CRACK BRIDGING PROPERTIES OF ELASTOMERIC WATERPROOFING WALL COATINGS

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In the mid-1950's, fluid-applied roofing membranes entered the Japanese waterproofing market. The current estimated shares for the Japanese roofing market are:

- Built-up roofing membrane: 65-70 percent
- Single-ply roofing membrane: 15-20 percent
- Fluid-applied roofing membrane: 10-15 percent

Although polyurethane elastomer is used mainly for the fluid-applied roofing membrane, the acrylic rubber also has been used for about 10 years. Since the acrylic rubber can be sprayed, it is used to waterproof external walls.

Recently, in Japan, rain leakage in external walls is increasing more than in roofs, because the concrete external walls have joints which crack due to shrinkage. The rain enters through these fine cracks. Since the fluid-applied roofing membrane of acrylic rubber can prevent this kind of leakage very effectively and also decorate the external wall, its use has been increasing. At present, over 50 manufacturers produce more than 40,000 tons of elastomeric wall coatings for waterproofing every year.

Although, there is a Japanese Industrial Standard (JIS) for fluid-applied roofing membranes, it does not apply to fluid-applied membranes for external walls. Therefore, the properties of those membranes depend on each manufacturer, and designers have trouble selecting waterproofing materials for external walls. Thus, we determined to improve the crack bridging properties of elastomeric wall coatings for waterproofing beyond that which is required at present. This paper reports the results of three types of crack bridging tests.

MATERIALS TESTED

Seven types of elastomeric waterproofing wall coatings shown in Table 1 were selected for consideration based on the forms: multilayer or single layer, main component of binder and actual results of use.

CRACK BRIDGING PROPERTIES: ENLARGING CRACKS

Sample preparation

The base coatings were applied to the rough surface of 100 by 250 by 8mm asbestos cement board. In the case of multilayer specimens a top coat also was applied.

The built-up coatings were 0.5, 1.0, 1.5, and 2.0mm thick.

After application, the coatings were cured in the laboratory at 20C for 28 days, then in an electric drier at 40C for seven days.

Test Methods

The center of the reverse side of each specimen was cut with a hacksaw to a depth of 4mm in the short side direction. Then a load was applied to the specimen as shown in Figure 1. When the specimen was bent, the load was removed and the surface of the coating was observed. The load was applied at the speed of 5mm per min using an Instron universal testing machine.

Next, tension was applied to the specimen at a rate of 5mm per min to enlarge the crack (*Figure 2*) until a failure, such as a pin hole or crack was observed in the coating.

The test temperatures were −10, 0, 20 and 60C.

The test result was indicated by the width of the crack of the base material at the time coating failure was observed.

Results of tests and observations

Examples of the test results are shown in Table 2 and Figure 3. An analysis of their variance is given in Table 3. From these results, the following can be estimated:

The thicker the coating, the better its crack bridging properties (*Figure 4*).

The crack bridging properties depend on temperature (*Figure 5*), and they are less at lower temperatures. Therefore, they cannot be judged only by the data obtained at room temperature.

The top coat and base coat of many multilayer coatings are not matched well and performance of the base coat cannot be measured sufficiently. The top coat must be improved.

CRACK BRIDGING PROPERTIES: CYCLIC MOVING CRACK

This test was performed assuming that the cracks were moving repeatedly as the cyclic temperature changes.

Sample preparation was the same as before.

Test Method

After performing the bending test, the test specimens were installed in the waterproof layer fatigue tester. Movement was applied to the specimen repeatedly according to the program shown in Table 4 until a failure was observed in the base coat.

Test Results

The results of the tests are shown in Figure 6 and the result of the analysis of the variances is in Table 5. These results prove that the crack bridging properties vary among the types of materials tested, and the thicker the coating, the better its performance generally.

CRACK BRIDGING PROPERTIES: FIXED CRACK

This test was performed assuming a fixed crack width.

