107. ビニロン繊維による石綿低減化及び石綿代替製品の耐久性に関する実験的研究

EXPERIMENTAL STUDY ON DURABILITY OF REDUCED ASBESTOS AND NON-ASBESTOS PRODUCTS WITH VINYLON FIBERS

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[KEY WORDS] Asbestos, Non-asbestos, Vinylon Fiber, Durability, Artificial Weathering Room, Accelerated Exposure, Degradation, Flexural Strength

[ABSTRACT] 石綿の安全規制が強化されつつある現在、石綿含有率の低減化及び石綿の代替化が推進されている。本研究では、人工気候室による促進暴露試験を行い、ビニロン繊維を用いた石綿低減化及び無石綿代替製品の耐久性について、従来の石綿製品と比較検討した。人工気候室は、屋外及び屋内条件設定用チャンバーから成り、屋外条件設定用チャンバーは、外気温の変動、雨水、日射熱をシミュレートするために、温度サイクル、散水、赤外線照射を与えることができる。これらの環境条件は、ここでは、関東地方の気象データを参考に、1サイクル6時間で与え、負荷サイクル数は３０７とした。また、劣化評価の項目は、促進暴露試験前後の試験体の外観、寸法、衝撃強度、曲げ強度などの変化である。

その結果として、次のような知見が得られた。すべての試験体について、暴露試験前後で外観及び寸法の変化はほとんど見られなかったが、衝撃抵抗性や曲げ強度の劣化が認められ、曲げ強度の劣化は、従来製品よりも石綿低減化及び無石綿代替製品の方がやや大きくなった。しかし、従来の石綿製品との比較ではなく、セメントマトリックスを短繊維で補強した板状製品としてみた場合、本実験で使用したビニロン繊維による石綿低減化及び無石綿代替製品は十分な強度と耐久性を有しているものと考えられる。

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1. INTRODUCTION

Reduction of asbestos content and replacement of asbestos in cement products by any suitable material have been agressively promoted conforming to safety regulations with respect to asbestos becoming more and more strict because of its hazardous nature when inhaled in human body for a long period of time and in large amount. In the present study, an accelerated exposure test in an artificial weathering room was conducted with reduced-asbestos products and a non-asbestos product utilizing Vinylon fiber, to compare their durability with conventional asbestos products.

2. METHOD OF EXPERIMENT

2. 1 SAMPLES

The present study used short-pitch corrugated cement slates with asbestos replaced by Vinylon fiber. Three products with reduced asbestos and one with no asbestos were tested together with two conventional products for comparison. The samples tested had a size of 590 X 590 mm and a thickness of about 6 mm. Table 1 shows their types and symbols.

Table 1 Types and symbols of samples

Sample	Manufactured by (company code)	Symbols	
		Before durability test	After durability test
Reduced-asbestos	Company A 〃 B 〃 C	A0 B0 C0	A1 B1 C1
Non-asbestos	〃 A	D0	D1
Conventional	〃 A 〃 B	E0 F0	E1 F1

2. 2 DURABILITY TEST

(1) Testing apparatus

Fig. 1 shows an outline of the artificial weathering room used in the experiment. The room contains a chamber for simulating outdoor conditions and one for indoor conditi-

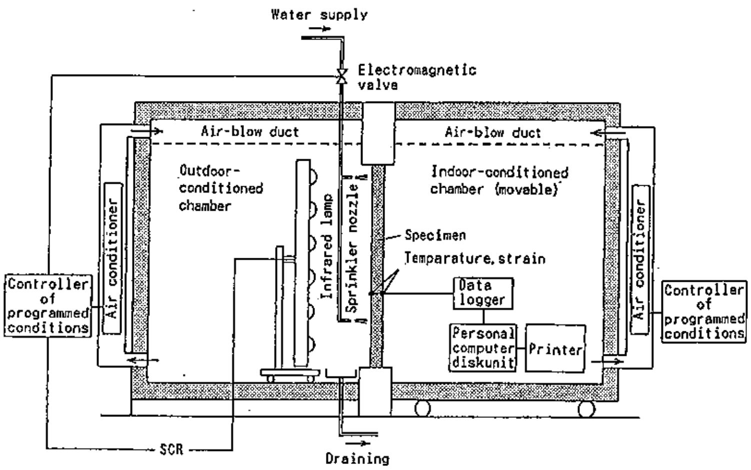

Fig. 1 Outline of the artificial weathering room

ons, the latter being movable. The outdoor chamber can be provided with temparature cycles, water spraying and infrared irradiation for simulating outdoor-temparature variations, rainfall and exposure to sunlight respectively, each of the conditions being automatically controllable aided by programming.

(2) Settlement of samples

Test samples were mounted on a steel frame having a size of 2.4 X 2.4 m and the frame was placed vertically between the two chambers.

