhesion. Finally, the purpose of the primer may be to reinforce the substrate materials. This has been particularly true in connection with porous and weak joint mortars and some types of concrete.

When two or more materials are used together, the materials must be compatible with one another. Not all combinations of materials are equally successful. Oil-based and asphalt-based sealing compounds most often react with each other.

When comparing the prices of caulking compounds volume prices rather than weight prices must be used. A certain volume always has to be filled and the weight prices are not directly comparable. The bulk density of caulking compounds varies between 1 and 2 kg/dm^3. By comparing weight prices one may easily be deceived.

4. Location and design of joints

Broadly speaking, foreign practice up to the present has been to place the caulkings in the outer shell of the buildings, and thus they are exposed. This practice is an example of a one-stage seal, as the caulking acts as a combined wind and rain barrier. NBRI has for several years promoted two-stage seals (4, 5), with separate air and moisture seals. According to this principle the rain barrier is placed outermost as an external rain screen, the wind barrier is placed a little farther in, and between the two sealings, a vented air space is created. In this way, the air seal is kept dry.

The advantages of one-stage seals are that they are simple to apply and easy to repair. The mastic is, however, fully exposed to sunshine and rain, high and low temperatures. It will consequently age more quickly than if it had been protected against climatic strains. Caulking becomes a critical part of the construction and an eventual failure could easily lead to serious damages. No sealings will last forever, and when the caulking fails after a certain number of years, leakage resulting from the failure of single-stage sealings may easily cause serious damage before the leakages can be repaired.

With two-stage sealing, it is more difficult to apply the mastic from the outside and difficult to repair; but eventual repairs must be considered. These problems are possible to solve if one takes them into account in the design of the joints. The mastic sealings may under certain circumstances also be placed on the inside. The advantages of two-stage sealing are evident. The mastic will be protected against weather and thus will age more slowly and, in many instances, be exposed to less movement. For these reasons one may accept the use of a lower quality and perhaps a considerably cheaper type of mastic. The sealing will no longer be so critical because an eventual failure will lead only to air leakage. Examples of single- and two-stage sealing in connection with concrete elements are shown in Figure 2.

It was recommended earlier that the joints be designed with square or rectangular cross-sections so that the ratio between width and depth would be 1 : 1 or 1 : 2, viz. fairly deep joints. For plastic compounds the square cross-section is recommended at the present (Figure 4A). This does not imply, however, that the depth should be made slavishly equal to the width. Width equal to depth is only a general rule and deviations have to be allowed where necessary. For the widest joints, the depth must be made a little less than the width, otherwise there is too big a risk of the mastic sagging in the joints. For the narrowest joints, the depth must be somewhat greater than the width, partly to get a sufficiently large adhesion surface area along the joint edges and partly so that there will be sufficient caulking considering the aging characteristics of the materials. This relates particularly to oil-based and asphalt-based mastics. The most appropriate depth will normally be between 10 and 20 mm.

For rubberelastic compounds the ratio between width and depth should be close to 2 : 1. It is recommended that the cross-sectional shape be a little biconcave as shown in Figure 4B. Substantially better adhesion to the joint edges is obtained in this way, and most of the deformation of the sealing will take place in the middle part of it. Sealings with a biconcave cross-section are easily obtained by means of a suitable back-up and some appropriate tool for smoothing the surface.

A general requirement for the backing is that it not prevent deformations of the mastic when the joints are moving. If the mastic sticks to a rigid backing, the movements will be concentrated to certain spots at the bottom of the joint. As a result, the sealant will crack from the bottom, as shown in Figure 5.

The problems in connection with plastic compounds are solved by using a backing of soft strips of some foamed plastic material. These are so soft and easily deformable that they do not transfer forces of any importance to the mastic. A backing of oakum is not good as traces of the oakum may easily come in contact with the joint faces and prevent the mastic from adhering. In connection with rubberelastic mastics it is all right to use a backing of foamed plastic. Alternatively, waxed or polyethylene-coated tubes of pasteboard may be used; in horizontal joints, strips of polyethylene may also be used. Rubber-elastic compounds do not stick to these materials after curing is completed.

In corner joints a backing also has to be applied to prevent stress concentrations. Figure 6 shows the wrong and the correct way to do it. Strips of foamed plastics or ribbonseals may be used here as a backing.

