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INVESTIGATION OF FACTORS INFLUENCING OUTDOOR PERFORMANCE OF TWO–PART POLYSULFIDE SEALANTS

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RÉSUMÉ

Un produit d'étanchéité à base de polysulfide à deux composants a subi des contraintes cycliques de traction et de compression pour déterminer son comportement lorsque soumis aux intempéries. Les résultats des essais et des observations ont révélé que les mouvements cycliques sont les principaux facteurs qui influencent la tenue du produit.

Investigation of Factors Influencing Outdoor Performance Of Two-Part Polysulfide Sealants

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A two-part polysulfide sealant had been exposed on a strain-cycling exposure rack to investigate the factors that influence its weathering characteristics. The results, evaluated by tensile tests and by visual observations, revealed that cycling movement is the most important factor the sealant undergoes.

INTRODUCTION

The behavior of building sealants subjected to natural weathering has been studied to determine how different chemical types respond and to establish the conditions necessary for developing laboratory test methods that will reliably predict how the materials weather. In these studies sealants were exposed on a strain-cycling exposure rack[1] that simulates the movements of exterior building joints. They were then assessed visually and tested mechanically, since it has been established[2] that tensile tests made at room temperature are appropriate for characterizing two-part polysulfide sealants. Previous papers have described the behavior of silicone sealants[3,4]; the present work reports the investigation of a two-part polysulfide sealant.

EXPERIMENTAL

A light grey, two-part polysulfide sealant was applied without primer on aluminum substrates. The sealant bead was 0.50 × 0.50 × 2.00 in. (12.7 × 12.7 × 50.8 mm), and the aluminum bars (grade 6061T6) were 0.50 × 1.00 × 3.00 in. (12.7 × 25.4 × 76.2 mm). Both bars were first rubbed clean with acetone and then cleaned with trichloroethylene vapors.

After two months of laboratory curing at 72° F (22° C) and 50% RH, the specimens were exposed for three years, starting in November 1974. They were installed at the yearly average temperatures of 32-37° F (0-3° C) to ensure full extension in winter and compression in summer. Forty-eight specimens were exposed in a vertical position on an outdoor strain-cycling rack facing south, where movements range from ±14 to ±30% yearly in 24 steps giving two repeat specimens at each movement. Another 36 specimens were exposed at movements of only ±16% yearly; these were used for tensile tests because they did not show the permanent deformation that occurs with larger movements. Some specimens were constrained so that no movement could take place on exposure, while others were stored at a constant temperature of 72° F (22° C) and relative humidity of 50%; these were tensile tested along with the strain-cycled specimens.

Tensile tests were made at 72° F (22° C) on an Instron machine at the beginning of exposure and after one-half, one, two and three years. Instead of testing several specimens at the same rate, four different extension rates were used. Although the direction in which the curves tend to move can be established by either method, the reliability of the results is increased if a similar trend is found at different rates.

RESULTS AND DISCUSSION

Visual Evaluation

The specimens exposed on the strain-cycling rack deteriorated progressively during the three years of

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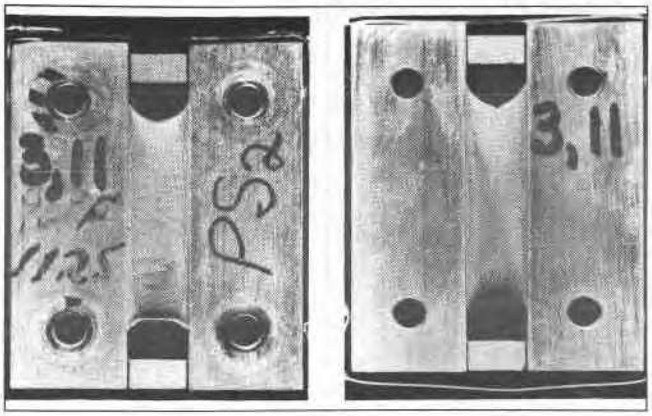
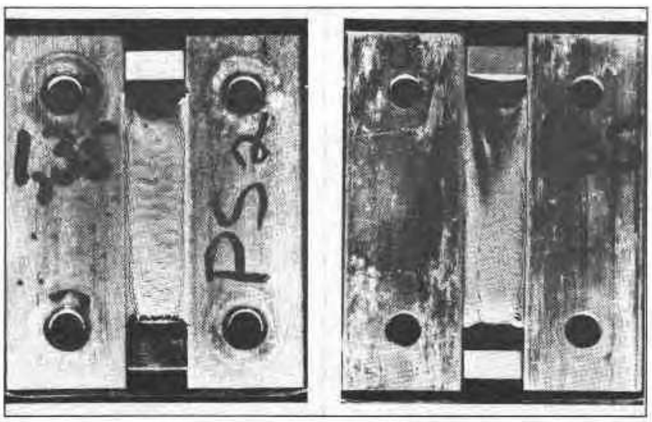


