LABORATORY TEST METHOD FOR EVALUATING DURABILITY OF PERFORMANCE OF ROOF MEMBRANE SYSTEMS

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ABSTRACT

Most test methods that have been commonly adopted as durability tests mainly focus on a roofing material itself because of easiness and low cost in tests. However, the information we really ask for is not durability of the individual materials, but long term performance of a roof membrane system. In this paper, new laboratory test methods for evaluating durability of performances of a roof membrane system are proposed by combining the performance tests reported in the 1995 IWA congress and various ageing processes.

First, the levels of specimens are determined in eight performances such as resistance to static puncture, resistance to dynamic puncture, resistance to cyclic fatigue, stability of joints between roofing membranes, resistance to sliding on vertical surface, stability at corners in supports, resistance to suction, resistance to pressure beneath membrane. Then, they are exposed in the four ageing conditions of heat, ultraviolet radiation, moisture and ozone gas. After the exposure, the levels of eight performances of them are measured again and the change in level of performances is investigated.

The evaluation by the methods was tried to apply the roof membrane systems that are commonly used in Japan, such as two kinds of built-up roof membrane systems, a torch-on system, a sheet-applied system and a liquid-applied system. Some results obtained from the tests were finally discussed.

1 INTRODUCTION

A roof membrane system is expected to prevent from ingress of rainwater into buildings for a long period. However, most membranes are composed of polymeric materials, and they are not able to last so long. We have to repair or replace of them once or twice during service life of a building. Therefore, it is needed for managing it properly to make clear the durability of a roof membrane system.

The durability of a roof membrane system is a matter of important concern in designing a building, and its performance is usually estimated by various durability tests. However the most test methods that have been commonly adopted mainly focus on a membrane material itself because of easiness and low cost in tests. The information we really ask for is not durability of individual materials, but long term performance of a roof membrane system. The durability of individual materials, of course, the fundamentals for estimating durability of a membrane system, however, it is not so easy to directly connect it to the durability of a membrane system.

In the previous paper in IWA congress in 1995, we reported the test methods to make clear performance of a roof membrane system[1]). The concept of performance of a membrane system is positively tried to introduce for estimating durability of it. In this paper, we describe the durability test methods for membrane systems and some results applied to roof membrane systems in our country.

2 DURABILITY TEST FOR ROOF MEMBRANE SYSTEM

This is constructed on basis of the performance tests for roof membrane system previously proposed as shown in Table 1. A membrane system is used as a test specimen in the test and therefore, we can directly obtain the information on durability of a membrane system if we degrade it by various ageing treatments.

The frame of the durability test is shown in Fig.1. The test procedure is as follows. Level in performance of a membrane system specimen is first determined by eight performance tests such as tests for resistance to static puncture, dynamic puncture, cyclic movement, failure at joint of membranes sliding on vertical plane, failure at corner of substrate, pull-off under suction and pressure beneath membrane.

Table 1.1 Performance test method of roof membrane system(1)