Sample preparation

The test specimens and the width of the cracks are shown in Figure 7. Coating thicknesses were 0.5, 1.0, 1.5, and 2.0mm.

Test method

After bending, the test specimens were exposed to the sun facing south at a 45 degree angle of elevation on the roof of our laboratory and in the room.

Test results

Test results after one year of exposure are shown in Table 6.

It was found that the crack bridging properties varied among the materials tested, and the thicker coatings performed better.

CONCLUSION

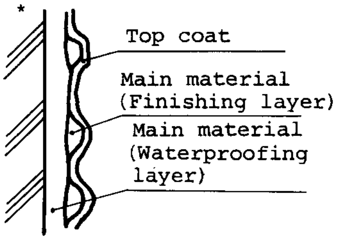
The test results are summarized in Table 7.

As can be seen in this table, samples A and C of acrylic rubber, and sample N of silicone are fit for waterproofing.

These test methods could be utilized to prepare the appropriate standards.

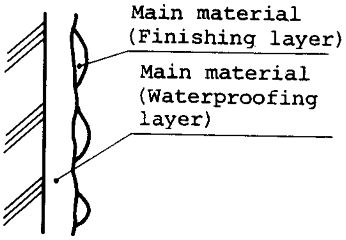
Form*	Main component of binder	Symbols of materials tested
Multilayer	Acrylic rubber	A, C, E, J
	Chloroprene (CR)	K
	Silicone	N
Single layer	Acrylic resin	S

*



Multi-layer type

Specification of two coatings of the same materials with top coating



Single layer type

Specifications of two coatings of the same materials without top coating

Table 1 Types of materials tested

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3. Yutaka Tsuruta, Johsuke Yamanaka and Kuniomi Suzuki; Measurements of Movement at Joint in Precast Roof Deck. International Symposium on Roofs and Roofing, Brighton, England, Sept. 9-13, 1974.
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5. Michio Koike; Tear Test for Fluid-Applied Roofing Membranes at Joint in Roof Deck. ASTM Special Technical Publication No. 409 (Apr. 1967)
6. K.G. Martin; Rupture of Built-Up Roofing Components. ASTM Special Technical Publication No. 409 (Apr. 1967)

Item		Material	Multilayer type						Single layer type
			Acrylic resin or rubber				CR	Silicone	Acrylic resin
			A	C	E	J	K	N	S
Tensile strength (kg/cm^2)		0°C	27.5	37.7	17.0	18.7	0.8	6.3	69.6
		20°C	17.4	19.4	15.7	5.9	0.9	6.2	31.9
Elongation for tensile breakage (%)		0°C	55	10	300	350	34	170	120
		20°C	240	130	390	750	47	170	182
Crack bridging properties (Enlarging crack)	0°C	0.5mm thick	3.2	3.2	2.0	1.9	1.6	3.5	1.1
		1.0mm "	4.0	4.6	2.2	5.6	2.2	10.5	2.0
		1.5mm "	6.0	6.0	2.5	8.5	6.2	12.5	3.9
		2.0mm "	6.4	8.6	2.7	16.1	9.3	13.0	5.6
Crack width at rupture of membrane (mm)	20°C	0.5mm thick	3.2	3.3	2.5	8.6	3.0	3.5	2.0
		1.0mm "	5.8	8.0	3.1	17.8	2.9	9.5	2.8
		1.5mm "	8.2	16.5	3.7	21.7	5.2	12.0	4.8
		2.0mm "	12.2	27.0	4.3	23.5	8.0	12.5	6.5

Table 2 Test results

Factor*	S	ø	V	Fo	F(0.05)
A: Temperature	135.78	1	135.78	22.93*	4.41
B: Coat thickness	504.95	3	168.32	28.43*	3.16
C: Material	669.40	6	111.57	18.84*	2.66
A x B	20.73	3	6.91	1.17	3.16
A x C	206.72	6	34.45	5.82*	2.66
B x C	193.04	18	10.72	1.81	
E: Residual error	106.58	18	5.92		
Total	1,837.19	55			

