NRC Publications Archive
Archives des publications du CNRC

Testing polysulfide sealant deformation on vises
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:

Adhesives Age, 28, 5, pp. 18-22, 1985-05

NRC Publications Record / Notice d'Archives des publications de CNRC:
https://nrc-publications.canada.ca/eng/view/object/?id=1f015db5-fa2c-42cd-a38c-897b9e3f7678
https://publications-cnrc.canada.ca/fra/voir/objet/?id=1f015db5-fa2c-42cd-a38c-897b9e3f7678

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.

National Research Council Canada
Conseil national de recherches Canada

Ser
TH1
N21d
no. 1340
c. 2
BLDG

14715

National Research Council Canada | Conseil national de recherches Canada

Division of Building Research | Division des recherches en bâtiment

Testing Polysulfide Sealant Deformation on Vises

by K.K.Karpati

ANALYZED

Reprinted from
Adhesives Age
Volume 28, No. 5, May 1985
p. 18-22
(DBR Paper No. 1340)

Price $2.00

NRCC 25204

NRC - CISTI
BLDG. RES.
LIBRARY
86- 02- 21
BIBLIOTHÈQUE
Rech. Bâtim.
CNRC - ICIST

DBR/DRB

Canada

6169801

RÉSUMÉ

On a exposé sur des étaux un produit d'étanchéité à base de polysulfures, à deux composants, afin de le soumettre manuellement à des changements de largeur, c'est-à-dire à des cycles annuels semblables à ceux qui se produisent sur un support d'exposition aux cycles de déformation servant à simuler le mouvement des joints de construction. Les résultats indiquent que pour réaliser l'essai, on peut remplacer le support d'exposition par des étaux.

CISTI / ICIST

3 1809 00210 4484

Testing Polysulfide Sealant Deformation on Vises

By **K.K. Karpati**
Research Officer
Division of Building Research
National Research Council Canada
Ottawa, Canada KIA 0R6

Test results establish a link between outdoor behavior and laboratory testing.

A two-part polysulfide sealant has been exposed on vises in order to subject it to width changes manually — yearly cycles similar to those occurring on a strain-cycling exposure rack that simulates the movement of building joints. The results indicate that the strain-cycling rack test can be replaced by one using vises, establishing a link between outdoor behavior and laboratory testing.

It has been established that movement is the most important factor influencing sealant behavior*(1)*. A vise*(2)* has been designed at the Division of Building Research of the National Research Council Canada (DBR/NRCC) that imposes movements on sealant specimens at arbitrarily chosen amplitudes and time intervals by manual adjustment. This paper reports the results obtained for tests on a two-part polysulfide sealant exposed outdoors on the vises and compares them with previous results from a strain-cycling rack*(3)* that imitates the movements of outside building joints.

Experiment

A light grey, two-part polysulfide sealant was applied without primer on aluminum substrates, as in previous work*(1)*. In both cases, the substrate was cleaned manually, then with trichloroethylene vapor. The sealant bead was 12.7 x 12.7 x 50.8 mm (0.50 x 0.50 x 2.00 in.), and the aluminum bars were 12.7 x 25.4 x 76.2 mm (0.50 x 1.00 x 3.00 in.). In accordance with the manufacturer's instructions, the substrate was not primed before application of the sealant. The specimens were cast using silicone release paper underneath the bead and on the end spacers that limit the length of the bead to 2 in.

The specimens were exposed outdoors as soon as they could be handled (within a few days of preparation) to duplicate practice as closely as possible. They were attached to vises*(2)* and placed in a vertical position facing south (Figure 1). Various extensions and compressions were imposed on the specimens to determine the ability of the sealant to withstand joint movements. The total yearly extension and compression ranged from ±10%-±80% in steps of 5%. From ±10%-±35% there were six replicates and above that two for each level. The vise widths were changed once a month, each change being one third of the total for the year.

