Evaluation of Building Sealant by Using Artificial Accelerated Test Apparatuses

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Abstract
In this research, the durability of the sealant was evaluated through two accelerated weathering testers with different light sources. One is an accelerated weathering tester using a sunshine carbon arc light which is popular in the Japanese Industrial Standard. The other is an accelerated weathering tester using a xenon lamp which is popular in Europe and North America and has been adopted in the Japanese Industrial Standard recently.

The purpose of the research includes the comparison of two types of the accelerated weathering testers and the comparison of sealants. The tested sealant samples were 12 in total including polyurethane system, modified silicone system and polysulfide system. The evaluation was performed after the irradiation of 500, 1000, and 3000 hours, respectively. Measurement of 1) color difference, 2) crack and chalking, 3) dynamic viscoelasticity and 4) tension test were performed in the study.

As the results of the tests, the difference due to two types of accelerated weathering testers was hardly recognized. No change was recognized in the measurement of the dynamic viscoelasticity between the samples before exposure and the samples after exposure. The results obtained showed that types such as polyurethane system, modified silicone system and polysulfide system could not classify the weatherability of the sealant, and that difference in weatherability among the commercial products was sometimes remarkable even in the same type of sealant.

Keywords: Accelerated test, Correlation, Sealant, Sunshine carbon arc, Xenon lamp

Introduction

Sealant for buildings is filled in the joints to be generated between members for obtaining water-tightness and air-tightness. The sealant is considered to be deteriorated gradually by the influence of various factors such as light, water, heat, gas when it is exposed in the atmosphere (Japan Sealant Industry Association 1993).

The deterioration rate of sealant varies due to conditions such as place, direction, shelter, and the painting on the surface; however, a type and quality of the sealant itself can be the one of the important factors among them.

It has been pointed out that the average service life of the houses in Japan is much shorter than that in the United States of America and Europe. However, as the “Housing Quality Assurance Law” has been enforced since 2000 (Motohashi and Nireki 2002), the houses aiming at the longer service life have been supplying through the house manufacturing companies in Japan. The ten years liability was introduced as a part of “Housing Quality Assurance Law.” Under this law, ten years of water tightness liability is compulsory for all the dwellings which was constructed after April, 2000.

From the abovementioned viewpoint, the proper applying process of the sealant and periodic inspection are necessary to keep its waterproof performance for a long duration. In addition, the improvement of durability for the sealant is essentially required. For this reason, the sealant of high weather resistant type is being intensively developed in each sealant manufacturer.

There are an outdoor exposure test and an accelerated weathering test to investigate the weather resistance of the sealant. The outdoor exposure test enables to know their service lives with high reliability. However, it takes extremely long time, from several years to tens of years to complete the outdoor exposure test. The accelerated weathering test is performed to solve such problems. The accelerated weathering test enables to evaluate the quality of the sealant quickly. In addition, the service lives could be predicted by studying the correlations with the results of the outdoor exposure test.

In this research, the two types of acceleration tests were carried out. One is the sunshine weathering meter (SWOM) using the sunshine arc. The other is the xenon lamp type of weathering meter (XWOM).

Accelerated Weathering Test Method

Table 1 shows the 12 samples of sealant used in the accelerated weathering test. The 12 samples consist of 1-component type polyurethane sealant, 2-component type polyurethane sealant, 1- component type modified silicone sealant, 2-component type modified silicone sealant, and 2-component type polysulfide sealant.

The curing condition for sealant was at 23 Celsius degrees, 50%RH for 14 days and at 30 Celsius degrees for 14 days for 1-component type and at 23 Celsius degrees, 50%RH for 7 days and at 50 Celsius degrees for 7 days for 2-componet type.

Figure 1 shows appearance of the sheet specimens of the sealant. The sealant was casted on the Teflon tape to be a sheet of 70mm wide × 150mm long × 2mm thick. The sheet was mounted on the fiber reinforced cement sheet as shown in Figure 1.

Table 2 shows the accelerated weathering tester and the test conditions. Both SWOM and XWOM were used in the acceleration test. The both testing machines were manufactured by SUGA Tester Co., Ltd. As to features of light source, SWOM has larger energy in ultraviolet region than the sunlight, and XWOM has the spectral distribution which is similar to the that of the sunlight.