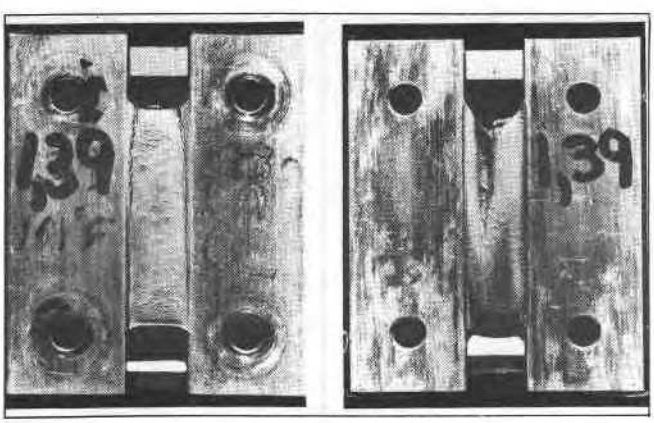
(a) (b)

Figure 1—Exposure on cycling rack, 3 years, ±16% yearly movement: (a) Exposed to south; (b) Exposed to north



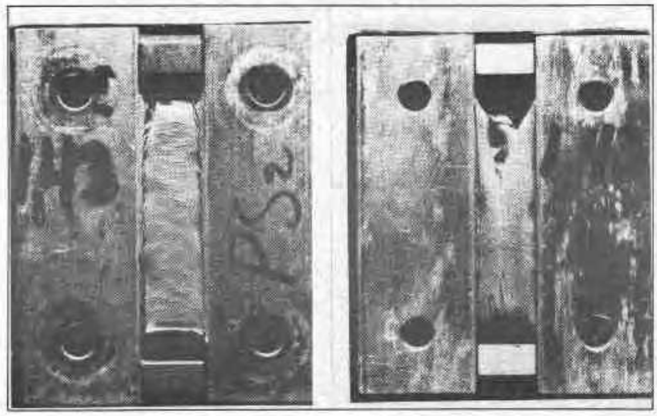
(a) (b)

Figure 2—Exposure on cycling rack, 3 years, ±21% yearly movement: (a) Exposed to south; (b) Exposed to north



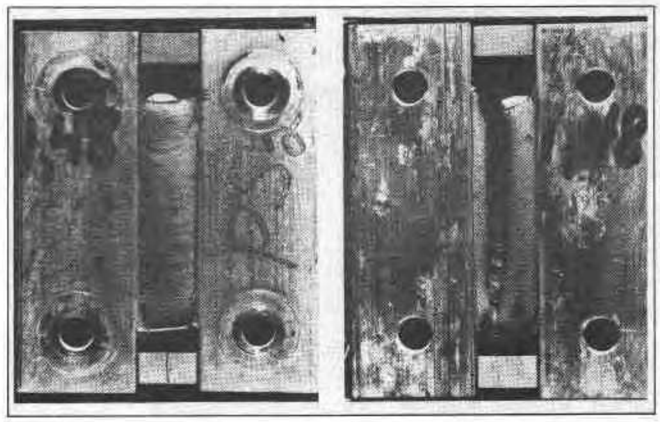
(a) (b)