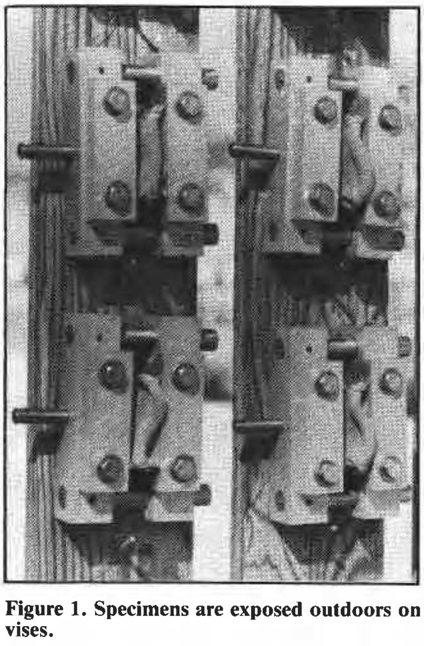


Figure 1. Specimens are exposed outdoors on vises.

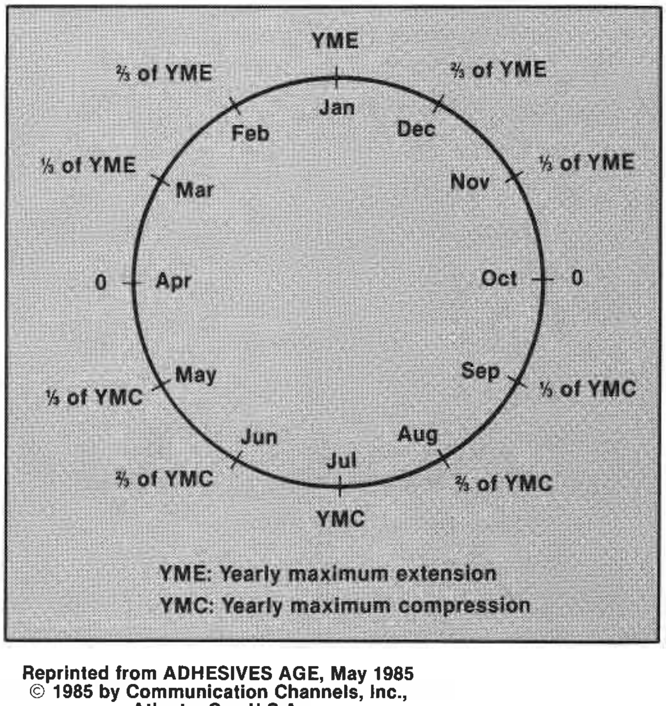
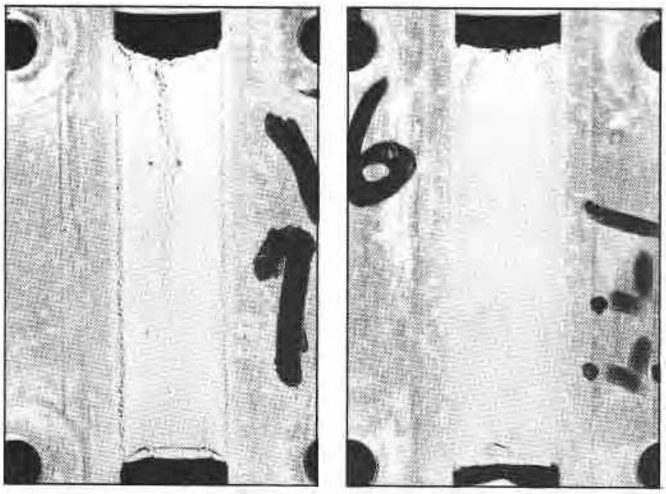
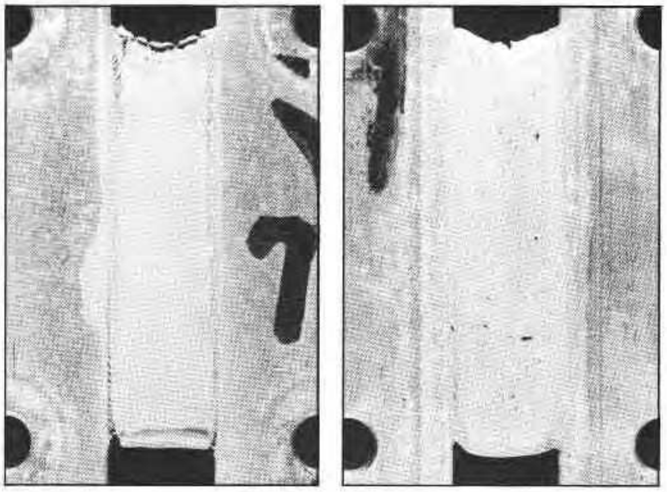


Figure 2. Time schedule of joint width changes.