Table 3 Results of analysis of variance (tests of enlarging cracks)

*Where:

$S = (\Sigma x_i - \bar{x})^2$: sum of squares

ϕ = (number of levels) – 1: degrees of freedom

$V = S/\phi$

$F_0 = V/V_E$, Example $F_A = V6_A/V_E = 135.78/5.92 = 22.93$

F(0.05) = value of F-distribution (significance level: 5%)

Process	Step / Temperature (°C) / Movement (Amplitude: mm)	1	2	3
		20	5	-10
1	0.12 ⇌ 0.5 (0.38)	①	②	③
2	0.25 ⇌ 1.0 (0.75)	④	⑤	⑥
3	0.5 ⇌ 2.0 (1.5)	⑦	⑧	⑨
4	1.0 ⇌ 4.0 (3.0)	⑩	⑪	⑫

Period: 6 sec. (10 times/min.)

Number of repeat: 2,000 times each < 1 ~ 12)

Table 4 Program for crack bridging with cyclic movement

Factor*	S	ø	V	Fo	F(0.05)
A: Coat thickness	252.9	3	84.3	45.3*	2.95
B: Material	334.4	6	55.7	29.9*	2.45
A x B	73.6	18	4.1	2.2*	1.99
E: Residual error	52.0	28	1.9		
Total	712.9	55			

Table 5 Result of analysis of variance of test of cyclic movement

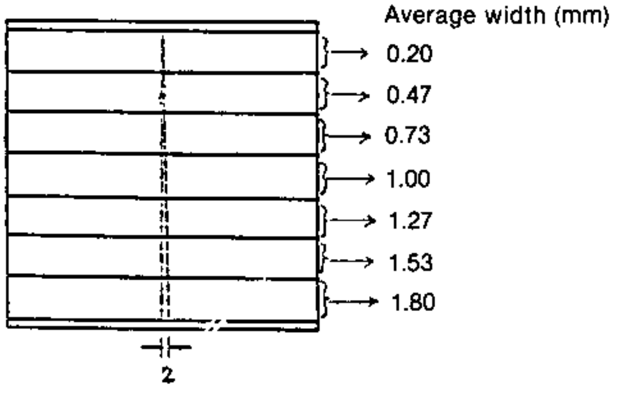
*See Table 3.

Exposure		Sunshine							Room						
Symbol	Coat thickness (mm)	Crack Width* (mm) 0.20	0.47	0.73	1.00	1.27	1.53	1.80	0.20	0.47	0.73	1.00	1.27	1.53	1.80
A	0.5	□	□	□	X	X	X	X	□	□	□	□	X	X	X
	1.0	□	O	O	□	O	□	X	O	□	□	□	□	□	□
	1.5	□	□	□	□	□	□	□	O	O	□	□	□	□	□
	2.0	□	O	O	□	□	□	□	□	O	□	□	□	□	□
C	0.5	O	O	O	O	O	O	X	O	O	O	O	□	X	X
	1.0	O	O	O	O	O	O	O	O	O	O	O	O	O	O
	1.5	O	O	O	O	O	O	□	O	O	O	O	O	O	O
	2.0	O	O	O	O	O	O	O	O	O	O	O	O	O	O
E	0.5	X	X	X	X	X	X	X	X	□	X	X	X	X	X
	1.0	O	O	□	□	X	X	X	□	□	□	□	X	X	X
	1.5	□	O	□	□	□	□	□	O	O	□	□	□	X	X
	2.0	□	□	□	□	□	□	□	O	O	O	O	O	O	X
J	0.5	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	1.0	□	□	□	X	X	X	X	□	□	□	X	X	X	X
	1.5	□	□	O	O	O	O	□	O	O	O	O	O	□	□
	2.0	O	O	□	□	□	□	□	O	O	O	O	O	O	O
K	0.5	O	X	X	X	X	X	X	O	□	□	□	X	X	X
	1.0	O	□	X	X	X	X	X	O	O	O	O	□	□	□
	1.5	O	O	O	X	X	X	X	O	O	O	□	□	X	X
	2.0	O	O	O	O	□	□	□	O	O	O	O	O	O	□
N	0.5	X	X	X	X	X	X	X	O	O	O	O	X	X	X
	1.0	O	O	O	O	O	O	O	O	O	O	O	O	O	O
	1.5	O	O	O	O	O	O	O	O	O	O	O	O	O	O
	2.0	O	O	O	O	O	O	O	O	O	O	O	O	O	O
S	0.5	O	X	X	X	X	X	X	O	O	□	X	X	X	X
	1.0	O	O	O	O	O	O	O	O	O	O	O	X	X	X
	1.5	O	O	O	O	O	O	X	O	O	O	O	O	O	X
	2.0	O	O	O	O	O	O	O	O	O	O	O	O	O	O