The test condition was based on the Japanese Industrial Standard JIS A 1415 (The exposure test method of polymeric building materials by use of laboratory light source).

The specimens were evaluated after 500, 1000 and 3000 hours' of irradiation. The irradiation energy was determined by the following methods. In case of the SWOM tester, irradiation energy in 300–400 nm ultraviolet region was estimated based on the energy ratio of the sunshine carbon arc light which was reported by the manufacturer. Regarding XWOM, irradiation energy in the ultraviolet region was directly obtained from the tester.

Sample	Composition	Curing system
PU1	1- component polyurethane	Moisture curing (Alicyclic non-yellowing isocyanate)
PU2		Moisture curing (Aromatic hard-yellowing isocyanate)
PU3		Moisture curing (Aromatic isocyanate)
PU4		
PU5	2- component polyurethane	Reactive curing (Aromatic isocyanate)
PU6		
MS1	1- component modified silicone	Moisture curing (Dimethoxysilyl group)
MS2		
MS3	2- component modified silicone	Reactive curing (Dimethoxysilyl group)
MS4		
PS1	2- component polysulfide	Reactive curing (Mercaptan group)
PS2		

Table 1 Type of the evaluated sealant (12 samples)

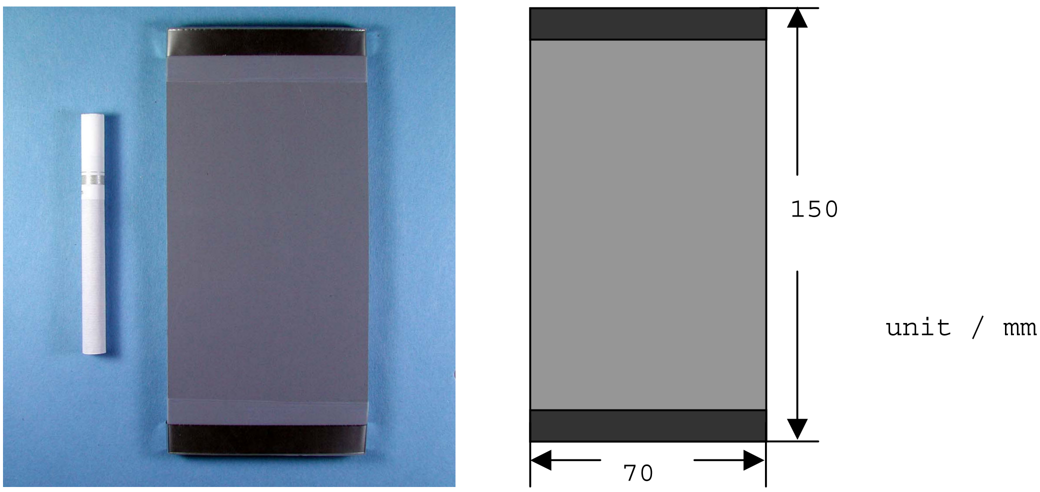

Figure 1 The specimen for the acceleration test

Tester	SWOM	XWOM
Types	WEL-SUN-DCH	X75
Manufacturer	SUGA Test Instruments Co.,Ltd.	
Light sources	sunshine carbon arc light	xenon lamp
Irradiance (Wavelength)	$76W/m^2$ (300-400nm)	$60W/m^2$ (300-400nm)
Irradiation method	Continuous irradiation	
Black panel temperature	63 Celsius degrees	
Relative humidity	50%	
Spraying time	18 minutes out of 120 minutes	
Irradiating time	500, 1000 and 3000 hours	

Table 2 Accelerated weathering testers and the testing conditions

Sealant Evaluation Method After The Acceleration Test

The following evaluation for the sealant was performed after the acceleration test.

Color difference of the specimens was obtained by measuring L*, a*, and b* values before and after the exposure. Crack and chalking were inspected visually.