Reprinted from ADHESIVES AGE, May 1985
© 1985 by Communication Channels, Inc.,
Atlanta, Ga., U.S.A.



Figures 3a (left) and 3b (right). Stage 1 of permanent deformation (exposure for > 3 yr, ±25%. 3a: south exposure, underside at preparation; 3b: north exposure, top side at preparation.



Figures 4a (left) and 4b (right). Stage 1 of permanent deformation (exposure for three winters, ±25%. 4a: south exposure, top side at preparation; 4b: north exposure, underside at preparation.

Accuracy was checked with calipers to ±0.13 mm (±0.005 in.). For example, the six specimens subjected to ±30% total movement were changed monthly by 10%. As shown in Figure 2, maximum deformations were achieved at the yearly extreme temperatures, and the original joint width was reached in mid-April and mid-October when the yearly average temperatures occur. Exposure was started in May 1977 with one third of the applicable compression.

Specimens marked with odd numbers were exposed with the side that was top during preparation towards the south. The top of the evenly numbered specimens faced the rack. All were assessed visually, and photographs were taken six times during the three-year exposure period. A few specimens were exposed without changes in width, and some were stored in a room maintained at 22° ± 2°C and 50% ± 5% relative humidity.

Some of the specimens exposed on the vises did not undergo permanent deformation. They were subsequently tested in tension at the rate of 5.0 mm/min at 22°C (72°F) together with the specimens exposed without width change and those stored in the conditioned room.

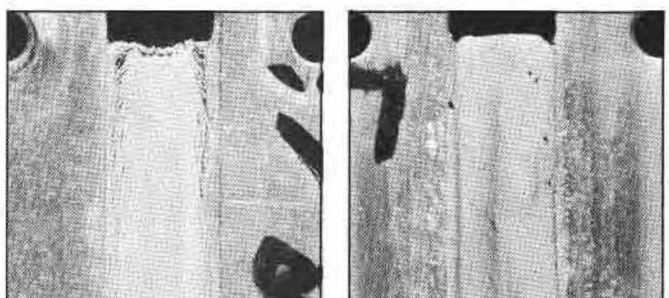
Results

Influence of Preparation on Appearance. Depending on the orientation of the specimens during exposure, there were slight variations in their appearance. In previous investigations*(1)*, it had been found that two-part polysulfide sealant specimens exposed on a strain-cycling rack designed to simulate the continuous movement of an outside building joint underwent permanent deformation, with cavity formation mainly on the side exposed to the north (facing the rack). On the side facing south only surface cracks appeared, and these were concentrated close to the interface between the bar and the sealant. These specimens were always exposed with the top facing south (casting was done in a horizontal position). In the present work half the specimens were exposed with the top facing south (odd numbers) and half with them facing the rack (even numbers) to investigate whether the difference might originate in the preparation.

