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EXPANSION BEHAVIOR OF REACTIVE AGGREGATE CONCRETE IN THIN SEALED METAL TUBE

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1. INTRODUCTION

It has been reported[1][2] that if concrete was left to dry, the alkali-silica expansion decreased and then stopped.
But in the case of a massive or mass concrete structure like a road bridge pier, drying occurs only near the surface. Inside concrete is kept humid because of its very low moisture diffusibility and cracks in the structure promote moisture supply inside the concrete.

For confirmation of these phenomena, the expansion behavior of model specimens having approximately the same restrictions as reinforced concrete and sealed against moisture loss were investigated. Environmental conditions, such as temperature, humidity and direction of moisture supply were varied.

2. EXPERIMENTAL PROCEDURES

2.1 Specimens and Measurement of Expansion

Three specimens were prepared as models of actual massive reinforced concrete structures resembling bridge piers having 2 m depth of concrete affected by the alkali-silica reaction. The specimens were made by casting concrete with alkali reactive aggregate into thin stainless steel pipe(200mm dia. x 1000mm length x 0.4mm thickness) sealed at one end in the axial direction. details of the specimens are shown in Figure-1.

The expansion of the specimens was measured by a water proofed wire straingage placed in axial and radial directions on the pipe, as shown in Figure-1. The measurement of initial length was done at 2 weeks after curing at 20°C in a sealed condition, and then No. 1 specimen was stored in 20°C, 60% R.H. and specimens No. 2 and No. 3 were stored in 40°C, saturated humidity. The expansion was measured at short intervals at first and then once or twice a month. The apearance of the specimens is shown in Photo.-1.

2.2 Materials and Mix Proportion of Concrete

Materials used for concrete were ordinary portland cement containing

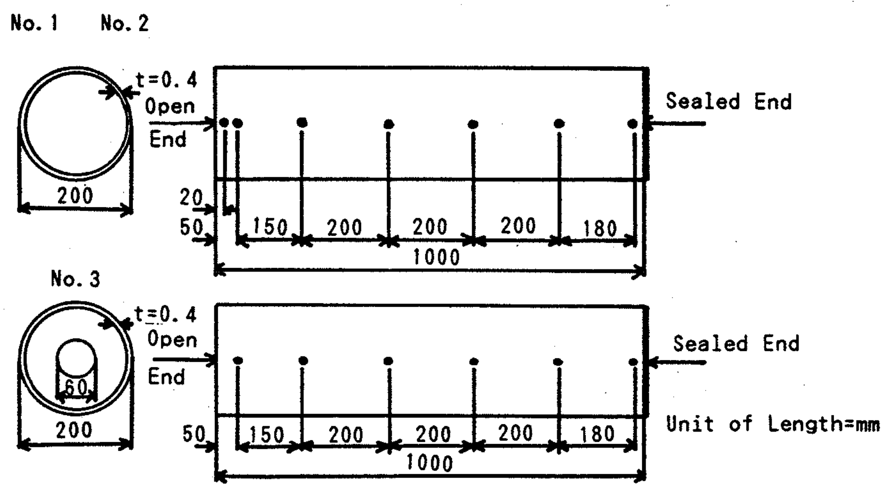

Figure-1 Detail of Model Specimens

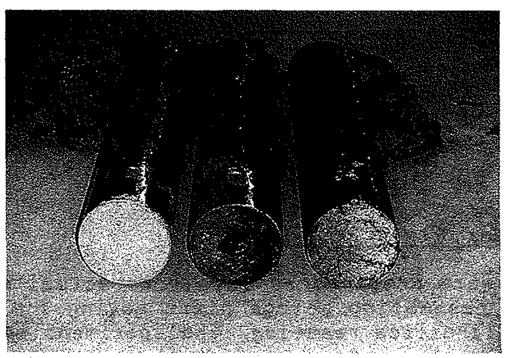

Photo.-1 Appearance of Specimens

0.63% Na_2O equi., sand(s.g. 2.60, f.m. 2.77, non reactive) and reactive coarse aggregate consisting of 50% non reactive gravel(s.g. 2.70, f.m. 6.66) and 50% reactive gravel(s.g. 2.55, f.m. 6.61). Reactive coarse gravel was bronzite andesite judged deleterious(Sc=807 m mol/l, Rc=119 m mol/l) according to chemical method.

Mix proportion of the concrete is shown in Table-1, the mix contained 8 kg/m^3 total alkali, adjusted by addition of sodium hydroxyl .

Table-1 Mix Proportion of Concrete

Slump (cm)	W/C (%)	S/a (%)	Unit Weight (kg/m³)				
			Water	Cement	Sand	Gravel	
						Reac.	Nor.
8	50	40	176	352	783	487	516

2.3 Measurement of Strength and Elastic Properties

Measurement of compressive strength ,static and dynamic elasticity and propagation velocity of ultrasonic waves was carried out using two 200mm dia. x 400mm length specimens taken from No. 2 specimen.