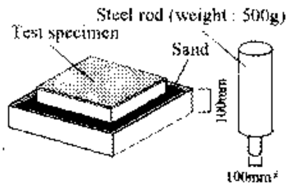
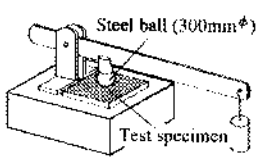
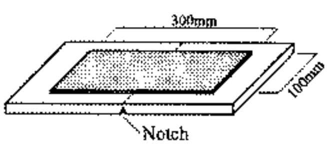
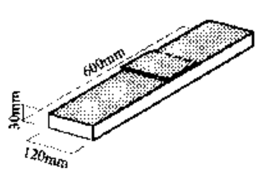
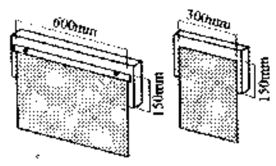
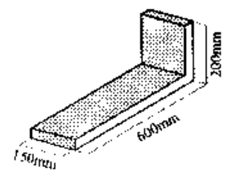
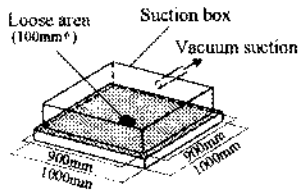
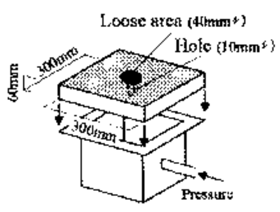
Performance	Outline of test method	Classification of test result
Resistance to static puncture 	A specimen is loaded via the steel ball of 30mm in diameter for 24 hours at the ambient temperatures of 20℃ and 60℃. The load is increased in steps if not punctured.	Level 1: Punctured at 50N Level 2: Punctured at 150N Level 3: Punctured at 250N Level 4: Not punctured at 250N
Resistance to dynamic puncture 	A specimen is loosely laid on substrate (a concrete panel is used as a standard substrate). The steel rod, of which bottom is shaped into hemisphere, is dropped from several heights at 0℃, 20℃ and 60℃. A height is increased in steps if not punctured.	Level 1: Punctured at impact from 0.5m Level 2: Punctured at impact from 1.0m Level 3: Punctured at impact from 1.5m Level 4: Not punctured at impact from 1.5m
Resistance to cyclic movement 	An asbestos board notched at the center is used as a standard substrate and a membrane is applied on it. The joint which is made by bending is repeatedly opened and closed 500 times, at the movement 0.5-1.0mm at 20℃, 60℃ and -10℃. Movement is extended to 1.0-2.0mm and 2.5-5.0mm in steps, if not failed.	Level 1: Tore or split at movement of 0.5-1.0mm Level 2: Tore or split at movement of 1.0-2.0mm Level 3: Tore or split at movement of 2.5-5.0mm Level 4: Not torn or split at movement of 2.5-5.0mm
Resistance to failure at joint of membrane 	A joint of membrane is made on a substrate. It is exposed in the air of 80℃ for 48 hours and then cooled down at 0℃ for 48 hours following at 20℃ for 72 hours. The operation is repeated five times. The joint is inspected and the length of differential slippage is measured.	Level 1: Defects observed or slid more than 5% of lap length Level 2: No defects observed and slid 1-5% of lap length Level 3: No defects observed and slid less than 1% of lap length

Table 1.2 Performance test method of roof membrane system(2)

Performance	Outline of test method	Classification of test result
Resistance to sliding on vertical plane  Mechanically fixed Bonded	The above area of 150mm of a membrane of 450mm in length is bonded and/or mechanically fixed to a substrate. The specimen is exposed in the air of 60℃ for 168 hours and then left in the atmosphere of 20℃. The length of slippage is measured from the position previously attached.	Level 1: Slid down more than 1mm Level 2: Slid down less than 1mm Level 3: Not slid down
Resistance to failure at corner of substrate 	A membrane applied on L-shaped substrate. It is exposed in the air of 80℃ for 48 hours and then cooled down at 0℃ for 48 hours. After the treatment, it is kept in the atmosphere of 20℃ for 72 hours. The operation is repeated five times. The membrane, in particular the area at the corner, is inspected.	Level 1: Split in membrane Level 2: Peeled off from substrate Level 3: No defect observed.
Resistance to pull-off under suction (Resistance to wind uplift) 	A membrane is bonded or mechanically fixed to a substrate. A suction box is put on the specimen. The inside pressure is reduced to -2.0kPa at 40℃ and is kept for 30 minutes. When any defects were not observed, the suction level is increased to -5.0kPa and -10.0kPa in steps.	Level 1: Failed at suction of -2.0kPa Level 2: Failed at suction of -5.0kPa Level 3: Failed at suction of -10.0kPa Level 4: Not failed at suction of -10.0kPa
Resistance to pressure beneath membrane (Resistance to blistering) 	A membrane is applied on concrete substrate at the center of which a hole of 10mm in diameter is opened. A circular loose area of 40mm in diameter beneath the membrane is also provided. The static pressure of 10.0kPa is applied to the specimen for 10 minutes at 60℃ through the hole. If not changed, pressure is increased to 20.0kPa and 50.0kPa in steps.	Level 1: Loose area spread at 10.0kPa Level 2: Loose area spread at 20.0kPa Level 3: Loose area spread at 50.0kPa Level 4: Not spread at 50.0kPa

Then the specimen is degraded by various ageing treatments. After ageing, the performance tests were carried out again. As performance is expressed as a classification level, the results can be obtain as the change in level of performance.