Legend O; No failure was seen
□; Failure was seen in only top coat
X; Failure was seen

*Crack width

Table 6 Result of the fixed crack widening test (one-year exposure)



Valuation of Crack Bridging Properties				
Symbol	Enlarging Crack	Cyclic Moving Crack	Fixed Crack	Total Valuation
A	B	A	C	B
C	B	B	B	B
E	D	D	C	D
J	D	D	D	D
K	D	D	D	D
N	B	C	B	B
S	D	D	B	C

Legend A; Very Good
B; Good
C; Passable
D; Bad

Table 7 Valuation of the materials tested

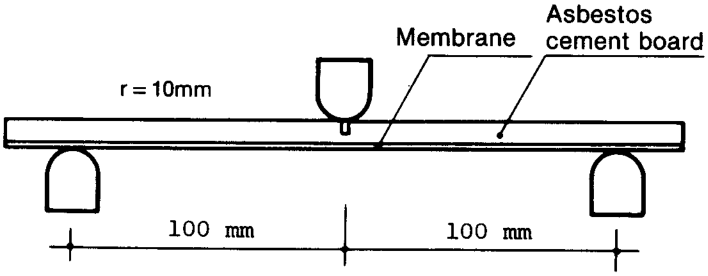


***Figure 1** Method of bending test*

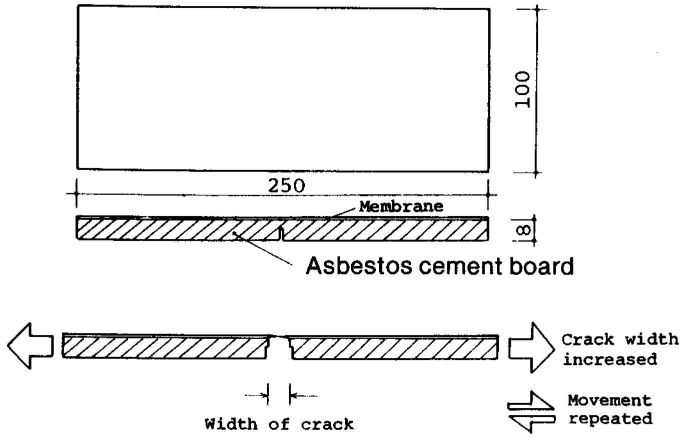
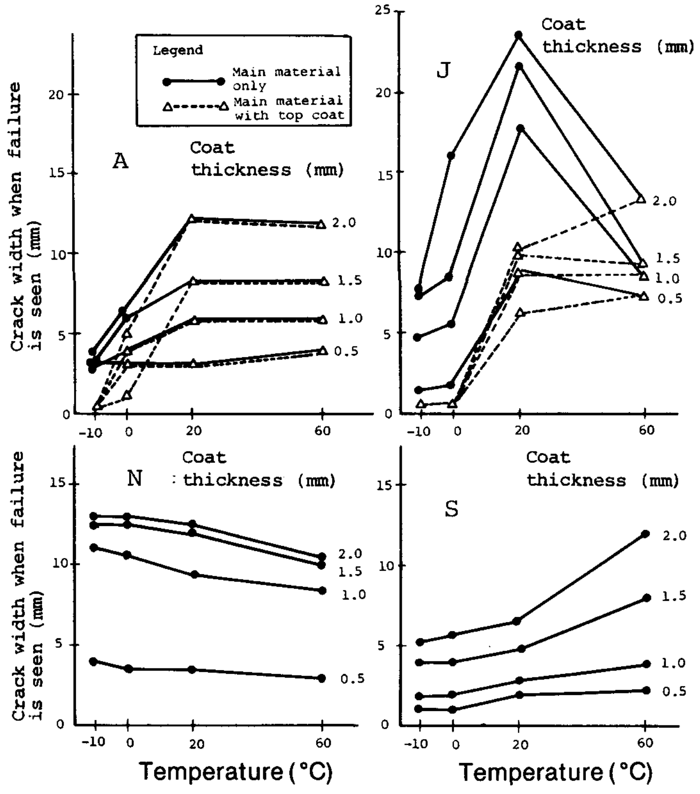