Each property was measured under restricted conditions and then measured under non-restricted conditions with a specimen taken from sealed stainless tube.

3. RESULTS AND DISCUSSION

3.1 Development of Alkali-Silica Expansion

Alkali-silica expansion (radial direction) at the surface and the interior of concrete specimens is shown in Figure-2·1 and Figure-2·2 . These results indicate that specimens No. 2 and 3 in a warmer, saturated humidity environment, revealed rapid expansion as shown in Figure-2·3 during the early stage of storage but expansion saturated at about 40 weeks. On the other hand, expansion of specimen No. 1 stored in ordinary conditions of 20°C, 60% R.H., was nearly static at the surface but interior concrete expanded linearly after a dormant period. Although the rate of expansion was low because of the low temperature, by 149 weeks, the expansion reached 60% that of the accelerated specimens (Figure 2·2).

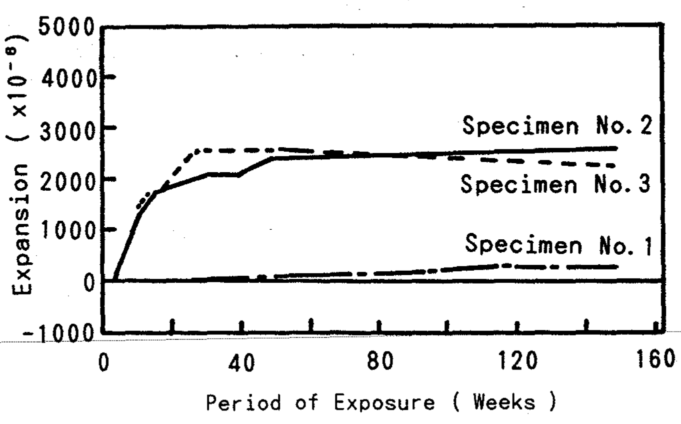

Figure-2·1 Expansion at 50mm Depth from Surface of Open End

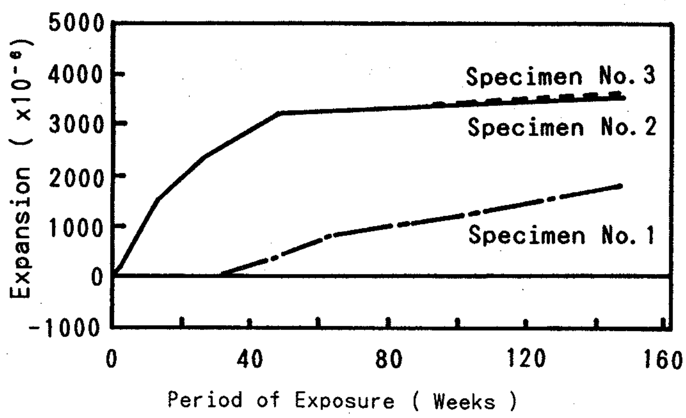

Figure-2·2 Expansion of Interior (Average of 600mm and 800mm Depth)

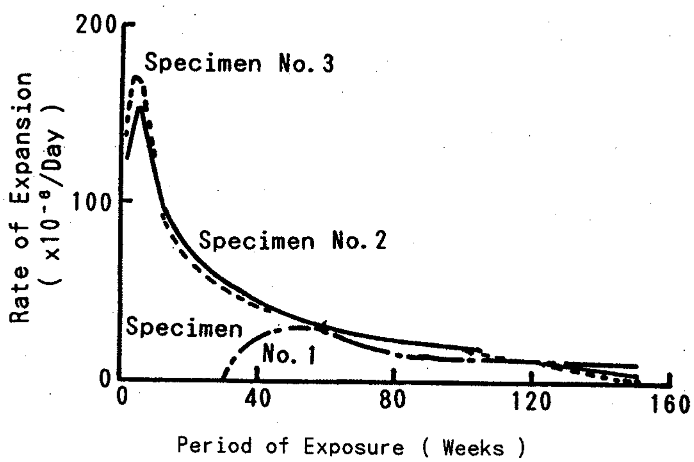

Figure-2·3 Rate of Expansion of Inside Concrete Dependent on Period of Exposure

3.2 Influence of Drying Condition

It has been reported that the drying of concrete is effective for inhibiting alkali-silica expansion[1] [2]. But in massive concrete, it was reported that alkali-silica expansion continued by absorbtion of the mixing water during a long period. Further, it was not clear wether alkali-silica expansion of interior concrete was promoted or not by moisture supplied through cracking of the concrete.

Figures 3·1 and 3·2 demonstrate distribution of alkali-silica expansion in the radial and axial directions at different depth from the surface. Trends of expansion in both directions is the same, except the end zone which is influenced by restriction in the axial direction.