(3) Test conditions

Fig. 2 shows the conditions of temparature, water spraying and infrared irradiation set for each one of the test cycles. One cycle completes in 6 hours and the total number of cycles loaded was 307. The conditions were programmed as follows in consideration of past weather data in the Kanto district. The outdoor temparature during cooling was set at -5℃ (corresponding to the monthly average of daily lowest temparature in Utsunomiya city of -4.9℃) and that during heating was 40℃ (the highest temparature in the above of 37.1℃). The temparature of the samples during heating cycle could not be settled but was allowed to follow its own course because of infrared radiation being applied. The temparature of the surface of the samples facing the outdoor chamber is set as follows. The maximum quantity of heat of solar radiation is about 800kcal/h•m^2. The temparature elevation of the surface of a roof irradiated by this quantity of heat is given by

$$\Delta T = a \cdot I / \alpha \qquad \text{-----} \quad (1)$$

where ΔT = temparature elevation

a = heat sink ratio

I = quantity of heat by solar radiation

α = coefficient of heat transfer

When $a=0.85$, $I=800$kcal/h•m^2 and $\alpha=15$kcal/m^2•h•℃, $\Delta T=45.3$℃. Then the maximum surface temparature, being ΔT plus the highest temparature, 37℃, will become about 82℃, and 85℃ was adopted in this experiment for safety.

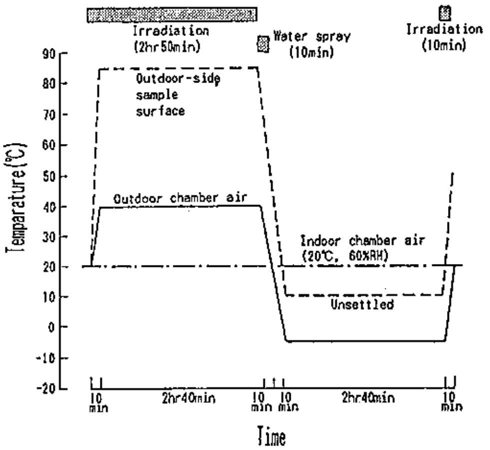

Fig. 2 Conditions of temparature etc.

(4) Measurements during the exposure

Measurements were made with a data logger at 10-minute intervals for the temparatures on the center of the surfaces of each of samples facing the outdoor and indoor chambers and the strain generated on the indoor chamber side, and the results were recorded in a floppy disc.

(5) Evaluation of degradation

Evaluation was made by checking the changes before and after the durability test, for the appearance, size, impact strength and flexural strength. In order to check appearance change, in addition to visual observation with a magnifier, infrared images were prepared for the surface temparature distribution by using an infrared camera, from which generation of swelling or cracks of the samples was examined. The size change was checked by measuring with a slide calipers the distance between guage marks provided before the test (300mm and 250mm in the longitudinal and transverse directions respectively). The flexural strength was tested according to JIS A 1408 and measured on specimens with a span length of 400mm. The impact strength was tested according to JIS A 1421 and measured on specimens remaining after the flexural test and having about half the original size. The load is of eggplant shape (weight:1000g; diameter:52mm) and dropped from a height of 60cm onto a ridge part of corrugation guided through a polyvinyl chloride pipe.

Table 2 Change of appearance

Symbol of sample	Result of visually observation
A 1-1 A 1-2	Nothing unusual ditto
B 1	Nothing unusual
C 1	Nothing unusual
D 1-1 D 1-2	Filaments raised slightly ditto
E 1	Nothing unusual
F 1	Nothing unusual

3. RESULTS AND DISCUSSION

3. 1 APPEARANCE CHANGE

Table 2 shows the results found by visual observation after completion of the durability test. Nothing unusual indicating any surface deterioration were observed except for a slightly raised filaments on non-asbestos product sample D1. No appreciable change was found between the temparature distributions of the specimen surfaces before and after the durability test, obtained with an infrared camera, and hence it is considered that no swelling or cracks generated by the test.

3. 2 SIZE CHANGE

Table 3 shows the changes of the distance between the marks and after the durability test. With all the samples, the changes (extension or shrinkage) were as small as within ±1mm for the gauge lengths of 300 and 250 mm in the longitudinal and transverse directions respectively.

Table 3 Change of size

Symbol of sample	Extension(+) or shrinkage(-) (mm)	
	Longitudinal	Transverse
A 1-1 A 1-2	−0. 1 +0. 2	+0. 1 0. 0
B 1	+0. 5	+0. 5
C 1	−0. 3	+0. 1
D 1-1 D 1-2	−0. 1 +0. 3	+0. 3 −0. 3
E 1	0. 0	−0. 4
F 1	−1. 0	0. 0

Table 4 Change of impact resistance

Before durability test		After durability test	
Symbol	Appearance change	Symbol	Appearance change
A 0-1 A 0-2	No change ditto	A 1-1 A 1-2	Partial cracks Full-width cracks
B 0-1 B 0-2	Slight dent ditto	B 1	Full-width cracks
C 0-1 C 0-2	No change ditto	C 1	Full-width cracks
D 0-1 D 0-2	Partial cracks Slight dent	D 1-1 D 1-2	Partial cracks ditto
E 0-1 E 0-2	No change ditto	E 1	Full-width cracks
F 0-1 F 0-2	No change ditto	F 1	Full-width cracks

3. 3 IMPACT STRENGTH

Table 4 shows the results of impact strength test on the samples before and after the durability test. Almost no samples before the durability test showed any appearance change. This is because that the dropping height had been so set from preliminary tests as to produce no appearance change. On the other hand, all samples showed after the durability test some unusual change, such as cracks, which indicated decrease of impact resistance due to the accelerated exposure. There were, however, found no significant difference in the degree of decrease between the samples.