A system is estimated to have sufficient durability when the level still stayed in the tolerable range after ageing. On the contrary, it might be judged to be poor in durability when the level becomes lower than the acceptable level. The judgment is belonged inherently to the work of a designer of a roof system. Therefore, the test method proposed here should be understood as a tool for estimating durability of performance of a roof membrane system.

3 AGEING ELEMENTS AND PROCEDURES

Among elements degrading performance of a roof membrane system, the following elements such as heat, ultraviolet radiation, moisture and ozone were selected as fundamental ones. As for moisture, it may be not needed because membrane materials are inherently durable to water. However, some failures of membrane such as separation from a substrate or blistering is closely related to the existence of moisture beneath a membrane, then moisture was also included. The ageing procedures are as follows.

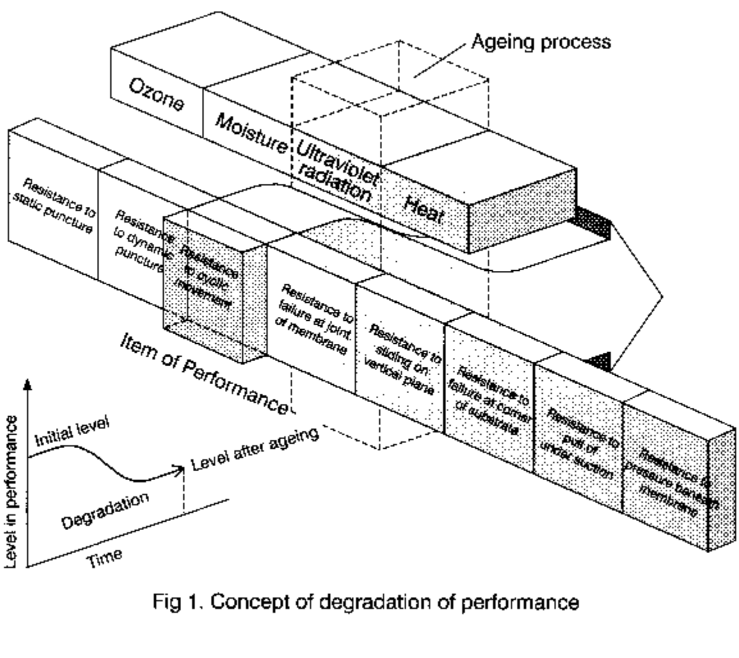


Fig 1. Concept of degradation of performance

(1) Ageing by heat

A specimen is exposed in the chamber controlled at the condition as shown in Table 2 for 112 days.

Table 2: Ageing condition for heat

Membrane	Substrate	Ageing condition
Membrane without protective layer such as concrete cover and gravel	Concrete substrate	80°C for 112 days
	Heat insulating board substrate	90°C for 112 days
Membrane covered with heavy protective layer		60°C for 112 days

(2) Ageing by ultraviolet radiation

A specimen is exposed to Xenon arc till to receiving 1000MJ/m2 at the condition as shown in Table 3.

Table 3: Ageing condition for ultraviolet radiation

Membrane system	Ageing condition
Membrane without heavy protective layer	UV radiation: 1000MJ/m^2 (300-400nm) Black panel temperature: 63±3°C Water spray: 18 minutes after UV radiation of 102 minutes

Table 4: Ageing condition for moisture

Membrane system	Ageing condition
Membrane without heavy protective layer	The below half of a concrete substrate is immersed in in water of 50°C for 56 days. The above half of it exposed in room temperature
Membrane covered with heavy protective layer	

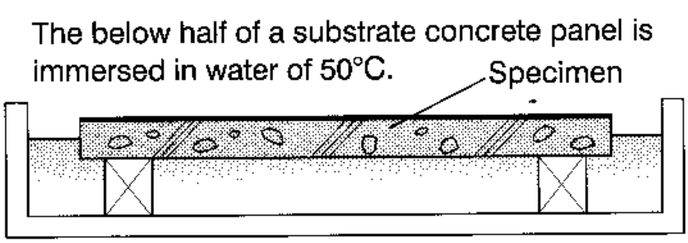


Fig 2. Ageing test method for moisture
(A specimen is shown for pull-off test as example)

(3) Ageing by moisture

A specimen is immersed in the water of 50°C to the below half of a substrate as shown in Fig.2 and Table 4. The above half of it is exposed in the room temperature for expecting moisture condensation behind a membrane.

