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Performance of Polyurethane Sealants on a Strain-Cycling Exposure Rack

by K.K. Karpati

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Résumé

Des échantillons de huit mastics d'étanchéité à base d'uréthane ont été exposés sur un support qui reproduit fidèlement les variations de largeur qui se produisent dans un joint de bâtiment. Des échantillons qui ne pouvaient bouger ont été simultanément soumis au vieillissement naturel seulement. Après un an, trois des mastics multicomposants présentaient une performance de bonne à excellente. Un de ceux-ci a confirmé les résultats d'une exposition antérieure mais, pour un autre, un deuxième essai effectué l'année suivante a révélé un taux de rupture beaucoup plus élevé en cas de lot nouveau. Les deux uréthanes multicomposants restants et les trois uréthanes monocomposants ont lâché en quelques mois, même si l'application d'un apprêt sur le substrat d'aluminium a retardé jusqu'à la fin de l'année la rupture d'un mastic monocomposant. Les échantillons qui pouvaient bouger n'ont pas lâché sur la performance des joints concernant les conditions.

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Performance of polyurethane sealants on a strain-cycling exposure rack

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Specimens of eight urethane-based sealants have been exposed on a rack that closely reproduces the width changes occurring in a building joint. Specimens that could not move were concurrently subjected only to weathering. After one year, three of the multi-component sealants exhibited good to excellent performance. One of the latter confirmed the results of a prior exposure, but with the other a repeat test in the second year revealed a much higher failure rate with a new batch. The remaining two multi-component and all three single-component urethanes failed in a few months, although priming the aluminium substrate delayed failure of one single-component sealant to the end of the year. The predominant effect of joint movement on sealant performance is shown by the lack of failure of any specimens that could not move. Recommendations are made on test conditions that provide the best evaluation.

1. INTRODUCTION

This laboratory has conducted several investigations of sealant behaviour aimed at deriving a laboratory test that correlates with outdoor performance. One of the more recent studies [1] showed that elongation-compression cycling is the most important factor in causing permanent deformation and eventual perforation of a sealant, while weathering without this cycling has little influence on whether or not failure occurs. Consequently, various sealants have been exposed on a strain-cycling exposure rack [2] on which air temperature variations produce a wide range of width changes in the specimens, thereby imitating building joint movements very closely.

In the present work polyurethane sealants and one epoxy-modified sealant were exposed for one year and in one case for two years. Those exposed in the first year were evaluated visually at the end of three weeks, four months and one year. Fresh specimens of two of the previously exposed sealants and specimens of three different sealants, as well as those of the one material that survived the first year, were exposed in the second year and examined at intervals of about a month for five months and then at the end of the year. Analysis of the results indicates that the performance of these sealants can be clearly distinguished in one year.

2. EXPERIMENTAL DETAILS

2.1 Materials

Specimens of one single- and three multi-component polyurethanes and one polyurethane-epoxy sealant, obtained from four manufacturers, were placed on the strain-cycling exposure rack at Ottawa in the autumn of 1983. In 1984 exposure of the specimens of the multi-

component material that performed well was continued. Specimens from a new batch of this sealant and from a new batch of the epoxy-modified polyurethane were also exposed. A multi-component polyurethane from a different manufacturer and one-part polyurethanes from two different sources were added to the programme. A few earlier exposure tests done under the same conditions are included in the discussion.

Specimens of the selected urethane sealants were cast on mill-finished aluminium bars that were first cleaned manually, then with trichloroethylene vapour. The sealant bead was 0.50 in. $\times$ 0.50 in. $\times$ 2.00 in. (12.7 mm $\times$ 12.7 mm $\times$ 50.8 mm), and the aluminium bars were 0.50 in. $\times$ 1.00 in. $\times$ 3.00 in. (12.7 mm $\times$ 25.4 mm $\times$ 76.2 mm). Primer was used where it was recommended. Where it was stated that priming is not necessary but improves adhesion, specimens were prepared both with and without primer. The code designation p in Table 1 indicates the use of primer while m and M are for multi-component and s and S for single-component sealants, with the capital letter placed first for the second year's exposure. For example, multi-component Sealant 2 was coded Um-2 in 1983 and MU-2 when new specimens were exposed in the second year.