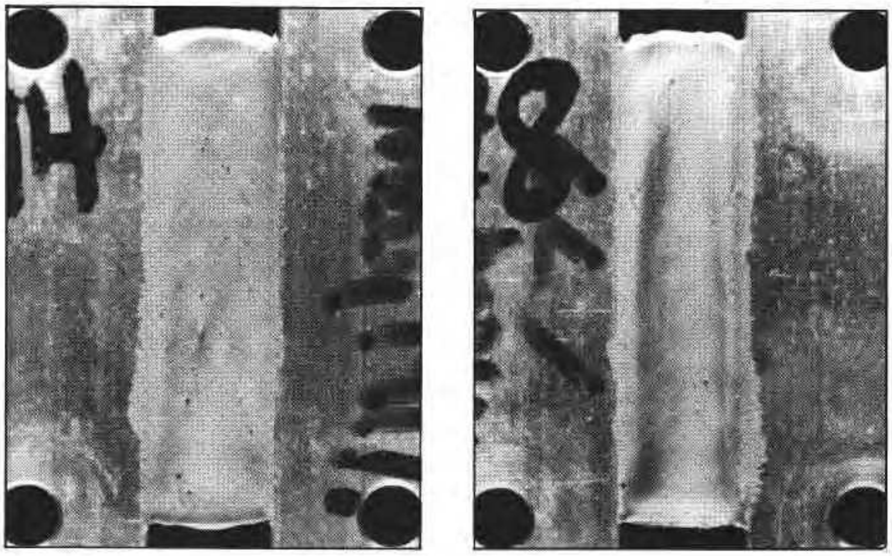
The results are shown in Figures 3-6. Comparison of the photographs shows that the underside, whether exposed north (4b, 6b) or south (3a, 5a), undergoes more permanent deformation in the form of a depression along the center. The depression on the underside exposed to the south is more visible because of the cracks that occur, but it is no deeper than that on the underside exposed to the north.

The depression is expected to form in the center because the material becomes thinner there on extension and continues to thin at this smaller cross-section in successive extensions. Why this does not appear on the top can be explained by the preparation method. The sealant is smoothed on top by a spatula that leaves two slight depressions close to the interface (Figure 7b); they are scarcely visible at preparaton but deepen with exposure. These marks are unavoidable. With two depressions on the sur-

Figures 5a (left) and 5b (right). Exposure past three winters, ±35%. 5a: south exposure, underside at preparation; 5b: north exposure, facing rack, top side at preparation.



Figures 6a (left) and 6b (right). Exposure past three winters, ±35%. 6a: south exposure, top side at preparation; 6b: north exposure, facing rack, underside at preparation.



Figures 7a (left) and 7b (right). Stage 1 of permanent deformation (exposure past one winter), north exposure, top at preparation. 7a: ±45%; 7b: ±55%.

face, the permanent deformation is divided between them, and the surface looks less disturbed than the other side. For this reason only the undersides will be compared in the remaining part of the discussion.

Establishing Stages of Permanent Deformation. The two-part polysulfide sealant underwent continuous change in appearance, attributable partly to exposure and partly to the imposed joint width changes ("movements"). Careful examination and photographic records showed that there are three recognizable stages in the changing appearance of the specimens:

- Stage 1 — largest movement at and below which permanent deformation is negligible;
- Stage 2 — formation of lengthwise bulges, with part of the sealant bead folded under;
- Stage 3 — smallest movement at and above which holes develop.

After each winter and summer, the amount of movement for each stage was determined; it could be estimated within about a 5% step. For example, after three winters the greatest amount of movement without permanent deformation was ±25%, as shown in Figures 3 and 4. At ±35% there was permanent deformation (Figures 5 and 6), while at ±30% it was less well defined. The Stage 1 limit for two winters was ±30%-±35% (not shown); for one winter it was ±45%-±50% (see Figure 7, where 7a is a specimen at its limit, and 7b is a specimen at the next higher movement).

