NRC Publications Archive Archives des publications du CNRC

Development of test procedure for predicting performance of sealants Karpati, K. K.

This publication could be one of several versions: author's original, accepted manuscript or the publisher's version. /
La version de cette publication peut être l'une des suivantes : la version prépublication de l'auteur, la version
acceptée du manuscrit ou la version de l'éditeur.

Publisher's version / Version de l'éditeur:

ACS Symposium Series, 113, pp. 157-179, 1979

NRC Publications Record / Notice d'Archives des publications de CNRC:

<https://nrc-publications.canada.ca/eng/view/object/?id=91a5559e-da3c-4594-97b4-5d87fc63870d>
<https://publications-cnrc.canada.ca/fra/voir/objet/?id=91a5559e-da3c-4594-97b4-5d87fc63870d>

Access and use of this website and the material on it are subject to the Terms and Conditions set forth at

<https://nrc-publications.canada.ca/eng/copyright>

READ THESE TERMS AND CONDITIONS CAREFULLY BEFORE USING THIS WEBSITE.

L'accès à ce site Web et l'utilisation de son contenu sont assujettis aux conditions présentées dans le site

<https://publications-cnrc.canada.ca/fra/droits>

LISEZ CES CONDITIONS ATTENTIVEMENT AVANT D'UTILISER CE SITE WEB.

Questions? Contact the NRC Publications Archive team at
PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca. If you wish to email the authors directly, please see the
first page of the publication for their contact information.

Vous avez des questions? Nous pouvons vous aider. Pour communiquer directement avec un auteur, consultez la
première page de la revue dans laquelle son article a été publié afin de trouver ses coordonnées. Si vous n'arrivez
pas à les repérer, communiquez avec nous à PublicationsArchive-ArchivesPublications@nrc-cnrc.gc.ca.

7778

Ser
TH1
N21d
no. 894
BLOG
cop. 2

National Research
Council Canada

Conseil national
de recherches Canada

DEVELOPMENT OF TEST PROCEDURE FOR PREDICTING PERFORMANCE OF SEALANTS

ANALYZED

by K.K. Karpati

Reprinted from
American Chemical Society Symposium Series No. 113
Plastic Mortars, Sealants, and Caulking Compounds
1979, p. 157 - 179

DBR Paper No. 894
Division of Building Research

Price \$1.25

OTTAWA

NRCC 18078

RÉSUMÉ

L'enveloppe extérieure d'un bâtiment subit des mouvements cycliques sous l'effet des conditions changeantes de température et d'humidité. Les éléments ou sections d'un bâtiment se dilatent ou se contractent en bloc sous l'effet de ces changements et ce sont les joints qui absorbent les mouvements. Pour prévenir le passage de l'air, de l'eau ou de la poussière, il faut sceller les joints. Les agents de scellement sont fortement sollicités à cause des importantes variations de température à l'extérieur d'un bâtiment, particulièrement dans les régions froides. Pour l'étude de leur rendement, il fallait une méthode d'essai qui permette d'établir une relation entre leur comportement en laboratoire et sur place. Dans le présent article, l'auteur décrit la mise au point d'une telle méthode.

CISTI/ICIST

3 1809 00210 1068

Development of Test Procedure for Predicting Performance of Sealants

K. K. KARPATI

Building Materials Section, Division of Building Research,
National Research Council of Canada, Ottawa, Canada K1A 0R6

ANALYZED

The outside envelope of a building undergoes cyclic movements in responding to changing temperature and moisture conditions. It may consist of building elements such as panels of various materials with joints between or large wall sections interrupted by expansion joints. These building elements or sections expand and contract as one unit with any change of temperature or moisture content and the resulting movements are accommodated at the joint. To prevent the passage of water, air or dust the joints must be sealed. Organic materials, called sealants, applied as viscous liquids are used for this purpose. To regulate the cross-section of the sealant bead, a solid back-up material that is most frequently a flexible closed-cell polyethylene foam rod of circular cross-section is first placed into the joint. It has to be wider than the joint and is forced into the opening in such a way as to allow the application of the sealant to an even depth. The liquid sealant is applied against the back-up material, to which it has no adhesion, but adheres to the edges of the building elements.