2.2 Exposure

Exposure started as soon as the specimens could be handled: in two to three days for multi-component and in five to six days for single-component materials. All were exposed at the same time in the autumn at yearly mean temperatures for the area of 32 to 37°F (0 to 3°C). Simultaneously, specimens that could not move were placed on an adjacent test fence.

All urethanes were claimed by their manufacturers to perform well up to $\pm 25\%$ joint width changes ($+25\%$

Table 1 Summary of sealants exposed

Manufacturer No.	Exposure year	Single-component		Multiple-component	
		Unprimed	Primed	Unprimed	Primed
1	1983	—	—	Um-1*	—
	1984	SU-1	SU-1p	MU-1	—
2	1983	—	—	Um-2	—
	1984	SU-2	SU-2p	MU-2	—
3	1983	Us-3	—	—	Um-3p
4	1984	—	—	—	MU-4p
5	1983	—	—	Um-5	—

*Epoxy-modified urethane.

Table 2 Cumulative number of failures occurring on exposure (all failures of adhesive except where noted)

Code	Specimens exposed	Exposure period						
		3 weeks	1½ months	2 months	3 months	4 months	5 months	1 year
Um-1	21	2				2		2(24–28%)*
Um-2	21	0				0		0
Um-3p	21	11				20		21
Um-5	21	15				21		21
Us-3	21	S1†				10(SI)		10(SI)
MU-1	20	—	2(23,25)	n.c.‡	n.c.	n.c.	n.c.	n.c.
		—	2B(14,19)§	4B(14–30)	5B(14–30)	n.c.	n.c.	n.c.
Um-2¶	17	—	1(25)	3(13–26)	n.c.	n.c.	4(13–26)	n.c.
			1B(26)	n.c.	n.c.	n.c.	3B(23–30)	4B(22–30)
MU-2	20	—	10(16–30)	14(15–30)	15(15–30)	n.c.	17(15–30)	n.c.
		—	20(18,21)	n.c.	n.c.	n.c.	21B(14–21)	n.c.
MU-4p	20	—	Ok	Ok	Ok	Ok	Ok	Ok
SU-1	20	—	—	7(17–30)	n.c.	10(16–30)	19(11–30)	n.c.
			4B(15–25)	5B(15–25)	7B(15–25)	8B(15–25)	n.c.	9B(14–25)
SU-1p	20	—	3(22–27)	5(16–29)	6(16–29)	n.c.	10(16–29)	20(11–30)
		—	—	—	—	—	—	—
SU-2	20	—	15(13–30)	20(11–30)	n.c.	n.c.	n.c.	n.c.
		—	3B(16)	n.c.	n.c.	n.c.	n.c.	n.c.
SU-2p	20	—	Ok	Ok	Ok	Ok	2(24,27)	29(12–30)
		—					1B(30)	n.c.

*Numbers in brackets are the range of yearly joint width changes expressed in $\pm\%$ of joint width.

†All specimens slipped down between the aluminium bars.

‡n.c. no change from previous result.

§B = spot failure, would not lead to leakage in a joint.

¶Add 1 year exposure to that stated in the heading.

extension; -25% compression), with $+40$, -25% for the polyurethane-epoxy material. The movements on the strain-cycling exposure rack ranged from ± 11 to $\pm 30\%$ with increments of about $\pm 1.5\%$ between adjacent rows of specimens. In one section the rack provided sufficient space in 1983 for seven specimens of each sealant to be subjected to the same movement of $\pm 16\%$, and six in 1984.

3. RESULTS AND DISCUSSION

The results of exposure on the strain-cycling rack are summarized in Table 2, where the numbers designate the cumulative number of failures at the end of a period and the numbers in brackets give the maximum yearly joint-width change, expressed in $\pm\%$ of the joint width. All failures were adhesive but the letter B indicates that the

failure was not extensive enough to produce leakage had it been in a building joint. Failures tended to occur earlier at higher joint-width changes but the correlation was poor as failures developed mostly at random, starting at weak spots. None of the specimens subjected to weathering with no movement failed.