Dynamic viscoelasticity was measured by using Rheovibron DDV-3 manufactured by A & D Co., Ltd. The measuring frequency was 110Hz, and the temperature range was from -100 Celsius degrees to 0 Celsius degrees with a temperature rising speed of 2 Celsius degrees•min.

The Tensile test of the dumbbell shaped specimens standardized JIS K 6251 was carried out. The tensile speed was 500mm•min.

Test Results and Considerations

Color Difference

Figure 2 shows the comparison of color difference at the same length of irradiation time for SWOM and XWOM. The positive correlation was recognized, but SWOM showed the larger influence than XWOM for some of the samples.

Figure 3 shows the relationship between the SWOM irradiation time and the values of color difference. The change in color difference after 500 hours' irradiation was larger in 2-component type polyurethane (PU5, PU6), 2-component type polysulfide (PS1, PS2) and PU3. In some specimens, color difference values at 1000 hours' irradiation were smaller than the values at 500 hours' irradiation. It is considered the this is due to the remarkable chalking of the sealant or fluctuated discoloration of the surface.

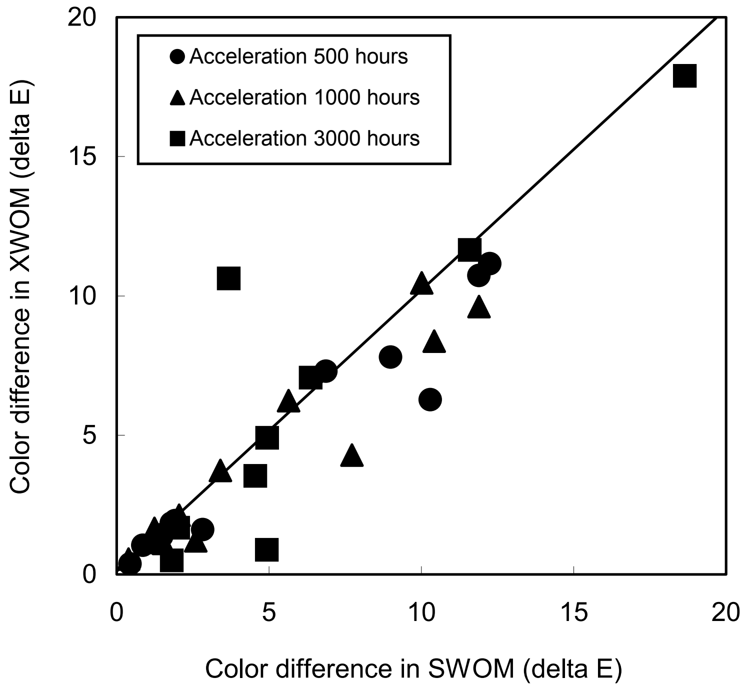