The sealant is so formulated that it keeps its shape as applied and hardens through chemical or physical processes to form a viscoelastic rubber-like material that withstands extension or compression. The sealant is extended at low temperatures and compressed at high temperatures because the building elements meeting at the joint contract with decreasing temperature and expand with rising temperature.

The demands on sealants are severe because of the large temperature changes imposed on the outside of buildings, especially in cold climates. To investigate their performance, a testing procedure is needed that provides a connection between laboratory and outdoor behavior. A great many factors influence sealant performance and systematic experimenting is needed to find a way of testing that defines the essential sealant properties and discards those that are secondary. Such a test procedure is based on complex relations between the different factors that govern polymer behavior, but it can be made easy to perform by means of

various simplifying steps in the development of practical testing conditions.

Tensile Test

The factors that govern the behavior of sealants are: stress, strain, temperature, rate of deformation, humidity, air, light, type and condition of substrate, and presence of water or chemicals. Of these, stress, strain, deformation rate, and temperature are of primary importance. They have to be known simultaneously in describing a material at any given age, humidity, substrate condition, etc. Consequently, these four factors must be included in any test method devised to measure mechanical properties, while the other variables must be kept constant at values considered to be realistic.

Cyclic tests provide the best representation of the conditions to which sealants are subjected in practice. They are very complex tests, however, and can be designed satisfactorily only if the material properties are well known from the results of tests using simpler loading patterns and if the rates are related to those of actual joints. Tensile extension at constant rate, stress relaxation under constant strain, and creep under constant stress are three of the simpler tests used to obtain the material properties of polymers. Tensile extension is not the simplest of the three tests (of the four basic variables only temperature can be kept constant), but it has been chosen because it is this type of loading that occurs in the sealant in a joint when the chance of failure is most probable. There is less likelihood of failure when the sealant is compressed in summer than when it is extended in winter. In addition, the tensile test is the least time-consuming and most laboratories are equipped for it.

Model Specimens

After selecting the tensile test as the basic method for investigating sealant behavior, in both laboratory tests and outdoor performance, the size and shape of the specimen have to be considered. Tensile tests are usually carried out on dumbbell or ring-shaped specimens, stress fields of which remain parallel during extension. The true stress can be calculated, therefore, through the minimum cross-section at any time during the experiment. Sealant beads in building joints, however, have an extremely complicated stress field because the side of the bead curves in on extension and the stress changes direction, concentrating at the ends and edges as extension progresses. Consequently, the specimen chosen for the investigation is a model of the sealant bead used in building joints, i.e., it has a stress field similar to that of the sealant in a building joint. The model can fail either cohesively or adhesively, as does a sealant in a joint. This is a distinct advantage compared with dumbbell

or ring-shaped specimens that can fail only cohesively. The model also permits the study of adhesive properties of sealants on various substrates. Another advantage of the model specimen is that most standards call for it and many investigators use it, so that data are available for comparison of materials or conditions. The size of the sealant bead is $\frac{1}{2} \times \frac{1}{2} \times 2$ in. ($1.3 \times 1.3 \times 5.1$ cm), as illustrated in Figure 1, unextended and extended, the latter showing curved sides.

Deriving the Test Procedure

Three-Dimensional Representation. Whatever the configuration of the specimen, an infinite number of tensile curves can be obtained by changing either temperature or tensile extension rate. Figure 2, for one-part chemically cured silicone, and Figure 3, for two-part polysulfide model specimens, show a few examples that are obtained by varying the test conditions. The question arises, which of the tensile curves defines the mechanical properties of a sealant unambiguously?