Figure 3—Exposure on cycling rack, 3 years, ±24% yearly movement: (a) Exposed to south; (b) Exposed to north



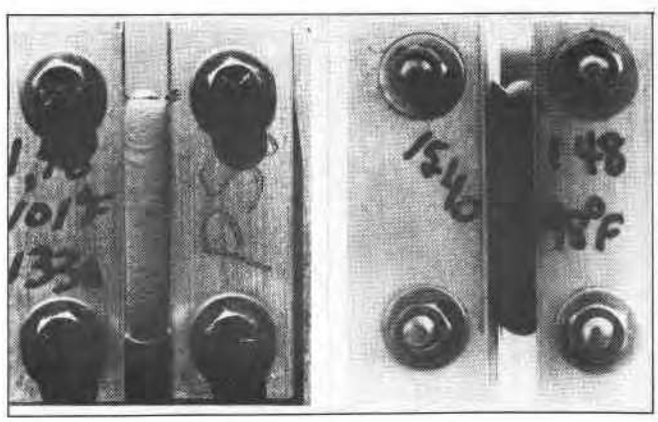
(a) (b)

Figure 4—Exposure on cycling rack, 3 years, ±27% yearly movement: (a) Exposed to south; (b) Exposed to north



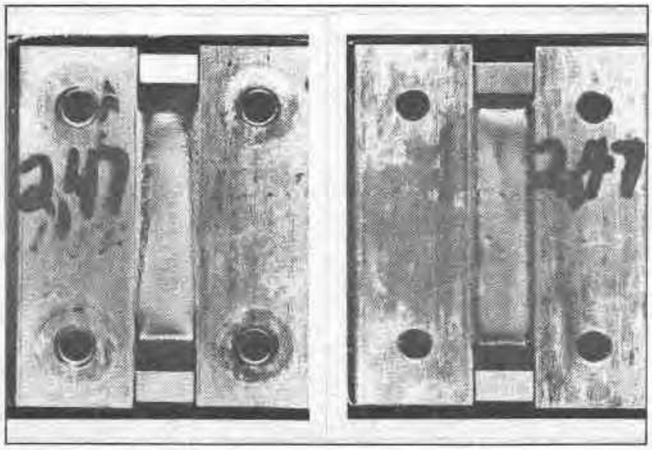
(a) (b)

Figure 5—Exposure on cycling rack, 3 years, ±30% yearly movement: (a) Exposed to south; (b) Exposed to north



(a) (b)

Figure 6—Compression occurring in the third summer at ±30% yearly movement: (a) Exposed to south; (b) Exposed to north



(a) (b)

Figure 7—Exposure on cycling rack, 2½ years, after 8 months of curing; ±30% yearly movement: (a) Exposed to south; (b) Exposed to north

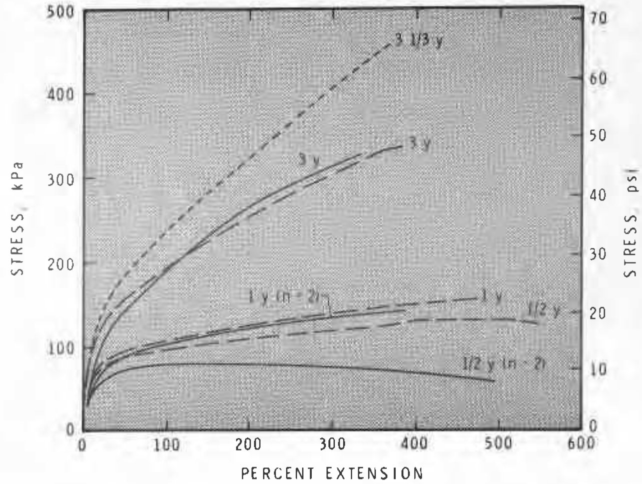


Figure 9—Curves resulting at 0.05 cm/min extension rate (22° C)

exposure, but none showed complete failure. Deterioration consisted of crack formation on the south side and cavities on the north side, which was somewhat sheltered by the supporting aluminum slabs. *Figures* 1 to 5 give representative pictures of the deterioration that occurred progressively over three years. One can see that at ±16% movement there is only a negligible amount of permanent deformation, although surface cracks appear. The cavities become more pronounced above ±20% and show a sudden increase around ±30%, with a marked thinning of the cross-section. The cracks on the surfaces receiving direct sunshine also increased with the amplitude of the yearly movement.