Results of this study show that for specimen No. 2, stored at high temperature and humidity, and specimen No.3, having a 20mm dia. center hole for supplying moisture into the interior inside of the concrete, expansion was the same regardless of depth. But specimen No. 1, stored in relatively low temperature(20°C) and low humidity(60% R.H.), showed different expansion properties. The influence of drying on expansion was clearly observed at different depth from surface to the interior of the concrete. Expansion changed from zero at the surface to 2500×10^{-6} strain at a depth of approximately 400mm. Expansion at a depth of 400mm was about same value as for specimens No. 2 and No. 3, therefore, it was estimated that interior concrete at over 400mm depth is not affected by drying conditions at the age of 149 weeks. This suggested that restriction of alkali-silica expansion, in massive concrete structures, by drying, was difficult because of the low moisture diffusibility.

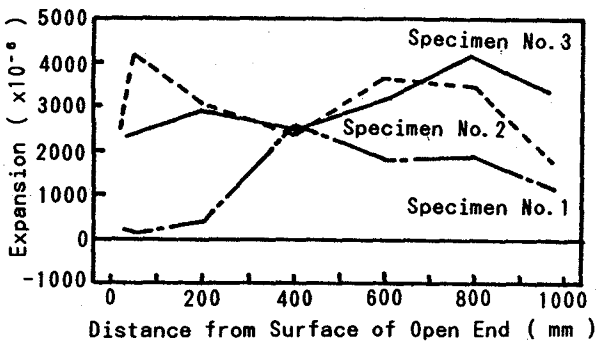

Figure-3·1 Distribution of Expansion with Radial Direction Gages

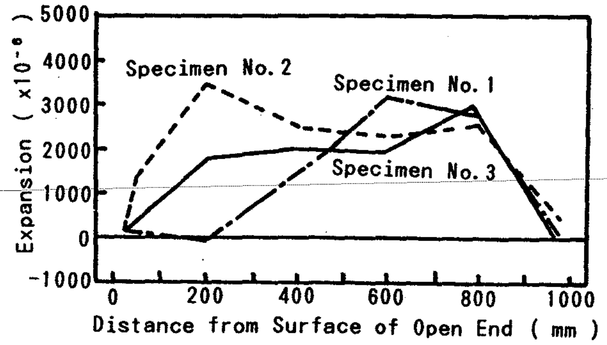

Figure-3·2 Distribution of Expansion with Axial Direction Gages

3.3 Strength and Elastic Properties

It has often been reported [3] that the modulus of elasticity of concrete affected by the alkali-silica reaction was, in general, very small. Particularly, the values of drilled concrete cores taken from affected structures was smaller than that calculated from load bearing tests of the affected structures. For this reason, it was believed that differences of elasticity were influenced by the degree of restriction of the concrete by reinforcement.

The results of our study are shown in Table-2. From the results, it is clear that the static and dynamic modulus of elasticity, propagation velocity of ultrasonic waves and compressive strength were influenced by restriction of reinforcement, and under a restricted condition, static and dynamic modulus of elasticity, propagation velocity of ultrasonic waves and compressive strength increased approximately 4×10^4kgf/cm^2, 6×10^4kgf/cm^2, 0.3km/sec and 90kgf/cm^2 respectively, compared to an unrestricted specimen.

Table-2 Strength and Elastic Properties

Specimen	Static Modulus of Elasticity ($\times 10^4$kgf/cm^2)	Dynamic Modulus of Elasticity ($\times 10^4$kgf/cm^2)	Propagation Velocity (km/sec)	Compressive Strength (kgf/cm^2)
Restricted	17.6 (65%)	26.2 (82%)	3.71 (82%)	289 (84%)
Unrestricted	13.7 (50%)	20.4 (63%)	3.41 (63%)	198 (53%)
Normal Concrete	27 (100%)	32 (100%)	4.5 (100%)	350 (100%)

4. CONCLUSION

Main results obtained are summarized as follows.

1. In a sealed specimen held at 20°C, alkali-silica expansion developed linearly and strain of expansion reached 60% that of accelerated specimens, after a dormant period.

2. Drying inhibited alkali-silica expansion, but at a depth of 400mm at age of 149 weeks, it was not effective for massive concrete structures.

3. Modulus of elasticity, propagation velocity of ultrasonic waves and compressive strength increased with restriction by reinforcement.

REFERENCE

[1] Nilsson, L., Moisture Effect on the Alkali-Silica Reaction, p.201, 6th International Conference, Alkali in Concrete Proceedings, 1983

[2] Ólafsson, H., Repair of Vulnerable Concrete, p.479, 6th International Conference, Alkali in Concrete Proceedings, 1983

[3] Imai, H. and Mizumoto, Y., Load bearing Capacity on the Member and Structure affected by Alkali-Silica Reaction, Concrete Journal, 24, 11, 79, 1986