Figure 2 Comparison of the color difference in SWOM and XWOM

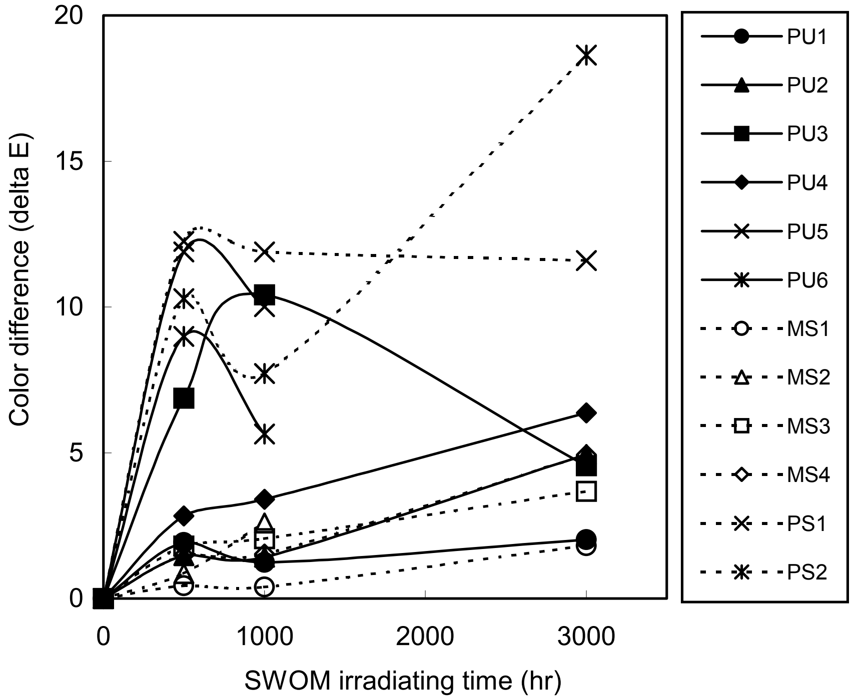

Figure 3 SWOM irradiation time and the change in color difference

Crack and Chalking

Figure 4 shows the photographs of the surface after 1000 hours' of XWOM irradiation. Though it was not shown, it was confirmed that the crack and chalking generated in SWOM were as same as in XWOM. Both crack and chalking were not recognized in the 4 samples, namely, PU1, PU2, MS1, and MS2. The crack or chalking was observed in the other 8 samples.

Figure 5 shows the photographs of the surface after 3000 hours' of XWOM irradiation. At this point, the specimens were deteriorated considerably and the missing of the sealant sheet was observed in some samples. However, it was confirmed that the crack was not generated in 2 samples, namely, PU1 and PS2 even after the irradiation of 3000 hours.

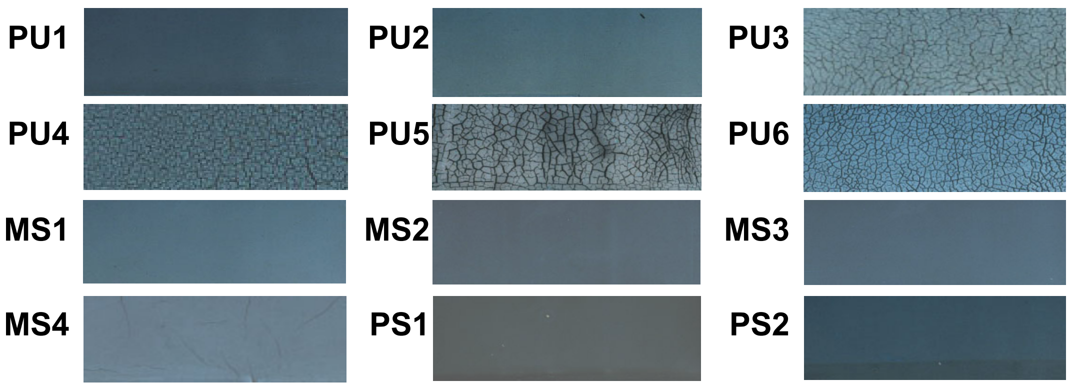

Figure 4 Photograph of the surface after 1000 hours of XWOM

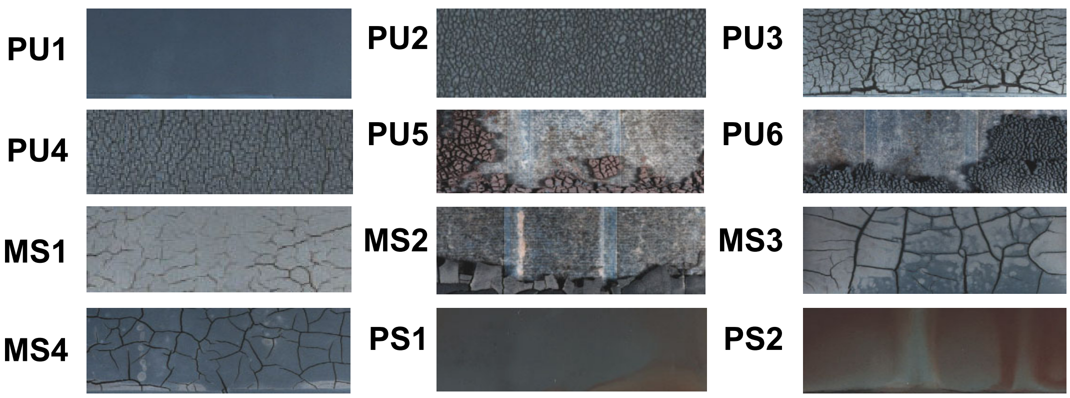

Figure 5 Photograph of the surface after 3000 hours of XWOM

The following can be pointed out from the results of color difference, crack and chalking.

