TABLE 1- MATERIALS USED

Materials	Kind	Properties
Cement	normal portland cement	Specific gravity : 3.15 SiO_2 21.3%, CaO 64.2%, SO_3 2.0%
Sand	land sand （for concrete）	Specific gravity : 2.65、FM : 2.67
	silica sand （for mortar）	Specific gravity : 2.57、FM : 2.76
Coarse Aggregate	Crushed stone	Specific gravity : 2.66、FM6.64 G_{MAX} : 20mm
Admixtures	AE water reducing admixture	Lignosulfonic acid system
	AE admixture	alkyl ether system

TABLE 2- MIXTURE PROPORION OF CONCRETE

W/C (%)	s/a (%)	Unit weight (kg/m^3)				SRA (C×%)	AE water reducing admixture (C×%)	AE admixture (C×%)
		C	W	S	G			
50	44	312	156	807	1043	1.5	0.25	adjusted

TABLE-3 MIXTURE PROPORTION OF MORTAR

W/C (%)	Unit weight (kg/m^3)			SRA (C×%)	AE admixture (C×%)
	C	W	S		
60	432	259	1296	1.0	adjusted

TABLE-4 PROPERTIES OF SRA

Ingredient	EO/PO Ratio	Molecular Weight	Surface tension※ (mN/m)	Cost (US $ /kg)
Polyoxyalkylene system	25/75	800	48.6	about 6.0

※1.67%aq.

TABLE 5- TIMING OF THE DELAYED ADDING OF SRA

CASES	ADDING METHOD
I	AE mortar (without SRA)
II	ordinary mixing
III	Delayed adding (15seconds-mixing after adding)
IV	Delayed adding (30seconds-mixing after adding)
V	Delayed adding (60seconds-mixing after adding)

Total mixing time is 300 seconds in all cases.

TABLE 6- PROPERTIES AND TEST RESULTS OF SRA SAMPLES

Samples	EO/PO Ratio	Molecular weight	Surface tension (mN/m)	Air content (%)
A	0/100	1200	37.1	0.7
B	5/95	1000	43.1	3.5
C※	25/75	800	48.6	5.7
D	50/50	1700	47.2	5.1
E	75/25	1000	53.2	6.5

※above SRA of Table 4.

TABLE.7- PROPERTIES AND THE TEST RESULTS OF SRA SAMPLES

Samples	EO/PO ratio	Molecular Weight	Surface tension (mN/m)	Air content (%)	Air-retaining rate※ (90min. after mixing, %)
F	75/25	750	46.8	10.2	68
G	75/25	1200	46.4	9.6	58
H	75/25	1400	45.3	9.9	60
I	75/25	1600	46.4	10.9	83
J	75/25	1800	45.0	11.3	79
K	75/25	2250	45.3	11.6	91

※air content percentage against at 0 min.

TABLE 8- RESULTS OF MORTAR

CASES	Air-void spacing factor	the number of Air-void
I	108	1311
II	165	943
III	113	1279
IV	105	1330
V	104	1379