In the first year's exposure only one make (Um-2) showed no failure. The next best was the polyurethane-epoxy sealant (Um-1), showing two failures among 21 specimens within the first three weeks but no further changes after that. Half of the two other multi-component sealants (Um-3 and Um-5) failed within the first three weeks and all or almost all failed within four months. The only single-component urethane slipped downward about $\frac{1}{2}$ in. (15 mm) between the aluminium bars within the first few weeks, then stopped. Half of these specimens failed within four months, with no further change occurring during the rest of the year.

During the second year's exposure, the sealant that performed well in the first year, Um-2, was kept on the exposure rack and started to show failures. One specimen failed at 13½ months, increasing to four specimens at 17 months, at joint movements ranging from ± 13 to $\pm 30\%$. There were no additional failures at the end of the two-year period. Similarly, one specimen showed at 13½ months a small degree of failure in adhesion that would not produce a leak in an actual joint, increasing to three at 17 months and four at two years at between ± 22 and $\pm 30\%$.

In the second year's exposure the Um-2 sealant was repeated (MU-2) using a new batch. Half of the repeat specimens failed within one month and more than three-quarters of them in one year at movements of ± 15 to $\pm 30\%$. Such irreproducibility of results from the same material is rare, as shown by other studies on silicone sealants [3], and is due either to changes in the formulation or the recommendation to use the material without primer.

The epoxy-modified polyurethane that showed only two failures, at amplitudes of ± 24 and $\pm 28\%$, among 21 specimens during the first year was repeated in the second year (MU-1), resulting in the same number of failures at 1½ months and ± 23 and $\pm 25\%$ width change and in some minor adhesion losses on five specimens at the end of 15 months.

Sealant MU-4p showed no failure. The same product exposed in a previous experiment starting in May 1978 had shown similar good performance: of 24 primed specimens exposed, only five failed in two years, three in the first and two in the second year. This indicates that the same material that showed no failure when exposed for one year, starting in 1984, could have produced some failures in the second year but in an acceptably low number.

The single-component sealants exposed without primer in 1984 all failed in the first few winter months. Six specimens of sealant SU-1 had also been exposed without primer, starting in May 1978. All specimens failed within six months, confirming the 1984 results. On primed

aluminium SU-1p showed 50% failure in the first five months and 100% in 12 months. The SU-2p primed specimens showed no failure in the winter but all failed by the end of the exposure year.

4. CONCLUSIONS

The most important factor in the failure of the polyurethane sealants is joint movement; exposed specimens not subjected to movement did not fail. This confirms the results obtained with one polysulphide sealant [1].

Failures tend to occur earlier at higher movements, but there is no distinct failure limit within the $\pm 30\%$ width change obtainable on the rack because failures were scattered over a wide rather than a narrow range.

Of the seven polyurethane sealants from five manufacturers only one multi-component material showed excellent performance for one year on primed aluminium. Other multi-component sealants were either erratic or may need priming in spite of manufacturers' claims to the contrary. Although polyurethane-epoxy sealant showed a low level of failure at the start it performed well after that and was not used or even recommended to be used on a primed substrate. The single-component urethanes lost adhesion within a year whether primed or not.

The exposure test can differentiate between satisfactory and unsatisfactory sealants very clearly, provided the test is repeated with different batches to confirm the results. Two or three failures among about twenty specimens are acceptable, especially if they occur right at the beginning. Very early failures in building joints are more likely to be observed and corrected during the warranty period than those that occur after the building has been in service for a few years.

Evaluation of sealant performance is best started at the beginning of winter so that the sealant has to extend under the most adverse conditions. If evaluation must be started in the summer, however, the specimens should be mounted when the highest temperatures occur so that they would be working in tension and failures more easily observed. The first three months of a winter exposure are sufficient to reveal poor performers among multi-component sealants, but the single-component polyurethanes harden progressively and failures may show up only after a year.

In future work the correlation between outdoor exposure and laboratory cycling tests should be established as has been done for a polysulphide sealant [3] and for silicones [4]. Heat should be applied to single-component polyurethane sealants to the extent that the heat-aged specimens show the same tensile properties as specimens exposed outdoors for at least one year. Acceleration of ageing by heat has to be carefully investigated, however, because previous experiments [5] showed that the adhesion of some silicone sealants improved after heat ageing or simple ageing at room temperature; this does not occur during natural

weathering. For that reason such materials should be tested both with and without accelerated ageing.

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