1) The polyurethane system had large difference even in the same type and the durability of PU1 was excellent.
2) The change in color difference of the modified silicone system was small in general, but the crack was observed in all test pieces after 3000 hours' irradiation.
3) The change in color difference of the polysulfide system was large, and the remarkable discoloration was observed even in visual inspection.

Dynamic Viscoelasticity

Figure 6 shows the comparison of loss tangent (tan delta) peak temperature between before and after the acceleration test. The change in the tan delta peak temperature after 500 hours' of XWOM irradiation and after 1000 hours' of SWOM irradiation was hardly recognized comparing with the temperature before the acceleration test. Accordingly, the glass transition temperature of the sealant was hardly changed. For comparison, the same measurement was performed for the PU1 specimen after soaking in the n-hexane and extraction of the soluble part. In this case, the tan delta peak temperature moved to 6 Celsius degrees higher. However, all the specimens after the acceleration test did not show such movement of tan delta peak temperature in both the SWOM test and the XWOM test. That is, even the sealant test piece (2mm thick) which showed visual deterioration such as discoloration or crack or chalking on the surface had no significant change to be recognized in tan delta peak temperature which was affected by viscoelastic property.

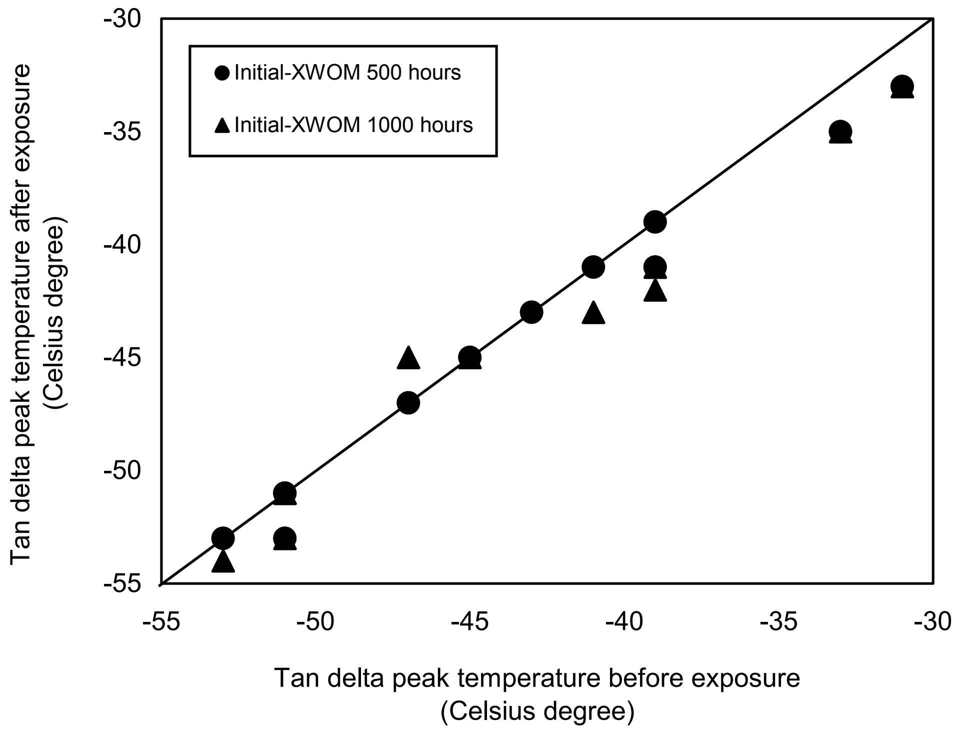

Figure 6 Comparison of tan delta peak temperature

Tensile Test

Figure 7 shows the comparison of the tensile strength retention in the SWOM test and the XWOM test. The difference between the two types of testers was hardly recognized as in the case of color difference.