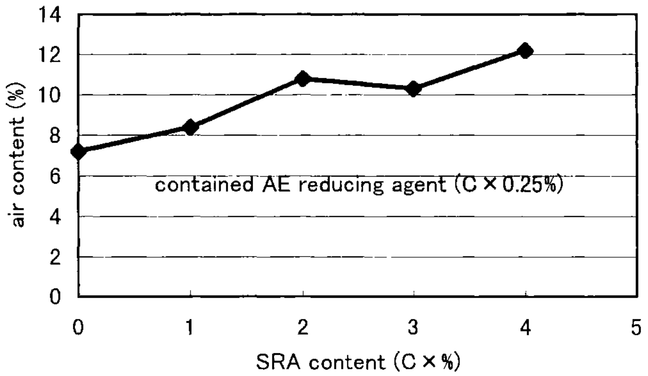

FIG.1 RELATIONSHIP BETWEEN AIR CONTENT AND SRA CONTENT

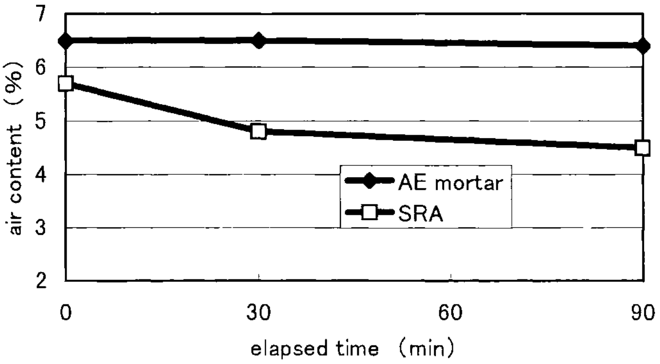

FIG.2 ELAPSED TIME CHANGES IN AIR CONTENT (MORTAR)