It is known that for some polymers, and using specimens with parallel stress fields, all tensile curves can be reduced to a single one at a given temperature if the stress and strain at each point of the curve are divided by the strain rate (producing time as abscissa) and if an empirical correction factor, λ , the extension ratio, is applied to stress (1). This treatment of results has also been applied (2) to tensile curves obtained with the model specimens. The resulting single curves of unit strain rate are shown in Figures 4 and 5, derived from Figures 2 and 3, respectively. As may be seen, the fit of the individual tensile curves to the single curve of unit strain rate is excellent for silicone and within acceptable limits for polysulfide sealants. This proves that the model specimen can be used for an investigation intended to establish the interdependence of the tensile curves. It would permit the derivation of a simple and rational method for presenting the deformation characteristics of sealing materials.

The unit strain rate curves are not fully suitable for describing the behavior of sealants, for they give little information on failure behavior because the failure points for given conditions fall at various points on them. To investigate failure properties as a function of the four basic variables a three-dimensional system has to be used: an example is shown in Figure 6 for two-part polysulfide sealant. Each line represents a tensile curve, calculated from the original curves, and the failure points form the upper curved edge of the three-dimensional representation.

There are several steps of calculation involved in arriving at the three-dimensional presentation. They are necessary in order to reduce the number of variables from four to three. The first step in obtaining the curves in Figure 6 is to recalculate

Journal of Paint Technology

Figure 1. Original and extended model specimens (4)

Journal of Paint Technology

Figure 2. Tensile curves of silicone specimens at different extension rates and two temperatures (2)

Journal of Paint Technology

Figure 3. Tensile curves of polysulfide specimens at different extension rates and two temperatures (4)

Journal of Paint Technology

Figure 4. Tensile curves reduced to unit strain rate for silicone specimens at different temperatures (2); λ , extension ratio (empirical correction (2)); S, load; and R, strain rate.

Figure 5. Tensile curves reduced to unit strain rate for polysulfide specimens at different temperatures (4); λ , extension ratio; R, strain rate; T, test temperature, degree Kelvin; T_0 , reference temperature, degree Kelvin; t, time; and S, load.

Journal of Paint Technology

Figure 6. The property surface for polysulfide sealant (4); λ , extension ratio; S , load; T , test temperature, degree Kelvin; T_0 , reference temperature, degree Kelvin; t , time; and a_T , time-temperature shift factor.

each point of the original tensile curves for plots of the type shown in Figure 7. The abscissa is the logarithm of time, derived by dividing the strain by the strain rate, and the ordinate is the load corrected for "true stress" by λ , the extension ratio, and by T_0/T , the reference temperature divided by the test temperature, both in degrees Kelvin (2). The temperature correction is that required by the theory of rubberlike elasticity. Figure 8 is the projection of the original tensile curves on the stress versus time plane. These curves are shown as dotted lines in Figure 7. The continuous lines are the best fits connecting the tensile curves at 5, 10, 15, 20, 25, 40, 60, 80, 120, 160 and 200 per cent extensions. From this plot the isochronal stress-strain curves can be derived by reading values from the best fitting lines for a given time. The times chosen were those at which failure occurred for each specimen. The actual breaking stresses and associated scatter were thereby preserved. The isochronal curves are shown in the background of Figure 6 in the log stress-log strain plane. The third dimension is added by shifting the curves along the time axis, which is perpendicular to this plane, according to the time at which each curve was read. This procedure is followed for each temperature, and with the help of the WLF shift factor, a_T , curves obtained at all temperatures are incorporated in the one three-dimensional representation.

It must be recognized that for silicone sealants the time-temperature superposition was not necessary because the unit strain rate curves fell on the same cumulative single line at each temperature (Figure 4). In other words, the silicone sealant was insensitive to temperature changes within the temperature region observed and within experimental error.

The WLF shift factor was also investigated and experimentally derived for polysulfide sealant using the model specimen (4). The best-fitting (continuous) lines of the various extensions (Figure 7) were used as guidelines for manually shifting the plots obtained at different temperatures along the time axis until the lines for each extension formed a smooth curve (Figure 8). From the measured shifts the constants of the WLF equation, often referred to as "universal constants," were calculated and compared with constants obtained for other polymers. The difference between those calculated here and the universal constants was small, but it was large enough to require use of the former in shifting the sealant data.