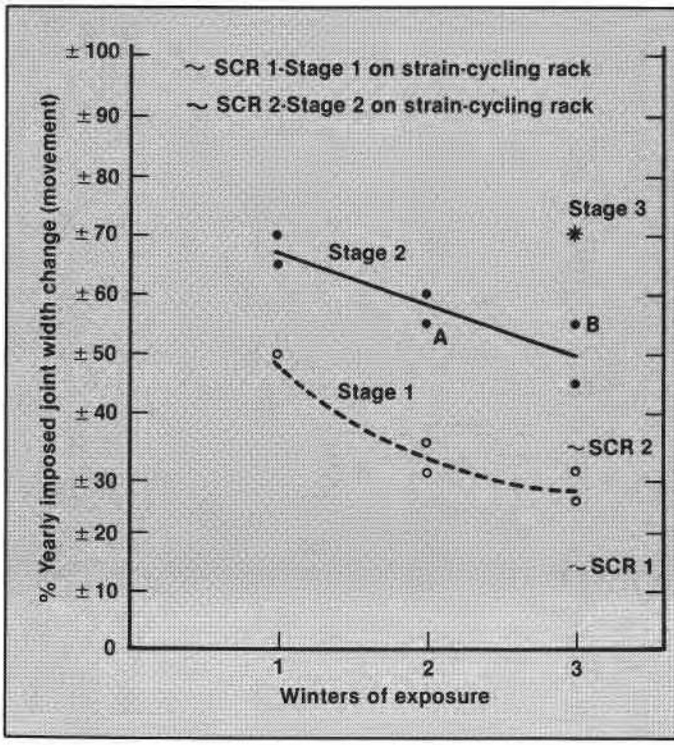


Figure 8. Stages of permanent deformation on vises.

The observed stages of permanent deformation are plotted as a function of number of winters of exposure on the rack (Figure 8). The number of winters is used in plotting because permanent deformations occur then.

As the amplitude of the yearly movement increases, Stage 2 of the progressive permanent deformation occurs, consisting of bulges and a thinned portion of material folded under the bulges. Photographs of specimens that have reached Stage 2 after one, two, and three winters on the exposure rack are shown in Figures 9, 10, and 11, respectively. The folds are usually single, but in some cases are multiple, as in Figure 11a. A single bulge is shown in Figure 11b, while 11c shows the opposite side of the same specimen with the thinned section protruding. The range of movement in which Stage 2 is reached can be seen in Figure 8. With movements between the two stages, the depression increases (as in Figures 5a and 5b), but there is no folding under.

Progress of Deformation with Exposure. Permanent deformation develops mainly in winter, when the sealant bead is extended and the surface curves inward. Stress is concentrated at the thinnest cross-section, the bonds in the material relax, and deformation becomes permanent. In subsequent winters the thinning continues at the already decreased cross-section.

The progress of permanent deformation during exposure can be followed on a specimen subjected to ±55% movement. When the horizontal line corresponding to this movement is followed from left to right in Figure 8, one can see that the specimen is just above Stage 1 after the first winter; i.e., permanent deformation has just started, as illustrated by Figure 8b. (This is the top of the specimen; the underside showed no change at that time.) As the horizontal line is followed, Stage 2 is reached at its lower limit (point A in Figure 8); the corresponding specimen is shown in Figure 10 (at intermediate extension). After the third winter the specimen is at the upper limit of Stage 2 (point B) and is shown in Figure 11 (b and c), front and back (at original width). The same specimen is at maximum extension during the third winter (Figure 12). Comparison with the previous figures shows that the sealant bead folds along the thinner section as the joint width diminishes and the bulge protrudes on one side (Figure 11b); the thin section does the same on the other side (Figure 11c). On compression, this process continues and the groove disappears (Figure 13a and 13b).

For Stage 3 (hole formation) there was only one occurrance after the third winter for specimens at ±70% (Figure 14) movement. Stage 3 is represented by an asterisk in Figure 8.

Possible Variations with Experimental Conditions. Mathematical equations can be fitted to the movements at which Stages 1 and 2 occur; the lines shown in Figure 8 are for the calculated best fit. Changes in operator, batch, curing, formulation, or any experimental condition will cause variations in results, but the uncertainty caused by different operators can be reduced if the photographs are used in evaluation. Tensile tests were carried out to discover whether a difference exists between batches or between specimens cured differently. A slight change in the formulation may change the position of the curves (Figure 8), while a substantial change could lead to a harder type of product where permanent deformation would not appear but failure might occur either adhesively or cohesively in the product.

Tensile Testing. In the previous study*(1)*, the modulus increased continuously with time (i.e., the material hardened), but specimens exposed only to weather hardened less than specimens aged in the laboratory, and those subjected to cyclic movement on a strain-cycling rack hardened even less. These results were derived from four different extension rates. Figure 15 shows the results at an extension rate of 0.50 cm/min for a strain-cycling rack, a rack without movement, and laboratory specimens. In the present work, the vises instead of the strain-cycling rack produced cycling, and the tensile results are shown in continuous lines labeled V. Although the previous and the present experiments are for different batches and curing conditions and, therefore, produce curves at different levels, they show the same trend: softening of the sealant by exposure and further softening by cycling. Furthermore, the softening was slightly greater in the vises, with increased amplitude of movement. The conclusion is that the cycles imposed manually on the sealant can produce an effect similar to that of the simulated joint movement cycles of the strain cycling rack.