Figure 8 shows the relationship between the XWOM irradiation time and the change in tensile strength retention. The tensile test was impossible for five samples, namely, 2-component type polyurethane (PU5, PU6), PU3, MS2, and MS3, because the cracking occurred at 3000 hours' of irradiation and the dumbbell shaped specimens could not be obtained. The decrease of the tensile strength retention was observed in 4 samples, namely, PU2, PU4, MS4, and PS1 after 3000 hours' acceleration.

Figure 9 shows the relation between the irradiation time and the tensile strength retention for both the specimens with cracking and the specimens without cracking. The tensile strength retention values of the 12 types of sealant were all plotted in each irradiation time of SWOM and XWOM. And, the linear regression equation could be obtained for both the specimens with cracking and the specimens without cracking. The decrease of the tensile strength retention was observed on the test specimens with the crack more clearly. That is, it is considered that the crack becomes the starting point of the fracture in the tensile test, and consequently, the lower tensile strength is obtained.

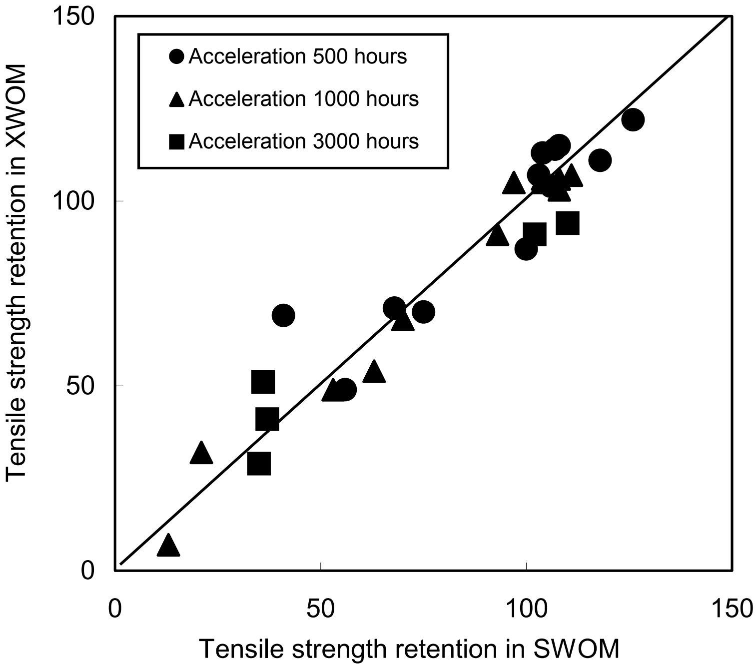

Figure 7 Comparison of the tensile strenght retention in SWOM and XWOM

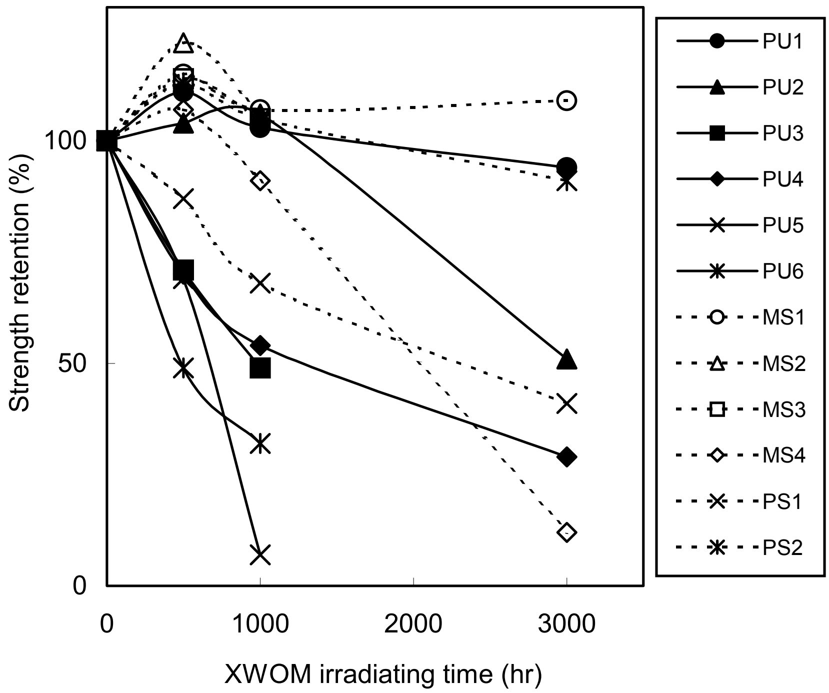

Figure 8 XWOM irradiation time and the change in tensile strength retention

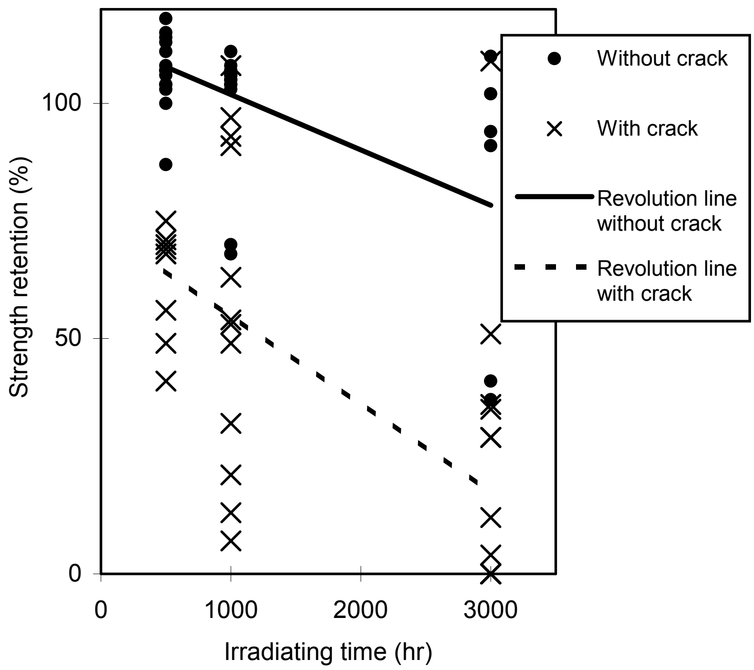

Figure 9 Relations between the existence of cracks and the tensile strength retention rate

Conclusion

The accelerated weathering tests by use of SWOM and XWOM were carried out up to 3000 hours for the 12 samples of the sealant. The following conclusions were obtained from various evaluations.