The surface formed by the calculated curves shifted along the $\log t - \log a_T$ axis (Figure 6) is the property surface of the polysulfide sealant. A similar surface could be derived for the silicone sealant. The three-dimensional system gives a complete and coherent description of sealant properties, i.e., from a single tensile curve any other can be calculated once this system is known. It is, however, too complex for everyday use and in the next phase of the investigation steps were taken to derive a simpler way of characterization.

Journal of Paint Technology

Figure 7. Time dependence of stress at 73°F (4)

Journal of Paint Technology

Figure 8. Determination of shift factors (4)

Projections of the Three-Dimensional System. To simplify the three-dimensional system, its projections into the various planes can be used. In particular, the projection of the break points is important because they define the limitations sealants have in practice. Their projection in the log stress-log strain plane is the failure envelope (5) shown for polysulfide sealant in Figure 9. The outer limit of the envelope is well defined and is drawn in with a dashed line, but the inner one disappears in the scatter. For the silicone sealant, Figure 10 gives the failure envelope where both the upper and lower limits are well defined.

The failure envelope is used in the literature to characterize polymers because it is independent of time and temperature, but its usefulness is limited with sealants. From the point of view of sealant performance, the projection of the failure points into the log strain-log time plane is the most important characterization; it is the strain that is imposed on the sealant by the movement of the joint and the stress develops as a consequence of the imposed strain. Consequently, the design of a sealed joint is usually based on an estimate of strain, not of stress, and the sealant is chosen according to its movement capability, that is, the $\pm$ per cent movement the sealant can take without failure in a yearly movement. Stress has to be considered only in those rare cases where the substrate is a fragile, porous material whose tensile strength approaches that of sealants. In this case, a sealant with the lowest strength possible has to be chosen.

Projections of the failure points are shown in Figures 11 and 12 for silicone and polysulfide sealants, respectively. The points plotted in the curves represent the strain at break at the time needed to reach the break. For silicone sealants it was found that the break points obtained at room temperature are sufficient for a final analysis. For polysulfide, data obtained at seven different temperatures are used, reduced to -30°F (-34.4°C).

The time dependence of the strain at break is very different for the two types of sealant. The break points of the silicone data can be fitted by a straight line, and confidence limits at various levels can be drawn on the plot (Figure 11). The break points of the two-part polysulfide sealant form a broad band, the upper and lower limits of which are drawn qualitatively. The upper limit is better defined than the lower one (as for the failure envelope). Because of the difference between the plots for silicone and polysulfide sealants the further simplification of characterization is different for the two types of sealant.

Silicone Sealant. Failure of the silicone specimens occurred at increasingly longer times with decreasing strain rates, covering $4\frac{1}{2}$ time decades, measured in minutes. With an extrapolation of $1\frac{1}{2}$ time decade, the extension at failure at half a year can be estimated. In Figure 11 the value obtained is 28 per cent,

Journal of Paint Technology

Figure 9. Failure envelope of polysulfide sealant (4)

Journal of Paint Technology

Figure 10. Failure envelope of silicone sealant (2)

Journal of Paint Technology

Figure 11. Time dependence of strain at break; silicone sealant at 72°F (22°C)
(2)

Figure 12. Time dependence of strain at break; two-part polysulfide sealant (4)

with 95 per cent confidence limits of 57 and 14; that is, 95 out of 100 tests will give failure points inside this confidence interval. Although the characterization could be done at any time value, the choice of half a year has the advantage of being a critical time in the life of a sealant as, on average, half a year is reached in winter, at maximum extension. If a sealant does not fail during the first winter, there is a good chance that it will last for many years.