***Figure 2** Method of crack bridging test*



(See Table 1 for letter symbols)

***Figure 3** Results of crack opening tests (enlarging crack)*

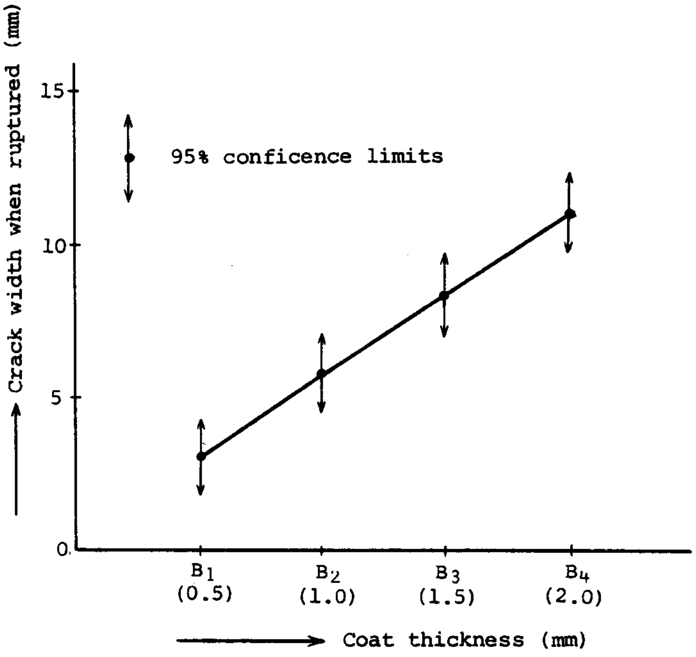
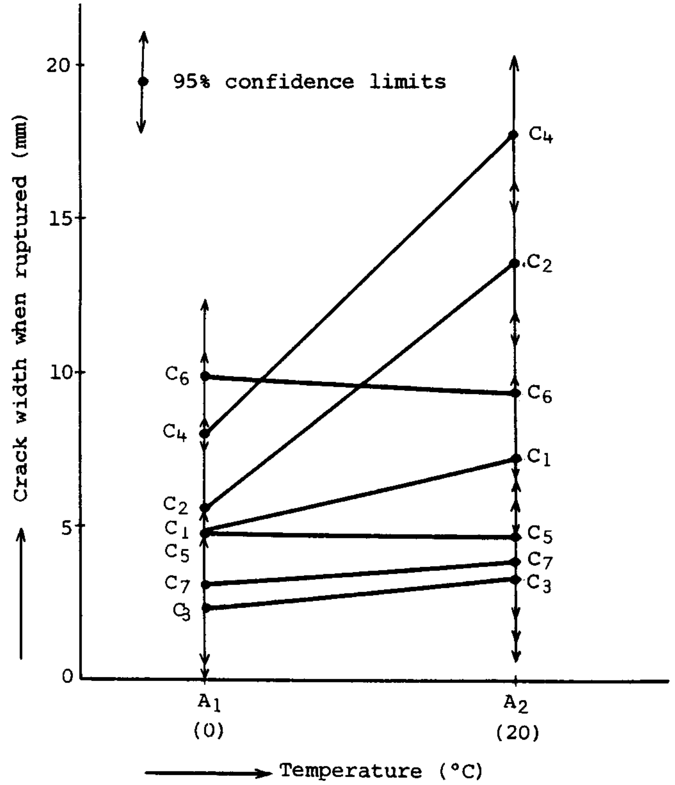