Cavities form in successive cycles of the movement that occurs every day during the yearly cycle. The daily movement has an amplitude of about one-fifth that of the yearly movement and is therefore quite substantial. As the sealant is extended, it may be presumed that viscous flow takes place, sulfur bonds can break, and molecular chains slip easily on each other. These bonds can reform at other places in relaxed positions. As a consequence, the sealant cannot take up its original shape at the end of the cycle and permanent deformation results. Once a decrease of the cross-section has occurred as a result of permanent deformation, it progresses in successive cycles because the stress is concentrated at the narrow part of the sample. As a result, the material bulges on one side and forms a cavity on the other. *Figure* 6 shows the compressed state, while the previous figures show the specimens at the original width.

The specimens exposed without movement showed no deformation but their surfaces were cracked, though less than in the cycled ones. No visual changes occurred in specimens stored in the constant-temperature room during the three-year period.

A few specimens were also exposed following laboratory curing for eight months. After 2½ years (including two winters) they showed no cavity formation, but cracks deeper than those on the other specimens developed on both sides (*Figure* 7). When zero exposure

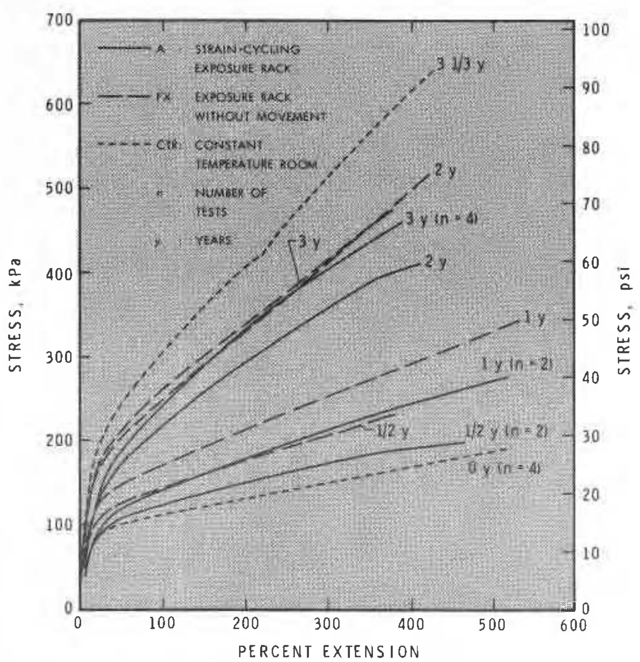


Figure 8—Two-part polysulfide sealant exposed on strain-cycling rack (A), without movement (FX) and stored in the laboratory (CTR). Number of curves averaged shown in brackets (n) if more than one. Extension rate 0.5 cm/min (22° C)

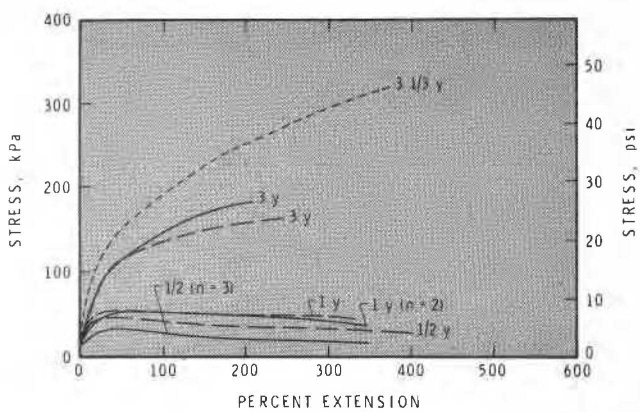


Figure 10—Curves resulting at 0.005 cm/min extension rate (22° C)