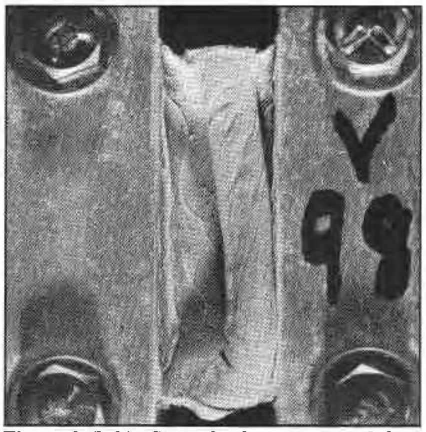


Figure 9 (left). Stage 2 of permanent deformation (exposure past one winter); south exposure, underside at preparation, ±65%.

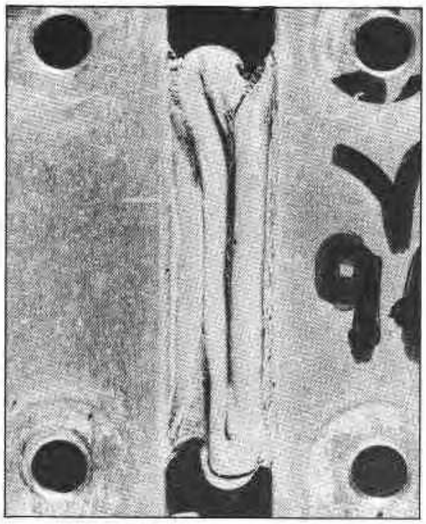
Figure 10 (above). Stage 2 of permanent deformation, ±55% movement (exposure past two winters); south exposure, underside at preparation extended ⅔ of ±55%.

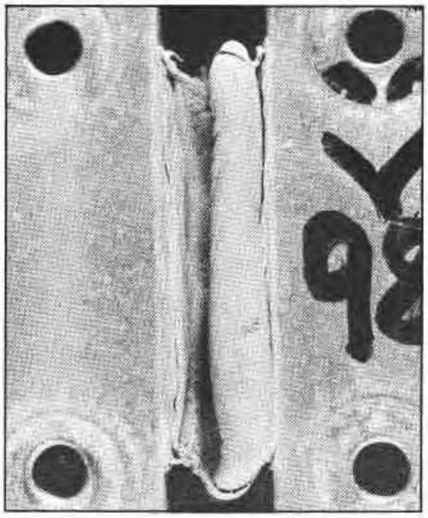
Strain-Cycling Rack Exposures. As reported earlier*(1)*, the ½-in.-wide specimens were exposed on the strain-cycling rack in the fall at the yearly average temperature. The movements on the rack ranged from ±14%-±30% yearly. In Stages 1 and 2, permanent deformation also was observed, occurring at ±16% and ±30% yearly movements, respectively, the latter shown in Figure 16. This behavior is similar to that illustrated in Figure 11 at ±50% movement. Stages 1 and 2 on the strain-cycling rack are located approximately in Figure 8, represented by a sinusoidal line marked SCR 1 and SCR 2, respectively, at the approximate time in which they occurred. They develop at lower movements than in specimens exposed on vises. This is understandable when it is recalled that every day the specimens undergo a cyclic movement that is about one fifth of the yearly movement. Because the permanent deformations are cumulative, the same degree of deformation occurs at lower annual movements.