On Correlation of SWOM and XWOM

In the comparison of SWOM and XWOM, the difference between the two was hardly recognized. That is, the same result was obtained on the deterioration of the sealant in the both acceleration tests.

On Durability of Samples

Table 3 summarized comprehensively the evaluation results based on the results shown in Figures 3, 4, 5, and 8. The PU1 obtained all “Good” rating and showed excellent durability. It is confirmed that the PU1 possesses high durability. It proved that the durability could not be classified based on the types of sealant such as polyurethane system, modified silicone system, and polysulfide system and that the difference in durability was recognized even in the same types of sealant. In particular, the remarkable difference could be observed among the sample of polyurethane systems.

Evaluation	Color difference		Crack		Chalking		Tensile test		Number of “Good”
Irradiation Time	1000	3000	1000	3000	1000	3000	1000	3000	
PU1	Good	Good	Good	Good	Good	Good	Good	Good	8
PU2	Good	Med.	Good	Poor	Good	Med.	Good	Med.	4
PU3	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	0
PU4	Med.	Med.	Poor	Poor	Med.	Med.	Poor	Poor	0
PU5	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	0
PU6	Poor	Poor	Poor	Poor	Poor	Poor	Poor	Poor	0
MS1	Good	Good	Good	Med.	Good	Med.	Good	Good	6
MS2	Med.	Poor	Good	Poor	Good	Poor	Good	Poor	3
MS3	Med.	Med.	Med.	Poor	Good	Med.	Good	Poor	2
MS4	Good	Med.	Med.	Poor	Good	Med.	Med.	Poor	2
PS1	Poor	Poor	Good	Med.	Med.	Med.	Med.	Med.	1
PS2	Poor	Poor	Good	Good	Med.	Med.	Good	Good	4

Note: Med. = Medium

Table 3 Comprehensive evaluation

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