3. 4 FLEXURAL STRENGTH

Table 5 shows the results of flexural test of samples before and after the durability test. Since it is difficult to obtain the section modulus of a corrugated slate, the test results were shown in terms of the maximum load of the specimen. The flexural strength itself depends of the specific gravity and thickness of the specimen. For this reason, values obtained by dividing the average maximum load (kgf) by [specific gravity X thickness (cm)] are shown in parentheses. Before the durability test, reduced-asbestos and non-asbestos products with Vinylon fiber showed the same or better flexural strengths compared with conventional products. This is attributable to the fact that Vinylon fiber is, when used even in a smaller amount compared with asbestos, effective for improving the flexural strength of cement matrix. Fig. 3 shows how the flexural strengths changed after the durability

Table 5 Change of flexural strength

Before durability test				After test	
Spec. gravity	Water absorption	Symbol	Maximum load (kgf)	Symbol	Maximum load (kgf)
1.57	22.4%	A0-1 A0-2 A0-3	393 402 398	A1-1 A1-2	353 301
		Mean	398(370)	Mean	327(304)
1.49	22.4%	B0-1 B0-2 B0-3	430 360 400	B1	357
		Mean	397(398)	Mean	357(358)
1.58	21.5%	C0-1 C0-2 C0-3	245 260 280	C1	230
		Mean	262(258)	Mean	230(226)
1.45	26.3%	D0-1 D0-2 D0-3	295 275 290	D1-1 D1-2	217 194
		Mean	287(304)	Mean	206(218)
1.61	20.1%	E0-1 E0-2 E0-3	290 330 335	E1	285
		Mean	318(299)	Mean	285(268)
1.68	18.6%	F0-1 F0-2 F0-3	260 285 320	F1	320
		Mean	288(254)	Mean	320(282)

Values in ( ) show those obtained by dividing the maximum load (kgf) by corresponding [specific gravity X thickness (cm)].

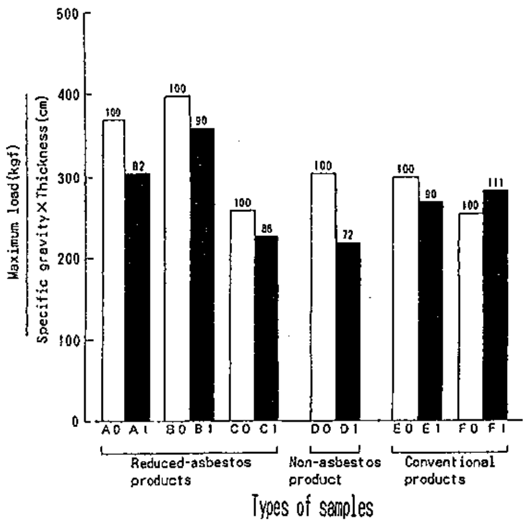

Fig. 3 Decrease of flexural strength

test. In the figure, numerical values show the ratio of the flexural strength after the durability test, based on 100 of that before the durability test. With conventional products, the sample F1 showed no decrease in the flexural strength and E1 showed a decrease to about 90%. On the other hand, reduced-asbestos products decreased to about 80 to 90% and non-asbestos product to about 70%. Although no definite conclusion is drawn due to a small number of samples tested for durability, it seems that the flexural strength of reduced-asbestos and non-asbestos products show larger decrease compared with conventional products.

4. SUMMARY

The following facts are found from the results of the accelerated exposure test in which reduced-asbestos and non-asbestos products with Vinylon fiber and conventional asbestos products were subjected to repeated cycles of temparature change, water spraying and infrared irradiation in an artificial weathering room.

Appearance and size

Nothing unusual indicating any symptom of surface deterioration was found on all the samples except that a non-asbestos sample showed slightly raised filaments. The surface temparature distributions before and after the durability test of each sample obtained with an infrared camera indicated no swelling or cracks after the exposure. Only negligible changes were obtained for the size change after the durability test.

Decrease of mechanical properties

All the test samples showed some decreases in the impact strength with no significant difference between the samples. Likewise, almost all the samples showed some decreases in the flexural strength, and a little larger decrease was found with reduced-asbestos and non-asbestos products than with conventional products. However, apart from comparison with conventional asbestos cement slates, it can be said that the reduced-asbestos and non-asbestos products both have excellent flexural strength and durability when viewed as slates comprising cement matrixes reinforced with randomly oriented short-cut fibers.

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