It has to be pointed out that the single value, 28 per cent, is based on one batch of a one-part chemically-cured white silicone sealant. This single value is presented only as an illustration of the testing procedure. One can expect variations from batch to batch and from manufacturer to manufacturer. Another important factor that may influence the characteristic single value is the aging process to which the sealant is subjected before testing (one month at 70°C in this case). It is only after investigation of all the above factors that a single extension value with its confidence limits can be derived to characterize all chemically-cured silicone sealants available on the market. Such work would need cooperation on the part of manufacturers, but it would remove much of the uncertainty involved in sealed joint design.

Polysulfide Sealant. The single value and its confidence limits have to be derived in a different manner for two-part polysulfide sealants because of the flat maximum formed by the break points. Another difference from the results obtained for silicone sealants is that the tensile properties change with temperature. To characterize extreme winter conditions when failure is most probable the extensibility is given for -30°F (-34.4°C) (Figure 12). According to the lower limit (drawn by dashed line), the sealant can last about 20 years at about 100 per cent extension at this temperature. This estimate is supported by only a few points in the neighborhood of this reading. A better way of characterizing the sealant is to consider that all the readings belong to the same "population" and calculate the mean of the logarithmic strain; this can be done because of the flat maximum. From the mean and its standard deviation one can calculate the extensibility at which only 1 per cent of the tests will fail; this was 119 per cent in the particular batch used. The same applies for polysulfide as for silicone sealants: several manufacturers' products and batches would have to be tested following the method described and the aging process investigated in order to derive an extensibility value that applies to all good quality two-part polysulfide sealants.

Cyclic Tests

Sealants undergo daily cycles superimposed on the yearly one as building movements follow weather conditions. To investigate

the connection between tensile and cyclical behavior, model specimens of one-part chemically-cured silicone sealant were strain cycled on a tensile tester (6). The amplitude and rate of the cycles occurring in practice were known from joint movement investigations (7, 8, 9, 10). The average daily movement is about ± 4 per cent of joint width for a joint that moves ± 25 per cent a year. The silicone sealant model specimen, the only sealant type used for the cyclical experiments so far, showed rubbery behavior when cycled at ± 4 per cent. To cause failure, the daily cycles had to be superimposed on the maximum yearly extension. For example, specimens were cycled between $25+4$ and $25-4$ per cent extensions. By choosing the cycles in this manner the laboratory strain rates were brought as close as practically possible to actual joint movement rates. It was also necessary to define the number of daily cycles to be imposed. Various considerations led to the selection of 120 cycles. It became clear from the experiments that a number of cyclical tests at identical conditions were needed in order to establish the probability of 50 per cent failure. Failures occur with a scatter, and if all tests pass or fail one does not know what the failure limit is.

In a series of experiments the initial extension, the superimposed cycles, and the rate of movement were varied. For the particular batch of silicone sealant used it was found that for a 25 per cent extension a cyclical movement of ± 8 per cent had to be superimposed at a rate of movement of 1.0 cm/min in order to achieve close to (but less than) 50 per cent failure in the number of specimens tested. Lower rates or higher extensions at the same rate of movement produced more failures. For example, the number of failures increased to four-fifths of the total number of tests when either the above ± 8 per cent to ± 12 per cent were increased or when the rate from 1.0 to 0.1 cm/min was decreased.

These results can be explained if they are examined in conjunction with Figure 13, which is similar to Figure 11 except that another batch of sealant was used. The strains and rates used in the cyclical tests can be located in this plot. The failure points at each rate form a line almost perpendicular to the best-fit line, the alignment of the points being indicated by arrows. Close to the intersection of a line formed by the break points and the lower confidence limit one may read the extension on which the daily cycle should be superimposed to obtain approximately 50 per cent failure in a cyclical experiment. The initially imposed strain with the superimposed daily cycles should reach less than half way to the best-fit line. The further one enters into the confidence limits by changing any of the cycling conditions, i.e., proceeding vertically on the plot by increasing the strain or horizontally toward decreasing strain rate, the greater the chances of failure.

