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# EVALUATION OF SURFACE TREATMENT EFFECT FOR PREVENTING EXCESSIVE EXPANSION DUE TO ALKALI-SILICA REACTION

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## 1. INTRODUCTION

Durability of concrete is effected by alkali-silica reaction(ASR) which causes excessive expansion,cracking and occasionaly significant deterioration of concrete. Many cases of concrete damage due to ASR have been obserbed in real structures subjected to constant wetting such as dams,bridges,retaining wall,and foundations(1). Since 1982, a number of instances of severe damage of concrete structures resulting from ASR have come to light in Japan,and ASR has become a subject of greate concern(2).

Concrete surface treatment systems to control the moisture in concrete can be a useful way of reducing excessive expansion due to ASR(3) while the effectiveness of the systems seem to vary widely depending upon coating materials,exposure conditions, applying time of coating, and moisture content in concrete.

The object of this paper is to evaluate the effectiveness of concrete surface treatment with coating materials under various conditions for controling moisture which may contribute to ASR in concrete.

## 2. OUTLINES OF TESTS

This investigation is divided into three test series as follows:

1st test series: Influence of the coating materials shown in Table 1 on the reduction of expansion due to ASR under an accelerating condition (40℃,>95%R.H.).

2nd test series: Influence of applying time of coating for deteriorated concrete specimen and the concrete type( plain concrete,reinforced concrete ) on the reduction of expansion due to ASR under the outdoor condition.

3rd test series: Influence of the moisture content of concrete specimens on surface treatment effects in reducing expansion due to ASR under an accelerating condition (40℃,>95%R.H.).

Table 1 Coating Materials

| No. | 1 st | 2 nd | 3rd | Thickness |
|---|---|---|---|---|
| 1 | Modified Silane * | —— | —— | —— |
| 2 | Alkyl Alkoxyl Silane* | Alkyl Alkoxyl Silane* | —— | —— |
| 3 | Acryl P-C # | —— | —— | 800~1000 |
| 4 | Acryl Primer | Acryl P-C # | Acryl P-C # | 700~ 800 |
| 5 | Acryl Compound* | Acryl Compound* | —— | —— |
| 6 | Silicon Compound* | —— | —— | —— |
| 7 | Silicon Primer | Silicon Coating | Silicon Coating | 350 |
| 8 | Epoxy Primer | Epoxy Coating | Epoxy Coating | 700 |
| 9 | Polyester Primer | Polyester Coating | Polyester Coating | 70 |
| 10 | Urethane Primer | Urethane Coating | Urethane Coating | 350 |

cf 1) * Surface Modifier unit : μm
# Polymer-Cement Composite
2) Epoxy Coating contains glass flake filler.

## 2.1 Applying Time of Concrete Surface Treatment

In the 1st test series, surface treatments was carried out on the specimens which had been stored in the room of 20℃ and 60%R.H.for 4 weeks.In the 2nd test series, the treatment was carried out on the specimens of plain concrete at the time when the expansion due to ASR reached 0%,0.03%, 0.10%,respectively while the specimens of reinforced concrete were surface-treated at the time when the expansion due to ASR reached 0%,0.05%,0.08%,respectively. In the 3rd test series, the treatment carried out on the specimens when their moisture content decreased down to 4.5%,1.5%,0%,respectively,in a drying chamber after storing in a room of 20℃ and 60%R.H. for 4 weeks. For comparision, specimens of which moisture content were 6.0% as of no accelerating drying were also pre pared.

## 2.2 Materials and Concrete Specimens

Ordinary portland cement, non-reactive crushed sand and crushed coase aggregate mixed with reactive and non-reactive aggregate were used. Concrete specimens were adjusted to have an equivalent alkali content of 7.0Kg/$m^3$ with an addition of NaOH and KOH. The potential reactivity of used aggregates is shown in Table 2.The mix proportion is shown in Table 3.

Plain concrete specimens( 10x10x40cm prism ) were prepared in all test series. In addition, reinforced concrete specimens( 10x10x40cm prism,ratio of reinforcement=1.57% ) were prepared in the 2nd test series.