For bevelled joints that are too narrow, it does not help to put on more mastic on the bevelling, as in

Figure 7. It is the relative movements at the bottom of the joint that are decisive. If the movements are too big, the mastic will crack from behind. Such joints must be sealed as corner joints. Also, with correctly dimensioned bevelled joints, the mastic should not, strictly speaking, be laid out on the bevelling; it should be placed well back into the joint.

Joints in floors with traffic are apt to need special attention. The best way is to protect the joints with flashing.

Mastics are normally so soft that they cannot transfer any big forces. The various components of the buildings will, therefore, have to mechanically secured in some other way. When mounting special glazing units, they must be supported in a special way and the mastic in the side joints must be secured by using spacers. Mounting of special glazing units as factory-sealed units usually produces many problems. These will not be treated in detail in this connection (See references 1, 6, and 7).

A problem associated with plastic sealing compounds has been oil bleeding. Recent investigations (8) have shown that the primary reason for the bleeding is that the joints have been designed so that the mastic has come under pressure. The oil has thus been squeezed out of the mastic. The basic mechanism is shown in Figure 8. To avoid oil bleeding, therefore, it is important that the joints be correctly designed.

5. Application Procedure

A successful sealing with mastic depends as much upon correct application procedure as upon the choice of mastic and design of the joints. It is, therefore, best to use specially trained persons.

For every sealing with mastic, the joint edge must be clean and free of dirt, dust, loose particles, oil and grease. All dirt must be carefully removed. When washing away oil and grease rags must be changed frequently so that the oil and grease will be removed completely and not just re-distributed on the edges.

In most cases the edges must be dry. Some mastics are said to stick to wet surfaces. But even in these cases there is a limit to how wet the joint edges may be, and the safest procedure still is to caulk on a completely dry surface. Cold weather will be particularly critical, because of the risk of condensation, frost or ice formation. Normally, 5°C is considered to be the lowest permissible temperature for working with mastics without taking any particular precautions. When working at a lower temperature, cover and eventual heating must be provided.

The backing must be pressed into the joints so that the depth of the joint will be correct, and at the same time give good support when the mastic is applied. Eventual priming and the mixing of multi-component mastics must be done carefully.

In the application of the mastic a good contact between mastic and joint edges must be assured. Particular care must be taken if the surfaces are very rough. If necessary, the mastic may be applied in two or more operations. The mass must not be too viscous since it must flow easily. In many cases, it will be necessary to smooth the joints, partly to obtain better contact and partly to obtain a smoother surface.

6. Summary

Successful sealing with mastics is dependent upon a correct choice of material, correct design and positioning of the joints, and correct and careful workmanship. There are many requirements for planners as well as for those executing the installation. If the guidelines in this paper are followed, there should be every possiblity of good results.

References

(1) Tore Gjelsvik: Glassfalser og glasslister for forseglete ruter. Byggmesteren nr. 26/63 og 1/64. Norges byggforskningsinstitutt, Saertrykk 86.

(2) Jointing with Mastics and Gaskets, 1 and 2. Building Research Station Digest (second series), No. 36 and 37.

(3) Povl R. Andersen: Facadefuger: Taetheds- og Tolerance-problemer. Nordisk Betong nr. 2/64, s. 263-284.

(4) Sven D. Svendsen: Driving Rain. Norges byggforsknings-institutt, Rapport nr. 20, Oslo 1955.

(5) Sven D. Svendsen: Prinsipper for tetting mot vind og slagregn. Bygg 2/62. Norges byggforskningsinstitutt, Saertrykk 71.

(6) Tore Gjelsvik: Innsetting av isolerglass. Byggmesteren nr. 2/62. Norges byggforskningsinstitutt, Saertrykk 71.

(7) Byggdetaljblad NBI (31). 202, Oslo 1961.

(8) Tore Gjelsvik: Hvorfor blør det olje fra kittet? Byggmesteren nr. 17/64. Norges byggforsknings-institutt, Saertrykk 97.

TABLE 1

MAXIMUM ALLOWED DEFORMATIONS FOR AGED MASTICS OF VARIOUS TYPES

	Deformations in per cent of mastic width	
Mastic-types	tension compression	shear
Quick hardening mastics	0*	0*
Plastic window mastics (one and two component)	2	10
Plastic oil-based caulking compounds	10	40
Viscous plastic caulking compounds (mainly butylrubberbased)	15-25	50-75
Thermoplastic caulking compounds	25	75
Rubberelastic caulking compounds (mainly polysulfidebase)	50	150

* approximately.