If this correlation of tensile breaks and failures obtained from the cycling tests is valid at rates of the naturally occurring average daily cycles (0.00014 cm/min (6)), then failure in the joint can be predicted from the tensile data. From Figure

13 one reads approximately 13 per cent extension at 0.00014 cm/min rate at the lower confidence limit. This predicts a failure for this particular batch of silicone sealant at a much lower yearly extension than the ± 20 to ± 25 per cent claimed by manufacturers as movement capability. The batch used for obtaining the data published by Karpati (2) is, however, within the claimed values. Apart from the large variation from batch to batch, this shows that the correlation of tensile data with cycling tests should be experimentally verified. Laboratory cycling tests are impractical at this rate of one cycle per day and the cycling facilities used for exposure of sealants have to be utilized.

Weathering Sealants

Once a simple but effective means of characterizing the sealant by a laboratory test method was found, outdoor exposures were started. The resulting changes in sealant properties are being followed by this test procedure as well as by visual assessment of the degree of failure. Different methods of exposing sealant specimens to outdoor weathering are used: a strain cycling weathering rack, a rack that imposes no movement on the specimens, and vice-type devices where the movement is produced by manual adjustments.

A vertical weathering rack 12.5 m (41 ft) long and 1.1 m (3.5 ft) wide, accommodating 216 model specimens (11), was erected in a position facing south (Figure 14). The rack utilizes the difference in the thermal coefficients of expansion of steel and aluminum to produce cyclic movements in response to temperature changes. It has a rigid steel frame to which aluminum bars are attached at one end, leaving them free to move on the other end. Differential movement between the bar and the frame is transferred to the sealant specimens with the help of vertical aluminum plates attached to the steel or to the aluminum bars. Figure 15 shows the bolting of the specimens to the vertical plates. The frame is so constructed that on three quarters of the total area the yearly movement increases from about ± 9 to ± 30 per cent in 36 increments, the amount of movement being dependent on the weather of each year. On the remaining one quarter of the area movement is the same on all specimens, being about ± 13 per cent per year. With this arrangement the limiting movement above which a sealant starts to fail can be determined from a series of specimens exposed to various amounts of yearly movement. Specimens that do not fail can be subjected to the testing procedure described above at chosen time intervals. Visual assessment of the specimens provides information on their performance characteristics; the tensile tests made on the specimens provide a basis for the design of accelerated aging tests related to performance. The evaluation of the performance of various types of sealant during a three-year period is in progress and will be published in the near future.

Figure 13. Time dependence of tensile strain at break for the batch of silicone sealant used in cyclical tests (13)

Figure 14. Strain cycling weathering rack (11)

Sufficiently large differential movements can only be produced with a large size rack. Because few users or manufacturers can afford the construction of this relatively expensive rack, there is need for a simple, inexpensive device that can subject sealant specimens to extension and compression while exposed outdoors or to various imposed conditions. The device shown in Figure 16 was developed to meet these requirements (12).

The device is designed to hold a single specimen and to impose intermittent movement on the sealant by manual adjustment of width, in contrast with the cyclical movement on the weathering rack where it is continuous and automatic. The device resembles a vice; the distance between two aluminum blocks can be adjusted by a screw traversing the center of both blocks so that the distance between them can be varied between 0 and 5 cm (2 in.). The specimen is attached to the aluminum blocks. Tension or compression can be imposed on the sealant bead by varying the distance between the blocks. Up to 300 per cent extension can be produced on a standard 1.3 cm (0.50 in.) specimen. Exposure and evaluation of various types of sealant using this device are in progress.

Summary

The properties of high performance building sealants have been studied as a function of four variables: stress, strain, time and temperature, using tensile tests. By time-temperature superposition the number of variables can be reduced to three and the material properties characterized in a three-dimensional coordinate system. For sealants the projection of the failure points to this system in the log strain versus log time plane is sufficient for characterization. Further simplification can be made depending on the properties of the various types of sealant.

Silicone sealant tensile failure data can be fitted by a straight line in the log strain versus log time plot and the equation of the line characterizes the sealant. A possible further simplification is to specify as a characteristic of the sealant the strain of failure, with its confidence limits, for an arbitrarily chosen time.