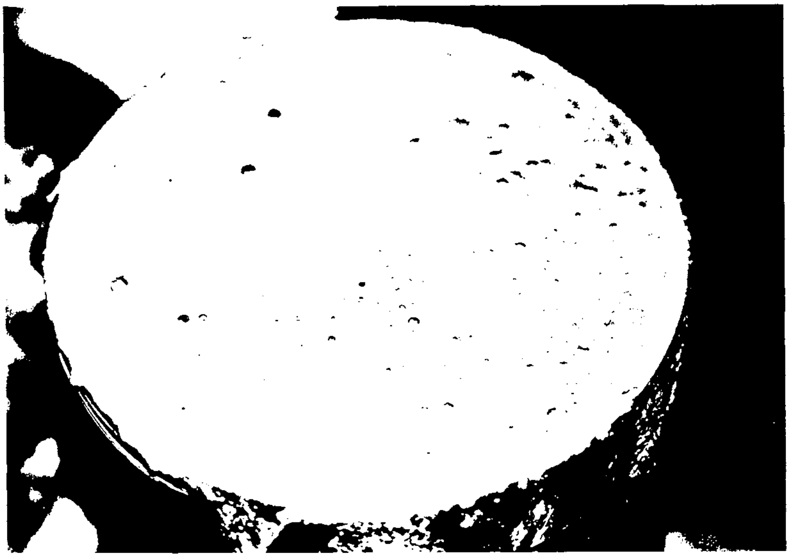

FIG.3 AIR VOIDS IN MORTAR CONTAINING SRA

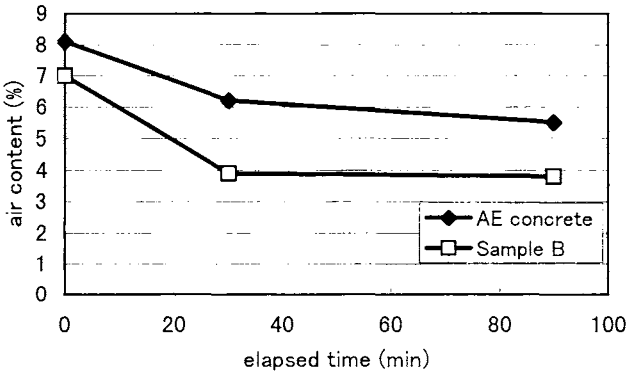

FIG.4 ELAPSED TIME CHANGES IN AIR CONTENT OF SAMPLE B

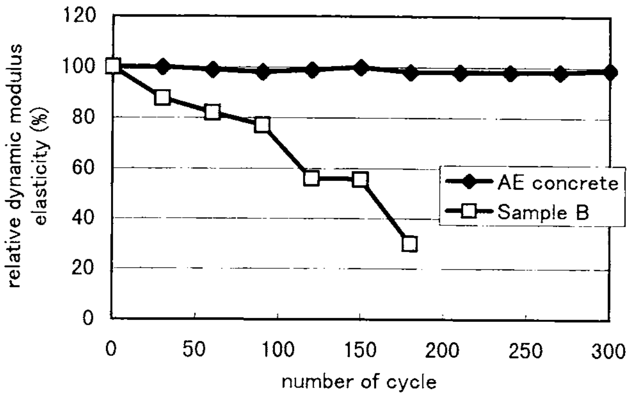

FIG.5 FREEZING AND THAWING TEST OF SAMPLE B

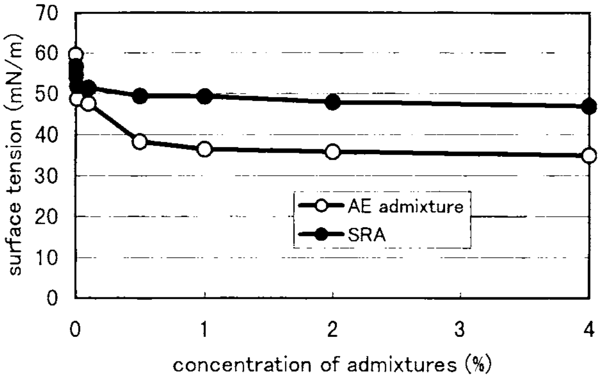

FIG.6 COMPARISON OF SURFACE TENSION

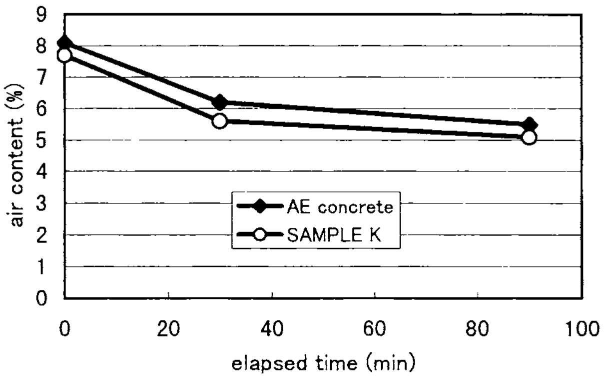

FIG.7 ELAPSED TIME CHANGES IN AIR CONTENT OF SAMPLE K

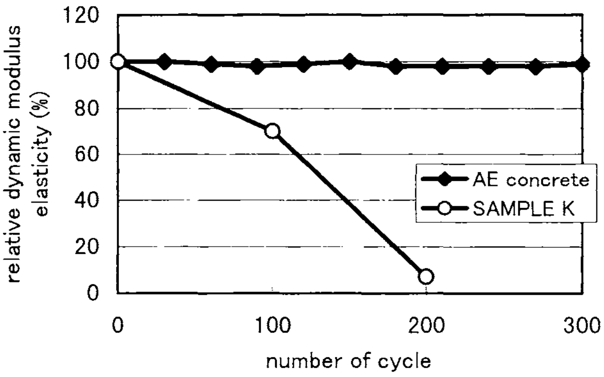

FIG.8 FREEZING AND THAWING TEST OF SAMPLE K

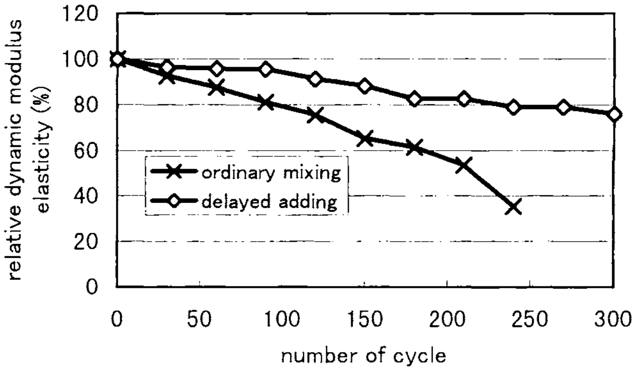

FIG.9 FREEZING AND THAWING TEST OF SAMPLE C

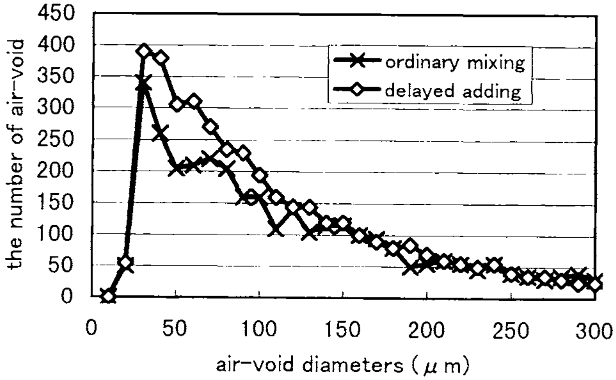

FIG.10 AIR-VOID DISTRIBUTIONS OF SAMPLE C

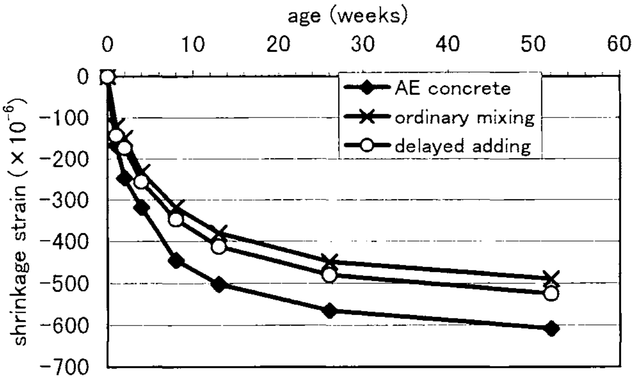

FIG.11 LENGTH CHANGE OF SAMPLE C

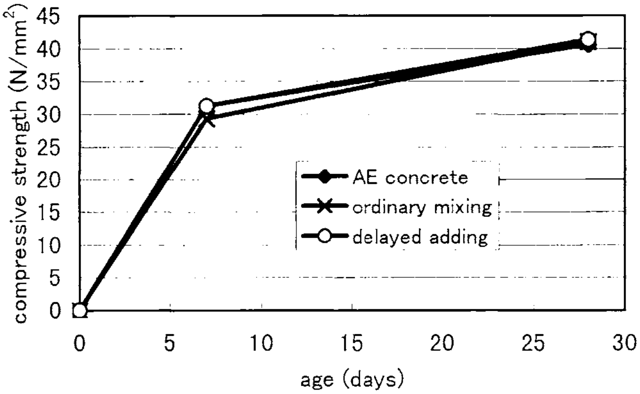

FIG.12 COMPRESSIVE STRENGTH OF SAMPLE C

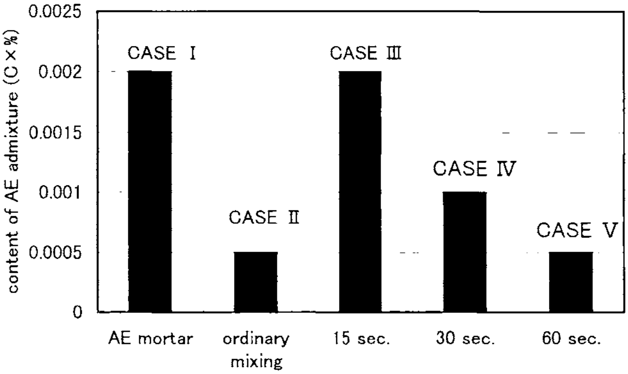

FIG.13 CONTENT OF AE ADMIXTURE IN THE CASES

SP 195–27

Influence of Silane-Based Hydrophobic Admixture on Oxygen Diffusion Through Concrete Cement Matrix

by F. Tittarelli, G. Moriconi, and R. Fratesi

Synopsis: The oxygen diffusion coefficient through hydrophobic cement-based materials fully immersed in water was determined by potentiostatic measurements on concrete and by the use of a diffusion cell on cement pastes and mortars. The results obtained show that very high oxygen diffusion occurs through cement paste, mortar and concrete made with hydrophobic admixture as opposed to negligible diffusion through the reference cement matrix without admixture. Moreover, the oxygen diffusion coefficients measured through hydrophobic cement matrices immersed in water were comparable with those reported in literature for unsaturated cement materials in air. These experimental results appear to confirm that oxygen dissolved in water directly diffuses as a gaseous phase through the empty pores of a hydrophobic cement matrix. This could explain the severe corrosion of steel reinforcement embedded in cracked hydrophobic concrete immersed in an aqueous chloride solution observed in a previous work.