Table 2 Potential reactivity of aggregates

| Aggregate | Type of rock | Chemical method | | | Specific gravity | Absorption (%) |
|---|---|---|---|---|---|---|
| | | Sc (mmol/l) | Rc (mmol/l) | Division | | |
| Crush stone A | Andesite | 613 | 262 | Potentially deleterious | 2.54 | 2.40 |
| Crush stone B | Sand stone | 56 | 76 | Innocuous | 2.66 | 0.80 |
| Crush sand | Sand stone | 52 | 92 | Innocuous | 2.62 | 1.91 |

Table 3 Mix proportion of concrete

| W/C (%) | S/a (%) | Unit Weight (kg/m³) | | | | | Admixture (Cx%) | | $Na_2O$ (Cx%) | $K_2O$ (Cx%) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | W | C | S | G | | | | | |
| | | | | | Reactive | Non-reactive | PZ #70 | #303A | | |
| 55 | 47 | 193 | 350 | 807 | 540 | 360 | 0.18 | 0.0027 | 0.91 | 0.98 |

## 3. RESULTS AND DISCUSSION

### 3.1 Influence of Coating Materials under an Accelerating Condition

The ratio of the expansion of coated specimens to that of non-coated specimens in percent with time passing is shown in Fig.1. Under an accelerating condition,the expansions of coated specimens decreases to 65% to 85% of that of the non-coated specimens at the expsure of 12 months regardless of the type of coating materials except No.8 shown in Table 1.

Based on Fig.1 and Fig.2 which shows the relationship between the expansion and the weight change of concrete due to water absorption,it is recoginized that the expansion increases with weight. However,the degree of the expansion with weight varies according to the type of coating materials. It seems unsatisfactory effect of surface treatment in reducing expansion was due to too much moisture content of the concrete specimens before coating and high moisture exposure condition.

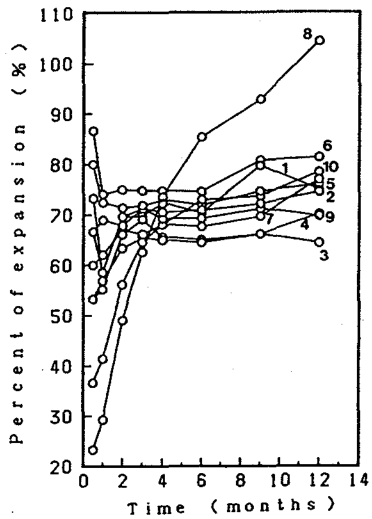


Fig.1 Expansion ratio of coating specimens to non-coating specimen

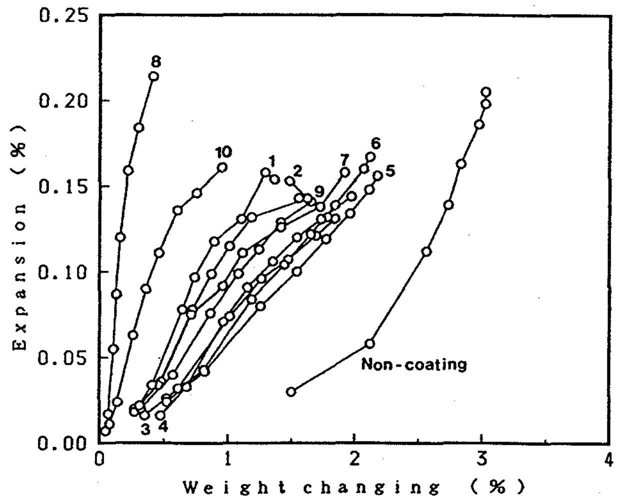


Fig.2 Relationship between expansion and weight changing of concrete

3.2 <u>Expansion Reducing Effect of Surface Treatment in Outdoor Condition</u>

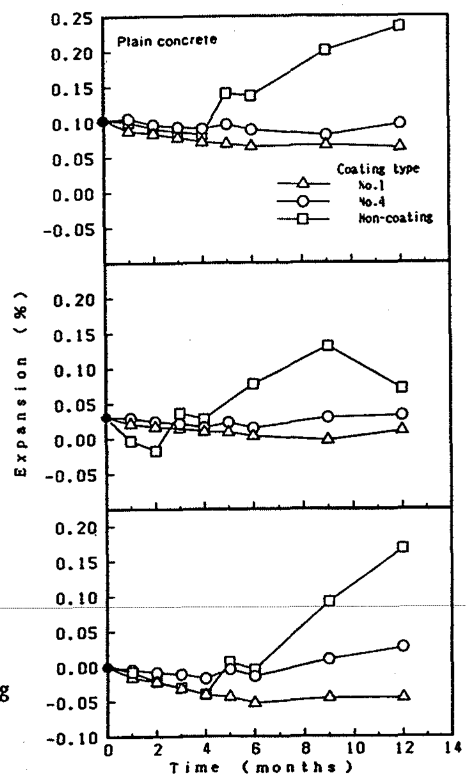


Fig.3 Expansion curves of concretes for several coating applying times

The expansion with time is shown in Figs. 3 and 4. Compared to non-coated specimens, the expansion of coated specimens were remarkably small, regardless of coating applying time and there were no defference either among specimens with and without reinforcement.