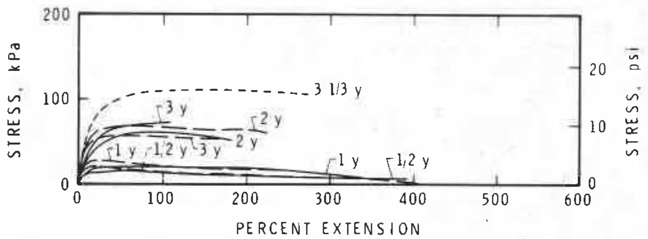


Figure 11—Curves resulting at 0.0005 cm/min extension rate (22°C)

is compared with half a year's exposure, it may be seen from the tensile curves in *Figure* 8 that these specimens have already undergone a considerable amount of hardening. This is not, of course, the way the sealant normally cures, but the same degree of hardness could be achieved at the start by changing the formulation; such products may exist on the market. In a harder type of product, therefore, the probable failure mechanism would be propagation of cracks through the cross-section near the interface. Tensile values could not be obtained from the specimens exposed after eight months' curing because of uncertainty about the loss of cross-section due to cracks.

Tensile Tests

The changes in the mechanical properties were investigated by tensile tests on specimens exposed at ±16% yearly movement, where deformation was negligible, and on samples without movement, exposed and unexposed. The curves obtained are shown in *Figures* 8-11 for rates of 0.5, 0.05, 0.005 and 0.0005 cm/min, respectively. All four plots have the same scale to permit easy comparison. The continuous lines indicate exposure with strain-cycling, the dashed lines exposure without it, and the dotted lines represent specimens stored in the constant temperature room. The number of years of exposure are marked on the curves, with the number of tests in brackets.

The curves of *Figure* 8 for a rate of 0.5 cm/min indicate that the modulus goes up with time under all conditions and reaches the highest values when stored in the constant temperature room. The modulus increase is less if the sample is exposed, and even less if subjected to both strain cycling and exposure. The differences between curves obtained after different exposure times tend to disappear with decreasing extension rate, especially after two to three years of exposure and at lower rates.

CONCLUSIONS

When weathered on the strain-cycling rack, a two-part polysulfide sealant formed cavities on the side sheltered from direct sunshine. The same material when weathered without cycling or stored in the laboratory did not undergo permanent deformation. This proves the importance of the effect of cyclic movement on the performance of two-part polysulfide sealants, revealing it as the most important factor in test methods intended to evaluate their performance. During the three years of observation there was no perforation of the cavities, but progress in that direction indicates that this is the mechanism leading to failure in this type of material.

At values lower than ±20% yearly cyclic movement the deformation was negligible, but it gradually increased above that value, and a cyclic strain of ±30% brought about a marked decrease in most of the original cross-section. This indicates that the sealant should not be exposed to more than over the ±25% movement recommended by the manufacturers and that service life would increase with decreasing yearly movement.

The cracks that developed on the south side, though shallow, deepened with exposure time and amplitude of movement. In a harder, more crosslinked product, failure would probably proceed along these cracks and cavity formation might not occur. This is evident from the specimens stored in the constant-temperature room for eight months, then strain-cycled on the exposure racks through two winters. This unnatural curing produced no sagging, but deeper cracks developed on both sides of the specimens. With a sealant of a different formulation, this type of failure could occur with natural weathering.

Tensile tests confirmed the visual observations. They revealed that although the modulus increased (that is, the material hardened in time, with or without exposure), both exposure and cyclic movement caused softening of the sealant. Tensile tests could be carried out only on specimens subjected to no more than ±16% yearly movement because permanent deformation or cracks developed at higher movements; but it is safe to assume that lowering of the modulus due to cycling would continue with increasing amplitude of movement. Thus, increased amplitude of joint movement could be used to accelerate failure in a laboratory test.

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