***Figure 4** Relationship between coating thickness and crack bridging properties (enlarging cracks) (main effect of factor B)*



Where:
C_1~$_7$: Sample A~S
C_1 = Sample A
C_2 = Sample C
C_3 = Sample E
C_4 = Sample J
C_5 = Sample K
C_6 = Sample N
C_7 = Sample S
See Table 1.

Figure 5 Relationship between temperature and crack bridging properties (Interaction of factor A and C)

(Remarks) Period: 6 sec (10 times/min.),
Number of repeat: 2,000 times each

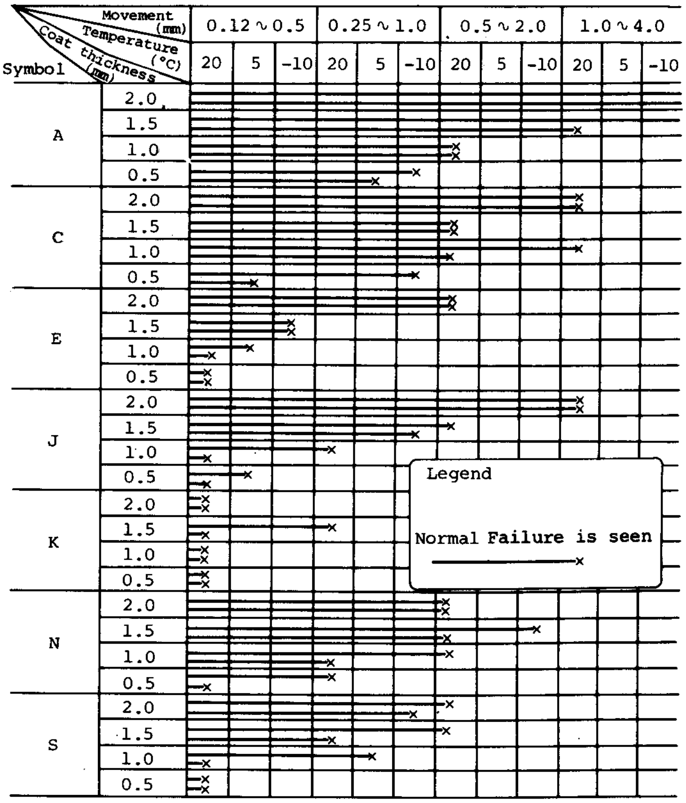


Figure 6 Test results (cyclic movement)

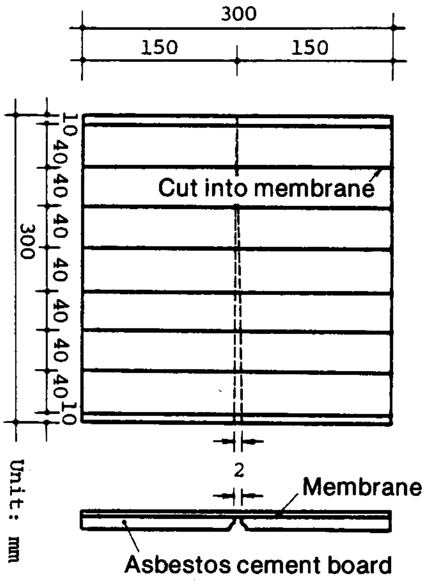


Figure 7 Test method with fixed crack width