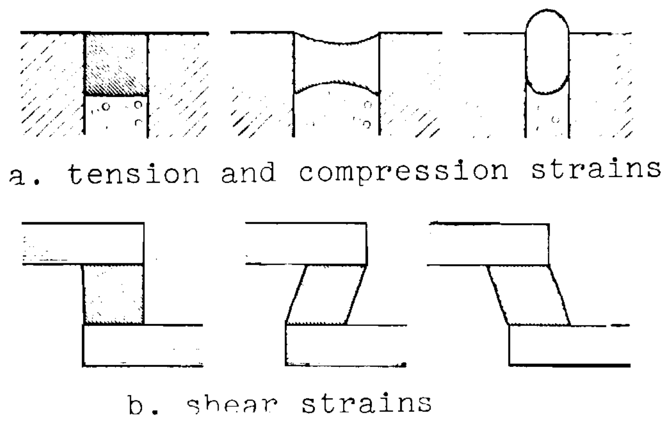

Fig. 1

Deformation of joints

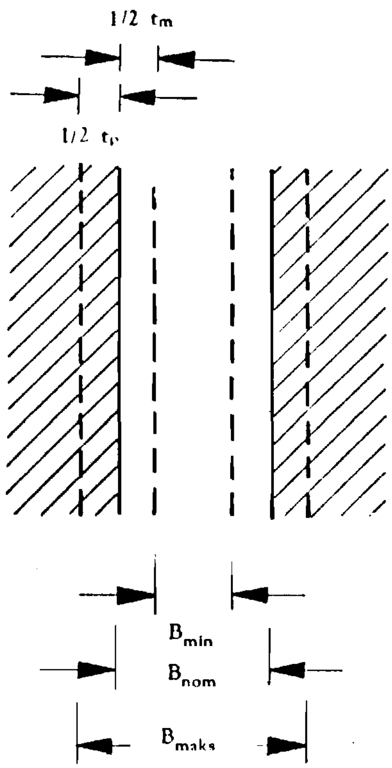

Fig. 2

Variations of the joint width

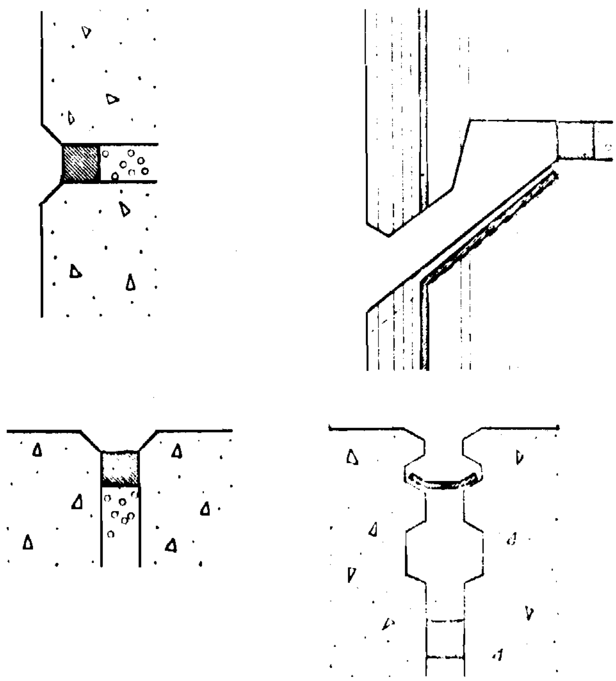

Fig. 3

One- and two-stage sealing for concrete elements

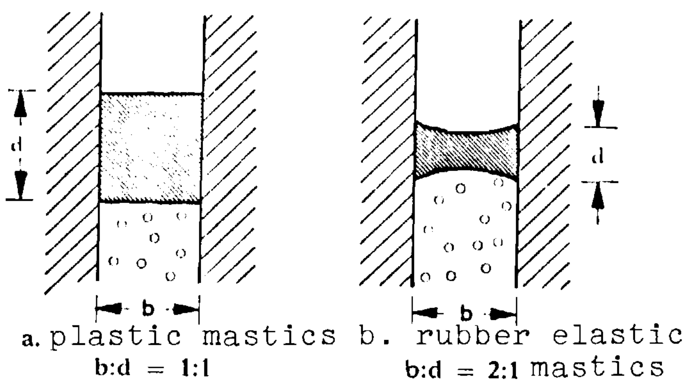

Fig. 4

Cross-sections of joints

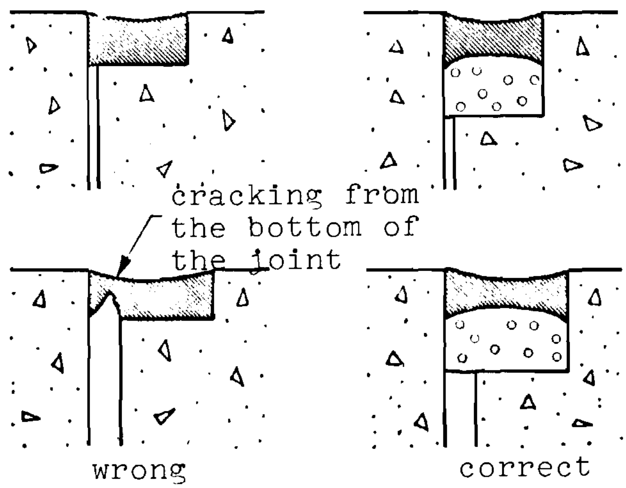