The coatings of No.1 and No.4 specimens seems to prevent the passage of moisture in the liquid but not in the vapor. Therefore, in outdoor condition, a significant reduction in expansion can be produced by surface treatments as compared to those effect in high moisture condition tested in the 1st series.

3.3 <u>Influence of Moisture Content</u>

The expansion curves of coated specimens which were stored in accelerating condition( 40℃, >95%R.H.) is shown in Fig.5. For coating materials, epoxy which showed a superior ability to prevent water penetration through the surface from outside was used in this experiment.

Concrete specimens which had the moisture content of 6.0% showed larger expansion while those which had the moisture content of 4.5% or less showed less expansion. However, in the case of the moisture content of 4.5%, the expansion is expected to go on even after 12 months, because compared to the moisture content of 0% and 1.5%, the specimens of which the moisture content is 4.5% indicate a large degree of expansion with weight due to water penetration from outside as shown in Fig.6. Therefore, it is considered that surface treatment using highly impermeable coating materials would give a remarkable effect in reducing expansion under high moisture condition provided that the moisture content does not exceed approximately 4.5%.

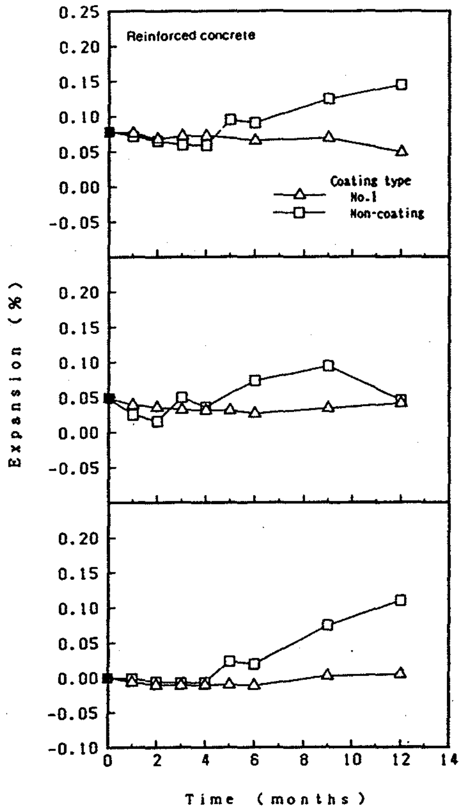

Fig.4 Expansion curves of concretes for several coating applying times

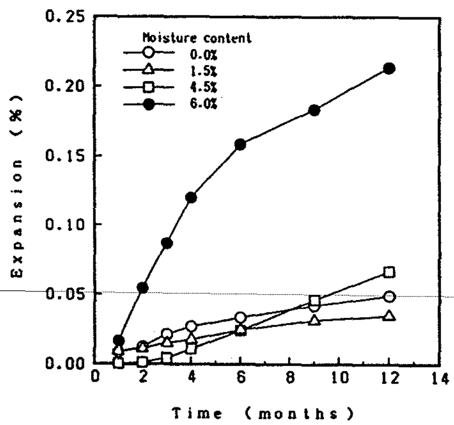

Fig.5 Expansion curves of coating concretes containing various moisture contents

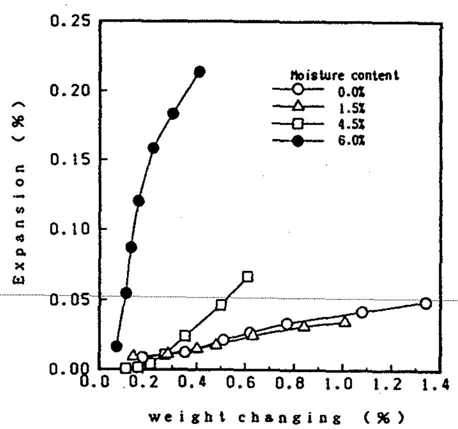

Fig.6 Relationship between expansion and weight changing of concrete

## 4. CONCLUSION

The major results obtained from the experiments are summarized as follows:

(1) Even under high moisture condition such as the accelerating test method of ASTM C 227, concrete surface treatment with highly impermiable coating materials gives a remarkable effect in reducing expansion due to ASR provided that the moisture content of concrete before being coated is approximately 4.5% or less.

(2) For concrete surface treatment materials, modified silane and polymer-cement composit give a remarkable effect in reducing expansion due to ASR under the outdoor condition in which moisture is expected to evaporate from the inside of concrete. The same effect can be obtained by these treatments in the case of both plain and reinforced concrete,and every applying times of coating for deteriorated concrete due to ASR.

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