Keywords: admixture; cement (hydrophobic); concrete

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INTRODUCTION

To prevent steel corrosion induced by chloride penetration into reinforced concrete, different methods are generally adopted. They include the reduction of w/c to decrease the porosity and permeability of the cement matrix, the resort to pozzolanic addition to reduce the chloride diffusion, the use of corrosion inhibitors, the protective surface treatment of either steel reinforcement or concrete, and the cathodic protection of the steel reinforcement.

However, static, dynamic and cyclic loading as well as shrinkage, creep and thermal stress can determine cracking of reinforced concrete structures. Moreover, in precast concrete, cracks can also be produced by shocks or flexural stress induced during transportation, lifting and mounting. In this occurrence, when concrete is cracked for some reason, most of the above methods can fail, particularly when the crack tip reaches the steel reinforcement (1-3).

On the other hand, it is evident that steel corrosion would not occur if water, which acts as a carrier for the diffusion of chloride ions, is permanently prevented from wetting the concrete porous structure. The water in contact with a porous material such as concrete, penetrates the material by means of capillary forces following the Washburn equation, but the molecular attraction between water and the concrete pores wall can be lowered by the use of hydrophobic agents, such as those currently named silanes and siloxanes (4-6). Their alkoxylic groups are chemically bound to the concrete hydrated silicates by a condensation reaction while their hydrophobic alkylic groups come out on the pores surface (7).

Many studies have already shown that concrete surface treatments with alkyl-alkoxy-silane supply an effective barrier against water penetration (7, 8). To this end, in 1994, the Danish Ministry of Transports decided to use hydrophobic treatments on all new concrete bridges as an additional protection against de-icing salts penetration (9, 10). The surface treatment effectiveness in time, depends on the alkali resistance of the used compounds, the treatment penetration depth, the resistance to atmospheric agents, and the integrity of the structure (4, 11-14).

To optimise the utilization of hydrophobic agents, they have been recently introduced directly in the concrete mixture in order to make both the surface and the whole concrete bulk, hydrophobic. The results obtained showed that in the absence of cracks, the hydrophobic concrete, fully immersed in a chloride aqueous solution, very effectively protects steel reinforcement against corrosion. On the other hand, in the presence of cracks, more than ten-fold higher corrosion currents were monitored with respect to those in the reference concrete specimens without the hydrophobic admixture (15).

The proposed hypothesis to explain these unexpected results admits that oxygen diffusion, feeding the corrosion process, could directly occur in a gaseous phase through the unsaturated porosity of the immersed hydrophobic concrete, while in concrete without silane, oxygen diffuses much slower through the water filling the pores of the saturated concrete.

SCOPE

The aim of the present paper is to confirm the validity of the above mentioned hypothesis. With this in mind, the oxygen diffusion coefficient of hydrophobic paste, mortar and concrete with different water-cement ratio was measured when fully immersed in water.

The oxygen diffusion through concrete was studied by means of electrochemical potentiostatic measurements on a steel plate embedded in the concrete specimen. The steel plate was polarized at a constant potential and the resultant oxygen reduction current flow was detected.

For cement pastes and mortars, a diffusion cell was manufactured instead, where the specimens acted as diaphragms between two water compartments with different oxygen concentrations. In this latter case, the cement specimens were either bulk or surface hydrophobic, in order to obtain further confirmation of the above mentioned hypothesis, as a similar behavior was expected in the two different cases.