Fig. 5

The backing shall not prevent
deformation of the mastic

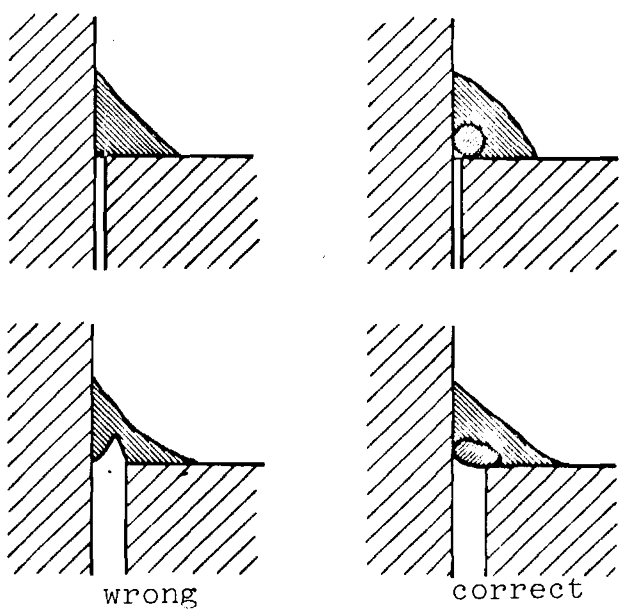

Fig. 6

Forming of corner joints

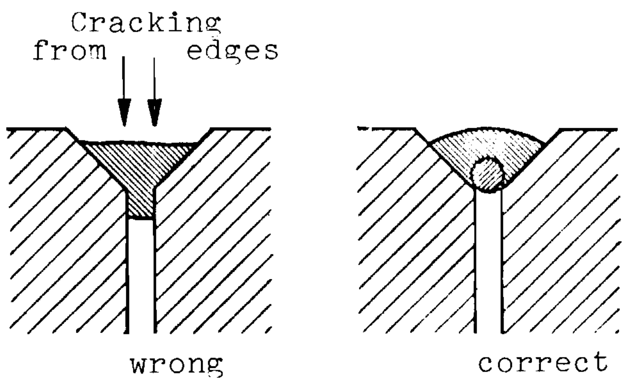

Fig. 7

Sealing of narrow joints
with bevelled edges

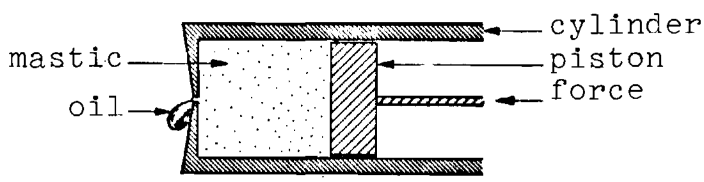

Fig. 8

Model illustrating the basic principle
of oil bleeding