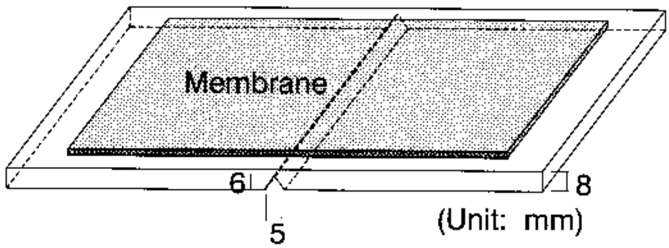


Fig 3. Specimen of ozone ageing

(4) Ageing by ozone

A substrate board as shown in Fig.3 is separated off at the notch and extended to 3mm crack width, and then exposed in an ozone chamber at the condition as shown in Table 5.

Table 5: Ageing condition for ozone

Membrane system	Ageing condition	
Membrane without heavy protection layer	Ozone concentration: Temperature:	100pphm 40°C
Membrane covered with heavy protective layer	Exposure duration: Crack width of substrate:	56days 3mm

4 RECOMMENDED COMBINATION OF AGEING ELEMENTS AND PERFORMANCE TESTS

It is needed for estimating durability of a roof membrane system to examine for all the combinations of ageing elements and performances. However, according to the items of performance, some ageing elements scarcely affect in practice. Therefore, the combinations that are considered to closely relating to each other were selected and recommended as shown in Table 6.

5 SELECTED ROOF MEMBRANE SYSTEM FOR THE STUDY

The following five kinds of roof membrane systems were selected among the standard specifications of Japan

Table 6: recommended combination of performance tests and ageing elements

Performance	Ageing elements			
	Heat	Ultraviolet radiation	Moisture	Ozone*
Resistance to static puncture	**A,B**	**A**	-	-
Resistance to dynamic puncture	**A,B**	**A**	-	-
Resistance to cyclic movement	**A,B**	**A**	-	-
Resistance to failure at joint of membrane	**A,B**	-	-	-
Resistance to sliding on vertical plane	**A,B**	-	-	-
Resistance to failure at corner of substrate	-	-	**A,B**	-
Resistance to pull-off under suction	**A**	-	**A**	-
Resistance to pressure beneath membrane	**A**	-	**A**	-

A: Membrane without heavy protection layer
B: Membrane covered with heavy protective layer such as concrete or gravel
* Effect of ozone is examined by another test method