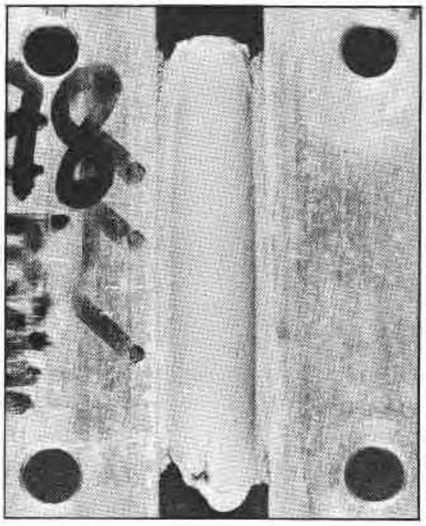
Conclusion

It is possible to produce with hand-operated vises the same permanent deformation of sealant specimens that occurs on the strain-cycling rack. This has been illustrated by defining stages of deformation and documenting them photographically. Complete failure, i.e. perforation, was obtained only on the vises because of the limitations of exposure time and of yearly movement of ±30% on the rack, but there is no reason to assume that it would not follow the same pattern as was observed with the vises provided the experiments were pursued long enough for both methods or the movement capability of the rack were extended.

Extrapolation of the vise results is very tempting. The number of years necessary to reach the different stages at ±25% yearly movement, the recom-







Figures 11a (left), 11b (center), and 11c (right). Stage 2 of permanent deformation (exposure past three winters). 11a: south exposure, underside at preparation, ±50%; 11b: south exposure, underside at preparation, ±55%; 11c: side facing rack, top at preparation, ±55%.

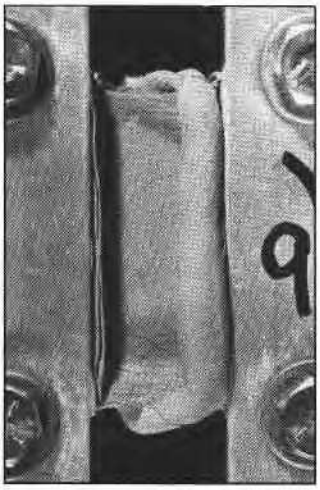
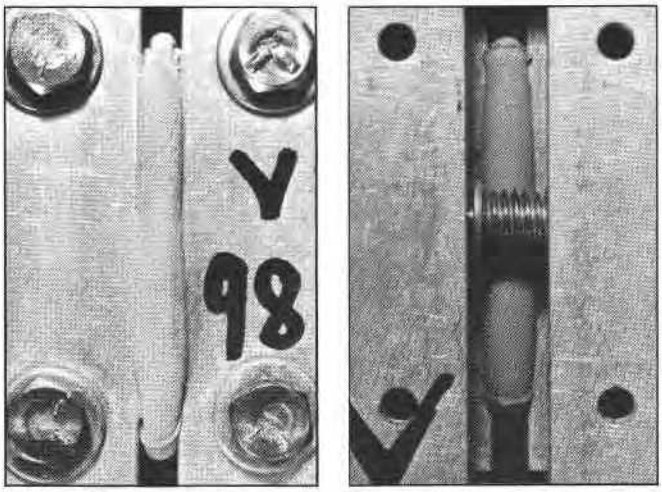


Figure 12. Maximum extension during third winter, south exposure, underside at preparation.



Figures 13a (left) and 13b (right). 13a: south exposure, underside at preparation; 13b: side facing rack, top at preparation.

Figure 14. Stage 3 of permanent deformation, exposure past three winters, ±70%.

mended minimum range for the sealant, could be estimated on that basis, but there is no supporting evidence of the validity of this approach, and it might take 10 years or more to provide it.

The results show that the vises can replace the strain-cycling rack that imitates the performance of sealants in building joints. This work is therefore a step forward in establishing a link between outdoor performance and laboratory tests of sealants, since the vises can be used in the laboratory, with some changes in the conditions imposed. It establishes three stages of permanent deformation for one make of two-part polysulfide sealant and provides photographs as a guide to the process. This can form the basis of an evaluation of sealants of any chemical type provided that deterioration occurs by a similar process of permanent deformation. In fact, tensile tests cannot give much information on this type of failure because they can be made only on specimens that have not undergone permanent deformation. The role of the tensile tests here was simply to confirm that the same phenomenon occurs for vises and strain-cycling racks; in both cases the movement softened the specimens. This evaluation does not apply to polysulfide sealants that are hard and fail by adhesion or cohesion.