The failure points of polysulfide sealants fall on a broad band with a flat maximum. This family of sealants is best characterized by the average of the log strain at failure and the associated confidence limits for a sufficient number of tests.

Cyclical movements are more difficult to analyse than tensile behavior and have been investigated for silicone sealants only. A connection between cyclical and tensile tests has been found by comparing the strain at failure for cycle testing on a log strain versus log time plot with that for failure in simple tension. This connection enables some degree of prediction of performance, i.e., behavior for cycling that occurs under natural conditions. The cyclical tests have shown that lowering the cycling rate or increasing the strain at a given rate increases the probability of

Figure 15. Bolting the specimens to the strain cycling weathering rack

Figure 16. Cyclic movement device (12)

failure. If it can be shown that the relation between strain to failure for cyclical and tensile tests is also valid for cycling at a daily rate, then prediction of performance can be made based on tensile tests. The results suggest that failure of silicone sealant might occur under natural cycling conditions at a lower extension than the claimed extensibility. At slow rates (one cycle per day) laboratory cycling is not practical. An exposure rack and a hand-adjusted device have been developed for imposing daily cycles of strains on sealant specimens. This investigation of the effect of weathering and strain cycles on sealants is continuing and results will be published in the near future.

This paper is a contribution from the Division of Building Research, National Research Council of Canada and is published with the approval of the Director of the Division.

Literature Cited

1. Smith, Thor. L., J. Polymer Science, 1956, XX, 89.
2. Karpati, K.K., J. Paint Technol., 1972, 44, (571), 75-85.
3. Williams, M.L., Landel, R.F. and Ferry, J.D., J. Amer. Chem. Soc., 1955, LXXVII, 3701.
4. Karpati, K.K., J. Paint Technol., 1973, 45, (580), 49-57.
5. "Fracture Processes in Polymeric Solids," B. Rosen, Ed., Interscience Publs. 1964, p. 379.
6. Karpati, K.K., "Extension Cycling of Sealants," Proceedings, XII PATIPEC Kongress 1974, Garmisch-Partenkirchen, May 1974, p. 455-459.
7. Karpati, K.K. and Gibbons, E.V., Mats. Res. Standards, 1970, 10, (4), 16-21.
8. Karpati, K.K. and Sereda, P.J., A.S.T.M., J. Testing and Evaluation, 1976, 4, (2), 151-156,
9. Karpati, K.K. and Sereda, P.J., Bâtiment International/ Building Research and Practice, CIB, November/December, 1976, p. 346-355.
10. Karpati, K.K. and Sereda, P.J., "Movement of Brick Panel Cladding." To be published.
11. Karpati, K.K. and Sereda, P.J., J. Coatings Technol., 1977, 49, (626), p. 44-47.
12. Karpati, K.K., J. Coatings Technology, 1978, 50, (641), 27-30.
13. Karpati, K.K., "New Testing Methods for Sealants." Presented to First International Conference on Durability of Building Materials and Components, Ottawa, Canada, 1978.

RECEIVED June 5, 1979.

Reprinted from ACS SYMPOSIUM SERIES, No. 113
PLASTIC MORTARS, SEALANTS, AND CAULKING COMPOUNDS

Raymond B. Seymour, Editor

Copyright 1979 by the American Chemical Society

Reprinted by permission of the copyright owner

This publication is being distributed by the Division of Building Research of the National Research Council of Canada. It should not be reproduced in whole or in part without permission of the original publisher. The Division would be glad to be of assistance in obtaining such permission.

Publications of the Division may be obtained by mailing the appropriate remittance (a Bank, Express, or Post Office Money Order, or a cheque, made payable to the Receiver General of Canada, credit NRC) to the National Research Council of Canada, Ottawa. KIA 0R6. Stamps are not acceptable.

A list of all publications of the Division is available and may be obtained from the Publications Section, Division of Building Research, National Research Council of Canada, Ottawa. KIA 0R6.