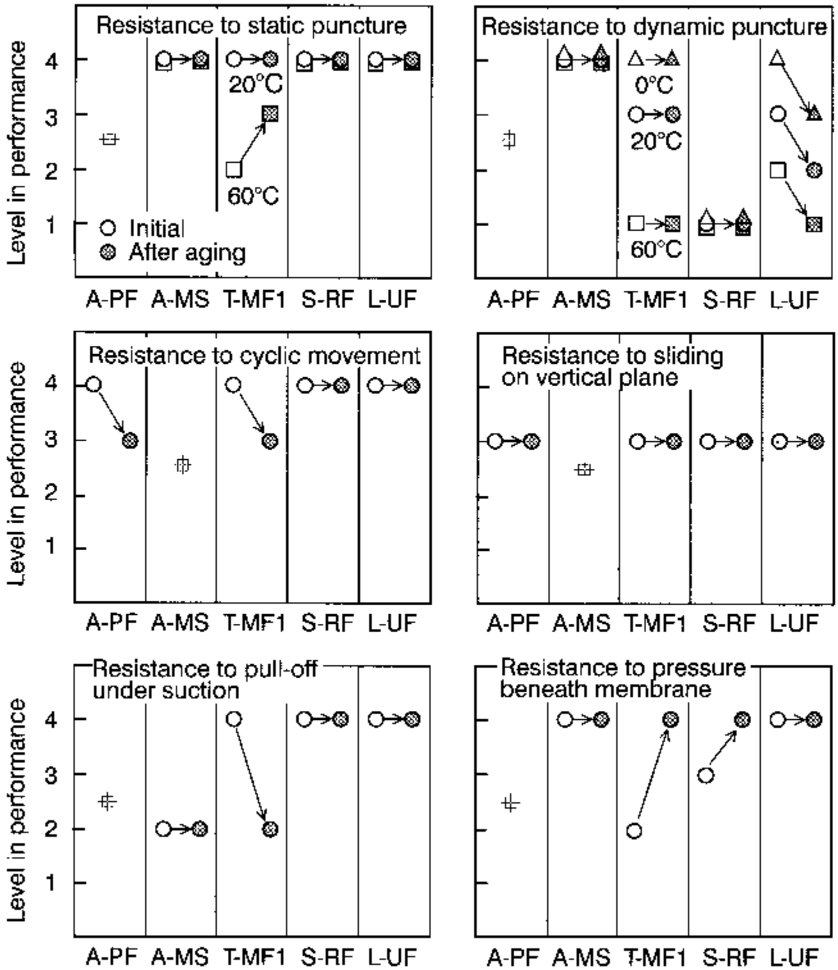
Architectural Institute[2]); Fully bonded built-up roof membrane system (code of system, A-PF), Partially bonded built-up roof membrane system (A-MS), Torch-on system (T-MF1), Sheet-applied system (S-RF) and Liquid-applied system (UF). The specifications of the systems are shown in Table 7.

Table 7: Specifications of roof membrane systems

Built-up system (Fully bonded)		Built-up system (Partially bonded)	
Code of system in JASS 8*	A-PF	A-MS	
Top layer:	Asphalt coating	Top:	Mineral surfaced roofing bonded in asphalt
3rd layer:	Polyester base roofing bonded in asphalt.	3rd layer:	polyester base roofing, bonded in asphalt
2nd layer:	Polyester base roofing, bonded in asphalt.	2nd layer:	Lag base roofing, bonded in asphalt.
1st layer:	Lag base roofing bonded in asphalt.	1st layer:	Perforated roofing, partially bonded in asphalt.

	Torch-on system	Sheet applied system	Liquid applied system
Code of system	T-MF1	S-RF	L-UF
	APP-modified asphalt roofing, torch applied	Vulcanised rubber sheet, adhered with CR rubber adhesive	3mm two coat urethane rubber reinforced by by polyester fibre mesh

* JASS 8: Japanese Architectural Standard Specification No. 8, waterproofing and sealing



A test was not done for the system

Fig 4: Results of heat ageing

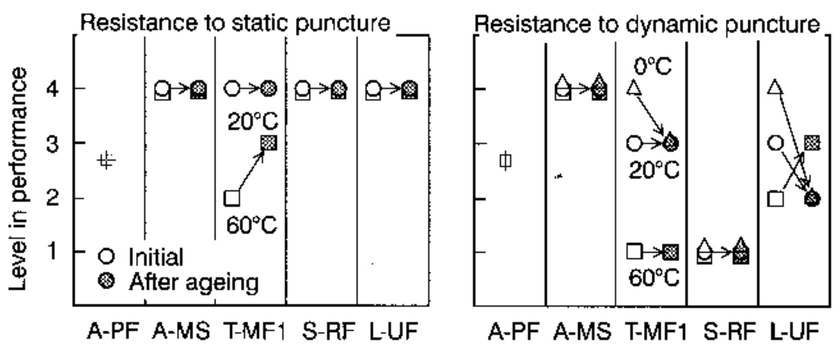


Fig 5: Results of UV ageing

6 RESULTS AND DISCUSSION

6.1 Ageing by heat

The results aged by heat are shown in Fig.4. As for resistance to static puncture, the system of torch-on was improved to one rank higher in the classification level at the test of 60°C. The other systems weren't changed their levels by heat ageing. As for resistance to dynamic puncture, the system of liquid-applied was degraded to one rank lower at the tests of 0, 20 and 60°C.