Acknowledgement

The author wishes to thank R.C. Seeley for experimental assistance. This paper is a contribution from the Division of Building Research, National Research Council of Canada, and is submitted with the approval of the director of the division.

References

(1) Karpati, K.K. Investigation of factors influencing outdoor performance of two-part polysulfide sealants. To be published.

(2) Karpati, K.K. 1978. Device for weathering sealants undergoing cyclic movements. In *Journal of Coatings Technology*, Vol. 50, No. 641, p. 27.

(3) Karpati, K.K.; Solvason, K.R.; and Sereda, P.J. 1977. Weathering rack for sealants. In *Journal of Coatings Technology*, Vol. 49, No. 626, p. 44.

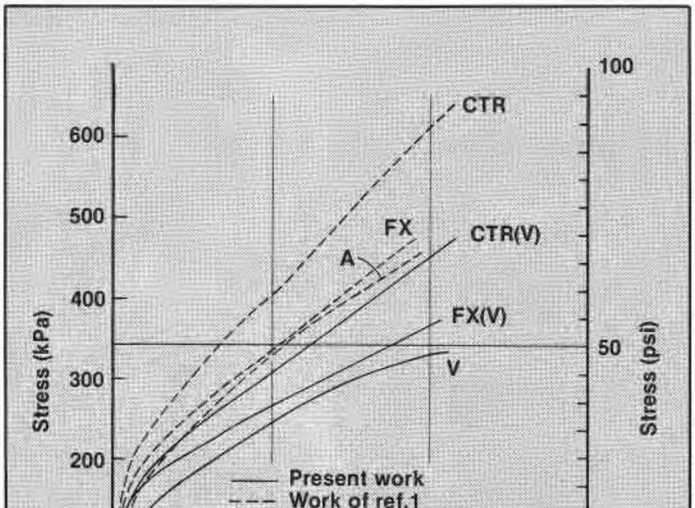
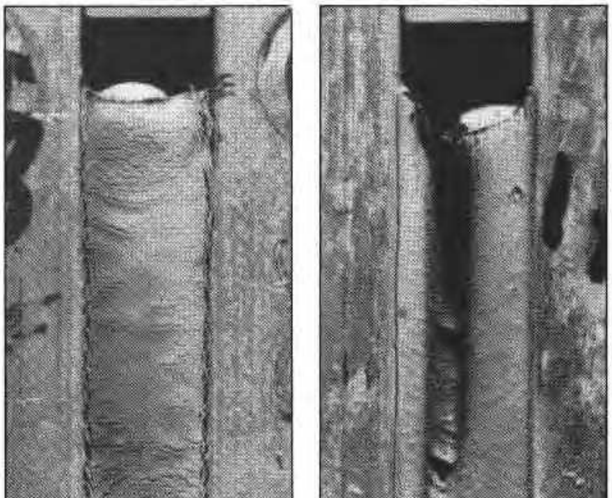


Figure 15. Tensile tests after various types of weathering (0.50 cm/min, 22°C, 3-yr exposure)



Figures 16a (left) and 16b (right). Three-year exposure on strain-cycling rack at ±30% maximum yearly movement. 16a: south exposure, top at preparation; 16b: north exposure, underside at preparation.

This paper, while being distributed in reprint form by the Division of Building Research, remains the copyright of the original publisher. It should not be reproduced in whole or in part without the permission of the publisher.

A list of all publications available from the Division may be obtained by writing to the Publications Section, Division of Building Research, National Research Council of Canada, Ottawa, Ontario, K1A 0R6.

Ce document est distribué sous forme de tiré-à-part par la Division des recherches en bâtiment. Les droits de reproduction sont toutefois la propriété de l'éditeur original. Ce document ne peut être reproduit en totalité ou en partie sans le consentement de l'éditeur.

Une liste des publications de la Division peut être obtenue en écrivant à la Section des publications, Division des recherches en bâtiment, Conseil national de recherches Canada, Ottawa, Ontario, K1A 0R6.