As for resistance to cyclic movement, the two systems of fully bonded built-up and torch-on degraded to one rank lower, probably because of loss of flexibility. No systems were changed their classification levels for resistance to sliding on vertical plane. As for resistance to pull-off under suction, the system of torch-on was degraded to two ranks lower in the classification level. However as for resistance to pressure beneath membrane, the two systems of torch-on and sheet-applied were improved to one rank higher.

6.2 Ageing by UV radiation

The results by aged UV radiation are shown in Fig.5. As for resistance to static puncture, the system of torch-on was improved to one rank higher probably because of increase of hardness. The other systems weren't changed their classification levels by UV radiation. As for resistance to dynamic puncture, the system of torch-on was degraded to one rank lower at the test of 0°C. Complicated results obtained for the system of liquid-applied. The classification level fell at 0°C and 20°C, and it however rose at the test of 60°C.

6.3 Ageing by moisture

The results aged by moisture are shown in Fig.6. No membrane systems were degraded by moisture for resistance to sliding on vertical plane and to failure at corner of substrate. As for resistance to pull-off under suction, the two systems of partially bonded built-up and torch-on were degraded to one rank lower because of loss of adhesion. As for resistance to pressure beneath membrane, the system of torch-on was degraded to one rank lower. The other systems weren't changed in their classification levels.

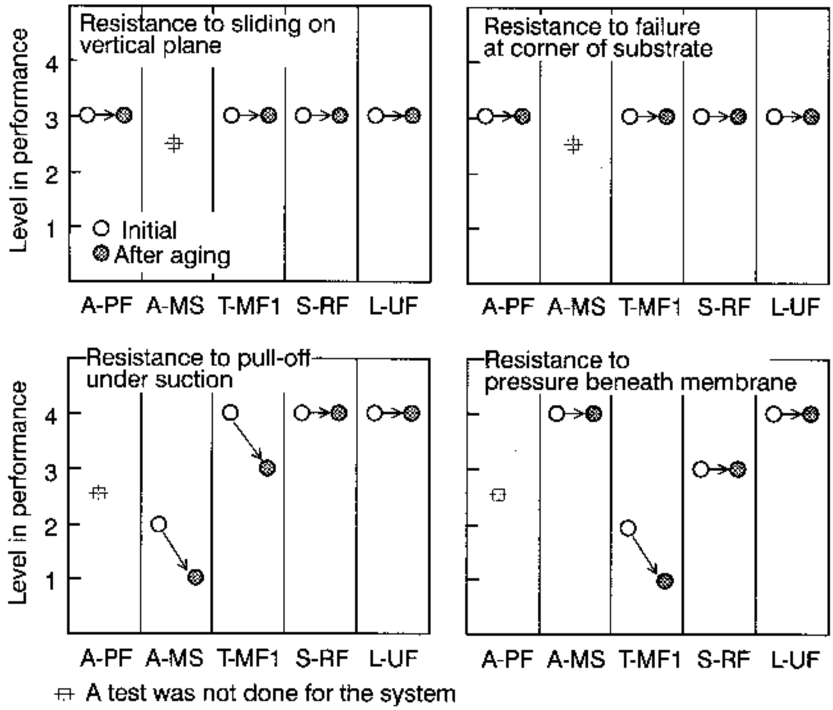


Fig 6: Results of moisture ageing

6.4 Ageing by ozone

The results were shown in Table 8. No failures were observed in all systems.

7 CONCLUSION

We proposed durability test methods of performances for a roof membrane system and tried to estimate durability of some roof membrane systems is our country. The knowledge about durability of performances such as resistance to pull-off under suction and durability of resistance to pressure beneath membranes, which might be difficult to obtain by the usual durability tests for only materials, was successfully obtained.

However, the proposed test methods are not able to estimate quantitatively service life of a membrane system. More performance test results should be collected and compared to the date obtained from actual buildings. A steady and persistent effort such as outdoor exposure tests of roof membrane systems might be also needed. At the present stage, we only proposed the durability test methods from a new point of view, durability of performance. We need further studies to make sure the usefulness of the durability test methods.

ACKNOWLEDGMENT

We would like to thank the members of the committee on durability test method of the performance of a membrane system for their activities, and the Japan manufactures associations of waterproofing materials for their preparing the specimens.

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